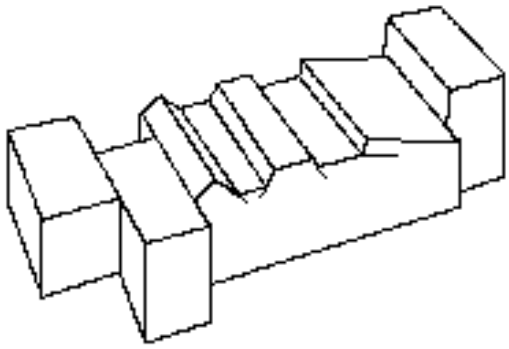
U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

How to Construct Seven Paper Models that Describe Faulting of the Earth



By Tau Rho Alpha* and John C. Lahr*

Open-file Report 90-257-A

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Description of Report

This report contains instructions and patterns for preparing seven three-dimensional paper models that schematically illustrate common earth faults and associated landforms. The faults described are: normal, reverse, right- and left-lateral strike-slip, and oblique-slip. There are also models and discussions of two fault-produced landforms, a graben and a horst.

These models are intended to help students and others visualize the principal classes of faults and learn some of the terminology used by geologists to describe faults. By constructing and examining these models, students will obtain a greater appreciation of the relationship between fault displacements and the landforms that result.

The date of this Open-File Report is 4/12/90 **(version 1)** . OF 90-257-A, paper copy; OF 90-257-B, 3.5-in. Macintosh diskette.

The date of **version 2** of this Open-File Report is 2/7/92. OF 90-257-A, paper copy; OF 90-257-B, 3.5-in. Macintosh diskette.

Purchasers of the diskette **version 2** of this report, which includes all of the text and graphics, can use HyperCard 2.0™ software (not supplied) to change the model (by adding geologic patterns, symbols, colors, etc.) or to transfer the model to other graphics software packages. Requirements for the diskette **version 2** are: Apple Computer, Inc., HyperCard 2.0™ software, and an Apple Macintosh™ computer. If you are using System 7, we recommend using at least 3 MB of RAM with 1.5 MB of system memory available for HyperCard.

To see the entire page (card size: MacPaint), select "Scroll" from "Go" menu and move the hand pointer in the scroll window. If you are experiencing trouble with user-level buttons, select message from the "Go" menu. Type "magic" in the message box and press return. Three more user-level buttons should appear.

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Educator's Guide

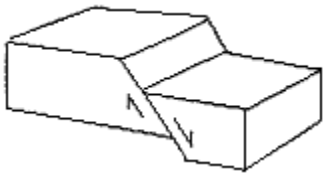
A fault is a fracture surface within the earth on which slip or displacement has taken place. The total displacement on a fault may be less than a few centimeters or may be measured in hundreds of kilometers. Large displacements are commonly achieved by a series of sudden slips associated with earthquakes, but under some conditions involving slow slip, called creep. Many possible fault configurations are possible; the fracture surface may be planar or curved, and the slip may be

uniform everywhere or may change from place to place, as in a rotational displacement or a displacement that becomes smaller and smaller and finally dies out. In this report we will focus on those portions of faults with uniform displacement on planar fracture surfaces (figure 1) and will not discuss complex faults or the details associated with the edges or intersections of faults (figure 2).

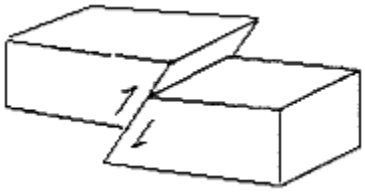
The three fundamental fault types are normal, reverse, and strike-slip (figure 1). Normal faults involve a dipping fracture surface on which the block above the fault plane, the hanging-wall block, is downthrown with respect to the block below, called the footwall block. Normal faults are common in regions of crustal extension. In contrast, reverse fault displacements, which are common in regions of compression, are such that the block above the fracture surface is uplifted with respect to the block below. Strike-slip faults generally involve no vertical motion, but instead are produced by two blocks that are sliding laterally past one another. The sense of lateral motion can be right lateral (dextral) or left lateral (sinistral). Imagine that you are standing on one side of the fault. If the other side has moved to the right, as may be indicated by offset streams, ridges, roads, fences, or other features that cross the fault, it is a right-lateral fault. If the other side has been offset to the left, the fault is left lateral. Few faults are, in fact, purely normal, reverse, or transverse, but instead combine transverse motion with either normal or reverse motion. This combined motion is termed oblique slip.

Figure 1. Simple fault types.

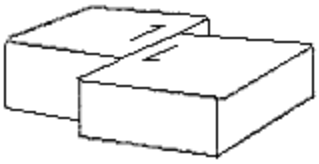
Normal fault



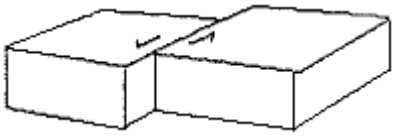
Reverse fault



Right-lateral strike-slip fault



Left-lateral strike-slip fault



Oblique-slip fault

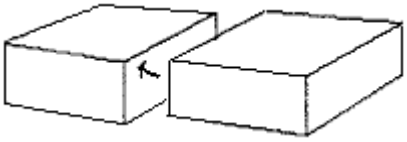
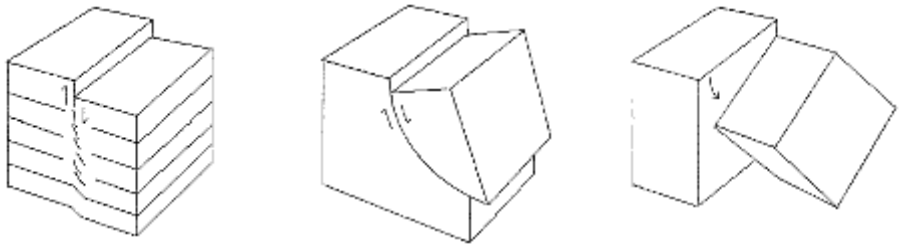


Figure 2. Complex fault types.

Fault displacement decreases with depth and fault terminates in a fold.

Fault surface is curved, resulting in block tilting.

One block is rotated with respect to another.



When faults extend to the Earth's surface, displacing parts of the landscape, landforms are developed or modified. The portion of the fracture surface that is exposed by faulting is called the fault scarp (figure 3). Fault scarps may initially be angular and well defined, but over time they are modified by weathering and erosion on the upper portions while the lower portions become buried by eroded debris (talus). If a region is sliced by a series of subparallel normal faults with sufficient displacement, horst-and-graben topography may develop. A horst is a block that has remained high relative to those on either side, whereas a graben is depressed relative to the adjacent blocks (figure 4).

Figure 3. Elements of a fault.

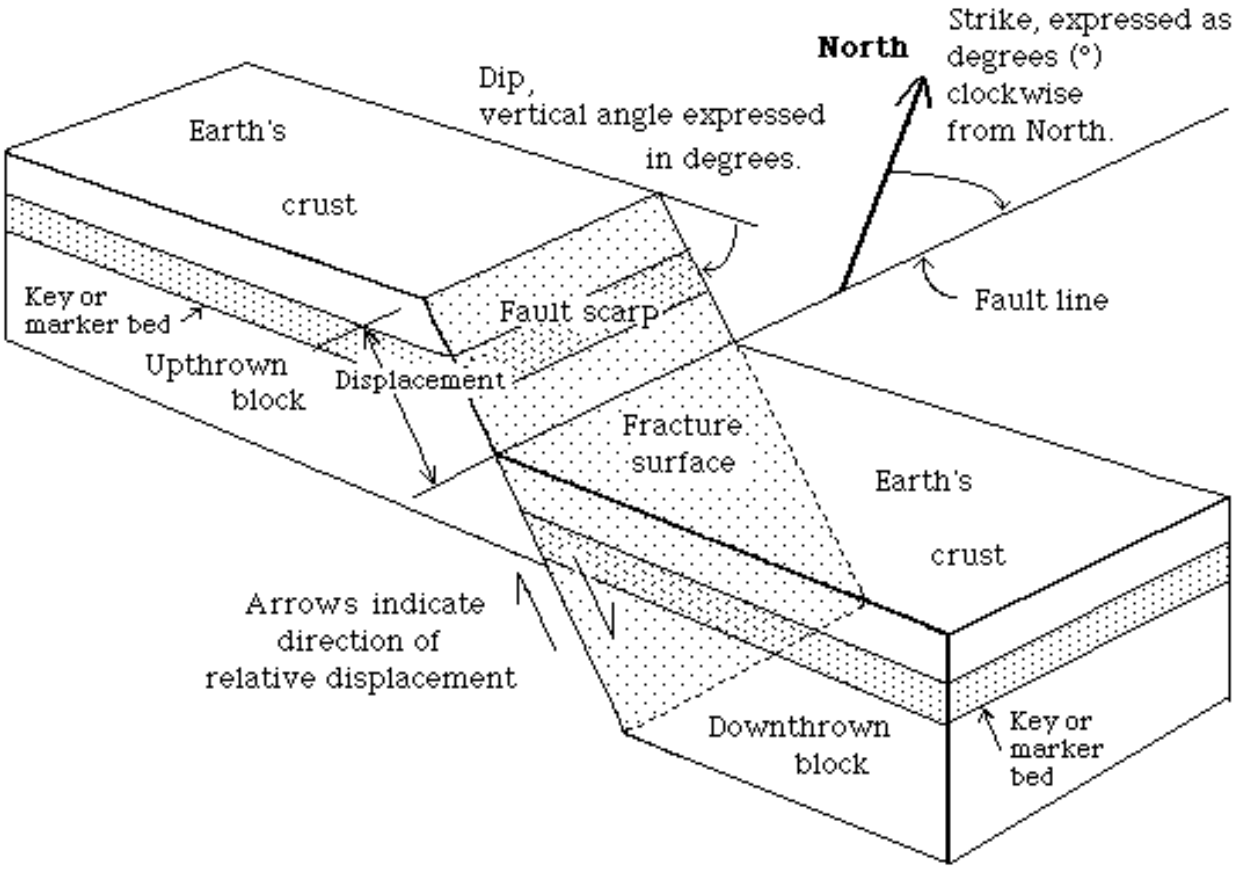
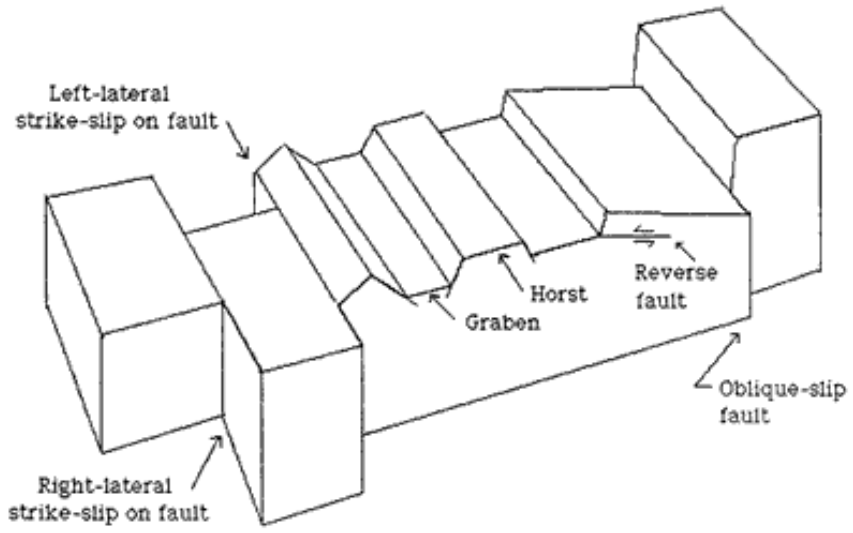


Figure 4. A collection of faults.



