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E: ISSN NO.: 2349-980X **Shrinkhla Ek Shodhparak Vaicharik Patrika**

Tsunami : A Geographical Analysis

Ashutosh Agnihotri
Teacher,
Deptt.of Geography,
Jaipuria College,
Kanpur

Abstract

Tsunami is Japanese word with the English translation, "harbor wave." Represented by two characters, the top character, "tsu," means harbor, while the bottom character, "nami," means "wave." In the past, tsunamis were sometimes referred to as "tidal waves" by the general public and as "seismic sea waves" by the scientific community. The term "tidal wave" is a misnomer, although a tsunami's impact upon a coastline is dependent upon the tidal level at the time a tsunami strikes, tsunamis are unrelated to the tides. Tides result from the imbalanced, extraterrestrial, gravitational influences of the moon, sun, and planets.

Keywords: Tsunami, Frequency, Amplitude, Diastrophic Movement, Plate Tectonic , Subduction Zone .

Introduction

Regular rise and fall of water of the surface of a water body like pond, lake, sea or an ocean is a wave. It is a typical type of movement in which water rises and falls in an alternate sequence, producing a symmetrical curve on the water surface. This type of motion is generated, when a stone is dropped into a still water or when a water vessel sinks into a sea. A similar effects is produced on the water surface when a block of ice breaks off from an ice sheet and falls into vast oceans of seas. A wave is also generated, when a portion of sea water is pulled by the gravitational force of some celestial body like moon or sun. The waves, which are produced from the attractive force of the sun or the moon or from the combined force of the both are known as tidal waves. Wind is another important force that can create commotion in the clam water or oceans and seas by its dragging effect. Storms of very high intensities named as cyclones, typhoons and hurricanes are known for producing violent waves in the Bay of Bengal, China sea, Caribbean sea and other parts of the world oceans. Five to ten meter high waves are commonly produced by strong winds. Wind driven waves are termed as forced waves. The raised portion of the water surface is termed as crest, while the depressed one as trough. The horizontal distance between a crest and a trough is known as amplitude or height of the wave. (Fig. 01) In storm generated disturbances, wave lengths of 200-25 meters are quite common. In exceptional cases, wave amplitude (wave heights) have been found to have crossed the make of 15 meters.

Review of Literature

According to Prof Stephen A. Nelson in his research paper entitled - Natural Disaster published in Tulane University journal published in 2016, he describe physical characteristics of tsunami quite comprehensibly including its wave length, frequency, velocity etc.

Similarly prof.Dr. D. S. lal in his book entitled - Oceanography ,published 2015 from Prayag Pustak Bhavan Allahabad discuss causes and consequences of tsunami waves with methods of mitigation and early warning system .In the same way Costa P J M , Lorey S A in his article entitle -Tsunami, Causes behaviour and mitigation published in 2016 in International Geographical Society Magazine also discuss Tsunami characteristics in detail.

Genesis of Tsunami

Tectonic movements of the crust * beneath sea beds and ocean floors are very important source of producing waves of high amplitude and long wave lengths. Being a global phenomenon, these movements have created large cracks in the earth surface as a result of which the crust has been divided into seven broad blocks and several minor pieces. These individual pieces of the crust are known as tectonic plates. The landmass comprising Asia and Europe continents is called Indo-Australian plate. Burma plate and Indian plate are minor plates and parts of the Eurasian and Indo- Australian plates respectively. All plates of the earth move slowly in relation to each other and the underlying mantle both vertically and horizontally along the ruptured zones which are known as faults. (Guidie, 1985, p. 337). Horizontal movements of plates are generally very slow and range from 3 cm to 17 cm per year. When the movements is sudden and it involves a vertical dislocation, one section of the crust is either up thrown or down thrown in relation to its counter part. In both the situations, a vertical wall normally several kilometers long and many meter high is developed in the ocean floor. Huge mass of water (which may be 3000 to 5000 meter thick deeper parts of the oceans) lying on the raised part of fault, jumps down from the wall and create a water fall like condition in the ocean for a short while, Since volume of falling water is huge, it generates a vast energy and produces destructive waves. The waves, thus generated, are known as Tsunami waves. These waves are very powerful and cause harm to ships anchored in harbours. People of Japan, for this reason, have named them as tsunami because in the Japanese language the word tsunami means harbour waves. Relative displacements of plates in sea beds are normally accompanied by earthquakes. It is, for this reason, That Tsunamis are often described as earthquake generated waves. In this regard, it must be noted that all undersea earthquakes do not produce tsunami waves. In reality, it is the sudden and vertical dislocation of some part of the sea bed which cause earthquakes and tsunami simultaneously (Mc Graw hill Encyclopedia, p.126) (Fig.1 a). Suddenness of this diastrophic event us therefore an important factor. No tsunami will generate if the ruptured part rises slowly.

