The Tsunami Mechanism

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Abstract

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The Tsunami Mechanism

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Abstract

The repetitive narrative that, "*Tsunami waves and receded coastal water initiated by an earthquake are closely related,*" is analyzed through the sequential events that followed the earthquake; a mechanism based on the interaction of receded water with magma is suggested to explain the amplification of Tsunami wave deep beneath the ocean floor (Fig.1), where earthquake occurred under the seabed's or in coastline; the mechanism explained how the water is amplified into steam in the magma chamber, as its volume increased 1,700 times, the transformed water encompass the tremendous force that uplifted the ocean water endowed it with such destructive force; the mechanism explained characteristics related to Tsunami wave, including relation with earthquake and volcano, receding costal water, the foams, inundation, runup, the nature of the great force of Tsunami, ideas to calculate the magnitude of Tsunami force and energy, volume of receded water, volume of tsunami wave, the repetition of its wave; these and related issues are stated; the idea is derived based on the continual flow of lava from earth's interior and the existence of magma reservoir bellow earth's surface in places like Yellowstone in USA and hotspot beneath Hawaii, such magma chamber when existed under seabed, if opened by crack during earthquake, can easily lead to an interaction between receded water and the magma, resulted in the suggested mechanism, all is based on logical analyses and deep thinking to attained the Tsunami Mechanism in response to 2004 and 2011 human tragedies; thus understanding this mechanism will help laying measures to counter the phenomenon, which will reflect positively in saving lives and mitigate its destructive force and reduce consequences of its impact on local societies and above all to understand its true mechanism.

Key Word: Tsunami Mechanism; Earthquake Cause; Withdrawal Water; Magma Chamber, Steam Production; Wave; Runup; Inundation; Tsunami Water Amplification.

1. Introduction

Tsunami, in Japanese language means the harbor wave (Wikipedia, 2021a), reflecting its related source deep in sea and the harbors it immersed, this included in description by the Greek historian Thucydides (460-400 BC), that *"at the point where <u>earthquake shock has been the most violent</u> the sea is driven back, and suddenly recoiling with <u>redoubled force</u>, causes the inundation"* (Wikipedia, 2021a), while the Roman historian Ammianus Marcellinus (c. 330-400 AD) illustrated sequence of tsunami, including an incipient earthquake, the sudden retreat of sea followed by gigantic wave (Wikipedia, 2021a), regardless of these repetitive narratives, the current Tsunami model, claimed the ocean receive energy from an earthquake to generate tsunamis (Song et al,, 2017), this energy is produced from relative motion between the plates, and when nearly all of an earthquake's energy is released in a thrust motion, a large tsunami is generated (USGS, Tsunami). Japan may have the longest recorded history of tsunamis, while Sumatran region is also accustomed to tsunamis, with earthquakes of varying magnitudes off its coast (Wikipedia, 2021a); from the past tsunamis experiences, five main characteristics repeatedly observed:

1- Tsunamis are always Triggered by earthquakes (Satake, 2014) (Frequently Asked).
2- Immediately after earthquakes, drawback of costal water started, which can extends to hundreds of meters (Ioualalen M, et al., 2007) (Wikipedia, 2021a).
3- The withdrawal is liked with sucking sound (Wikipedia, 2021a)
4- Water comes back with white foams (Boxing Day Tsunami, 2004).
5- Withdrawal water (1-5 m) amplified in coming back (2-50 m) by ratio exceeds 1,000%; exhibited by Runup that can exceed 34 meters (Prasetya G. et al., 2011).

Mechanism is defined scientifically as "*A doctrine that holds natural processes (as of life) to be mechanically determined and capable of complete explanation by the laws of physics and chemistry*" (Webster.com); based on this, the explanation of tsunami mechanism must answer these related phenomena, based on laws of physics.

