100

Geology Models

Study Guide

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HUBBARD Scientific

GEOLOGICAL MODELS

The purpose of these models is to show typical topographic forms, and their relation to underlying geologic structures. They are not a representation of actual landscape, except in a very general way. However, if a line were drawn from the state of Washington to the state of North Carolina, most of these land forms would be encountered within a few hundred miles on either side of such a line.

Great forces that have been at work for hundreds of millions of years have shaped the crust of the earth. These forces are still at work and will continue as long as the earth exists. All geologic processes can be classified under three heads: **Diastrophism, Volcanism,** and **Gradation.**

Diastrophism is any deformation of the earth's crust. Lands and sea basins are uplifted or depressed. Continents, plateaus and plains are uplifted. In places the crust is folded and faulted to form mountains.

Volcanism is the processes by which molten material (magma) is emplaced in the earth's crust to cool and crystallize as instrusive igneous rock, such as granite; or by which the molten material comes to the surface as lava in volcanoes or along fissures.

Gradation is the wearing down or building up of the crust. The wearing down — erosion — is by water flowing over the lands or in streams; by water dissolving soluble rocks below the surface; by winds; by ice of glaciers; and by waves of seas or lakes. The building up is by deposition of the eroded material as alluvium by rivers and streams; sand and dust by wind; unsorted debris by glaciers; and most important of all, by deposition in seas of materials eroded from the lands or of materials formed by hard parts of animals and plants.

Erosion and deposition — **gradation** — eventually would bring the earth to an even surface, but **diastrophism** uplifts part of the earth's surface from time to time so that gradation can begin again. The positions of seas and continental shelves thus change and old lands are submerged and new lands emerge. Along shores coastal plains are formed by uplifted continental shelves and at other places irregular shorelines are formed when coasts are drowned and river valleys become bays.

After studying these models, we should be encouraged to observe the landscape about us more carefully and hopefully be better able to recognize the features of our landscape and the forces that have produced these topographic features.

PROJECTS AND EXPERIMENTS

The projects and experiments outlined in the Study Guide are planned to supplement the models and to demonstrate basic geologic processes represented by each specific model. These activities will help explain why and how the features appear as they do. The experiments were developed for the **Geology and Earth Sciences Sourcebook** and are used with permission of the publisher, Holt, Rinehart and Winston, Inc. Numerous other projects are outlined in this publication and many others may be developed by students.

COASTLINE OF SUBMERGENCE VOLCANISM FAULT BLOCK MOUNTAINS ALPINE GLACIATION

IN EIGHT SECTIONS

FIELD TRIPS

The Geology Models will prove helpful in connection with field trips and should be used whenever possible both before and after the trips have been taken. Features to be studied on a trip may be pointed out on the models to facilitate recognition of such features. After a trip the models will aid in reviewing and may be related to photographs taken in the field. Topographic maps and U. S. Geological Survey maps used for field trips should also be related to the models.

SUPPLEMENTARY MAPS

A list of topographic maps relating to each model is given in the Study Guide. Each of the maps contains some of the features on the model and the maps provide excellent study projects. Students should recognize features on the maps and then find similar features on the models.

INDEX KEY

Each model contains an index key along the edges with numbers running east and west, and letters north and south. This key is designed to facilitate the location of features on the models. The numbered features listed in the Study Guide include an index key for each item. The index also may be used for testing purposes.

MOUNTING AND DISPLAYING

The Geology Models are ideal for displays, special exhibits, museums, etc., and should be displayed when they are not being used for teaching purposes. They may be mounted individually or as a complete series either horizontally or vertically. There are numerous ways to display mount the models including standard pegboard racks, picture hooks with gummed hangers, bulletin boards, display shelves and permanent display cabinets. The models are coated with a special surface so that they may be washed with a damp cloth.

TESTING MATERIAL

The Study Guide outlines and suggests test questions for each model. There are 156 numbered features on the complete set of eight models, and many more that are not numbered. Students may be tested on the identification and definition of these features, however, the tests should also include questions pertaining to the causes and effects of the geologic forces that form the features.

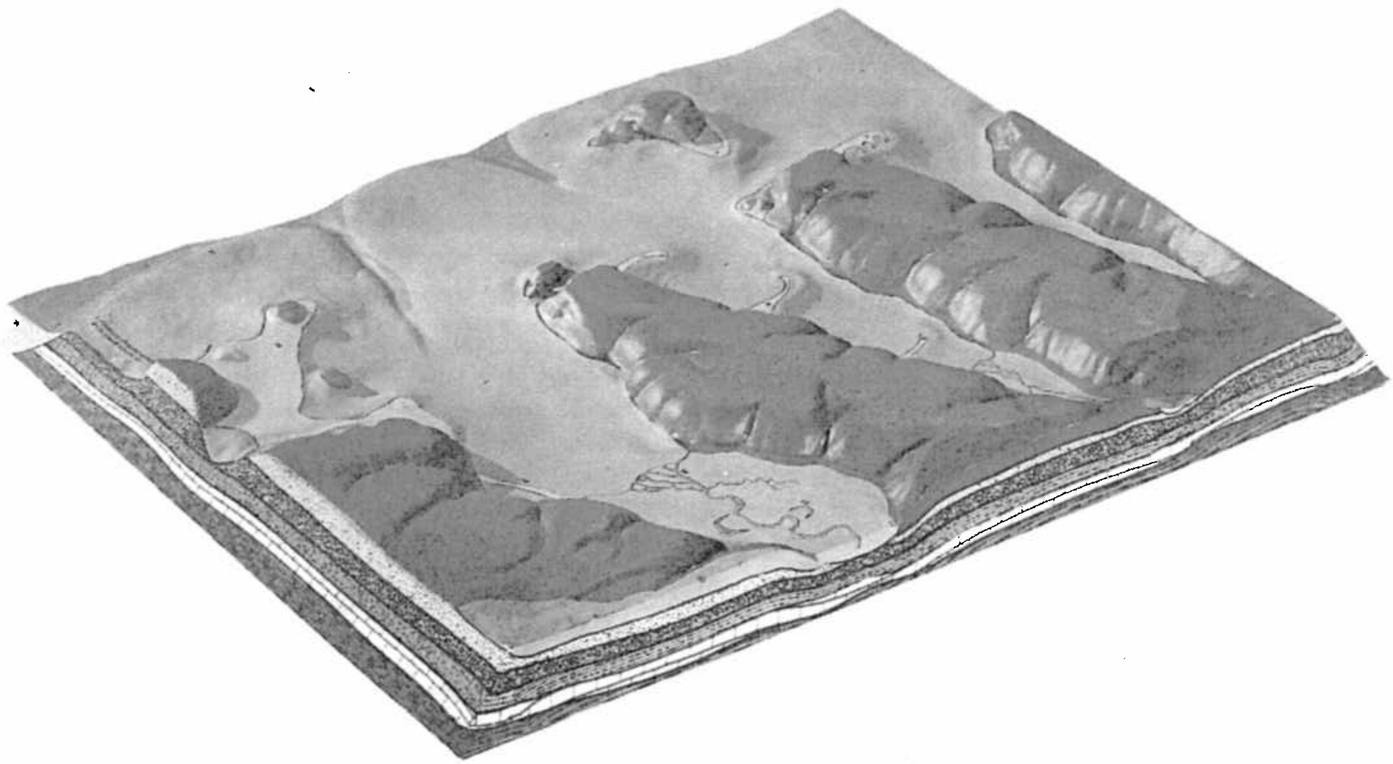
The models lend themselves to open end questions that will stimulate thought in the subjects of geology, geography, meteorology, and climatology. Typical questions would be: Where would the population centers be located and why would they be there? What natural resources would you find and where would they be located? Suggest various climates that might be found. Locate point 21-D and describe the subsurface bedding at this point.

The questions in the Study Guide may be expanded or simplified depending upon the level of instruction.

DOME MOUNTAINS — CONTINENTAL GLACIATION — FOLDED MOUNTAINS — COASTAL PLAIN

MODEL 1

COASTLINE OF SUBMERGENCE



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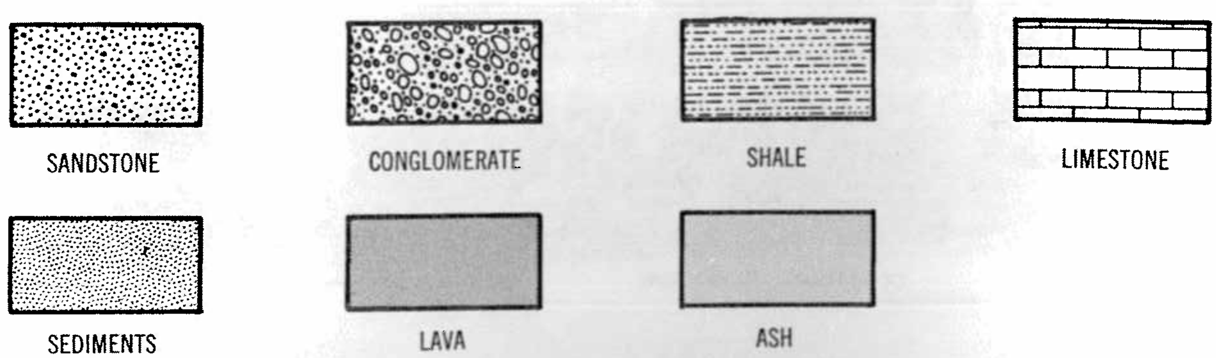


FEATURES

1. C-4 **BAY** — An indentation into the land occupied by the sea.

2. D-4 **PROMONTORY** — A headland projecting into the sea.

3. F-1 **ISLAND** — Land surrounded by the sea. In this case, the island is related to the promontory. The island was a hill on the drowned ridge, the main part of which is now the promontory, No. 2.

4. G-3 **BEACH** — The strip of deposits bordering the sea, usually lying between high and low tide. On exposed coasts a beach is frequently made up of rocks or pebbles, on protected coasts it is made up of sand. The "material is in more or less active transit along the shore, or on and off shore."

5. F-2 **LOOPED BAR** — A continuous bar built by currents sweeping around an island.

6. H-3 **COMPOUND RECURVED SPIT** — An embankment of sand or gravel deposits formed by longshore currents. The "hooks" are remnants of the former curved ends of the spit, which has now grown beyond the former positions.

7. E-3 **SIMPLE RECURVED SPIT** — An embankment of sand swept out from the headland and deposited by longshore currents.

8. E-4 **MIDBAY BAR** — A bar formed by currents within the bay.

9. F-6 **BAYHEAD BAR** — A small bar deposited at the head of a bay.

10. F-7 **CREEK** — A small stream.

11. D-3 **STACK** — A rock pillar on the coastline isolated by wave action.

12. D-4 **WAVE-CUT CLIFF** — Steep cliff formed by wave erosion.

13. B-5 **CUSPATE FORELAND** — Material deposited seaward in a triangular shaped form.

14. C-6 **DELTA** — The deposit of alluvium at the mouth of a river that empties into a relatively quiet body of water, such as a bay. The delta shown is a bay-head delta. A delta formed in more open water may be triangular ("delta") in shape.

15. D-7 **OXBOW LAKE** — A lake formed by the cutting off of a meander loop. The river cuts across the narrow neck of land between the two loops, leaving the old channel as a lake. (See also 115, 116, and 117).

16. A-3 **TOMBOLO** — A bar that connects an island with the mainland.

17. B-1 **CONTINENTAL SHELF** — The marginal part of a continent which is covered by shallow water, its seaward margin slopes more steeply to the ocean floor.

18. A-1 **CONTINENTAL SLOPE** — That part of the ocean floor extending from about 100 fathoms to about 2000 fathoms characterized by a marked increase in gradient.

19. C-1 **SUBMARINE CANYON** — A narrow underwater gorge with steep slopes, often of considerable size.

20. A-1 **SEDIMENTS** — Particles of rock that have been removed from their original sites and deposited on the ocean floor, or material deposited from the water by chemical precipitation or by accumulation of shells of animals or plants.

I. COASTLINE OF SUBMERGENCE

This model represents a sinking coastline. As the land slowly sank, the sea filled the valleys to form bays. Former ridges now protrude into the sea as promontories. Seaward from the northernmost promontory is an island that was a hill on the old ridge which has been isolated by drowning of the lower land between the hill and the higher part of the ridge.

This model represents a coastline that is constantly changing, and the forces of erosion and deposition are working to produce these changes. Let us first examine the force of erosion; the sea is the most dramatic agent of erosion, it constantly tears away at the promontories, to produce cliffed headlands. Remnants of the original land remain as steep-sided, almost chimney-like remnants, called stacks. On the seaward side of the islands, the force of the waves has produced steep cliffs, similar to those on the promontories. As the waves come in from the sea, they are usually parallel to the trend of the coast. Waves hit the high land around the promontory first, bend around it, concentrating energy on the end of the promontory and as a result most of the erosion occurs here.

The refraction of the waves causes them to bend around the promontory and the eroded material is moved along the sides of the promontory towards the head of the embayment.

