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Key Technologies of a Large-Scale Urban Geological Information Management System Based on a Browser/Server Structure

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ABSTRACT Urban geological information management systems based on a B/S structures are an inevitable trend in the development of smart geology and big data. Such systems are important platforms for promoting the sharing of data and services among different city entities. It is necessary to overcome the limitations of C/S or partial B/S structures and establish an urban geological information management system based on a comprehensive B/S structure, which is currently rare. According to the above questions, this paper focuses on three types of technical tasks to construct an urban geological information management system based on a B/S structure. In terms of data management, we leave many functions to the server, and group data by type. In terms of data application and sharing, we quickly query and graphically display the data from massive data sets, and perform collaborative analyses of different professional data. In terms of 3D geological modelling and analysis, in order to efficiently provide large-scale 3D geological model analysis in the browser, we explore a new data structure and algorithm for optimization modelling to reduce the amount of model and the number of calculations. Using the above technical methods, we develop a geological information management system for a city in eastern China. The system realizes the ‘‘One Map’’ function for land and resources, creates a platform for the sharing of geological data and services among different entities, and provides technical support for the construction of ‘‘smart cities’’.

INDEX TERMS B/S structure, large-scale geological data management, data sharing, 3D geological modelling and analysis, urban geological information management system.

I. INTRODUCTION

Geological data have played an increasingly important role in the work of different entities, such as land and resource, planning and construction, water conservancy, and transportation entities. The sharing of geological data and services among various entities has become an urgent need for urban geological surveys. An urban geological information management system is crucial for providing access to urban geological surveys. Through the management, application and sharing of massive geological data sets, key urban geological problems in various industries can be solved.

Urban geological information management systems based on C/S (Client/Server) structures or partial B/S (Borwser/Server) structures generally have limitations. These systems face challenges with sharing geological data and services among different departments, so urban geological information management systems based on B/S structures are essential. With such systems, users can manage, apply and share geological data and promote data and service sharing among different entities.

The research on urban geological information management systems has had different goals and forms based on various

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applications. Such methods can mainly be classified into the following two categories. (1) The systems are developed based on research and applications in a specific field and provides solutions to a specific problem. In [1], the author established an engineering geological database for storing and querying borehole records, groundwater data and other geological data. In [2], the author showed that technological advances (mainly in computer science) can increase the potential range of applications of data from the Geological Survey of Canada (GSC). In [3], the author reviewed the applications of geographic information system (GIS) technology in the 21st century. In [4], the authors proposed practical procedures for modelling basin structures based on the management and analysis of geological data, such as borehole data. In [5], the authors developed a software platform to construct a 3D hydrogeological model applicable in urban environments. The platform can manages a large amount of different data types coming from different sources. In [6]–[9], the authors used GIS technology to establish platforms to evaluate natural resource inventories, the environment, unstable risk areas and geohazards, respectively. In [10], the authors utilized geotechnical data and GIS to build a digitally formatted and integrated spatial database. And used stratigraphic data stored within the spatial database to construct 3D subsurface models. Through these mothods, they provided an exhaustive database and an integrated 3D environment for a city in southern India. In [11]–[13], the authors studied the use of natural language processing technology to extract geological information. These studies applied geological data in different fields, but there are shortcomings in the comprehensive management, application and sharing of geological data. (2) The systems are comprehensive urban geological information management systems that provide services for multiple fields and departments. For example, China began a project in 2003 to conduct three-dimensional urban geological surveys and establish urban geological information management systems in six cities (Beijing, Shanghai, Nanjing, Tianjin, Guangzhou and Hangzhou) [14]. These systems provide multiple professional services for multiple entities. However, due to the limitations of network technology, the systems are based on a C/S structure and lack geological data sharing among multiple entities. With the increasing demand for geological data sharing and the progress in information technology, urban geological information management systems are increasingly using a combination of C/S and B/S [15], [16]. The modules of the system are mainly based on C/S structures, such as data applications, 3D geological models and other modules, and some modules for which data sharing and/or cloud services are needed are based on B/S to facilitate data sharing.

WebGIS is widely used in spatial information management and publishing under the Internet environment, and has been widely used in many fields. In [17], the authors used WebGIS for land price information services. In [18], the authors used WebGIS to manage the urban planning information. However, as the WebGIS system is mainly used for information management and publishing, and doesn't have enough support for applications and sharing of geological data, only some functions of the geological information management system can be completed.

There are two key problems in the existing urban geological information management systems: (1) the systems are mainly developed based on C/S structures, and they are unable to realize the sharing of geological data and services across multiple departments with different requirements. However, comprehensive urban geological systems based completely on B/S structures have not been reported. (2) Due to the large amount of data, a large-scale 3D geological model may be displayed and analysed slowly on a browser. These limitations affect the efficient utilization of the urban geological system and make it difficult for different entities to share geological data and services.

In view of the above problems, the key technologies of large-scale urban geological information management systems based on B/S structures are studied, including efficient management technology for large-scale geological data, application and sharing technology, 3D geological optimization modelling and analysis technology. Based on the above technologies, we developed an urban geological information management system for a city in eastern China. The system provides ''land and resources in one map'', thereby establishing a platform for the sharing of geological data and services among different entities, such as land and resource, urban planning and construction, water conservancy and transportation entities, and providing technical support for the construction of ''smart cities''.

II. MANAGEMENT OF LARGE-SCALE GEOLOGICAL DATA BASED ON A B/S STRUCTURE

Geological data management is the basis of an urban geological information management system. It provides support for the application and sharing of geological data and an independent working management environment for multisource and heterogeneous geological data. The existing data management methods are mainly divided into two kinds: based on a C/S structure and based on a BS structure.The methods based on C/S structure has many limitations in big data management, application and sharing. In terms of the methods based on B/S structure, due to the multitype and multispecialty geological data, a specific problem often involves multiple databases and multitype data. For geological data, the general data management methods may lead to excessive data query and analysis. In large-scale geological data management based on a B/S structure, we need to solve the following two problems: (1) the large amount of data reduces the efficiency of data storage, querying and analysis and slows down the browser speed, and (2) the large numbers of specialties and types of data lead to redundancy in data management tools and affect the efficiency of system operation.

The solution to the above problems is as follows. First, we need to study the front-end and back-end data management modes based on a B/S structure; second, we need to optimize the efficiency of multitype and multispecialty data management based on a B/S structure. For the former, the necessary functions must be established for the browser, such as display and management functions, and many other functions are established for the server, such as data storage, querying and analysis functions, to reduce the browser load and improve the efficiency of data management. For the latter, we group the data by type to reduce the number of data management tools for the browser and avoid problems such as slow browsing caused by too much data.

A. FRONT-END AND BACK-END DATA MANAGEMENT MODES BASED ON A B/S STRUCTURE

Geological data are characterized by large amount of data, multiple topics and multiple types. For a specific application, there may be many data tables involved and most of the data in these tables is useless. For a system based on a C/S structure, we may need to query a large number of data tables on the client to solve a problem. But for a system based on a B/S structrue, by the front-end and back-end data management modes, we can set all the data tables and query operations on the server and return the result data to the browser.