Assumptions Made in the Compilation of the Models

These paper models represent simple faults and illustrate some of the landforms associated with faulting of the Earth's crust. For scale, the models assume total displacement somewhere in the neighborhood of 40 feet or 12 meters. To make the models more realistic, some of the fault scarps are cut by gullies and are eroded in ways indicative of an arid landscape. All of the paper models show displacement on the fault by the use of arrows and by the offset of a marker bed or a stream.

- The normal and reverse fault models represent recent fault movement with no erosion. The arrows indicate the direction of relative movement, and the marker bed gives a clue as to the amount of displacement of the blocks.

- The right- and left-lateral strike-slip fault models, illustrate the occurrence of horizontal fault movement. The arrows indicate the direction of relative movement. Note the offset in the stream channels.

- On the oblique-slip fault, there has been horizontal and vertical slip on the fault line. The arrows indicate the direction of relative slip, and the marker bed gives a clue as to the amount of displacement of the blocks. The fault scarp on the upthrown block has been eroded and a stream has eroded a small canyon into this block. Note the right-lateral offset of the stream channel.

• The graben model portrays three fault blocks in which the middle block has fallen relative to the two blocks on either side. The movement on the two near-parallel faults is vertical, as indicated by the arrows. and displacement is implied by the marker bed. On one of the upthrown blocks, a stream has eroded a gully and deposited an alluvial fan.

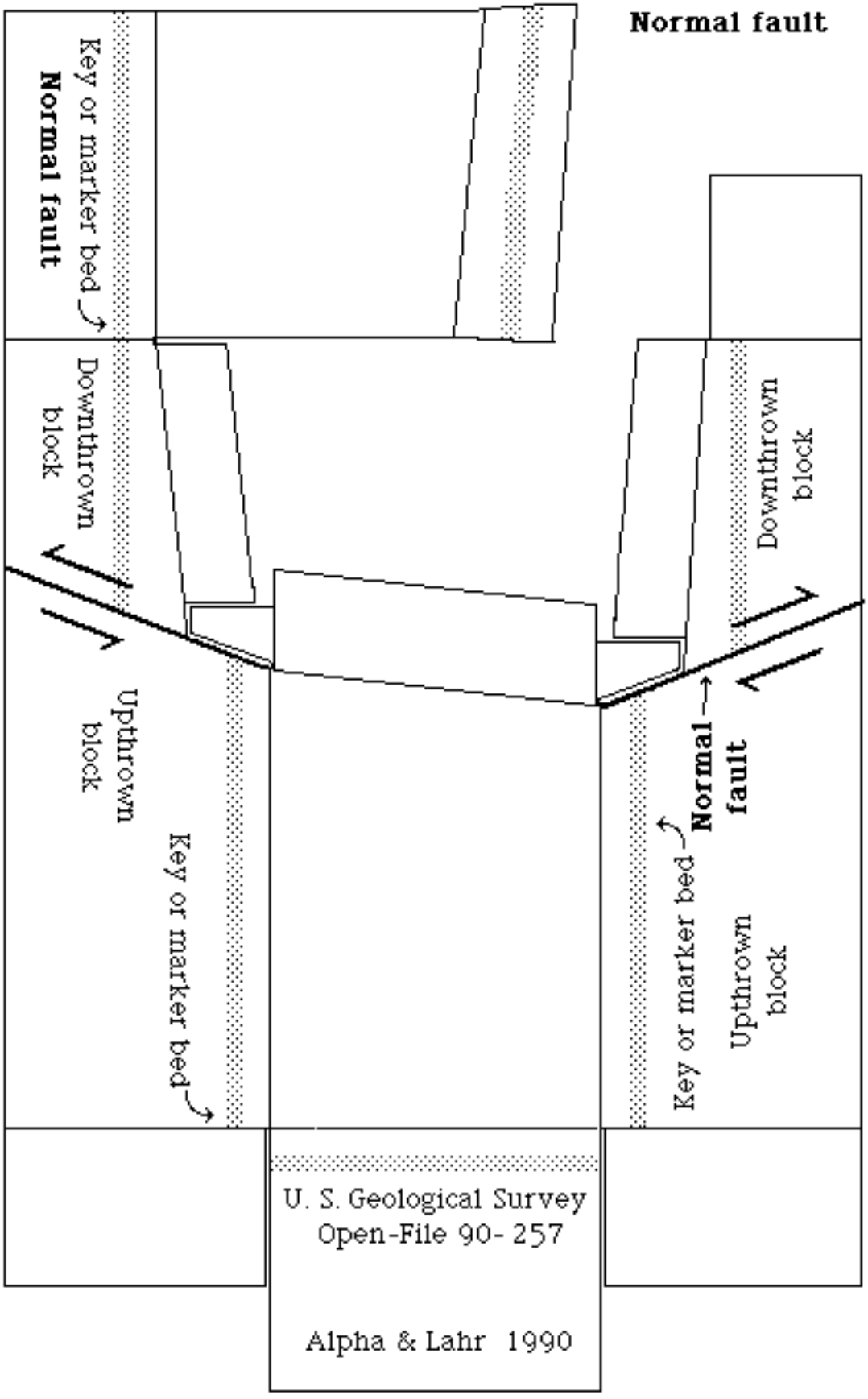
• Three fault blocks make up the horst model with the middle block higher than the blocks on either side. The relative movement is indicated by the arrows, and the marker bed expresses the displacement of the faults. On the upthrown block (horst) there is an intermittent stream with associated gully and alluvial fan.

General Directions for Constructing the Models

To cut out the models, scissors may be used, but a small knife, such as an X-ACTO knife with a number 11 blade may be the best. For constructing the models, a water-soluble glue, preferably a stick glue, works well. Read the special instructions and study the cutting and folding steps. Look at the folding diagrams to see how the patterns fit together to make the model landforms. Make a photocopy of the pattern, carefully cut out the pattern, and fold all corners and tabs. Fold the pattern into the model before applying glue, then glue the tabs, which are indicated with a dot pattern.

By using a computer and a graphics software program (not included) geologic patterns and symbols can be added to the models before construction to represent, rock types, surface material, or the influence of man. Color can be added to the models before or after construction. Have fun customizing your three-dimensional paper fault models.

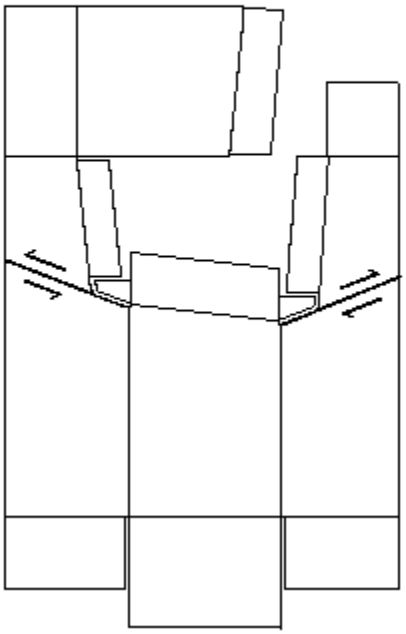
Normal fault pattern



Normal fault model directions

Step 1

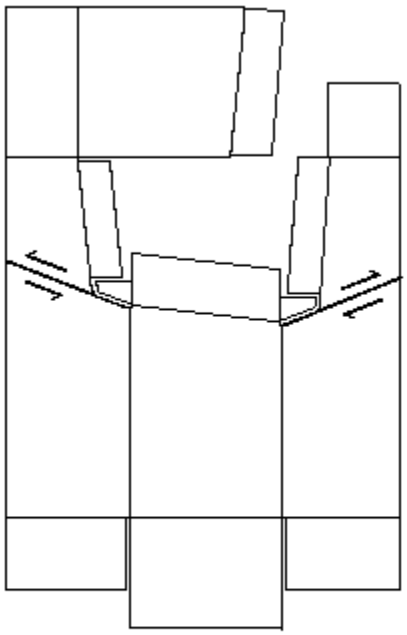
Cut out the pattern of the paper landform by cutting along its borders.



Step 2

Make creases and fold along the solid straight lines within the pattern, folding so the printed side faces outward.

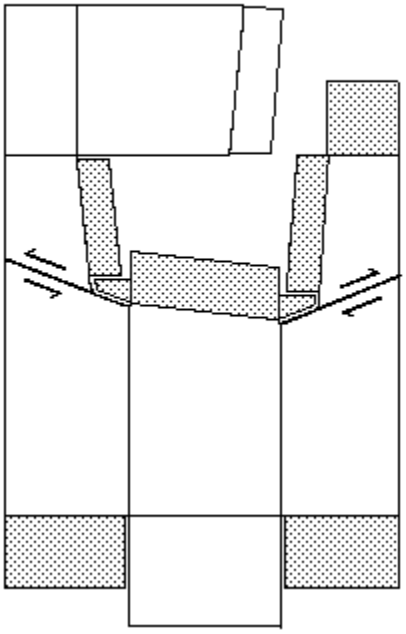
Do not fold fracture surface.



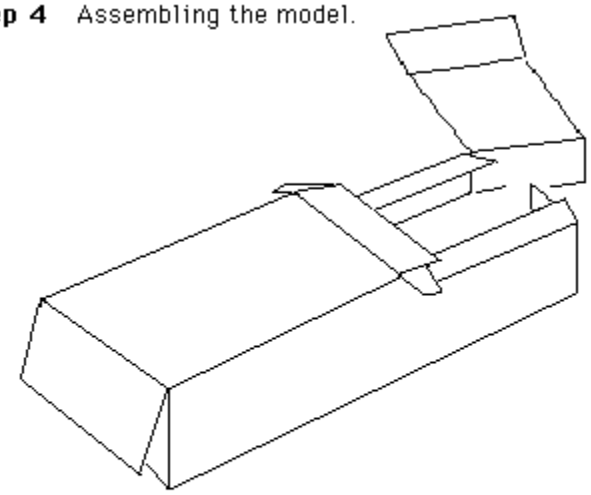
Step 3

Glue the marked tabs.

glue

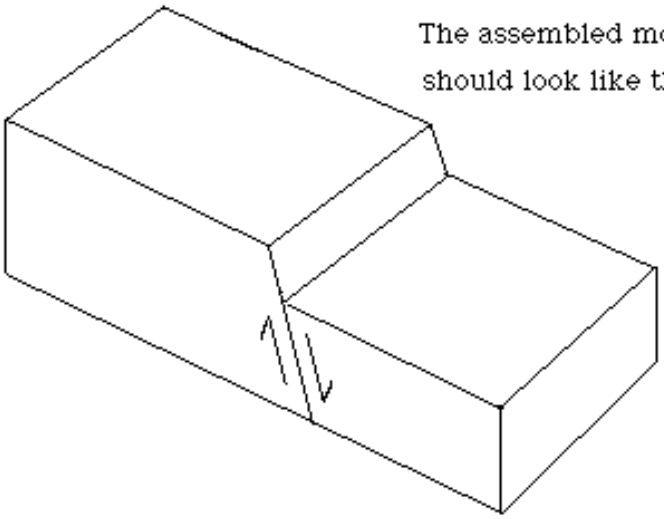


Step 4 Assembling the model.

