3-D Geologic Modeling and Visualization of Faulted Structures: Theory and GIS Application

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1 Introduction

Modeling of geologic structures plays an important rule towards a better understanding and deciphering many problems in the field of the subsurface structures. Geological mapping of subsurface structures formed through various successive events can be conducted through logical modeling of these events in relation to the geologic units and surfaces.

In the present work, we extended an algorithm for logical modeling of geologic structures formed through a sequence of sedimentation and erosion to be used in modeling of the faulted geologic structures [1].

In our approach, we defined the fault as a plane dividing a three-dimensional geologic unit and the open space into two blocks, with the geologic structures formed through sedimentation and erosion saved in each block [2]. With such an extended logical model, faulted geologic structures can be analyzed in space and time in an easy way of computer processing including estimation of surfaces and 3-D visualization of the geologic structure.

In the next few sections, an algorithmic approach for the sedimentation and erosion logical model will be conceptually introduced, and an expression for the logical model of faulted geologic structures will be presented. Further, the example of application for the logical model of faulted geologic structures is shown using a 3-D visualization tool “Nviz” in GRASS GIS.

2 Geologic structure of sedimentation and erosion

Let a 3-D subspace Ω be a survey area and suppose that the area Ω is divided into open space (air) a and geologic units b on boundary surface S. b is composed of n geologic units that are relatively prime:

$$b = b_1 \cup b_2 \cup \cdots \cup b_n$$

In initial state, geologic unit b_1 is defined by a boundary surface S that divides Ω into two subspaces as follows;

$$a = S^+$$
$$b_1 = S^-$$

where S^+ and S^- give subspaces that lie above and below the surface S, respectively.

In sedimentation, for adding substance to area below one surface, geologic unit increases and open space decreases. Such an event is set to c.

In erosion, for deleting substance to area above one surface, geologic unit decreases and open space increases. In case of large-scale erosion that erodes all the surfaces of the existing geologic units, it is considered that sedimentation and erosion are one event. Such an event is set to c^*.

