WAVES

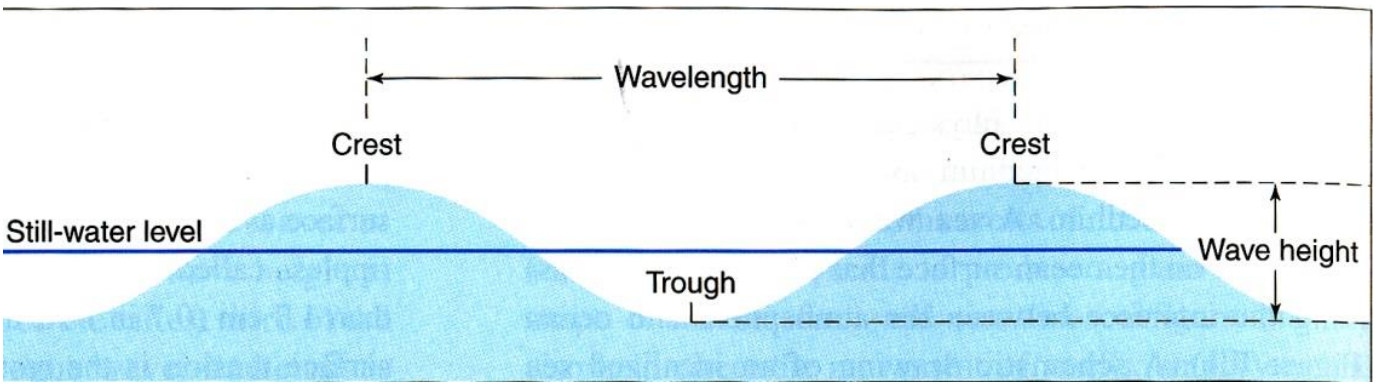
We will discuss 5 different kinds of waves:
1. Wind driven
2. Rogue
3. Tsunami
4.Tidal
5. Underwater or undersea

Waves are important to people since the have an impact on life in the ocean, travel on the ocean and land near the ocean. So we need to look at some of the different types of waves and how they have an impact on things.

WIND DRIVEN WAVES

While there are many kinds of motions in the ocean, probably the most obvious are the waves. We need a way to discuss waves, so first we need to see how they are measured

Waves are measured in specific ways



There are many kinds of waves as well. Most of the waves are called “wind driven waves”. These waves are caused by two fluids of different densities moving across one another. In this case one is air the other is water.
(You can notice this on a small scale if you blow across a cup of water, or coffee. When you try to cool the liquid and blow across the surface you will notice small “ripples” forming. It is the same principle.)
As the wind blows across the water, it sets small “capillary” waves in motion. These are often called “ripples”. (The surface tension of the water, works to end them) These ripples give greater surface area for the wind to blow against and the waves become larger. (These are called “gravity waves” because the force of gravity works to pull them back down to a level ocean.)

The area where wind driven waves are created are called “seas”. When waves continue to move outside the area in which they are generated they are called “swells”. Since they move out of the area where the wind produced them it is possible for them to move faster than the wind!

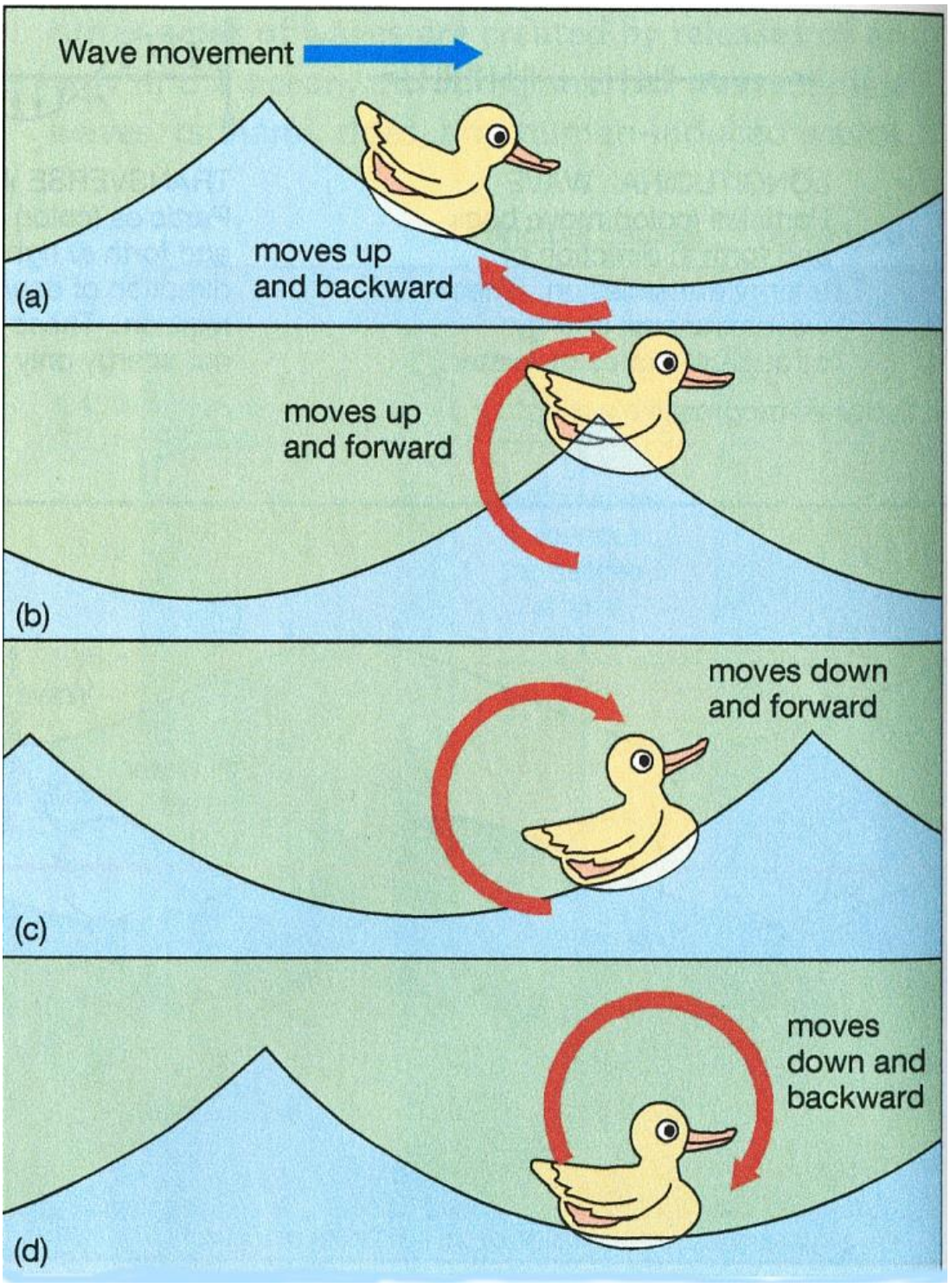
Ocean waves during storms can become very high and very dangerous. Even large ships can be in danger.