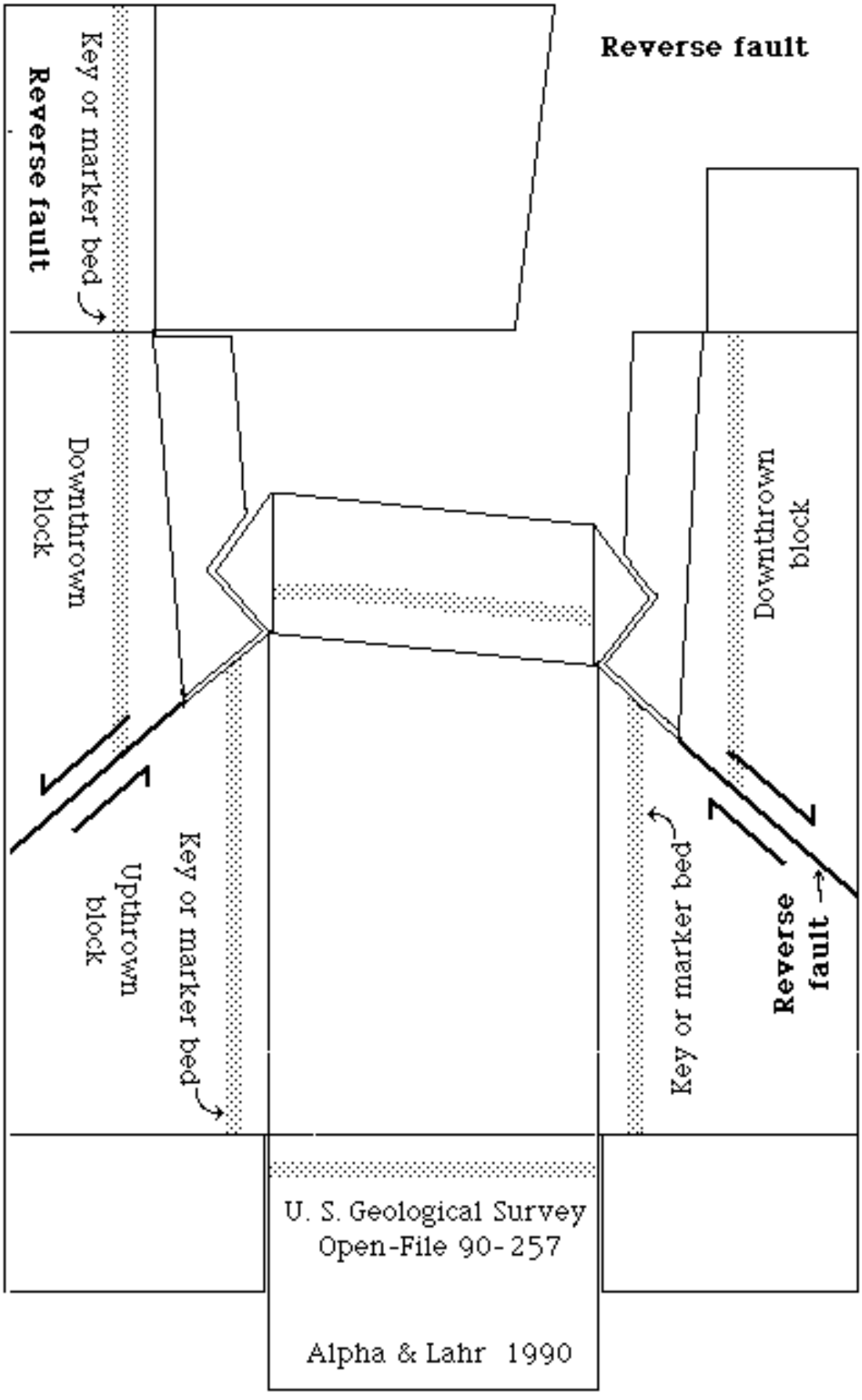


Step 5

The assembled model should look like this.



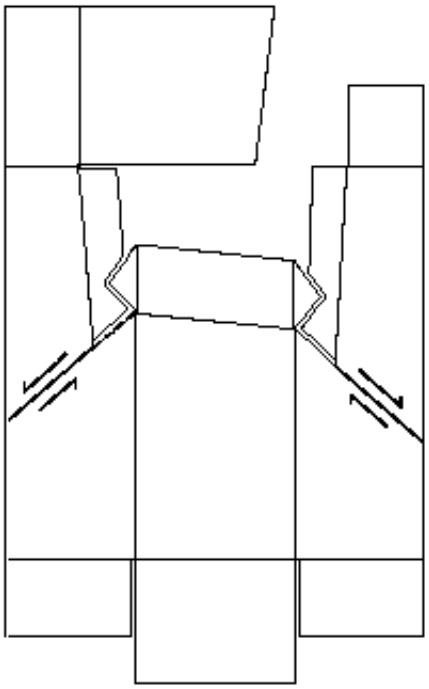
Reverse fault pattern



Reverse fault model directions

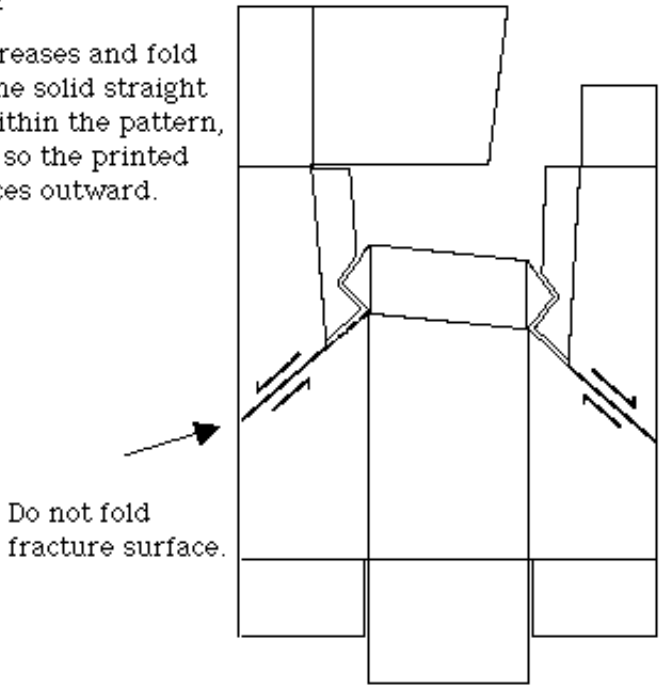
Step 1

Cut out the pattern of the paper landform by cutting along its borders.



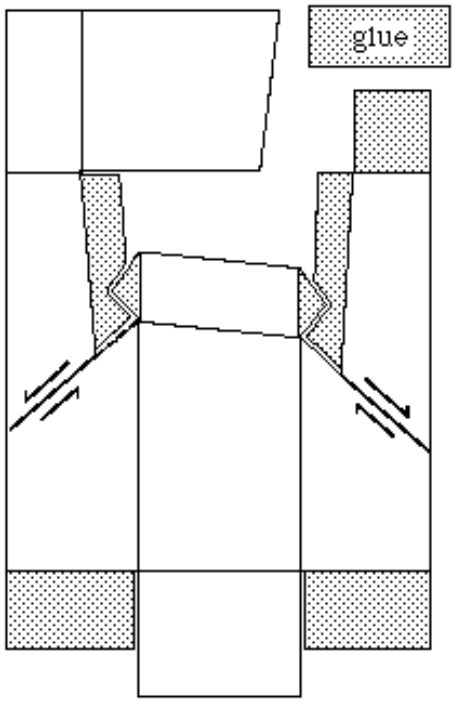
Step 2

Make creases and fold along the solid straight lines within the pattern, folding so the printed side faces outward.

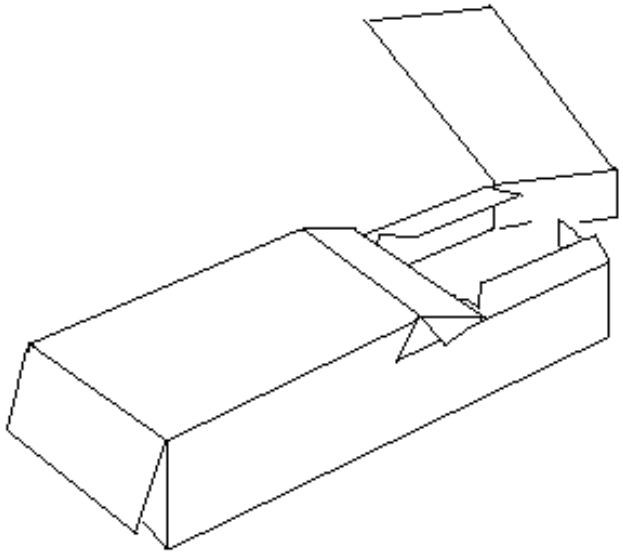


Step 3

Glue the marked tabs.

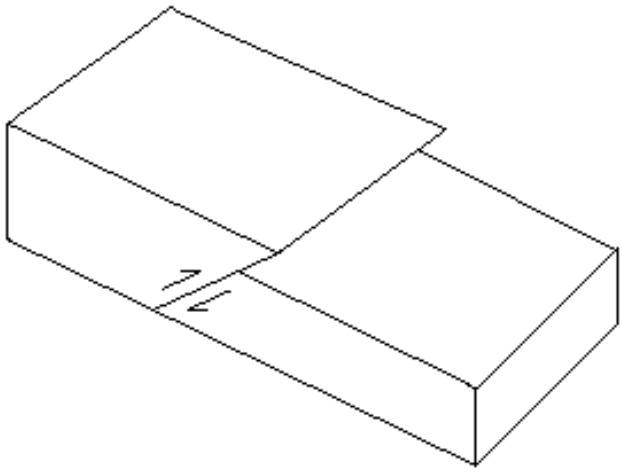


Step 4 Assembling the model.