The relationship between the browser data and the background server data is shown in Figure 1. The background server is responsible for the storage, querying and analysis of all geological data, and the front end is responsible for user interaction tasks, such as displaying data and obtaining user instructions. When the user operates in the browser, front-end modules package some information into JSON format data. These information include the corresponding function interface and data table name obtained from the front-end modules, as well as the parameters input by the user. By these information, fornt-end controller requestes data from the back-end server. Then the server passes the request data to the servlet components deployed in the server. The servlet components generates query statements based on the request data and obtains data from the database, then processes the data according to specific needs and sends the result data back to the front-end browser for display. The "small front end, large back end" approach can reduce the network transmission of large-scale data and front-end resource use and improve the efficiency of large-scale geological data management.

A data management task may involve querying and displaying multiple types of data simultaneously, which may lengthen the system response time. To solve this problem, we studied the technique of data correlation and step by step loading, which enables browser to load and display the main information and load other relevant data according to the data correlation when users query geological information.

B. MULTITYPE AND MULTISPECIALTY DATA GROUPING MANAGEMENT BASED ON A B/S STRUCTURE

Geological data can be classified into various types of data, including basic geographic data, engineering geological data, bedrock geological data, hydrogeological data, mineral resource data, geological disaster data, etc. Moreover, the data formats include tabular data, spatial data for 3D geological models, GIS-type layer data, document data and so on. Determining how to classify and manage data is an important factor that affects the efficiency of data management and application tasks.

The system provides different management tools for different types of data in browsers, including tools for inserting, modifying and exporting tabular data and tools for viewing, uploading and downloading document data. The data should be classified by type first, so that the data management tools can be set in each major category. However, if the data type is classified by application area first, the browser may become slow due to the use of too many data management tools. Thus, data management will become less efficient. Therefore, geological data should be classified into several categories according to the data type and format. Then, in these categories, data can again be categorized according to the application area. A classified management scheme for urban geological data is shown in Figure 2.

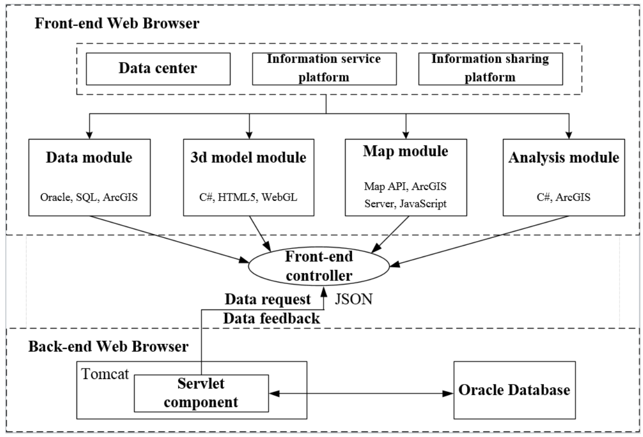


FIGURE 1. Data management mode between the browser and server.

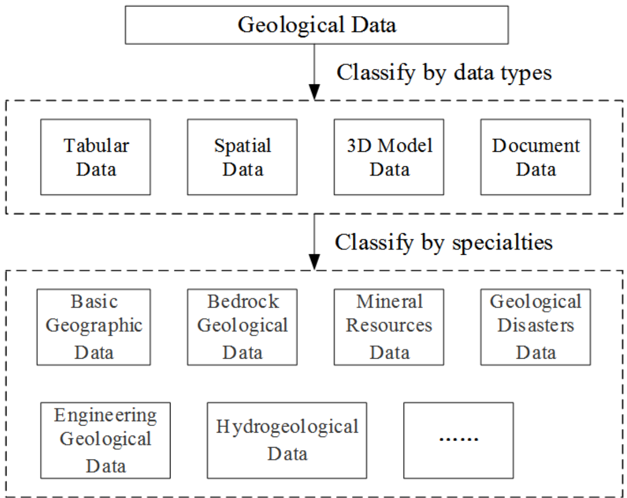


FIGURE 2. Classified management of urban geological data.

Compared with other classification methods, this geological data classification method can use fewer data management tools and is more suitable for the gelogical information management system based on a B/S structure.

Developing front-end and back-end data management modes and multitype and multispecialty data grouping management methods based on a B/S structure can reduce the browser load for large-scale geological data management and improve the efficiency of data management to increase support for the application and sharing of geological data.

III. APPLICATION AND SHARING OF LARGE-SCALE GEOLOGICAL DATA BASED ON A B/S STRUCTURE

Based on a B/S structure in large-scale geological data applications, geological data management involves the comprehensive evaluation and visual analysis of geological data, including the management of underground space resources, cultivated land resource management, the management of groundwater resources, mineral resource management, the management of geological landscape resources, geological hazard point identification, and soil assessment. In the application and sharing of large-scale geological data, the following two problems must be solved: (1) geological data are massive and unintuitive, and (2) data isolation among different entities and specialties is not conducive to collaborative analyses of data. To solve these problems, it is necessary to quickly find the data matching the target function from the massive data set and display these data graphically. Additionally, collaborative analyses among different entities with specific data should be strengthened to improve the application and sharing of geological data.

A. AUTOMATIC DRAWING OF GEOLOGICAL MAPS BASED ON A B/S STRUCTURE

In the application of large-scale geological data, the data involved in a specific task are generally only a fraction of the total data and may be distributed in many different data tables or even databases, which causes certain difficulties in the application of geological data. Moreover, some types of data are not intuitive, such as tabular data, which are not conducive to user's quickly understanding the data and not ideal in certain applications. Therefore, to efficiently use large-scale geological data, the information matching the target function must be identified from massive multitype and multispecialty geological data sets and sended to browser in the form of professional maps.

For example, when users need to query a geological database of borehole data, they may query in accordance with the coordinates in engineering and borehole tables and then use a borehole number query to sort the information. Then, standard penetration information in borehole data tables and standard penetration test tables may be used. This process requires 3 queries, as shown in Figure 3. Moreover, the queried information exists in the form of words and numbers, which cannot directly reflect the geological situation at a given location and not ideal for some applications involving

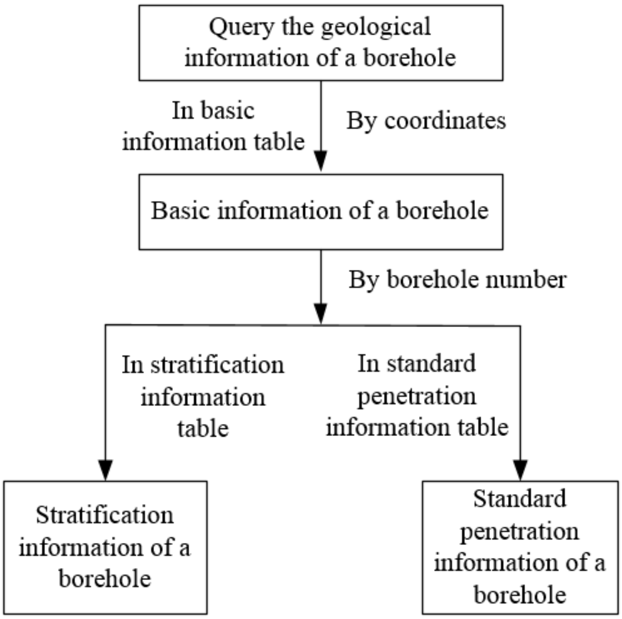


FIGURE 3. Query process of tabular data.

