A System for Dynamic Modeling of Geological Objects PCheGeol (I) (by the Oriented Programming Object)

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Abstract
The present work takes places within an overall research on computer modeling of the geological scenes. The approach of dynamic modeling describes the geological scene. Starting from a simple initial object (sedimentary strata) and reading the geological processes (folds and faults) that cause the geometric deformation of the scene, one can obtain the form of the current state. The technic of object oriented programming permits a very simple way to obtain such software allowing modeling the indicated objects and processes.

1. Introduction

The geological scene can be considered as a rigid assembly of solid bodies. The scene in its set, like each one of the objects, verifies the classical properties defined by REQUICHA for solids (Requicha, 1977).

Rigidity: invariant form, independent of the position and the orientation of the considered body.

Homogenous-Three-Dimensionality: well defined interior and absence of isolated points or dangling portions.

Spatial Finitude: the solids occupy a limited part of the space.

Closure w.r.t. Geometric Position Operations and Composition Operations: these operations applied to valid objects that provide valid objects.

Descriptive Finitude: possibility to describe every object from a limited number of elements.

Determinism of Border: the border describes unambiguously the interior of the object.

PCheGeol: is a computer program that was developed and implemented within the IT department of the Lebanese University. It allows the modeling of geological objects based on the dynamic modeling process starting from a simple object we can obtain complex geological objects. PCheGeol considers the geological scene as a set of n related polygons $(P_i)_{1<i<n}$ one after the other, according to their chronological order and their border (do not have emptiness's between them) via a generation algorithm (figure 1).

1.1 Algorithm 1: Generation Algorithm

If the point A is entered on the polygon P_i as a point with a distance Epselon of the border of the polygon $P_j(1<=j<i)$, then the point A will be replaced by the border point B of the polygon P_j $(1<=j<i)$.

2. The Computer Objects

The necessary computer objects to obtain a geological scene are: Point, Segment, List Segment, and Polygon, defined by:

```
class Point{public: double x,y,z;};
class Segment{public: point A, B;};
class List Segment{
    public:
   Segment Ele;
   ListSegment *Next;};
class Polygon { public:
                int Color;
                List Segment* Head;};
```

In order to facilitate the usage of the memory one uses a structured chain of computer objects allowing a flexible usage of the memory of the computer.

3. Representation of the Interior of the Scene

Representing a scene assumes the following steps (Cheaito, 1993):

1-Characterize the form of the different objects as well as the relative geometric position of these objects one w.r.t. the others. 2. Create an explicit or implicit geometric model. 3. Give the means to visualize it.

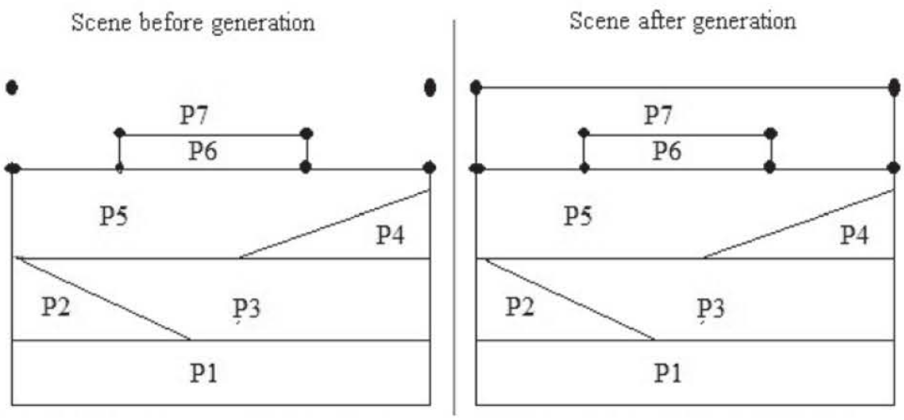

Figure 1: Construction of the geological scene and the generation of the polygon

Figure 2: Representation of the scene and it's interior

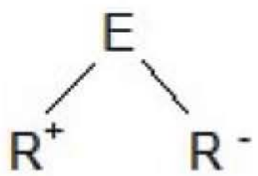

Figure 3: Edge representation as a tree

If one wants only to be able to visualize the objects, while considering each one of them as completely homogenous, it is sufficient to define them by their external surface (Basei et al., 2010); in this case, every object can be represented on the computer screen by a homogenous color (figure 2).