VIDEO of 100 ft high wave

https://www.youtube.com/watch?v=t8xNfMBoMMM

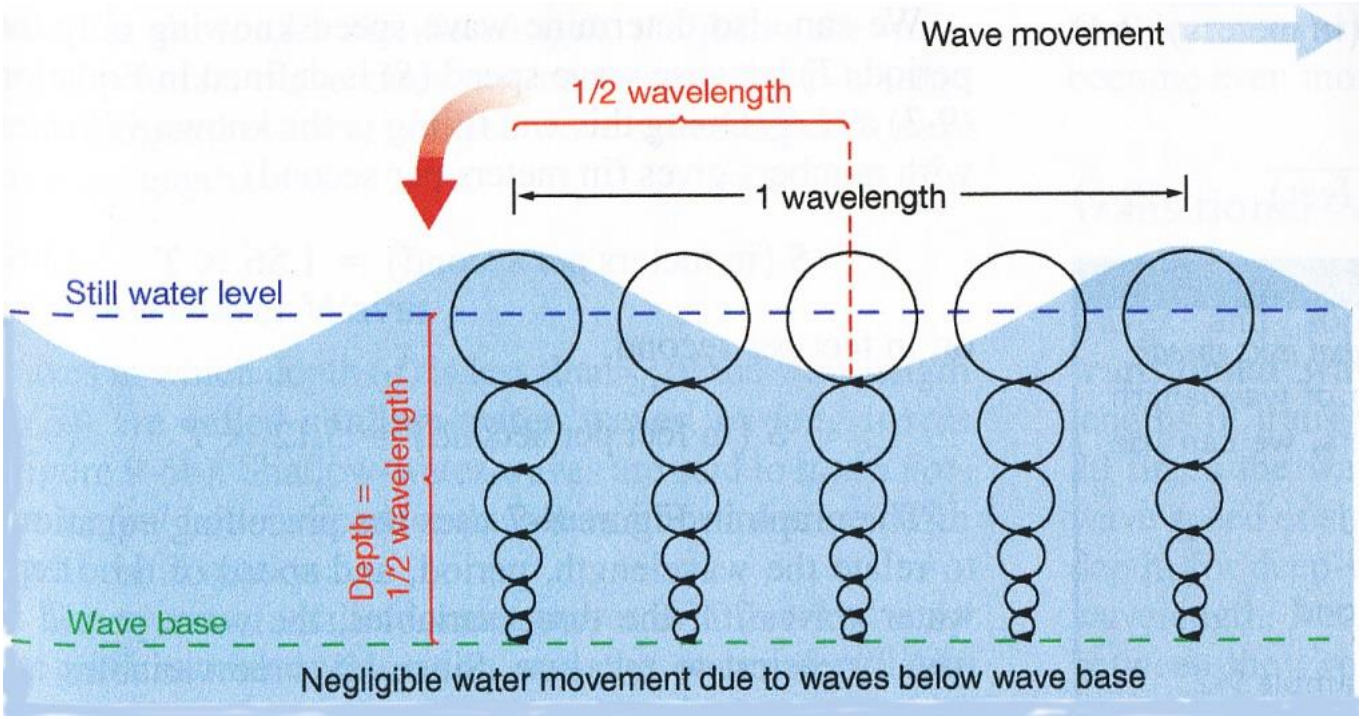
When the wind blows, it transmits energy to the water and the energy moves through the water. This energy is what causes the wave. The water in the wave does not move forward any more than wheat does when wind blows across it and causes the wheat to bend. The energy moves across the field, the wheat doesn't. Similarly, the energy moves across the ocean and in the ocean and the water rises and falls as the energy passes by.

This can be seen by the movement of an object in the water when a wave comes by:



SEE VIDEO IN POWER POINT

https://www.youtube.com/watch?v=7yPTa8qi5X8



2 WAVE PHASE VIDEOS

As the top level starts to rotate, it presses against a lower level which also starts to rotate and so on down into the depths. At a certain level, the is negligible rotation and this is the wave “base” There are three factors that have an impact on the wave. One is how long the wind is blowing, the second is how hard the wind is blowing and the third is over what distance the wind is blowing. The distance over which the winds blows without interruption is called the “fetch’

.

Wind speed is measured in a scale called the Beaufort scale.