While reviewing studies on the phenomenon, the absence of wildlife in epicenter of 2004 Indian Ocean earthquake and tsunami (Wilson, 2004), with piles of mud hundred meters thick discovered in the epicenter (Connor, 2005), linked with the recurrence of tsunamis in eastern Hokkaido (Sawai et al., 2009), Tohoku, Sanriku and Jogan (Satake, 2014), within the Japan Trench; always started with withdrawal of water, all these pointed to the existence of a great crack sucking water and wildlife and dumped huge piles of mud at epicenter; therefore we suggested the existence of holes around epicenters of earthquakes where tsunami normally occurred; particularly with the discovered ~20-km long trench near epicenter of 2004 earthquake and tsunami (Moran, 2006), that reinforced our suggested mechanism that, the energy of the Tsunami is derived from the interaction of the huge amount of the receded water with magma inside a chamber opened by the earthquake, the expansion ratio in our model is 1,700:1 at 100^{o} C (Hartin, 2010), with this great force of steam pressure, and based on the shape of the crake outlet, the pressurized steam can raise sea level by one to ninety meters or push water upwards and sideways with great force; the tragic events of the Indian Ocean tsunamis in 2004 and the Japan Tsunami in 2011 demonstrated the vulnerability of coastal populations irrespective of the level of preparedness, particularly as Asia Oceania accounted for 80% human lost Globally (AOGS website), and Asia experienced the highest number of climate-related disasters (IPCC, 2012), and 80% of tsunamis are in Pacific Ocean (Wikipedia, 2021a), these vulnerabilities highlight the need for timely and accurate forecasts and warning (Tang, L., et al. 2012), and above all knowing the locations of magma chambers, thus as stated before, "*without knowing the mechanism of tsunamis and their energies, it would be difficult to develop a reliable warning system for saving lives and property in tsunami emergencies*" (Song et al,, 2017), therefore, these ideas suggested answers to the above questions in addition to preliminary idea on estimating quantity of both receded and tsunami waves and its magnitudes; I hope these ideas may help in understanding the phenomenon of Tsunami in order to protect humanity from its dreadful destructive forces.

2. Tsunami Precursor (Indicators)

A- The Earthquake

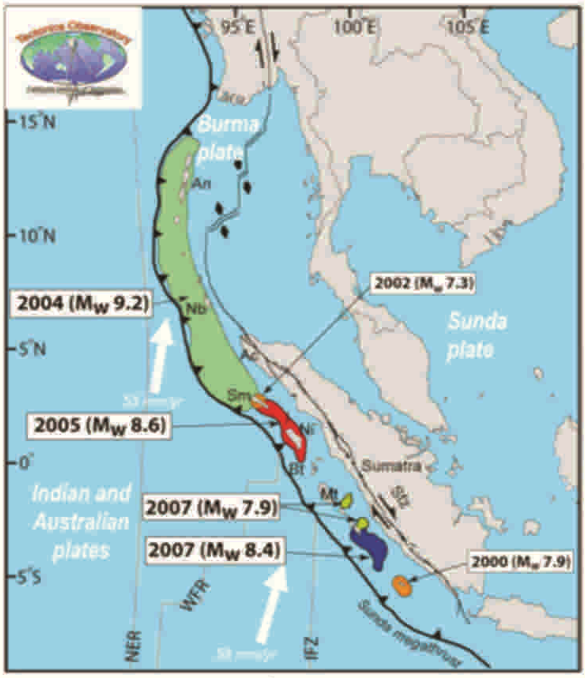

Fig. 1

Fig. 1. Earthquakes are the first precursor for tsunami, Indonesia is the second worldwide prone to earthquakes (World Atlas), and the figure shows six earthquakes and their magnitudes, leading by 2004 earthquake-tsunami (Tectonics Caltech.edu).

B- The Withdrawal

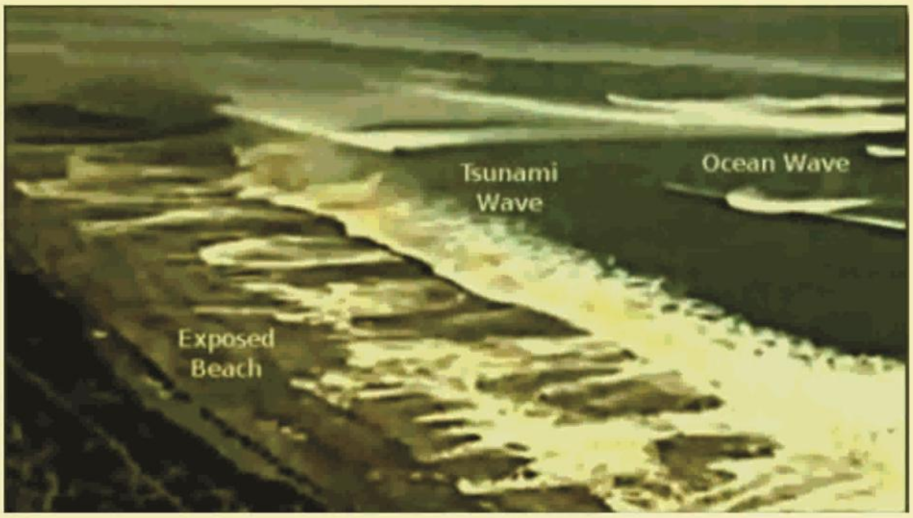

Fig. 2

Fig. 2. Coastal area exposed after earthquake, tsunami wave seen approaching with foams, while ocean wave followed at back (SMS Tsunamis, 2018), foams is a unique characteristic

of tsunami wave (Ioualalen M, et al., 2007).