According to the usage that one wants to do on the obtained model, several types of voluminal representations are possible: We will strive to define a structure of type binary partitioning of the space (Binary Space Partitioning=BSP) (Lysenko et al., 2008) based on the recurrent usage of the delimiters of the planes by dividing a given space into two (Naylor, 1990, Naylor and Thibault, 1986 and Fuchs et al., 1980). From a formal point of view if e is an equation edge $ax+by+c=0$, then it separates the space into three regions: R^+: $ax+by+c>0$, R^0: $ax+by+c=0$, and R^-: $ax+by+c<0$. By convention, such an edge will be represented as a node of the tree (figure 3). This structure allows a very direct classification of any point of the space as exterior, interior or border of the object (Wang, 2010). This classification is obtained while inserting the point M in comparison with the existing nodes of the tree until to classify it as a leaf (Fuchs et al., 1980 and Fuchs et al., 1983).

1- If M does not belong to any delimiter of the tree, then it is internal or external to the object. Therefore, it is found at the end of the procedure in a leaf of the tree and single, and classifies as "in" or "out".
2- If M belongs to a delimiter in the tree. In this case, M can belong to the border of the object. It is then classified as "in" or "out" according to the obtained value. If this value is a point on one of the segments, then it is classified as "in" otherwise it is classified as "out".

The node of the tree is a list of segments as seen in figure 4.

Algorithm 2: Algorithm of construction of the BSP tree: To construct the BSP tree nodes, we insert a segment in the tree as seen in figure 5.

