Research on the application of large area 3D geological modeling splicing technology

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Abstract: Three-dimensional geological modeling is widely used in the field of geological research. A successful three-dimensional geological model is a three-dimensional anatomy and integration of the study area. Large-scale three-dimensional geological modeling is limited by software performance and technical difficulties. There are disadvantages such as unequal model splicing elements, morphological distortion and attribute incompatibility. Based on the discrete storage method of DepthInsight software, this paper explores the large-area model fusion and splicing technology to deal with various geological conditions, and carries out large-area multi-block model fusion and splicing from the aspects of element type, quantity and attribute. The large-area 3D geological modeling technology scheme of discrete storage and block splicing is realized, which provides a reference for establishing a large-area 3D geological model.

Keywords: Large area 3D geological modeling; discrete storage; fusion splicing.

1. Introduction

Three-dimensional geological modeling is an organic combination of geological theory and computer three-dimensional visualization[1], the comprehensive interpretation of geological data and the establishment of geological model in three-dimensional space environment can clearly and intuitively express the superposition relationship of geological bodies on spatial scale. As early as the 1970 s, developed countries have begun to develop three-dimensional geological modeling software. After decades of continuous development and update technology, it has become increasingly mature[3], among them, there is GoCAD software developed by Nancy University in France[4], Micromine software developed by Micromine Australia[5], And Petrel software developed by Schlumberger[6]. The research and development of domestic 3D modeling software began in the 1990s, and the MapGIS series software of Zhongdi Digital Group [7], Creatar Xmodeling geological modeling software developed by Beijing Chaowei Chuangxiang Information Technology Co., Ltd[8], DepthInsight software developed by Beijing Grid Tiandi Software Technology Co., Ltd[9]. In 2012, China Geological Survey deployed three-dimensional geological survey pilot work, and deployed 13 pilot sub-projects in three typical areas : important orogenic belt, metallogenic belt and ore concentration area, economic zone and urban agglomeration. In 2017, the China Geological Survey formulated the construction of the ' underground transparent Xiong 'an ' project ; since 2019, Chongqing has successively carried out three-dimensional spatial and temporal information database pilot of natural resources, three-dimensional geological model construction of Jinyun Mountain area in Chongqing, three-dimensional geological modeling project of Chongqing demonstration mining area, three-dimensional visualization model of urban geology in Tongnan District of Chongqing, three-dimensional basic geological survey project of Wulong District of Chongqing, etc.

With the increasing demand for modeling software performance and the continuous expansion of the research area, the three-dimensional modeling of large areas is seriously limited by the performance and technical difficulties of modeling software, and it is difficult to realize the construction of three-dimensional geological model of large areas at one time. Aiming at the difficulties of large-area 3D geological modeling, this paper proposes the modeling idea of ' discrete storage + block splicing ', and discusses the multi-block 3D model fusion splicing technology.

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2. Rationale

Discrete storage is a combination scheme of big data distributed storage technology and relational database. The basic idea is to store the model data discretely in the database first, and then to fuse the type, quantity and attribute of the elements. It supports the call extraction of any local model, avoids the location deformity and attribute impassability caused by the model stored in file form, and is the basis for constructing the update mechanism of three-dimensional geological model[10].
Block splicing is to integrate two adjacent models into an overall model one by one according to the type, quantity and attributes of elements. The information storage form in the large work area module is tables and fields. In the actual research, the cells are specified, that is, the block size is set to create a new model, and the partition results are saved to the database file (Figure 1a). Each cell is stored in the database, and the information set is called the slice element (Figure 1b). Generally, the information is recorded in the form of fields. When the local model is called, the slice element is judged to be locked, and the slice element data and grid within the call range and the extension area data and grid are guaranteed. The data is edited, and the model is established under the constraints of the extension area data and grid, so as to establish the local model (Figure 1c). The export of the local model is also derived by some kind of processing, which makes it into multiple slice models (cell models). The information of each slice model is recorded in the database (Figure 1d) and recorded in the corresponding cell table in the form of fields to realize storage (Figure 1e).