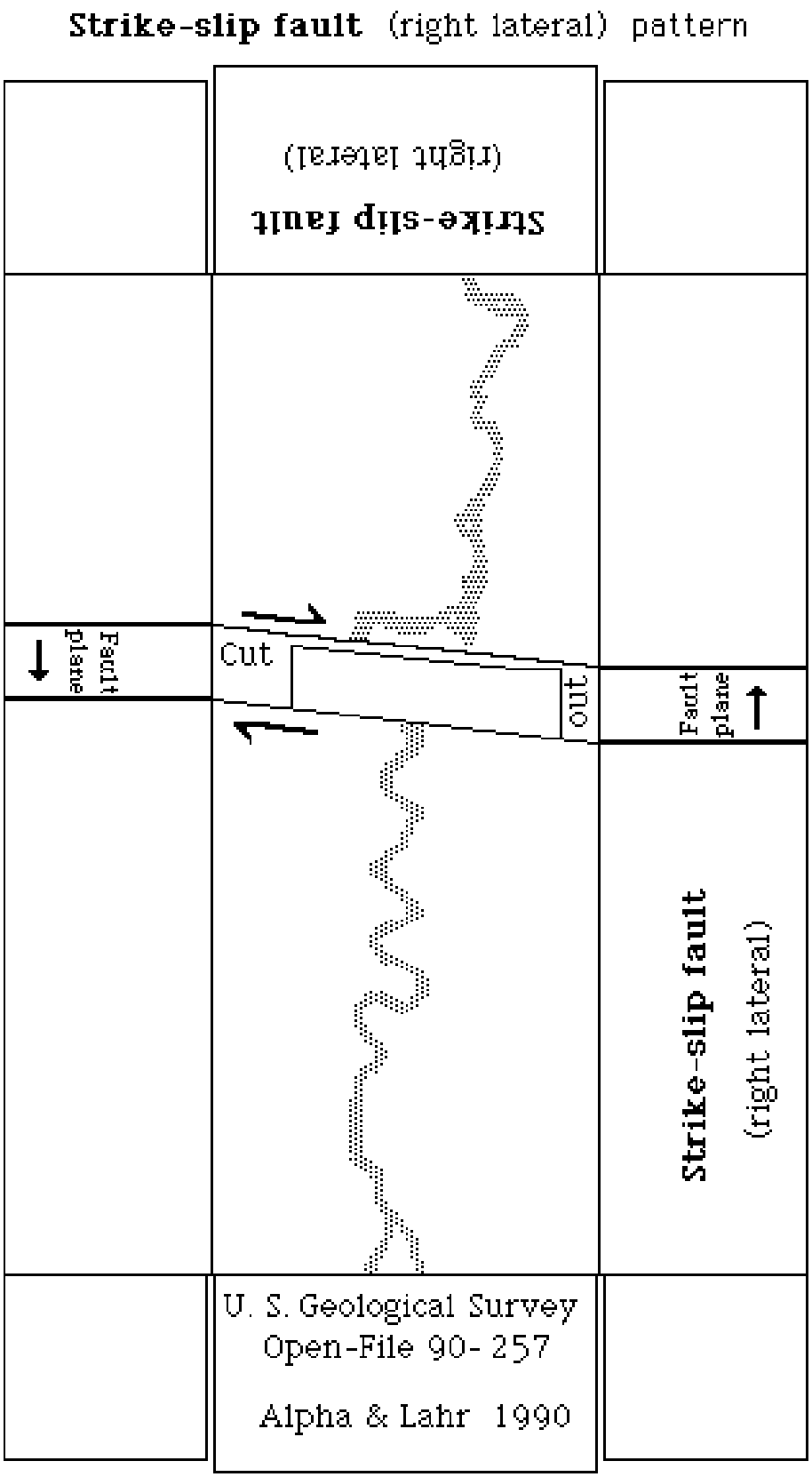


Step 5

The assembled model should look like this.



Right-lateral strike-slip strike-slip fault pattern

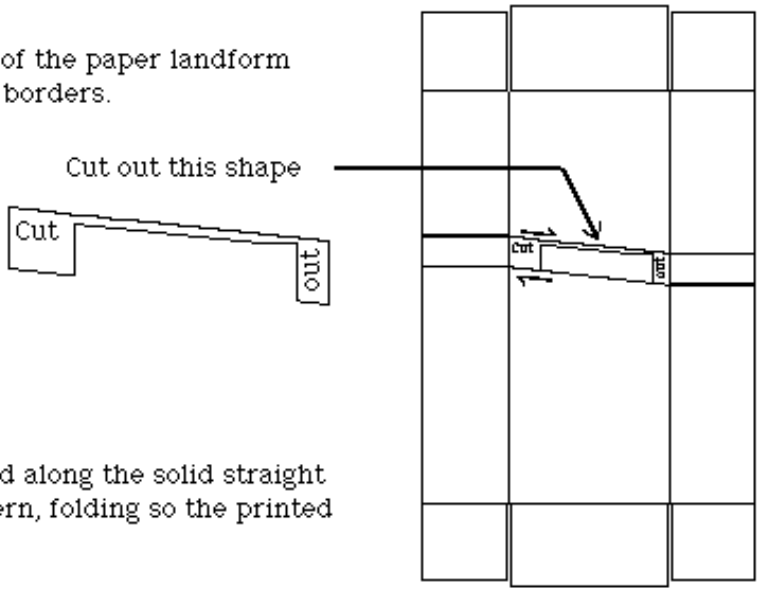


Right-lateral strike-slip strike-slip fault directions

Strike-slip fault (right lateral) instructions

Step 1

Cut out the pattern of the paper landform by cutting along its borders.

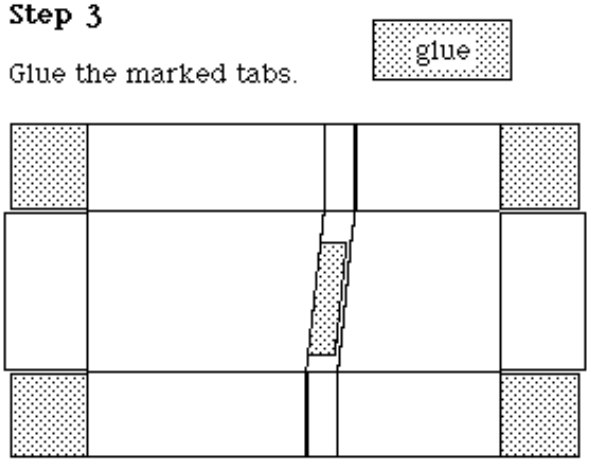


Step 2

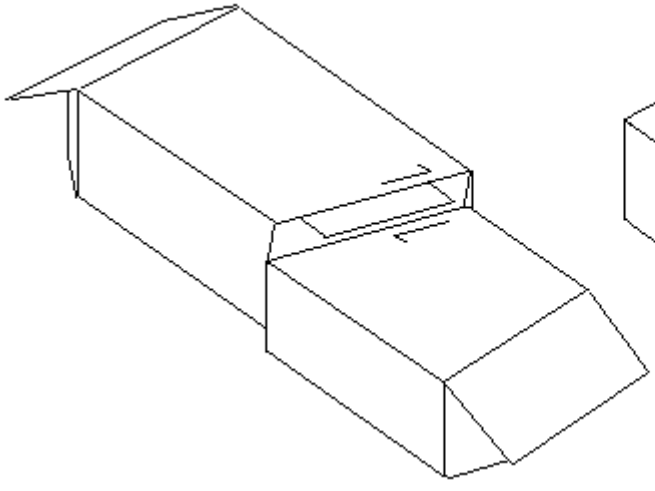
Make creases and fold along the solid straight lines within the pattern, folding so the printed side faces outward.

Step 3

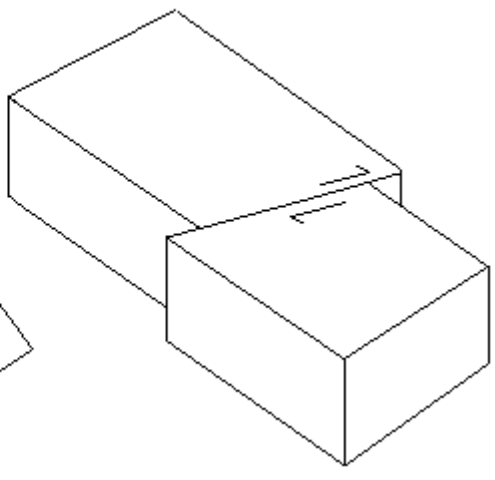
Glue the marked tabs.



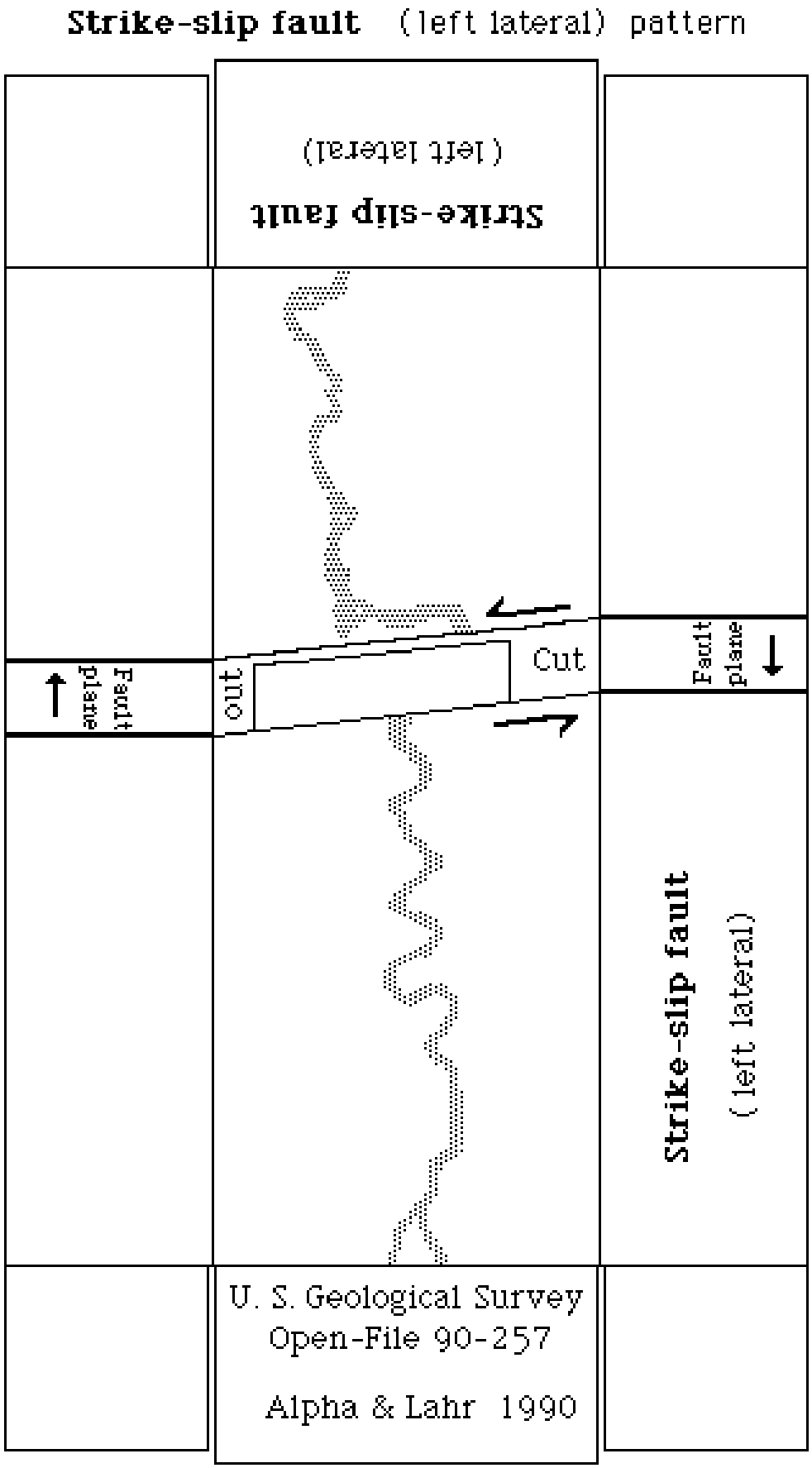
Step 4 Assembling the model.