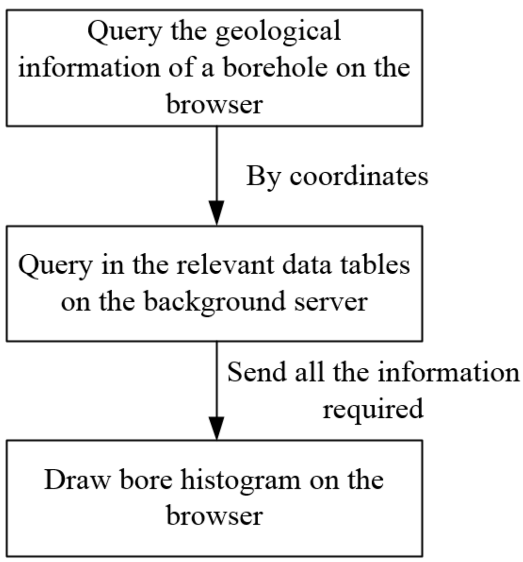


FIGURE 4. Automatic creation process of borehole histograms.

geological data and data sharing. The efficiency of applying geological data can be improved by the professional rendering of unintuitive and discrete data. The automatic creation of borehole histograms is one such approach to address the above problems. The location information is passed from the background server to the front-end browser, and the server quickly queries the relevant borehole data in the database and sends all the information required for borehole histogram creation to the front-end browser to complete the histogram creation process, as shown in Figure 4.

Automatic drawing on a B/S based system needs to automatically draw pictures in standard format on the webpage.

However, due to the insufficient support for drawing on the webpages, there are a series of problems with drawing pictures in standard format. In terms of the drawing of bore histogram, the method of drawing table on the webpages cannot deal with some complicated table lines well, while the method of drawing image may cause format confusion due to too much text information and pagination. To solve this problem, we develope a method of associating canvas and table to realize the standard bore histogram drawing on the webpages. In terms of the drawing of geological profile, There are two main problems: (1) how to draw seamless and non-overlapping profile automatically; (2) how to draw and modify vectorized sections on the webpages. For the former, we develope a method to unify the stratigraphic sequence, which can automatically judge the special situations such as stratum-absence, stratum-reversion and so on without manual intervention. The method can avoid the formation gap and overlap fault. For the latter, we develope a method of completely vector mapping, which can vectorize the formation boundaries and fill the vectorized lithologic textures, and provide the function of modifying in the browser.

The automatic creation of professional maps is based on the current general query method and takes into account the characteristics of multisource heterogeneity of geological data. By this method, the server quickly finds information matching the target function from multiple related data sets and sends the information to browser in the form of professional maps. It can solve problems related to the size of geological data sets and unintuitive of the data to visualize geological data, thus improving the efficiency of data application. Based on the B/S structure, the resulting maps and even functions can be shared among different entities to enhance the application efficiency of geological data.

B. COLLABORATIVE ANALYSIS OF MULTISPECIALTY DATA BASED ON A B/S STRUCTURE

Users can publish geological survey data and results in a spatial database using WebGIS technology and display the data in a mapping interface. This function is very common in urban geological information management systems. With this function, the visualization of geological data can be realized, but collaborative analyses of multispecialty data are rare. Such analyses play an important role in the application of massive multispecialty geological data sets and resource sharing among various entities.

In collaborative analyses of multispecialty data, geological data should be published as spatial layer data that conform to the standard OGC (Open Geospatial Consortium) service, and these spatial layers can be displayed and overlain. An effective analysis system can also analyse the relationships among layer data sets in the background server and then display the results in the browser.

Collaborative analyses of multispecialty data are often performed for comprehensive data analysis, including in engineering construction suitability zoning, determining the distribution of weak strata, and land use status zoning for project site selection. Collaborative analyses of data, including for underground space utilization suitability zoning, engineering construction suitability zoning, groundwater resource distribution zoning, and land use status zoning, can aid in underground space development.

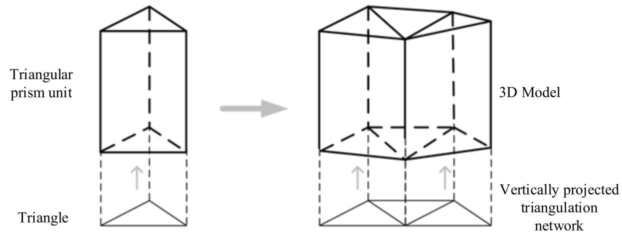


FIGURE 5. Relationship between the vertically projected triangulation network model and the triangular prism model.

IV. OPTIMIZATION MODELLING AND ANALYSIS OF LARGE-SCALE 3D GEOLOGICAL DATA BASED ON A B/S STRUCTURE

The data structure is the basic form of 3D geological model storage and is very important for 3D geological modelling. Notably, the structure influences the amount of model data, the recording method of topological relations and the efficiency of correlation calculations. Because of the data structure, it is difficult to further optimize the data and computational redundancies of the current commonly used triangular prism model [19], [20]. When the model is sufficiently large, it is difficult to display and analyse data quickly in a browser. Therefore, a new data structure and algorithm are necessary to optimize the data and implement the 3D geological model.

This paper uses a two-dimensional projection to simplify the model data and proposes a new data structure for the 3D geological model based on a vertical projected triangulation network to describe the triangular prism model. Based on the vertical sides of the triangular prism, the horizontal coordinates and topology of the 3D model can be recorded by a 2D vertical triangular network. A triangular prism can be seen as an extension of a two-dimensional triangle in three dimensions. Similarly, each stratum in a three-dimensional geological model can be considered a vertical extension of part of the vertically projected triangulated network, as shown in Figure 5. The vertically projected triangulation network can record the coordinates and topological relations of the 3D geological model in the horizontal direction and can reduce the data volume and the computation burden of cutting operations.

