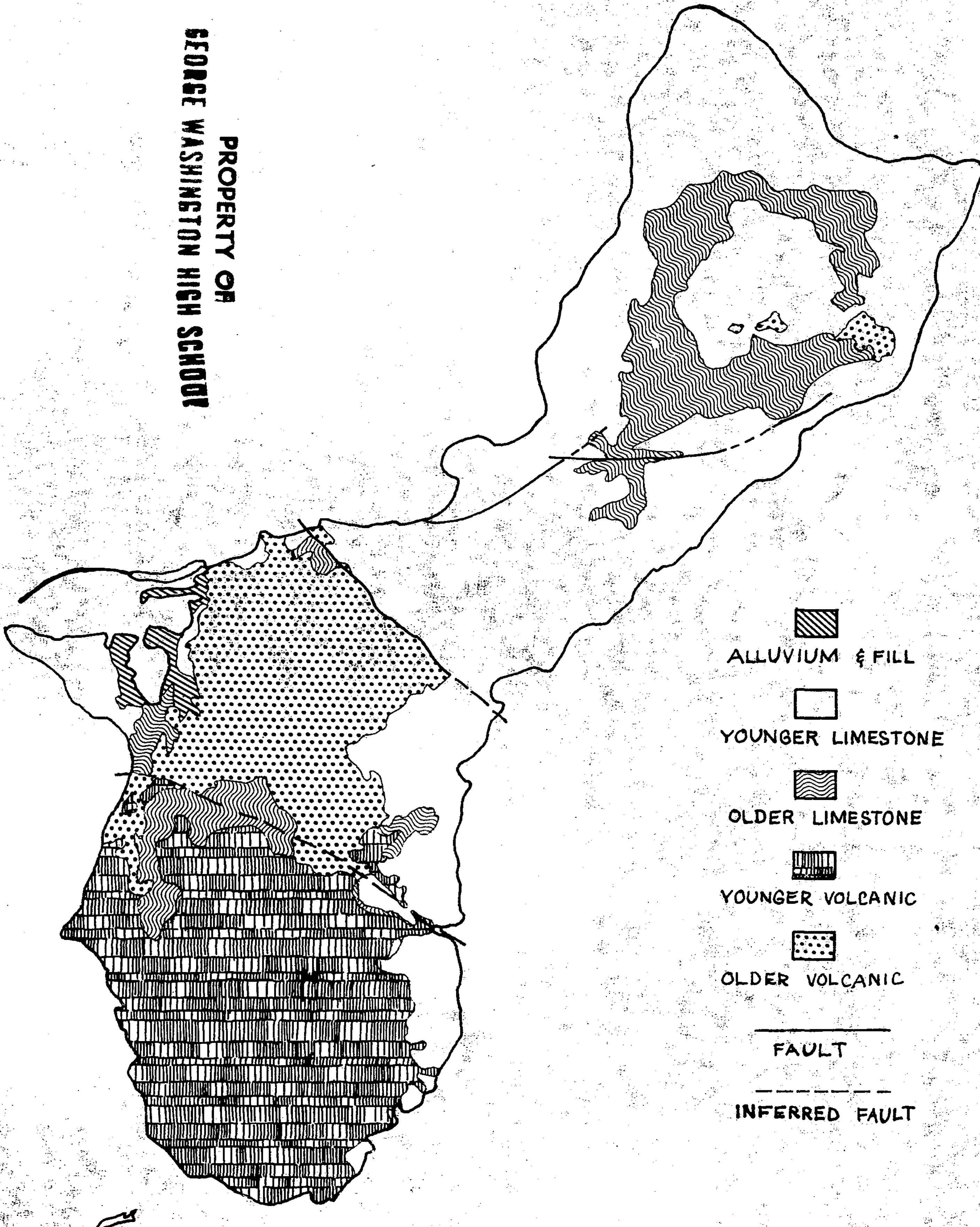
Life On Guam Geology

by Gail Elkins,

Dave Hotaling, and

Richard H. Randall

art Lita Payne



Geologic Map of Guam
(After C. J. Huxel, U. S. Geological Survey Office, Guam)

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Life On Guam

...a project to produce locally relevant class, lab, and field materials in ecology and social studies for Guam junior and senior high schools. This project is funded by a grant under ESEA Titles III and IV, U. S. Office of Education - Department of Health, Education and Welfare——whose position, policy or endorsement is not necessarily reflected by the content herein.

"....to ultimately graduate citizens who are knowledgeable and conscientious about environmental concerns of Guam and the rest of the World."

The other units of this project and their authors:

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I. Introduction

If you're interested in things like volcanoes and earthquakes, this unit is for you. But that's just part of it. We're also going to look at some of our nonrenewable resources——those that can't reproduce themselves. Can you name some of these? Did you ever hear of a 'baby' rock? No?——neither did anybody else. Rocks, then, are nonrenewable resources, at least over a short period of time, like several million years! So are minerals, soil, and water. Once you get into it you'll find out that there's a lot of interesting stuff to geology!

For example, did you know that Guam sits next to two submarine volcanoes, and has several earthquakes every day? That can be shocking news! There's a big push now to increase farming here, so we'll check out the soil situation.

Enough of the giveaways; read on and find out what else is in store for you!

One helpful thing you could do is to go on a rock-examining field trip, with the class, your parents, or other friends (See Going Around Guam in the Appendix, page 47).

Remember, Life On Guam is a new program. Do all you can to make it work; if you've got suggestions, give them to your manager (the teacher). This is your program; your opinions are valuable!

What's Going to Happen

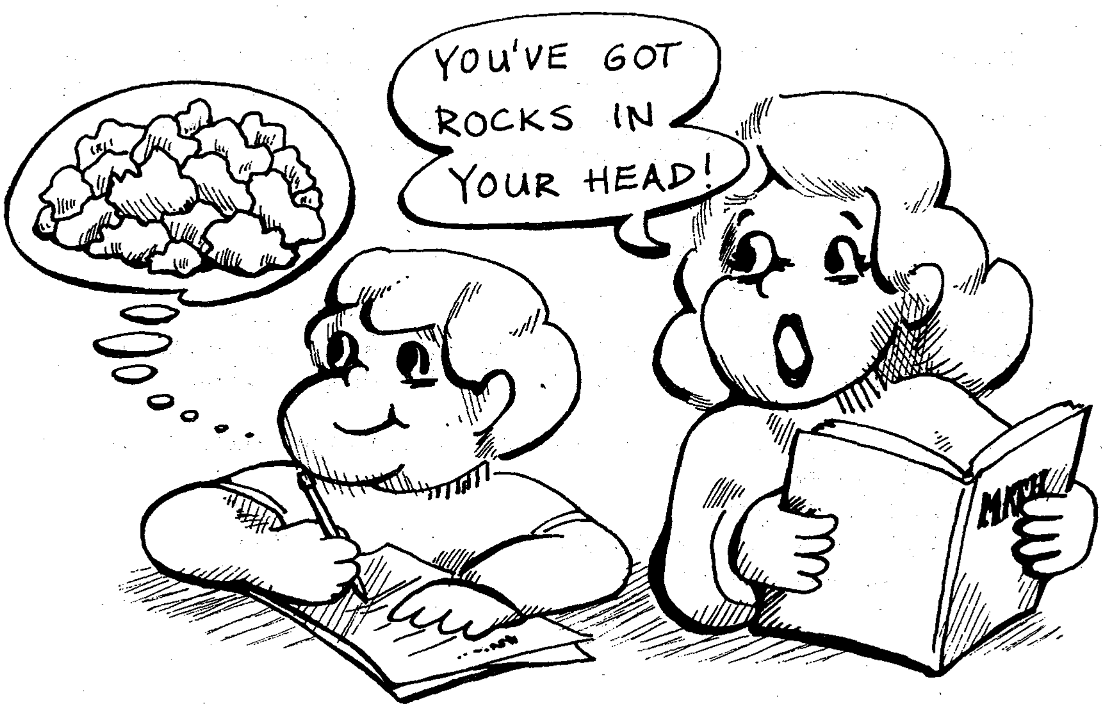
Most of the time, completing the activities and contributing in class discussions are all you will be asked to do. Here are some of the activities:

- Identifying, defining and analyzing minerals and rocks
- Analyzing soil
- Experimenting with plants' use of water
- Going around Guam

Each activity has several parts. But if you know what you're doing, and do it carefully, they should be very simple for you.

Things you will know after finishing the unit:

1. How to use a hand lens.
2. How to use acid in rock analysis.
3. The two major types of rock on Guam.
4. The Principle of Uniformitarianism.
5. Why there's so much limestone in northern Guam and so much igneous rock in the south.
6. How Cocos Island probably formed.
7. How weathering affects rocks, the Earth's surface, and buildings.
8. Some ways to combat weathering.
9. The causes of earthquakes and why earthquakes occur in certain areas.
10. What the Richter scale is.
11. What can be done to minimize earthquake destruction.
12. How soil forms and why different soils have different qualities.
13. About the different types of reservoirs (aquifers) on Guam.
14. The path a drop of water takes through the water cycle.
15. Why over-pumping and water pollution are important environmental concerns.



II. Rocks

Rocks are the first nonrenewable resource we'll investigate. What is rock; what is a mineral? What do the words igneous, sedimentary, and metamorphic mean?

For your first exercise, you will have samples of minerals and rocks. Right now it's not important to know their names, but rather just be able to tell the differences between them.

ACTIVITY 1. Rock or Mineral?

Materials: 1 tray of several different minerals
1 tray of several different types of rock
1 hand lens or magnifying glass for each person or group

Hold the hand lens up to your eye and bring the sample up to it.

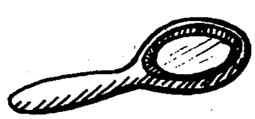

hand lens

Figure 1. The right way to use a hand lens.

In groups of 3 or 4 examine each of the minerals and rocks. Use a hand lens so you can see them in greater detail. Be sure each member of your group examines each one of the samples.

In your notebook make a chart like this one and record the general characteristics of each specimen.

Characteristics	
Mineral	Rock
Seems to be made of one kind of material only.	

Now, as a group, write down the characteristics that you see are common to minerals, and those common to rocks. After all the groups have finished, discuss your findings. Come up with definitions for minerals and rocks. Check your definitions with a dictionary or encyclopedia. How was your definition the same as the book one; how was it different? If you were careful and observant, they should have been very close!

Now, what about igneous, sedimentary, and metamorphic? Probably most of you are familiar with the terms but may need a refresher course. If possible, a movie or filmstrip should be enough to stimulate those brain cells. If your teacher hasn't already made plans to show a film or filmstrip, ask him/her to try to get one for you. (Please – no popcorn!!)

If you got your way, the next activity——identifying igneous, sedimentary, and metamorphic rocks——should be easy. For those of you who didn't get to see the film a quick trip to the library should refresh your memory. Otherwise, see page 8.

ACTIVITY 2. The Three Kinds of Rock

Materials: 1 tray of igneous rocks (including basalt)
1 tray of sedimentary rocks (including limestone)
1 tray of metamorphic rocks (including marble)
1 hand lens/student or group
1 nail/group (no rusty ones)
Dilute (10%) hydrochloric acid (HCl) with eye dropper

Read carefully before beginning the lab!

Again, for this activity, get into groups of three or four. Carefully examine each of the rocks in your trays. Use your hand lens and discuss your observations with the group.

This time we're going to look for 5 different characteristics:

1) Texture: The size, shape, and arrangement of the rock's particles. Let's describe the texture as either interlocking or non-interlocking. These are general terms but they will help in determining the origin of the rock. Interlocking means that the particles seem to be regularly arranged and fit together like a jigsaw puzzle, as in most igneous and metamorphic rocks. Noninterlocking means randomly arranged particles that seem to be separated by a 'cement' as in most sedimentary rocks.

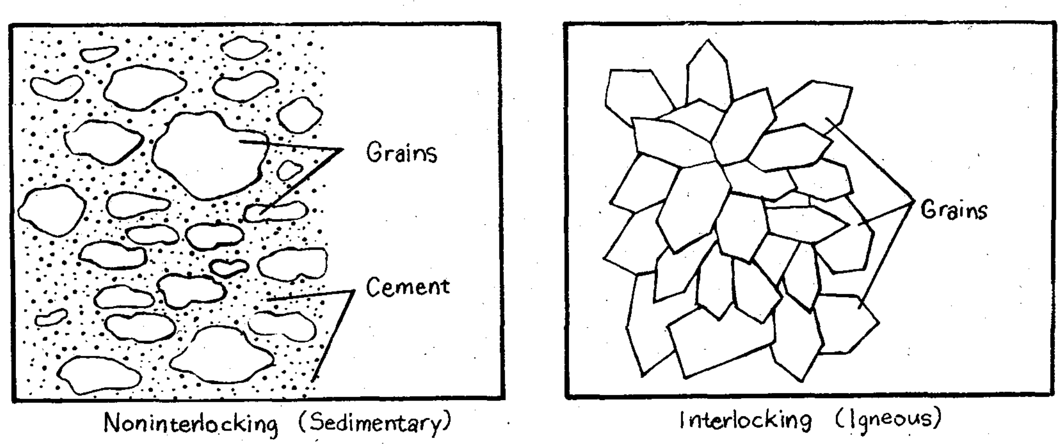


Figure 2. Rock textures (highly magnified).

2) Fossils: the remains or imprints of plants or animals. Fossils are mainly in sedimentary rocks but can be found, although usually distorted, in metamorphic rocks. They are rarely found in igneous rocks (we do have some on Guam!).

3) Bubbling reaction: IMPORTANT: Your teacher will demonstrate how to check for this. He/she will caution you on the use of acids. You can take turns, but test each rock only once. This is because once a sample is exposed to acid, it is contaminated and may not give the same results when tested again.

NOTE: Before using any acid be sure to have running water and paper towels immediately available. If you get acid on yourself or clothes, rinse well with running water immediately and tell your teacher.

To get a fresh surface, scrape the rock with the point of the nail a couple of times. This should remove any weathered surface. (Be careful, nails are very hard and sharp!) With a dropper, place 2 or 3 drops of acid on the freshly scraped surface. If the acid bubbles, the sample contains carbonate material. In most cases that means that the rock is sedimentary (limestone), or metamorphic (marble). Rinse the acid off the sample when you have completed the test.

4) Porosity: the amount of space between the particles of rock. This can be tested by putting several drops of water on each sample (make sure the sample is dry). If the rock soaks up a lot of the water, it has high porosity. This is usually the case with sedimentary rocks. If the water does not soak in, the sample has a low porosity, as do metamorphic and most igneous rocks.

5) Hardness: the breaking strength of a rock. This will tell us how strong the rock is and thus how easy (or difficult) it is to break down. Geologists refer to sedimentary rocks as soft, while igneous and metamorphic rocks are hard. To do this test, scratch the nail on each rock. If the sample flakes or wears away easily it is soft. If it is difficult to scratch particles away, then the rock is hard.

Now you can begin the activity. Follow each procedure carefully. If any of the samples does not 'follow the rules', put it aside and record in your notebook what is unusual about it. At the end of the activity, discuss these exceptions with the class and see if they agree with you! What conditions might cause these exceptions? Are there any questions on the procedure you just read?

Okay, that was a 'dry run', working with rocks already known to have certain characteristics. Now we're going to do a little research. Let's see what types of rocks are found on Guam. We can tell a lot about the origin of a rock just by knowing if it's igneous, sedimentary or metamorphic. So it seems likely that we should be able to tell a lot about how the Island formed by examining characteristics of the rocks. Now let's get out the samples of Guam rocks (along with the map showing where they were picked up) and analyze them.

ACTIVITY 3. Guam Rocks

For this activity also, get into groups of three or four. Follow the same procedure you used in identifying igneous, sedimentary, and metamorphic rocks. That is, determine texture, fossil content, bubbling reaction, porosity and hardness of Guam rocks. (You should have already numbered each rock and its corresponding location on the map.) Make a chart in your notebook like the one below and record characteristics of your samples. The last column, labeled 'Rock Type', is your conclusion as to what type of rock it is: igneous, sedimentary, or metamorphic. Questions? Okay, go to it.

Characteristics of Rock Types

Sample Texture	Fossils	Chemical Reaction	Porosity	Hardness	Rock Type
1. non-interlocking	+	+	high	soft	sedimentary
2. interlocking	–	–	low	hard	Igneous
3.					