Step 5 The assembled model should look like this.



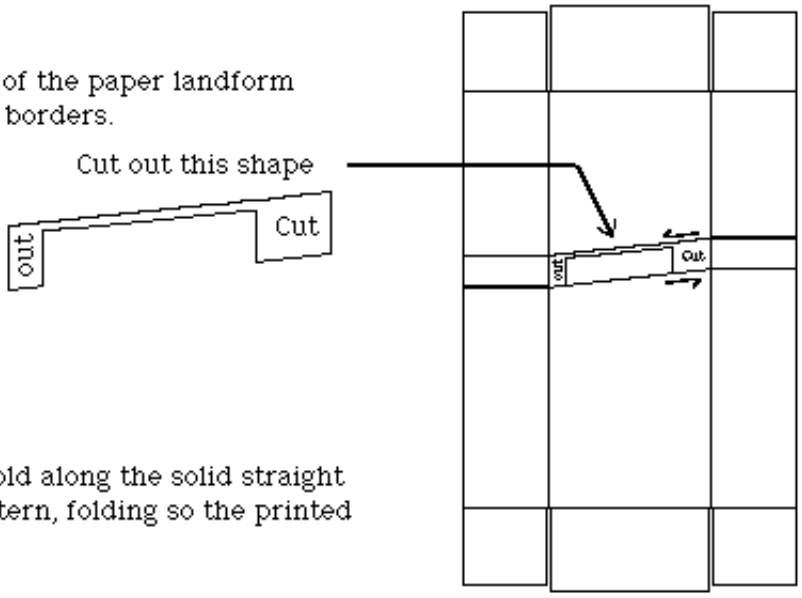
Left-lateral strike-slip strike-slip fault pattern



Left-lateral strike-slip fault model directions

Step 1

Cut out the pattern of the paper landform by cutting along its borders.

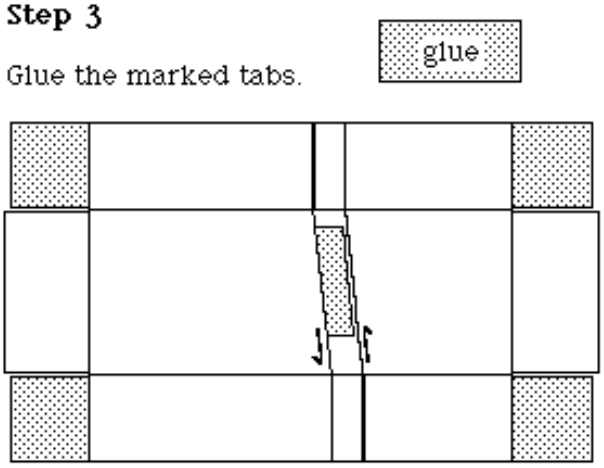


Step 2

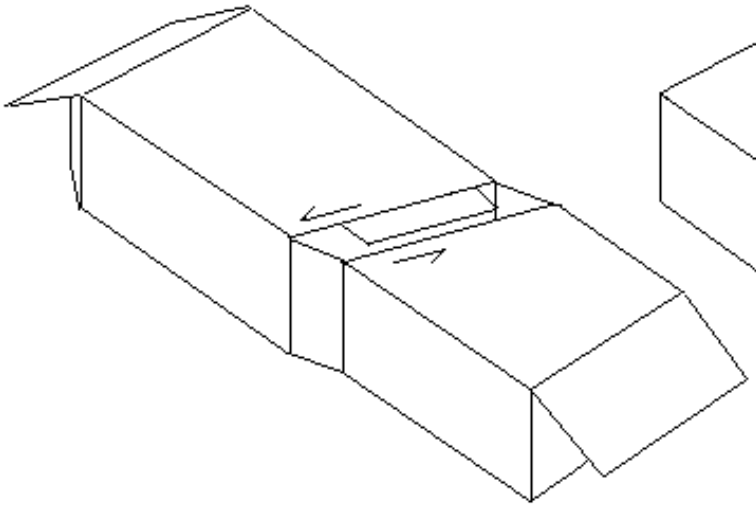
Make creases and fold along the solid straight lines within the pattern, folding so the printed side faces outward.

Step 3

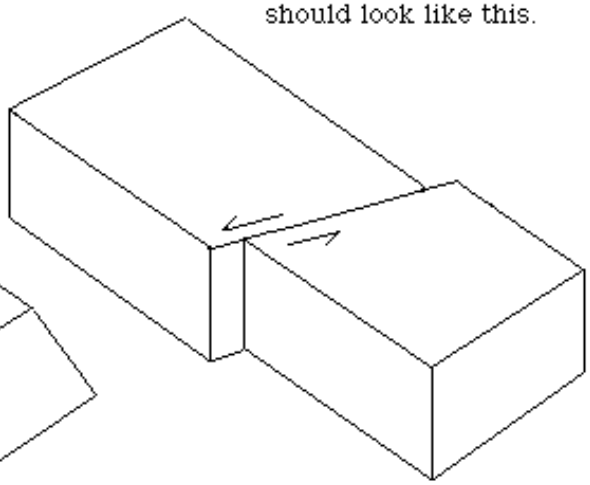
Glue the marked tabs.



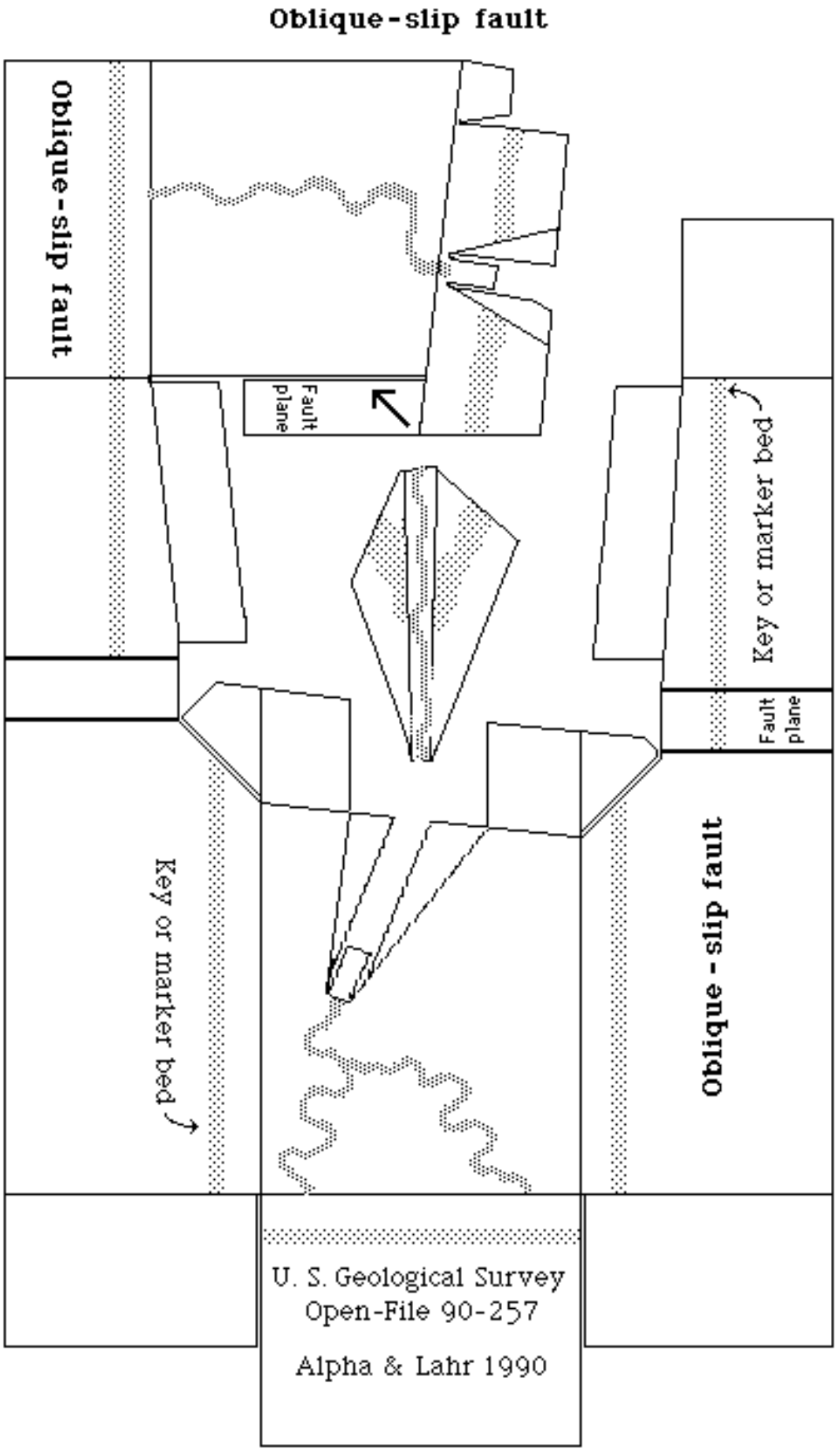
Step 4 Assembling the model.



Step 5 The assembled model should look like this.