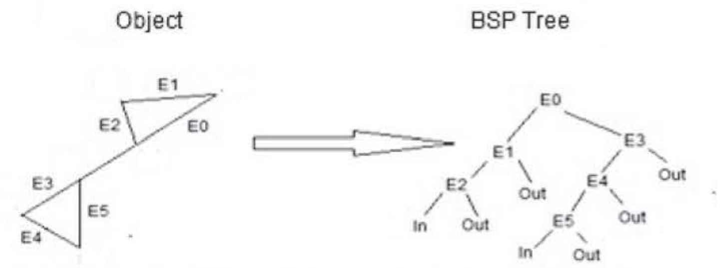

Figure 4: Two special cases of the representation of BSP tree

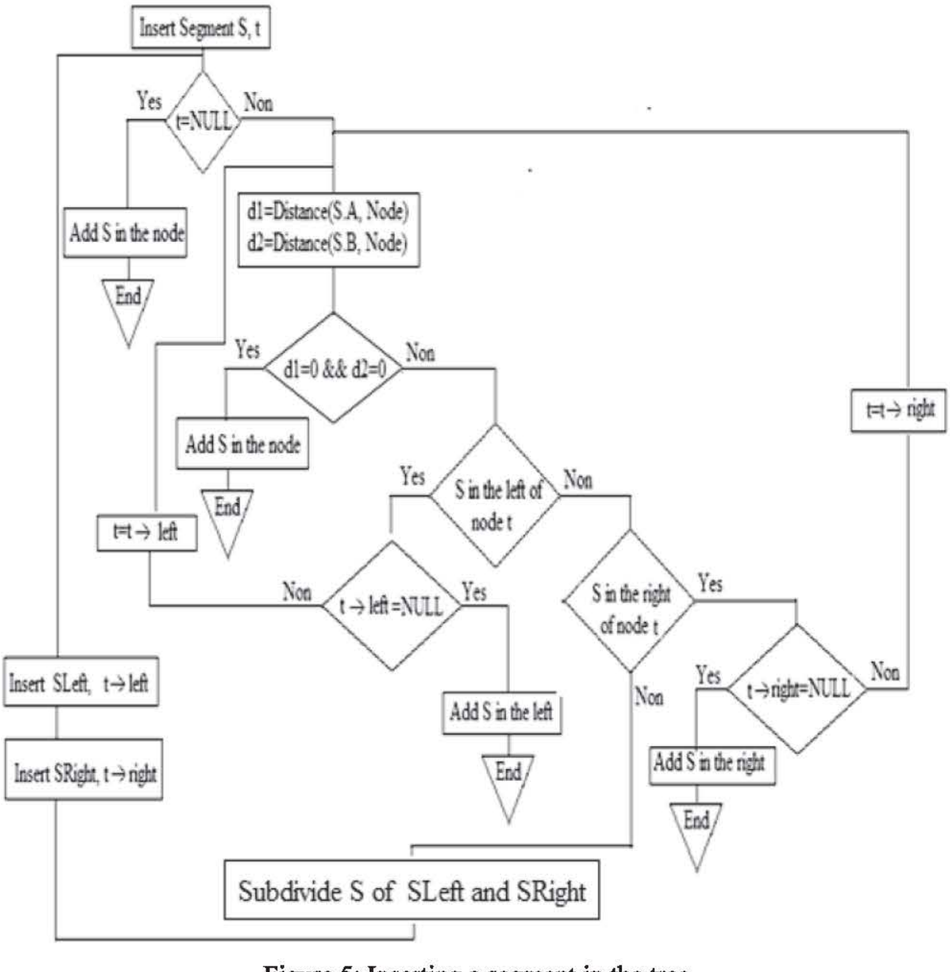

Figure 5: Inserting a segment in the tree

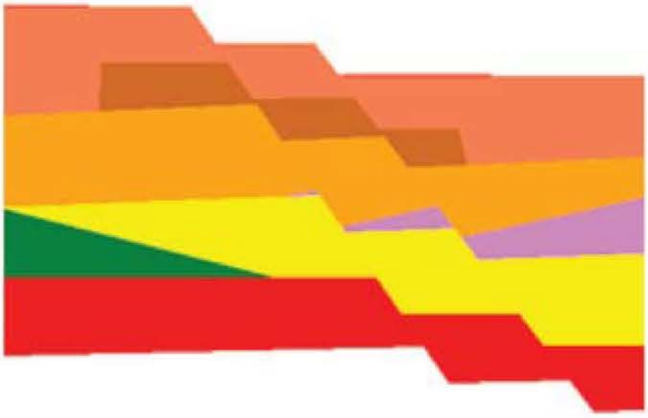

Figure 6: Geological scene undergroes a deformation

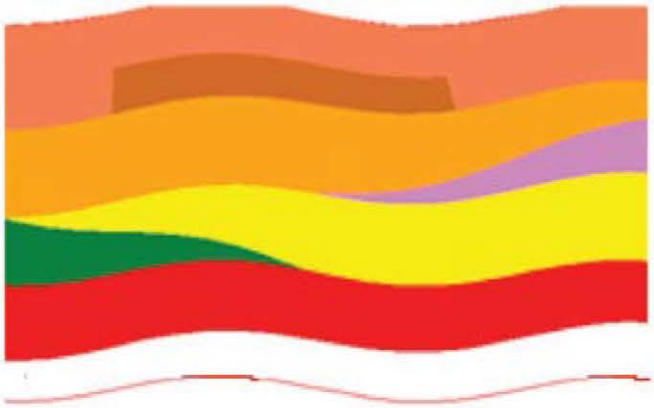

Figure 7: Geological scene undergroes a fold

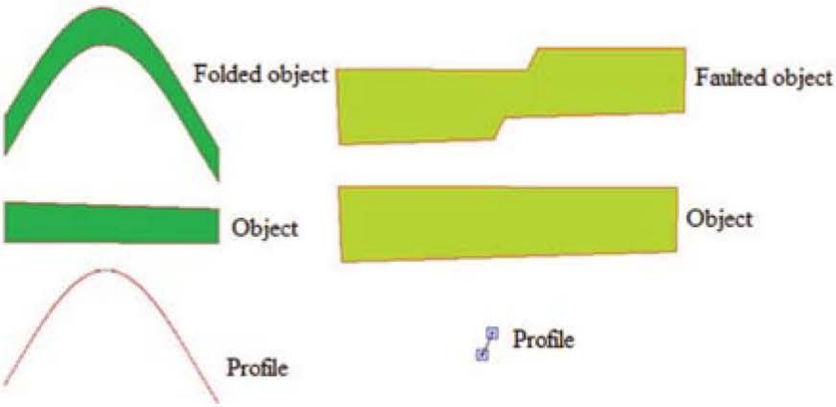

Figure 8: Elaboration of similar folds and faults

4. Deformation of the Geological Scene

Any modeling approach based on the interpolation and the extrapolation of data participates in two tendencies that combine variable propositions: a "descriptive" approach or again "static" on one hand, and an "interpretative" approach or again "dynamic" on the other hand (Lanoe, 1981). The "static" approach will aim to find the geological objects while returning their observable form from a discreet number of given data. The "dynamic" approach departs from the inverse of a simple form and the abstraction of the responsible processes of the forms taken by these objects in order to obtain the current object. A fault translates the gap affecting two sections of a land on either sides of a "fault plane". The similar folds that are the flexible deformations the most widespread on the lands after having undergone in depth deformations can be represented geometrically by a model in which the planes are oriented in a special direction, "fold", and slip one on another alongside a determined direction called "sliding direction" (Douillet et al., 2013).

- In the case of a fault, respectively for all the points that belong to the one or the other half of the spaces are limited by the fault plane (figure 6).