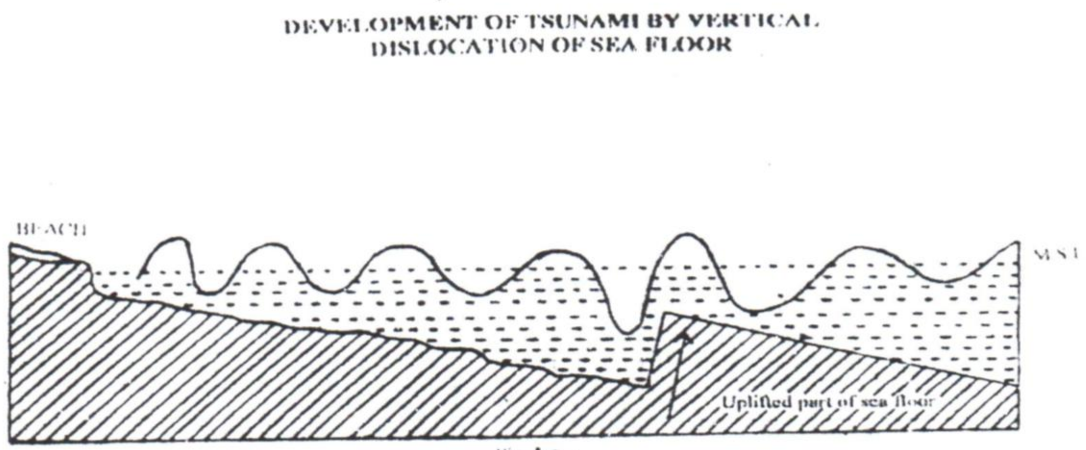

Fig. 1a.

The tsunami disaster of 26th Dec., 2004 is the result of tectonic disturbances at the sea bed in the Bay of Bengal. The Indian plate which has been sliding north eastward at an approximate rate of 2-3 cm a year of several decades, pushed considerably beneath the Burma plate. As a result, The Burma plate was uplifted by 10-20 meters. Some experts believe that the old Rangoon fault situated north west of Phuket island of Thailand became active due to the sliding of the Indian plate beneath of the Burma plate. According to some scholars, a new fault developed in the crust which runs roughly north south in the north west of Sumatra island. Sonar images from the Royal Navy Survey Ship HMS Scott have located a portion of this fault which is 65 to 85 km. long when a collision between two plates occurs, lot of fracturing takes place in and around the fault in a narrow zone known as shear zone. Boulders as big 2 km. wide and 100 meter thick have been located near the site of the collision of Indian and Burma plate. Most of the worst earthquakes of the world have their origin in these shear zones. The current deadly under sea earthquake of 25th Dec., whose intensity was measured as high as 9.3 on Gotenberg Richter scale had its seismic origin (known as seismic focus) in the colliding zone of the above plates. No doubt, it was second most powerful earthquake ever recorded in the world's history and it is released strong vibrations to shake the earth. But the main cause of the recent tsunami waves was the vertical uplifting of the edge of the Burma plate. Near the site of the fault, the sea is 1000-2000 meter deep. Hence, 1000-2000 meter thick sheet of water resting upon the raised side of the fault was also pushed up. When this his water mass stretching about 100 km. in length along the edge, fell from an uplifted elevation of about 20 meters it produced a great thrust on the water surface and generated powerful tsunami waves of great wave length. The pushing force of the falling water was so high that it provided them enough energy to travel a distance of 2000-3000 km. upto the coast of India and Sri Lanka with a destructive speed. In the source region, the velocity of the waves was estimated to be more than 800 km/hrs. By the time, they reach the Indian and Sri Lanka shores, they slowed down to a speed of 50-100 km/hr. But the velocities of 50 km-100 km per hour were more than enough to cause vast devastation and destruction.