Oblique-slip fault pattern



Oblique-slip fault model directions

Step 1

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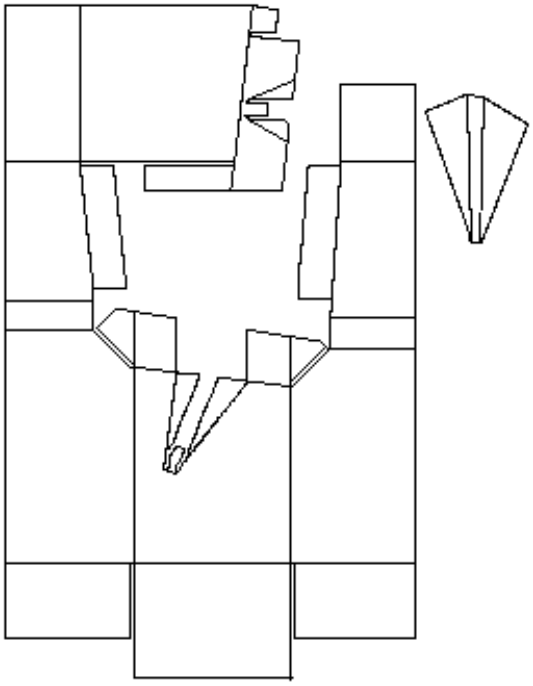
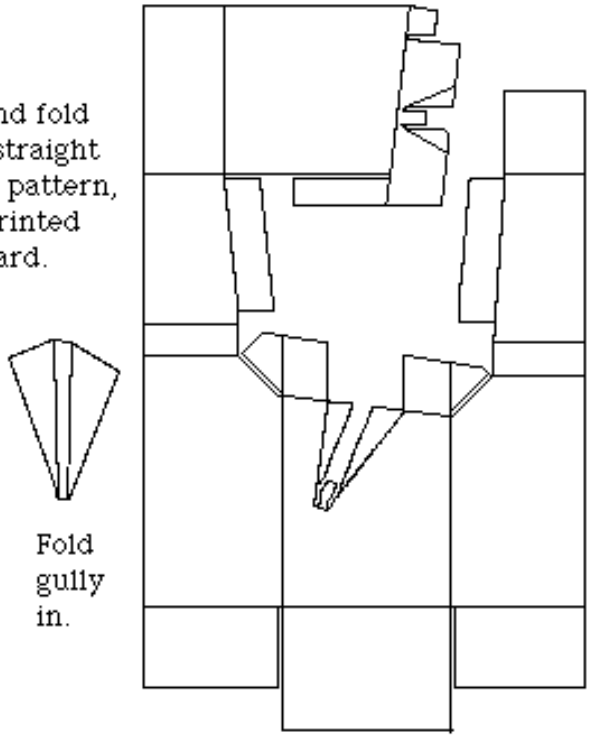


Step 2

Make creases and fold along the solid straight lines within the pattern, folding so the printed side faces outward.

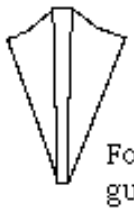


Fold gully in.

Step 3

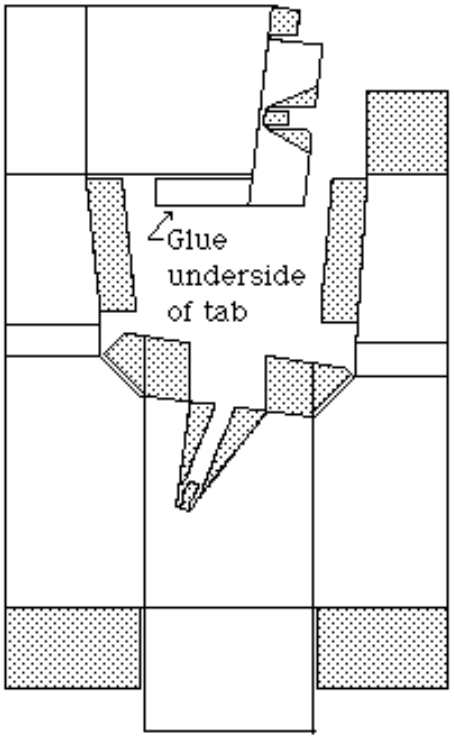
Glue the marked tabs.

glue

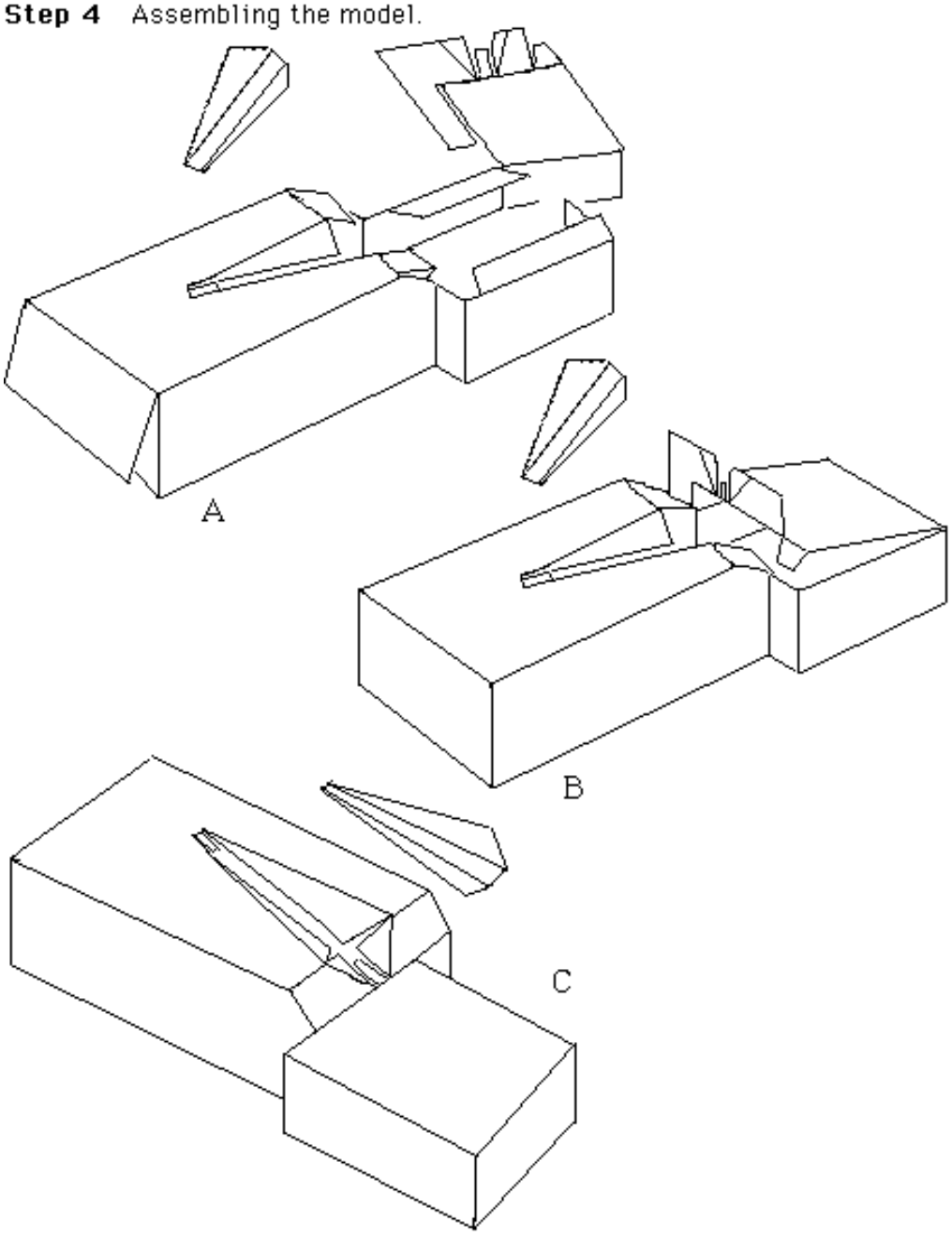


Glue underside of gully.

Fold gully in.

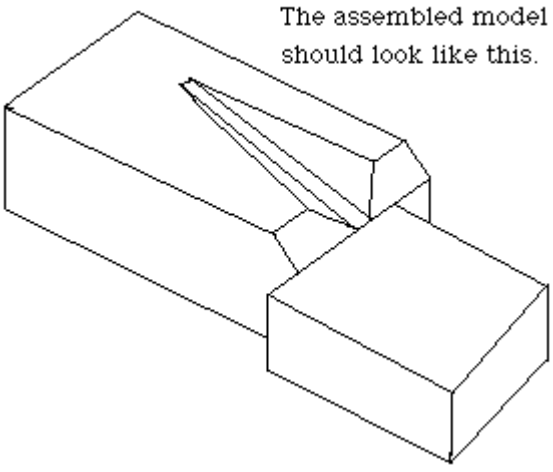


Step 4 Assembling the model.

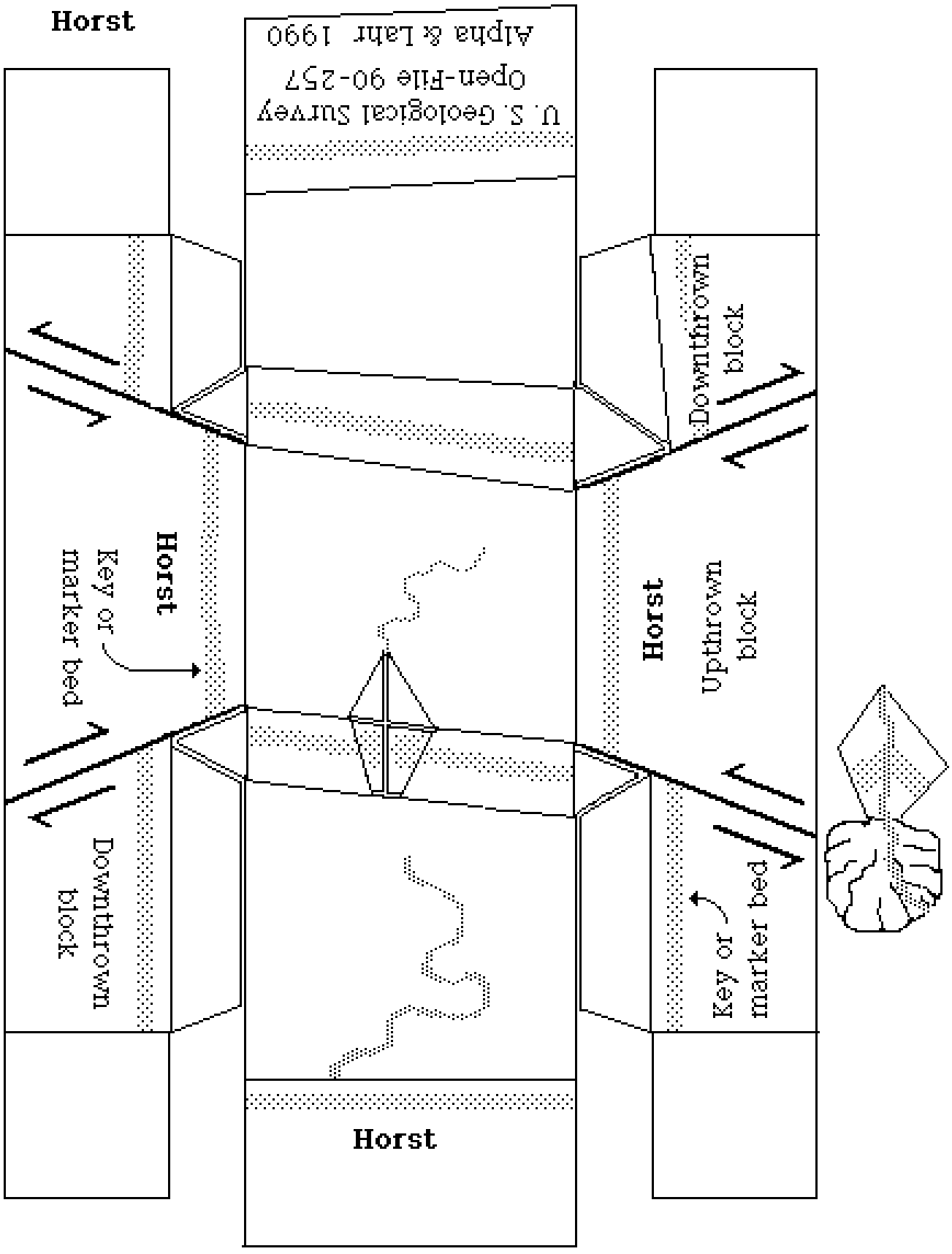


Step 5

The assembled model should look like this.