BEAUFORT WIND SCALE WITH CORRESPONDING SEA STATE CODES					
Beaufort Number	Wind Velocity (Knots)	Wind Description	Sea State Description	Sea State	
				Term and Height of Waves (Feet)	Condition Number
0	Less than1	Calm	Sea surface smooth and mirror-like	Calm, glassy 0	0
1	1-3	Light Air	Scaly ripples, no foam crests		
2	4-6	Light Breeze	Small wavelets, crests glassy, no breaking	Calm, rippled 0 – 0.3	1
3	7-10	Gentle Breeze	Large wavelets, crests begin to break, scattered whitecaps	Smooth, wavelets 0.3-1	2
4	11-16	Moderate Breeze	Small waves, becoming longer, numerous whitecaps	Slight 1-4	3
5	17-21	Fresh Breeze	Moderate waves, taking longer form, many whitecaps, some spray	Moderate 4-8	4
6	22-27	Strong Breeze	Larger waves, whitecaps common, more spray	Rough 8-13	5
7	28-33	Near Gale	Sea heaps up, white foam streaks off breakers	Very rough 13-20	6
8	34-40	Gale	Moderately high, waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks		
9	41-47	Strong Gale	High waves, sea begins to roll, dense streaks of foam, spray may reduce visibility		
10	48-55	Storm	Very high waves, with overhanging crests, sea white with densely blown foam, heavy rolling, lowered visibility	High 20-30	7
11	56-63	Violent Storm	Exceptionally high waves, foam patches cover sea, visibility more reduced	Very high 30-45	8
12	64 and over	Hurricane	Air filled with foam, sea completely white with driving spray, visibility greatly reduced	Phenomenal 45 and over	9

Figure 8-1. Beaufort wind scale.

When a wave approaches the shore, it ‘breaks”.

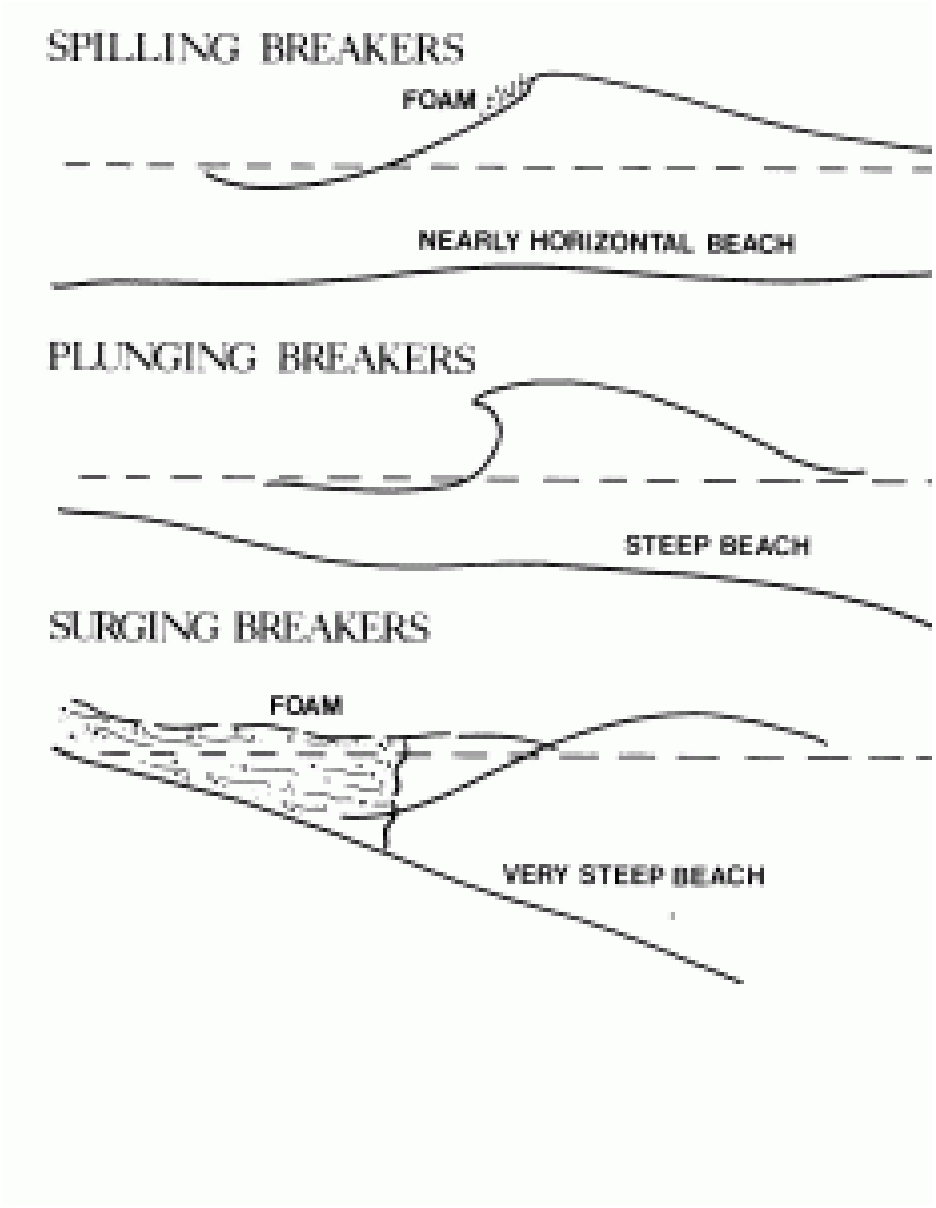
When the water depth decreases to one half of a wave’s wavelength, the wave starts to “feel the bottom”. That means that the deepest water molecules set into circular motion by the wave’s energy run into the seafloor. This forces the wave to grow upwards, so wave height increases. The base of the wave is slowed down by friction against the sea bottom, while the top of the wave rushes ahead, so the wave crest begins to

lean more and more forward until it topples over, and breaks on the shore.

Waves begin to break when the ratio of wave height/wavelength exceeds 1/7. Example: when a 14-foot wave length reaches a height of two feet, the wave breaks.

WHY IS THIS IMPORTANT?

The way the wave breaks is both caused by the shoreline and has an effect on the shore line. The way the waves break are classified as spilling, plunging or surging and are the result of different kinds of sea bottoms. The different kinds of breakers are significant because of the way they impact the coast. Generally there are 3 basic kinds of beakers (although they can be subdivided) (Notice here the definition of the kind of breaker is based on specific criteria –technical definitions. The definition is made for specific reasons)
If a beach is nearly horizontal (little slope) it will produce “spilling breakers”. If the beach is steep, it will cause the breaker sot be of the “plunging” type. Extremely steep beaches will produce “surging” breakers.