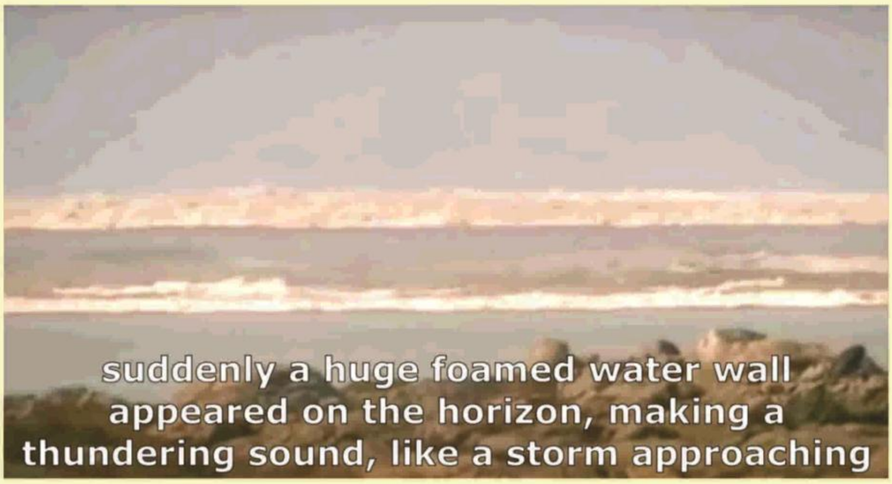

Fig. 3

Fig. 3. At the Boxing Day in December 26, 2004, a witness at Pokut in Thailand described the arrival of tsunami as "*arrival of huge foamed water wall, making thundering sound like storm*" (Boxing Day Tsunami, 2004), these are characteristics of condensation of steam.

Fig. 4

Fig. 4. Drawback in Phuket, Thailand, on Boxing Day 2004, people unaware of danger observing the exposed seabed (SMS Tsunamis, 2018), only panic watching approaching wall of water; survivors reported an accompanying sucking sound during withdrawal (Wikipedia, 2021a). Where did the water have gone, and why coming amplified with foams?

C- Withdrawal and Tsunami Waves

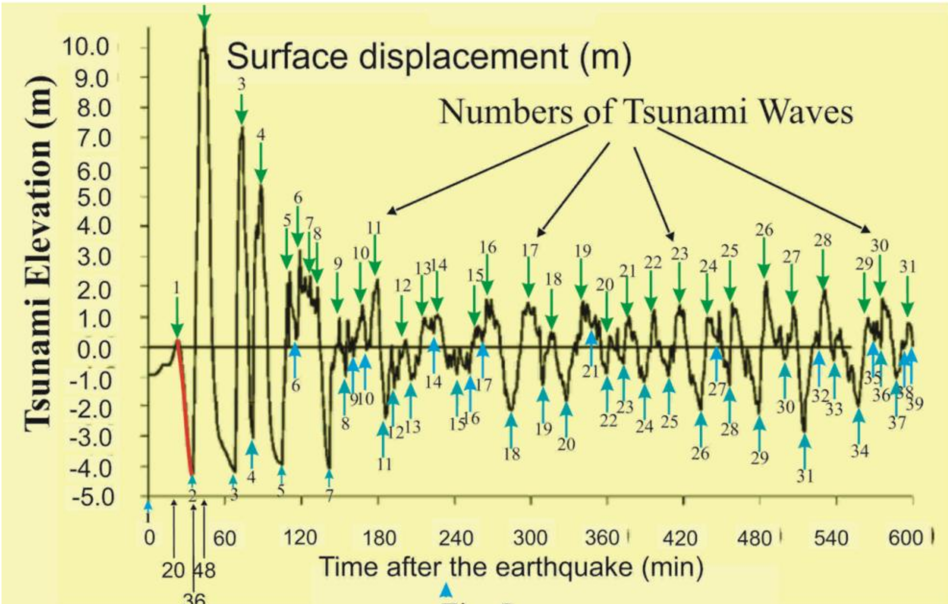

Fig. 5

Fig. 5. Time series of computed tsunami wave profile of uplift and subsidence at Ulee Lheue coast in Banda Aceh (Sasaki et al., 2011), withdrawal started with earthquake, it means a crake was opened on seabed swallowing the water. Main withdrawals are 39 times, while tsunami waves are 31 times, each withdrawal followed by amplification bellow the seabed, what repetitive mechanism can do this other than steam?

