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Three-dimensional Geological Modeling by FOSS GRASS GIS –Using Some Field Survey Data–

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1 Introduction

The horizontal projection and the cross section created by the results of an investigation of a geological survey when grasping the structure and the generating mechanism of a geological structure are important. If it becomes possible to see the cross section of a geological structure, etc. dynamically by three-dimensions on computer system, it makes us grasp the geological structure easily. Moreover modeling of geological information plays an effective role in the geohazard assessment and mitigation. The geologic information consisting of complex sequences of interrelated three-dimensional geologic surfaces is traditionally spatially represented in two dimensions. Three-dimensional representation of such information is now afforded with the rapid advances in computer technology enhancing the interpretability of the model. Therefore, it is thought important to build a three-dimensional geological model on a computer.
In this research, we built a three-dimensional geological model based on logical model of geological structure by FOSS GRASS GIS. We introduced modelling methods using some field survey data based on logical model. For this purpose, we used geological survey data (Field survey data, Landform classification data and Drilling data) of the studied area along the median tectonic line of northern Wakayama Prefecture to create our model.

2 The Used Data and Program for Three-dimensional Model Creation in Northern Parts of Wakayama Prefecture.

Study area

The study area is located in the southern part of Izumi mountain range of northern part of Wakayama Prefecture along the median tectonic line. In Fig.1 a location map for the studied area is shown. This area is consist mountainous district and plain. Mountainous district, which consist Cretaceous Izumi Group is in contact with plain, which consist Syoubudani formation and terrace bordering on the fault. It is presumed that this fault is a low angle reversed fault (median tectonic line) of the north inclination, which touches the Izumi Group in the Shoubutani formation. Fig.2 is geological cross section in this area.

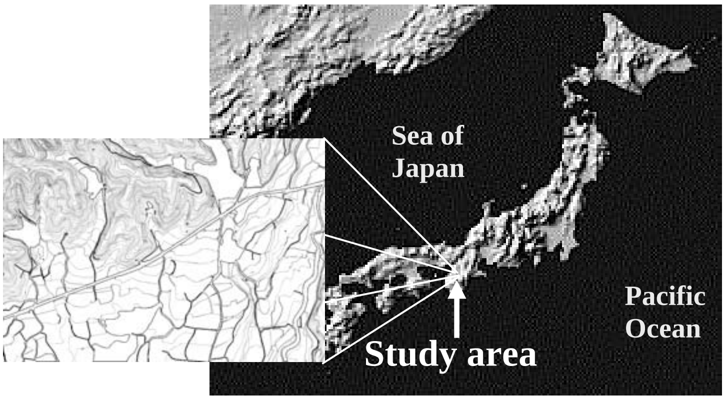


Figure 1: Location

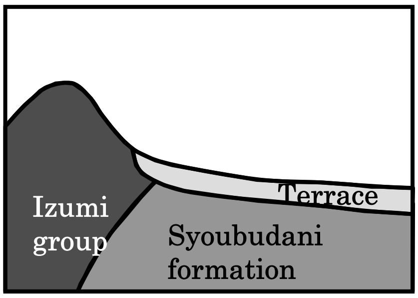


Figure 2: Geological structure in study area

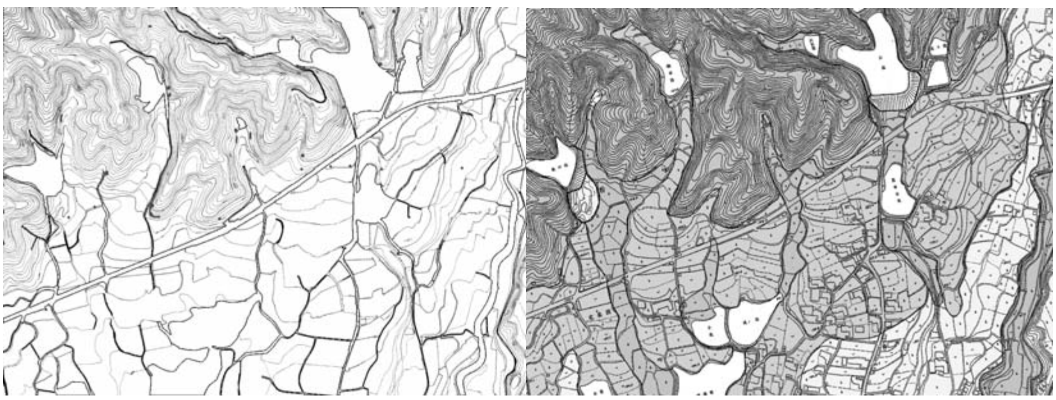
In this research, building three-dimensional geological model we used some data and some program which is as follows.