The depositional features which have resulted from these processes are as follows:

Mid-bay Bar (8) — Deposited here as the refracted waves carried material towards the head of the embayment where they lost most of their force. **Cuspate Foreland** (13) — Waves and current action have carried the materials seaward and deposited them in this triangular form. **Looped Bar** (5) — The action of the waves which were refracted around the island, produced longshore drift along each side of the island. Longshore drift carried sand along each side and toward the back of the island and the two streams of sand met and produced a horseshoe shaped or "looped" bar. **Simple Recurved Spit** (7) and **Compound Recurved Spit** (6) — Waves erode the end of the promontory and longshore currents carry the sand northward into deeper water to form spits. Spits are usually recurved because of wave action. **Tombolo** (16) — The material eroded from the cliffed headlands of the island has been swept from the island toward the land. This material has formed a deposit joining the island to the land to form a "tied island".

Another agent of erosion is the many streams that occur in the valleys of the promontories. These streams have steep gradients and are fed by the rainfall that is characteristic of this coastal region. The streams tend to deepen their beds as the water rushes to the sea. Submarine canyons may also be found along the continental shelf. These may be ancient drowned river valleys or may have been formed by underwater currents in ways still being studied by marine geologists.

TOPOGRAPHIC MAPS

BARRIER BEACH
Jacksonville Beach, Fla.
Point Reyes, Calif.

BAYHEAD BAR
Lynn, Mass.

BAYMOUTH BAR
Kingston, R.I.
Lynn, Mass.
Provincetown, Mass.

DELTA
East Brownsville, Texas

RECURVED SPITS
Provincetown, Mass.

SEA STACKS
Point Reyes, Calif.

SPITS AND HOOKS
Fennville, Mich.

TOMBOLO
Lynn, Mass.

PROJECT

Stream Table Experiment to Show Delta and Stream Formation

The stream table is one of the important demonstration and laboratory tools in the study of geological processes. It is particularly useful in the study of stream development, coastal features, glaciation, and water tables; however, numerous other subjects may be studied with the stream table.

Stream tables are available commercially or they may be constructed. Directions for construction are outlined in the **Geology and Earth Sciences Sourcebook,** page 334. (The **Sourcebook** is listed on page 36.) Many of the projects outlined below and in other sections of the Study Guide may be conducted with a large shallow pan, 18″ to 24″ in length.

The stream table is basically a watertight tray or box at least 3 feet long, 2 feet wide and 3 inches deep. It contains a drain or siphon at one end and a water inlet at the other. It should be partially filled with sand, preferably silica sand. Several experiments relating to shoreline and stream development are given below.

Wave Action and Contour Lines or Coastal Terraces:

Preform the sand to form a lake basin with arm, bay, inlet, and island. Fill the lake with water, and create waves from the broad end toward the inlet at the narrow end using a small paddle. When a wave-notched terrace has formed at the shore line, lower the water level with a siphon and create a new shore line by the same method. Siphon off water to a lower level. Introduce wave action along one shore by using a paddle. Drain the lake. Shore line features, contour lines, and wave and current effects are visible.

For variation, change water level by tilting table instead of siphoning off water.

Relation of Slope to Stream Formation:

Fill the box with sand leaving about 18 inches free of sand for a lake area. Place table parallel with floor and smooth the sand. Adjust the rate of water to a medium flow. With the table still flat allow the water to flow on to the sand for five minutes. Elevate the box so the water flows toward the lake in the glass end of the box by placing a 2 inch block under the opposite end of the box. Allow the water to flow for five minutes. Then put an additional 4 inch block under the end and form a stream in another part of the box. Use the same rate of flow of water. The steeper slope should cut a deeper stream and move more sand. Which stream is narrower?

Relationship of Rate of Flow to Stream Formation:

Elevate one end of table 3 inches. Starting with smooth sand, allow water to flow very slowly from the source for five minutes. Move source of the water to another area of stream table and increase to medium flow for five minutes. Repeat at full force.

Stream Meandering, Undercutting, Cutbanks, Slipoff Slopes, and Effect of Resistant Rock Masses:

Starting with basic design, shape the initial guide trench in two or three sweeping curves. Let the water run slowly, and it will develop meanders, cutbanks, and slip-off slopes (flood-plain scrolls). Try placing a 3 or 4 inch pebble, almost completely buried, at different positions along a meander and along the "stream" banks. A delta will form where the stream flows into the water at the end of the stream table.

(Experiments from **Geology and Earth Sciences Sourcebook,** 1962 by Holt, Rinehart and Winston, Inc., New York, N.Y. By permission of the publisher.)

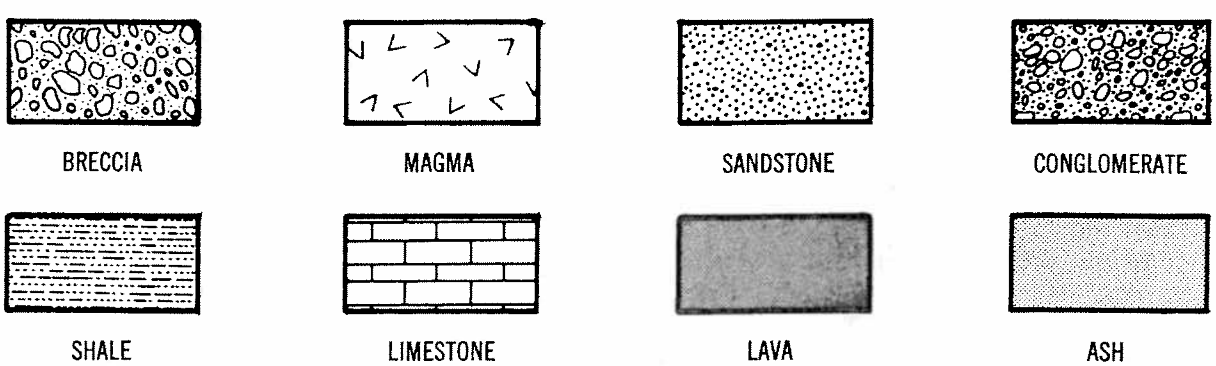
QUESTIONS

1. What is happening to the seaward side of the offshore islands?
2. What deposits are built up by material deposited from refracted waves?
3. What deposits are caused by longshore currents?
4. Why does no vegetation grow on the rocky outcrops (12)?
5. What forms of animal life would you suppose might inhabit the offshore islands?
6. What forms of animal life would you expect to inhabit the rocky ledges on the wave cut promontories (12)?
7. Draw two sketches showing before and after views of this coastline. In the first, show how the offshore islands were once a part of the mainland. In the second, sketch the "after" view. Show an intermediate view of how the coastline would have looked at a period between the first sketch and the condition depicted by the model.
8. The sediments (20) are formed partly from the debris eroded from the land and partly from the remains of both large and small creatures that live in the sea. In your reference books, look up such words as radiolarians, heliozoans, and diatoms, and write a short report on the formation of undersea deposits made from the skeletons of these microscopic organisms.
9. What would happen to the appearance of the coastline if the sea level rose? Describe in words and, if you wish, make a few sketches to illustrate your predictions.
10. Write a report on the changes in sea level that have occurred in past geologic periods. Books on oceanography, glaciation, climatology and the Scientific American magazine contain references and articles reporting various theories associated with this subject.

MODEL 2

VOLCANISM

LEGEND



FEATURES

21.	G-10	**OLD VOLCANO** — A volcano built by successive flows of lava. The volcano is no longer active.
22.	H-10	**CALDERA** — A large bowl-shaped crater which may have steep cliffs, formed by inward collapse of the top of the volcano or by violent explosions which blow off the top; sometimes contains a lake.
23.	H-10	**SMALL CONE IN CALDERA** — Small volcano built up from the floor of the caldera. This cone is younger than the larger volcano and the caldera.
24.	F-10	**RADIAL DRAINAGE** — A series of streams radiating from the summit of a volcano or dome mountain.
25.	F-14	**SERIES OF SMALL CINDER CONES** — Conical elevations formed by the accumulation of volcanic ash or cinder-like material around a vent. This series is located along a fault.
26.	D-8	**BRAIDED STREAM** — The division of a large channel of a river into several smaller channels, usually occurring in an overloaded stream, the bed of which usually has a gentle gradient.
27.	E-11	**LAKE** — Lake formed by a lava flow (31) from the young active volcano (29) damming a stream valley.
28.	A-10	**COMPOSITE VOLCANO** — A volcano built up by alternate deposition of cinders and ash and of lava flows.
29.	C-11	**CRATER** — The funnel-shaped depression at the summit of a volcano. The bottom of the funnel opens into the channel or pipe through which the erupted material finds its way to the surface.
30.	C-11	**BREACHED CRATER** — This volcano has a crater which has been breached by the lava flow (31).
31.	D-11	**LAVA FLOW FROM BREACHED CRATER** — A breached crater is formed by a stream of molten lava that has broken through the crater rim. The lava has now cooled and forms rock, also called lava.
32.	C-12	**LAVA FLOW FROM SIDE OF VOLCANO** — Lava flows emerging from a fissure connected to the main pipe of the volcano.
33.	C-14	**LAVA FLOW** — Molten lava which has flowed from beneath the earth's crust through a fissure to the earth's surface.
34.	A-13	**RADIAL DIKE OUTCROPS** — Fed by dikes from a magma below.
35.	A-13	**DIKE** — A dike is a mass of igneous rock, usually vertical, formed from magma that filled (and expanded) a crack.
36.	A-14	**SILL** — An intrusive body of igneous rock of approximately uniform thickness, and relatively thin compared with its lateral extent, which has been emplaced parallel to the bedding of the intruded rocks.
37.	H-14	**LACCOLITH** — A concordant intrusive body that has arched up the overlying rocks and has a floor that is generally horizontal.
38.	H-14	**MAGMA** — Molten rock beneath the surface of the earth.
39.	A-10	**CONDUIT** — Pipe or tube through which lava flows to the surface.
40.	A-10	**LAVA** — Molten rock that flows over the surface of the earth.
41.	A-10	**VOLCANIC ASH** — Fragmental material ejected by a volcano; particles generally less than 4 mm.
42.	H-13	**FAULT** — A break in the earth's crust along which movement occurs either in a vertical or horizontal plane.

II. VOLCANISM

Volcanic activity produces many interesting structures. The most dynamic is the volcano itself, and it is important for us to realize that most volcanoes are relatively recent. Notice that all of the volcanic structures on the model occur on top of the flat sandstone beds. These sedimentary beds extend to the east and west of this model. The volcanic activity began after the sedimentary beds had risen above the level of the sea.

Volcanic activity is caused by great heat below the earth's surface, melting rock and sending it to the surface through vertical conduits. (39). The molten rock or magma travels up through the overlying layers of rock and forms volcanoes.

This model shows two main types of volcanoes, a composite volcano (28) and a lava type volcano (21). The composite type volcano is made up of alternate layers of lava and volcanic ash or cinders. The depression in the top of the composite volcano is called a crater.

A smaller, more recent volcano (30) is located on the flank of the composite volcano (28). One of the lava flows (31) emerging from the volcano has dammed the river and created a lake (27).

Cinder cones (25), in contrast to the larger volcanoes, are composed almost entirely of cinders. An explosion cone is shown in cross-section. On the southeast corner of the model are several radiating dikes (34).

Downstream from the point where the river is dammed by the lava flow, it emerges onto a sandy flood plain and divides into numerous channels, becoming a braided stream (26). Rain falling on a symmetrical mountain such as a volcano forms a special kind of drainage pattern, called radial drainage (24). The streams radiate from the summit of the mountain. The large lava type volcano (21) has a huge depression known as a caldera (22). In time, this caldera filled with water to form a huge lake. Later a small cone (23) formed as a result of further volcanic activity. In this manner Crater Lake in Oregon was formed. The cone in Crater Lake is called Wizard Island.

To the southeast of the large lava volcano can be seen an extrusive lava flow (33). This lava flow has poured over the land in a relatively quiet fashion, quite in contrast to the lava flows that originate from the craters of volcanoes. The great Columbia Plateau in eastern Washington and Oregon originated in this manner. Notice that this lava flow has affected the course of the river.

In the cross-sections, notice the locations of horizontal masses of lava called sills (36). The dome at the intersection of the grids (H & 14) is caused by a laccolith (37). A laccolith is a large subterranean body of magma which was squeezed between layers of rock causing uplifting of the overlying rocks.

TOPOGRAPHIC MAPS

BRAIDED STREAM
Ennis, Montana
CALDERA
Crater Lake National Park, Oregon
CINDER CONES
Menan Buttes, Idaho
DIKES
Ship Rock, New Mexico

PARASITIC CONE
Bray, California
RADIAL DRAINAGE
Mt. Rainier, Wash.
VOLCANIC CONE
Chemult, Ore.
Mt. Lassen, Calif.

