

## AN OBJECT-ORIENTED VECTOR DATA MODEL FOR 3D GEOLOGICAL VOLUME MODELING\*

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### ABSTRACT:

The 3D data model is an important issue to be solved in 3D GIS. Based on the study of the basic characteristics of geological objects and the especial requirement for computational 3D geological volume modeling, the authors give out an object-oriented 3D topologic data model for geological volume modeling. In this data model, the geological volumes are divided into four classes: the composite volume class, the complex volume class, the simple volume class and the component class. The component is the basic volume element for the division of a geological volume, and is constituted by points, characteristic links, arcs, polygons on the profile and component faces. The data model is useful in the modeling of geological volumes and relevant topologic query and analysis.

### 1. INTRODUCTION

Geological volumes are 3D spatial objects. Using computer to model geological volumes plays an important role in the study of geological issues and the exploitation of mineral resources. The 3D data model is one of the key issues of geological volume modeling. At present, some mining modeling software systems such as LYNX, Surpac, Vulcan are capable of carrying out geological volume modeling. But because of the limitation of 3D data models there are some disadvantages including the shortage of topologic query and analysis.

In recent years many scholars have made a lot of researches on the 3D data model (e.g. Houlding, 1994; Molenaar, 1990; Molenaar, 1992; Morakot, et al., 1994; Chen, et al., 1995; Chen and Guo, 1998; Li and Li, 1997; Li, 1997; Gong and Xia, 1997; Cheng and Gong, 2001; Xiao and Zhong, et al., 2001). Some of these researches have taken into account of the topologic relations between geological objects and their geometry elements. But most of the models proposed by the scholars have not been used in the practice because of many reasons. One of the reasons may be that they can't satisfy the geologists. So the 3D data model is still an issue deserving study.

The paper will firstly discuss the basic characteristics of geological volumes and the especial requirements for 3D geological volume modeling through computer, and then bring forward an object-oriented 3D topological data model for geological volume modeling.

### 2. BASIC CHARACTERISTICS OF GEOLOGICAL VOLUMES

A geological volume is of definite spatial scope, definite shape, attributes, spatial relations with other volumes, which will be change with the time. Spatial characteristic describes the spatial location of a geological volume, so called as geometrical or positioning characteristic. The shape of a geological volume may generally be irregular and has different azimuth and inclination.

The study of the attributes of the geological volume is one of the important aspects of geology study. The attributes of a geological volume can be parted as qualitative attributes and quantitative attributes. Color, lithology, constitution, structure, and so on, are the qualitative attributes. Mechanics parameters and the mineral contents and so on, are the quantitative attributes. Such quantitative attributes as mineral grade, expressed as a ratio or percentage by weight of metal to ore, exhibit spatial variability and can be measured in terms of real numeric values. They are also regarded as geological variables.

The spatial relations between geological volumes include the measuring spatial relations, the sequence spatial relations and the topologic relations. The topologic relations such as inclusion, adjacency and conjunctions should generally be described and represented in the geological volume modeling.

The geometrical characteristics and attributes of a geological volume may change with the time. Generally we are safe in assuming static conditions with regard to stratigraphy and structure. In most cases, the spatial variation of an attribute variable can also be considered static for geological modeling. But some of the attributes may change during the period of investigation. The variations of contaminant concentrations and

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the scope of subsurface contamination are typical examples. This kind of spatial variation is not considered in this paper.

### 3. THE REQUIREMENT FOR GEOLOGICAL VOLUME MODELING

The geological volume is generally located under the surface. Geologists can't acquire all of the information about the geological volume through drilling, geophysical exploration and so on. To acquire a basic cognition to the geological volume, geologists must make interpretation or prediction based on the limited information. Interpretation of complex geological conditions from limited information is a complicated task itself, whether we perform it manually on paper or with the assistance of a computer. In the conventional approach, geologists have considerably simplified the essentially 3D task by limiting it to a set of 2D sections. This has the advantage of reducing the complications to manageable proportions on each section. Every section can show the factual data and the predicted data.

We must also consider that the computer screen is a 2D interface. Although we can achieve visual simulation of three dimensions by means of perspective transformations, efficient interaction with such a simulation to define 3D localization is not so readily achievable. Attempts to define off-screen locations are confused by the ambiguity of the perspective transformation. On the other hand, interactive definition of geometry on a 2D visualization of a geological section is much more efficient and precise.

It is advantageous both to the geologists performing the interpretation and to computerization of the process itself if this 2D approach to interpretation can be maintained. Assuming, of course, that we subsequently have the means to extend and correlate these initial 2D interpretations in the third dimension to achieve a complete 3D interpretation. By reducing interpretation to a two-stage process we both simplify the process and maintain an approach that is familiar to all geologists. So the interactive interpretation based on the 2D sections is the basic requirement for the modeling of geological volume.

However, this dictates that the data model for discrete geological volumes must be compatible with an initial definition of geometry derived from a sectional approach to interpretation and, subsequently, allow modification of this geometry to accommodate interpretation in the third dimension.

### 4. THE OBJECT-ORIENTED VECTOR DATA MODEL

The object-oriented method developed in recent years is a novel and advantageous method. It regards the object as the basic element, and the objects of the same attributes and operations as a class. The object can represent not only the simple object but also the complex object. We can establish the relationships between objects through the identity number. The object-oriented model can directly represent the relationships between objects, and can record the attributes of objects at different recording length. So the object-oriented data model is regarded as the ideal model to describe the 3D objects (Chen and Gong, 2001).