- In the similar case of a fold, for all the points that belong to the same sliding of the plane (figure 7).

The movement of the different material points, parallel in the two cases to a fixed direction having the same value. Thus, the defined transformations are called "similar type" (Perrin et al., 1988). They are characterized as follows (figure 8):

- By a plane direction (plane of fault or axial plane).
- By a right direction in this plane (sliding direction)
- By a function profile F(X). The Transformation of Similar Type (TST) defined by (Perrin et al., 1988, Perrin and Peroche, 1989 and Perrin et al., 1987) is a point M(x, y,z) transformed to point M'(x', y',z') such that x'=x, y'=y, z'=z+f(x).

The simulation of the complex geological transformations can be obtained by layering several different TST, the corresponding transformation express itself under the form seen in figure 9 (Cheaito, 1993).

Here:
n: denotes the number of applied TST
M_i's: denotes the matrices of the transformations of each of these TST in a local indicator which is bounded.
$\Phi_{i,i+1}$: denotes the matrix that allows the passage of the indicator of the transformation i into i+1.

The interest of these types of transformation is due to the fact that it permits building analogous land, having undergone excessive and complicated deformations. In fact, the obtained result from the application of the initial stratification leads to two similar types of transformations or give more complex figures that simulate sometimes in a relatively realistic way (Perrin et al., 1993) (figure 10).