PROJECT
Model Vocano

An ammonium dichromate volcano model may be used as a class or laboratory demonstration; but it may be preferable as an extra-curricular or local science club project. The volcano in action is depicted by igniting ammonium dichromate to produce nitrogen, water, and chromic oxide, as in:

$$(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4H_2O + Cr_2O_3$$

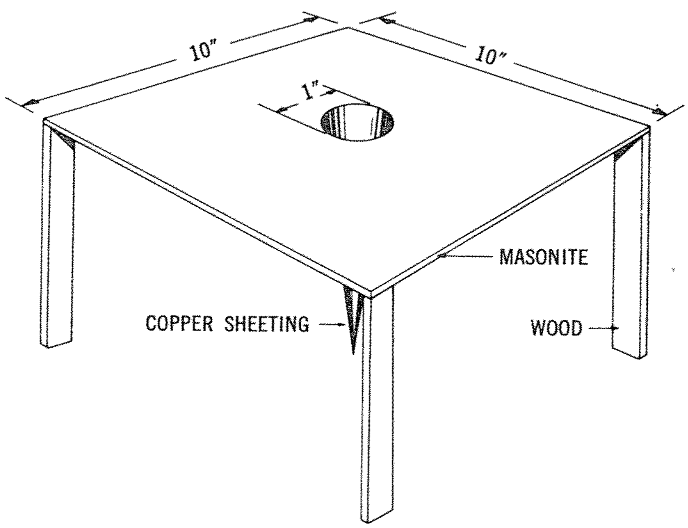
The illustration details the fairly simply constructed apparatus of size adequate for a class or small club group. Most of the dimensions need not be exactly as shown. It is essential, however, that the shape of the copper-sheeting cone taper to a point so that the walls form an angle as close as possible between 19.5° and 20°. This angle has been found critical for successful operation.

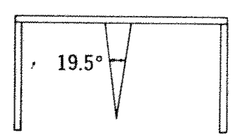
A few physical characteristics and directions contribute to success of the demonstration. It is important that the ammonium dichromate be in granular form with the best grain size closely approximating that of coarse sand. The chemical should be poured into the copper cone up to the level of the platform but should not be packed down. Igniting the chemical requires more heat than from matches; careful tweezer handling of fresh magnesium ribbon (obtain from the chemistry teacher) will give a sufficiently hot burning primer or fuse effect to quicken lighting of the compound.

Many users of this demonstration gain greatest satisfaction by running it twice in succession. A first run in the dark gives some spectacular aspects of eruptive features. Other aspects, such as depositional building of the volcanic cone, are then more readily observed during a second run with the lights turned on in the room.

It is well to remember that, although interesting, this is essentially a crude way of demonstrating volcanic eruption and building. Perhaps more thought and experiment in the future will yield much better demonstrations.

(Experiment from **Geology and Earth Sciences Sourcebook,** 1962, by Holt, Rinehart and Winston, Inc., New York, N.Y. By permission of the publisher.)



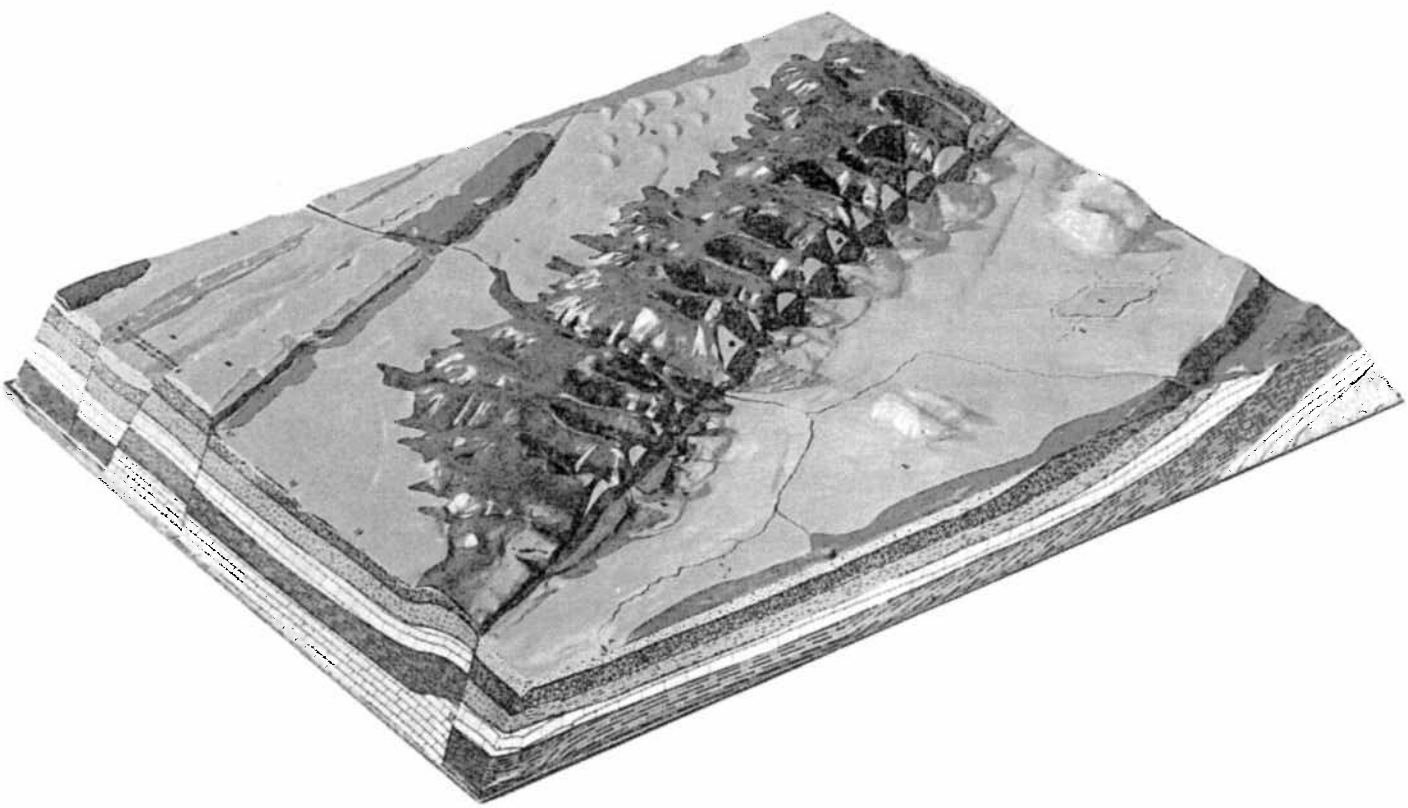


QUESTIONS

1. Why is the gradient of the lava type volcano less steep than the gradient of the composite type volcano?
2. What evidence do you see on this model that suggests a relationship between faulting and volcanic activity?
3. Describe ways in which volcanoes may be destructive to man and his property.
4. Describe ways in which volcanoes may benefit man.
5. How do sills form between layers of sedimentary rock?
6. Describe and relate locations of economic activity, natural resources, population centers, and climate conditions that might be found on the model.

MODEL 3

FAULT BLOCK MOUNTAINS



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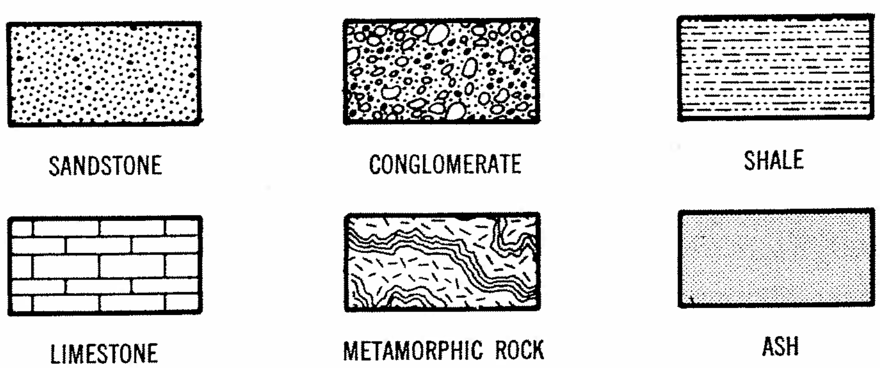

FEATURES

43.	G-20	**PLAYA** — A slight depression in the earth's surface which becomes temporarily filled with water and forms a shallow lake after heavy rains. Playa lakes are generally short-lived due to seepage and evaporation.
44.	G-20	**INTERNAL DRAINAGE** — A drainage system without an outlet to the sea.
45.	H-17	**FAULT SPLINTER** — A wedge shaped block lying along the fault scarps.
46.	G-18	**ALLUVIAL FAN** — Fan-shaped deposit of sediment formed by a mountain stream as it flows out onto a plain or an open valley.
47.	D-18	**BLOCK MOUNTAINS** — Mountains carved by erosion from large uplifted earth-blocks bounded on one side or both by fault scarps.
48.	D-19	**TRIANGULAR FACETS** — Triangularly shaped remnants of the fault scarp lying between the canyons that have been eroded in the fault-block mountains.
49.	C-17	**ANTECEDENT STREAM** — A stream that was present before a structure rose beneath it. The stream was able to maintain its course as the structure, in this case a fault block, slowly rose.
50.	D-21	**DESERT BASIN** — Basin between block mountains.
51.	D-16	**PIEDMONT ALLUVIAL PLAIN** — A plain composed of several connected alluvial fans which have been made by neighboring fans uniting to form a continuous plain.
52.	G-17	**CANYON** — A narrow gorge formed by the erosive force of a river, the height of whose walls generally exceeds the width of the floor.
53.	F-15	**CRESCENT DUNES (OR BARCHANES)** — Half-moon shaped sand dunes formed by the wind blowing mainly in one direction; in this case from the northwest.
54.	A-15	**GRABEN** — A depression formed by the subsidence of land between two parallel faults.
55.	A-16	**HORST** — A raised block of land between parallel faults.
56.	G-15	**CONDUIT** — Pipe or tube through which lava flows to the surface.
57.	A-21	**FAULT** — A break in the earth's crust along which movement occurs either in a vertical or horizontal plane.

III. FAULT BLOCK MOUNTAINS

This model represents the region where the underlying sedimentary beds have become disturbed by various kinds of faulting, causing block mountains to be formed. The main fault block range (47) has been partially eroded, while the block mountains to the east of the main range have been greatly eroded and only remnants of the former range remain. The steep fault scarps of the range are on the east of the crest of the range, while the long back slopes of the uplifted blocks are to the west of the crest. Immediately after the faulting, mountain ranges probably appeared singly as great blocks faulted and uplifted on the east and sloping off toward the west. Then the forces of erosion produced steep-walled canyons (52) in the fault blocks. The canyons in the front of the block, which are cut in the fault scarp, have steeper gradients than the ones on the back, which are cut in the more gentle back slopes. In arid climates, land forms tend to be angular, in contrast to the rounded land forms of a moist climate.

The fault scarp now appears as a series of triangular facets (48) and the presence of these triangular facets is further evidence of faulting.

Where each canyon leaves the mountains a large alluvial fan (46) occurs deposited by the intermittent streams. As a stream comes down the canyon cut into the fault block, its gradient is very steep. Suddenly the gradient decreases and the carrying power also decreases and material is deposited in the form of an alluvial fan. Fans which have become joined are known as a "bahada". As erosion reaches a greater stage of maturity, the mountains will become smaller and the bahada slopes larger. The bahada slopes and the basins will become integrated and the mountains will remain islands protruding from the bahada lands.

The several fault block ranges produce enclosed desert basins. The drainage of such a region is not integrated and the streams which periodically come from the mountains produce intermittent lakes in the enclosed basins. Since there are no outlets to these lakes, they accumulate great quantities of minerals and salts.

A fault splinter (45) appears at the north edge of the model. This is a newer fault and occurs parallel to the plane of the original fault, producing a fault scarp in the bahada slope. Mineralization often occurs along fault lines and thus mineral deposits may be found in some fault block mountains.

TOPOGRAPHIC MAPS

ALLUVIAL FAN
Ennis, Mont.
Furnace Creek, Calif.
ANTECEDENT STREAM
Yakima East, Wash.
ERODED FAULT BLOCK MOUNTAINS
Furnace Creek, Calif.
Sonoma Range, Nev.

FAULT-LINE SCARP
Furnace Creek, Calif.
Flaming Gorge, Utah-Wyoming

PLAYA
Sonoma Range, Nev.

PROJECT
Normal and Thrust Faults In Sand

MATERIALS: Glass-fronted open-top box with a movable wall — glass should be very thick and strong, and movable wall can be a metal partition on threaded handle or a jack against a wall as suggested in diagram; sand, plaster, chalk dust, or flour.

PROCEDURE: 1. Put in layer of sand, make smooth and then cover the part against the glass with a thin layer of plaster. Put in another layer of sand and plaster marker and continue until there is an adequate thickness (which will depend on the size and strength of the box you have had built). The plaster layers have no effect on the characteristics of the deformation if they are thin compared to the sand layers; they are added to enable the student to see a series of lines being bent and broken so that the interior deformation is more easily visualized.

2. Before movable partition is moved, the pressures on each sand grain are equal in all directions. This pressure is equal to the weight of the overlying sand grains. As the partition is moved against the sand the horizontal pressure is increased until the difference in pressures is large enough to cause the sand to slide along a **thrust fault.** By watching closely it can be seen that the break is not a single plane but a narrow zone several sand grains wide. Slippage along this break is not continuous but instead goes on as a succession of small jumps. This is the same mechanism observed on faults that are moving today. On these faults the pressures in the earth cause a continuous slow bending until eventually the rocks snap and the bend is straightened. This release of energy along the fault causes vibrations which shake the earth and causes an earthquake.