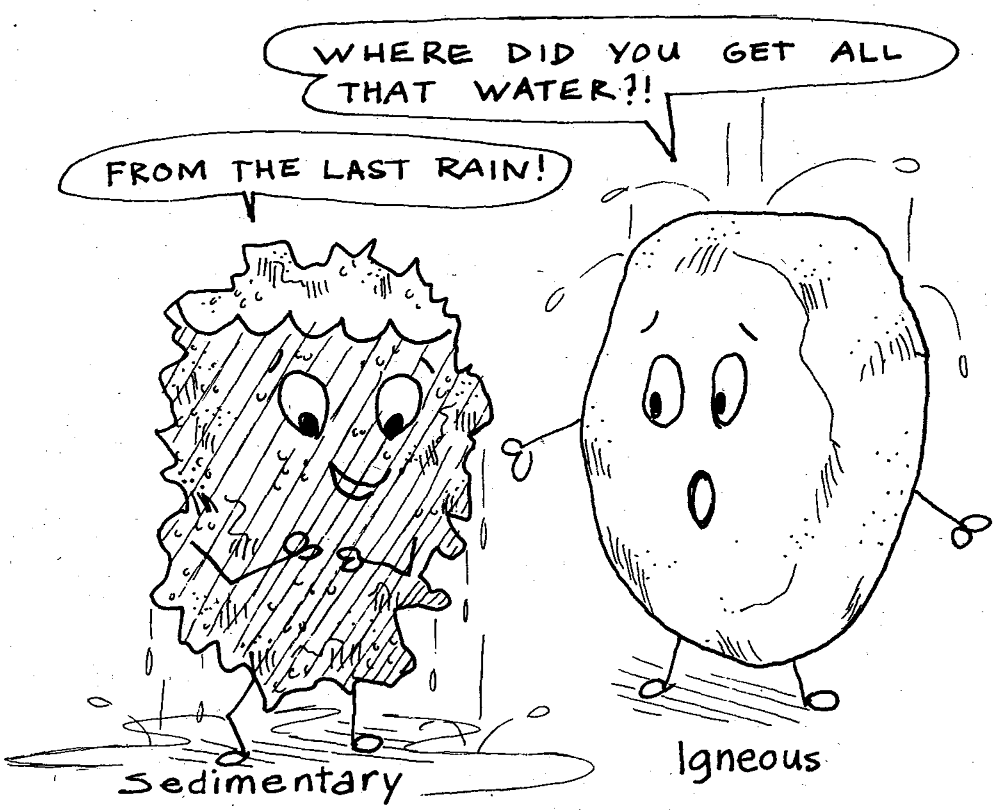
Once you've completed the chart, record on your map the type of rock you found at each location. Now compare your maps with others in the class. Are they the same? Should they be? Now, as a class, make up one map that shows the sampling sites and types of rocks you found. What do you notice generally about the types of rocks and where they are found? From these data, what can you conclude about the origin of the Island?

Very briefly, here are the three kinds of rock:

Igneous (like ignite - ignition - fire) - formed by heat.

Sedimentary (= settled) - carried downslope by flowing water, and dropped where the current leveled out and slowed down.

Metamorphic (meta = after, morph = shape) - formed by either of the above two ways, then changed by further pressure or heat or both.



III. How Guam Was Formed

What happened on Guam before there was someone here to take notes on its origin? The Island started maybe 70 million years ago. (See the Earth Time Chart, pp 26-27. About when did people first arrive here?) Geologists are often faced with the problem of land origins. They use one basic idea, the Principle of Uniformitarianism, to solve it. The principle is simply that 'the present is the key to the past'. James Hutton, an early geologist, developed the theory. He reasoned that the geologic processes now happening on Earth are the same as those which formed and evolved the planet in time past. We observe how the Earth is changing today, and assume it changed in the same way since its formation. Geologists depend on and support their theories by this assumption.

Volcanoes——Igneous——South

Can we use this Principle of Uniformitarianism for 'discovering' Guam? We've already found that some igneous rocks were formed by volcanoes. We might learn about Guam's volcanoes by studying ones that are presently erupting elsewhere, such as those in Hawaii. It will be helpful for you to read about volcanoes in general.

From your own knowledge and outside research, discuss some general characteristics you would look for to find out exactly where an early Guam volcano was located.

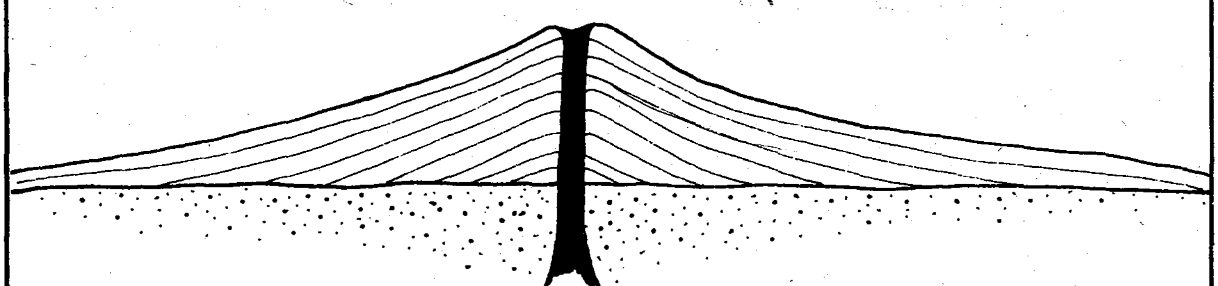


Figure 3. Generalized diagram of a volcano.

The U. S. Geological Survey was curious about the origin of the Island and sent a team of experts here to find out the facts.

Briefly, this is what they found: Guam is indeed partly volcanic. But the volcano we were looking for on the Island is out at sea. As a matter of fact, there were two volcanoes. The first one to erupt was northwest of Guam. The other, which erupted millions of years later, was southwest. As each one collapsed, minor cones developed nearby. Today Guam is the only part of the whole mass still above water. The two sets of diagrams below show the geologic development of the area.

THE FORMATION AND COLLAPSE OF THE TWO VOLCANOES

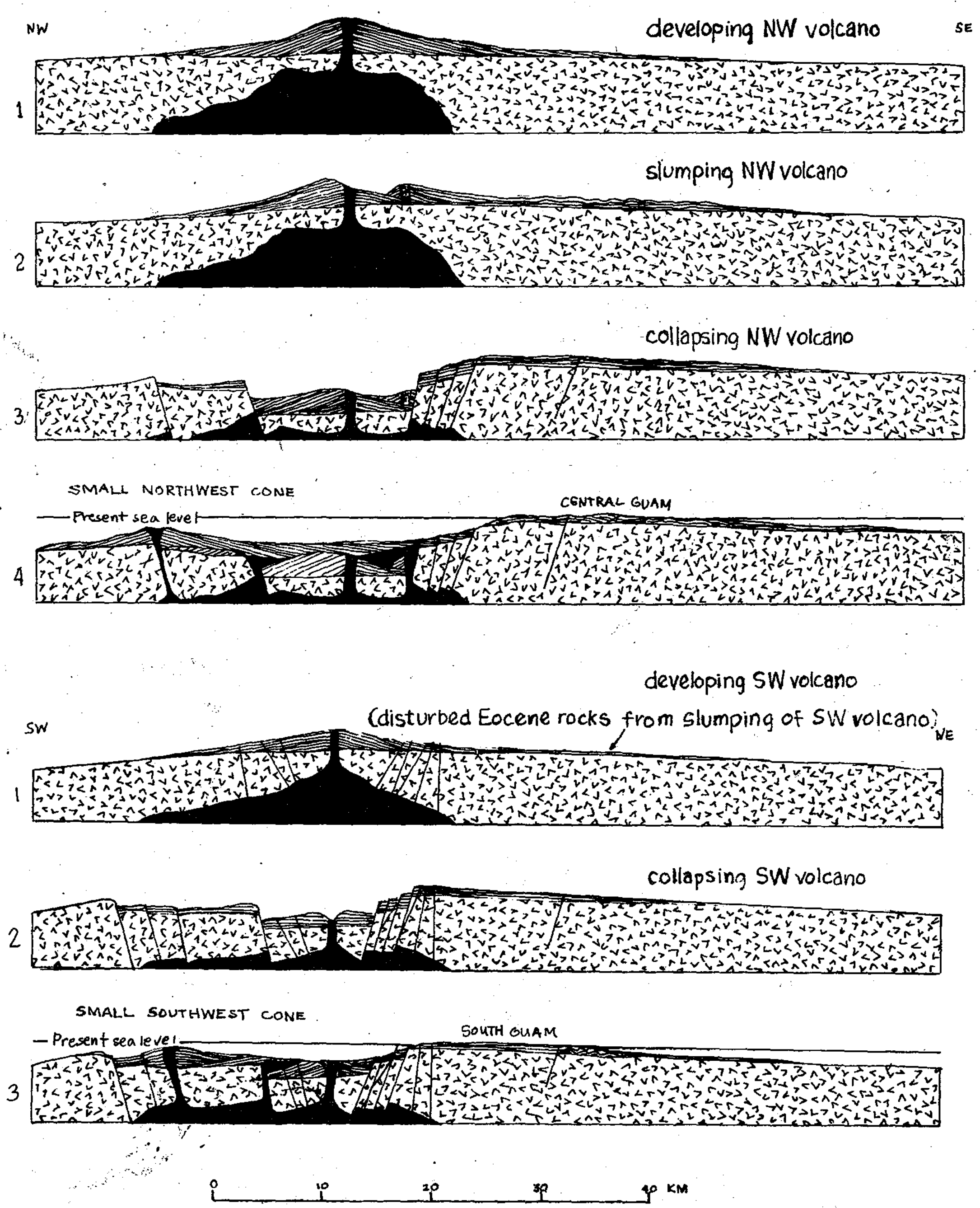


Figure 4. Development of Guam (After Tracey).

The map below shows the Island today, the two huge collapsed volcanoes, the two small submerged cones, and some faults and fault zones.

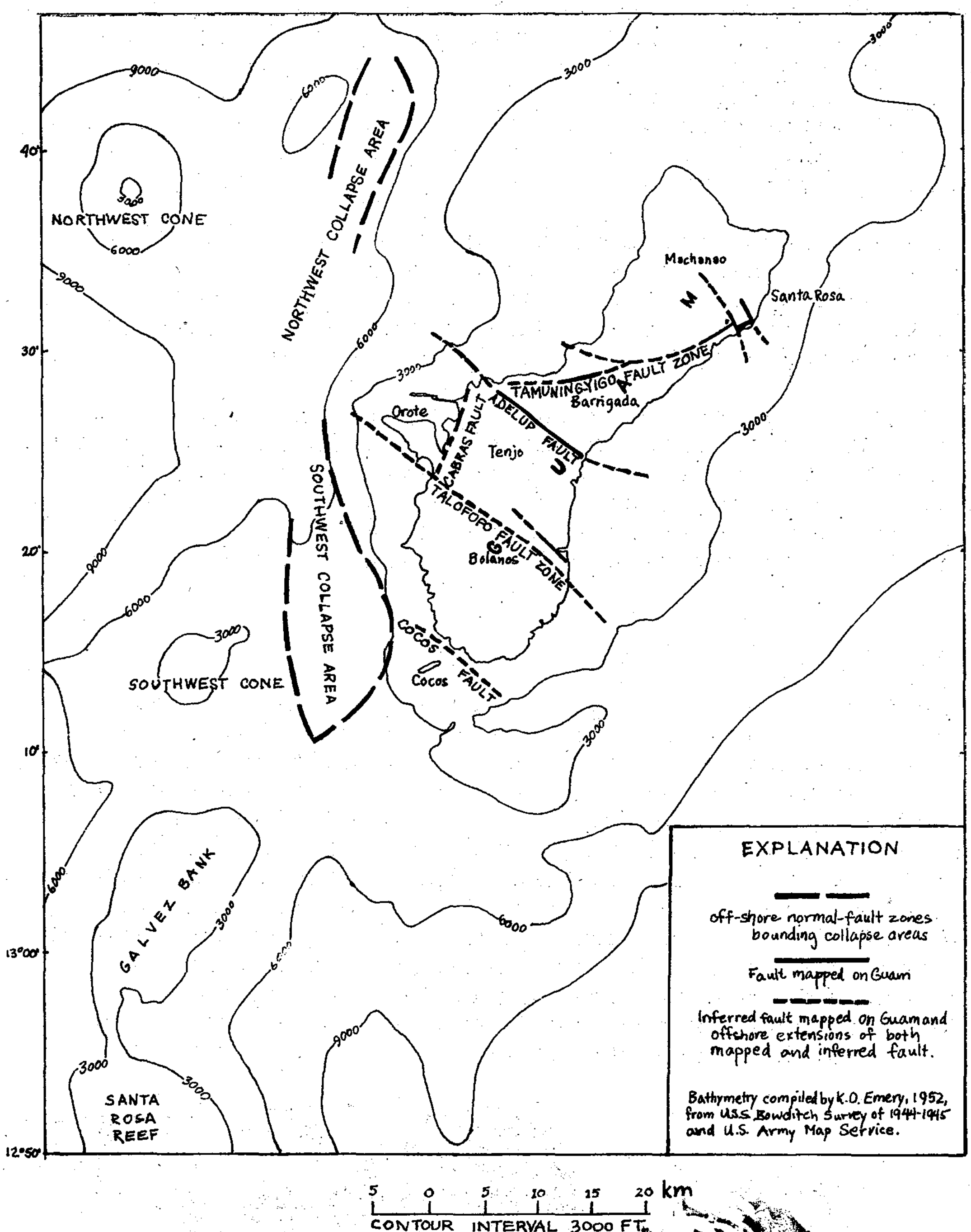


Figure 5. Map of Guam and vicinity.

Coral——Limestone——North

Now that we know the origin and sources of Guam's igneous rock, what about the sedimentary rock we discovered? This sedimentary rock is limestone. If 'the present is the key to the past', knowing how limestone forms today will help us know how it formed ages ago. Here's how: Certain animals——especially corals——and some 'seaweeds'——stony algae——build skeletons of limestone under water. The skeletons all become attached together. Spaces in between them get plugged up with more skeletons. A nearly solid mass of long-lasting limestone is thus formed.

Take a walk on the reef and give a good look at the stationary animals and plants growing there. Read the section on reef-building in the Coral Reef unit in this series, Life On Guam. Try your library for other materials.

From information you gather, you should come to much the same conclusion as geologists from the geological survey. But there's one perplexing question. If coral limestone is always formed under water, how can we have limestone as much as 180 m above sea level (as at Ritidian Point)? Discuss this question.

Nips and Other Features

Where water meets a cliff over a period of time, waves wear away the rock. Certain organisms, for instance boring algae, limpets and chitons, also wear away the rock in this splash zone. You can see this happening today on both sides of the Island at sea level. If you look up at the face of some of our cliffs you can see several 'nips' where the rock has been worn away. These nips indicate former higher sea levels. If you are a scuba diver you can find at least three more nips in the submarine cliffs surrounding Guam. At some places more prominent features such as sea level benches and terraces are cut into the rocky shorelines.

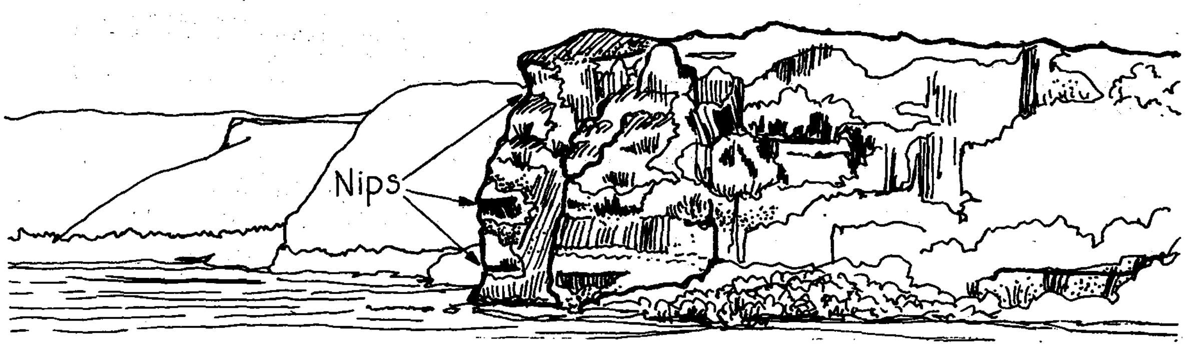


Figure 6. Nips at Puntan Dos Amantes

Faulting

Our geologists found many faults (no pun intended!) running through the Island as well as near it. These geologic faults are caused by crack stress, rocks forced against each other by subterranean (underground) pressures. When the rock can no longer stand the strain, it usually breaks. This causes shock waves which we call earthquakes. Sometimes the stress is not very great and the rocks return to their normal position when the pressure is reduced. This is called elastic rebound. Sometimes, however, the stress is so great the rock is violently moved some distance. This is how the limestone was raised above water. (Faults can also be horizontal.)

Look again at Figure 5 to see some of Guam's fault zones. Notice particularly the Adelup fault that almost cuts the Island in half and indeed separates north from south. South of this fault zone the rock is mainly igneous, and to the north, mostly limestone. (Maybe the location of the fault explains this, or this explains the location of the fault?)

Ever wonder how the small islands off Guam were formed? Let's take a quick look at two of them. The second largest off-shore island (after Cabras) is Cocos. Any of you who have been there know how flat it is—being partly a true coral cay, a 'low island'. Cocos is about 1800 m long and 250 m wide. It is the remains of millions of reef animals and plants. These died in the water and were broken down by storm waves into finer and finer particles. Water currents collected the tiny pieces together in an eddy (a place where currents curl around and slow down). Here they eventually were piled high enough to break the surface and finally, deep enough to support land plants. (How could these plants get to Cocos Island?) The seaward side of Cocos has a low band of solution-sculptured limestone along its length. (How is such limestone formed?)