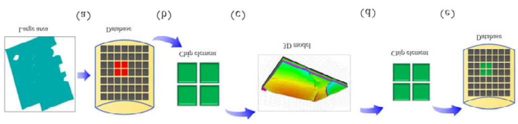

Fig.1 Flow chart of large area 3D model splicing technology

3. Model Integration

The three-dimensional geological model fusion splicing is divided into three cases : stratum splicing, structural splicing and attribute splicing. The general steps are four steps : (1) Call the working area in the large work area for editing, and the working area needs to be larger than the range of a single model ; (2) The common area needs to ensure the consistency of the number of data elements and attributes to form a determined standard profile ; (3) Trend adjustment of adjacent model dataThe boundary of two patches is connected to the standard profile. (4) Return the modified data to the large work area to complete the fusion splicing.
Of course, the following situations will occur when the model is spliced:
（1） When the occurrence of adjacent stratigraphic model elements is inconsistent, it is necessary to adjust the occurrence of both sides to be consistent with the common profile (Fig.2a).。
（2） The names of layered elements of adjacent geological models are inconsistent, such as phase change zones, which are unified according to the modeling unit standard (Fig.2b).。
（3） When the occurrence of fold structure is not coordinated in the adjacent stratigraphic model, the occurrence of both sides is adjusted according to the common section (Fig.2c).
（4） When there is inconsistency in the stratification criteria of adjacent stratigraphic models, if there is segmentation ambiguity in different models, they are unified to the group level according to the division criteria of sedimentary units (Fig.2d).

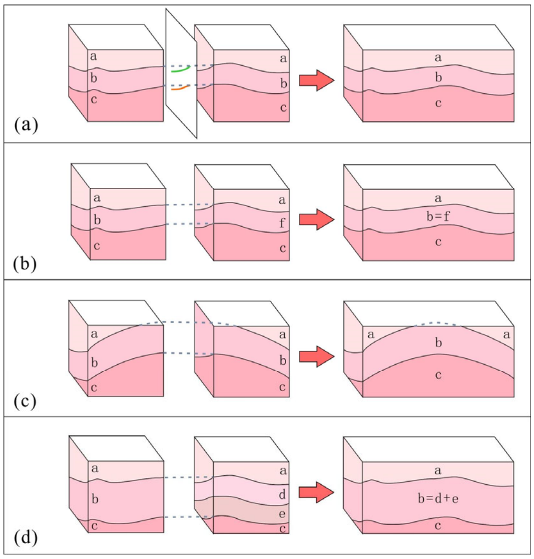

Fig.2 Different situations of model splicing (letters represent stratum code)

3.1 Strata Model Splicing

The geological data of different ranges and different fields construct a three-dimensional stratigraphic model under a unified framework. Firstly, the anisotropy of geological data between different ranges and different fields is eliminated, and the geological structure characteristics of the modeling area are uniformly recognized to ensure the consistency and correctness of the data. Secondly, it is necessary to establish a geological model database to realize the unified management and application of geological data, set up a unified grid size in the geological model database and generate an overall geological model. For applications in different ranges and different fields, models in different ranges and different fields can be mined from the model database for professional research (Fig.3).

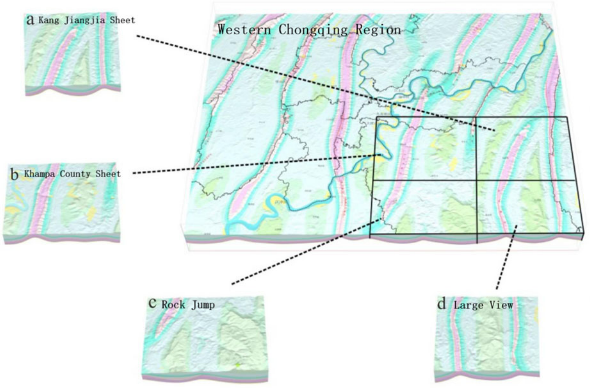

Fig. 3 Stratum model splicing results

3.2 Constructing Model Splicing

When the structural model is spliced, there are cases where the fault elements only expose a certain model or the fault elements are distributed in multiple models. Therefore, the structural model splicing is dominated by data, that is, the fault surface generation is not constrained by the boundary of the sub-region model and is only related to the data of the fault itself (Fig.4).