D- Volume of Withdrawal Water

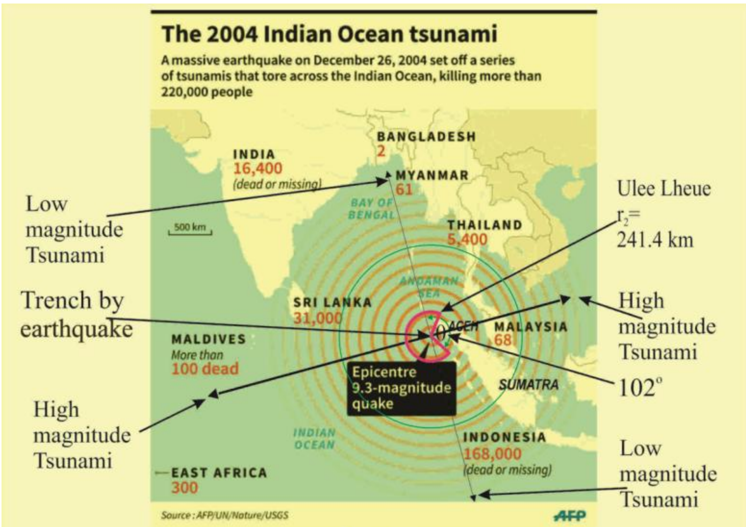

Fig. 6

Fig. 6. Volume of tsunami water was estimated as 4.e+7 m^3 (4.e+13 cm^3) (Satake and Kanamori, 1991) while (Abe, 1973) estimated water from several large earthquakes, like 1964 Niigata earthquake (M_w = 7.4), as 1.25e+11 m^3 (5 km^3) (Kanamori et al., 1993), while (Satake and Kanamori 1991) suggested 1.e+12 to 8.e+12 m^3 (10 to 20 km^3) (Kanamori et al., 1993); using Eq. (1), we derived the larger area of withdrawal in Fig. 6, from the map of 2004

Sumatra tsunami (AFP/UN/Nature/USGS), and given by as

$$A_{SL} = (\pi r^2) - \left(\frac{\theta}{360^o} \pi r^2\right) \quad (1)$$

Where, r is the radius in Fig. 6 is the epicenter to Ulee Lheue which is 241.4 km (150 miles) (TOBITA et al., 2006), θ is an angle in degrees (102^o), and A_{SL} is the area of the larger sector Area = 1.3120235e+11 m^2, multiplying this by the depth of receded water (4.25-12 m) we get the volume of water in Table. 1.

E- Volume of the receded water

Data	Area of receded water for Ulee Lheue = 1.3120235e+11 m^2	
Depth of receded water in m	4.25	12
Volume m^3 of total water	5.576e+11	1.574e+12
Inlet area	Flow Time (min)	Flow Time min
Period to fill the chamber if inlet area = 1.6e+8 m^2	58 minutes	164 minutes
Period to fill the chamber if inlet area = 4.e+6 m^2	2,323.3 minutes	6,558minutes
Flow Time (min)	Area of the entrance to the chamber	
12 m = 720 sc. (2 Fig. 5)	7.744e+8 m^2	2.186e+9 m^2
23 m = 1,380 s (2 Fig. 5)	4.040e+8	1.140e+9

Table 1

Fig. 7. Table 1. Volume of withdrawal water from Ulee Lheue in Sumatra 241.4 km (150 miles) from 2004 tsunami epicenter (TOBITA et al., 2006) using Eq. (1), the area of the large sector in Fig. 6, is obtained (1.3120235e+11 m^2), multiplied by the two reported levels of withdrawal, 4.25 and 12 meters, the volume of the receded water, around 5.576099875e+11 m^3 and 1.574e+12 m^3.