SPILLING BREAKERS
FOAM
NEARLY HORIZONTAL BEACH
PLUNGING BREAKERS
STEEP BEACH
SURGING BREAKERS
FOAM
VERY STEEP BEACH

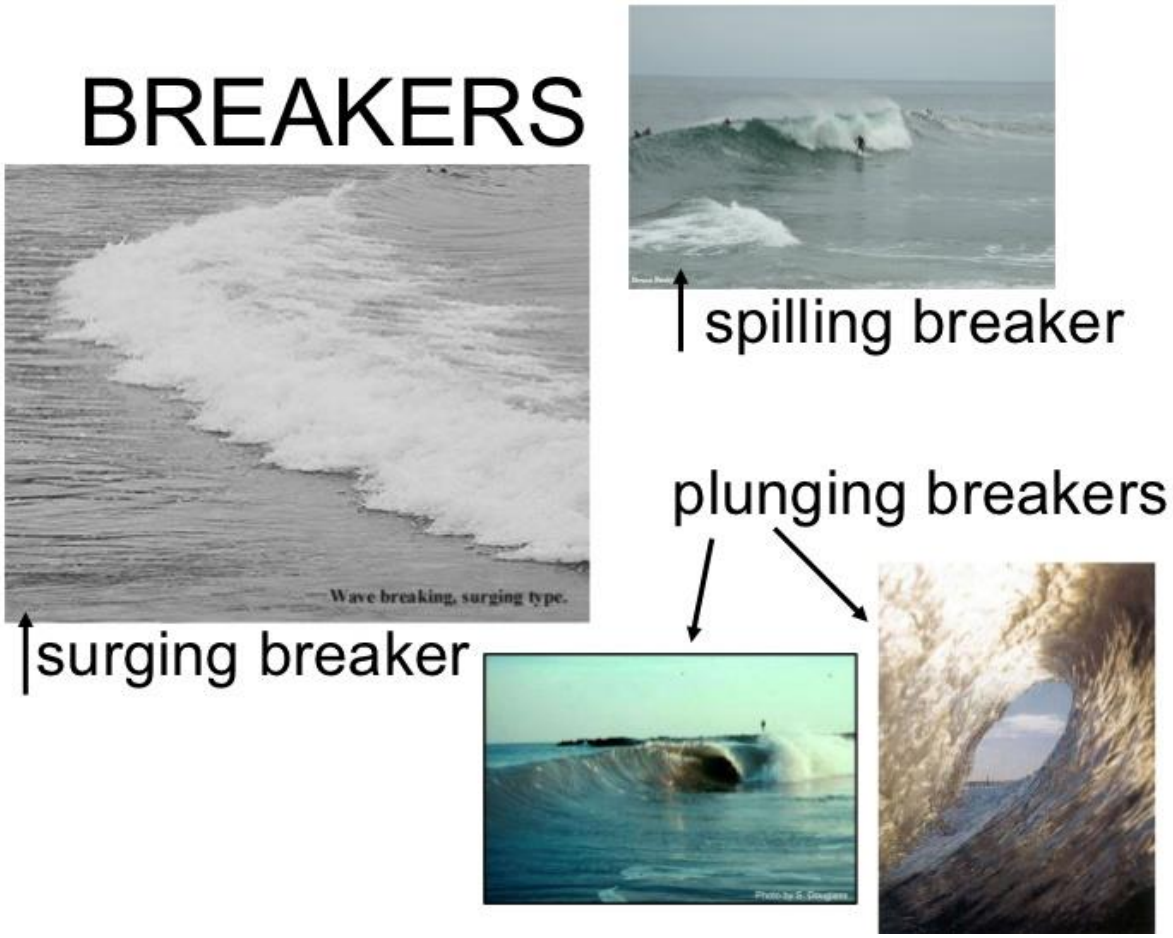
3 Main Types of Breakers

1. Surging:
   - Steep slope beach; wave rolls instead of breaks right onto beach

2. Plunging:
   - Moderate slope; wave curls; surfing!

Manos, Northern Indonesia

3. Spilling:
   - Gentle slope; break far from shore over long distance; crest spills down face of wave



SURGING WAVE (Never breaks)

Plunging
These are the kinds most surfers like.

Spilling Wave

A NOAA site (http://oceanexplorer.noaa.gov/edu/learning/9_ocean_waves/activities/breaking_waves.html) asks these questions and gives these answers.

Surging waves cause the most coastal erosion.

Which type of breaker - spilling, plunging, or surging – will cause the most coastal erosion? Explain.

A surging breaker will cause the most erosion because it slams into the beach at full speed. Spilling and plunging breakers slow down as they drag across the seafloor, so their energy is dissipated over a wider zone.