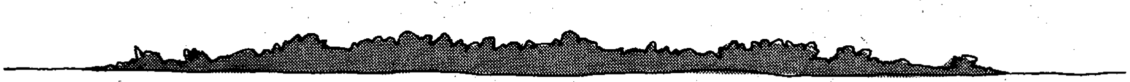


Figure 7. Cocos Island.

Guam has two barrier reefs——Cocos, and Luminao (near Glass Breakwater). Most of the rest are fringing reefs. (Refer to Coral Reef.)

Another island, Fakpe (Facpi), not as well known, has a different story. It is one of several limestone islets (little islands) along the west coast. Fakpe Point is steep-sloped volcanic mountain land. The islet above sea level is the solid remains of former reef, but its base and the flat platform between it and the Point are mostly basalt (volcanic).

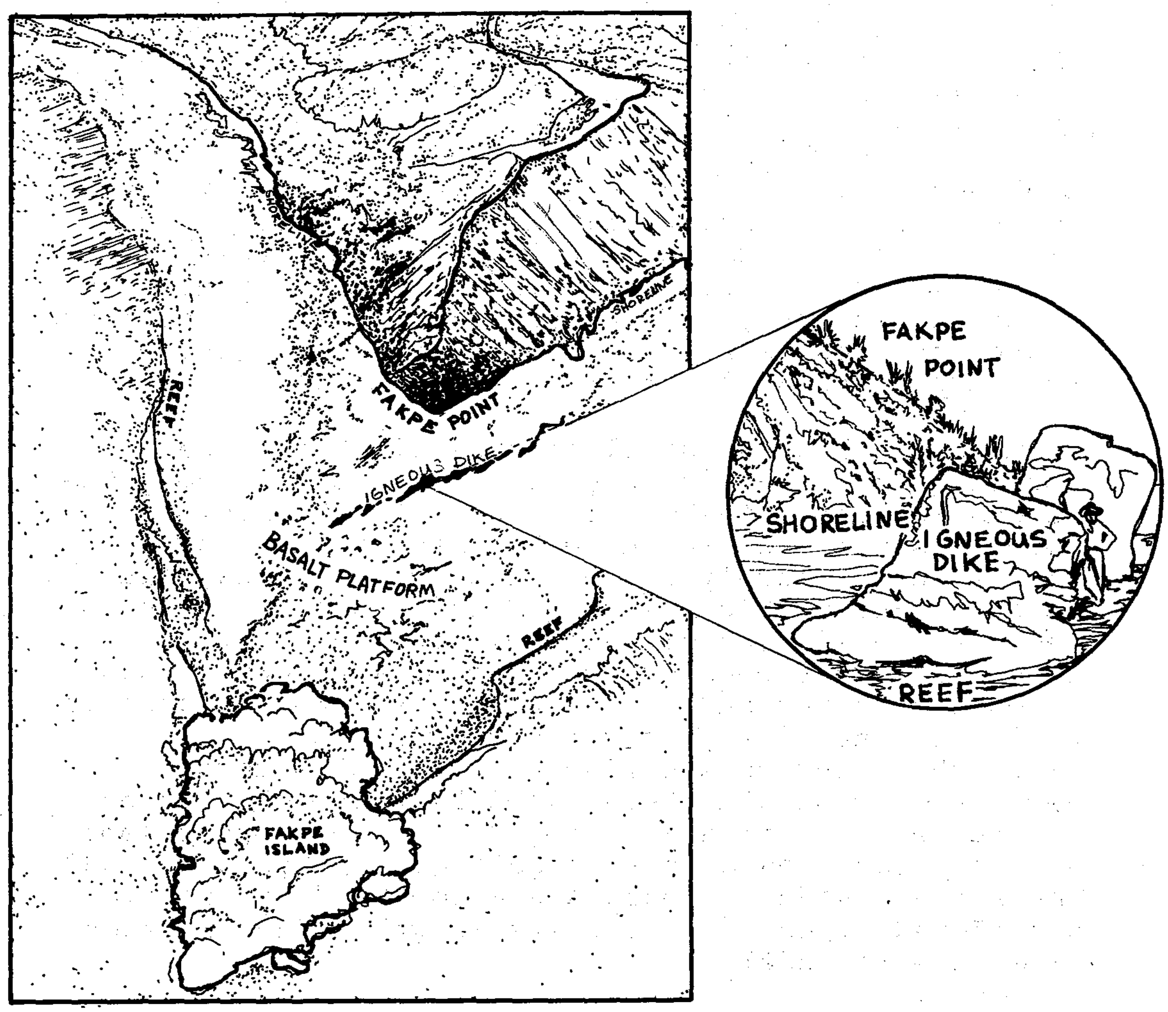


Figure 8. Fakpe Point and Island.

A volcanic dike sticks up through the present platform. Millions of years back it forced its way upward, cooled and solidified. It has resisted erosion more than the basaltic platform around it. At some places Recent reef deposits have formed thin patches on the basaltic platform.

Bays

The shoreline of southern Guam is dented in at major river mouths, forming bays of various sizes and shapes. Along this coast most bays were formed by ridge-and-valley patterns of erosion along the steep volcanic slopes. The sea has flooded the river mouths, as shown here:

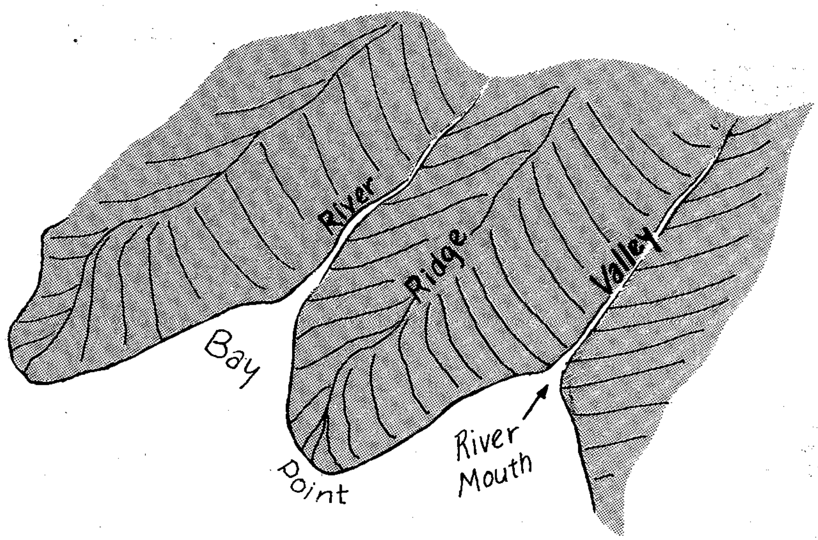


Figure 9. Southern ridges, valleys, and bays.

There are a few large bays on the northern half of the Island, for instance at Tumon and at the mouth of the Pago River. These bays contain very wide reef flats and are much shallower than those in southern Guam. The origin of the northern bays is much more complex and harder to figure out. Geologic evidence suggests that Tumon and Pago Bays formed when large pieces of the shoreline slumped downward in the past (Figure 10). These lowered sections of shoreline could provide the shallow sea platforms necessary for fringing reef development. (Again, see <u>Coral Reef</u>.)

Slumping has occurred elsewhere on Guam, on a large scale (Figure 11) and on a much smaller scale—— ever notice those many bare spots on the southern hills? Many of them are slumps.

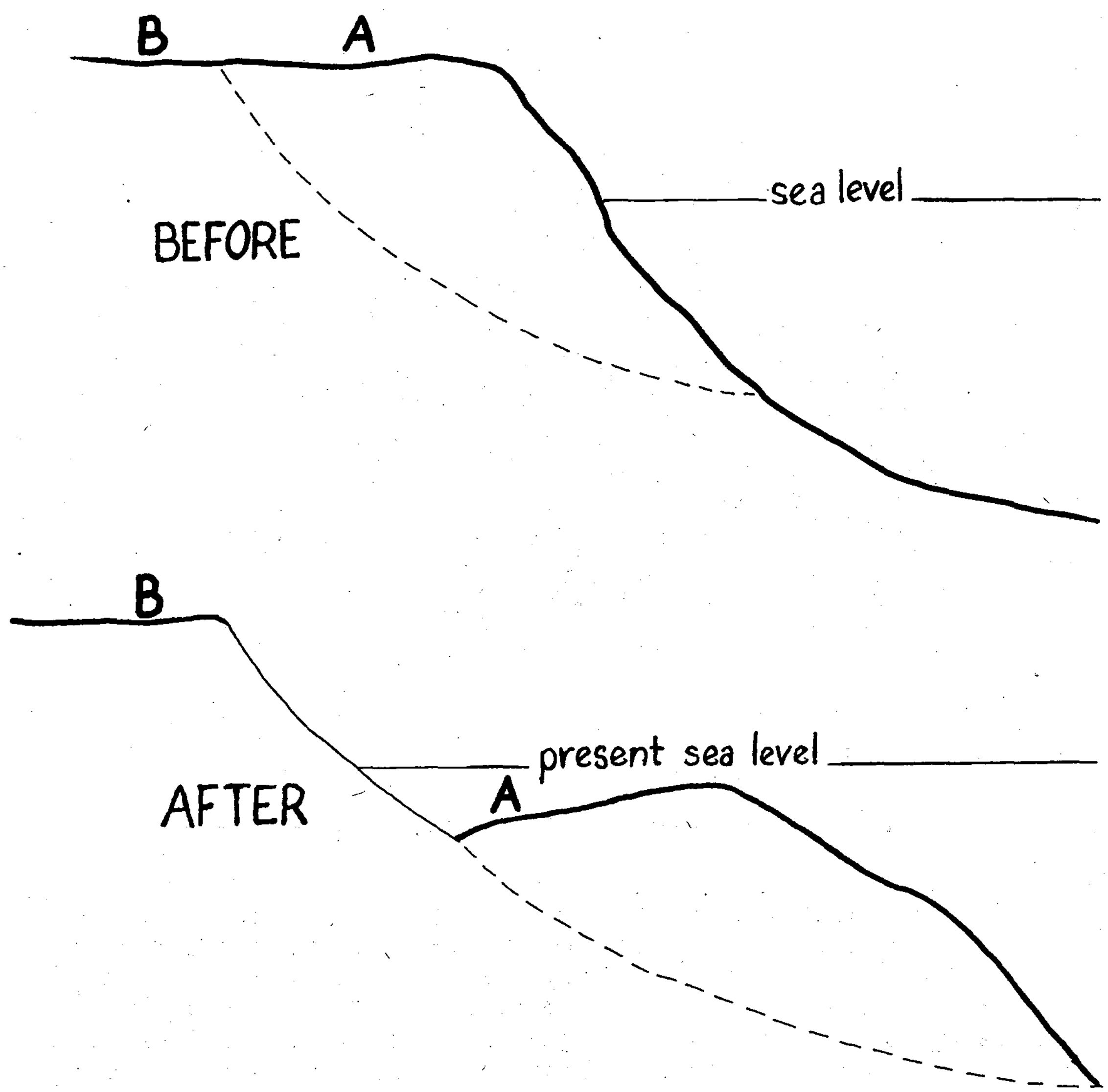
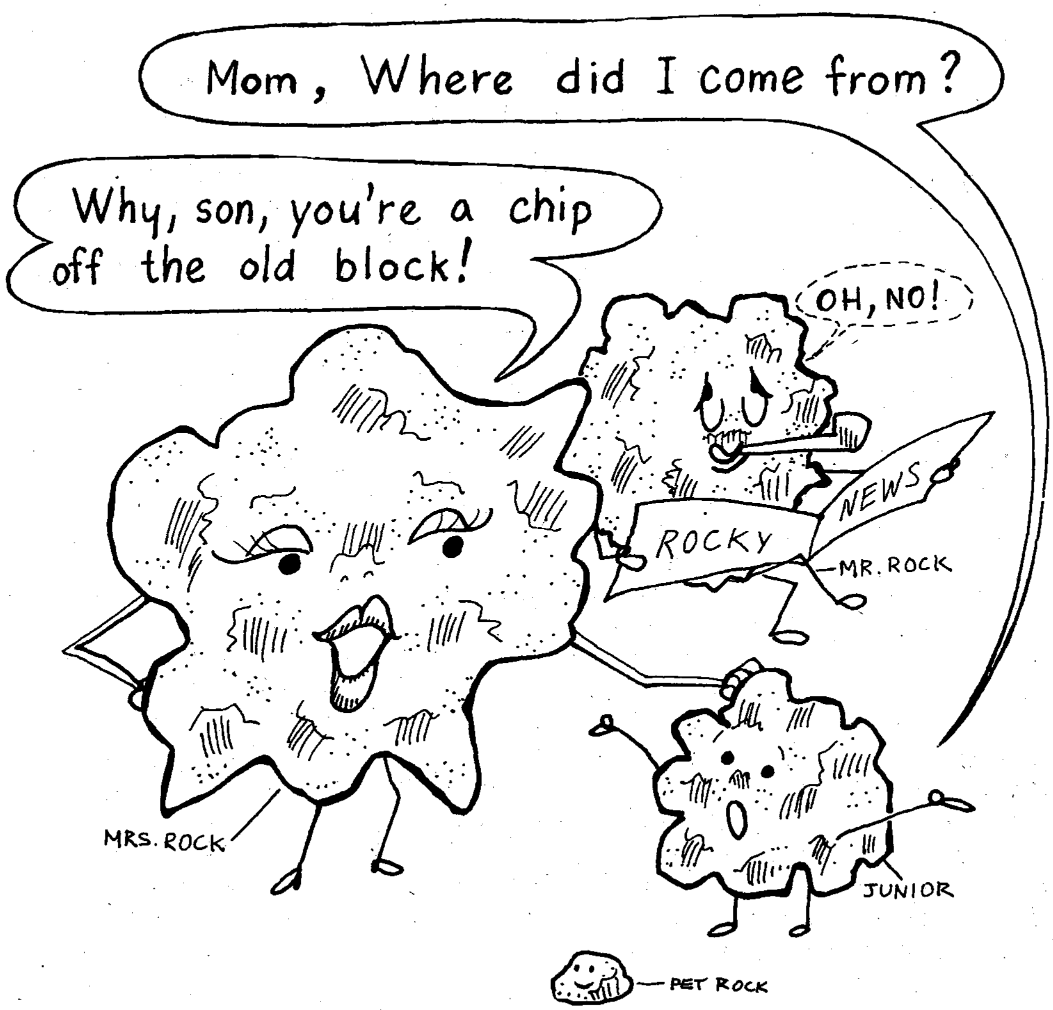


Figure 10. Slumping (showing how Pago and Tumon Bays could have formed).

Now that we know generally about the formation of different parts of the Island, how does this affect us? Why are these inanimate (not living) rocks considered a resource? To answer this question take a look around your schoolyard, and your home. Make a list of all the things you see that are made from rocks. Rocks can be broken down and mixed with other ingredients to make products like bricks and concrete. Try to list them all. You should be able to find quite a few.

We already know that rocks are a limited resource. They don't reproduce themselves, except over long periods of time by reef formation, and through even longer periods of time by rock cycling. For this reason it's important that we use this resource wisely. To do it we have to know how rocks are affected by different elements, we must work at making them last, and we must recycle the products when they finally do break down or wear out.



IV. Weathering and Erosion

Without the 'help' of man, rocks, minerals and other natural materials are exposed to the attack of waves, rain, wind and other forces of nature. The breaking down of materials is called weathering. Carrying them away is called erosion.

Let's see how Guam's surface is being weathered and eroded.

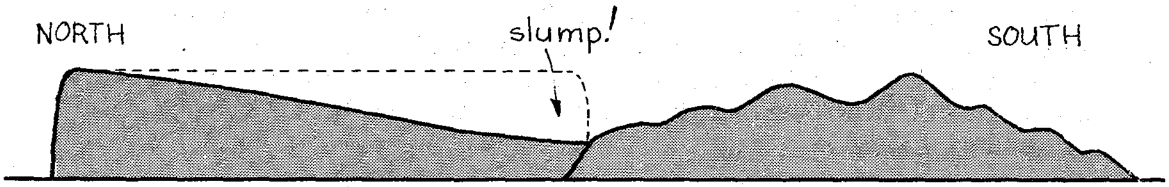


Figure 11. Diagrammatic long section through Guam.

Notice that the rock in the north——the limestone ——is flat (called a plateau) and dips gently toward central Guam. In contrast to this, the igneous areas of the south are much hillier. (Watch out! This is a generalization——limestone can be hilly, too!) It seems likely that the difference is a result of the different rock types, but why? Do you have any ideas?

Remember when you did the porosity and hardness tests on those Guam rocks? Recall your results? You probably found that the limestone soaked up more water, while the igneous rocks were harder than the limestone. These two factors combine to produce the two distinct land forms: the flat plateau in the north and the hills in the south. This is what happens: Rain water soaks into the limestone. That's why there aren't any major streams in the north. In the south the water soaks in, but slowly. Most runs off, forming the many, many streams in that end of the Island. At the same time, the igneous rocks resist weathering and erosion. But eventually Nature has her way and the continuous flow of water in the streams begins to break down even these strong rocks.

These diagrams show a sequence of how southern Guam may have looked in the past and what it may look like in the future.