5. Deformation method
To obtain the modeling of the processes of similar fold one enters the profile of the fold as a list of points as seen in figure 11.

$$\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = P^{-1} * (\prod_{i=1}^{n-1} M_i * \Phi_{i,i+1}) * M_n * P * \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

Figure 9: Geological Tranformation

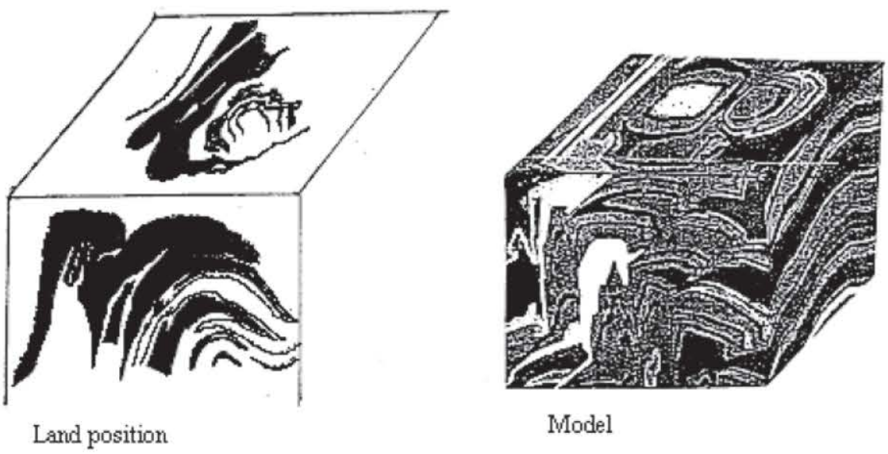

Figure 10: Models of the "Montagne noir" by POLYLPI (Demage, 1979)