If, instead of pushing against the sand, we move the wall away from the sand, we decrease the horizontal pressure until it is small enough to allow a **normal fault** to develop.

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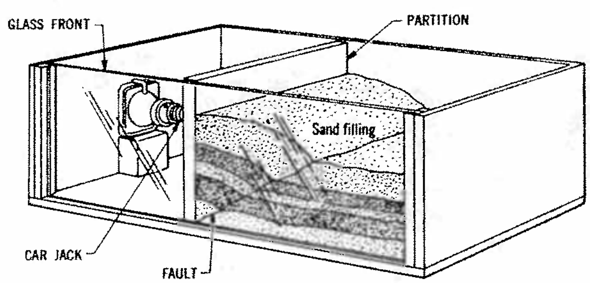
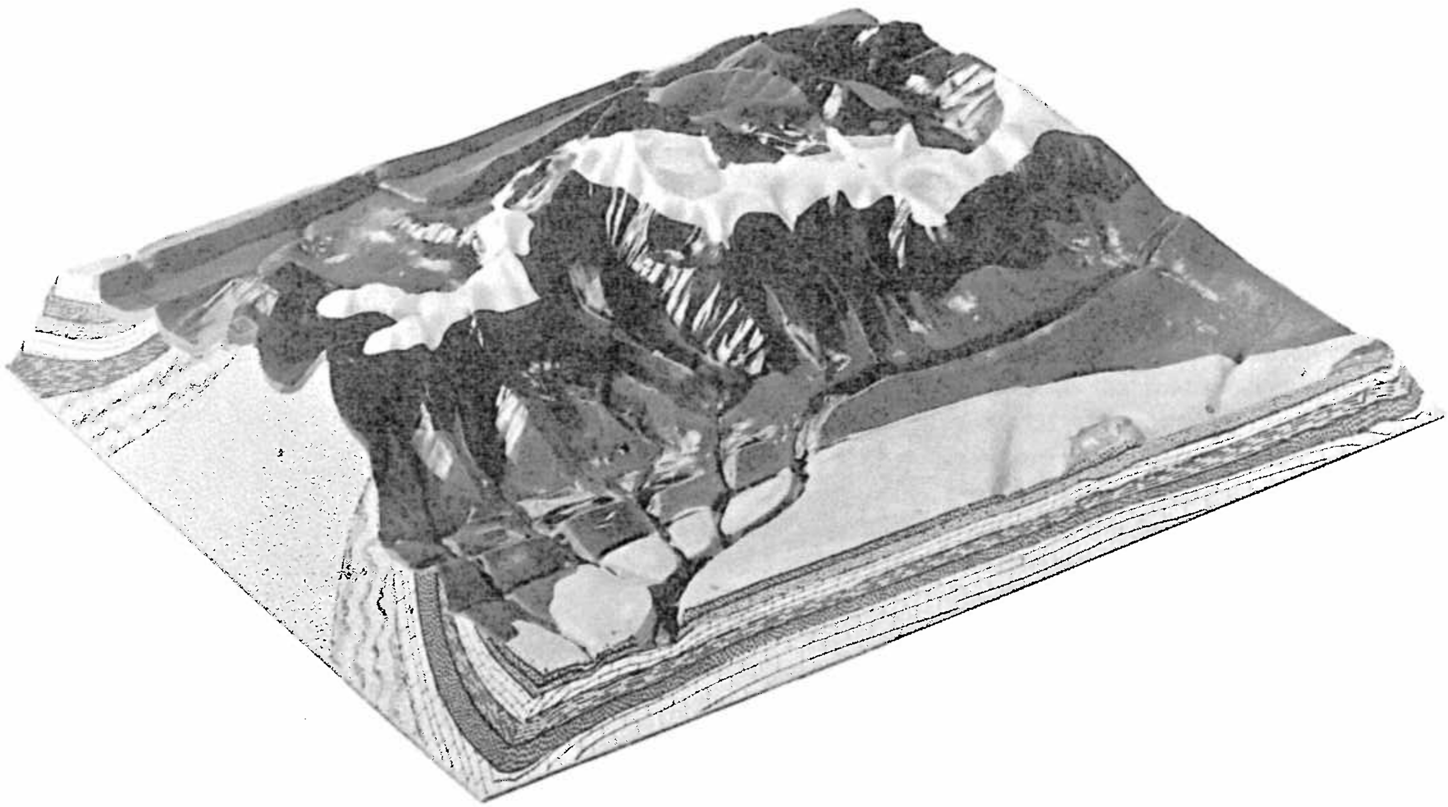


QUESTIONS

1. Examine the crescent-shaped sand dunes (53). From what direction does the prevailing wind blow?
2. Notice that there is a bed of shale outcropping in the fault-block mountains south of the main river. What statement would you make relative to the degree of upthrust in the southern part of the block fault range as compared with the degree of upthrust in the northern part?
3. Note that a river (49) flows across the fault-block mountain range. If a stream followed this same general course before the fault-block mountains were elevated, what statement would you make regarding the rate of cutting power of the stream and the rate of elevation of the mountains.
4. Examine the subsurface features on the north-eastern corner of the model and note that the conglomerate rock shown in orange forms a ridge as does the limestone to the east. Also note that a valley occurs between these two ridges. What would you say about the resistance to erosion of shale which occupies this valley, compared to conglomerate and limestone?
5. At the coordinate H-19 and E-20, you will find remnants of fault block mountains. They have no cover of vegetation. Do you suppose this might be tied in with the climate of the region? If so, how would you describe this climate?
6. What would you say about these same mountain remnants in respect to their age as compared with the main fault-block mountain range to the west?
7. The dotted line around the playa (43) represents an ancient shoreline of this lake. If there were more water in this playa lake at one time than there is at present, how would this relate to the past and present climates of the region?
8. Describe and relate locations of economic activity, natural resources, population centers, and climate conditions that might be found on the model.

MODEL 4

ALPINE GLACIATION



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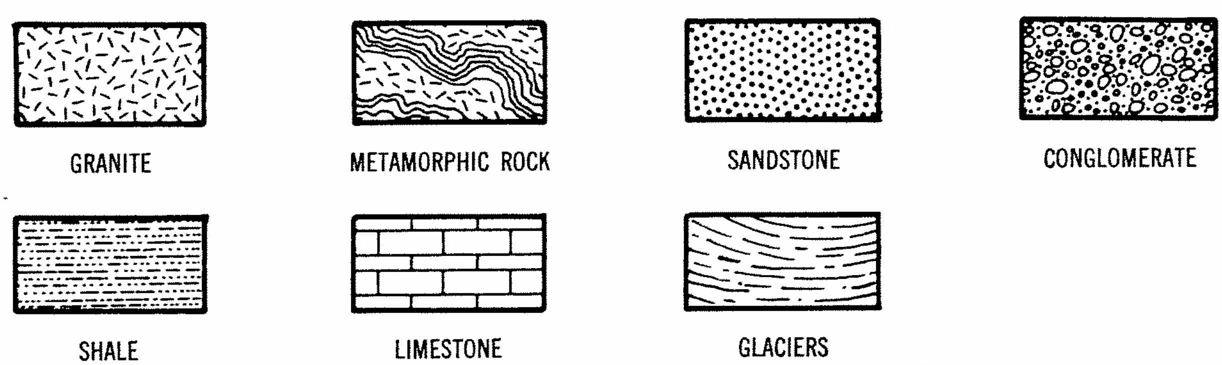


FEATURES

58. H-23 **HANGING VALLEY** — A glaciated valley, tributary to a larger glaciated valley, which has been cut below the level of the tributary, thus leaving the tributary valley "hanging" above the main valley.

59. G-23 **FINGER LAKES** — Long narrow lakes whose basins have been carved out of a valley floor by a glacier.

60. B-22 **END MORAINE (TERMINAL MORAINE)** — The rock debris deposited at the furthest extent of a glacier. This debris is composed of rock fragments picked up by the glacier and incorporated in the ice mass and transported to the glacier terminus.

61. B-22 **LATERAL MORAINE** — A lateral moraine has the same origin as an end moraine but is deposited along the side of a glacier.

62. E-23 **CREVASSED AREA** — At the lower end of the glacier the surface is likely to be cut by great cracks in the ice called crevasses.

63. G-24 **HANGING CIRQUE** — A cirque that is perched high on the flank of the valley.

64. G-23 **WATERFALL** — A stream of water cascading down a valley wall.

65. E-24 **VALLEY GLACIER** — A mass of ice that moves slowly down a valley.

66. F-24 **HANGING GLACIER** — A small glacier terminating on a steep slope or at the lower end of a hanging valley.

67. E-25 **CIRQUE** — A bowl-shaped hollow that has steep sides, eroded from a mountain side at the head of a glacier.

68. F-24 **BISCUIT BOARD TOPOGRAPHY** — Relatively level upland surface into which many cirques have been eroded. This phenomenon resembles the remaining dough after biscuits have been cut.

69. D-25 **TARN** — A small mountain lake in the floor of a cirque.

70. C-24 **HORN** — A high pyramidal peak with steep sides formed by the intersecting walls of three or more cirques.

71. C-24 **COL** — A low pass in a mountain ridge; formed by intersection of two cirques.

72. D-26 **PATERNOSTER LAKES** — A string of small lakes or tarns found in alpine valleys. ("Paternoster" means "Our Father" in Latin and such lakes were named because they resemble the beads in a rosary).

73. B-28 **CANYON** — A narrow gorge formed by the erosive force of a river.

74. F-27 **HOGBACK** — A ridge produced by erosion of steeply dipping strata. The "dip slope" (parallel to dipping beds) is about as steep as the "scarp slope" formed by erosion of outcropping margins of the beds. Compare with cuestas No. 134 and No. 152, which have gentle dip slopes and steep scarp slopes.

75. C-26 **INTERSTREAM AREA** — Region between two streams.

76. A-25 **IGNEOUS ROCK** — Rock formed from molten magma that cooled and then crystallized.

77. A-26 **METAMORPHIC ROCK** — Rocks that were formerly sedimentary or igneous which have been changed by heat, pressure or solutions.

78. A-27 **SEDIMENTARY ROCK** — Rocks formed by the accumulation of sediments in water or on land. The sediment may consist of rock fragments or particles of various sizes (conglomerate, sandstone, shale); of the remains or products of animals or plants (certain limestones and coal); of the products of chemical action or of evaporation (salt, gypsum, etc.); or of mixtures of these materials. A characteristic feature of sedimentary deposits is a layered structure known as bedding or stratification.

IV. ALPINE GLACIATION

This model displays features found in a glaciated alpine region. The eastern edge of the model portrays a broad band of arid plains with a canyon cut through the southern end. To the west hogback ridges have been formed in the foothill regions. Beyond the line of vegetation, or timberline, there is an area of bare rock which is capped with snow and in some regions with the ice of glaciers. Many lakes are evident in the valleys and in the mountain basins, called cirques. At the eastern edge of the mountain range several long hogback ridges may be observed.

If we examine the sub-surface geology as depicted on the margins of the model, we will be able to understand how this complex mountain topography was formed. The western edge of the model tells us that the rocks of the western flank of the mountains are sedimentary. The eastern edge also consists of sedimentary beds; however, the sequence of beds on the eastern edge is different from that on the western edge. If we examine the southern and northern edges of the model we see a large instrusive mass of granite (76) that forms the backbone of the mountain system. Between the granite mass and the sedimentary beds is found a layer of metamorphic rock (77). This model contains examples of the three major rock types — igneous rock, represented by the granite; metamorphic rock (examples of metamorphic rock are quartzite, schist, marble and slate), and sedimentary rock (examples of sedimentary rock are sandstone, shale and limestone).

The most characteristic feature of this mountain range is the sculpturing that has taken place as a result of the action of alpine glaciers. Glaciers are masses of ice that form in basins and valleys in mountain ranges.

The alpine glaciers that are shown in this model are but the remnants of a much larger glacial system that sculptured the granite peaks, ridges and valleys of these mountains. The deep U-shaped valleys now partly occupied by vegetation, in times past contained glaciers. Originally these valleys were V shaped in cross section. Their U-shaped form today is evidence of the broadening and deepening effect of glacial ice. As the larger glaciers moved down the larger valleys, their greater scouring action cut below tributary valleys. These tributary valleys now above the main valley, are called hanging valleys (58). Isolated cirques are called hanging cirques (63). This mountain range is shown as it would appear in late spring or late fall with snow covering the higher mountain peaks and ridges. The lakes are fed by meltwater from the mountain snows and glaciers.

TOPOGRAPHIC MAPS

ARETE
- Chief Mountain, Mont.
- Holy Cross, Colo.
- Mt. Tom, Calif.

ARROYO
- Antelope Peak, Ariz.
- San Luis Rey, Calif.

BISCUIT-BOARD TOPOGRAPHY
- Katahdin, Maine

CIRQUE
- Chief Mountain, Mont.
- Holy Cross, Colo.

CIRQUE LAKE
- Mt. Tom, Calif.

FINGER LAKES
- Chief Mountain, Mont.