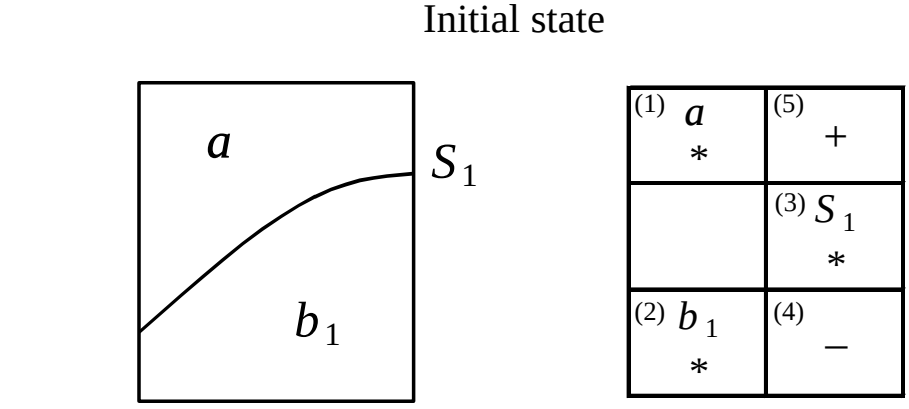

Figure 1: The initial state of the logical model

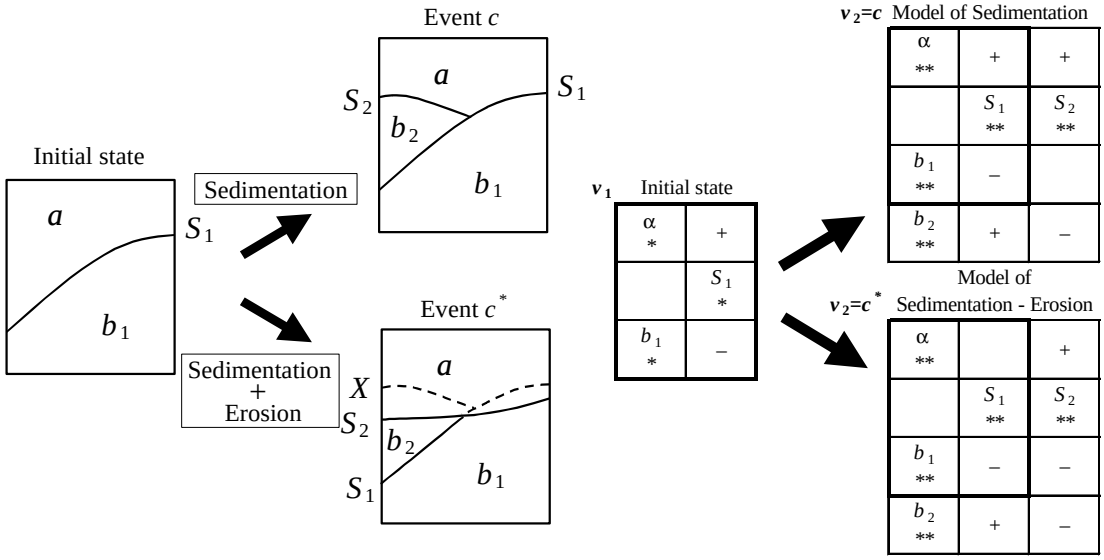

Figure 2: Model of sedimentation and erosion

3 Logic model expression for a geologic structure

The initial state of the logical model shown in Fig.1 shows labeling and coding of an example of the supposed represented units. The initial state of Fig.1 signs, names and codes of the represented open space, geologic units, and boundary surfaces are arranged in orders as follow;

(1) Open space (a) and character code ($*$).
(2) Geologic unit (b_1) and character code ($*$).
(3) Boundary surface (S_1) and character code ($*$).
(4) Geologic unit of the area below a boundary surface (–).
(5) Open space of the area above a boundary surface (+).

4 Logical model of geologic structure for sedimentation - erosion

An expression of the sedimentation and erosion logical model is shown in Fig.2. Starting from the initial state (v_1) shown in Fig.2, events such as sedimentation (c) followed by sedimentation and erosion (c^*) can be logically modeled.