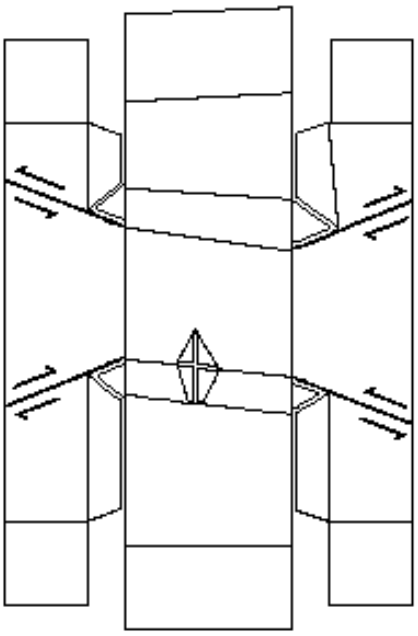
Horst pattern



Horst model directions

Step 1

Cut out the pattern of the paper model by cutting along its borders.



Step 2

Make creases and fold along the solid straight lines within the pattern, folding so the printed side faces outward.

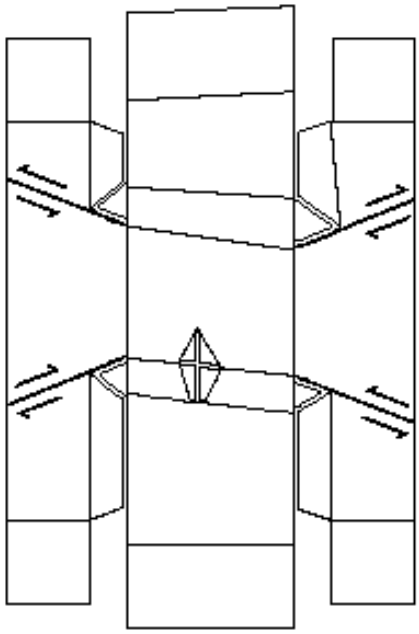
Do not fold fracture surface.

Do not fold fracture surface.

Fold gully as shown.

Fold gully in.

Fold alluvial fan out.



Step 3

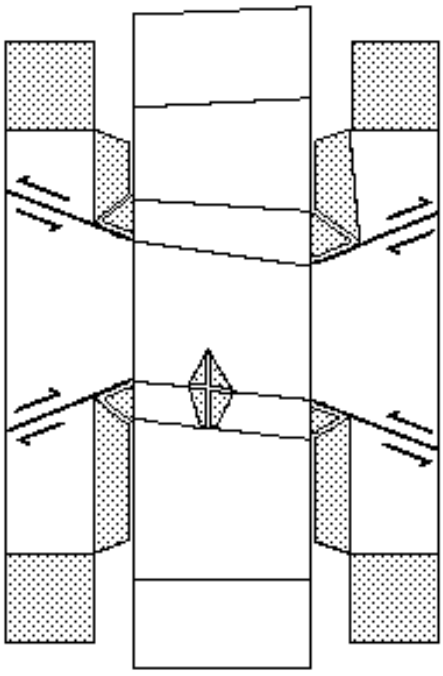
Glue the marked tabs.

glue

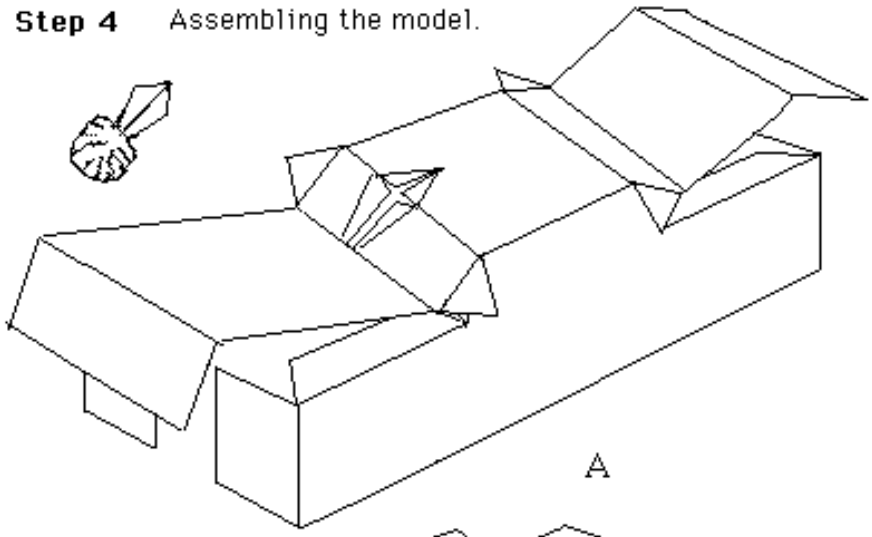
Fold in.

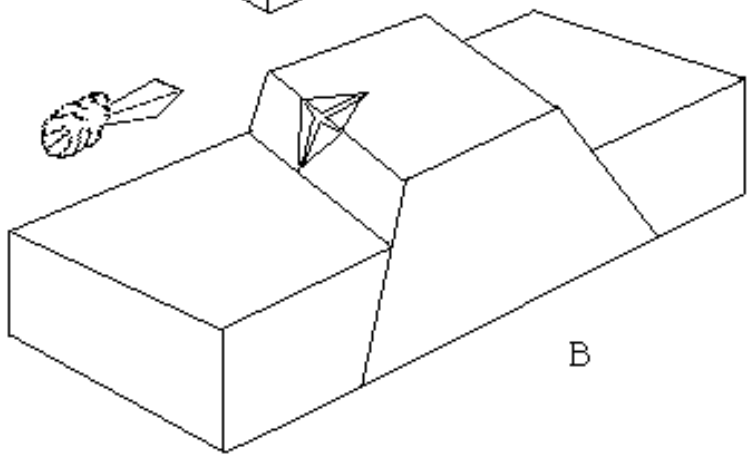
Glue underside of gully and alluvial fan.

Fold out.



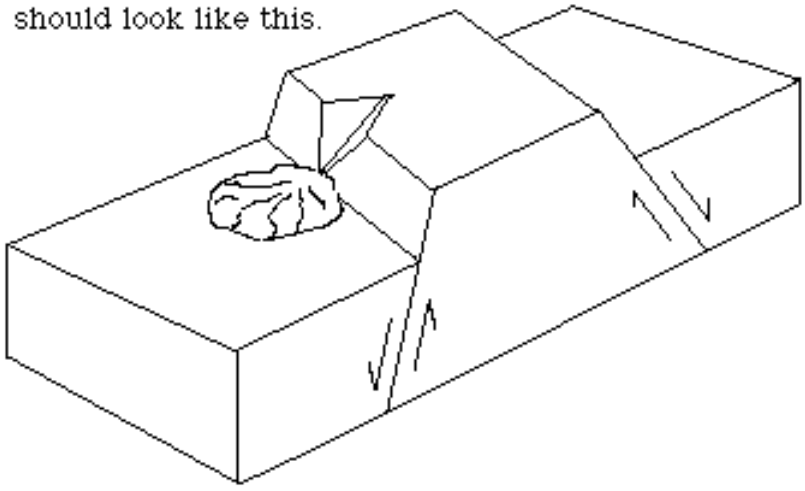
Step 4 Assembling the model.



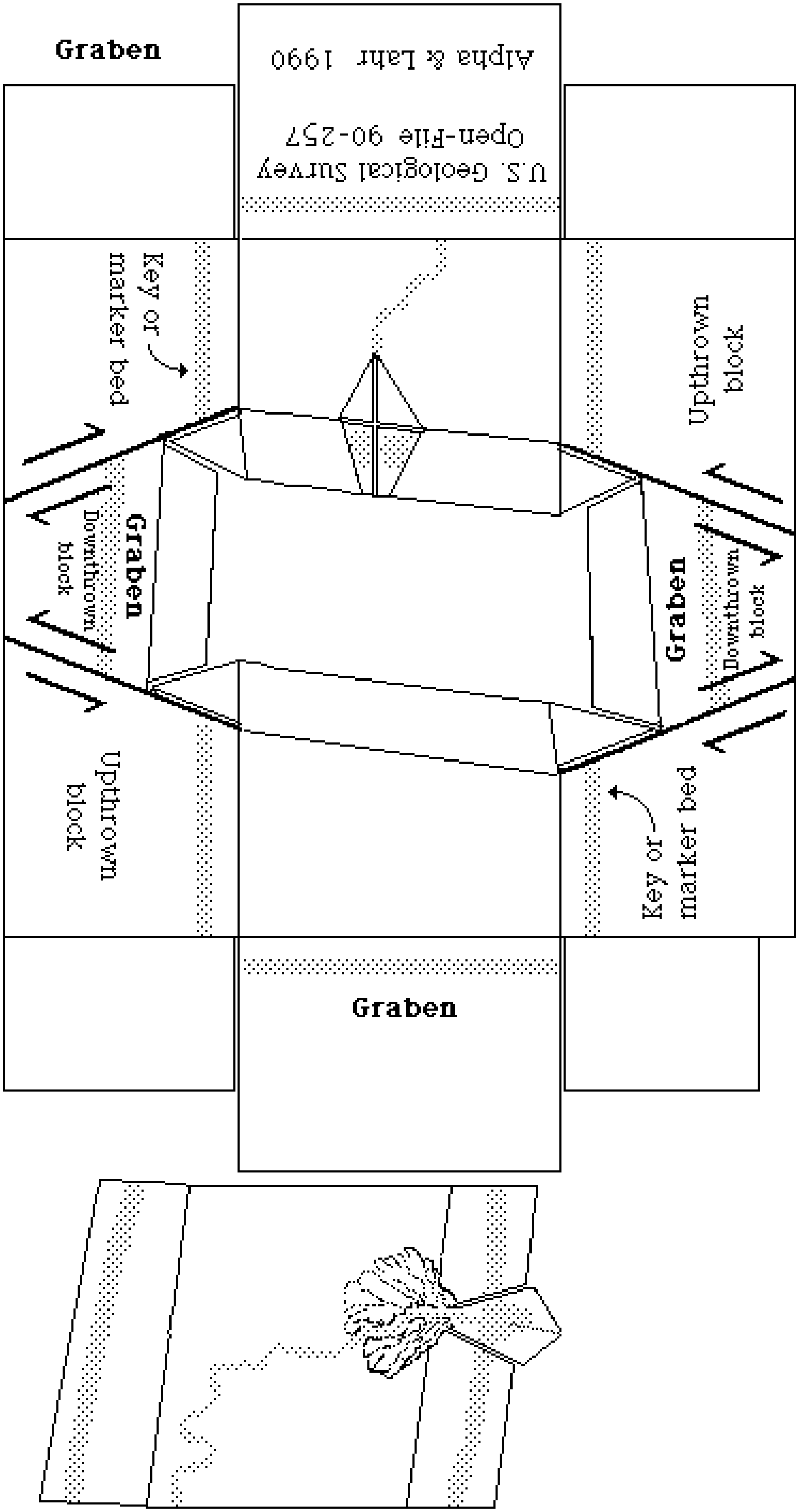


Step 5

The assembled model should look like this.