The quantum of casualties and other losses by tsunami is determined by the magnitude of vertical dislocation. But which will be the areas of maximum devastation is decided by the orientation of dislocation. Distance of an area from the source region of tsunami is an important factor. But in the current disaster, the direction of the displacement of the crust played the dominant role. The recently developed fault near Phuket and Sumatra island stretches in north-south direction and its uplifted side faces the eastern shores of India and Sri Lanka. The tsunami generated from this north-south trending vertical fault will directly hit the areas most which fall in front of the waves in the east and in the west. On the western side of the fault, Andaman & Nicobar islands coastal areas of Tamil Naidu and Sri Lanka suffered heavy losses, while on the eastern side, the easy victims of the Tsunami were the coasts of Thailand, Malaysia and Indonesia. In contrast areas to the north and south of the fault suffered minimum damages. Rangoon area of Myanmar is much nearer to the site of the fault. But it did not suffer any loss of life property for the simple reason that it lies to the north of the dislocated block. Tamil Naidu and Sri Lankan coasts, on the other hand, are more than 2000 km. distant, but the combined casualties in both the regions crossed of the mark of one lakh people. If the rupturing of the crust had been in the east-west direction, Bangladesh, West-Bengal and Myanmar (Burma) in the north would have been the worst victims of the tsunami. In the south there is no landmass, hence, the tsunami would be lost in the deep waters of Indian ocean.

Velocity and wave length of a tsunami is directly related to the dimension of dislocation. Generally, tsunamis have very long wave lengths, ranging from 100 to 200 km. (Strahler, 1971 p. 172). From the sources, they advance with a speed of a jetliner, measuring 800 km./hr. or even more. Since velocity is a direct function of gravity and depth of water, their velocity is greatly reduced, when they enter shallow waters. Around the shore of Tamil Naidu, the velocity of the current tsunami was estimated to be 50-100 km/hr. only, while near the fault the wave speed was in the range of 750-950 km./hr. When a large volume of water is forced to pass through a narrow passage, its speed is increased by a narrow passage, its speed is increased by a funneling effect (Mc Graw Hill Encyclopedia, 1962, p. 126). The gaps between the long chain of Andaman and Nicobar islands which extend north to south in a linear pattern, produced the funneling effect in the t tsunami waves, and played a pivoted role in increasing their velocities. Standing like a long wall, these islands blocked the advancing huge mass of water coming from the source region in the east and forced it to pass through narrow gaps between them. Most of this water escaped from the Andaman & Nicobar islands through two narrow passages known as the Great channel and Ten Degree Channel (Fig. 02). These Channels are relatively wide gaps but other gaps between these islands are very narrow particularly in the Andaman group of Islands. Much of the velocity and energy of the tsunami waves would have been lost in covering a long distance upto the coasts of Indian sub-continent and Sri Lanka, if in the Bay of Bengal, there had been no chain of islands with funnel like openings. This type of effect can be seen in rivers, when they register tremendous increase in their velocities while passing through narrow gorges.