3. The Energetic Steam

A- The Amplification of Steam

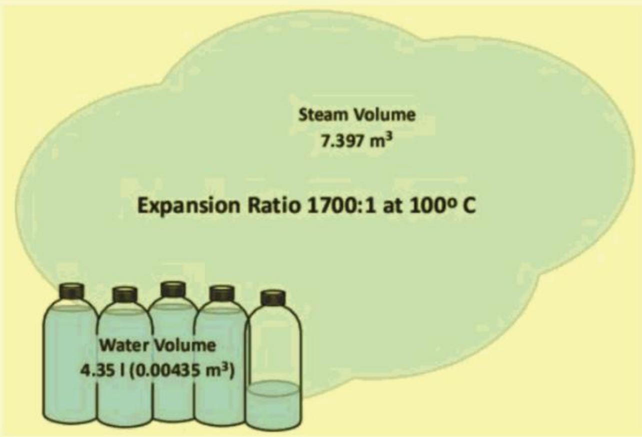

Fig. 8

Fig. 8. Water expands in volume by 1:1,700 times at 100^{o} C, when vaporized to steam (Hartin, 2010). Steam is commonly formed by boiling or evaporating water (Wikipedia, 2021b); if water comes in contact with a very hot surface or depressurizes quickly below its vapor pressure, it can create a steam explosion (Wikipedia, 2021b).

B- The anomalous Behavior of Water

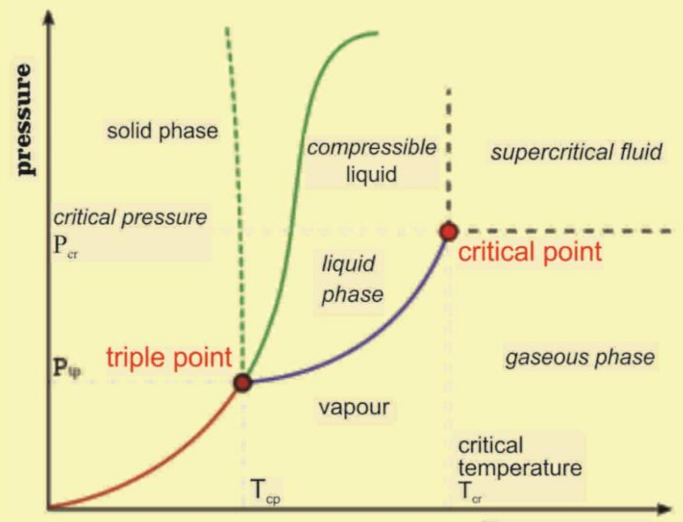

Fig. 9

Fig. 9. The **phase diagram** showing the pressure and temperature for the three states of solid, liquid and gaseous, which occur and coexist at equilibrium. The dotted green line gives the anomalous behavior of water. The green lines mark the freezing point and the blue line the boiling point, showing how they vary with pressure (Wikipedia, 2021c).

C- The Uncontrollable Steam

Boilers must withstand tremendous amounts of heat, pressure and vibration (Wikipedia, 2021d).

Fig. 10

Fig. 10. The explosion of boiler (Baker, 2017), 96 boilers exploded in ships/trains/power

stations between 1716-2017 (Wikipedia, 2021e).

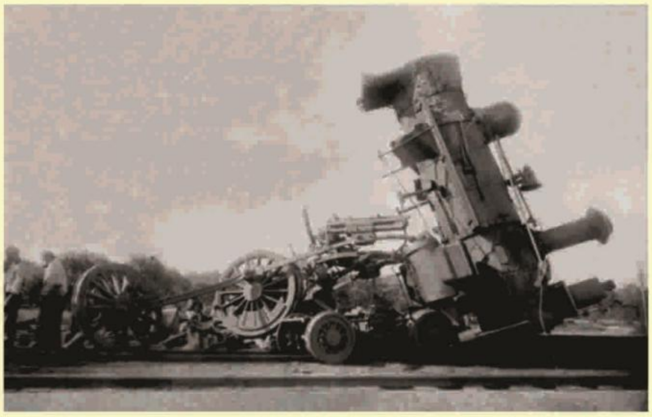

Fig. 11

Fig. 11. Crumbled within by exploded boiler! (Wikipedia, 2021e), what role does a sudden expansion of gas 1,700 times have on that?