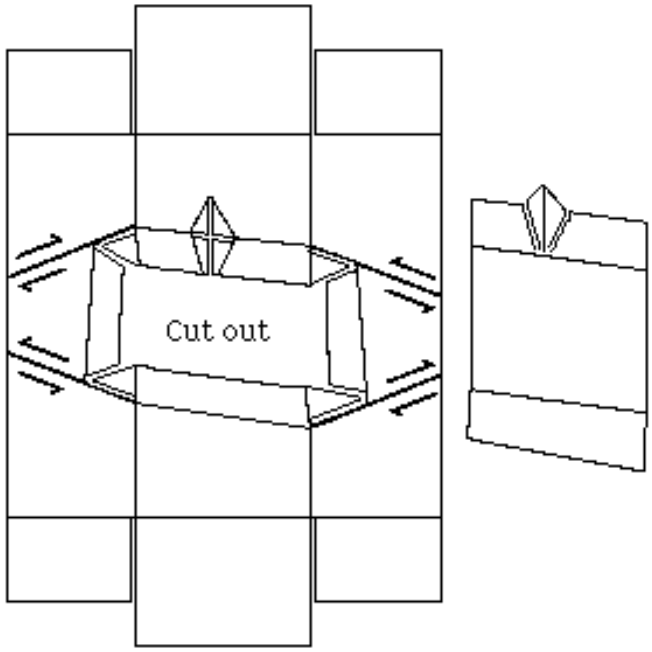
Graben pattern



Graben model directions

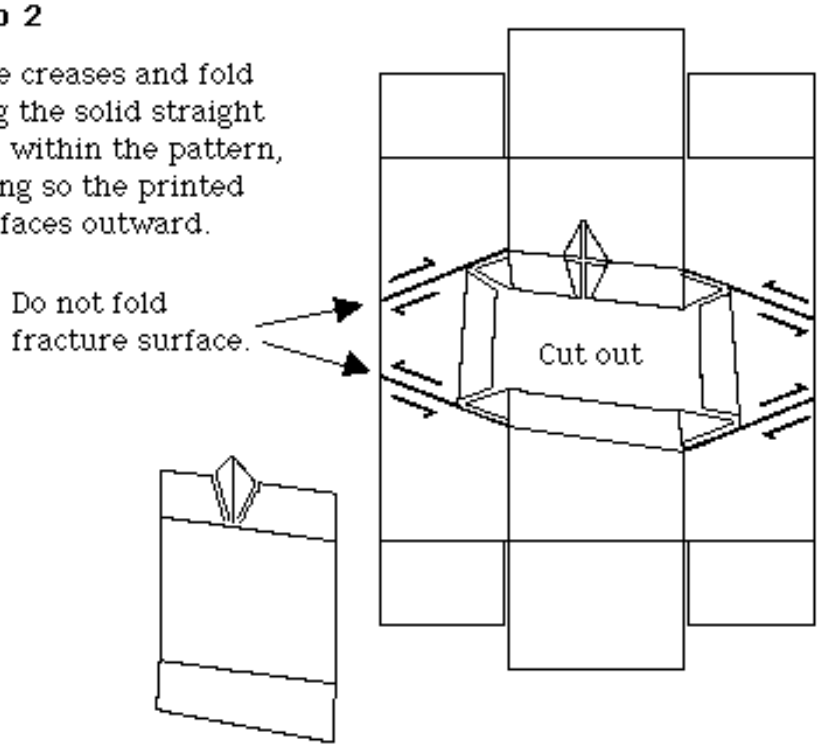
Step 1

Cut out the pattern of the paper model by cutting along its borders.



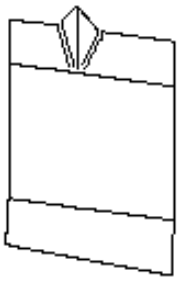
Step 2

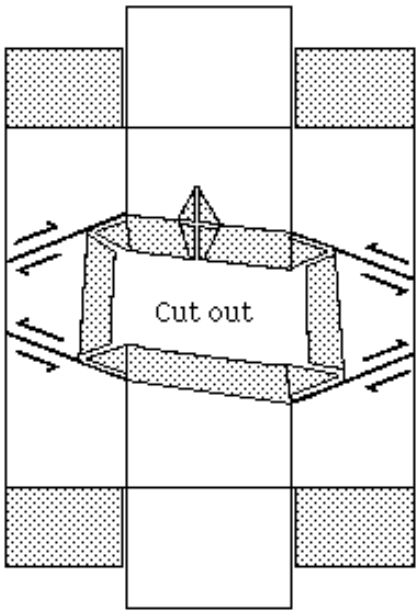
Make creases and fold along the solid straight lines within the pattern, folding so the printed side faces outward.



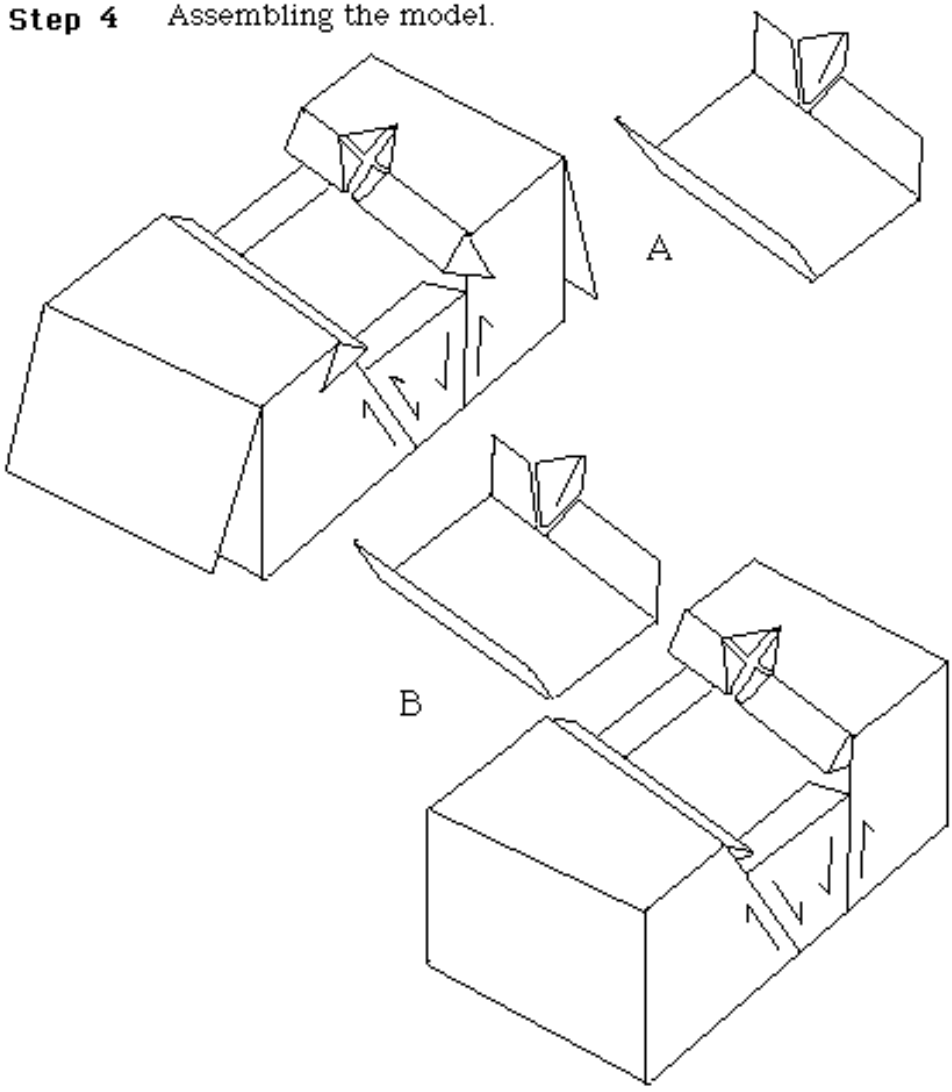
Step 3

Glue the marked tabs.



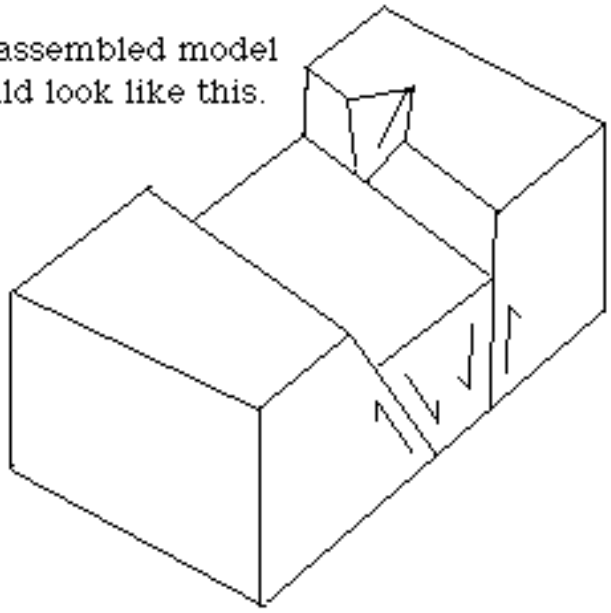


Step 4 Assembling the model.



Step 5

The assembled model should look like this.



Acknowledgment

The authors thank Robert E. Wallace for reviewing an earlier version of this report.

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