Data

Four kinds of following materials were used for creation of three-dimensional geology model.

(1) Topographical map (S=1/2500)
(2) Landform classification map
(3) Field survey data
(4) Drilling data

Fig.3(a) is topographical map with field survey data and drilling data and Fig.3(b) is Landform classification map using this research.



(a) Topographical map (b) Landform classification map

Figure 3: The Materials

Methodology

The program used for creation of three-dimensional geology model is following three.

(1) Horizon2000

Horizon2000 is a FORTRAN-77 program created by Shiono et al. (2001) can estimate surface data (DEM; Digital Elevation Model) from some elevation data (XYZ data). This program also can input inequality altitude data and dip strike data and estimate surface.

(2) Ps2xyz

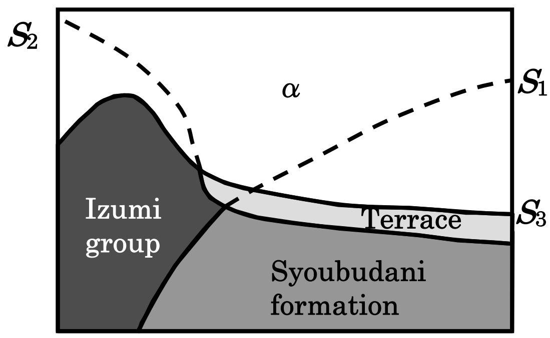
Ps2xyz is a FORTRAN-77 program created by Noumi et al. (1999) and can make surface data from the contour line map. The input file of this program is the picture painted by one color in between each contour line. The output file is the input form of horizon2000.

(3) The program, which distributes geology data

This program is a FORTRAN-77 program created by Kajiyama et al. (2004) and can make surface data from some geological data. The input files of this program are logical model of geological structure, geological data like field survey data and drilling data and topographical data. The output files are each geological boundary surfaces.

Logical model of geological structure

Logical model of geological structure proposed by Shiono *et al.*(1994,1997,1998) is a mathematical model in which geologic unit is expressed by the distribution of geologic boundary surface. Suppose that it is structure as a geology section shows in Fig.4(a), then we have the logical model of this geological structure, as shown in Fig.4(b). S_1 is median tectonic line. S_2 is the boundary surface of terrace and Izumi group and Syoubudani formation. S_3 is landform.



(a) Geological structure

α			+
	S_1	S_2	S_3
Syoubudani formation	−	−	−
Izumi group	+	−	−
Terrace		+	−

(b) Logical model of geological structure

Figure 4: Geological structure and logical model in research area

3 Building process of Three-dimensional Geological Model.

Building process of three-dimensional geological model is shown below using field survey data. Fig.5 is the flow chart.