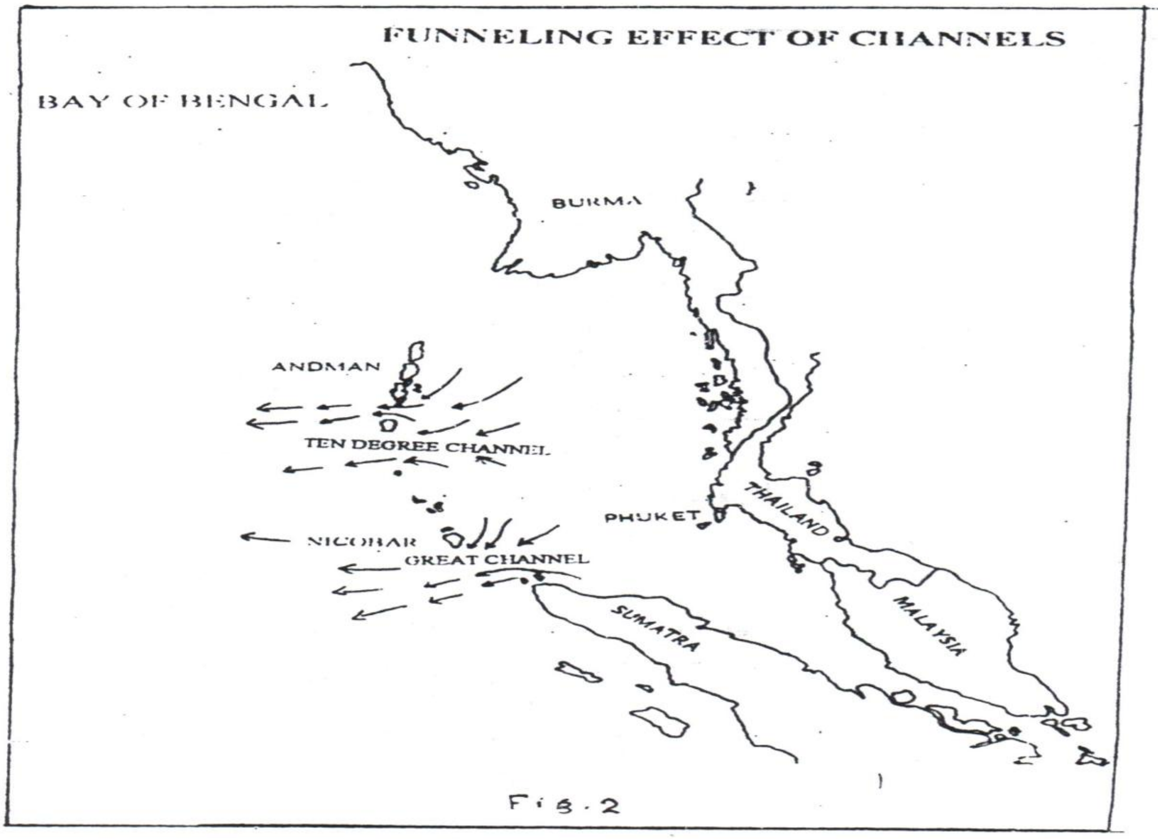

Fig. 2

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Velocity of a wave is also governed by a depth factor. In shallow waters when depth is less than half of the wave length i.e. the ratio between the depth (D) and wave length (L) expressed as D/L is less than 0.5, circular movement of water particles becomes elliptical due to the friction offered by the bottom of shallow seas (Fig. 03).

