GREAT WAVE IN HARBOR!

They are waves like no others. They can race across the Pacific from Alaska to Antarctica in less than a day. Yet you can’t see them from an airplane and you wouldn’t feel them on a boat. Strung out over the open ocean, they may be only a foot high with a hundred miles’ distance from crest to crest.

But when all that speed and power rolls up into a harbor or onto a beach, the waves grow higher and higher. And they can become monster versions of the waves you’ve watched that break on the shore and pull back. If the wave comes in first, it can crash down like a mountain of water higher than a six-story building. If the trough between the waves comes in first, it can suck a harbor dry.

They are often called “tidal waves” — but they have nothing to do with the tides. Their international name is tsunami (soo-NAH-mee), meaning tsu “harbor” and numi “great wave.” The word comes from the Japanese who have suffered much from these killer waves, as have Alaskans and other people who live along the restless shifting rim and islands of the Pacific.

What makes tsunamis? How do they act? How can we tell when they are coming? What can we do to escape them?
The Latest Greatest Tsunami

Next time you're out in a canoe, watch the wave your paddle makes as you push it through the water. The same thing happens on a huge scale when pressure is applied to seawater by a sudden shift of land on the ocean floor. This can be caused by earthquakes under or near the sea, by submarine landslides, or by volcanic eruptions.

Now imagine you are a giant, standing with your left foot in the Chugach Mountains north of Prince William Sound and your right foot on Kodiak Island. [Some giant!] And with your 500-mile-wide paddle (some paddle) you dip down into the Gulf of Alaska and push your paddle towards the southeast (see map).

In a way, that's the kind of action that sent the latest greatest train of tsunami waves on their way across the Pacific late in the afternoon of March 27, 1964.

On that terrible day, the strongest earthquake ever recorded in North America struck Southcentral Alaska. It was centered 12 to 30 miles down deep in the earth beneath College Fiord, a long narrow arm of water reaching up from Prince William Sound into the Chugach Mountains. And it measured an awesome 8.4 to 8.7 on the Richter scale.*

For six and a half minutes the ground rolled, heaved, cracked and buckled. When it was over, a land mass about the size of the State of Oregon, including thousands of square miles of ocean floor, had "tilted" like a teeter-totter.

On one side, an area including Kodiak Island, most of the Kenai Peninsula, Cook Inlet and up beyond Anchorage had dropped as much as six feet. And on the other side, most of Prince William Sound, coastal areas as far east as Yakataga and big section of the sea floor under the Gulf of Alaska rose as much as 50 feet. It was one of the most massive land shifts ever known.

Landslides caused much of the damage at Anchorage. But farther south, Homer, Seldovia and other Kenai Peninsula towns found their docks and other waterfront facilities under water at high tide. The city of Kodiak and its harbor dropped five to six feet.

But to the east, Cordova's docks and small boat harbor, together with the rich clam beds along the beaches of Prince William Sound, were left high and dry when the land rose six feet. And hibernating bears on Montague Island got a rude awakening when half the island shot up 35 to 40 feet.

In the enclosed basin of Prince William Sound near the center fo the quake, it was an instant tsunami. The waters churned and sloshed as in a madly tipping bathtub. There was no time for warning.

While the ground still shook at Valdez, the city dock vanished with an underwater landslide. A unloading freighter was tossed over the dock and back again like a toy boat. Half the village of Chenega near the entrance of Prince William Sound was wiped out by a wall of water 90 feet high within seconds after the earthquake struck. Railroad docks and much of the towns of Whittier and Seward were destroyed in a nightmare of earthslides and raging seawater.

Outside Prince William Sound, the violent upward movement of the ocean floor started a series of long low waves fanning out to the far corners of the Pacific. These were the true tsunamis.

On the open sea, the waves look like ripples only a foot or so high. But their power stretches How the land tilted after the 1964 quake. Draw your other giant foot on Kodiak Island. Then put an arrow in the Gulf of Alaska pointing southeast along the path of the tsunami.
all the way down to the ocean floor like a wall of energy. They "feel the bottom" as they race along, and their speed depends on the water depth. In the deepest ocean they can reach speeds of up to 600 miles an hour. But as they near shore they slow down to around 30 miles an hour and the height of the waves builds up.