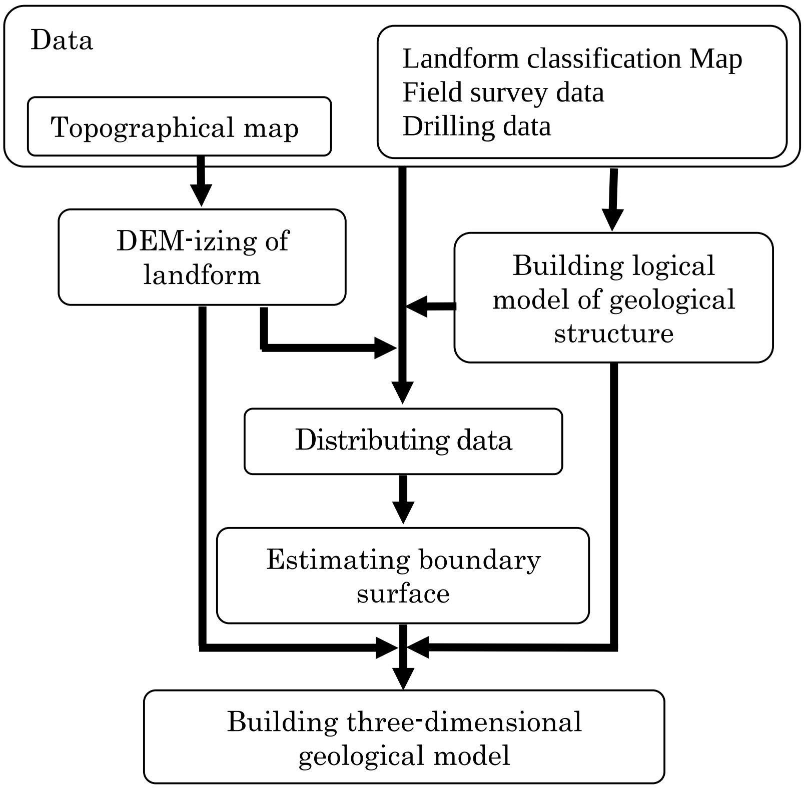


Figure 5: Flow chart

(1) DEM- izing landform

DEM-ization of landform is performed using program ps2xyz and horizon2000.

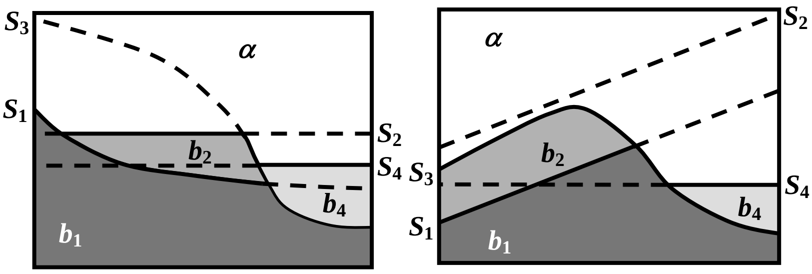
(2) Building the logical model of geological structure

The logical model of geological structure is built based on data.

(3) Distributing data

The data that will be estimated for each geological boundary surface are distributed using DEM created by (1) the logic model of geological structure built by (2).

Logical model of geological structure is the relation between surfaces and geologic units (bed and rock), and + and – signs related to *S* show the position of the geologic units from surfaces. From this, when the sign of + and – in logical model are carried out in reverse, the position of the surfaces from geologic units will be shown. For example, suppose that the geologic unit b_2 is distributed in a certain place in the area of geological structure of Fig.6(a). The distribution of the of geologic unit b_2 position is upper side of S_1 and lower side of both S_2 and S_3 from logical model of Fig.6(b). And we can say that S_1 is below distribution position of geologic unit b_2



(a)Geological structure

a			+	+
a	+	+		+
	***S*₁**	***S*₂**	***S*₃**	***S*₄**
b_1	-		-	
b_2	+	-	-	
b_4	+	+		-
b_4			+	-

(b)Logical model

Figure 6: Geological structures and logical model of geological structure

and S_2 and S_3 are above one. By performing such operation to all data, the data for presuming each boundary surface can be created. In next section we actually introduce the creation method of three-dimensional model using some field survey datas.

(4) Estimating geological boundary surface.

Each data created by (3) is inputted into horizon2000, and each geological boundary surface (DEM) is estimated by horizon2000.

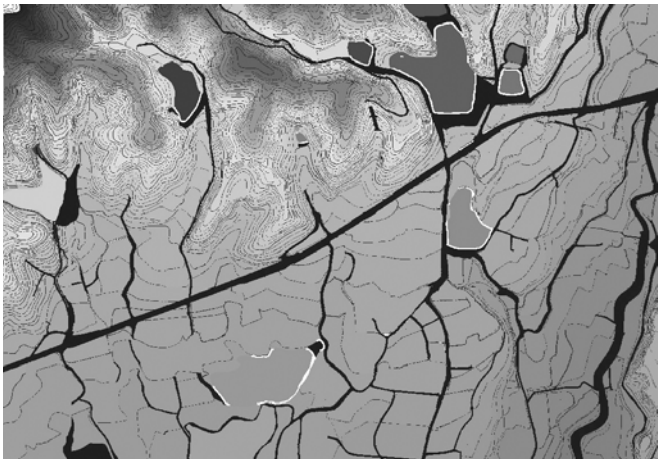
(5) Building the three-dimensional geological model.