Spilling waves deposit more sand on shore and expand Beaches

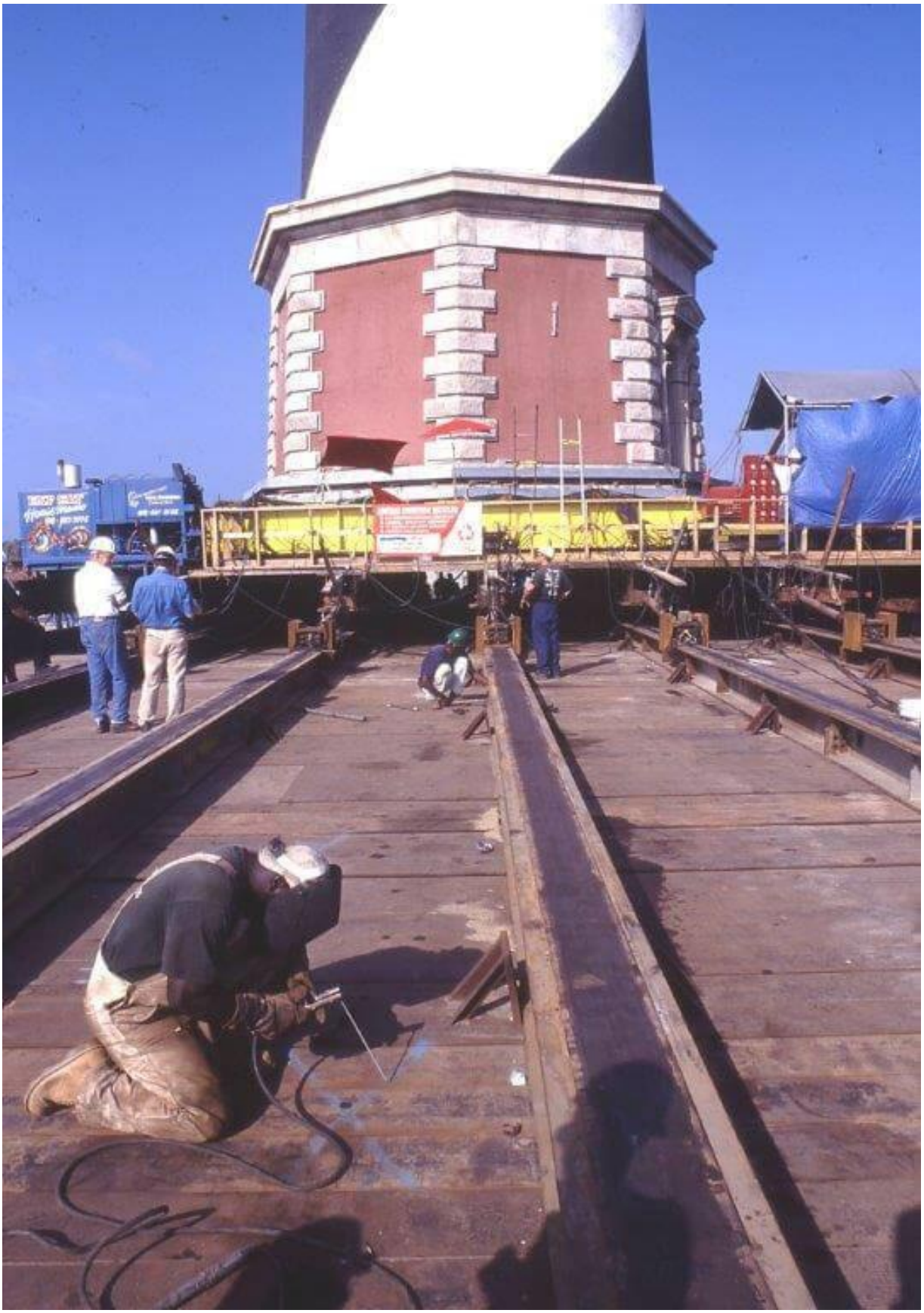
Which type of breaker - spilling, plunging, or surging – will deposit sand onshore and expand beaches? Explain.

Waves can move sand when their energy is in contact with the bottom. Spilling breakers spend the most time and energy dragging across the seabed, so they should be able to push more sand onto the beach. Surging waves hardly interact with the bottom at all, so they will have little effect on offshore sand.

So wave types is important not only to surfers, but to people who worry about coastal erosion –especially to those who build houses, highways, and other edifices on the shoreline.

It became necessary to move the Cape Hatteras Lighthouse that was built on Cape Hatteras Barrier Island in 1870 1500 feet (457 meters) from the shore. By 1970 the water was a mere 120 feet from the base of the lighthouse because of erosion. In 1999 it was moved 2900 feet (884 meters) from its original location!

Cape Hatteras Light House (2) Dangerously near the water



ROGUE WAVES

Rogue waves: a wave more than 2x the significant wave height (SWH=the mean of the largest third of waves in a wave record). Rogue waves are unusually high waves for the surrounding seas. 1826 one was reported at 108 ft. (33 meters). The report was ridiculed by some scientists who, at that time believed a wave of more than 30 feet was not possible. Later it was thought (as a result of mathematical proof) a wave higher than 60 feet was impossible.

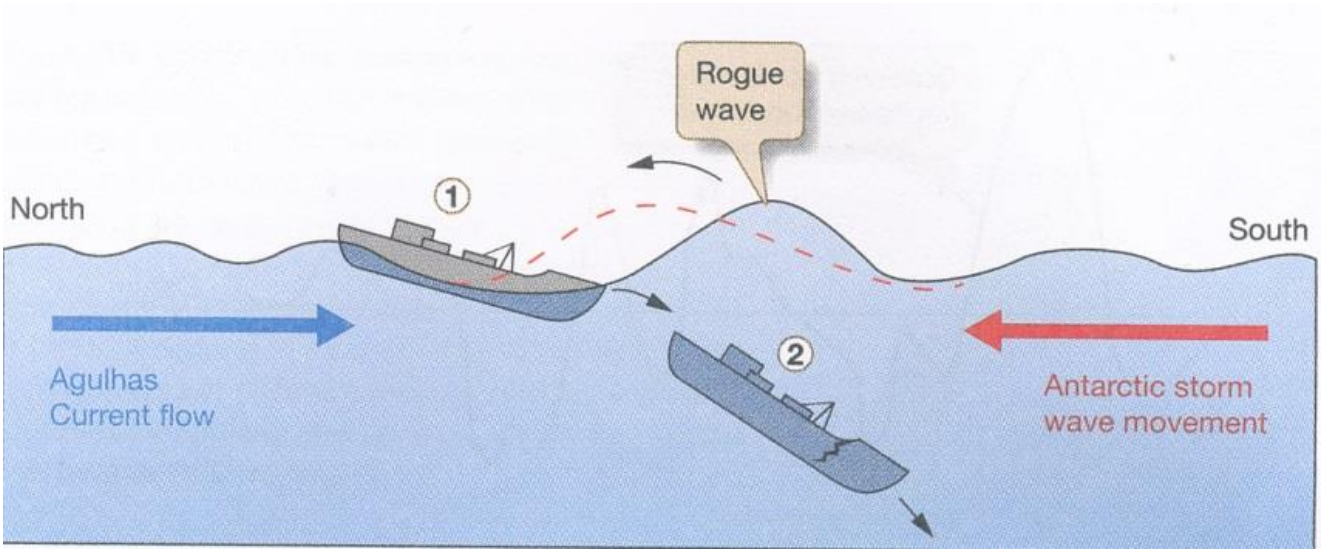
Video 100 ft. wave
https://www.youtube.com/watch?v=YL2XL17z8Fs

The Drauper Wave. In 1995, a wave was measured off Norway by an oil rig that was fastened to the sea bottom and was equipped to measure a number of things including wave height, wave slope and acceleration on deck and foundations.