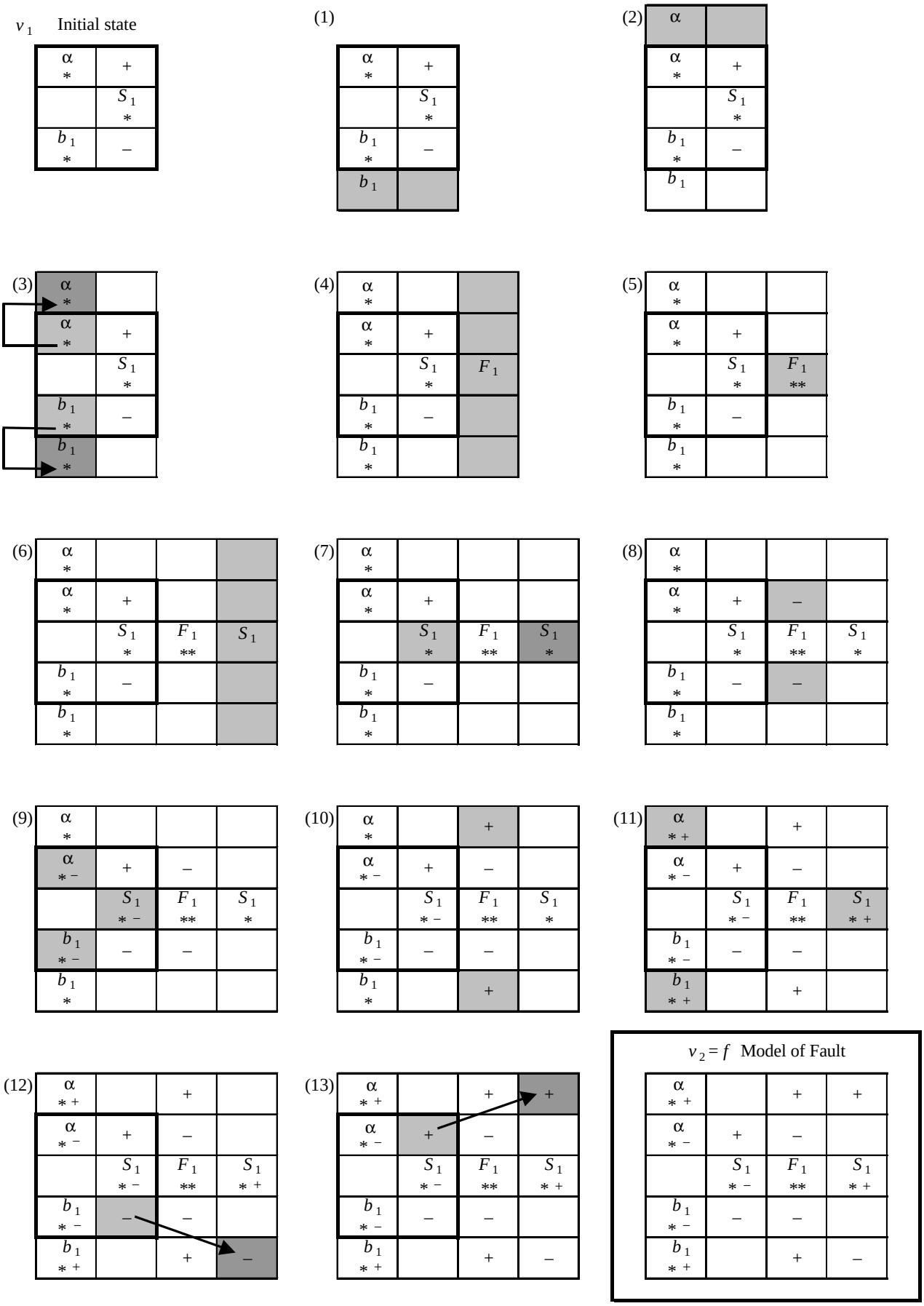

Figure 4: Model of fault (v_1 f)

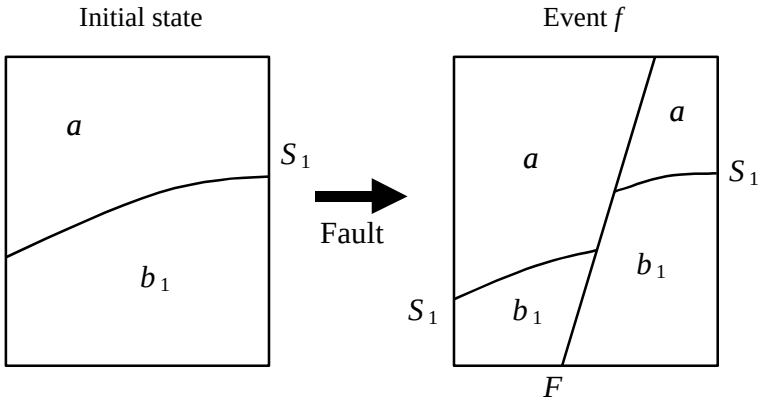

Figure 3: Event *f*

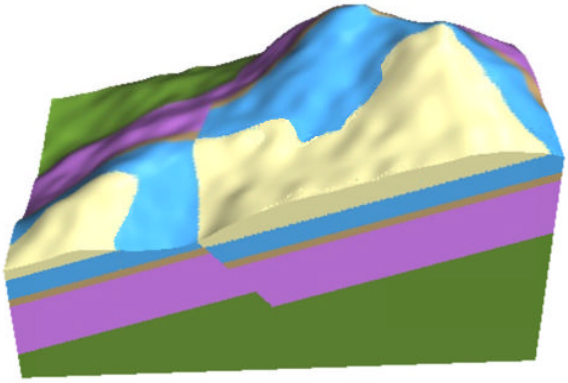

Figure 5: Example of 3-D faulted geologic structures using Nviz

5 Logical model of faulted geologic structure

Logical model of faulted geologic structure can be generated in the same way suggested for sedimentation and sedimentation-erosion. Open space, geologic units and surface boundaries are assigned (+), (–), or (∗), if these units above, below, or unrelated to the fault plane, respectively. Assuming that a faulting event (*f*) cutting the existing geologic unit and the open space into two blocks (Fig.3), preserving the geologic structures formed through sedimentation and erosion in each block, a logical model for these faulted structures can be built based on the proposed algorithm in Fig.4. The example of faulted geologic structures is presented in Fig.5 using 3-D geologic model. Visualization was conducted utilizing Nviz visualization tool in GRASS GIS environment.

6 Conclusions

Based on the proposed algorithm, a logical model of the faulted geologic structure was successfully generated that may help towards a better understanding of the subsurface, relationships between the geologic units and surface boundaries by a 3-D visualization of these relationships.

References

[1] Shiono K., Masumoto S., Sakamoto M. Characterization of 3D Distribution of Sedimentary Layers and Geomapping Algorithm -Logical Model of Geologic Structure-. *Geoinformatics*, 9, 3, pages 121-134.1998.

[2] Yonezawa G, Shiono K., Masumoto S. Logical Model of Faulted Geologic Structures. *Geoinformatics*, 12, 2, pages 154-157. 2001.