Building the three-dimensional geological model is carried out by using the method proposed by Yonezawa et al. (2003) and Masumoto et al. (2000) using landform created by (1), geological boundary surface (DEM) created by (4), and the logical model of geological structure built by (2).

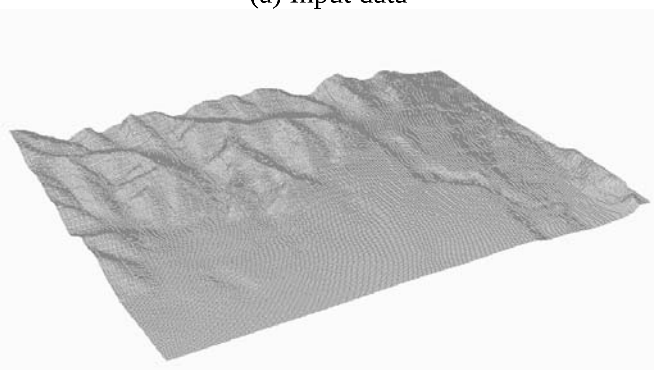
4 Building Three-dimensional Geological Model. in Northern Parts of Wakayama Prefecture

(1) DEM-izing landform

From the topographical map of Fig.2(a), we created the input form of Ps2xyz like Fig.7(a). Fig.7(b) is the topographical data, which is estimated by Horizon2000 using this data.



(a) Input data



(b) Surface data of landform

Figure 7: Topographical data

(2) Building the logical model of geological structure

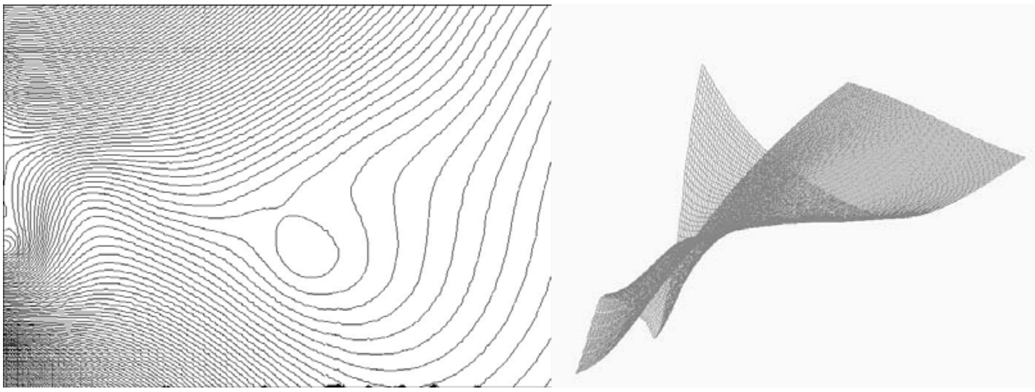
The logical model of the geological structure of this area is built as shown in Fig.2(b).