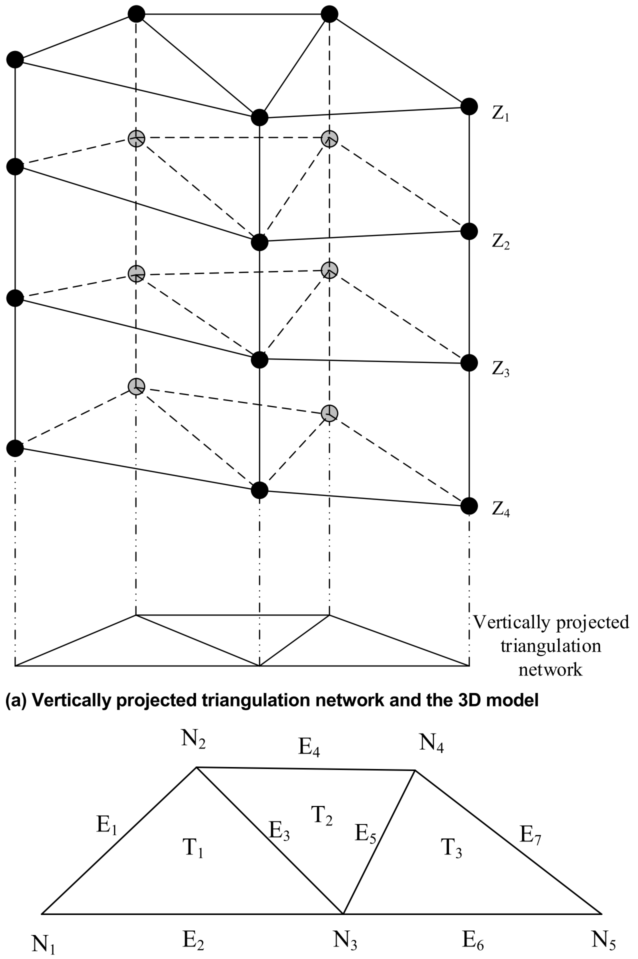
The data structure of the vertically projected triangulation network records all the nodes, edges, triangles and their interconnections, and is composed of three data structures: Node, Edge and Triangle. Node represents a mesh node and contains the following attributes: index of the nodes, two-dimensional coordinates, and an array of adjacent triangle edges; Edge represents a triangle edge and contains the

TABLE 1. Point elements and the information recorded.

Element	Coordinate (x,y)	Edges	Coordinates(z)
N_1	x_1, y_1	E_1, E_2	$z_{11}, z_{12}, z_{13}, z_{14}$
N_2	x_2, y_2	E_1, E_3, E_4	$z_{21}, z_{22}, z_{23}, z_{24}$
N_3	x_3, y_3	E_2, E_3, E_5, E_6	$z_{31}, z_{32}, z_{33}, z_{34}$
N_4	x_4, y_4	E_4, E_5, E_7	$z_{41}, z_{42}, z_{43}, z_{44}$
N_5	x_5, y_5	E_6, E_7	$z_{51}, z_{52}, z_{53}, z_{54}$

TABLE 2. Edge elements and the information recorded.

Element	Nodes	Triangles
E_1	N_1, N_2	T_1
E_2	N_1, N_3	T_1
E_3	N_2, N_3	T_1, T_2
E_4	N_2, N_4	T_2
E_5	N_3, N_4	T_2, T_3
E_6	N_3, N_5	T_3
E_7	N_4, N_5	T_3



(a) Vertically projected triangulation network and the 3D model

(b) Nodes, edges and triangles of the vertically projected triangulation network

FIGURE 6. Nodes, edges and triangles of the model.

TABLE 3. Triangle elements and the information recorded.

Element	Nodes	Edges
T_1	N_1, N_2, N_3	E_1, E_2, E_3
T_2	N_2, N_3, N_4	E_3, E_4, E_5
T_3	N_3, N_4, N_5	E_5, E_6, E_7

following attributes: index of the triangle edge, two nodes of the triangle edge, and adjacent triangle; Triangle represents a triangle and contains the following attributes: index of the triangle, three nodes of the triangle, and three edges of the triangle. Figure 6 shows the nodes, edges and triangles of the model. Table 1, 2, and 3 record each node, edge and triangle element of Figure 6 and the information they record and associate. An element among node, edge, triangle can be quickly found by other elements. For example, it can be quickly found that the two endpoints of E_3 are N_2 and N_3, and the triangles on both sides of E_3 are T_1 and T_2. This provides convenience for the vertical cutting of the model: the cutting of a series of triangular prism elements is simplified into the cuttting of a series of triangle. And in the triangular prism elements corresponding to triangle T_2, the second layer of triangular prism elements can be expressed as the space surrounded by 6 nodes corresponding to the second and third z coordinates of N_2, N_3 and N_4.

The data stored in the 3D geological model can be divided into two main categories: coordinate data and topology data. The coordinate data are the coordinates of all the nodes in the model, and the topology data reflect the relationships among the elements, such as the nodes that form edges, edges that form surfaces and surfaces that form bodies. The remaining data, such as the strata layers, physical properties and mechanical properties, are relatively independent. Therefore, the remaining data are not considered in this paper.

In terms of coordinate data, we assume that each number occupies 1 memory space and that the traditional data structure occupies 3 memory spaces per node because of the three dimensions. In the new data structure, because the sides of the triangular prism are vertical, the node coordinates of the triangulation network can be used to record the node coordinates of the 3D model. We assume that the 3D geological

FIGURE 7. Data centre page.

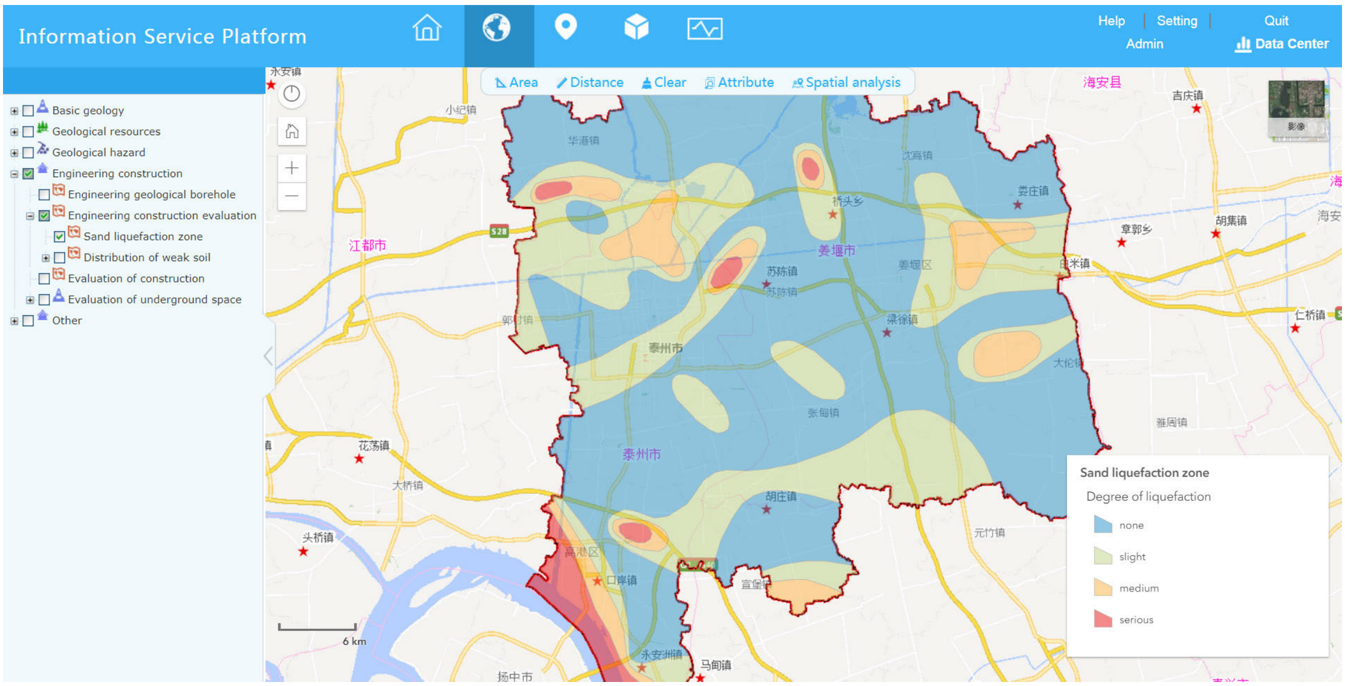
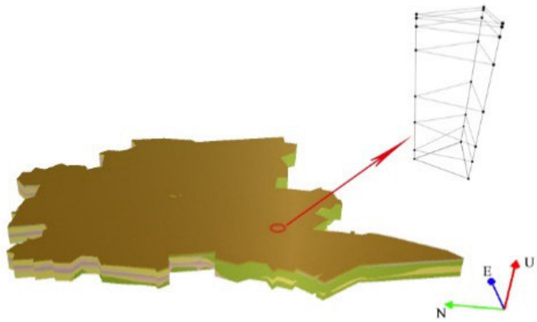