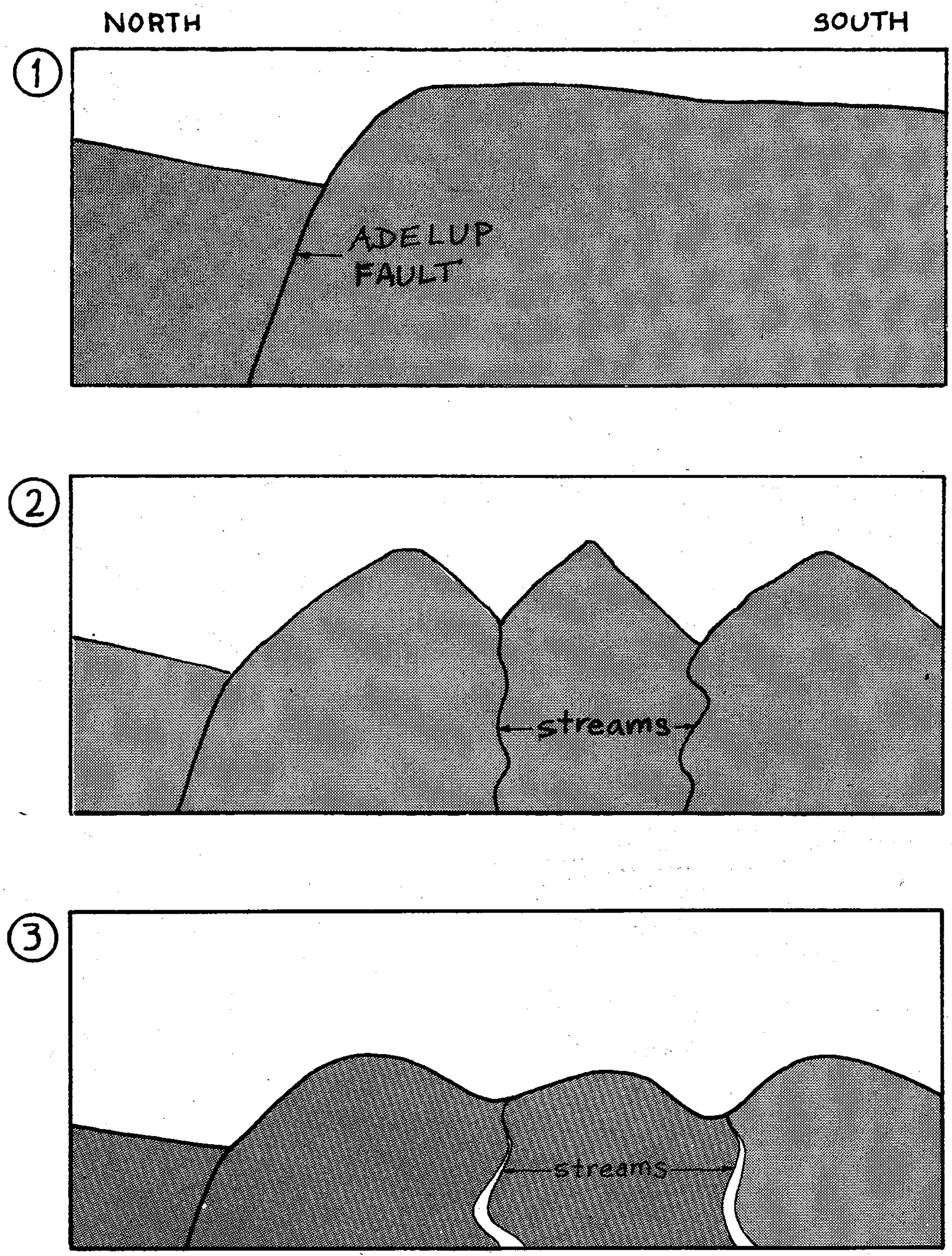


Figure 12. Erosion of the Earth's surface.

The Two Basic Processes

There are two basic types of weathering and erosion: physical and chemical.

Physical (mechanical) weathering and erosion break down materials by cracking, chipping, and abrasion. Ice, wind, water and gravity are the main causes. Since natural ice isn't found in the tropics, we'll pass it by. The other agents, however, are actively at work on the Island. Wind blows particles of rock against each other causing chipping and abrasion. Water carries bits of sand and other rock materials as it makes its way downhill to sea level. The particles rub against each other causing abrasion. And gravity is that invisible force always acting on us. When rock particles are loosened, gravity carries them downhill causing them to hit and rub other rocks on the way.

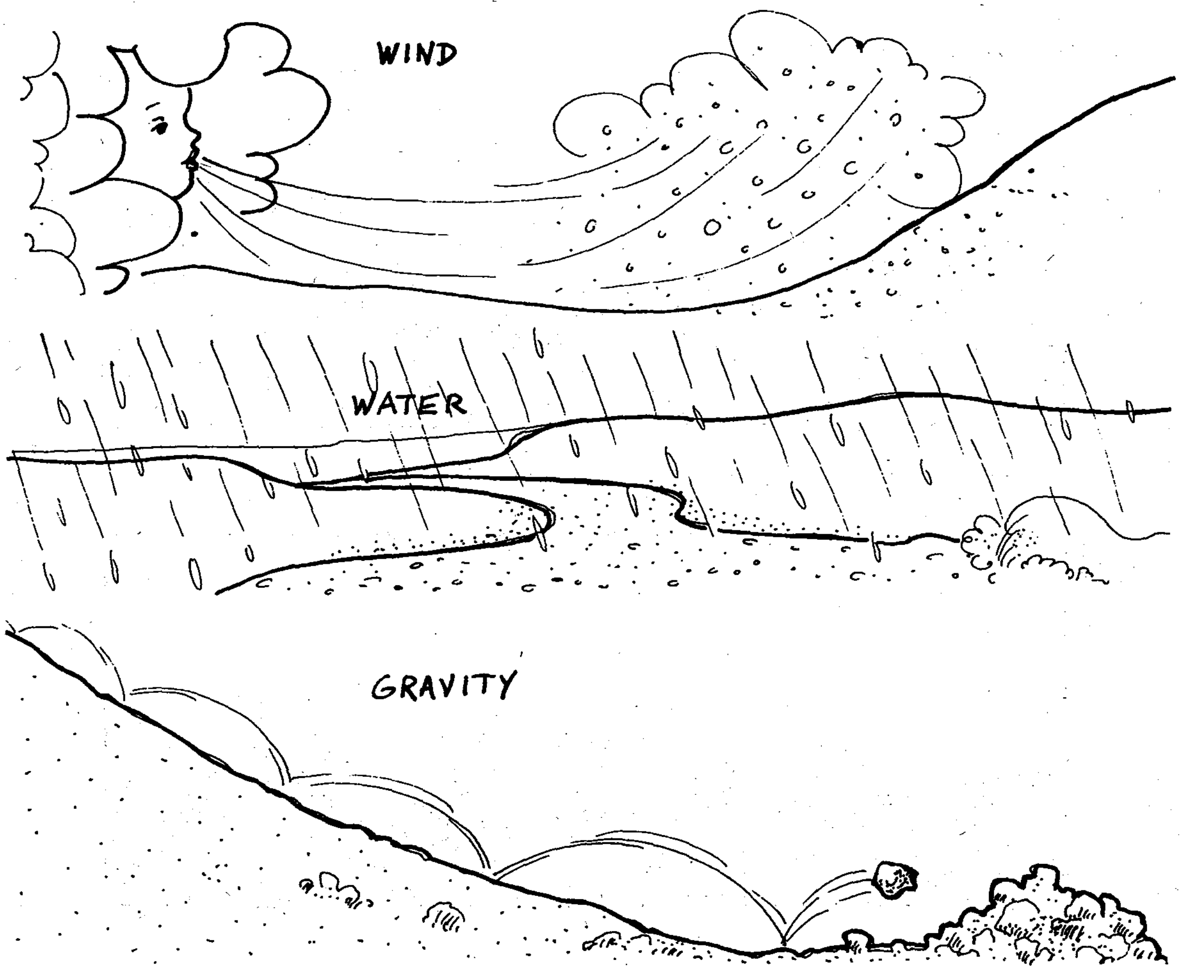
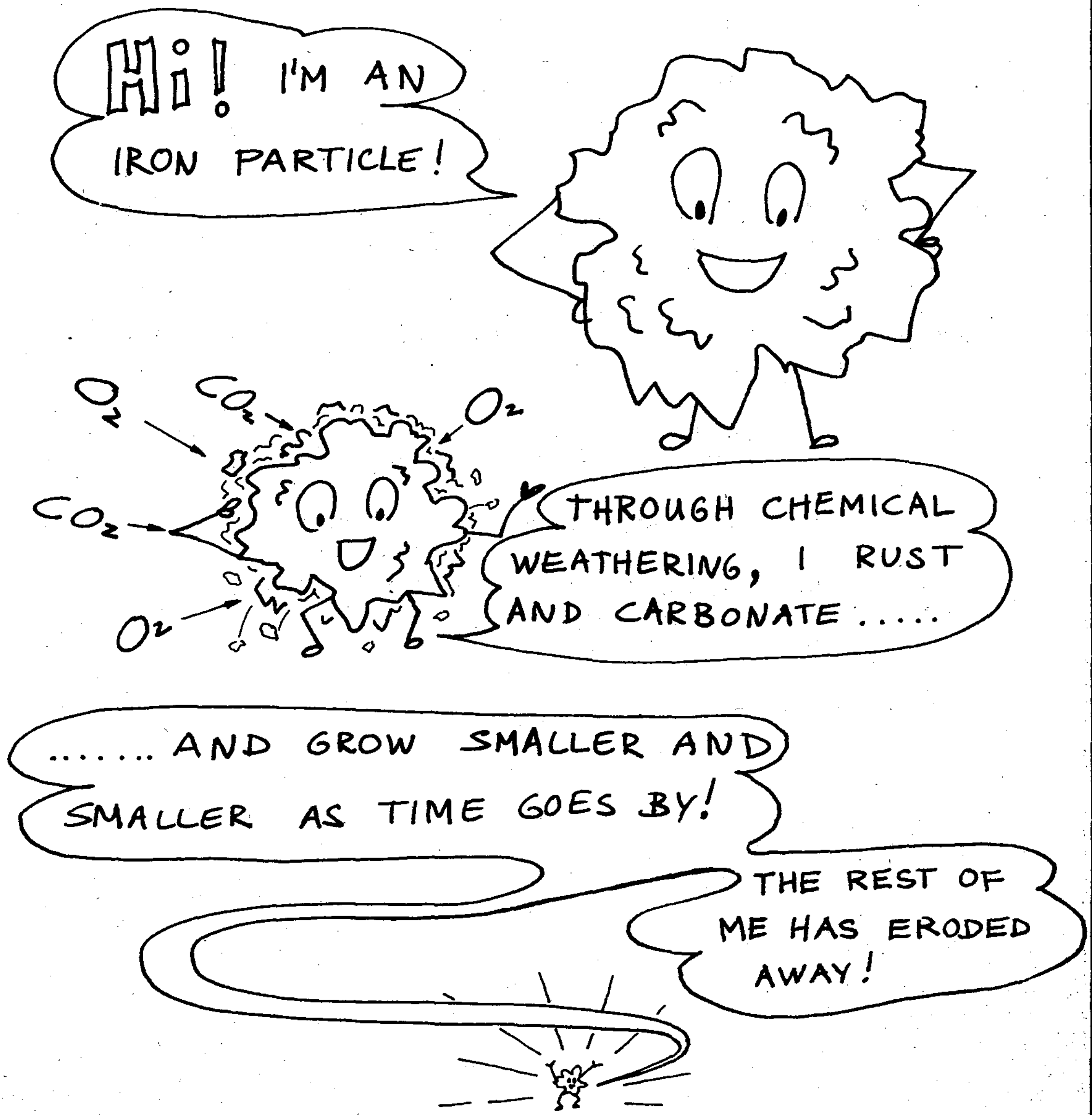


Figure 13. Three tropical erosional processes.

Chemical activity, on the other hand, breaks down materials by chemical reaction, thereby forming new substances. Rusting, tarnishing, and dissolving by weak acids are the most common types of chemical weathering. Rusting (oxidation) is very common on Guam and attacks many materials, particularly those containing iron. To show how the rusting process works, leave an iron nail outside for a week. What happens to it?

In another chemical process called carbonation, carbon dioxide (CO_2) in the atmosphere combines with water (H_2O) to form carbonic acid (H_2CO_3). This weak acid continually works at breaking down the rock materials of the Earth.



ACTIVITY 4. Weathering and Erosion Around School

Materials: Notebook and Pencil

Now that you've got an idea how weathering and erosion work, let's see what they've done around your schoolyard. In your notebook make a chart like this one.

Weathering and/or Erosion			
Material Being Affected	Process	Weathering or Erosion	Physical or Chemical
Metal railing	Rusting (oxidation)	Weathering	Chemical

Spend about an hour going around the campus observing weathering and erosional processes. Record your observations on your chart.

When you have finished, answer these questions in your notebook:

1) What were the most common weathering/erosion processes you found evidence of?

2) What are people doing to prevent this decay?

3) What else could we do to 'control' these processes?

V. Earthquakes

Seismology: The study of earthquakes

Guam is about 100 km from the seismically active Mariana Trench, where, further along, the deepest spot in the ocean is. (How deep?) Earthquakes are not yet fully understood, and it's a little hard to say why they occur more often in some places than others. This is a young and changing branch of geology. We increasingly learn that this great planet is not so settled as we sometimes think. One theory, closely related to continental drift, says the Earth is divided into 'plates' that float around on a soft layer beneath.

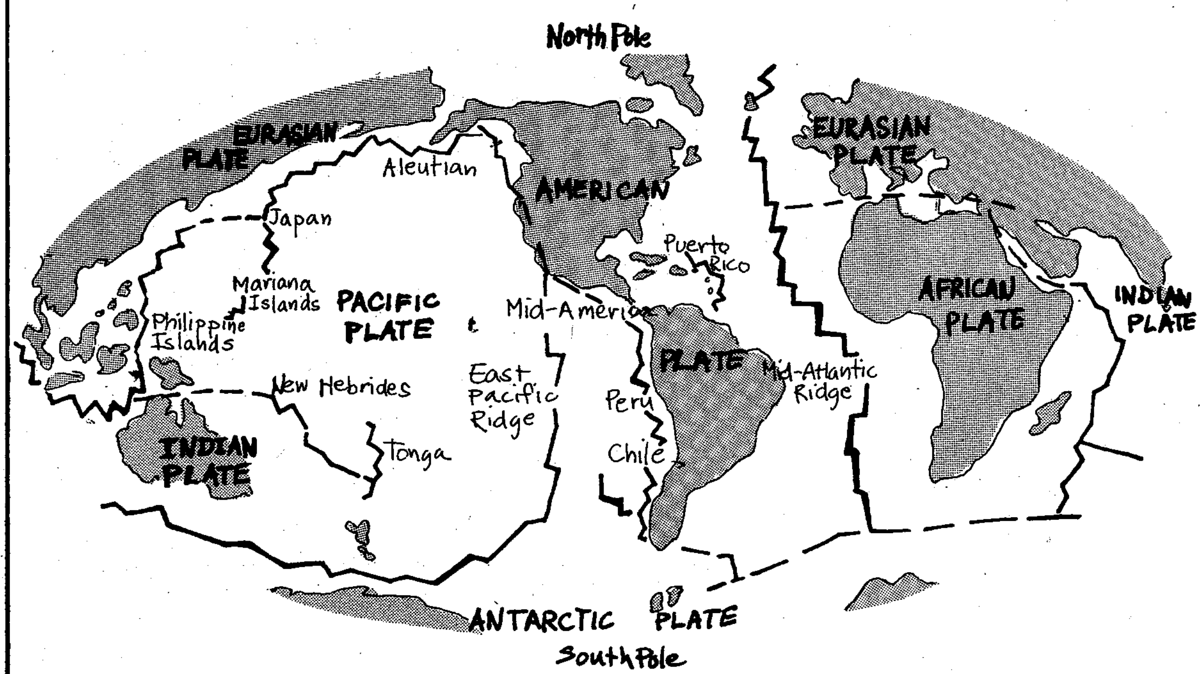


Figure 14. Plates of the Earth's crust.

This theory of plate tectonics is now accepted as the best explanation of Earth's structure. Read more about it in *National Geographic*, *Scientific American* or an up-to-date encyclopedia.

Causes of Earthquakes

According to this theory, Guam is on the edge of a small plate including the Philippine Sea. Because we're floating freely, we keep bumping into the gigantic Pacific Ocean plate, or it into us. This causes lots of stress. Eventually the rocks can't take the pressure any more and they snap, causing earthquakes.

Early Man was probably perplexed and frightened by earthquakes. Here the guy settles in a nice cozy cave with his family. He even has it furnished in Early Caveman. Everything goes okay until that earthquake destroys the home and he has to find another. He undoubtedly wishes he knew how to stop earthquakes, or at least how to predict them. Well, we're still not able to do either to any great extent, although research is going on in both areas.

China, for instance, now has 10,000 trained fulltime workers plus thousands of amateurs involved in earthquake research. China has a long history of tremors. (The worst natural disaster on Earth was the 1556 earthquake in Shensi Province. At least 820,000 people died.)