In January, a rogue wave hit the platform which was 85 feet high and traveling 45 miles anhour. This was a wave higher than any mathematical model had predicted was possible.

Rouge waves form in relatively calm seas. Several waves come together and a large wave forms. The wave appears suddenly and can be more than 70 feet high. These waves are clearly dangerous to almost

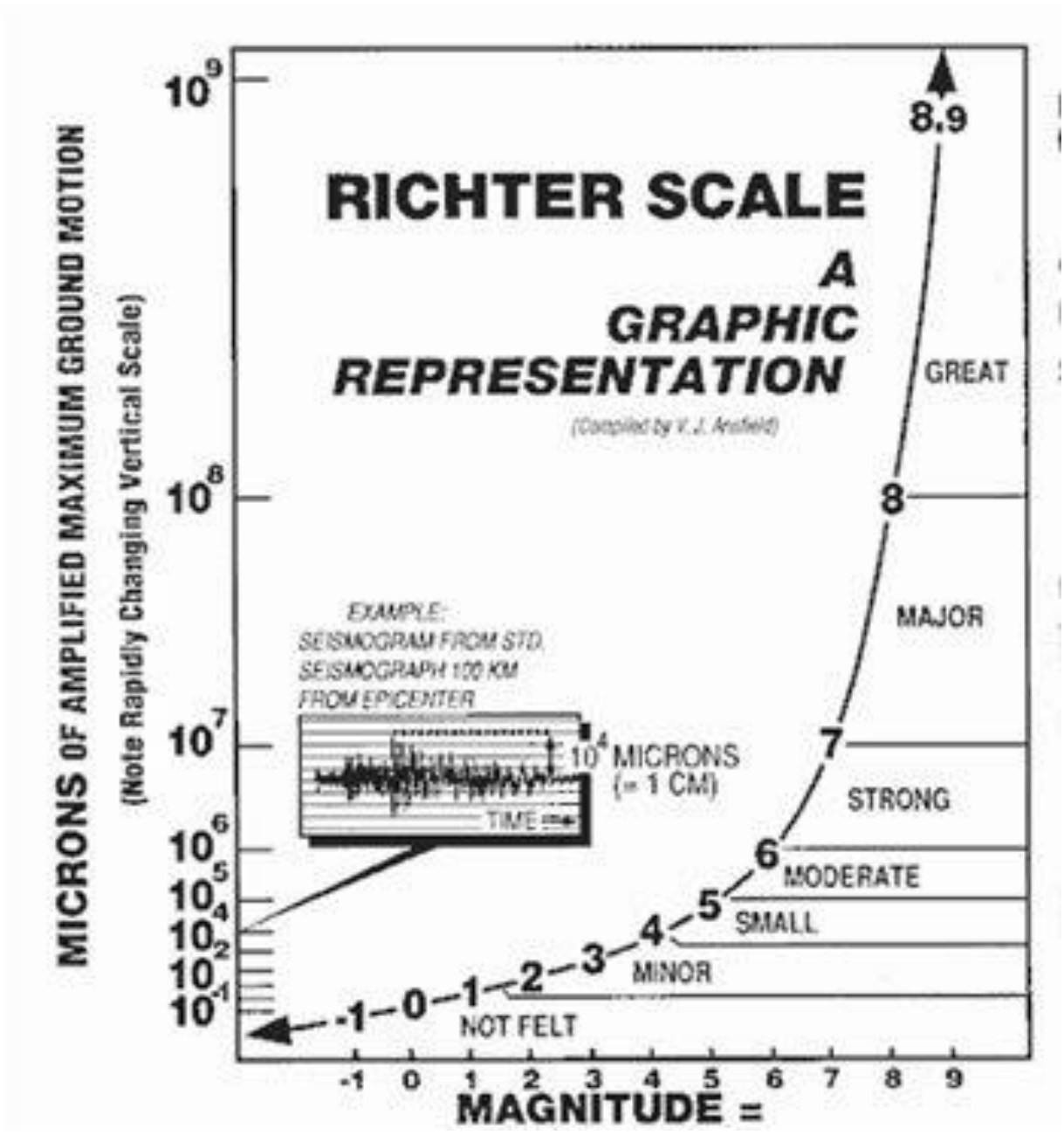
any ship since ships can be overturned by such huge waves. The general approach is not to take such a wave broadside or hear on, but rather to take the wave at an angle and ride over it
Even large ships can be severally damaged or sunk by rogue waves which can also have an impact on off shore drilling wells.