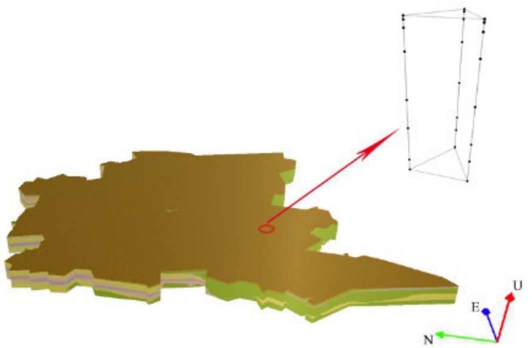
FIGURE 8. Geological data display in "One Map".

model consists of n strata ($n \geq 1$), and we focus on a vertical side. The space occupied by the model based on a triangular prism is $3\,(n+1)$, and the memory space occupied by the data structure of this paper is $2 + (n+1)$. When $n \geq 3$, the new model reduces the number of node coordinates by 50% or more compared to the number in the old model. Additionally, more strata can be included in the model, and more memory can be saved, approaching a total memory reduction of 66.7%.

In terms of topological data, spatial analysis such as cutting, underground roaming, requires a complete topology of the model, and this new data structure can fully express the



(a) 3D geological model based on a triangular prism structure



(b) 3D geological model based on a vertically projected triangulated network

FIGURE 9. 3D geological model.

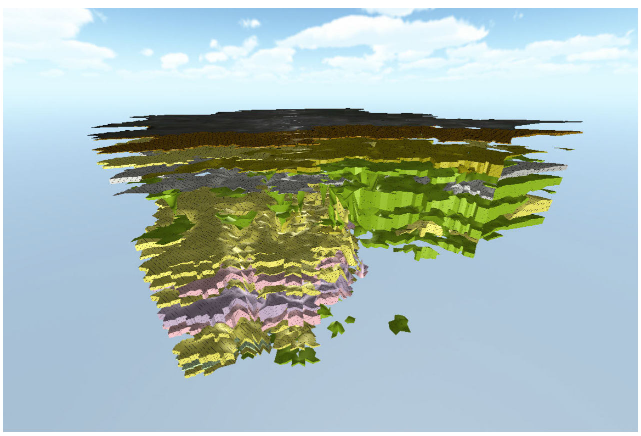


FIGURE 10. Strata hierarchical display.

topology of the model, so this simplified model can be used for spatial analysis in the browser. The new data structure can simplify the topology of the 3D model. The simplified topology is based on a two-dimensional triangulation network with a series of z-coordinates, so it does not need to store the topological data between faces and units, so the memory usage will be further reduced. Also, because of this topology, we can quickly update the model as the modeling data changes. For example, when we collect new borehole

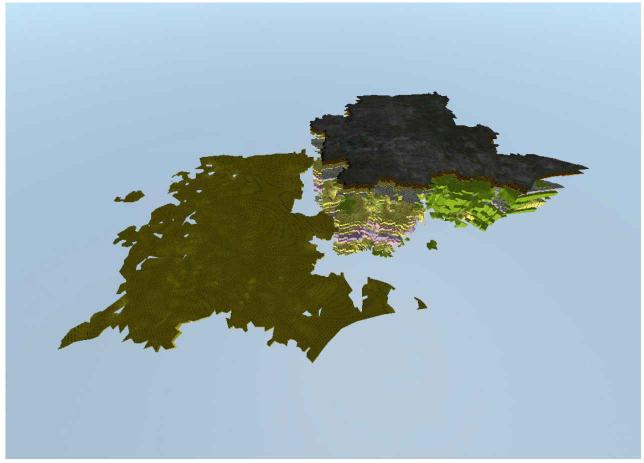


FIGURE 11. Strata dragging.

data, we first add new nodes, then edges and triangles to the projected triangulation network, and then calculate which original nodes will be affected by the newly added nodes, and finally modify the corresponding z-coordinates of these nodes. With this approach, we can complete a quick local update of the model instead of remodelling it.

To sum up, Compared with the triangular prism data structure, the new data structure has a significantly smaller data volume that can better support analyses of 3D models in browsers. At the same time, based on the simplification of topological relationships of this data structure, the computation amount of a series of spatial operations, such as cutting and roaming, can be reduced. These characteristics can reduce the load of browsers and servers during the model runtime.

V. APPLICATION

The above technical methods are applied to the geological information management of a city in eastern China to establish an urban geological information management system. Based on the B/S structure, the system integrates the management, application and sharing of geological data and is divided into three platforms: a geological data centre, an information service platform and an information sharing platform. The system includes the construction of 12 attribute data tables, 4 special spatial databases and 68 spatial data layers. The size of the designed geological data set exceeds 100 GB. A total of 786 boreholes were used for 3D geological modelling, with a modelling area of 1567 km^2. The models include engineering geological models, hydrogeological models and quaternary geological models.