(1) Because the data source unit and time are different, there are different model numbers, and the modeling needs to be uniformly named.

(2) It is necessary to integrate all model data to clarify the fault occurrence, fault properties and strata of the upper and lower plates when interpreting the structure.

(3) The model boundary fault only exposes a certain map at the surface boundary, but may cross multiple models below the ground.

(4) When the fault crosses multiple models, it is necessary to call all fault and stratum data in the working area to carry out modeling.

(5) The modification of the fault model must be accompanied by the reconstruction of the stratum model, so it is necessary to modify the fault surface to reconstruct the stratum model.

(6) When modeling back, the fault can be directly spliced without modification ; fault changes have no effect on adjacent blocks, and fusion splicing can be automatically realized. Fault changes affect adjacent blocks, and blocks need to be remodeled to achieve fusion splicing.

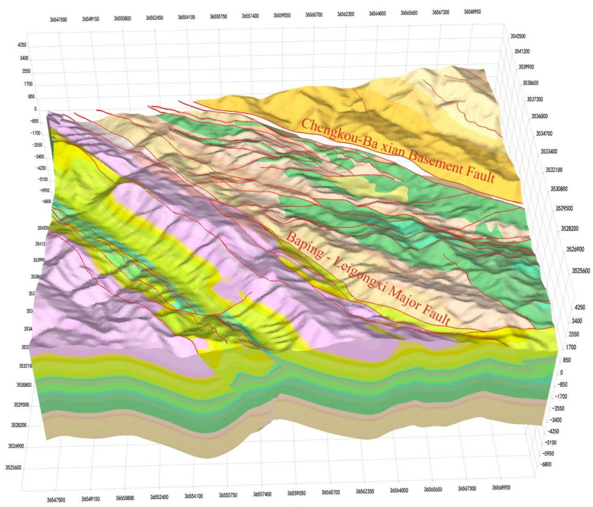

Fig.4 Structural model splicing results (Chengkou three-dimensional geological model)

3.3 Attribute Model Splicing

The attribute model is the same as the splicing method of the construction model. The whole work area is divided into many cell blocks, and the grid model, vector model and attribute model are established and stored in the model database. There is a certain splicing grid when meshing between the block attribute models. The number of grid splicing can be set by interaction. The splicing attributes can be extracted from adjacent blocks. A certain algorithm is used internally to ensure the fusion and splicing of adjacent regions of attributes. The block attributes can be updated at any time, and the model and data are synchronized in real time.

The attribute model is stored in the database in the form of three-dimensional discrete data volume. The grid structure is similar to the seismic data format. The data matrix of the attribute model information depends on the grid division in the X direction, Y direction and Z direction. When modeling, there is a certain overlap between the call modeling area and the completed area. When the local attribute modeling is performed, the reference data volume is used to extract the existing attribute data as the known data to participate in the attribute interpolation, and the boundary attributes of the control area are the same to achieve the splicing effect (Figure 5).

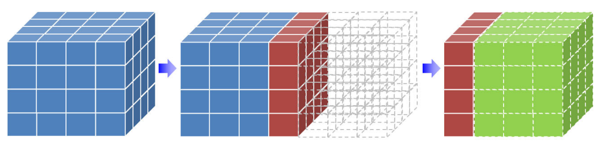

Fig.5 Attribute model splicing principle ((a) completed area, (b) overlapping area (c) overlapping area control interpolation)

4. Conclusion

In this paper, the method of large regional geological model fusion and splicing technology is discussed, and the modeling idea of ' discrete storage + block splicing ' is proposed. Aiming at the problems of stratum model splicing, structural model splicing and attribute model splicing, the corresponding solutions are given, which can effectively solve the contradiction between model accuracy and scale, and establish a large regional high-precision provincial 3D geological model. Fusion splicing technology can splice adjacent models into an overall model with unified elements and consistent attributes, which can be extended infinitely outward, and support local calls and updates inward to improve model reusability.

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