Several things have been noticed to precede earthquakes. Physical events include changes in the amount of radon gas in well waters; lowering, then rising of water levels in wells; changes in electrical resistivity; the ground tilting; land rising or sinking; and changes in speed of seismic waves.

Animals too seem to behave unusually before earthquakes——deepwater fish rise to shallow water, insects gather in huge active swarms at the shore; snakes, lizards and small mammals come out of burrows; zoo animals won't enter their shelters; cattle seek high ground; and domestic animals get agitated.

Richter Scale

So far, we've had to be satisfied with recording earthquakes and placing a 'degree of destruction value' on them. There are lots of scales used to do this. One of the best known was devised in 1935 by

American seismologist Charles F. Richter. It's based on how strong the shock waves are at the source.

The scale goes from 0 to 10. Each number on the scale represents about ten times more energy than the number below it. To give you an idea of magnitude, here are some examples. Quakes with a magnitude of 2 or below are not felt by people but are recorded on a seismograph. Quakes of 3 or 4 can be felt, but only shake the dishes a bit. Those registering 5 on the scale shake everything but don't do any physical harm. Above 6, buildings are damaged.

The Guam (seismological) Observatory records several shocks here daily, about 2 a month strong enough to be felt, and about 3 per year between 5 and 6 on the scale.

'Our' earthquake of November 1, 1975, hit 6.3 on the Richter scale. The center of this earthquake was about 30 km northwest of the Island and 110 km deep. It was our first '6 or better' shock since the 6.0 one of September 16, 1970. The San Francisco earthquake of 1906 hit 7.8. 10 is only theoretically possible; 8.9 is the highest number ever recorded.

There are several ways we can minimize the effects of quakes. Name some and list them in your notebooks. By learning from other people's mistakes, we can be ready if a large earthquake does occur.

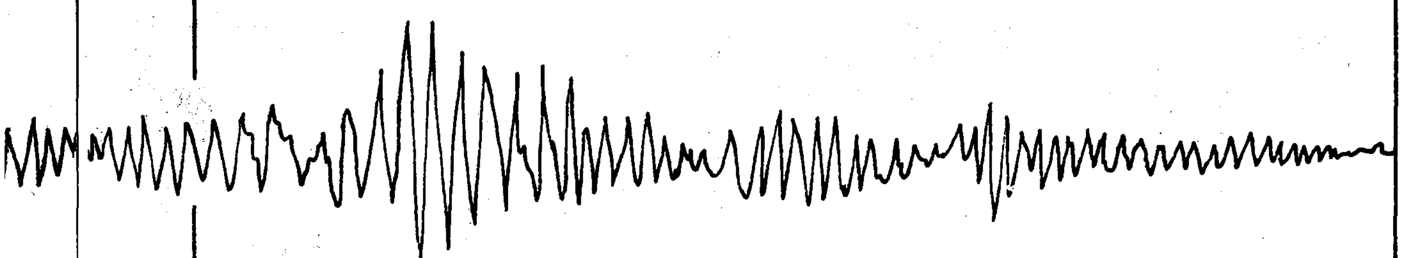


Figure 15. A seismogram ('shake-picture') of an earthquake.

You may want to set up a seismograph and record earthquakes. Seismographs are relatively easy to make. If you don't have one at your school, just look in a science project book and learn how to build one!

Earth Ti

E A R T H ' S 5 B I L L I O N Y E A R S

This planet was born in the first second of the year

A R C H E O Z O I C

Line 1 - This is the entire history of Earth, in one year.

J A N | F E B | M A R | A P R I L | M A Y | J U N E

Great volcanic activity
Primeval soup
Metal ores form (iron, copper, nickel, gold)
Life appears and
fossil fuels

ONE BILLION YEARS = 2.5 MONTHS

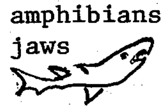
Line 2 - We zoom in on the month of December. Many familiar things happened this month.

December

CARBONIFEROUS

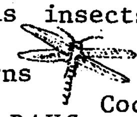
DEVONIAN | MISSISSIPPIAN 5 | PENNSYLVANIAN 10 | PERMIAN | TRIAS 15

First forests
First amphibians
First jaws



Sharks and amphibians flourish
First ferns

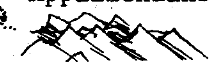
Giant insects



First reptiles
Coal-forming swamps
Cockroaches

Corals abundant

Appalachians



Dinosaur flourish

Fly

100,000,000 YEARS = 7.5 DAYS

Line 3 - A look at the last day of December. (Ever think of a horse with more than 1 toe?)

December — 31

M I O C E N E | P L I

00 | 04 | 08

Forests decline
Fakpe dikes form

Mammals domi
First one-toe

1,000,000 YEARS = 1.8 HOURS

Line 4 - A zoom in on the final minute of the year. Man's whole written history takes 30 seconds!

Final Minute of —t

(R E C E N T

10 | 20

1,000 YEARS = 6 SECONDS
100 YEARS = 0.6 SECOND

Egypt f

On this scale, the year would extend from Dededo to Ti

Since the start of the Industrial Revolution we have used

prepared by Dot Hotaling with assists from W. Kyselka and G.G. Simpson, among others.

h Time Chart

\RS ON A SCALE OF ONE YEAR

year and it is now the stroke of midnight on December 31st.

CAMBRIAN
ORDOVICIAN
SILURIAN

P R O T E R O Z O I C

NE JULY AUG SEPT OCT NOV DEC

Simple marine organisms
and First known plants
uels start forming

First shelled
invertebrates

First
fishes

Shells
common

1st air breathers
(scorpions)

r in Days

PALEOCENE EOCENE OLIGOCENE MIOCENE PLIOCENE

:IASSIC JURASSIC CRETACEOUS

15 20 25 31

inosaurs
lourish
ans

First
birds
and
mammals

Sierra Nevada

Cycads (fadang)
flourish

First
flowers

Last of the
dinosaurs

Rocky Mountains

Mount
Santa
Rosa
(Guam starts forming)

Alps and
Himalayas

Flying reptiles

– 31st in Hours

I O C E N E

P L E I S T O C E N E

NOON 16 20 24

lominant
:-toed horse

Northern Guam plateau

Man
shows up

Last ice age
Great Lakes

—the Year in Seconds

N T E P O C H)

30 40 50

pt flourishes

Marianas settled

Moses

Buddha

Ancient Greece

Christ

Muhammad

Leonardo
Columbus
Magellan

Industrial
Revolution
begins

Right now!

o Tinian.

sed up about half of Earth's fossil fuels and many other resources.

rs.

VI. Soil

How It Forms

Some call it dirt, others call it soil. Whatever it's called, it's made up of some things that might surprise you. And it's a very important part of ecology!

In this section we will check out different Guam soils, and relate them to plant growth and land use.

Using your own words, describe soil. Give as complete a description as possible, but limit your writing time to five minutes (unless otherwise instructed by your teacher).

Now divide yourselves into groups of 3 or 4. Predict what things you would expect to find in the first two inches of soil. List your predictions on a sheet of paper and report them to the class. (Expected time: 20 minutes.) The next paragraphs will give you a basic introduction to soil. See how close your predictions were.

Soil is vital to all plants, and plants are vital to all animals, including man. Plants supply us animals with food and oxygen and are the basic part of the World food web. Have you thanked a green plant today? Without soil, plants could not flourish. So let's look at it a little closer. Where does soil come from?

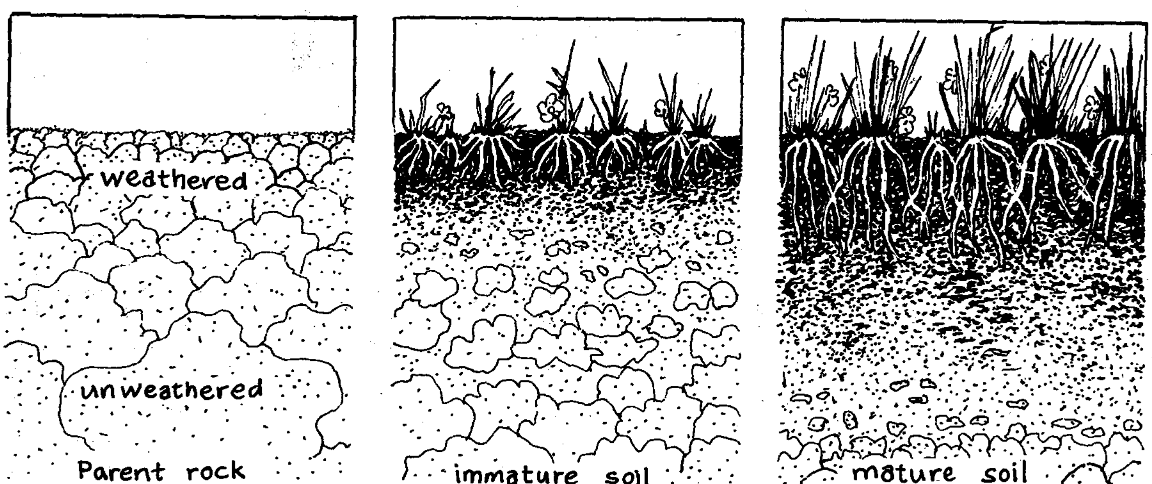


Figure 16. Stages in the formation of soil.

Origin of Soil

Those same processes of weathering and erosion which attack buildings also make molehills out of mountains. Chemical and physical weathering and erosion gradually (it takes a very long time) break down rock into the fine particles we call soil. It makes sense then that soil is made up of the same ingredients as the 'parent rock' it came from.

Soil Analysis

Loam is soil made of sand, silt, and clay. It's good for growing plants but to be ideal it should also contain humus (decaying organic matter). Organic matter provides food for plants. It also holds more water than plain mineral soil can, another benefit to plants. The more water the earth can absorb, the less chance of puddling or flooding.

The color of soil depends on what's in it. For instance, humus makes soil dark. Humus is generally less abundant the nearer you get to the Equator, so tropical soils generally are higher in minerals and lighter colored than other soils. (Local exceptions can always be found.) Red to yellowish soil indicates iron oxide. Name some areas on Guam with different color soils. What color is the earth at your home or ranch? What's in your soil?

Another important aspect of soil is its pH——acidity or alkalinity. The pH scale runs from 1 to 14. A substance with a pH of 7 is exactly neutral. Anything below 7 is acidic, above 7——alkaline (also called basic). Most plants grow best when the pH is between 5.5 and 6.9.

Here are some terms to be used next:
Litter - identifiable dead things on surface.
Duff - partially decomposed organic matter - compacted (pressed together).
Humus - almost completely decomposed non-identifiable organic matter.
Subsoil - the material immediately beneath the humus.

Let's put this information to good use by analyzing some soils on Guam.

ACTIVITY 5. Schoolyard Soil

Materials: Hand lens - for identifying small objects
Hammer - for pounding stakes
Trowel - for digging
Notebook and pencil
Meterstick (or other ruler)
Stakes
Crayon or marker to label stakes

Procedure: In the area you and your group have selected or been assigned, stake out a plot 1 m square. Label the stakes—you'll return here later. Dig up the top 8 cm or so at one spot and examine it carefully. Use the hand lens. Make a table like the one below in your notebook. Record your observations. Repeat the digging, examining, and recording at several places within the plot.

Schoolyard Soil

	Vertical Part	Feel	Odor	Plant & Animal Parts, Other observations
First Dig	Litter			
	Duff			
	Humus			
	Subsoil			
Second, etc.				

Later: Questions for discussion:

1. What did you find?
2. How do you think these things affect the soil?
3. What are reasons for odors in the soil?

ACTIVITY 6. More About Soil

Here are some more soil characteristics we can look into: Profile, color, texture, structure and pH.

Soil Profile - Soil layers are horizontal and are called horizons. They occur where the soil changes in color, appearance, and content. Generally there are 3 major horizons, A——Topsoil, B——Subsoil, and C——Parent Materials.

Increase the depth of one of your sample holes to at least 15 cm. Measure and record the depth of each major layer. Draw your group's soil profile in your notebook and alongside it a soil profile from your home or ranch. Make sure you measure the depths accurately and make a scale——for example, 1 cm = 3 cm (1 cm of your drawing equals 3 cm of the soil) so your drawing will be in proportion.

Color - Describe and record the color of each major layer.

Texture - How does the soil feel to you? Since this is sometimes rather difficult at first, your teacher may have samples of sand, silt, and clay for you to examine. You determine the texture by feel. You'll have to push and rub the moistened sample between your thumb and fingers. If your sample needs moistening, spit on it. Use the following terms as a guideline:

COMPOSITION		TEXTURE
Sand	——	Gritty
Silt	——	Smooth & slick, not sticky
Clay	——	Smooth, plastic, very sticky

Structure - How is the soil put together? Take a trowel full of soil from each layer and examine its structure carefully. Is it in columns, or blocks, or plates or grains?

pH (acidity/alkalinity) - The degree of acidity or alkalinity greatly affects how plants will grow. Lime is often added to soils that are too 'acid'. Why? Predict what you think the soil will be - acidic or basic. To measure pH of soil you need to use a specially prepared pH kit. Your teacher will show you how to use the kit and you should practice with it before analyzing your sample. Be careful not to compact it. It must be loose...also apply just enough pH reagent to saturate the soil - not drown it.

In temperate climates soil temperature varies with the seasons and is a limiting factor in the growth of crops. Discuss soil temperature and its effect here on Guam.

Chart: Some Characteristics of Guam Soils.

Parent Material	Volcanic	Mixed volcanic and limestone (In valleys streams and swamps)	Limestone
pH	Acid		Alkaline
Consistency	Thick	Heavy clay	Thin clay
Color	Red, gray, purple with streaks of blue or green	Black	Reddish
Drainage	Poor		Good

VII. Water, Water, Everywhere.. ...Everywhere?

What do you think is the Earth's most valuable resource——gold, silver, diamonds? No, it's water! Surprised, or don't you agree? How can water, which covers about 70% of the Earth's surface, be so valuable? Discuss this in your class.

Unbound water has not combined with elements or compounds, and so is usable as ordinary everyday water. Bound water has combined with something else, such as minerals: the water molecules bind together with other elements to produce a particular compound. For example, the mineral calcium sulfate is made of 1 part calcium, 1 part sulfur and 4 parts oxygen ($CaSO_4$). But this mineral 'likes' water (H_2O) and attaches not one, but two water molecules to itself. The formula is $CaSO_4 \cdot 2H_2O$, and the mineral is now called gypsum. Gypsum doesn't give away its water molecules, so in effect that water is bound to the minerals in the crust and cannot be used as water. (Even though gypsum is partly water, it's not wet!)

Thank goodness we don't have too many minerals that crave water!

Where Water Comes From.

We all know that we need water and get it from the faucet at home. Except for a few reports of polluted drinking water, we don't tend to think much about where our water comes from or where it goes. We use it for more than just drinking, however, and get it from sources other than the tap. Fruit, for instance, is an excellent storehouse of water. We all wash every day, and wash our clothes at least once a week. What if there were no water for washing dishes! What other ways do we use water? What about other animals and plants? Are their needs the same as ours? If not, how do theirs differ? Let the class as a whole make a list of the ways water is used by both plants and animals, and divide the list into two categories, 1) absolutely necessary, and 2) not so vital, like the examples on the next page. Make the list as long as you can.

Water Use	Essential	Non-essential
1. car radiator	✓	
2. water pistol		✓
3.		

Which column has more checkmarks? Did you have any trouble deciding between 'essential' and 'non-essential'? Most likely you've produced a short list of essentials, only a few of them relating to plants. Right? Since you are not a plant, it may be hard for you to know just what a plant needs. Let's experiment a little with a plant's water needs. Then maybe we'll better know just how important water is to plants. We hope you already know how important it is to us!

ACTIVITY 7. Plants' Use of Water

Materials: 3 cardboard milk containers, any size
gravel (small amount for each container)
soil
3 potted plants, as nearly identical as possible
1 nail

Total Time: approximately 2 weeks.

1) Cut the milk containers to 5 cm high.
2) With nail, punch holes in bottom for drainage.
3) Label one container #1.
4) Cover the bottom of each container with gravel.
5) Fill the rest of each container to 1 cm from top with soil.
6) Place plants in containers and water well. Put at or near a sunny window. Continue to water when it's needed.

After two-three days, begin the main experiment:

Continue to water container #1 regularly.
Do not water the others.

Observe the plants at least once a day. Keep accurate records of the dates and the observations you make. Use a chart like this one:

	Observations		
Date	Plant #1	#2	#3

When the 2nd or 3rd plant shows the first signs of wilting, label it #2. Now water it too, daily, and record how long it takes to recover.