4. Magma Networks & Energy

A- The Magma Networks

Rivers & fountains of Lava

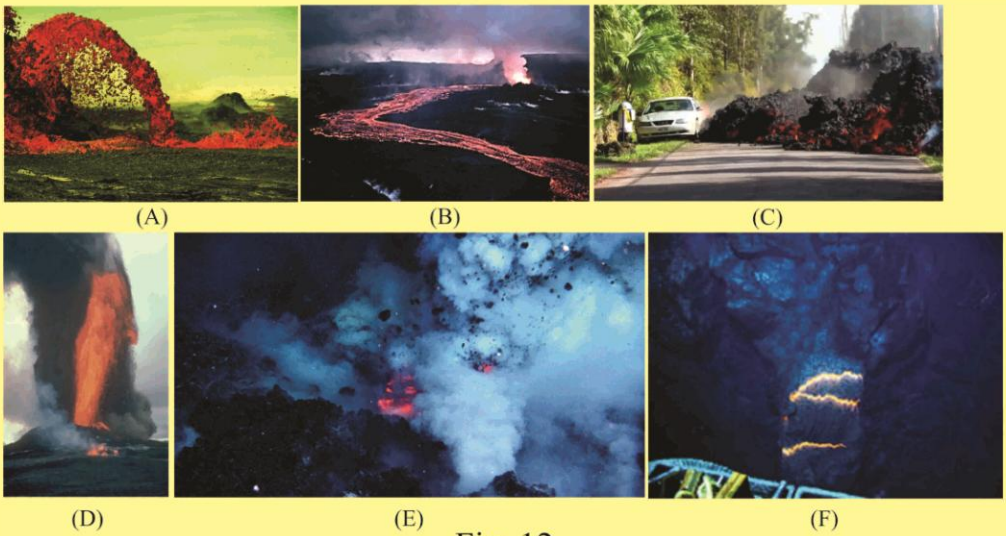

Fig. 12

Fig. 12. Lava in volcano sites, reflecting internal energization inside earth! In (A) 10 meters fountain in Hawaii (Wikipedia, 2021b) (B) Lava flow in Krafla, Iceland (Wikipedia, 2021b), (C) Lava and car in Hawaii (The Guardian, 2018), (D) 450 meters lava fountain at Kilauea (Wikipedia, 2021b), (E) Eruption of West Mata Volcano in 2009 Image courtesy of NOAA/NSF /WHOI, (F) the deepest ever filmed submarine volcano, West Mata, May 2009 (Wikipedia, 2021e).

B- Lava Tunnels revealed Magma Activities and the Massive Internal Flow

Fig. 13

Fig. 13. Manjanggul Cave in Eastern Jeju-do, in South Korea, formed between 200,000-300,000 years ago (Tuomas Lehtinen / Getty Images), the Cave is 22.8 meters across at its widest point and reaching heights as tall as 30.4 meters (TAMARA, 2020), the existence of such huge cave shows the capabilities of magma to be delivered in huge flow.

C- Magma Existed at the Low-Shear-Velocity Provinces (LLVPs)

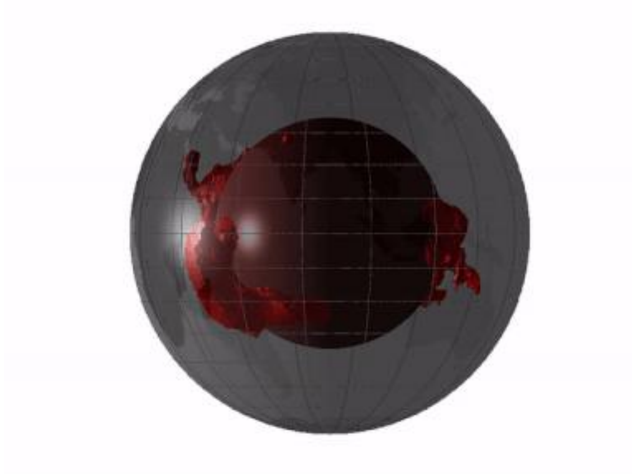

Fig. 14. Animation of the Large Low-Shear-Velocity Provinces (LLVPs) as inferred using seismic tomography, shown are the African and Pacific LLSVP, both extending laterally for thousands of kilometers, vertically from core-mantle boundary, the pacific LLSVP extend 3,000 km across, and underlies four hotspots, suggesting multiple mantle plums underneath (Wikipedia, 2021h), this shows the source and distribution of magma networks and how it can be replenish.