A tsunami train is made up of dozens of waves, spaced 10 to 90 minutes apart. Wave arrivals can go on for hours. Near the origin of the quake, the first wave is usually the largest, as it was in Prince William Sound. Farther away it can be the second or any of the following waves. And if the trough between the waves arrives first, the waters fall back as if drawing a breath for the big blow to come.

That is what happened at Kodiak less than an hour after the quake. First the water oozed in like a high tide. Then suddenly it drained out completely, leaving the harbor bottom bare and boats tipped every which way in the slimy mud. Then with a crashing roar the main wave rolled in, destroying the waterfront and sweeping boats up and down the channel. The skipper of one crabber went on a wild ride back and forth on the top of the wave until his boat was finally deposited in the school yard.

Once the tsunami train gets under way, scientists can predict when it will arrive where (see page 6). But they can't say how high or how hard the waves will hit at any given point. A small wave on one beach could be a giant just a few miles away.

Why some places are struck and others are spared, scientists aren't sure. But it seems to depend on such things as the nature of the coastline, shelter from islands, the depth of nearshore waters, the height of the tide, and the shape of bays and harbors, together with the direction they face in relation to the thrust of the tsunami.

For example, the same wave that pounded Kodiak was only eight feet high when it washed ashore at Yakutat across the Gulf. Four hours after the quake, a small wave of less than a foot was measured at Attu in the Aleutians, while Crescent City in California was being battered by an 18-foot tsunami. In Hawaii, the largest wave was less than two feet high. But thousands of miles to the south in New Zealand it was nearly four feet high.

Finally, when a two-foot wave lapped the shores of Antarctica 22 hours after the Good Friday earthquake struck Alaska, the latest greatest tsunami came to a halt.

When it was over, damage was estimated at nearly $400 million—worth far more 17 years ago than it is today. Thousands had been left homeless. Hundreds of boats had been destroyed. But the fact to remember is that, of the 131 people who died, 119 were killed by the action of the great wave.

These lines show the position of the tsunami front at one-hour intervals after the 1964 earthquake. How many hours did it take to get to San Francisco? To San Cristobal, Ecuador? If an earthquake started a tsunami in Hansaksi, Japan, about how long would it take to get to Unalaska? (The figures on the lines represent the time of the day in Greenwich Mean Time, which is used as the basis for standard time throughout most of the world.)
JIGSAW PUZZLERS:
What Makes Our Quakes?

If earthquakes make most of the tsunamis, what makes most of the earthquakes? And why does Alaska have so many of them?

Well, we do have more than our share. Just since 1900, eleven Alaska earthquakes have measured 8.0 or higher on the Richter Scale and more than 60 have topped 7.0.

Many of these ‘biggies’ have occurred near the Aleutian Trench, a deep undersea valley that runs along the south side of the Aleutian volcanic arc from the Gulf of Alaska almost to Siberia. This trench is 50 to 100 miles wide and drops to a depth of 25,000 feet in places.

It has long been known that earthquakes are caused by underground volcanic forces or by rocks shifting and breaking in the earth. But what is going on below in that trench that causes so much erupting, shifting and breaking?

The answer, most scientists now believe, lies in a new theory called ‘plate tectonics.’ (The word ‘tectonics’ (tek-TAHN-iks) comes from the Greek tekton which means ‘carpenter’ or ‘builder.’)

The idea is that the crust of the earth, including the continents and the sea floor, is made up of huge rigid plates that grind along ever so slowly on the hot plastic-like layer of molten rock (mantle) that lies between the surface of the earth and the fiery core in the center. When these plates meet head-on, either one slides under the other—as appears to be happening along the Aleutian Trench, or they slide and crunch together forming a volcanic mountain system—like the range in Washington State where Mt. St. Helens is erupting. All of this leads to a lot of breaking, shaking and fireworks, as you can imagine.

OK, but what makes the plates move—if, indeed, they do? For centuries that question has been bothering scientists, map-makers, and anybody else who couldn’t help but notice how the continents of the world (especially Africa and South America) look as though they once fitted together like pieces of a jigsaw puzzle.

An imaginary map, showing the continents all bunched together as one land mass surrounded by one vast ocean, was first published in 1858 by American scientist Antonio Snider, who suggested that they may have been washed apart during the Biblical 40-day flood, starring Noah.

In 1912, the German scientist Alfred Wegener proposed the same thing on geological grounds. Over the years, evidence of physical links between continents piled up—matching veins of rocks and mineral formations, similar plants and animals separated by thousands of miles of ocean. But without some explanation of how the continents moved apart it was just like so much science fiction.