GLACIAL VALLEY
- Holden, Wash.
- Holy Cross, Colo.

GLACIER
- Chief Mountain, Mont.
- Mt. Rainier, Wash.

HANGING VALLEY
- Chief Mountain, Mont.
- Holy Cross, Colo.

HOGBACK
- Waldron, Ark.

LATERAL MORAINE
- Mt. Tom, Calif.

MATTERHORN
- Mt. Bonneville, Wyo.

MEDIAL MORAINE
- Mt. Rainier, Wash.

PATERNOSTER LAKES
- Mt. Tom, Calif.

TARN
- Mt. Tom, Calif.

PROJECT
Experiments Demonstrating the Properties of Ice

1. On each of two ice cubes place a small

heavy weight, on the other a light weight. Observe that the cube with the heavy weight melts faster than the cube with the light weight. This demonstrates that the melting point of ice is determined by pressure as well as temperature. The higher the pressure, the lower the melting point.

2. One can either gather snow after it falls or make it by directing the blast from a carbon dioxide fire extinguisher or cartridge into a deep freeze. The change from snow to granular ice can then be demonstrated. Pack the snow tightly in your hands. As the snow is compacted, it will change from minute, flaky, snow crystals to granular ice which is similar to firn. After further packing, the mass will resemble compact ice (providing it is not too warm).

3. To demonstrate the character of ice, perform two experiments.

a. Strike ice with a hammer. It will shatter.
b. Freeze an elongated bar of ice approximately 18 x 2 x 1 inches. (You may use aluminum foil to make a tray of the proper size.) Remove the ice from the tray and, while keeping it at freezing temperature in the refrigerator, suspend it at both ends. Place a weight in the middle of the bar. After a few hours, the bar of ice will bend but will not spring back to its original shape after the weight is removed.

The two demonstrations show that ice can be both brittle and plastic depending upon the speed with which pressure is applied. The colder the ice, the more brittle it is. The more pressure there is on ice, the more plastic it is. This is why glacial ice moves plastically near its base and tends to fracture near its surface where pressure is low. Crevasses in glaciers seldom extend far down into the ice because of increasing plasticity at depth. At depth the ice has less tendency to break. Moreover, if it does break, it moves plastically and closes the break.

4. Suspend a bar of ice at both ends in a refrigerator or deep freeze where the temperature is at or slightly below freezing. Loop a wire around the center of the block and suspend a weight from the wire. The wire will be seen to "eat" its way down through the block. The water produced by melting under the pressure of the wire will refreeze in the crack above the wire where the pressure is less. This demonstrates that the melting point of ice is lower when the ice is under pressure. It also demonstrates that when pressure is not uniform throughout a body of ice, the ice will melt at the points of greatest pressure and refreeze at the points of lesser pressure. The process is called regelation. This is a principle of physics known as Rieke's Principle. Some of the movement of a glacier and the formation of firn and glacier ice can be attributed to Rieke's Principle.

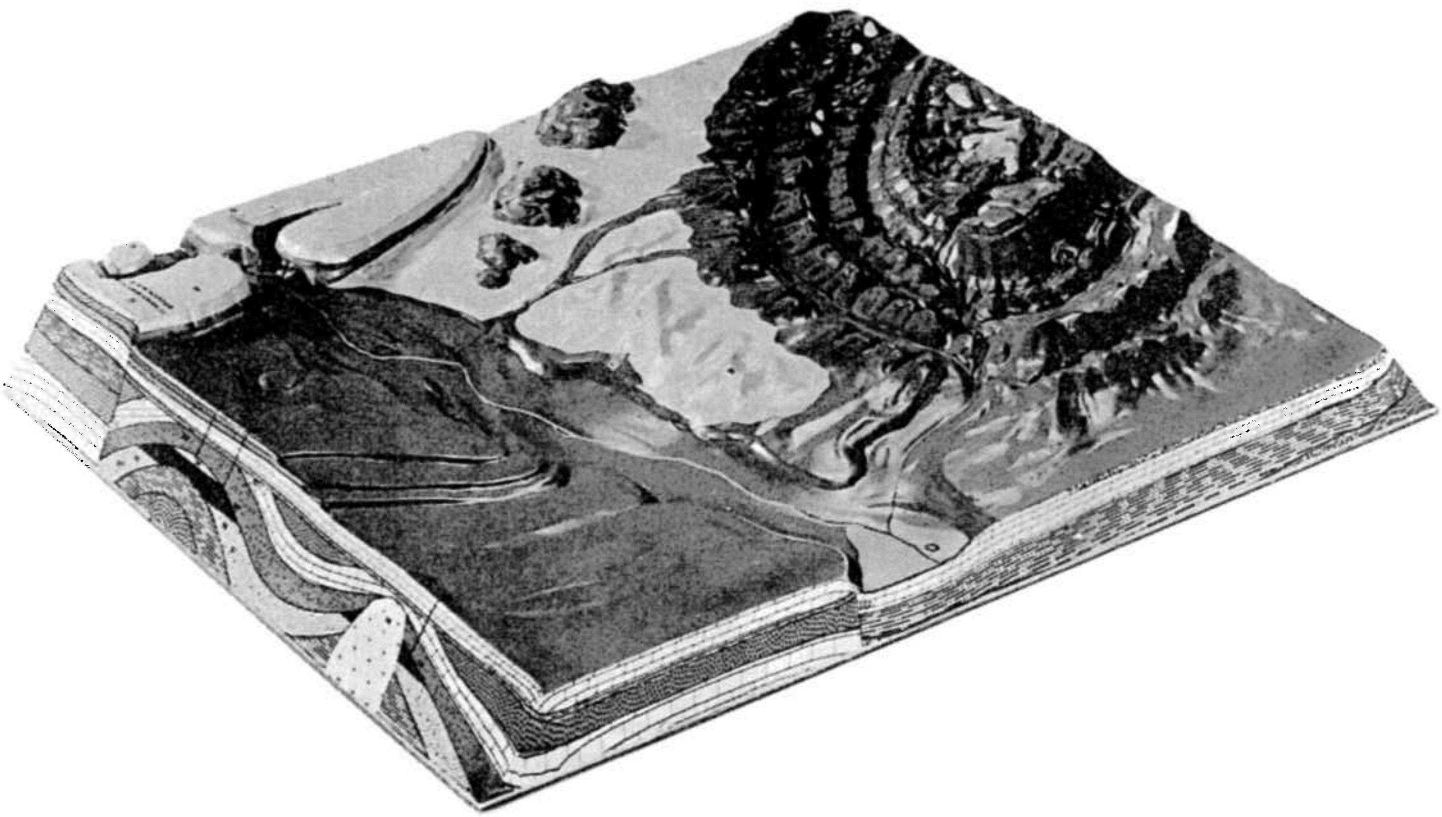
(Experiment from **Geology and Earth Sciences Sourcebook,** 1962, by Holt, Rinehart and Winston, Inc., New York, N.Y. By permission of the publisher.)

QUESTIONS

1. How many active glaciers are present on the model?
2. How many hanging cirques are present on the model?
3. How many alpine valleys contained glaciers in the past?
4. The majority of the glaciers in the model occupy valleys and cirques facing more to the north than to the south. What explanation can you give that explains this phenomenon?
5. By using the coordinate system, locate a water gap.
6. Trace the course of the tilted sandstone bed that forms a hogback on the eastern flank of the mountain range. How many water gaps are cut through this hogback?
7. Examine the floor of the valley of the canyon on the eastern edge of the model. If the erosion by the river continues, what is the next rock type that will be revealed?
8. Describe and relate locations of economic activity, natural resources, population centers, and climate conditions that might be found on the model.

MODEL 5

DOME MOUNTAINS



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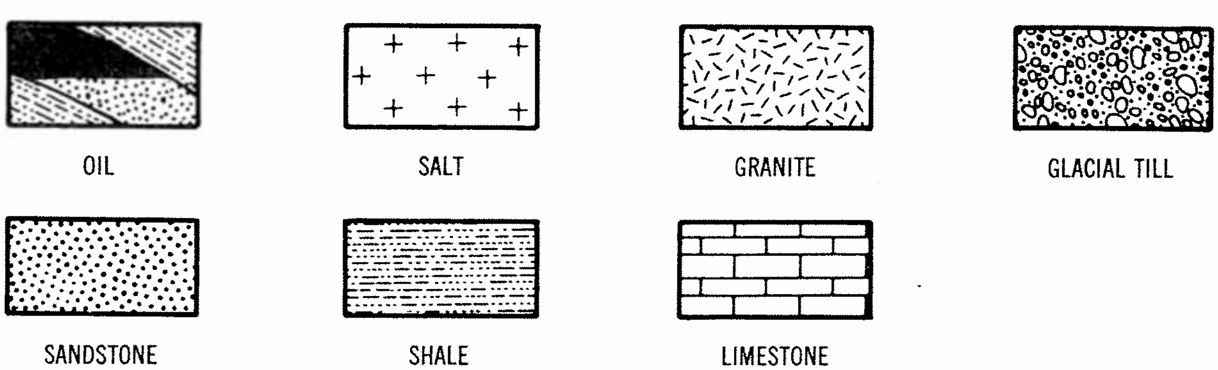


FEATURES

79.	H-31	**DOME MOUNTAIN** — A mountain uplift, circular or oval in shape. The Black Hills, a typical example, has a central core of granite from which sedimentary strata dip away in all directions.
80.	H-33	**CIRCULAR HOGBACKS** — The outcrops of the resistant sedimentary beds that have been uplifted; these beds were once continuous over the dome.
81.	H-32	**ROCK OUTCROP** — Limestone outcrop forming a hogback on the flank of the central core.
82.	F-33	**SUBSEQUENT STREAM** — A stream that follows a belt of weaker rock and which was adjusted to the structure after the uplift. The stream flows along the strike of the beds.
83.	D-33	**SAND HILLS** — Hills of sand deposited by the wind from sand originating in the arid sandy region to the west. Much of the land is fit only for grazing, but the depressions between the sand hills may be occupied by ranches having cropped fields irrigated by the water that accumulates between the sand hills. The Sand Hill section of Nebraska is such an area.
84.	E-30	**LONGITUDINAL DUNE** — A sand dune formed parallel to the wind direction.
85.	D-29	**BUTTE** — A hill, produced when hard strata of rock overlie weaker layers and protect them from being worn down. The summit area is much more restricted than that of a mesa.
86.	A-29	**CANYON** — A gorge, relatively narrow but of considerable depth, bounded by steep slopes.
87.	B-31	**MATURE VALLEY** — A valley in which the stream is no longer actively deepening the valley and the flood plain is of considerable width.
88.	F-29	**CAP ROCK** — Resistant strata that prevent erosion of weaker strata beneath them.
89.	B-30	**STREAM TERRACE** — Remains of former flood plain into which and below which the river has now eroded its valley.
90.	A-29	**FAULTED SANDSTONE PLATEAU** — Table land formed by movement along the fault at the eastern edge, forming a steep fault scarp.
91.	H-31	**GRANITE** — A coarse-grained igneous rock which always contains the two minerals quartz and feldspar, and may contain other minerals. It is one of the hardest and most durable rocks, and also one of the most abundant rocks in the earth's crust.
92.	A-32	**UNCONFORMITY** — Frequently folded or tilted sedimentary rock units are overlain by horizontal ones. The first series of beds has been folded, worn down to a level plane, and covered by later sediments. The contact zone between two series of beds, the lower of which is folded, is called an angular unconformity.
93.	A-31	**ANTICLINE** — An upward fold. A downward fold to right of the anticline is a syncline.
94.	A-31	**NATURAL GAS** — Gaseous hydrocarbons, usually found above oil deposits.
95.	A-31	**PETROLEUM** — Liquid hydrocarbons.
96.	A-31	**RESERVOIR ROCK** — Rock that is porous and contains oil interspersed between its grains.
97.	A-32	**SALT WATER** — Water that contains salt; probably "fossil sea water" preserved in the reservoir rock.
98.	A-34	**SALT DOME** — A structure resulting from the upward movement of a salt mass, and with which oil and gas fields are frequently associated.
99.	A-34	**TRAP** — The structure formed by a bed of oil-bearing rock covered by impervious rock which prevents the oil from escaping.
100.	A-34	**OIL WELL** — A hole drilled into the earth which has encountered underground deposits of oil.
101.	A-31	**GAS WELL** — A hole drilled into the earth which has encountered natural gas.
102.	C-36	**FAULT** — A fracture in the earth's crust along which movement has taken place. Therefore, the rock strata on the two sides do not match. The fault is a reverse fault in which the right side moved up.

V. DOME MOUNTAINS

The mountain mass in the northern part of the model is an example of a dome mountain. Originally sedimentary rocks arched over the large granite mass. The sedimentary rocks have been eroded from the highest part of the range, leaving a granitic area exposed in the center (79). The dipping sedimentary formations surrounding the granite now appear as ridges around the edge of the dome. The stronger beds such as the sandstones and limestones form hog-backs or cuestas (80). The weaker beds, such as the shales form valleys. This landscape has been created mainly by erosion. The subsequent streams (82) of the region have carried away the eroded material and deposited it on the broad flood plain of the main river valley shown on Model No. 6. The eastern two-thirds of the model is covered with vegetation with the exception of two areas of wind blown sand (83). This suggests higher rainfall in the areas colored green. The western portion of the model depicts arid land lying in the rain shadow of the alpine peaks to the west.