Core-mantle boundary (CMB) the Source of Magma

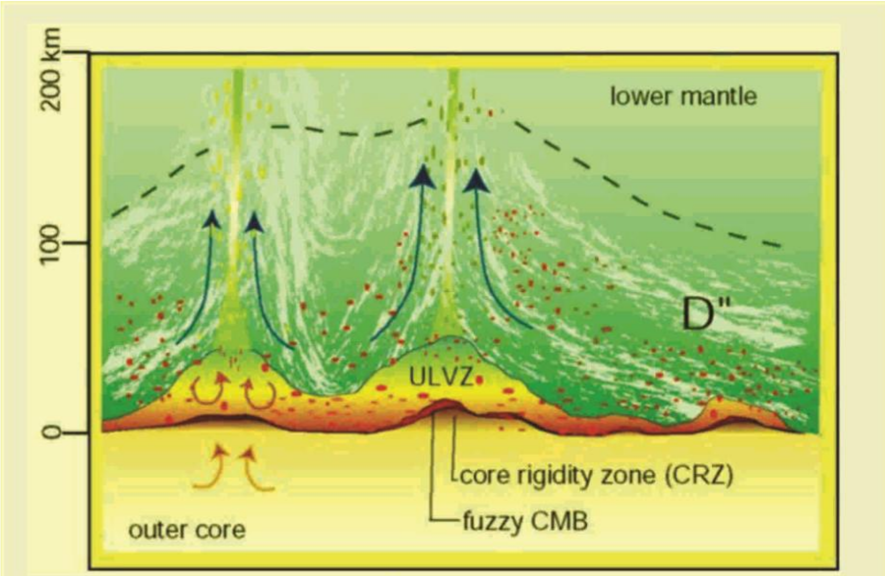

Fig. 15

Fig. 15. At Core-mantle boundary (CMB) ~2885 km, Vs = 0, Vp drops, this is the Ultra Low Velocity zones (ULVZ) possibly due to partial melt (University College London); ULVZs are patches on the core-mantle boundary (Wikipedia, 2021i), ULVZs have higher density than their surroundings (Wikipedia, Magma, 2021m) explaining the very reduced seismic velocities in ULVZs also requires massive local melting within the lowermost mantle (Jeanloz R. and B. Romanowicz, 1997), That's where we suggested the melting of the boundary materials adjacent energization resulted from the production of the geomagnetic field at the outer core of the sun (Yousif, AGOA 2021).

Magma is transported from the Boundary of Mantle and Outer Core

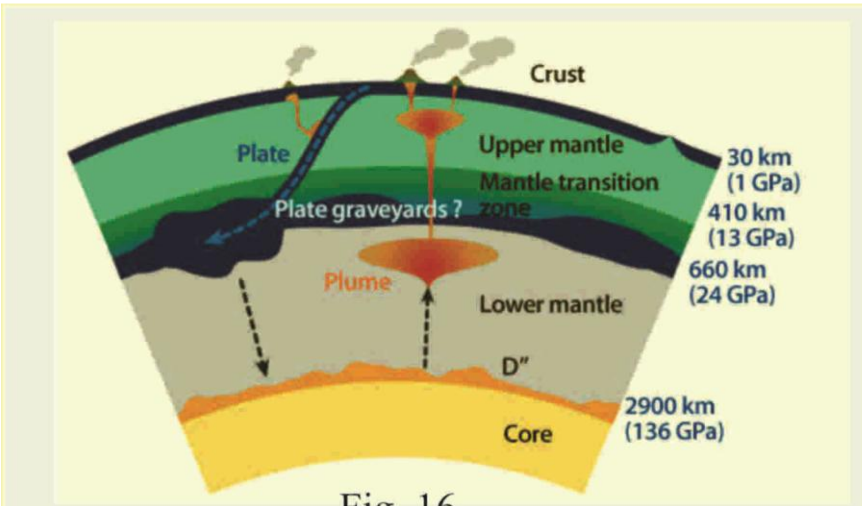

Fig. 16

Fig. 16. Magma from 150-180 kilometers deeper the 70 kilometers previous thought (Andrei, 2019), although this is a different view, but all agreed that magma are produced deeper inside the earth, the networks shows magma storages.