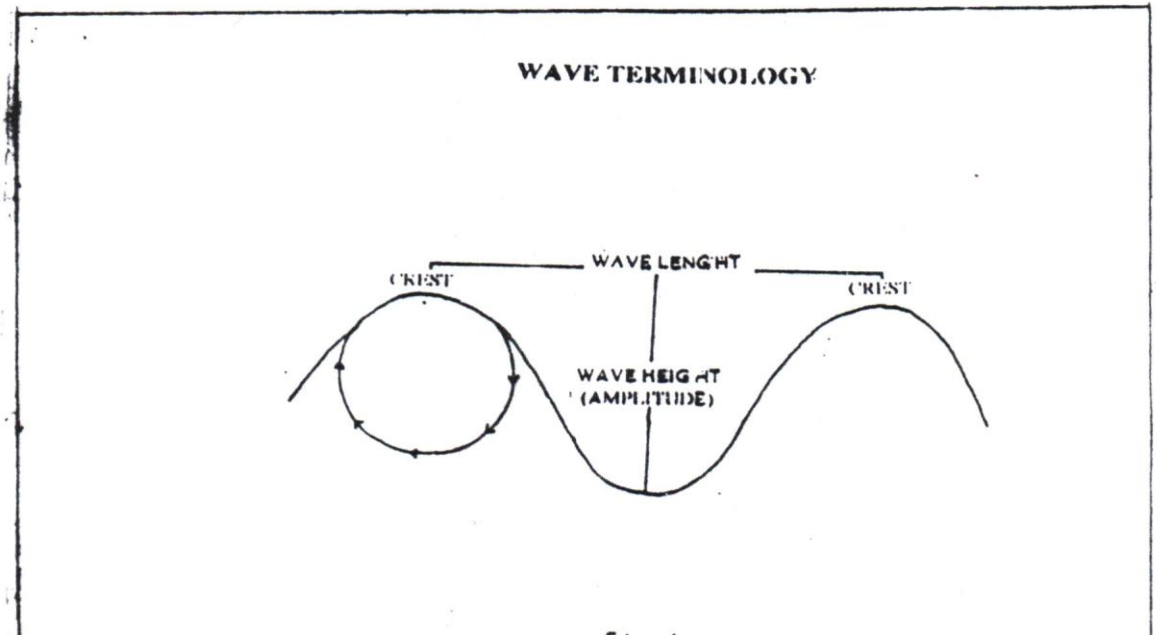

Fig. 1

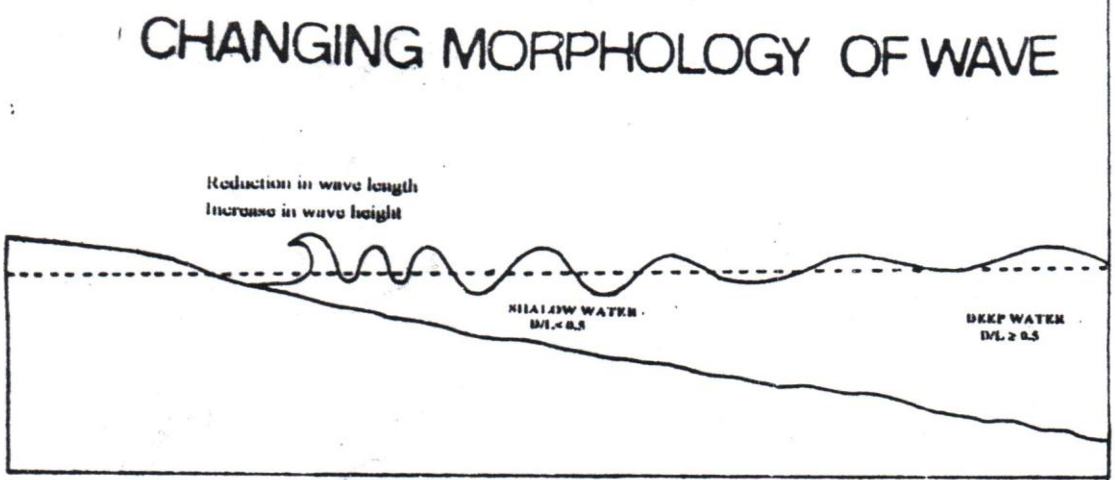

Fig. 3

It causes great reduction in the velocity of a wave. This is the reason that the velocity of tsunami waves near Sumatra islands was said to be more than 800 km/hr., while on the shores of India and Sri Lanka it was measured less than 100 km./hr. in deep waters where the value of D/L is high velocity is directly governed by wave length and is given by a mathematical expression v= $\sqrt{2gL/2\pi}$ (King, 1962 p.196). In the formula, 'g' represents the gravity acceleration while 'L' is the wave length. In the case of recent tsunamis, the wave length in the deeper part of the sea was, 200 to 300 km. Therefore in those areas , the velocities were also very high.

It mays sound surprising that the destructive energy of a tsunami or any other sea wave does not lie in its speed. In reality, wave height and wave length are two prominent factors that determine the destructiveness of a wave. this relationship is described mathematically in an equation: E $\propto L$ x H^2 in which E represents energy, L wave length while H stands for wave height. The above relationship shows that wave elevation is the most dominant source of a wave energy and that velocity plays little role in it.