TSUNAMI

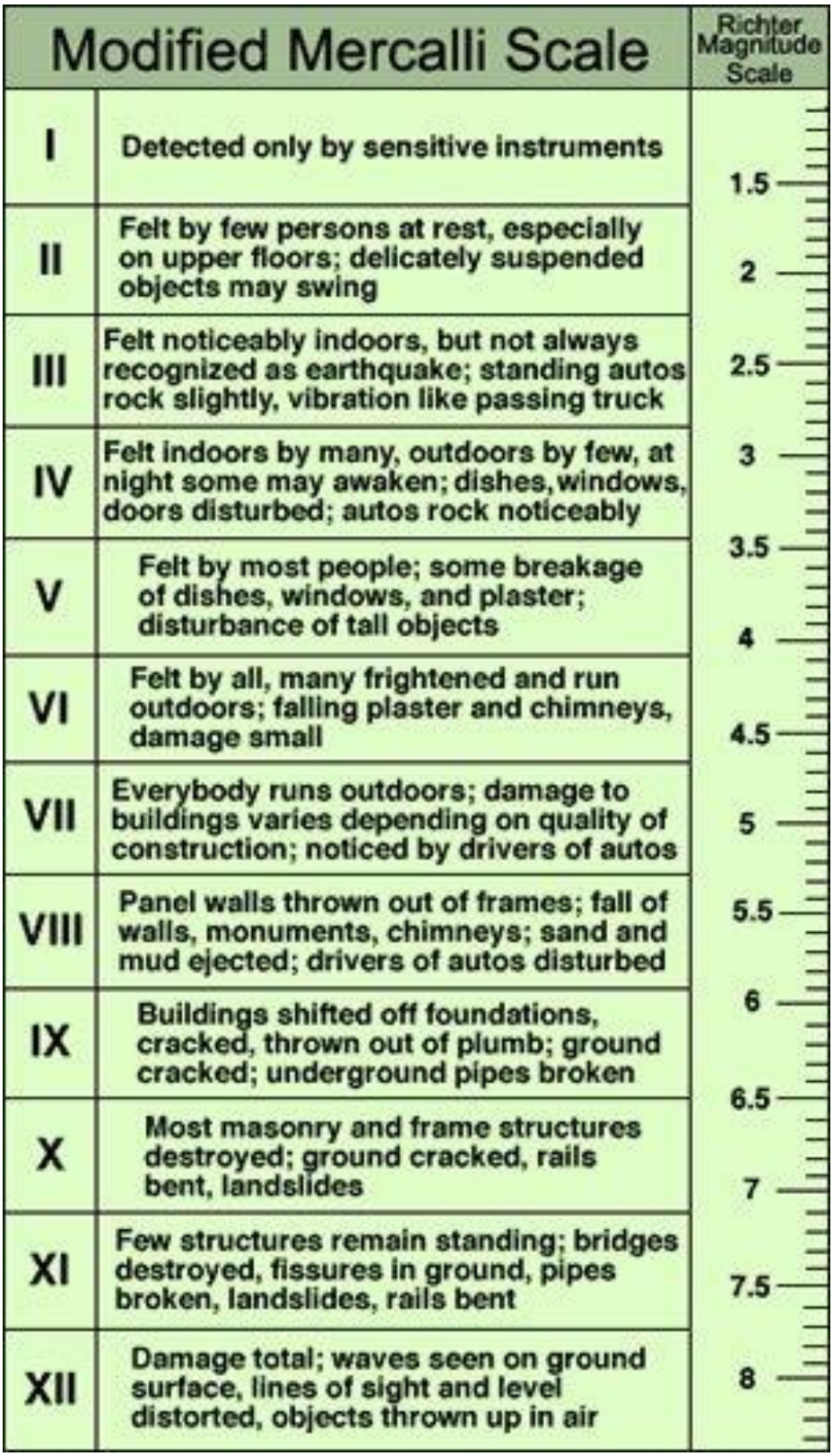
Tsunami: These are caused by displacement – usually undersea earthquakes, landslides, meteor strikes. Tsunami are not like wind driven waves, but are caused by a change in the basin in which the ocean lies.

Earthquakes are measured on the Richter Scale or the Mercalli Scale. The Richter Scale measures the amount of energy released whereas the Mercalli measures the amount of damage the earthquake is capable of. Here again scales are scientific artifacts produced with a specific goal in mind. Neither is right or wrong nor in conflict with the other.


RICHTER SCALE
A GRAPHIC REPRESENTATION
(Compiled by V. J. Anfield)
MICRONS OF AMPLIFIED MAXIMUM GROUND MOTION
(Note Rapidly Changing Vertical Scale)
MAGNITUDE =
EXAMPLE:
SEISMOGRAM FROM STD. SEISMOGRAPH 100 KM FROM EPICENTER
10⁴ MICRONS (= 1 CM)
TIME
8.9
GREAT
8
MAJOR
7
STRONG
6
MODERATE
5
SMALL
4
MINOR
-1 0 1 2 3
NOT FELT

RICHTER SCALE

Magnitude	Description	What it feels like	Frequency
Less than 2.0	Micro	Normally only recorded by seismographs. Most people cannot feel them.	Millions per year.
2.0–2.9	Minor	A few people feel them. No building damage.	Over 1 million per year.
3.0–3.9	Minor	Some people feel them. Objects inside can be seen shaking.	Over 100,000 per year.
4.0–4.9	Light	Most people feel it. Indoor objects shake or fall to floor.	10,000 to 15,000 per year.
5.0–5.9	Moderate	Can damage or destroy buildings not designed to withstand earthquakes. Everyone feels it.	1,000 to 1,500 per year.
6.0–6.9	Strong	Wide spread shaking far from epicenter. Damages buildings.	100 to 150 per year.
7.0–7.9	Major	Wide spread damage in most areas.	10 to 20 per year.
8.0–8.9	Great	Wide spread damage in large areas.	About 1 per year.
9.0–9.9	Great	Severe damage to most buildings.	1 per 5-50 years.
10.0 or over	Massive	Never Recorded.	Never recorded.


Modified Mercalli Scale
Richter Magnitude Scale
I
Detected only by sensitive instruments
II
Felt by few persons at rest, especially on upper floors; delicately suspended objects may swing
III
Felt noticeably indoors, but not always recognized as earthquake; standing autos rock slightly, vibration like passing truck
IV
Felt indoors by many, outdoors by few, at night some may awaken; dishes, windows, doors disturbed; autos rock noticeably
V
Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects
VI
Felt by all, many frightened and run outdoors; falling plaster and chimneys, damage small
VII
Everybody runs outdoors; damage to buildings varies depending on quality of construction; noticed by drivers of autos
VIII
Panel walls thrown out of frames; fall of walls, monuments, chimneys; sand and mud ejected; drivers of autos disturbed
IX
Buildings shifted off foundations, cracked, thrown out of plumb; ground cracked; underground pipes broken
X
Most masonry and frame structures destroyed; ground cracked, rails bent, landslides
XI
Few structures remain standing; bridges destroyed, fissures in ground, pipes broken, landslides, rails bent
XII
Damage total; waves seen on ground surface, lines of sight and level distorted, objects thrown up in air
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8

Tsunami do not look like breaking waves. Rather they look like an extremely high incoming tide. They appear as though someone has been adding more and more water to the ocean and the level keeps rising.