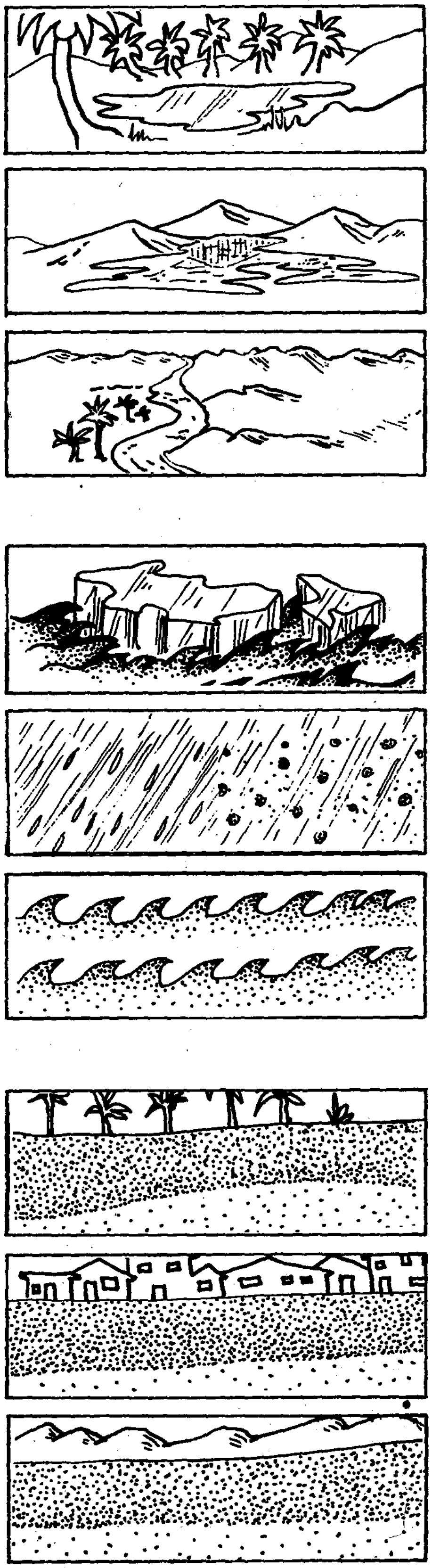
When plant #3 really sags, begin to water it. Record the day you begin watering it, and its progress. Continue your records for several more days. Discuss the findings in class.

How did plant #1 do?
What happened to plant #2?
Did plant #3 survive? If so, how long did it take to recover after you started watering it? Let's look at some other aspects of our resource, water, while the experiment is in progress.

Where does our water come from? Where does it go? How is it 'tapped' as a resource? Where is our water now? Is all of it usable? If not, how much of it (what percent) is usable?

On this 'water planet', where do we find water and in what percentages? Got any guesses? You might be surprised at the answers! The following table shows how the water in the World is distributed.

36



Location	Percentage of total water
Freshwater lakes	.009
Salt lakes and inland seas	.008
Streams and rivers	.0001
Icecaps and glaciers	2.15
Atmosphere	.001
Oceans	97.2
Soil water	.005
Ground water down to 1 km	.31
Deep-lying ground water	.31

Where the World's water is.
(After U. S. Geological Survey)

From the table opposite, answer these questions:

1. a) Which location has the highest percentage of water?
   b) How much is this percent?
2. a) Where is the second most abundant water source?
   b) How much is this percent?
3. What is the combined percentage of the two (1b and 2b)?

The next question will be a toughie: How much of the combined water source (#3) is immediately available for man's use? Talk it out until you're satisfied you've discussed all possibilities. What did you come up with?

Let's start with the largest bodies of water——the oceans, which make up 97.2% of all the unbound water in the World. It's used in transportation and we appreciate it for supporting sea life, but this water is of little <u>direct</u> use for humans, because it's too salty. You usually don't wash either your clothes or your body in it, and you certainly can't use it for drinking. (See <u>Human Impact</u>, p 72, for other possible uses of seawater.)

Icecaps and glaciers, the next largest storehouses, make up 2.15% of the total water supply. But they too are not a valuable source of water for human use. Although they are made of freshwater, they are too far away from population centers to be of immediate value to anyone but Eskimos. Towing them out of polar regions for use by more people has been considered. What is the feasibility of this?

So only 0.65% of World water is available for us to share with land plants and animals. With such a small amount of water for us organisms, how come we didn't run out of it long ago?

<u>Reservoirs——Types</u>

This brings us to another very important question: Where do we get our water from——the water that we use every day and which comes out of our faucets (except during those dry spells when some people don't have any water coming out of their faucets!)?

To find out, let's follow the path of a drop of water back through the faucet.

As you've probably already guessed, we get most of our water by 'trapping' rain that falls on the ground. Various methods of trapping exist and we use several, even on this small Pacific Island. After the water is trapped, it must be pumped up and treated before reaching your faucet.

Let's take a closer look at each of the steps in the process. Remember when we talked about porosity in rocks and soils?

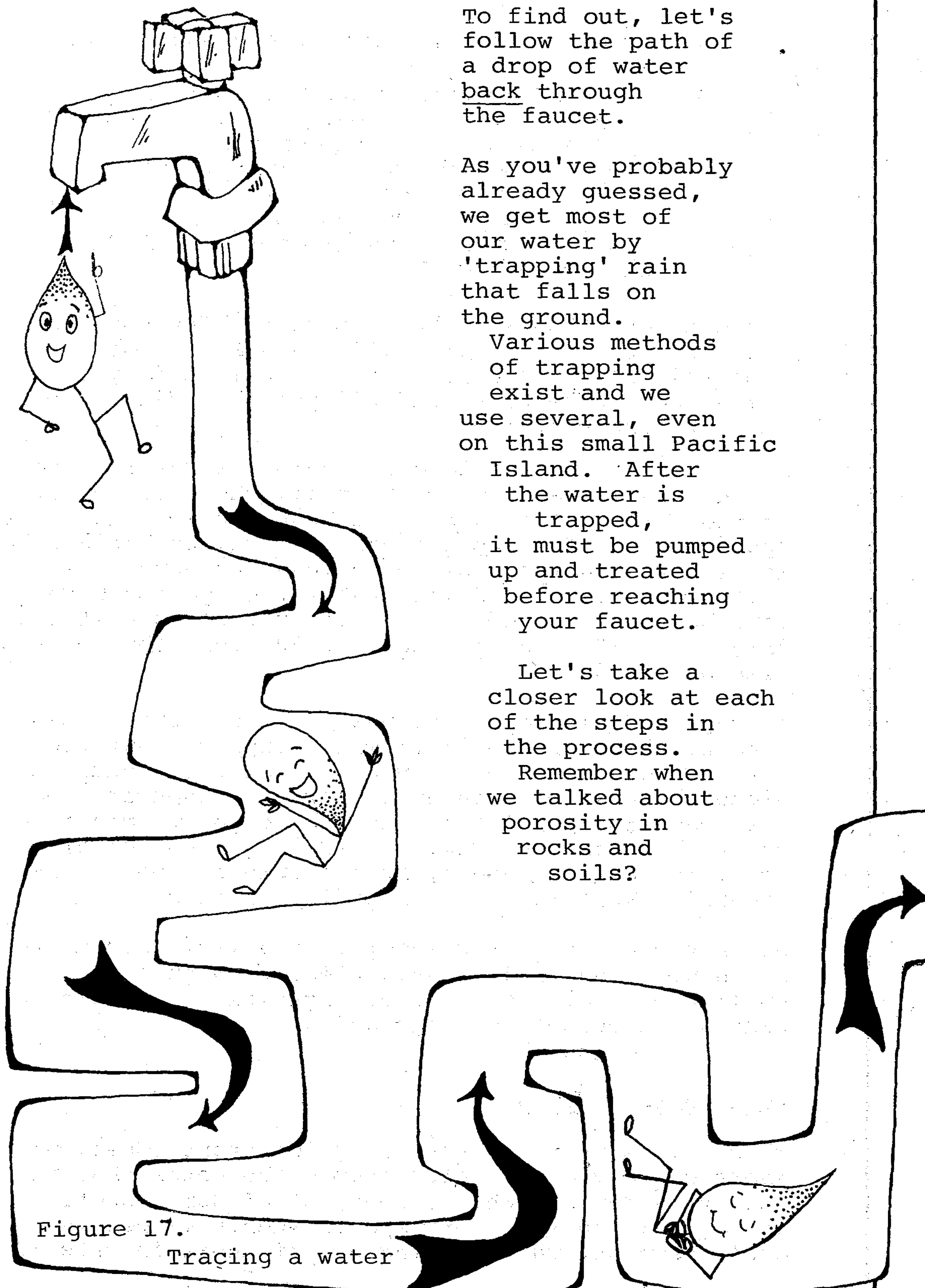
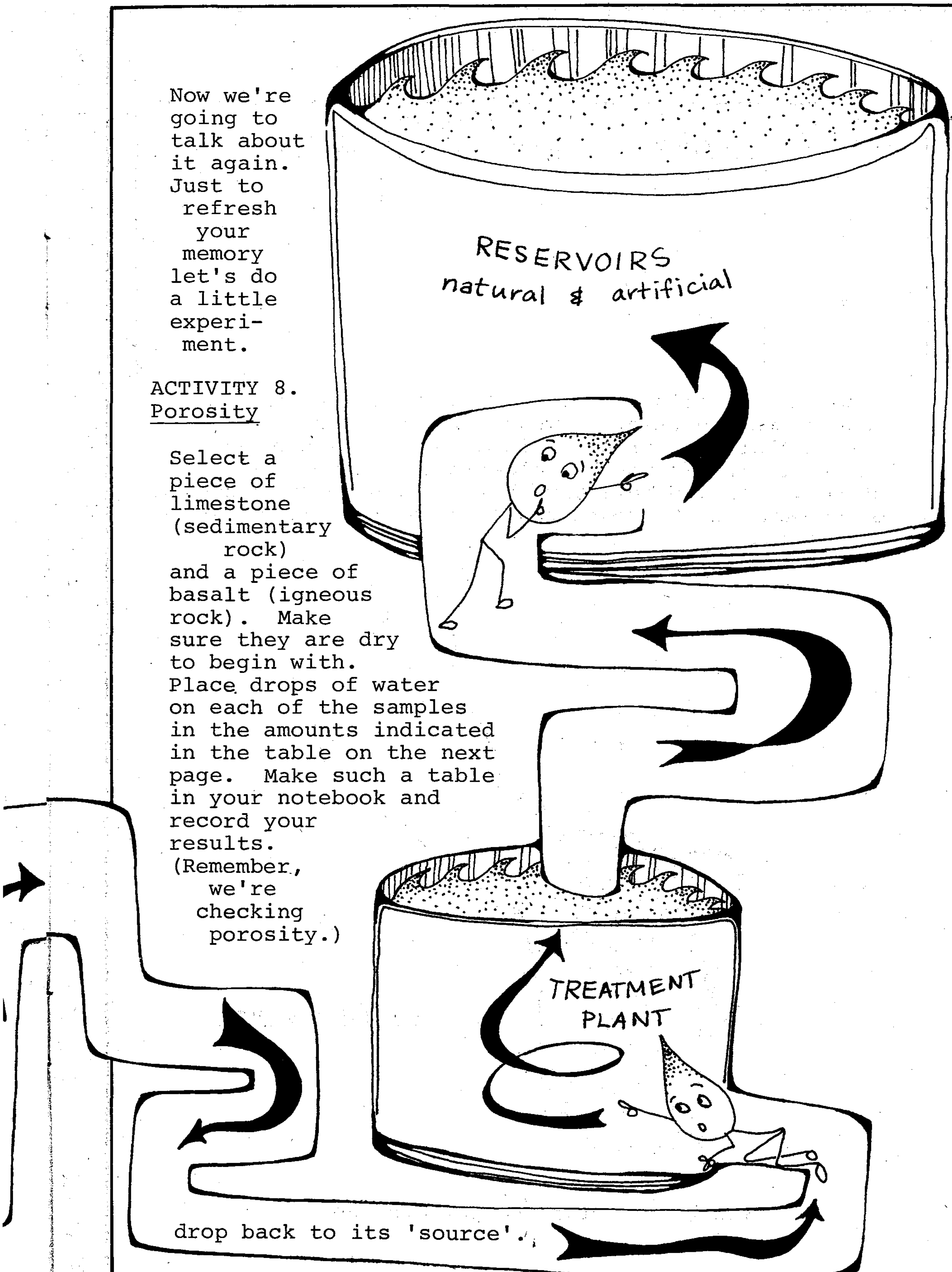


Figure 17. Tracing a water

Now we're going to talk about it again. Just to refresh your memory let's do a little experiment.

ACTIVITY 8.
<u>Porosity</u>

Select a piece of limestone (sedimentary rock) and a piece of basalt (igneous rock). Make sure they are dry to begin with. Place drops of water on each of the samples in the amounts indicated in the table on the next page. Make such a table in your notebook and record your results. (Remember, we're checking porosity.)



drop back to its 'source'.

Trial	Drops of water	Porosity Igneous	Sedimentary
1	2		
2	4		
3	6		
4	8		

From this experiment write a conclusion about what happens to the rainfall we receive on Guam. (Don't forget that the north end is mostly limestone, and the south end is mostly volcanic with some limestone). Can you tell why this has led to an abundance of streams in the south and none in the north? Look at the map:

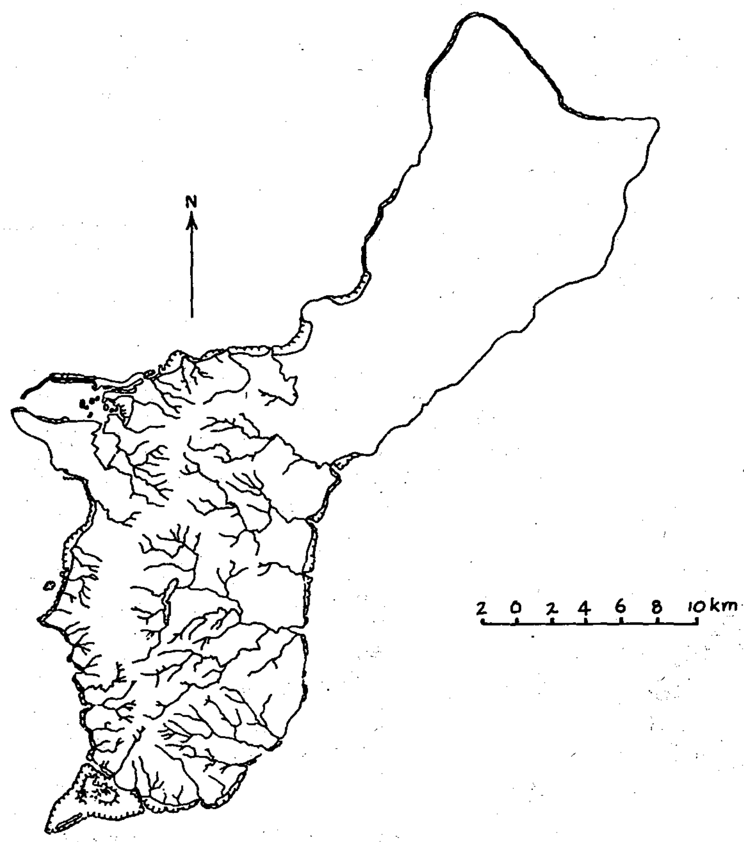


Figure 18. Drainage pattern map.

Discuss your conclusions with the class. Many different explanations may come up; through your discussions, you can modify them to arrive at some possible answers.

You may be able to visit some of the various water resource facilities on the Island. The U. S. Geological Survey office near Naval Station gate, the University Marine Lab, and the Environmental Protection Agency would be good places to contact for further information and field activities.

On Guam we have two types of reservoirs, both extremely important. Let's backtrack a little. Basically, rain falling on land either soaks into the ground and is called ground water as in northern Guam, or it stays on the surface. Some evaporates or is given off by plants in the process of transpiration. Some flows in streams. This second type of water is surface water or runoff. Because of the low porosity of the volcanic rock in southern Guam, much of the rainfall there runs off to form an extensive stream system.

We must collect this water to make it useful here. Fena Lake, the largest reservoir on the land surface, traps stream runoff and ground water which forms natural springs. These natural springs are high level water because they are above sea level. Simple enough. 'But,' you ask, 'how can there be ground water on the volcanic end of the Island?' Well, water does penetrate some into volcanic rock, but not nearly so much as it does into limestone. Look at the map on the inside front cover. Notice the limestone in the south. This limestone sits on top of volcanic rock.

Do you get the picture? Any ideas now on where this ground water comes from?

See the next illustration.

Rainwater seeps through the limestone to the less porous volcanic rock, thus forming the natural springs. Here it is in cross section, the arrows marking the flow of water:

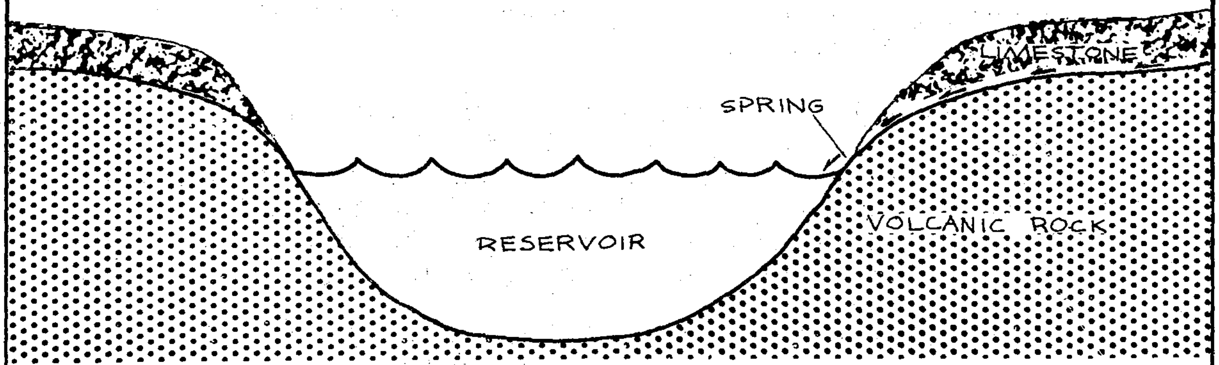


Figure 19. Surface reservoir.