The geological data centre is the data foundation of the entire system and provides data support for the information service and information sharing platforms. Additionally, the centre provides an independent management environment for multisource and heterogeneous geological data and manages and maintains massive geological data sets. Data management is divided into three categories: attribute data management, file management, and map

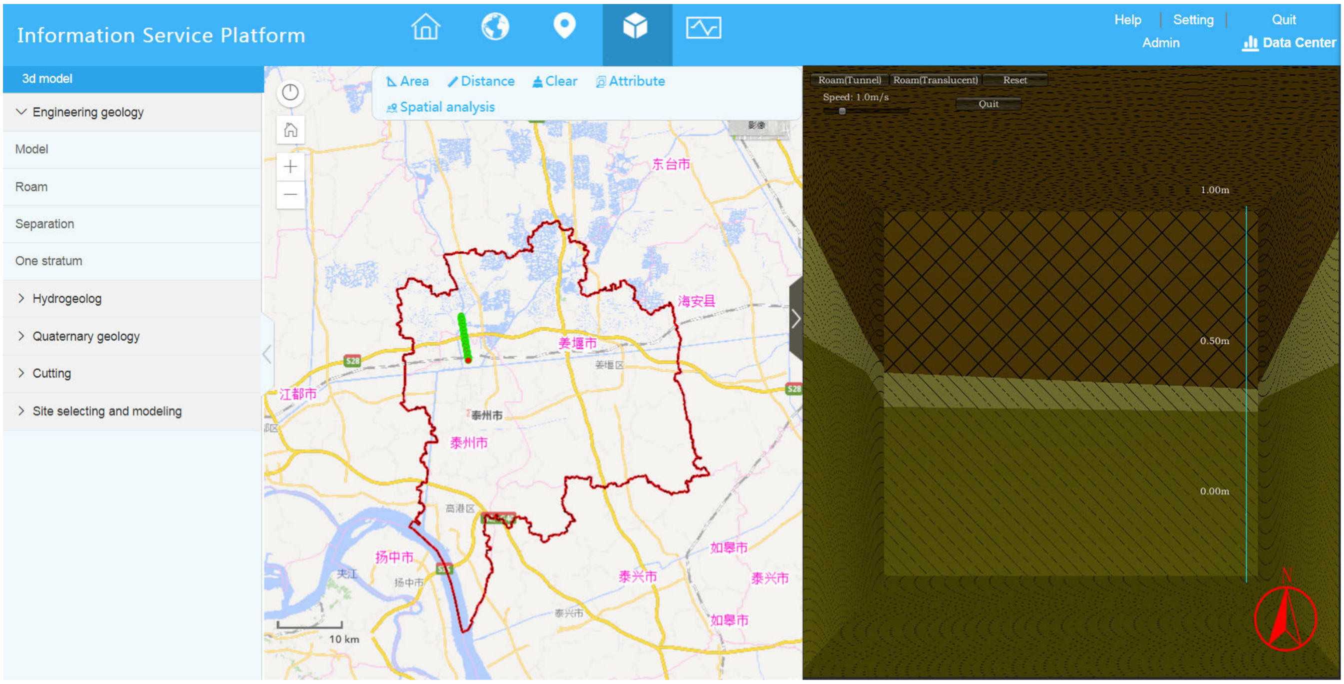


FIGURE 12. **Underground roaming a linkage between two and three dimensions.**

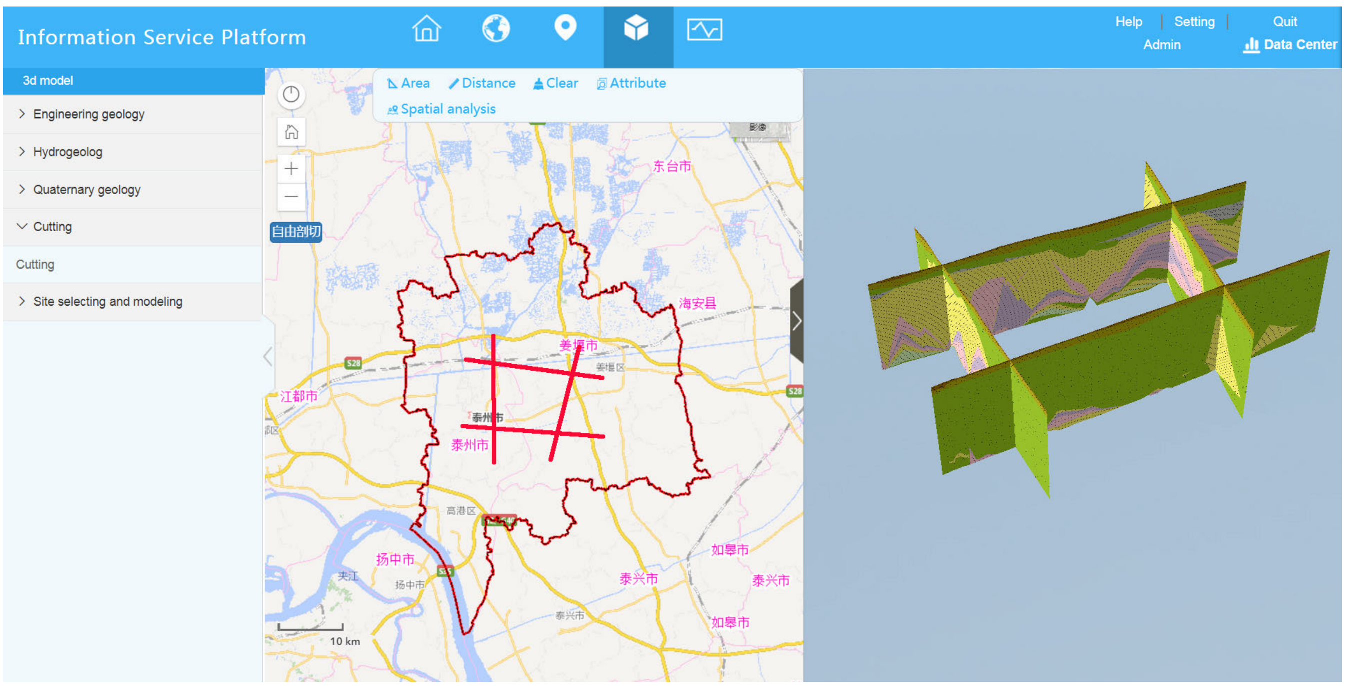


FIGURE 13. **Cutting with a linkage between two and three dimensions.**

service management. Data in each category are integrated and managed according to their specific types, such as basic geography, basic geology, engineering geology, hydrogeology, geophysics, geochemistry, geological disaster, mineral resource, ecological and environmental safety data types. This approach allows for large-scale geological data management in the browser. The data centre page is shown in Figure 7.

An information service platform is used for the application of geological data. Based on the multisource heterogeneous data provided by the geological data centre, the platform generalizes the rules of geological data and