This is the reason that strong tsunami wave of very high velocities could cause no harms to vessels in deep waters, because here the wave elevation was as low as lees than one meter. As the waves approach large islands and continental shores, their velocities and wave lengths are greatly reduced. But they register a rapid increase in their elevation as the value of depth and length ratio (D/L) falls below 0.06 with decreasing depths. As soon as a critical height is reached they become unstable and break. Theoretically, no wave can attain a height of more than $1/7^{th}$ its length (King, 1962, p. 197). Another change occurs in the shape of the wave crest. In shallow waters the crest becomes narrow and sharp and its gradient steepens (Spar, 1962, p. 90). Consequently, when Tsunami waves enter the coastal areas, their crests become steeper and higher (Fig.03). This increased height and steepness of the crests provide enormous energy to tsunami wave which become the main cause of vast devastation in the coastal areas of affected countries.

Source Regions of Tsunami

Tsunami waves can develop any where in the earthquake prone zones of oceans of the world. However, maximum frequency tsunami has been reported from the Pacific Ocean. Violent tsunami storms have also developed several times in the Atlantic Ocean. As per available records, Indian Ocean is the best tsunami affected ocean in the world. Until recently, tsunami was an unknown word to the people of Indian sub-continent. But is would be wrong to state that Indian Ocean is a tsunami free zone. There have been few cases in the past when tsunami wave had hit coastal areas of the Indian peninsula and caused enough destruction. Firm believers in Indian mythology say that the drowning of Dwarika-the legendary city built by Lord Krishna occurred due to the invasion of massive tsunami waves. Geographers and geologists, of course, do not subscribe to this theory. According to them, it was the foundering and subsequent sinking of the western coast which resulted in the submergence of the city under sea water. In recent years, tsunami struck the western shores of the country on Nov. 27, 1945 causing considerable losses of lives and property on the coasts of Gujarat, Maharashtra, Karnataka and Goa. The cause of the tsunami disaster was the submarine earthquake that originated in a fault near the Pakistan border. Reactivation of any fault in Arabian sea or in the Bay of Bengal may trigger off a sudden slip of a tectonic plate and generate tsunami any time in future.

The Pacific Ocean is known for generating tsunami waves more frequently than any other ocean of the world does. Geological structure of the ocean floor of the Pacific is the main factor that provides favorable condition for the development of tsunami waves. Pacific is a unique ocean in many respects. It is the largest ocean on the globe and covers about one half of the total area of the earth. Between California on the side and New Zealand on the other, the width dimension of the ocean is about 12, 800 km, i.e. slightly less than one third of earth's perimeter. Of the seven major tectonic plates which comprise the earth crust, the Pacific oceanic plate is the biggest one. On both the sides of the plate there are large transcurrent or tear faults, The san Andreas rift in California region of the ocean is a huge crack in the earth crust. Great Alpine fault in New Zealand in the east is another major fault system of the Pacific plate (Fig. 04).