That's where the southern end gets most of its water, but what about the north? Where does the water in the limestone go, and how do we get it out? The answer to the first question: Into the water supply referred to as <u>basal water</u> because it is at sea level. This freshwater reservoir or <u>aquifer</u> (= water-bearer) is a <u>water lens</u> and <u>floats</u> on the seawater also contained in the rocks. Look at the diagram:

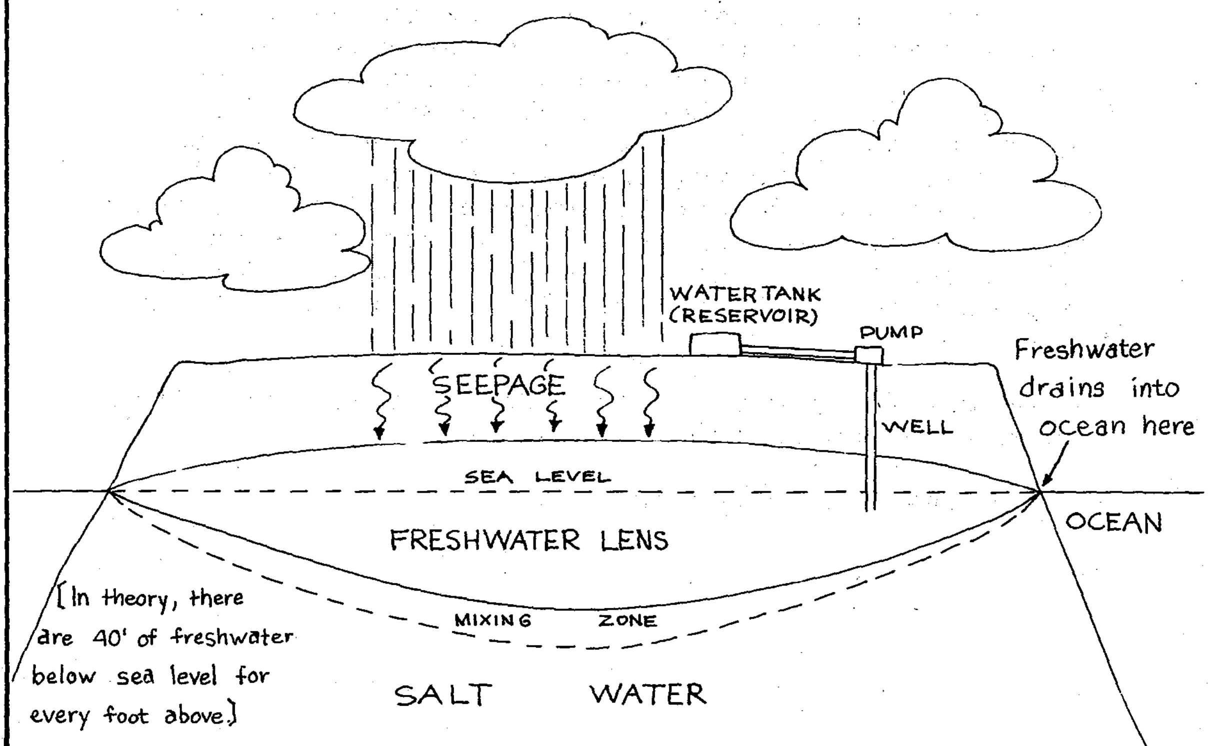


Figure 20. Cross section through lens.
(After Guam Environmental Protection Agency)

Freshwater can float on seawater because it is less dense than the salt water. The area where the two meet and mix is the transition (mixing) zone (Figure 20). Wells are drilled into the lens, and the freshwater is pumped out.

In a nutshell, that's how we get our water. All the water we use comes from these 2 sources. If we want plenty of water for now and for the future there are several things we must consider. One of the most important 'natural laws' about water supply is this:

> *The number of people that can live in an area depends on how much water is available there.*

Isn't this the reason deserts are sparsely populated? On the basis of its available water, what would Guam's population capacity be?

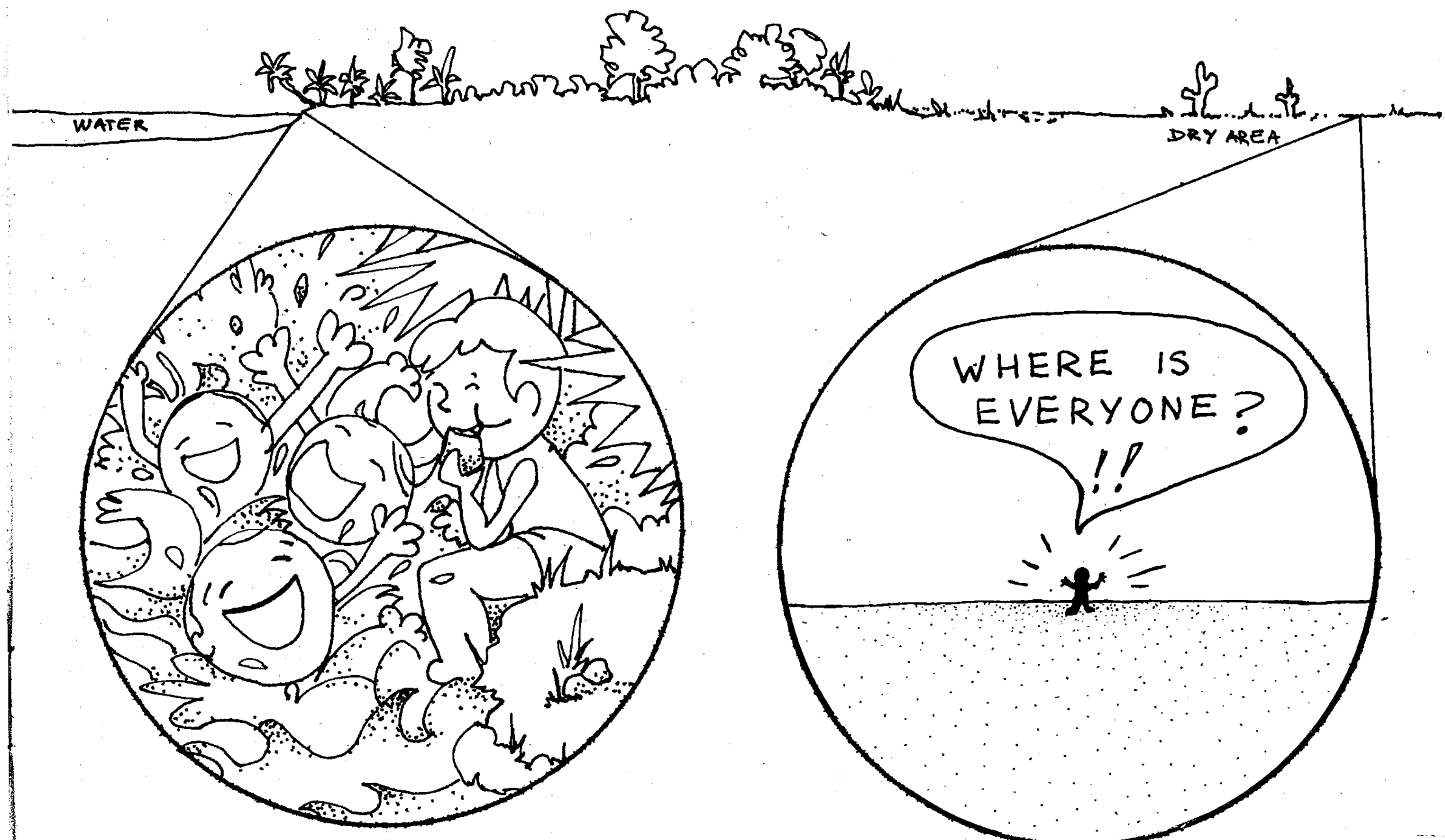
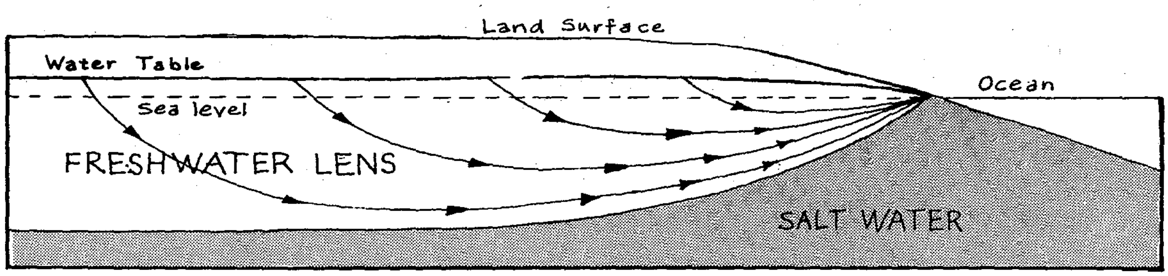


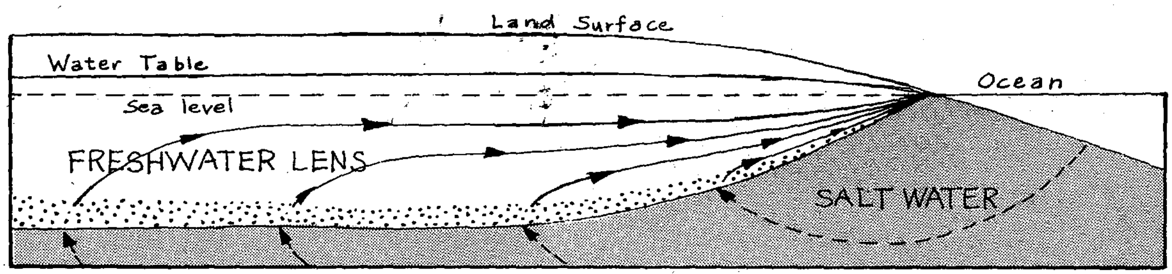
Figure 21. Where water is and isn't.

This is a question which planners are very seriously considering right now.

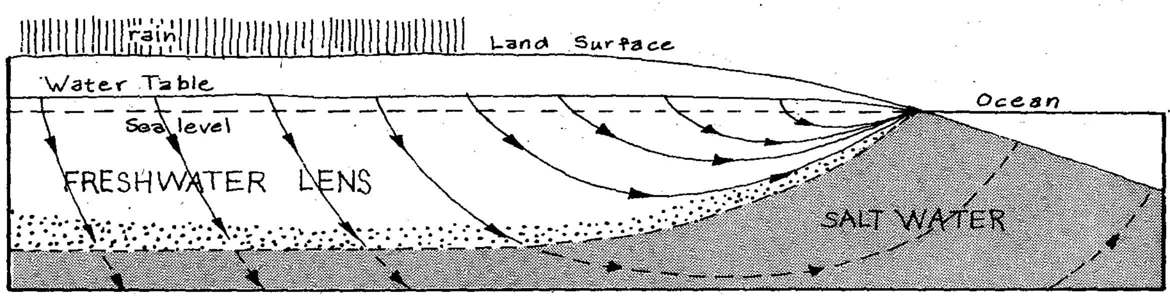
Let's look at the water problem. We now continually draw water from wells and reservoirs. What factor limits the amount of water available?——the amount of freshwater we can get back, right? Right. Let's look at the only three possibilities here:



1) Water comes into the aquifer at the same rate it is pumped out.



2) Water is pumped out faster than it comes in.



3) Water comes in faster than it is pumped out.

Figure 22. The three recharge possibilities. (After Visher and Mink)

Under continuous recharge conditions (Figure 22-1) the transition zone is very clear, with little mixing of freshwater and saltwater. In Figure 22-2 (no recharge), the transition zone moves upward as the saltwater takes the place of freshwater that's been removed. Notice that there is quite a lot of mixing of the fresh with the saltwater. In Figure 22-3 (increasing recharge) the lens gets thicker as more freshwater pushes on the saltwater, again causing mixing. Discuss our population capacity as it might relate to each of these cases.

So far we've looked at conditions which might allow seawater to be pumped into the domestic water supply. That would be a disaster, and wouldn't you be surprised to get a drink of salt water out of your faucet? It could happen!

There are other factors besides salty water which are important to hydrologists (people who study water supplies). On Guam and on the Mainland a growing concern is pollution. Uncontrolled urbanization (housing development) here would probably add the danger of pollution from improperly treated and mis-managed sewage.

We've already met some water problems, and as the population increases we're going to have to face others.

From what you know, what do you think some of the major problems are going to be? How are we going to avoid overtaxing our reservoirs? If you have answers to these questions, you just might become our next governor!

Now, getting back to where our water comes from, let's review for a minute. Some rain soaks into the the ground and becomes part of the aquifer. The rest evaporates, transpires, or flows in streams, ending up either at sea or at our high level reservoir, Fena Lake.

Water that is trapped for our use is pumped through a purification plant and eventually to our homes or other buildings.

From there, what happens to the water going down the drain? It has to go somewhere——into the ground, perhaps? That's partly right, it goes into the ground or into the ocean. So our earlier question comes back to us: 'Why don't we run out of water?'. Have you figured out the answer yet? It's pretty simple, but something we really depend on. Rainwater evaporates, or runs off into lakes, rivers, and seas, or seeps into the ground and transpires through plants, or enters the water table. Surface water vaporizes into the atmosphere where it can condense and form clouds. Clouds return the water to Earth as rain, snow or hail. This common, necessary, and all-important process is the water cycle, and here it is:

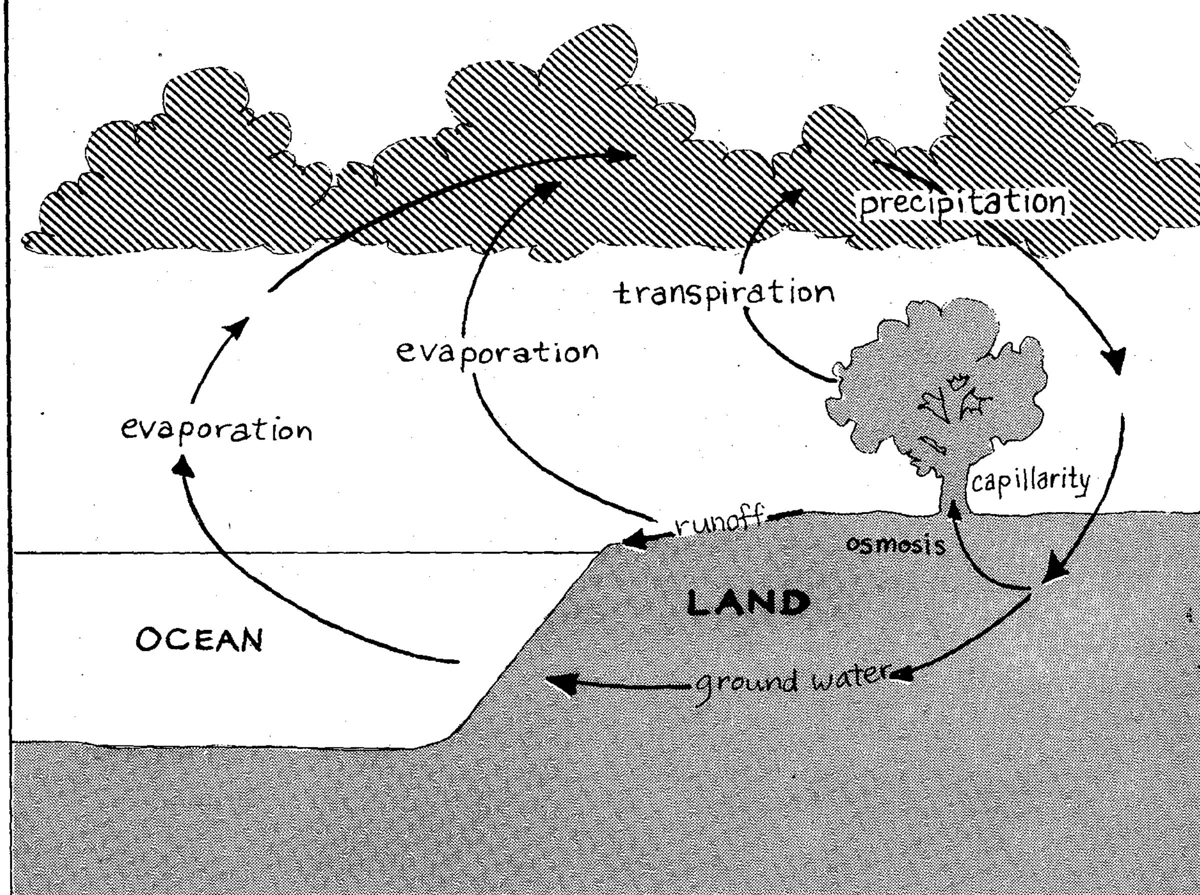


Figure 23. The water cycle.