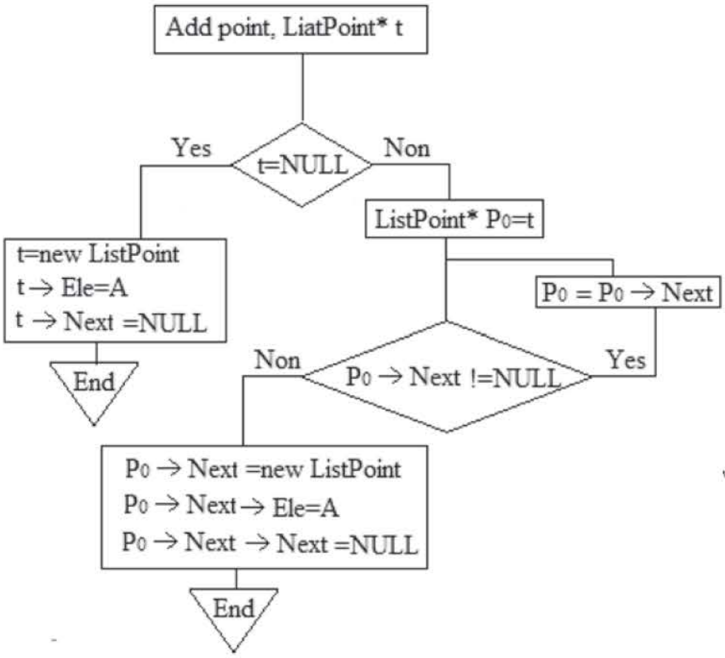

Figure 11: Add a point to the profile

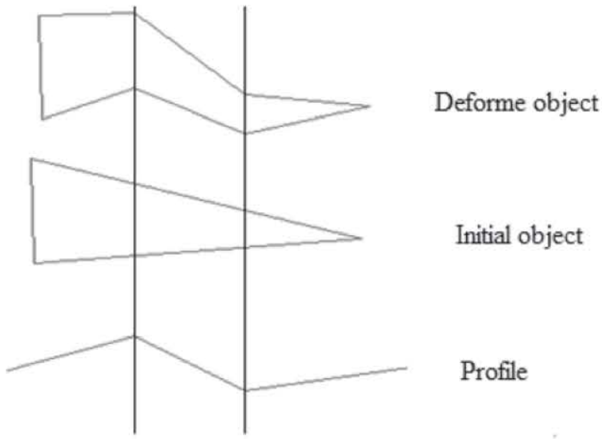

Figure 12: Deformation of Similar fold

6. Geometric Characteristic of the Representative Models of Objects

The geologists, in principle, are more interested by the form of the objects than by their return. For this reason, we have defined the different geological bodies only that possess the assistance of polygons limited by edges (Wolfgang, 2010). Every object is considered as "uniform", which implies that the surfaces that limit the corresponding volume are related, oriented, not auto-intersected and of finished dimension (Mortenson, 1985). The outlines that limit each object must verify the property of not auto-intersection (Mantyla, 1988). If the function profile F(X) of T is continuous, the transformation preserves the continuity of the layers that it affects and their traces on the whole plane that cuts them, more in each of the slices and therefore the whole space, the character whether intersects or not- the surfaces is preserved in figure 12. It results in these cases, that the topology of the scene is strictly preserved. On the other hand, when the function profile F(X) is discontinuous (profile simulating "faults"), this topology is preserved by "pieces" on one side, and on the other side of the surfaces the discontinuity corresponding to the plane of the fault, leads to layers dying alongside the fault surfaces (figure 13). The operators that we have considered belongs to five different categories: (movement, rotations, ladder change, similar Fold, similar Fault) that preserve very unequally the different characteristics of the scene.