Then in the 1950s, scientists began mapping the ocean floor with new instruments, such as echo-sounders and sonar, that were developed during World War II. They found a vast undersea mountain range that wound round the world like the seam on a baseball. Running down the middle of the range was often a deep valley, floored with hot lava oozing up through the earth’s crust.

The scientists came away with a theory of “sea-floor spreading” which goes something like this: the hot lava forms new edges of the plates and pushes them along until the outer edge dips back down into deep ocean trenches (like the Aleutian Trench) and returns to its original molten state within the earth. Could that have been what caused the continents to move? How could they prove it?

Enter an even newer science with the big name, “paleomagnetism.” (Paleo (PAY-lee-oh) is the Greek word for “ancient” and magnetism refers to the lines of magnetic force running between the poles of the earth.)

Scientists had known for some time that when rocks form, the small bits of iron inside line up like natural compasses pointing toward the magnetic North Pole. Now, with a new sensitive instrument called a magnetometer, they were able to trace these tiny arrows in the earth’s bedrock.

When they compared notes on rocks of the same age on different continents, they found that these natural compasses pointed in many different directions—which didn’t make sense. But when they “closed up” the oceans and fitted the continents together, the tiny signposts in rocks of the same age all pointed to one magnetic pole in the same direction.

That seemed to cinch the theory that the continents once were joined together. But was it sea-floor spreading that moved them apart?

During their studies, the scientists had run across another surprising discovery. They found that every half-million years or so, the magnetic pull of the poles reverses, swinging from the North Pole to the South Pole and back again. Why, they don’t know. But there was that record, frozen into rocks of the same age, with the polar flip-flops clearly marked by magnetic arrows sometimes pointing north and sometimes pointing south. This knowledge gave them an important tool for testing the crust formation and movement of the sea floor.

So they towed their magnetometers back and forth across the undersea mountain ranges. And they found that there were strips on both...
Where Did Alaska Come From?

Would you believe that the Alaska Peninsula once was a tropical island in the South Pacific? That if Southeast Alaska stayed where it was 80 million years ago, Juneau might have been a suburb of San Francisco? [Talk about moving the capital!]

That may sound pretty wild. But clues from magnetic tracings, rock types and fossil remains from ancient plants and animals indicate that most of Alaska drifted here from somewhere else.

And it didn’t come in a chunk either, says Dr. David B. Stone of the University of Alaska’s Geophysical Institute. It came in pieces.

Alaska, he explains, is like a geological jigsaw puzzle. It is made up of many different land masses that seem to have been picked up from other continents. His theory is that some of those pieces once were part of an ancient continent near the equator, call “Pacifica.” This map shows how he thinks Alaska all came together:

2. 120 MILLION YEARS AGO: Riding along on a separate plate, the largest piece of Pacifica heads for what will some day be Siberia. Other fragments, that will meet later along the coast of Alaska, are caught on a plate moving northeast.

3. TODAY: The blank spaces have yet to be identified. The Aleutian Islands, says Dr. Stone, “are perhaps still arriving.”

4. 40 MILLION YEARS AGO: The southern coast of mainland Alaska starts rotating west to open up the Gulf of Alaska. (Join by pieces of southeast Alaska.)

5. 80 MILLION YEARS AGO: The Alaska Peninsula, south Kuskawin, southern Alaska coastal area and “Wrangellia” (now the Wrangell Mountains) get together for the first time. Pieces of southeast Alaska and northwest British Columbia start moving up the California coast.

Sides of the ridges, marking these magnetic reversals at exactly the same time and in exactly the same order. In other words, if a magnetic strip pointing south was found 500 miles away from one side of the ridge, the same thing was found 500 miles away from the other side. It was as though the whole history of sea-floor spreading was being recorded on giant rolls of magnetic tape.

So today, by dating the rocks and lining up those natural compasses, scientists believe they can tell where continents and other land masses were at any given time in their stately movements across the molten sea over the past millions of years.

And that’s not all. By studying the slow spreading and colliding and shifting and breaking going on in the earth right now, they believe they can tell what the world will look like millions of years in the future.

Plate Tectonics is still a brand new science—so new that what is “proved” today may be “disproved” tomorrow. But it is fun to think about.