Classification, union, aggregation, and generalization are the basic concepts of the object-oriented method. Using these concepts we can design the data model to describe geological

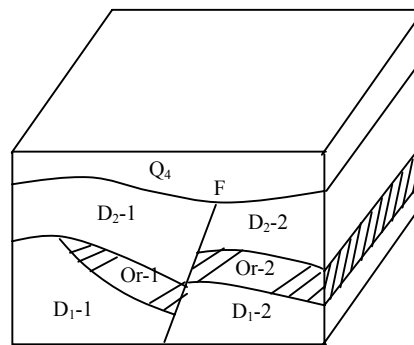


Figure 1. A skeleton map of different kind of geological volumes

volumes. The geological volumes in a 3D geological model can be divided into four classes, composite volumes, complex volumes, simple volumes and components. The composite volume is the integration of all the geological volumes in the researched area. It consists of a number of simple volumes and complex volumes. A simple volume is a volume continuously distributed in the researched area without interruption. A complex volume is a volume consisted of several simple volumes of the same type, which are discretely distributed in the researched area. A simple volume can be generally divided into a number of components. Fig.1 shows an example of 3D geological model, in which Q4, D2-1, D2-2, D1-1, D1-2, Or-1 and Or-2 are simple volumes, D2-1 together with D2-2, D1-1 together with D1-2, and Or-1 together with Or-2 are complex volume. The composite volume is consisted of one simple volume and three complex volumes. According to the view of object-oriented method, the simple volume is the union of the same type of components, a complex volume is the union of the same type of simple volumes, and a composite volume is the aggregation of the different type of simple volumes and complex volumes.

The component is the basic element for the division of geological volumes. In order to satisfy the requirement of the interactive interpretation based on 2D sections, each component should be located in space by means of global NEL coordinates and rotations, which define the origin and orientation of the component plane (cf. Fig.2). The geometry of the component is then defined in terms of its local XYZ coordinates. The geometry consists of three closed polygonal boundaries, a mid-plane (MP) boundary coincident with the component plane; and two parallel boundaries extended normally on both side of the component plane, referred to fore-plane (FP) and back-plane (BP) boundary, respectively (cf. Fig. 2). These boundaries are connected by straight link-lines. The Z coordinate values of each of the extended boundaries are constant, determined by specified fore- and back-thickness values. Each thickness and boundary can subsequently be modified independently to represent a wide range of geometrical shapes. The mid-plane of a component is generally coincident with the exploration section.

The geometrical elements can be divided into five object classes, points, arcs, polygonal boundaries, characteristic straight link-lines and component faces. A point is located by XYZ coordinates. An arc is a line that defines the boundary of two adjacent components. The straight link-line joins two characteristic points on the adjacent boundaries. Generally, the straight link-line is interactively specified by geologists. The polygonal boundaries refer to the above-mentioned three closed

polygonal boundaries. Each of the polygonal boundaries consists of several arcs. A component surface is a TIN generated by the arcs and characteristic straight link-lines.

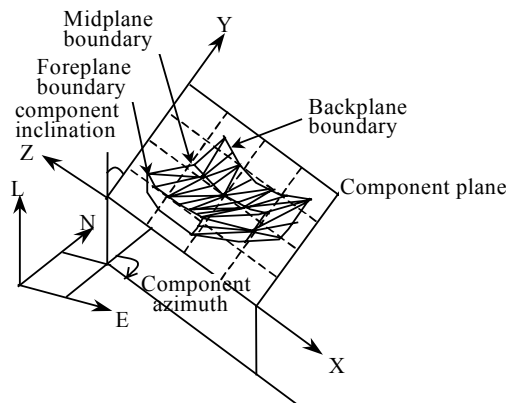


Figure 2. Geometrical definition of the component (after Houling, 1994)

Fig. 3 shows the object-oriented 3D vector data model. In order to describe the topologic information between the object classes,

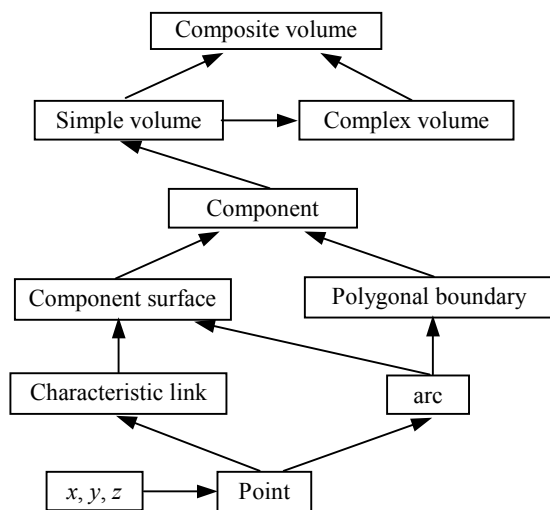


Figure 3.

nine kinds of topologic relations are designed as follows:

- Relations between composite volumes, complex volumes, simple volumes and the geological model.
- Relations between complex volumes, simple volumes and composite volumes.
- Relations between simple volumes, components, composite volumes and complex volumes.
- Relations between components, component surfaces, component polygonal boundaries and simple volumes.
- Relations between component surfaces, characteristic straight line links, arcs and components.
- Relations between polygonal boundaries, arcs and components.
- Relations between arcs, points and polygonal boundaries.

- Relations between characteristic straight line links, points and component surfaces.
- Relations between nodes and arcs.

The corresponding data structure can be designed by means of the object-oriented method. In addition, a pointer can be used to indicate the TIN model of a component surface.

### 5. CONCLUSION

Based on the present situation of 3D data model in GIS and geological modeling, the basic characteristics of geological volume and the requirement of geological volume modeling are analyzed. A new object-oriented 3D vector model is discussed. The 3D vector model is an improvement of volume model based on geological component, and is an innovation in 3D geological and can satisfy the needs of interactive interpretation on the section, topologic querying and analysis.

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