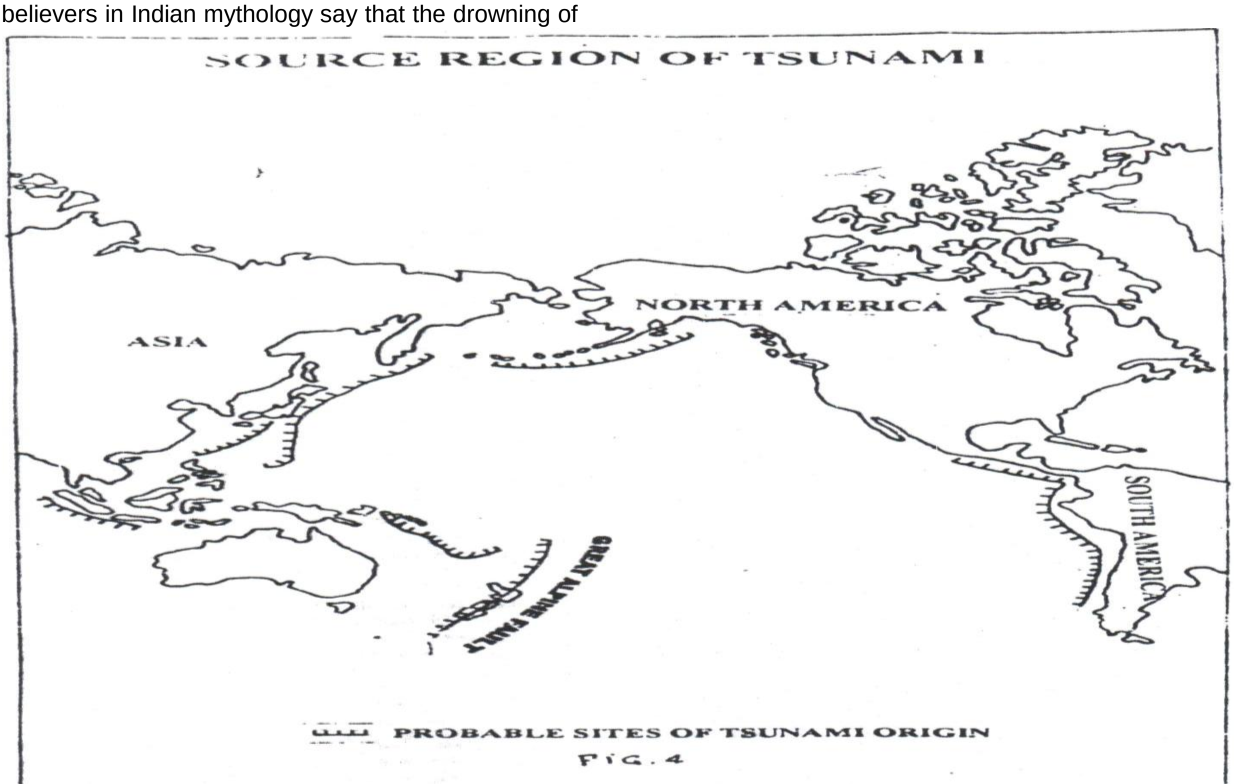

FIG. 4

This deeply fractured zone extends for a long distance in the north and south of New Zealand on the floor of the ocean. It is a well known fact that all volcanic and seismic activities are associated with such faulted zones of the earth. Many destructive earthquakes of North America had their seismic foci in the shear zone of San Andreas fault. In the long chain of islands right from Sakhalin, Hokkaido and Honsu (Japan) in the north through east Indies upto New Zealand, there are tremors almost every day in one part or the other. The obvious reason is that in this part, the whole margin of the Pacific plate is badly fractured.

In other parts of the ocean also, faulting and displacement of the crust have occurred on a grand scale. Most of the deep trenches like Challenger deep, Philippine deep. etc, are the result of reverse faulting in which one part of the crust rides over the other. The middle America trench of the western coast of North America is actually a 2000 km. long and 5500 m deep rift in the bottom of Pacific ocean. The cracks of the Pacific are long and deep seated, along which both vertical and horizontal movement have been occurring. Recent studies suggest that the Pacific plate has been shifting north westward at varying rates if 2 cm to 18.3cm per year. When in any area, a part of the oceanic plate composed of dense material (SIMA) plunges beneath the lighter rocks of “SIAL” of a continental plate, a weak zone is created in the sea bed which in known as subduction zones. Sometimes, the pushing plate extends several hundred kilometers deep into the interior of the earth in a layer known as asthenosphere.In this layer, temperatures are extremely high and some melting of the material takes place. This melting of rocks release lot of energy and gives rise to all types of seismic and volcanic activities. The current destructive earthquake of 26th Dec. had its origin in the subduction zone at the boundary of Indian and Burma Plate. In the Pacific ocean, the number of such weaker zones of the crust is larger than those in other oceans. The main subduction zones are situated at the margins of the plate and along the prominent trenches of the ocean.