Where was the site of your town or village 120 million years ago? Were you wearing a parka or a bathing suit?
Alaska’s Tsunami Warning Center

When the 1964 earthquake struck, the only tsunami tracking center was in Hawaii—too far away to keep pace with the fast-moving waves, too far away to warn Alaska’s coastal residents. Obviously, what Alaska needed was a warning system of its own.

Such a system was completed in 1967 with the opening of the Palmer Seismological (earthquake) Observatory, which serves as the nerve center for a network of quake and tidal detectors scattered throughout the state [see map].

The center is located 40 miles north of Anchorage in the middle of the rich farmlands and fields of the Matanuska Valley. That seemed like a strange place for anything to do with tsunamis, and when Tidelines visited there recently, the center itself looked more like a farmhouse than an observatory. From the outside, that is. Inside, it was a different story.

The walls were banked with highly sensitive instruments constantly keeping track of the pulse of earth and tides. Telephone and teletype machines stood at the ready, to spread the word if an earthquake struck. Everything in the building is run on batteries so that even if the power goes out, the system goes on.

“Our job isn’t just to record and locate earthquakes and tsunamis—it’s to get the message out as quickly as possible,” explained John Sindorf, who heads the six-member crew which keeps a 24-hour standby watch at the center.

“That’s one of the reasons why we’re located here in the valley. We’re far enough away from the water so we won’t get knocked out, and we’re close to all communication links.”

Earth movements are traced on paper photo film and magnetic tape. They were steady that day, except for occasional squiggles from heavy trucks rolling by the seismic station near Farmers’ Loop Road in Fairbanks and the ground shaking under a bad storm at Sand Point.

But when a big earthquake strikes, it is anything but quiet. An automatic alarm shrieks an alert to the staff. Data from the seismographs are fed into the center’s computer which can pinpoint the location, size and depth of the quake in less than a minute.

If the quake is centered in the Aleutian Islands or near coastal areas, and measures 6.8 or more on the Richter Scale, it is considered a tsunami threat. The information is passed on immediately to communities in the area and to the military, the Alaska Division of Emergency Services and other agencies who relay it.

“One of our guys is on the telephone and another is on the teletype—and within six minutes the word can be all over the Pacific Ocean,” Mr. Sindorf said.

A tsunami warning is issued for all coastal communities within 200 miles of a quake measuring 6.8-7.7, or within 500 miles if it measures 7.8 or more. A tsunami watch is issued for the rest of the
Alaska coastline to let people know there is a possibility of a tsunami.

Then the staff turns its attention to the tidal gauge recorders nearest the quake. If the tsunami shows up on these charts, the warning may be extended to the rest of Alaska and even throughout the Pacific. At that point, estimates also are made as to when the tsunami will reach various points along the coast.*

*The speed of a tsunami can be determined by the square root of the water depth over which it travels. The "square root" is the product of a number multiplied by itself. For example, 9 is the "square" of 3 and 3 is the "square root" of 9.

Like other U.S. warning systems in the Pacific, the Palmer Observatory is operated by the National Oceanic and Atmospheric Administration's National Weather Service. Mr. Sindorf has worked at the center since the day it opened. And despite the 24-hour-a-day responsibility, there have only been three changes in the original staff of six.

"At first we had sleeping bunks and a kitchen at the center so somebody could be here round the clock," he said. "But then we decided it was better for morale to get home at night.

"We all live close by. And we have that earthquake alarm wired so that when it goes off at night, it rings the phones and activates the radios at home. We can all get here in four or five minutes. And believe me, when we get here we're awake."

So while the Matanuska Valley is beautiful country to jog through, when John Sindorf goes out for an early morning run he carries a radio in his hand—and he just jogs around the house.

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Do's and Don't's in Tsunami Country

If you live along the Arctic coast or the mainland shores of the Bering Sea, you don't have to worry about tsunamis. Earthquakes are rare in those areas, and a tsunami rolling in from the south would break up very quickly in the shallow waters of the Bering Sea.

But if you live anywhere else along the coastline of the North Pacific Ocean and the Gulf of Alaska or in the Aleutian Islands, you should know what to do in case of a tsunami emergency. Here are some of the safety rules:

1. When you feel a strong earthquake in your area, there may not be time for any further warning. Get away from the shore and take to high ground of once. That means at least 50 to 100 feet above sea level or, in flat country, at least a half a mile inland.

2. A sudden strange rising or falling of coastal waters also is a warning that a tsunami may be on its way. Again, take to high ground or get out of the area as quickly as possible.