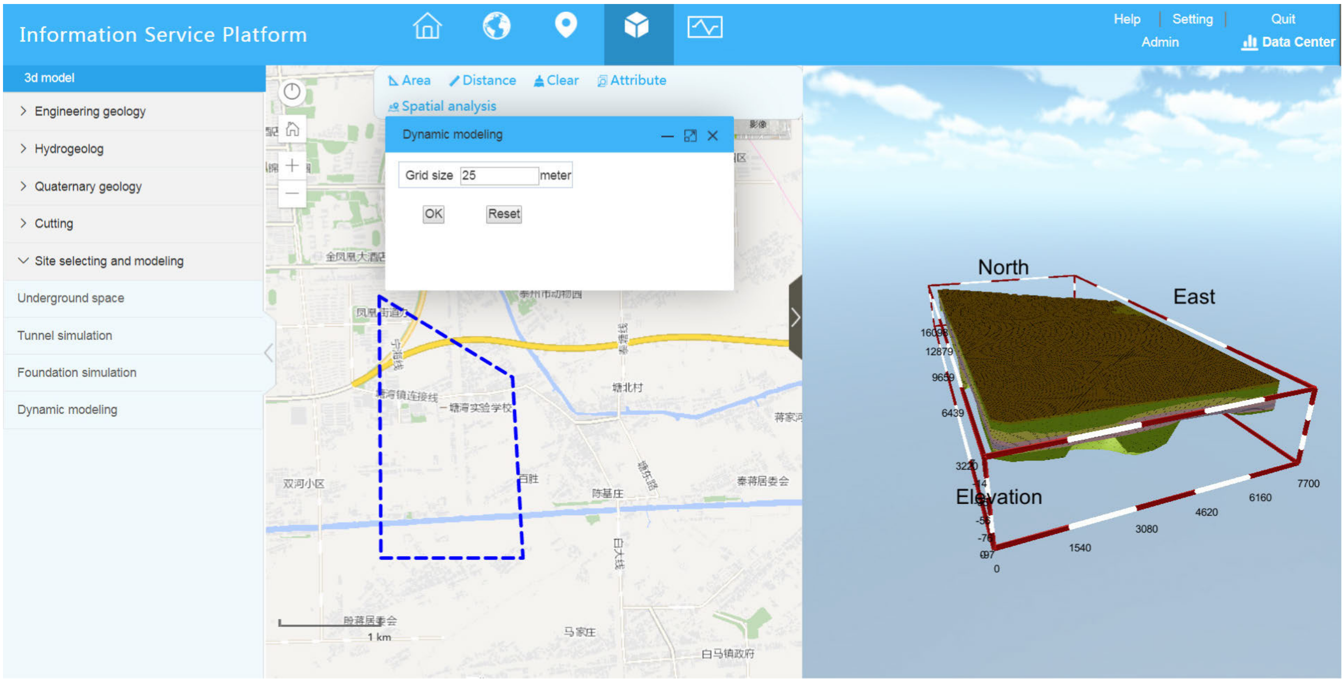


FIGURE 14. Site selection and modelling.

serves in application tasks. Using the urban geological information service platform, geological surveys can be integrated into the daily work processes of the government, geological professional analyses and decision-making consultation processes for different departments, and comprehensive, intelligent and standardized basic service platforms can be provided for professional technical personnel to support the construction of "smart cities". The information service platform includes four submodules: geological data in "One Map", aided drawing, three-dimensional analysis and environmental monitoring. The "One Map" display of geological data in the information service platform (Figure 8) can also be used for the collaborative analysis of geological data.

The traditional tri-prism structure and vertically projected triangulation network structure were used for modelling. The modelling results are shown in Figure 9. The 3D geological model based on the tri-prism structure is shown in Figure 9(a), and the 3D geological model based on the vertically projected triangulation network is shown in Figure 9(b). There is no obvious difference between the two modelling methods in the appearance of the model, but the model in Figure 9(b) uses 25.3% of the running memory of the model in Figure 9(a). Therefore, the model based on the vertically projected triangulation network can obviously reduce the amount of model data needed and lay a foundation for large-scale 3D geological modelling and analysis in browsers.

Compareing the TP model and VPTN model, there is no significant difference in the appearance. The number of elements and the memory space occupied at runtime are shown in the Table 4 and Table 5.

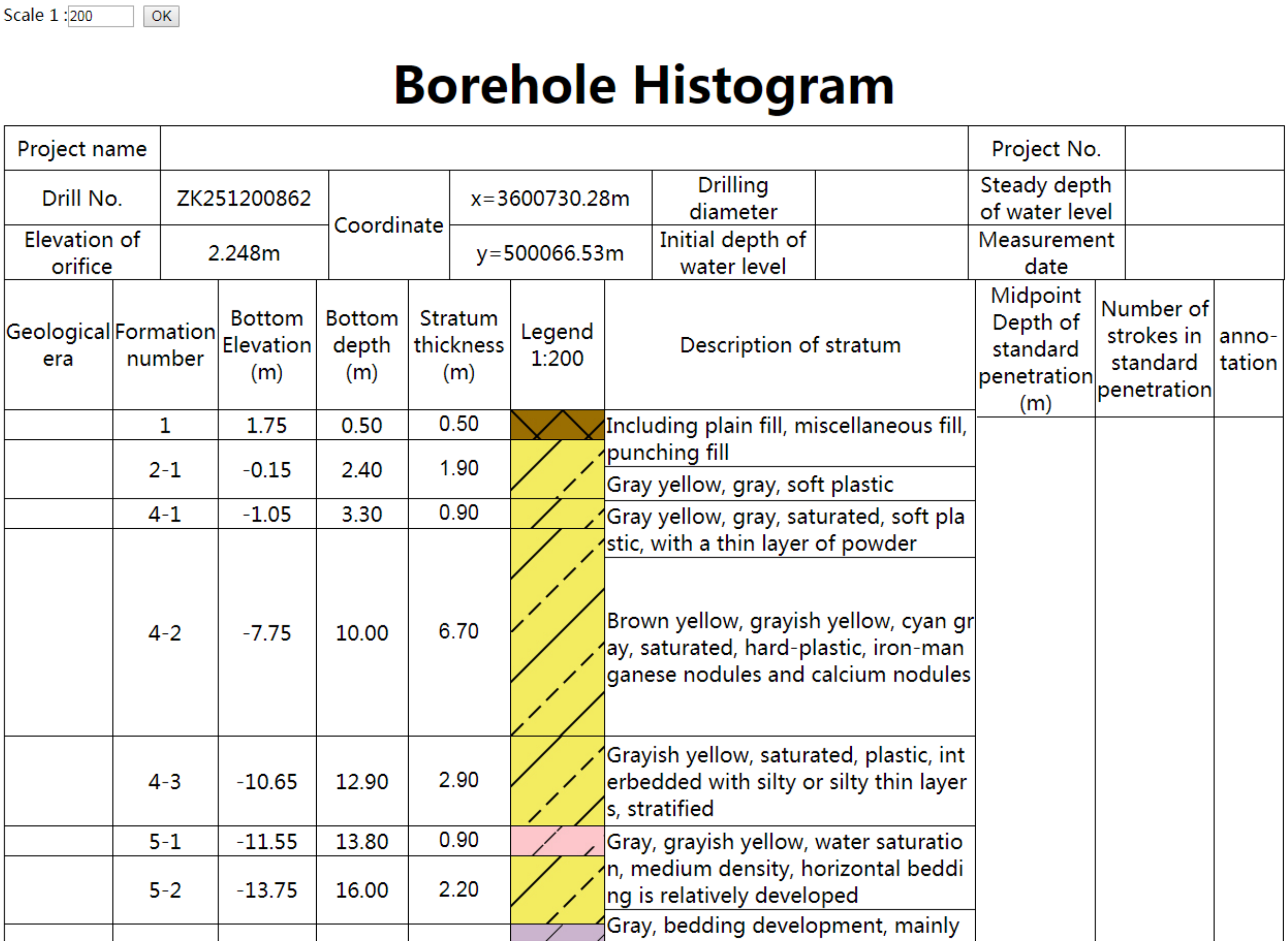
TABLE 4. Data volume of TP model.