Appendix

Going Around Guam

We're going to take a theoretical and/or actual geology fieldtrip around the south end of the Island, starting at Paseo de Susana. You should have at least some of these materials:

- Road map of Guam
- Hand lens
- Hammer
- 10-12 small plastic bags (for rock samples)
- Labels
- Notebook and pencil
- Magnetic compass
- Test tube and stopper, 2-3 per team, for silt

Observe and collect samples of rock at different stops. Use the hammer to chip off small pieces from large exposed rocks in such places as quarries, road cuts, shorelines, cliffs, etc. Place each sample in a plastic bag. Number the bag and number the location accurately on your map and/or describe it briefly in your notebook.

Distances between stops will be given in kilometers and miles. For instance, from the Paseo to the first stop it's 2.4 km, 1.5 mi; from there to the Piti sign it's 4.0 km, 2.5 mi., okay? Your odometer may not agree exactly with ours, but it'll be close enough. (You can start anywhere and go either way!)

0.0 km
0.0 mi

About 75% of the Paseo is 'fill', land that's been built up in shallow water. This was made by dumping tons of boulders, gravel, and metal objects (e.g. old cars and refrigerators) onto the reef. Rocks were placed all around the edge to check erosion by the waves.

2.4 km
1.5 mi

Parking lot on right (NAPA).

Adelup fault zone 'visible' straight south across the road; note flat terrain to left, hilly to the right. It's all limestone or it wouldn't be covered with tangantangan.

How many rivers (streams) have we crossed so far? Keep count. This is an area of volcanic rock and limestone all mixed up. The openings the road goes through are natural (Adelup, Asan).

4.0 km
2.5 mi

Sign: Entering/Leaving Piti. (Blown down in Pamela)

Turn around and look at the huge chunk of rock which has slumped away from the cliff. What kind of rock is that?

Maybe somebody can fill a test tube with silt from the bay. How do you suppose that silt collected there, smothering the reef?

1.6 km
1.0 mi

If you turn right at Piti power plant you can drive out along Glass breakwater. (It's not glass, it was named for the U. S. Navy captain who relieved the Spanish of Guam in 1898.) Inner Apra Harbor is nearly surrounded by fill.

2.4 km
1.5 mi

Volcanic rocks with scattered deposits of limestone near the warehouse.

4.0 km
2.5 mi Along here is the oldest volcanic formation on Guam.

1.1 km
0.7 mi Agat turnoff.

The little ridge across from Camp Roxas is limestone.

5.1 km
3.2 mi Agat Junior High turnoff.

At the school, climb on the rock formation at the outside corner of the fence. The dark rock is volcanic——how did those light chunks of limestone get embedded in it?

Inside the fence walk around behind the school. A lot of different kinds of volcanic rocks here have limestone fragments embedded in them.

1.0 km
0.6 mi Back onto Marine Drive.

3.4 km
2.1 mi Nimitz Beach.

Look at the offshore limestone islets:
Anae is to the west, slightly left;
Fakpe is southwest, far left.

Left is the mouth of Taleyfac River and its natural channel through the reef between you and Anae. To the right, another channel. Landward is the Alifan-Lamlam ridge with its limestone cap. (Some of the trees visible from the pavilion——monkeypod, Samanea saman; dokdok (wild breadfruit), Artocarpus mariannensis; gagu (ironwood, Casuarina equisetifolia; niyok (coconut), Cocos nucifera; kamachile, Pithecellobium dulce; and on the road side of the parking lot is seagrape, Coccoloba uvifera.

0.5 km
0.3 mi River and old Spanish bridge.

0.3 km
0.2 mi Start climbing.

That's Mt. Lamlam directly ahead. A little farther on you can see a place where water falls over the cliff when it's rainy. (It's easier to see when driving north on this stretch.)

5.1 km
3.2 mi Cetti Bay overlook.

This is a fine viewpoint for bays, Cocos Island and Lagoon, and Fakpe Point. The black hunk of rock you see to the right between you and the bay is pillow lava. We think it erupted or flowed under water and hardened there to resemble a mass of pillows.

0.3 km 0.2 mi	Cracks in the road show where mass movement has occurred. This stretch is a road builder's nightmare ——volcanic rock weathers into several kinds of clay which expand when wet and shrink when dry.
0.6 km 0.4 mi	A beautiful place to study mass slumping. Do you notice any evidence of fires?
3.2 km 2.0 mi	I Lalahita Park. Go out to the edge. Almost all that you can see is volcanic. The three mountains, left to right, are Bolanos (east), Sasalaguan (far), and Schroeder (southeast). The Umatac river, and its tributary right below you, are in a little flood plain they've made themselves. South, in the way of Cocos Island, is a mesita (little table) of soil very different from what you're standing on——it's much more acid than its surroundings. Note the chunks of pink limestone in the park wall. Where does pink limestone occur naturally on Guam?
2.4 km 1.5 mi	Umatac River.
0.5 km 0.3 mi	Overlook turnoff - Fort Soledad. Umatac Bay is fringed by narrow reef platforms. At places, slightly deeper terraces are visible. The black volcanic boulders probably rolled down from the slope below you. Go out to the point. From here you can see surge channels cutting into the reef. To the left are two black volcanic points that have been cut down nearly to sea level. Limestone has grown around some of the visible volcanic rock.
1.3 km 0.8 mi	'Cocos Overlook' - Cocos Island (p 13) is built on the outer part of a barrier reef.
0.5 km 0.3 mi	Toguan River - You'll cross about 20 streams in the next 16 kilometers.
4.5 km 2.8 mi	Geus River. Alluvium is material which is first carried downstream and then dropped as the slope flattens out and the water slows down and fans out. For 3 km east of the Geus River the road lies on alluvial terraces, except for one small limestone patch just before the river at Achang Bay.

1.6 km
1.0 mi — Achang Bay (opposite Quinene Road).

Here begins the widest fringing reef on Guam and it's another good place to see what fill looks like up close. (Note the jetties built out into the bay.) The road leaves the water for a km or so, then goes right along the shore parallel for another km with Guam's widest fringing reef. This is a 2-km stretch of road with beach strand on the sea side and alluvium on the land side.

6.8 km
4.2 mi — Guijen Rock.

2.4 km
1.5 mi — Bear Rock - limestone.

1.3 km
0.8 mi — Inarajan Pool

It's volcanic with limestone on top. Stand at the edge of the pool facing the sea. The smoothly rounded rocks on the shore to the immediate right are volcanic. Turn west (right) and walk along the water's edge 50 m to the first tiny 'bay' interrupting your way. The small dense shrub which seems to grow right out of the rock is nigas (<u>Pemphis acidula</u>). It's growing on limestone which is on top of volcanic.

1.0 km
0.6 mi — Inarajan River.

0.3 km
0.2 mi — Inarajan Junior High turnoff.

At the school you get a magnificent view of the southern savanna. It is the actual flank of the southwest volcano which collapsed long ago (pp 9-11). This is rock formed by being ejected and deposited under water. That's Mt. Sasalaguan to the west. Look across the valley north at the different colors of exposed rock. You can see the results of much weathering and erosion.

0.0 km
0.0 mi

Back to the bottom of the hill. From here to Pago Bay the road runs through limestone almost all the way. See if you can notice the exceptions——they are volcanic and alluvium.

1.1 km
0.7 mi — Pauliluc River.

3.9 km
2.4 mi — Limestone borrow pit on right——it's fossil reef.

3.2 km
2.0 mi — Talofofo Park.

Stop at the first turnoff. Solid limestone——no soil. Look at the shoreline to the right. Wave action alone does not wear away rock in that way (p 12). The overhang on the right is the result of a lot of erosion by dissolving. Walls of Talofofo Bay are limestone.

0.5 km
0.3 mi The Talofofo River is cutting away on one side and depositing on the other.

4.2 km
2.6 mi Ypan Beach.

0.6 km
0.4 mi Togcha River.

3.7 km
2.3 mi Ylig River.

4.8 km
3.0 mi Pago Bay overlook.

We conclude with a stop at Pago Bay overlook. Note the natural channel and the wide reef on both sides of it. The river mouth is to the extreme left of the bay. Across the bay the reef flat disappears about in front of the Marine Lab.

Although it may not be apparent, you're standing on one end of the Adelup fault zone. (We looked at the other end of it earlier.)

Note Barrigada Hill, a very prominent feature to the northeast. It's probably a former reef bank which stood out as an island during much of the formation of the Marianas.

Schoolyard Geology

Here's a brief look, north to south, at several sites some of you may be interested in:

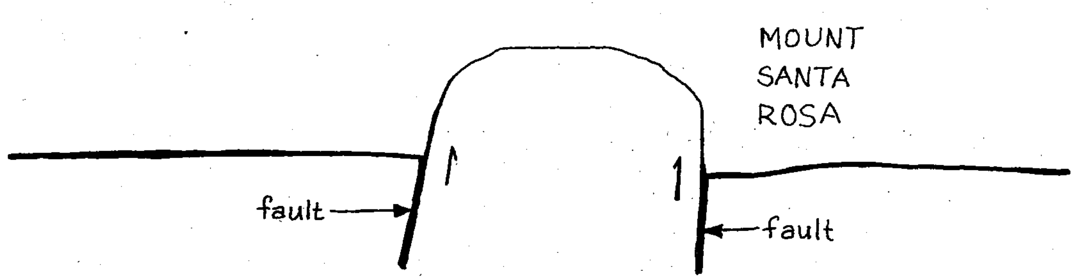
Simon Sanchez Jr. High - This school is sitting on the limestone plateau. As in most of the Guam school areas, man has bulldozed, graded, taken out trees, put in gravel, and planted grass. This disturbs the natural geology of the area.

So to get valid soil samples, go out just into the boonies.

If you look carefully, east of Marine Drive you can see one of the fault zones that run through the Island—it connects with the ones that created the cliffs along Marine Drive in East Agana and Tamuning.

Simon Sanchez is the only high school that gets a close view of Mount Santa Rosa.

Mount Santa Rosa is a horst. A horst forms when faults occur on at least two sides of a rock formation and the block in between is thrown up. The diagram below will help to explain this relationship better. Limestone has been deposited around the horst since its upheaval.



A horst

Dededo Jr. High - Mt. Barrigada is to the south. From the top of the bleachers and from the second floor you can just see Mount Santa Rosa to the east. West, across the highway (where the road has been built up) are some excellent limestone outcrops (exposed rock). Take a hand lens with you on your trip around the area. Look at the limestone to see if it has any fossils (altered remains of dead plants and animals). Notice the different colors of the soils in the area.

South, along the fence, notice how the rain has eroded the soil. By the bleachers you'll notice that the soil is red, but on top of it in places are darker grains. Pick up some and look at them with your hand lens. How do these particles differ from the red soil? Where do you think these particles came from?

Go around the rest of the schoolyard looking at rocks and soil. Discuss the differences that you see. What evidence is there that man has changed the natural geology of the area?

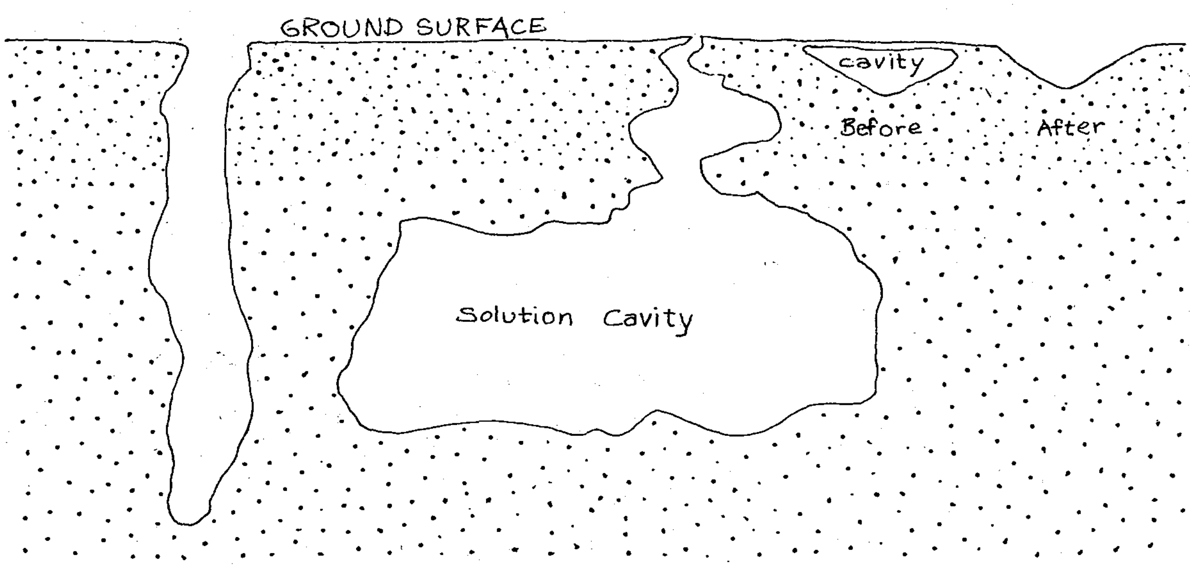
John F. Kennedy High School - Here you can see quite a bit of geology in just a small area. In many places, the soil is thin or non-existent with bare limestone showing. Across the street you should be able to see the Tamuning fault (the cliff line behind the Rehab Center). It's connected to the fault zones forming the cliffs along Marine Drive in East Agana and Tamuning.

Barrigada Jr. High - Walk behind the fence in back of the school. This area has been upset by man, but we can still see some natural things. What type of rock are the boulders? Is it the type of rock that's common in northern Guam or southern Guam?

George Washington and Vocational-Technical High Schools - Going on the limestone forest field trip is a must! As you enter the trail, look at the vegetation on the side of the hill. It is almost entirely tangantangan. And at the top of the slope, very conspicuous, is a nunu (fig tree). Do you think it's part of the natural forest? Not far from the start of the trail is a giant fossil clam, embedded in the ground. The trail winds along on jagged limestone out to the edge of the cliff.

In the front yard of GW is a large sunken area with several things in it, including plants. It was purposely filled up in Summer 1976 with debris from typhoon Pamela and other things. Can you still find it? The rock underneath is limestone. As rain water, which is slight acidic, soaks into the ground, it dissolves and erodes the limestone, faster in some places than others. This creates caves, and sinks or sinkholes like GW's, the 3 in the Andersen antenna field a mile from Price School, the narrow one at Two Lovers' Point, and some others around the Island. Try to explore them before it's too late. Erosion like this produces karst topography, named for a famous limestone plateau in Yugoslavia. It's sometimes deceiving, like icebergs——on the surface there may be a small hole, but beneath a large cave system may have developed. Can you see what problems might arise if this karst topography spreads?
Will it spread?

KARST TOPOGRAPHY



Agueda Johnston Jr. High - Compare the land the school is on with the mountains to the west. Go around the school and check out the soils. Don't pick just one or two spots, look the whole area over. Even go out in the boonies behind the school (but don't forget to come back!).

Sometime when the weather is dry, examine a patch of ground that's barren (no plants). If the ground has cracks in it, notice that they almost always come together in threes (at what average angle?). Why do you think this is? Now compare this barren area with one that has lush vegetation—is the latter ground cracked?

If you get a chance when it rains, notice the drainage pattern (the way water flows) on the hills in back of the school.

Much of the grading here is artificial. Man has filled in here and taken soil away there in order to level the school ground.

As a short field trip, go down to the Chaot quarry near the school. That area in the valley is very interesting—on both sides of the road. True, quarrying is changing the topography, but it exposes some things that are worth looking at. Compare the earth on both sides of the road. Is dark reddish soil visible on top of the light limestone? Note the contact (the place where the different colors meet). What happens to the soil after it's removed? What happens to the removed limestone?

Agat Jr. High - Along the fence in the back of the school notice how rain has started to cut valleys in the hills. It really floods during a rain. Where do the sediments carried by those newly formed streams go?

The slope of the land greatly increases in this area. What causes this place (like Santa Rita) to be hillier than some of the places where other schools are? What type of rock do you find here?

Also see the preceding section, Going Around Guam.

Inarajan Jr. High - See the preceding section, Going Around Guam.

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Suggested Equipment

Notebook and Pencil	Nails
Hand lens (magnifying glass)	Eyedropper
Dilute hydrochloric acid (HCl)	Map of Guam
Meterstick (or other ruler)	Hammer
Crayon or marker to label stakes	Trowel
Cardboard milk containers	Stakes
Samples of rocks and minerals	String
Magnetic compass	Gravel
Test tube with stopper for silt	Plastic bags
Soil test kit	3 potted plants

E P I L O G

We've looked at many facets of geology and especially how they apply to Guam. We've seen the importance of minerals, rocks, soil and water to life on this planet.

Going through this unit you could have sampled Guam by seeing, hearing, tasting, feeling, digging, smelling, snorkeling, wading, climbing, scratching, breaking——in short, really getting acquainted with the natural Island. And there's a lot more to it ——good luck!