3. Before the arrival of some tsunamis (but not all), a harbor may drain completely dry, leaving fish flopping around and old wrecks exposed. If this happens, don't be tempted to run out and look. The killer waves are coming along right behind.

4. When you hear a large earthquake has taken place along the coast of Alaska or anywhere in the Pacific, stay tuned to your radio or television station and stand by for a tsunami emergency.

5. The Alaska Tsunami Warning Center will issue a tsunami warning if the size and location of the earthquake might start a tsunami. Don't ignore the warning. If no wave is observed, the warning will be cancelled.

6. If a tsunami is formed you will be told, whenever possible, about what time it will arrive in your area. Get away from the coast well in advance. If you have a small battery radio, take it with you. Never go down to the beach to watch for the wave. By the time you see it, you are too close to escape.

7. Boats are able to ride out tsunamis over deep open water. If there is time, you may want to move your boat out of the harbor. Here are a few tips:
   a. Don't try to move your boat unless you have one to two hours before the first wave is due to arrive. (The waves could come earlier or later.)
   b. Put as much distance as you can—at least one mile—between your boat and the nearest point of land. (It's a good idea to know your shoreline and water depths ahead of time.)
   c. Be prepared to stay out there for awhile because wave and sea conditions will remain dangerous for several hours.

8. Remember that a tsunami is not a single wave, but a series of waves. If the earthquake is close by, the biggest wave will probably come first. If the quake is farther away, the biggest wave could be the third, fifth, or whatever. A small wave on one beach can be a giant wave just a few miles away.

9. Stay out of the danger area until the "All Clear" signal is given by someone in a position to know (by radio or local authorities). During a tsunami emergency, police and other emergency personnel will be trying to save your life. Give them your fullest cooperation.
Dear Spout,

In your issue about funny-looking fish, you didn’t mention the kind I seem to catch the most—Irish Lords. All they do is steal my bait, and I’d like to get back at them.

Frustrated Fisherman

Don’t Make Waves

Starred (*) words are based on information in this issue.

ACROSS

1. The Japanese word “tsunami” means “great ___ in harbor.”
5. They travel fastest over ___ water.
9. Alaska Tsunami Warning Center (init.).
10. Opposite of “unreal.”
11. Right Turn (appr.).
12. The theory of ___-floor spreading only developed within the past 20 years.
14. The continents of Africa and ___ (init.) look like they could fit together like pieces of a jigsaw puzzle.
15. Good for squirrels and people.
17. During the great Alaska earthquake, a large area under the northern Gulf of Alaska rose as much as ___ feet.
21. International Waters (init.).
22. The 1964 earthquake was the largest ever recorded in ___ (init.).
24. Most tsunamis are caused by sudden land shifts near or beneath the ___.
25. No one is quite sure why some stretches of coastline are ___ by giant waves and others nearby are spared.
28. Post Office (abbr.).
32. Many scientists believe that (12 across) is pushing the leading ___ of the Pacific Plate into the Aleutian Trench.
34. The (21 across) is often called the ___ Friday earthquake.
36. When you feel a large earthquake, don’t stay ___ the water.
37. Not any.

DOWN

1. A tsunami ___ is issued when a quake near the ocean measures 6.8 or more on the Richter Scale.
2. The 1964 tsunami was only a foot high when it reached ___ at the tip of the Aleutian Islands.
3. Letters of the alphabet between U and X.
4. Eastern Chukchi Sea (init.).
5. If the trough between tsunami waves comes in first, it can be a harbinger dry.
6. Equal Employment (abbr.).
7. Clues in rocks and fossils indicate that long ago south ___ Alaska was located off the coast of California.
8. Don’t run out to around with flopping fish if (5 down) happens.
10. East Forelands (init.).
13. To make a knot.
15. Expression of scorn, like Bah!
20. The speed of a tsunami depends on the depth of the ___ over which it is traveling.
22. Most boats can ride out tsunamis safely if they are in deep ___ (20 down) at least a mile from land.
23. A set of symbols or signals for passing along information, as in Morse or secret ___.
24. Not “yes,” but ___.
26. When rocks are formed, bits of ___ inside line up like tiny compasses.
27. Tsunamis often are called “tidal waves,” but they have nothing to do with the ___.

18. Pacific Great Northern (init.).
33. Georgia (abbr.).
35. 0 twice.

(Answers in April issue)

February X-Word Answers

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