(3) Distributing data

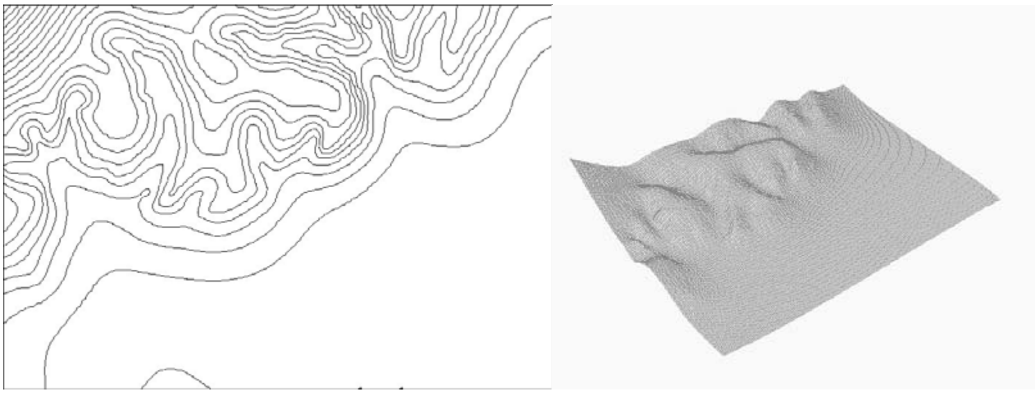
The program created by Kajiyama et al. (2004) creates the data for estimation each geological boundary surface from landform classification map of Fig.2(b), field survey data and drilling data, logical model of geological structure, and the topographical data (DEM) created by (1).

(4) Estimating geological boundary surface.

Fig.8 is each geological boundary surface, which estimated by horizon2000. Fig.8(a) and Fig.8(b) are S_1 of Fig.2(a) and is a median tectonic line. Fig.8(c) and Fig.8(d) are S_2 of Fig.2(a) and is the boundary surface of terrace and Izumi group and Syoubudani formation



(a) Topographical map of S_1 (b) Surface data of S_1



(a) Topographical map of S_2 (b) Surface data of S_2

Figure 8: Each geological boundary surface

(5) Building the three-dimensional geological model.

Here, a three-dimensional geological model is built using the method using Free Open Source Software GRASS-GIS (FOSS-GRASS-GIS) proposed by Masumoto et al.(2000).

The topographical data created by (1) and the each geological surface created by (4) is inputted to database. Then the three-dimensional geological model can be built by the method proposed by Masumoto et al. (2000) using this database. Fig.9 is the example of visualization of the three-dimensional geological model using NVIZ, which is three-dimensional visualization tool. This tool can create the section of the three-dimensional geological model etc. dynamically.

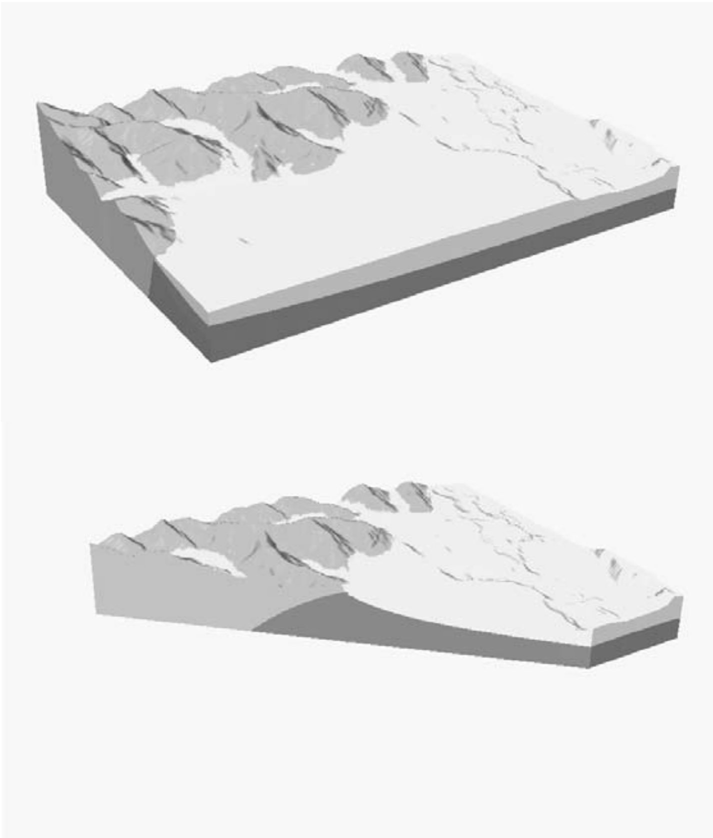


Figure 9: Visualization of three-dimensional geological model

5 Conclusion.

Shiono et al. (1994, 1997 and 1998) showed that distribution of geologic units could be defined by the disposition of boundary surface and named logical model of geological structure. This model is the base when expressing geological structure on a computer.