Straight walled canyons, mesas, buttes are the characteristic topographic features to be found in arid regions where the sedimentary strata have been undisturbed.

The southern edge of the model depicts oil deposits beneath the surface. Many years ago this region was beneath the sea and tiny plants and animals that lived there died and sank to the bottom of the inland sea. As sediments were washed in from the land, the remains of these organisms were trapped in the sediments. As time passed, more and more sedimentary deposits were laid on top of the remains of these organisms. As great pressure compressed the lower layers into rock, a combination of heat, chemical action and pressure changed the remains of these organisms into droplets of oil and gas.

Later the sedimentary beds were disturbed by pressure from beneath. This pressure produced a series of arches or anticlines.

The oil and gas are lighter than the water that saturates the porous rock layer (97). The lighter oil and gas tended to rise to the top of the anticline, and the oil and gas were prevented from going further by a layer of impervious shale, here depicted in green.

A salt dome may also be seen on the south edge of the model. Salt domes are formed by the upward movement of salt from a deeply buried deposit. Here we see how a salt plug has penetrated a shale, a sandstone, and yet another shale bed. An oil trap has been formed on either flank of the salt dome.

TOPOGRAPHIC MAPS

DISSECTED DOME MOUNTAINS
Hot Springs, S.D.

MESA
Juanita Arch, Colo.
Promontory Butte, Ariz.

RIVER TERRACE
Ennis, Mont.
Alma, Wisconsin-Minnesota

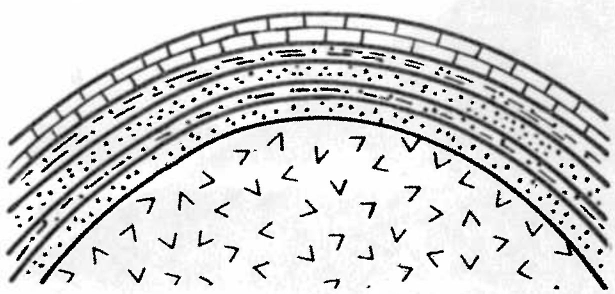
SAND HILLS
Ashby, Neb.

PROJECT

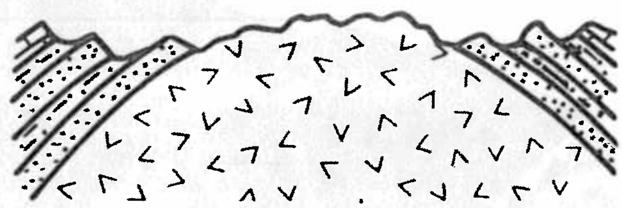
A. Make several models depicting different stages in the formation of a dome mountain system.

1. First, obtain some modeling clay, preferably in several colors. Roll the modeling clay out into flat sheets with a rolling pin or a bottle. Then take a piece of styrofoam plastic and shape it to represent a granite dome. Next place the layers of modeling clay over the styrofoam and you will have a model of a dome mountain before erosion has taken place.

2. In the second model, carve the sedimentary beds in such a way as to simulate a dome mountain in its mature stage. (See diagram below). Carve the beds down to the styrofoam core that represents the granite core. The styrofoam dome can be carved with a knife to represent the erosion that takes place over several millions of years. The models now represent two stages in the development of a dome mountain system.



BEFORE EROSION



AFTER EROSION

B. Make a model showing an unconformity.

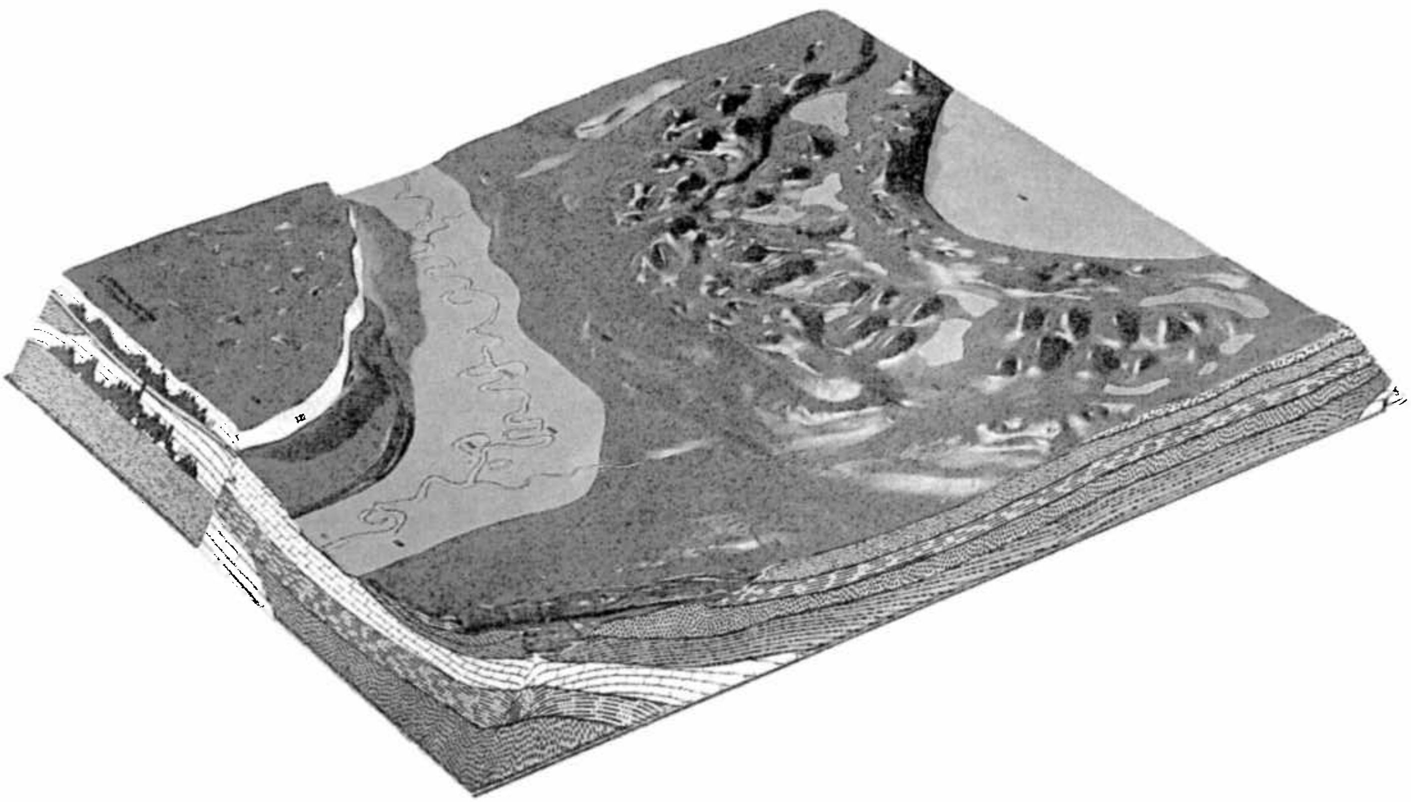
1. Take several layers of colored modeling clay and by pressure from either side, force them into a series of folds similar to the anticlines and synclines shown on the south edge of the model. Now take a sharp knife or wire and slice the top parts of the folds away. You have now simulated the process called peneplanation which means the base leveling of a region by erosion. If this land were now to sink and the sea were to flow inland over this region, in time sedimentary deposits of shale, limestone and sandstone would be formed on the bottom of the inland sea. Later, if the land were elevated, these units would be exposed after further erosion.

   You may simulate the deposition of such marine formations by placing several flat layers of modeling clay on top of the peneplane surface. When you have finished, you will have produced a model similar to the cross-section shown on the southern margin of the model.

QUESTIONS

1. How many limestone outcrops can you find on the model?
2. Are there any surface features on the model that might indicate an oil-bearing anticline or oil dome?
3. If there are no such surface features, how do you suppose it is possible to locate the presence of an underground oil dome? The answer to this question may be obtained by looking up the subject of oil exploration in an encyclopedia.
4. Examine the northern edge of the model and list the sedimentary rock types that you find there. Is the rock series identical on either side of the dome mountain? If not, indicate which beds are missing, as the case may be, on the eastern and western flanks of the dome mountain.
5. Why is it that oil is not trapped in a syncline?
6. Describe and relate locations of economic activity, natural resources, population centers, and climate conditions that might be found on the model.

CONTINENTAL GLACIATION



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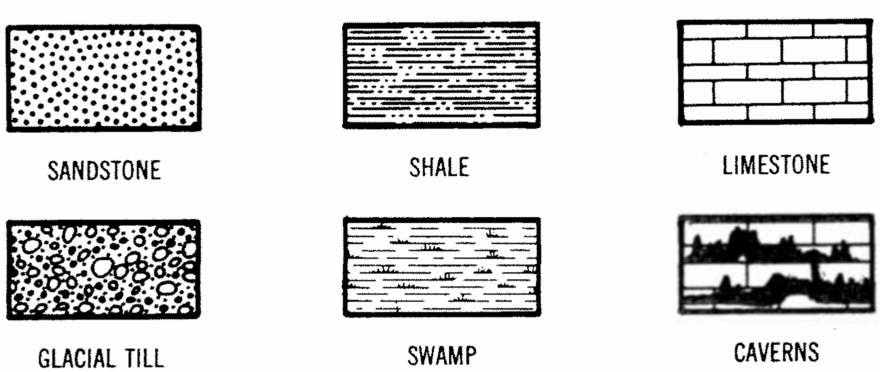


FEATURES

103.	G-39	**RECESSIONAL END MORAINE** — A large deposit of glacial drift formed at the edge of the ice when the receding glacier oscillated for a time behind the position of its maximum advance.
104.	H-39	**MORAINAL LAKE** — Lake formed by the blockade of drainage by a moraine.
105.	D-39	**TERMINAL MORAINE** — A moraine formed at the end of a glacier at its farthest advance.
106.	E-41	**GROUND MORAINE** — The material carried forward in and beneath the ice and finally deposited from its under surface, constitutes the ground moraine. The flat to undulating surface forms a till plain.
107.	D-39	**OUTWASH PLAIN** — A plain of sand and gravel sometimes containing silt and clay deposited by melt water streams which flowed from the ice when it stood at the terminal moraine.
108.	G-42	**DRUMLINS** — Elongated hills or ridges of boulder clay (till), usually oval and shaped like half an egg. Their long axis is parallel with the direction of advance of the glacier.
109.	F-39	**ESKER** — A long, narrow ridge of sand and gravel which was deposited in the bed of a stream flowing beneath or in the ice of a glacier.
110.	G-38	**KAME** — A mound of gravel and sand which was formed by the deposition of the sediment from a stream against the front of the ice or in a hole in the ice.
111.	E-40	**KETTLE LAKE** — A kettle (or kettlehole) is a hollow depression formed by the melting of an ice block which had been covered by ice laid material or by gravel borne by streams emerging from the glacier. If the bottom of the kettle is below the water table, a lake occurs in it.
112.	H-42	**SWAMP** — A tract of low-lying land which is just at the water table and is thus saturated with moisture; moisture loving plants grow in it.
113.	E-39	**KETTLE** — A hollow formed by collapse of material when a buried ice block melted. See KETTLE LAKE, number 111.
114.	B-39	**STREAM TERRACE** — A shelf-like remnant of material once continuous across the valley at this level. As the river swings from side to side in the flood plain, it erodes the material.
115.	C-40	**MEANDER** — One of a series of somewhat regular and looplike bends in the course of a stream flowing through a relatively flat valley.
116.	B-40	**OXBOW LAKE** — A crescent-shaped lake formed in an abandoned river bend which has become separated from the main stream by a change in the course of the river.
117.	C-39	**CUTOFF** — A channel eroded through the neck of a meander, leaving the former meander cut off which will eventually form an oxbow lake.
118.	A-42	**HOGBACK** — A long, narrow ridge in which both dip slope and scarp slope are steep. Hogbacks are formed in regions of steeply dipping strata.
119.	A-38	**KARST TOPOGRAPHY** — A limestone region in which most or all of the drainage is by underground channels. The calcium carbonate in the limestone is carried away in solution leaving underground caverns. Often the roofs of the caverns collapse causing uneven topography.
120.	A-37	**SINK HOLE** — A depression in the surface in a limestone region, through which water enters the ground and passes along an underground course. It may be cone shaped or may have steep sides with a flattened bottom.
121.	A-38	**CLIFF** — Steep rock face, approaching the vertical, in this case formed by faulting (125).
122.	A-40	**FLOOD PLAIN** — A plain, bordering a river, which has been formed from deposits of sediment carried by the river. When a river rises and overflows its banks, the water spreads over the flood plain, depositing a layer of sediment at each flood.
123.	A-38	**CAVERNS** — Natural cavities, recesses, or chambers beneath the surface of the earth. Caverns in limestone are formed by dissolving and eroding action of underground water.
124.	H-37	**GLACIAL TILL** — The mass of boulders, cobbles, pebbles, sand and finely ground rock flour dragged along largely in the lower part of the ice of a glacier and left behind when the ice melts. A layer of glacial till covers the northern third of the model and is shown in yellow.
125.	A-39	**FAULT** — A fracture in the earth's crust along which movement has taken place; the rock strata on the two sides therefore do not match.