Some serious Tsunamis:

Santorini (Thera)
An enormous volcanic eruption which produced a tsunami Somewhere around 1628 BCE Evidence from Greenland, California tree rings Climate affected – crop failure in Chine, part of Egypt impacted, (information appears on the stele of Ahmose). Some felt that this ended Minoan Civilization but archaeological evidence finds Minoan culture after the eruption. It is possible that the society was so damaged that it became perhaps too weak to defend against a very militant Mycene. There is some speculation that this eruption is the bases of Plato's Atlantis myth.

Lisbon
1755 Nov, 1st at 9:40 am. (All Saints Day) Earthquake followed by a tsunami. People reported seeing the tide go out far enough to expose some ship wrecks. Churches where many had fled for protection were destroyed. Many candles which had been lit helped ignite fires all over. Many other cities hit. About 200,000 people in Lisbon. About 30,000 to 40,000 people killed about 10,000 more in Morocco. This event triggered the beginning of the science of seismology

in Germany, Led to many theological problems – why did this happen on a High holy day (All Saints Day) destruction of Churches and people looking for refuge in them being killed.

Krakatoa
or Krakatau August 27 1883. The eruption of Krakatoa was preceded by minor rumblings and ventings. Then on Aug 27 there was the first major eruption which generated a cloud plume 20 miles high and triggered several tsunami. The following day there were 4 major eruptions in a 4 and a 1/2 hour period. The last is credited with being the largest sound recorded on Earth. It was heard in Australia and an island called Rodrigues 3,000 miles away. Villages on Java and Sumatra were destroyed. An estimated 35,000 people died. Chunks of coral weighing 600 tons were found on the shore. Tsunami went nearly around the world with places. Thousands of miles away having large waves. Sunlight in the immediate area was blocked for several days and within weeks people all over the world saw the sun a strange color. This was caused by the dust in the stratosphere. Global temperatures fell for several years as a result of the reduced sunlight from the ash. Krakatoa basically blew itself apart but a new volcano called Anam Krakatoa is forming at the crater of about 5 inches a week.

Indonesian Earthquake and Tsunami or Indian Ocean Earthquake and Tsunami Dec, 26, 2004 (9.1 - 9.3 on Richter Scale) The death toll across 14 countries was about 230,000 people. It was the third largest earthquake ever recorded and lasted 8.3 to 10 minutes. Indonesia was the hardest hit, with Sri Lanka, India and Thailand also suffering

major losses. In 1960 the Great Chilean Earthquake registered 9.6 and the 1964 Good Friday Prince William Sound Earthquake which registered at 9.2 are the only greater earthquakes recorded.

There was great ecological impact both in the ocean itself and along the coastlines. Scientifically there has been the development of a much greater warning system in the Indian Ocean.

Tohoku earthquake and Tsunami March 11, 2011
A 9.0 earthquake off the coast of Tohoku (N.E. Japan) resulted in a tsunami the struck Fukushima, Iwate Prefecture. The number of confirmed deaths is 15,891 as of April 10, 2015, according to Japan's National Police Agency. Most people died by drowning. More than 2,500 people are still reported missing.
It was estimated that in one part of Iwate Prefecture, the tsunami may have been 127 to 133 feet high.

VIDEO TSUNAMI

Sendai (the major city in Fukushima) has an airport near enough to the water that wave washed cars and planes away at the airport.

The Japanese, as the only people against whom nuclear weapons of mass destruction have been used (in Hiroshima and Nagasaki near the end of WWII) have a great deal of concern about nuclear matters and there is a split in the population about nuclear reactors. The Fukushima Daiichi Nuclear Power Plant suffered a meltdown and a good deal

of radioactive material was washed into the ocean. In Fukushima, Tochigi, Gunma, Tokyo, Chiba, Saitama, and Niigata prefectures, there were reports that radioactive material was found in tap water. The fishing of some species of fish was also banned because they were found to have radioactive material in them.

Nuclear meltdown:
The tsunami caused a cooling system failure at the Fukushima Daiichi Nuclear Power Plant, which resulted in a level-7 nuclear meltdown and release of radioactive materials. The electrical power and backup generators were overwhelmed by the tsunami, and the plant lost its cooling capabilities. In July 2013, TEPCO, the Tokyo Electric Power Company, admitted that about 300 tons of radioactive water continues to leak from the plant every day into the Pacific Ocean.

LITUYA BAY ALASKA (1958)

Lituya Bay megatsunami occurred in Lituya Bay Alaska in 1958. It was a 7.8 earthquake which caused a landslide dumping 40 million cubic yards, and about 90 million tons) to fall from several hundred meters into the narrow inlet of Lituya Bay, Alaska. This displacement of water by the slide caused a wave to form which measured 1710 feet at the inlet to the bay (Empire State Building 1,250′, 1,454′ to tip).

TIDAL WAVES

Tidal waves are not tsunamis. A tidal wave is a wave that forms when the tide comes in and forms a wave. Sometimes they will form in a river as the tide pushes its way inland. These are sometimes called “tidal bores” These can be dangerous to people because in narrow beaches with high hills or cliffs, a person or an animal might not be able to escape in incoming tide. Bay of Fundy Tidal Bore

https://www.youtube.com/watch?v=YDNg101oLkE

In Cuxhaven in Germany, the shore is almost horizontal, so the tide comes in suddenly and with great speed.

Watt in Cuxhaven

https://www.youtube.com/watch?v=yTpzaZa9vhs

Undersea Waves

Undersea or underwater waves are caused, like wind driven waves, by 2 fluids of different densities moving against one another at different speeds.

With undersea waves however, the 2 fluids are both water, but in this case the water is of 2 different densities. So a level of water of one density, moving against a level of water with a different density can (and will) produce a wave, but in the case it is underwater.

In general this is not a problem for people since most are not under water. However it has been the case that submarines have been affected by these. Submarines are rated for specific water pressures, and if they go deep enough to exceed that pressure they can implode.