In this research, we performed data processing, etc. based on this model and the method shown by Masumoto etc. (2000) was applied and the three-dimensional geological model was built using Free Open Source Software GRASS-GIS (FOSS-GRASS-GIS). Three-dimensional model created by this method can create a sectional view dynamically. Therefore we can grasp three-dimensional space more easily rather than it imagines from a geological cross section and a geological horizontal projection of two-dimensional. When database creates in GRASS-GIS, as shown in Fig.10 and Fig.11, a landform classification map and an aerial photograph can be put on landform. We can know a position more easily by doing in this way. If the accuracy of this created model is high, we can use it for various analyses like various foundation analyses (underground-water analysis and dynamics analysis) or the design of a construction enterprise.

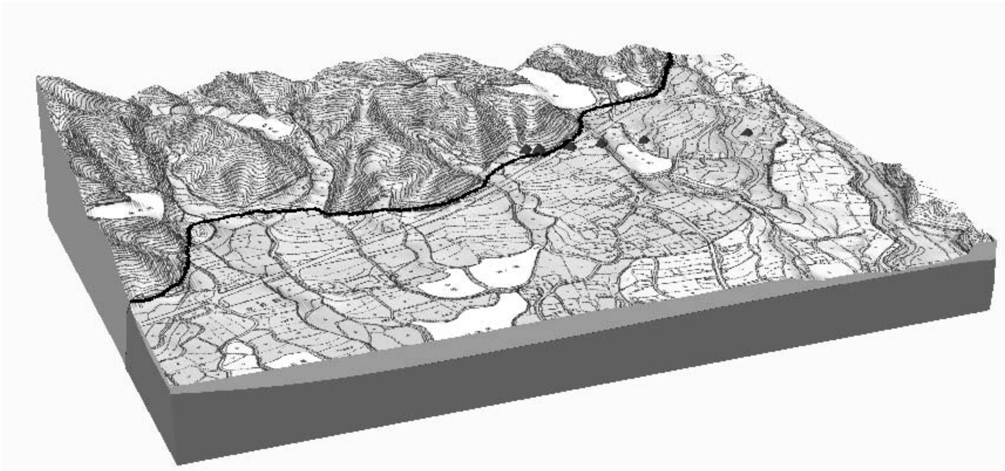


Figure 10: Visualization of three-dimensional geological model putted a landform classification map

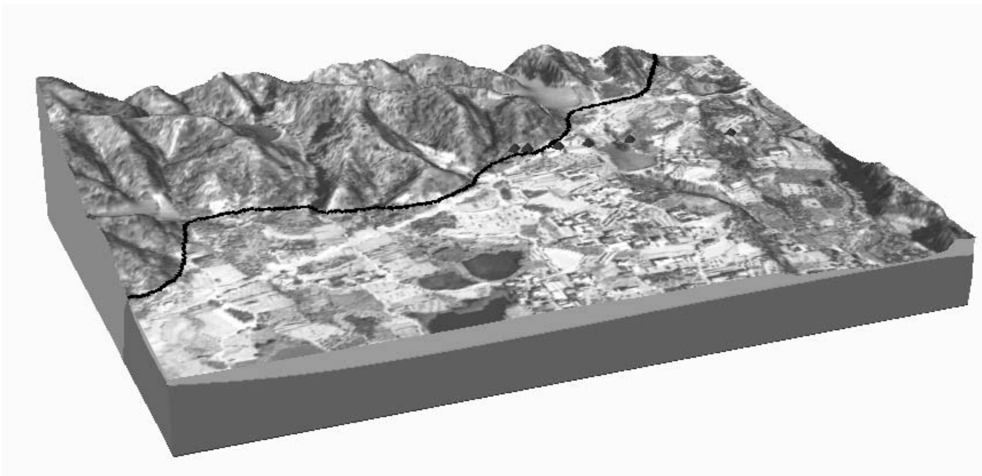


Figure 11: Visualization of three-dimensional geological model put an aerial photograph

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