VI. CONTINENTAL GLACIATION

This is a model of a region which has features resulting from continental glaciation. A large lake fills the basin which has been carved by one of the main lobes of the continental glacier. This may be seen at the north end of the model. All preglacial rock outcrops have been obscured by the thick till deposits The glaciated region has undergone little erosion; therefore, the till plain is considered young.

Typical moraine features may be seen on the terminal moraine (105). These include kettles (113) kettle lakes (111) as well as numerous mounds and hummocks. The kettle depressions were created by the melting of isolated blocks of ice left by the retreating glacier; these blocks of ice were buried in the till and when they melted, the overlying till settled, leaving depressions. An esker (109) is a ridge-like deposit of sand and gravel left by a stream which ran in a tunnel in the ice of the glacier.

North of the terminal moraine is a recessional moraine (103). This is a till deposit left during the glacier's retreat. A group of drumlins (108) may be seen at the northeast end of the model. The steeper ends of the drumlins usually face toward the direction from which the glacier came.

South of the terminal moraine all of the topography is unglaciated. Some glacial material has been deposited by stream action on the outwash plain (107).

There is a limestone area in the southwest corner of the model with extensive subterranean caverns. These caverns have been formed by water dissolving the calcium carbonate (limestone). Water running through underground fissures has dissolved caves in the limestone. Where the limestone overlying these caves has collapsed, depressions are formed. Originally, drainage in the limestone area was on the surface, however in a mature karst region such as this the drainage is subterranean.

The large river meanders across the broad flood plain created between the glacial outwash and the limestone cliff (121). The river has cut a terrace (114) in the limestone. Several stages in the creation of ox-bow lakes can be seen in the course of the river on this model.

TOPOGRAPHIC MAPS

CUTOFF MEANDER
- Fennville, Mich.
- Philipp, Miss.

DRUMLINS
- Ayer, Mass.

END MORAINE
- Kingston, R.I.
- Pelican Lake, N.D.

ESKER
- Delaware, Mich.
- Jackson, Mich.

GLACIAL DRIFT
- Ticonderoga, New York-Vermont

KAMES AND KETTLES
- Lake Tapps, Wash.
- Kingston, R.I.

KARST TOPOGRAPHY
- Mammoth Cave, Ky.

LAKES AND PONDS IN GLACIALLY SCOURED BEDROCK BASIN
- Lynn, Mass.
- Mt. Desert, Maine

OXBOW
- Boltaire, N.D.

OXBOW LAKE
- Campti, Louisiana
- East Brownsville, Texas

PITTED OUTWASH PLAIN
- Jackson, Mich.
- Kingston, R.I.

WIDE MEANDER
- Strasburg, Va.

PROJECT
Demonstration of the Development of Glacial Topography

Various glaciated features represented on the Model No. 6 may be demonstrated with a stream table or large pan as described on page 7. Partially fill the stream table with sand and well packed crushed ice as shown on the diagram below. This will represent a glacier and terminal moraine prior to recession of the glacier.

Once the ice has melted the features described below may be observed.

KETTLES: Kettles will form where pieces of ice partially buried in the sand have melted.

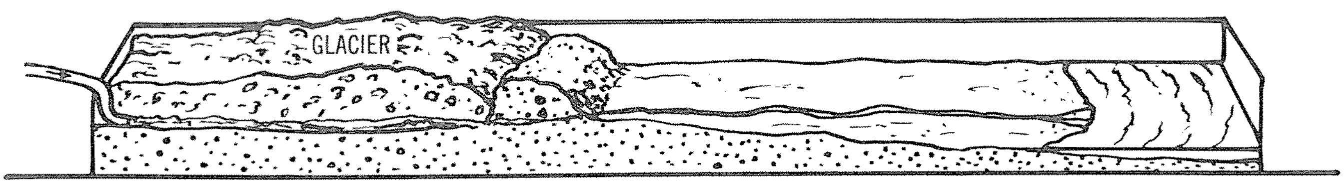
TERMINAL MORAINE: The features of a terminal moraine, including knobs and kettles, may be seen along the edge of the ice after it has melted. Usually a stream will flow through the moraine.

ESKER: An esker will form where the stream flowed beneath the ice. This will appear as a snake-like ridge.

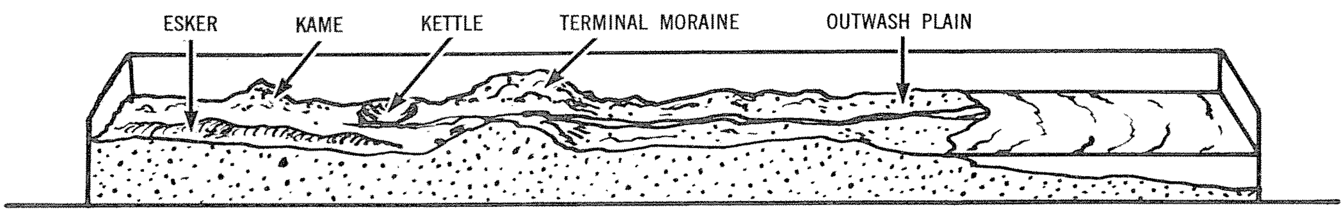
KAMES: Kames are irregular, mound-like deposits of material carried by streams that flowed on the glacier and deposited the material in holes in the ice or in crevasses at the edge of the ice.

OUTWASH PLAIN: The outwash plain will occur beyond the terminal moraine and the features deposited by the melt water from the glacier may be seen when the ice has melted.

Other glacial features may be observed and they should be related to the model wherever possible.



BEFORE GLACIER MELTS



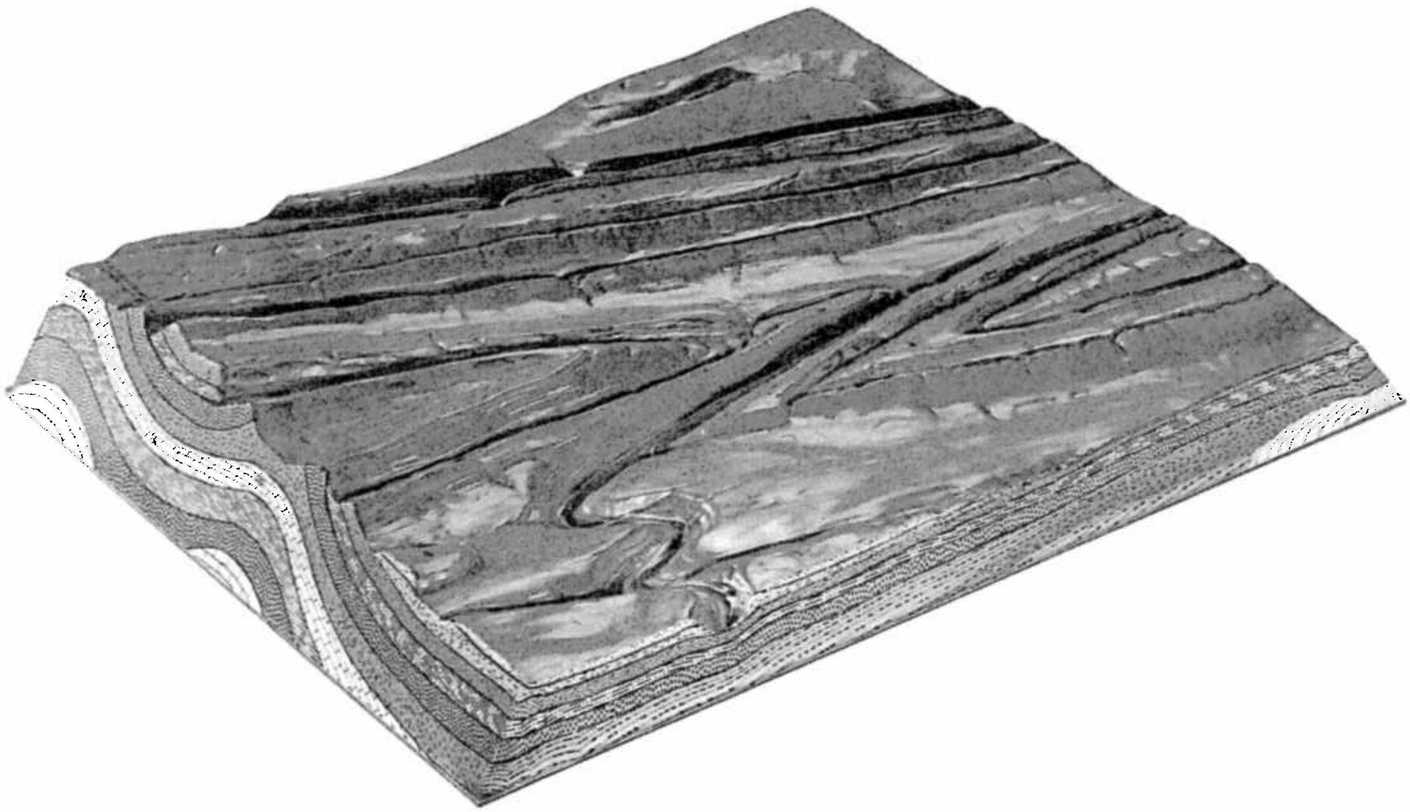
AFTER GLACIER MELTS

QUESTIONS

1. On the northern edge of the model, can you see evidence where the glacier may have eroded part of the sedimentary rocks?
2. What do you suppose happened to this material that was gouged out by the glacier?
3. Can you locate several former lakes that have turned into marshes? What do you suppose will happen to these marshes in time?
4. Look up the subject of pond succession in a biology book or an ecology book in your library. Write a brief report on the stages of pond succession and relate it to one of the lakes on this model.
5. Study the extent of the glacial till on the cross-section on the west edge of the model and the extent of the glacial till on the east edge. Now make a drawing of the model and show the extent of glacial till deposited by the glacier in the regions between the east and west edges of the model.
6. Make a map of the United States showing the farthest extent of the continental glaciers that covered the northern part of the United States during the ice age.
7. Make a drawing of several stages in the formation of an ox-bow lake.
8. Draw several stages in the development of a limestone cavern.
9. Write a short paper on the formation of stalactites and stalagmites and with a sketch, distinguish between the two.
10. Describe and relate locations of economic activity, natural resources, population centers, and climate conditions that might be found on the model.

MODEL 7

FOLDED MOUNTAINS



LEGEND

SANDSTONE SHALE LIMESTONE COAL

FEATURES

126. E-44 **ANTICLINAL MOUNTAIN** — A long mountain produced by the original upwarping of the strata. Some material may have been removed by erosion, but the mountain is formed by the anticlinal fold.

127. A-46 **ANTICLINAL VALLEY** — A valley which follows the axis of an anticline and drained by a subsequent stream. The topography has been "reversed", for such a valley now occupies the former site of an anticlinal ridge.

128. E-48 **PLUNGING ANTICLINE** — An anticline whose axis is inclined from the horizontal. Compare with 126, which is an anticline whose axis is horizontal.

129. A-44 **SYNCLINAL MOUNTAIN** — Formed by the erosion of anticlines on either side of the syncline, leaving the syncline as a mountain higher than the adjacent territory.

130. H-47 **SYNCLINAL VALLEY** — A valley in a syncline, between two adjacent anticlines.

131. G-45 **HOMOCLINAL RIDGE** — A ridge formed by resistant strata dipping in one direction. This ridge is also a hogback.

132. G-44 **DIP SLOPE** — The sloping surface of a hogback or homocline that is parallel to the inclination of the dipping beds.

133. A-48 **OUTLIER** — A remnant of a once more extensive rock unit isolated by erosion and now surrounded by older rocks.

134. C-49 **CUESTA** — An asymmetrical ridge with its gentler slope controlled by the dip of the underlying rock.

135. C-49 **DIP SLOPE OF CUESTA** — The gentle slope of a cuesta, in this case to the east, which is parallel to the dip of the resistant rock unit which caused the cuesta.

136. C-49 **SCARP** — An escarpment, cliff, or steep slope of some extent along the margin of a plateau, mesa, or terrace. This scarp is the scarp slope of a cuesta.

137. A-49 **OLD COASTAL PLAIN** — A plain bordering the sea and extending from the coast to elevated regions inland.

138. D-43 **TRELLIS DRAINAGE** — A rectangular pattern of stream drainage which resembles a garden trellis. The major streams flowing along the strike are termed subsequent streams. The small tributaries flowing at right angles into the latter streams are called resequent streams if they flow down the dip of the beds and obsequent if they flow down the scarp slope in a direction opposite to the dip.

139. C-48 **ENTRENCHED MEANDER** — Streams which have reached the mature stage of one cycle hold their courses in the second cycle and cut down in the old meanders to form a meandering valley incised below the general upland level.

140. A-45 **COAL BED** — Coal deposit between layers of other sedimentary rock. The coal bed is formed by burial of an ancient swamp.