Findings and Solution to Tsunami disaster

In all the oceans and seas of the world, there are numerous major and minor zones where the ocean floor is structurally very weak. These weak areas may be the subduction zones, large faults or merely the deep cracks of the crust. Prominent zones have been mapped and studied in detail. But minor once have not been fully investigated. They are as much the sources of potential threat as the major zones. At any times, they may generate tsunami wave of high magnitude to cause widespread devastations. Recent tsunami has originated in a relatively small fault. Therefore detailed study and mapping of all the faults and cracks of sea beds is the first and foremost necessity of the day. The Bay of Bengal and the Arabian sea are very poorly surveyed parts of the world. So the most urgent and important task is that the concerned departments should conduct detailed surveys of all such weaker areas and prepare upto date maps. Close monitoring of the crustal disturbances in sensitive faults is another important precautionary measure. The present tsunami disaster has shown what are the anger of the nature can do. At the same time, the incident has exposed the failure of concerned scientists who could not sense out what was happening in the undersea fault near Phukut island.The prediction part of the Indian Meteorological Department has always been very poor. But this time, Geological survey of India and National Institute of Oceanography also presented a flop show of their sincerity and ability. Close co-ordination among the scientists of the related fields (e.g. geology, meteorology, seismology, oceanography etc.) at the regional and global level is a desirable step.

Threes are known for offering the best defence against advancing currents of wind or water. Indian coasts do not have any protective forest belts which can save people from catastrophes caused by strong cyclones or killer tsunamis. Hence erecting a fence of at least 500 meter width of forest in the sensitive coastal areas, is a good safety measure for the likely victims of such disasters. From this point of view, a change in the existing landaus is desirable. Demolition of lagoons and feeling of trees are dangerous practices in the coastal areas, hence must be stopped without any further delay.

Occurrence of natural calamities is a recurring feature in our country. To deal effectively and promptly with emergency situations, an efficient delivery system must be evolved so that relief supplies reach the affected people in time. In the present tragedy, it was sadly learnt that some people could not get any assistances even after two weeks of the incident. Formation of disaster management boards at the lower administrative level is as important as the development of disaster information system. It must be ensured that inaccessible areas get some route connectivity, through a minimum network of roads, railway or airways. Information connectivity may be provided by opening up few radio, T.V. and telephone in such remote area.

Tsunami Warning System

Drawbacks can serve as brief warning. People who observe drawback (many survivors report an accompanying sucking sound), can survive only if they immediately run for high ground or seek the upper floors of nearby buildings. In 2004, ten-year-old Tilly Smith of Surrey, England, was on Maikhao beach in Phuket, Thailand with her parents and sister, and having learned about tsunamis recently in school, told her family that a tsunami might be imminent. Her parents warned others minutes before the wave arrived, saving dozens of lives. She credited her geography teacher, Andrew Kearney.

In the 2004 Indian Ocean tsunami drawback was not reported on the African coast or any other east-facing coasts that it reached. This was because the wave moved downwards on the western side. The western pulse hit coastal Africa and other western areas.

A tsunami cannot be precisely predicted, even if the magnitude and location of an earthquake is known. Geologists, oceanographers, and seismologists analyse each earthquake and based on many factors may or may not issue a tsunami warning. However, there are some warning signs of an impending tsunami, and automated systems can provide warnings immediately after an earthquake in time to save lives. On of the most successful systems uses bottom pressure sensors, attached to buoys, which constantly monitor the pressure of the overlying water column.

Regions with a high tsunami risk typically use tsunami warning systems to warn the population before the wave reaches land. On the west coast of the United States, which is prone to Pacific Ocean tsunami, warning signs indicate evacuation routes. In Japan, the community is well-educated about earthquakes and tsunamis, and along the Japanese shorelines the tsunami warning signs are reminders of the natural hazards together with a network of warning sirens, typically at the top the cliff of surroundings hills.

Conclusion

Tsunami tragedy will be a blessing in disguise, if our scientist start working on research projects aimed at designing tsunami proof structures. Japanese scholars have succeeded in developing earthquake resistant buildings. The result is that in Japan now-a-days, even powerful earthquake cause negligible damage in comparison to what they do in other countries. In Latur and Gujarat earthquakes, causalities in India were in several thousands. But few months after the Latur quake when an earthquake of the same intensity hit the Tokyo area of Japan, only ten or twelve deaths were reported. Unfortunately, we are poor at learning lessons. Skyscrapers are emerging in all big cities, in which there is no systems which may resists or withstand the shocks of earthquakes. We should awaken now. If we awaken now, we can defeat the catastrophes that may again knock our doors tomorrow.

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