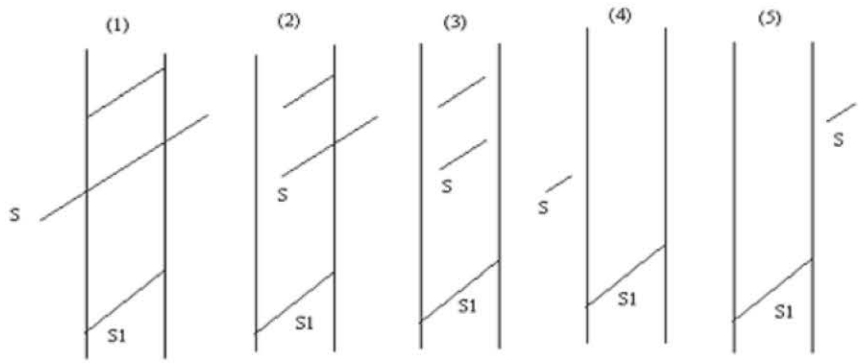

Figure 14: State of deformation of a segment S by profile segment S

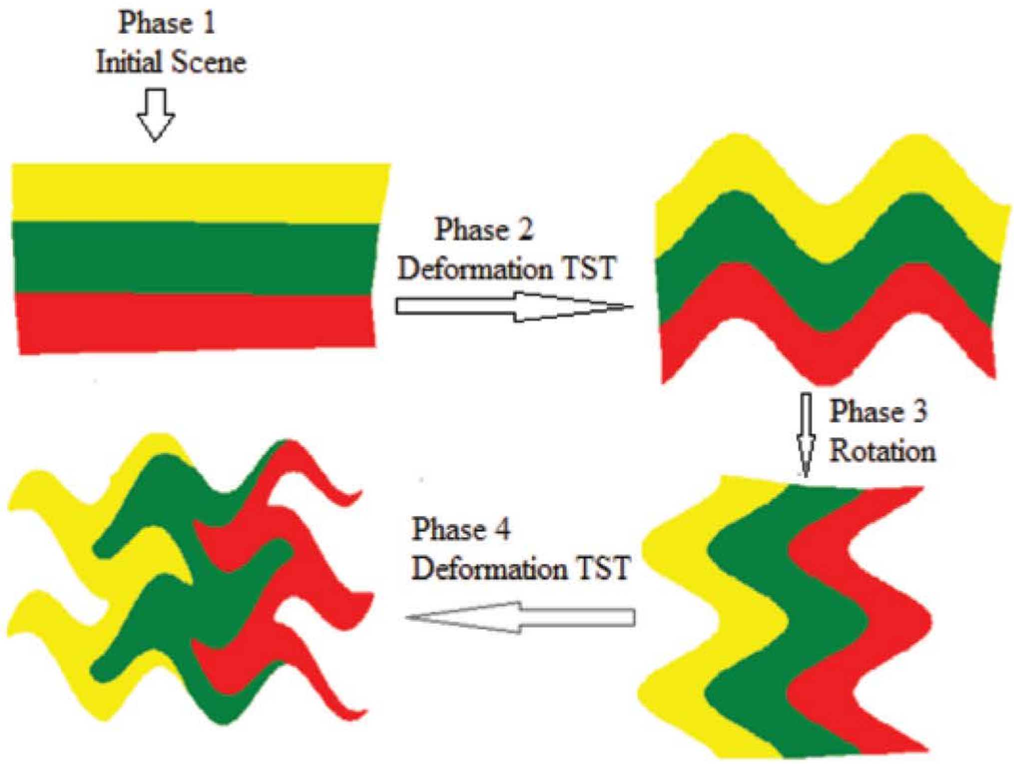

Figure 15: Deformation of scene after 4 phases (realized by PCheGeol)

Algorithm 3: Algorithm of deformation of a polygon.

```
void DeformerPolygone(Polygone& MaPol)
{
Segment S1;
ListSegment* Po =
MaPol.Head;while(Po!=nullptr){
        S1=Po->Ele;
/* deforme the segment S1 by the segment S of the
profile as seen in figure 14*/
        Po=Po->Next;
      }
}
```

7. Some Technical Results

The following figures are the technical results taken from software PCheGeol of an initial scene of three objects which undergoes four phases of TST deformation and then six phases of TST deformation (figures 15, 16 and 17).

8. Conclusion

The geometry of different objects, as well as the spatial relations maintained between them, is narrowly conditioned by the geological processes succeeding them. They depend on the relative ages of these objects.

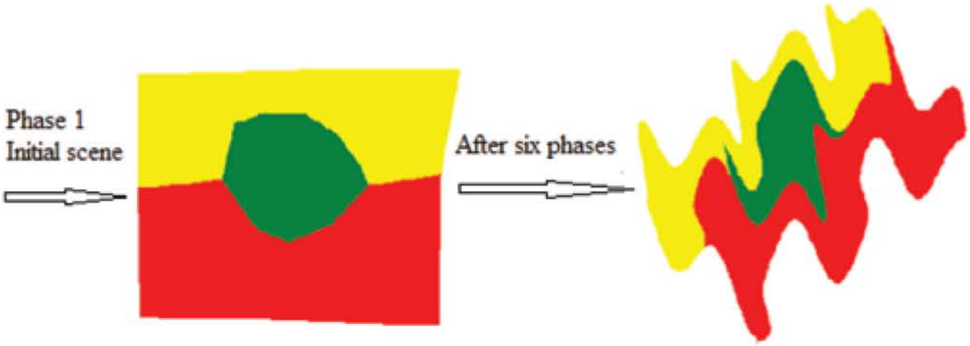

Figure 16 : Scene after six phases (realized by PCheGeol)

Figure 17: Fault (realized by PCheGeol)

Furthermore, the form of the geological bodies, especially when they are of big size, cannot be restored from the observation of the discreet data with certain moderate approximation that often involves adoption of a geological model. Modeling objects make the implementation of such software easy and gives the possibility to see some geological effects by a change of the order of display, since the objects of the chains are independent as computer objects. This present study has no interest of the optimization of the obtained BSP tree, but it focuses on the geometric form of the geological scene. The objects that are treated within PCheGeol software are fairly rudimentary, since we can only realize the drawing of geological objects in 2D using the mouse on the screen. But our ambition is to get the maximum profit from PCheGeol software. We wish to achieve a 3D drawing of geological objects that are considered quite complex and intrusive (like granite, magma, etc...). Finally, using this software we think we can estimate the quantity of petrol and water that exists in the underground.

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