141. A-46 **ANTICLINE** — An arch formed by rock layers that have been bent upward.

142. A-44 **SYNCLINE** — A trough ("downward arch") formed by rock layers that have been bent downward.

VII. FOLDED MOUNTAINS

This model shows a region of folded strata which have formed mountains. The upward folds are **anticlines** (141) and the downward folds are synclines (142).

Anticlines and synclines may be **horizontal** or may be **plunging.** An anticline may form a mountain (anticlinal mountain) (126) and a syncline may form a valley (synclinal valley) (130). However, erosion of the folds usually removes the crests of the anticlines, and the more resistant strata of the sides **(limbs)** of the folds form long mountain ridges, known as **homoclinical ridges,** or **hogbacks** (131). If a fold is horizontal, the resistant strata on each side of the fold will form **parallel ridges,** but if the fold is plunging, the ridges on either side of an anticline will **converge** in the direction of the plunge and those of a syncline will **diverge** in the direction of the plunge.

Continued erosion may further wear down the center of an anticline, reducing the anticline to a lower level than the adjacent synclines, thus forming an **anticlinal valley** (127). The mountains at the side are now the preserved synclines and form **synclinal mountains** (129).

The main stream (or streams) crossing the folded region persisted in their course as the folds were uplifted. They now cut across the structure as antecedent streams (not shown on this model). They cross the ridges in narrow valleys called **water gaps.** Tributaries to the master stream (or streams) draining the region have taken their courses later and these courses are controlled by the structure of the rocks. Those streams which have valleys cut along the outcrop of weak rocks, between ridges of more resistant rocks, are called **subsequent.** They usually have straight courses and enter the master stream at right angles. The pattern of these streams is like a trellis, and the pattern is called a **trellis drainage pattern.**

TOPOGRAPHIC MAPS

ANTICLINAL RIDGE
- Cumberland, Maryland-Pennsylvania-West Virginia
- Yakima East, Wash.

ANTICLINAL VALLEY
- Altoona, Pa.
- Whitwell, Tenn.

ANTICLINE
- Altoona, Pa.

ENTRENCHED RIVER
- Renovo West, Pa.

FOLDED MOUNTAINS
- Waldron, Ark.
- Harrisburg, Pa.

OUTLIER
- Hillsboro, Ky.
- Rover, Tenn.

SYNCLINAL VALLEY
- Strasburg, Va.
- Tyrone, Pa.
- Yakima East, Wash.

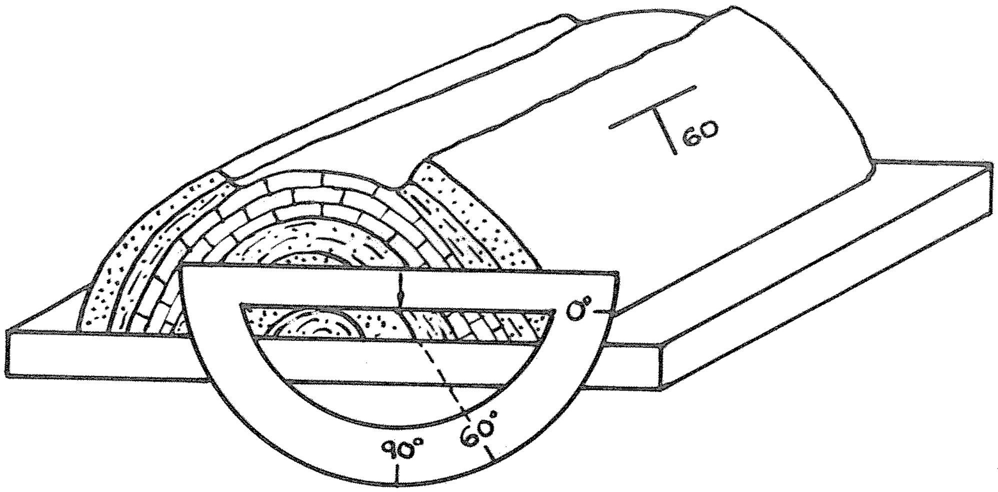
TRELLIS DRAINAGE
- Cumberland, Maryland-Pennsylvania-West Virginia
- Waldron, Ark.

WATER GAP
- Tyrone, Pa.

WIND GAP
- Delaware, Mich.
- New Britain, Conn.
- Yakima East, Wash.

PROJECT

You can make a model that will help you understand the terms dip and strike which are used in reference to angle and direction of the slope of beds. First, make a model out of clay similar to the drawing below. The dip of the bed is the angle from the horizontal at which the bed is inclined and the direction of this inclination. You can measure the angle of dip on your model by holding a protractor in the position shown.



DIP AND STRIKE MODEL

The strike of the bed is the direction of outcrop on a level surface: it is always at right angles to the dip. The T-shaped symbol shown in the diagram represents the dip and the strike. The long line or top of the T represents the strike and the line at right angles to it represents the direction of the dip. The number of degrees indicates the inclination from the horizontal. Measure the angle of dip on your model and make little symbols on paper and cut them out and attach them to the model in the appropriate positions.

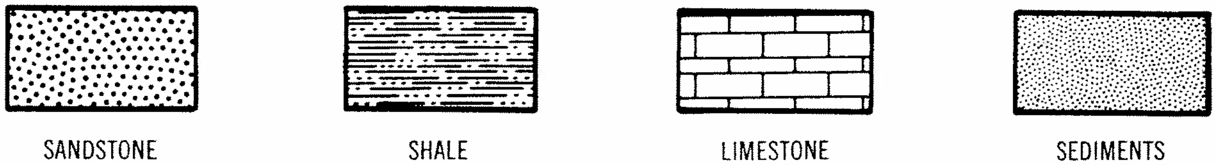
QUESTIONS

1. Locate the presence of glacial till on the model.
2. Describe the position of the oldest rocks shown in cross-section on the model.
3. Indicate the position of the oldest rocks that are outcropping on the surface of the model.
4. Locate the position of the youngest rocks on the model.
5. Why is the red sandstone shown as an outcrop on the folded mountains and the plunging anticlines.
6. Why do the shales not show up as outcrops?
7. Locate a wind gap on the model.
8. After studying the trellis drainage system on the model, make a drawing as accurately as you can to illustrate the drainage pattern on this model. Do not show contours. Then compare your diagram with the model itself.
9. Study the two diagrams below and review the material on the dip and strike of sedimentary beds. One diagram represents an eroded syncline and another diagram represents a plunging anticline. See if you can decide which is an anticline and which is a syncline.
10. Describe and relate locations of economic activity, natural resources, population centers, and climate conditions that might be found on the model.

MODEL 8

COASTAL PLAIN

LEGEND



FEATURES

143. E-53 **COASTAL PLAIN** — Broad low plains between the higher land farther inland and the seashore are called coastal plains.

144. G-56 **BEDROCK ISLAND** — An island composd of bedrock, rather than of recent marine sand and gravel deposits.

145. B-54 **OFFSHORE BAR** — A long, narrow, low, sandy ridge with a belt of quiet water separating it from the mainland.

146. D-54 **LAGOON** — A shallow body of water separated from the sea by an offshore bar.

147. C-54 **INLET** — A narrow opening in the bar through which the tide ebbs and flows.

148. D-53 **SALT MARSH** — A swampy region on tidal flats and in shallow lagoons. Salt marshes contain plants that have a high tolerance for salt water. Marshes may grow and expand to occupy much of a formerly open lagoon.

149. B-53 **OLD SHORE CLIFF** — A cliff that was formerly eroded by incoming waves, but which is now protected from the action of the sea by the off shore bar.

150. B-50 **RIVER VALLEY** — A young valley cut so recently that the valley is still narrow and has few tributaries.

151. B-51 **ESTUARY** — The shallow mouth of a river where the fresh water of the river mixes with the sea water at high tide, producing brackish water. The mouth of the valley has been "drowned".

152. F-50 **CUESTA** — An asymmetrical ridge with its gentler slope controlled by the dip of the underlying rock.

153. G-51 **DENDRITIC DRAINAGE** — The dendritic drainage pattern is characterized by irregular branching in all directions with the tributaries joining the main stream at all angles. This pattern resembles the branching of a tree.

154. F-56 **SUBMARINE CANYON** — A narrow underwater gorge with steep slopes, often of considerable size.

155. D-56 **CONTINENTAL SHELF** — The marginal part of a continent which is covered by shallow water, its seaward margin slopes more steeply to the ocean floor.

156. D-56 **CONTINENTAL SLOPE** — That part of the ocean floor extending from about 100 fathoms to about 2000 fathoms characterized by a marked increase in gradient.

VIII. COASTAL PLAIN

The irregular form of this coastline is caused by its having first been raised so that river valleys were formed, then it slowly sank drowning the valleys, forming estuaries. A prominent feature shown on the model is the offshore bar (145) which was formed in the following manner: The sea bottom slopes very gently away from the land so that incoming waves break in the shallow water some distance offshore. Along the line of the breaking waves sand is stirred up and thrown landward. The sand deposit grows higher and higher by deposition of more sand thru the action of the waves, as well as by sand that is deposited by long shore currents. Sand dunes may form on top of the bar.

After the offshore bar has emerged above the surafce of the water, a lagoon is present between the bar and the shoreline. A lagoon, (146) is a sheltered, calm, stretch of water that is frequently used for coastal navigation. The rivers that drain the coastal plain and flow into the lagoons bring great quantities of sediments. These sediments are gradually deposited in the lagoon and eventually tend to fill it up.

In the shallow waters of the lagoon, salt marshes are formed. These salt marshes (148) are laced with an intricate pattern of tidal channels in which the water level fluctuates with the rising and falling of the tide.

At certain intervals in the offshore bar, inlets (147) occur through which the tide flows. On the landward side of the tidal inlet, a tidal delta may be deposited. Gradually the lagoon tends to fill up with sediments, and fresh water plants then begin to invade what was formerly a salt marsh. In this stage of shoreline development, the offshore bar itself is attacked by the waves and driven landward across the lagoon or marsh, leaving a relatively straight coastline.

TOPOGRAPHIC MAPS

COASTAL BAR
Jacksonville Beach, Fla.
Barnegat, N.J.

DELTA CHANNELS
Mobile, Alabama

DROWNED COASTLINE
Mt. Desert, Maine

DROWNED VALLEY
Mobile, Alabama
Point Reyes, Calif.

ESTUARY
Point Reyes, Calif.
Washington West, D.C.-Maryland,-Virginia

LAGOON
Point Reyes, Calif.
Provincetown, Mass.

OFFSHORE BAR
Tom's River, N.J.

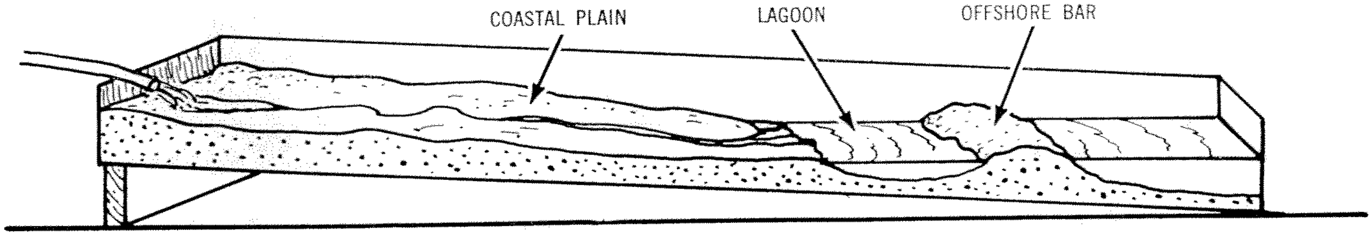
TIDAL MARSH
Little Creek, Del.
Lynn, Mass.

PROJECT

A Model to Represent the Deposition of Silt In a Bay

When a river (150) enters an ocean bay or lagoon, it rapidly loses its velocity; therefore, the carrying power of the river is reduced and the materials that it is carrying are soon deposited on the floor of the bay or lagoon. For even better examples, see No. 10 and No. 14 on Model No. 1.

You can make a model to demonstrate this fact. Use a metal pan or stream table as described on page 7 and partially fill it with sand. Tilt the box or stream table to duplicate the gradient shown on the model and form the sand as shown on the diagram below to resemble the coastal plain, lagoon and off-shore bar. Adjust the water flow so that a small stream flows into the lagoon. The stream will carry sand into the water, depositing it and thereby gradually filling the lagoon.



CROSS SECTION OF STREAM TABLE

You can experiment further by varying the angle of the board. This will give your stream a greater or lesser velocity and you should be able to make observations relating to the carrying power of streams of different gradients.

QUESTIONS

1. Explain why many people like to spend their summer by the seashore or by a large body of water such as a lake.
2. Examine the salt marshes to the west of the offshore bar. Would you expect to find the same kinds of organisms living in these salt marshes as in the salt marshes close to the river mouth? Give several reasons for your answer.
4. Draw a sketch of a dendritic drainage pattern and one of a trellis drainage pattern and compare them.
5. What is the source of the material that forms the offshore bar?
6. Would you say that this model represents an area of high relief or low relief?
7. Describe and relate locations of economic activity, natural resources, population centers, and climate conditions that might be found on the model.

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