		Amount
Number of elements	Point	35840
	Face	160163
	Unit	65002
Memory space occupied at runtime		19.3MB

TABLE 5. Data volume of VPTN model.

		Amount
Number of elements	Node	2962
	Edge	8376
	Triangle	5391
Memory space occupied at runtime		4.9MB

As we can see from Table 4 and Table 5, the ratio of the number of triangle elements in the TP model to the number of unit elements in the VPTN model is about 1 to 10. It indicates that there is about 10 layers on average in this model. For the models in different areas, this ratio may be different, which is related to the stratigraphic conditions in the modeling area


Scale 1 :200 OK

Borehole Histogram

Project name						Project No.	
Drill No.	ZK251200862	Coordinate	x=3600730.28m	Drilling diameter		Steady depth of water level	
Elevation of orifice	2.248m		y=500066.53m	Initial depth of water level		Measurement date	

Geological era	Formation number	Bottom Elevation (m)	Bottom depth (m)	Stratum thickness (m)	Legend 1:200	Description of stratum	Midpoint Depth of standard penetration (m)	Number of strokes in standard penetration	anno-tation
	1	1.75	0.50	0.50		Including plain fill, miscellaneous fill, punching fill			
	2-1	-0.15	2.40	1.90		Gray yellow, gray, soft plastic			
	4-1	-1.05	3.30	0.90		Gray yellow, gray, saturated, soft pla stic, with a thin layer of powder			
	4-2	-7.75	10.00	6.70		Brown yellow, grayish yellow, cyan gr ay, saturated, hard-plastic, iron-man ganese nodules and calcium nodules			
	4-3	-10.65	12.90	2.90		Grayish yellow, saturated, plastic, int erbedded with silty or silty thin layer s, stratified			
	5-1	-11.55	13.80	0.90		Gray, grayish yellow, water saturatio n, medium density, horizontal beddi ng is relatively developed			
	5-2	-13.75	16.00	2.20					
						Gray, bedding development, mainly			

FIGURE 15. Site selection and modelling.

and has an effect on the memory space of model. In general, the larger the average number of layers is, the smaller the ratio of the VPTN model data volume to TP model data volume is.

The information service platform provides a 3D engineering, geological, and hydrogeological model and a quaternary geological 3D model and includes functions such as the hierarchical display of strata, underground roaming with linkages between two and three dimensions, cutting with linkages between two and three dimensions, site selection and modelling, which strengthens the application of the 3D geological models. The main functions are shown in Figure 10 to Figure 14.

The information service platform performs professional drawing based on the B/S structure and can quickly draw borehole histograms and engineering geological sections in the browser. Example borehole histograms and sections are shown in Figure 15 and Figure 16, respectively. Based on the 3D geological model data, the system can draw the histograms of virtual boreholes and the virtual profiles in areas without boreholes, which strengthens the application of the 3D geological modelling data.

The information sharing platform is open to public and professional application users, mainly to provide geological survey results to the public, data sharing capabilities for service modules and data support for comprehensive decision making by various government entities. The main components of this platform include the news centre, open data view and download and management of results release.

The main user of this system is the Land and Resources Bureau of the city. They use this system to strengthen the support of geological work for the construction of new urbanization, and to explore a new mode of urban geological survey. The staffs respond that compared with theirold working software which based on a C/S structure, the new system has the following advantages: (1) the functions of geological data application are more powerful; (2) real-time updating of geological data becomes easier; (3) work products are more easily shared and submitted. Additionally, the technical information presented in this paper are also used in the urban geological information management system of another city in eastern China, whose users' response are similar to the above.

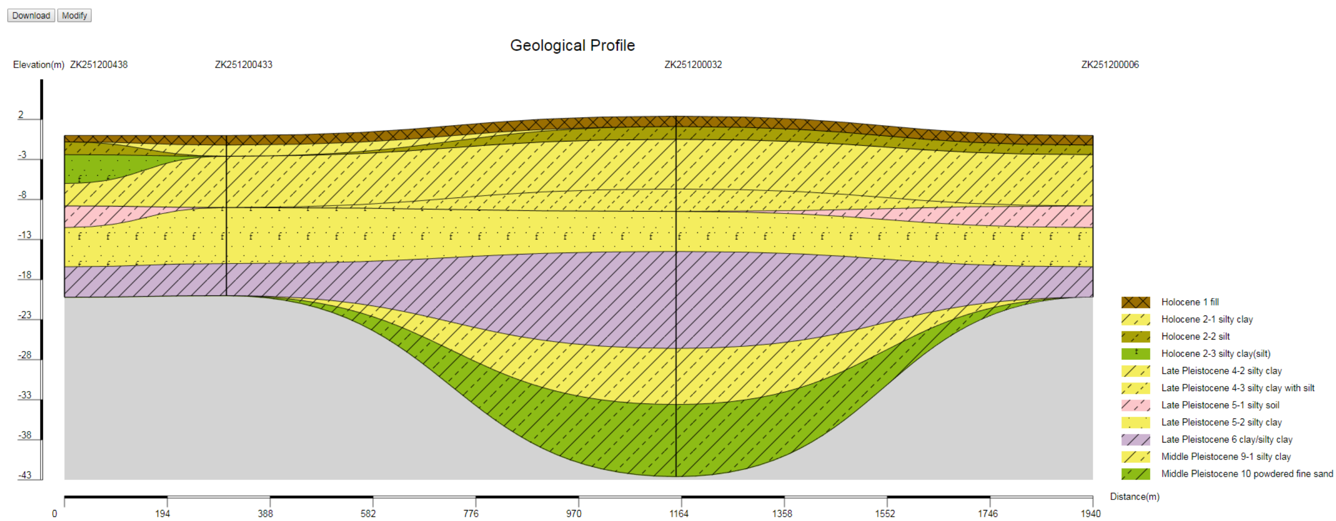


FIGURE 16. **Geological profile in the browser.**

VI. CONCLUSION

1) Aiming at the problem of how to efficiently manage large-scale geological data based on a B/S structure, based on the characteristics of large amount and multisource heterogeneity of geological data, this paper proposes front-end and back-end data management modes and a multitype and multiprofessional data grouping management method to greatly improve the efficiency of geological data management. The application and sharing of large-scale geological data based on the B/S structure are studied and improved by adopting automatic drawing technology to obtain professional maps and collaborative analysis technology for multiprofessional data.

2) In terms of 3D geological optimization modelling and analysis, a new data structure is proposed that can effectively reduce the data and calculation requirements of large-scale 3D geological models and better support the analysis of 3D models in browsers.

3) These technologies are applied to the geological information management system of a city in eastern China, and they are successfully implemented for the management, application and sharing of large-scale geological data in a browser for large-scale three-dimensional geological model analysis. This system verifies the reliability of the technical method proposed in this paper and provides important technical support for promoting the sharing of geological data and services among different entities, such as land and resource, planning and construction, water conservancy and transportation entities.

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