Yellowstone: An Example of Deep Magma Storage

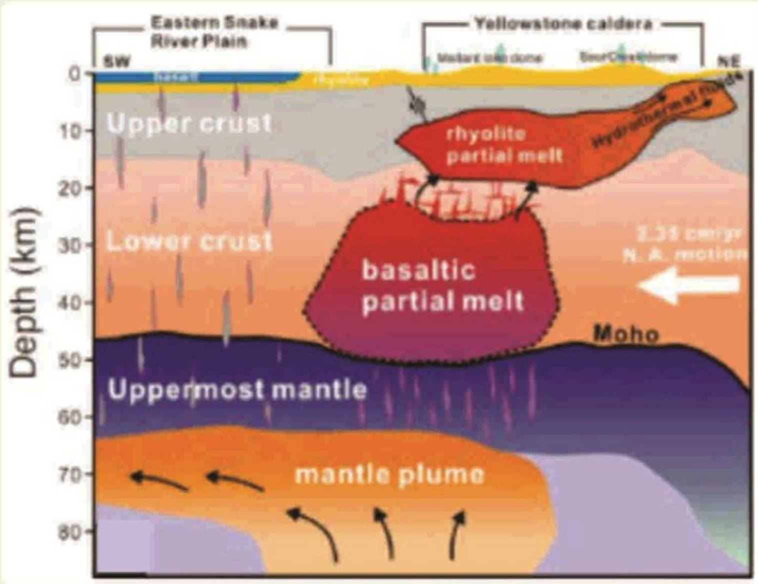

Fig. 17

Fig. 17. Yellowstone in United State, it contain the largest supervolcano (the caldera) on the continent, over half of the world geysers and hydrothermal features including lava flows are in Yellowstone (Wikipedia, 2021j). The high heat flux in Yellowstone is 40 times the continental average, its coming from the hotspot, which provides the heat for a large basaltic magma reservoir at depth of 20–50 km, the basaltic magma reservoir provides heat for a lower-temperature rhyolite magma reservoir at depths of 4–14 km, it is this rhyolite magma that fuels Yellowstone's geothermal system of geysers and hot springs. The basaltic magma body has a volume of 46,000 cubic kilometers (4.6e+13 cubic meters). Yellowstone system provides insights into how other magma systems around the world work (*Smith*, 2018). The volume of magma body in Yellowstone to be compared with the withdrawal water in Figs. 2, 3&4 and tabulated in Table. 1 (Fig. 7).

D- Geyser in Yellowstone: Result of water interaction with Magma

Fig. 18

Fig. 18. Liquid phase eruption of Castle Geyser in Yellowstone Park (Wikipedia, 2021b), these phase of magma-water interaction exhibited in the Geyser, existed under seas, oceans and the Japan, Nicaragua, Mentawai and Andaman-Sunda trenches.

Video: Micro-Tsunami

View of the steam rising from Steamboat Geyser after an eruption earlier in the day (Yellowstone National Park). This is resulted from interaction of water and magma, similar to tsunami generation!

E- Hawaii hotspot is a Huge Magma Chamber

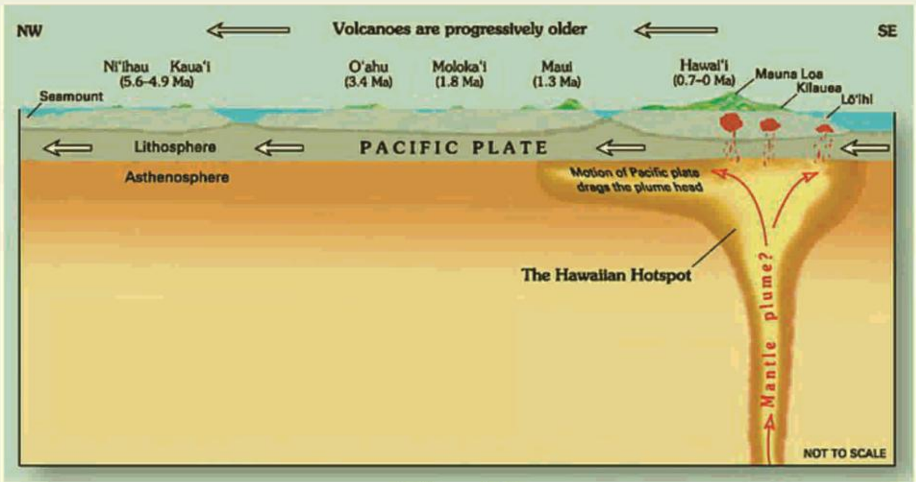

Fig. 19

Fig. 19. Age-progression of volcanic islands and seamounts at the Hawaii hotspot (Wikipedia, 2021k), The temperature of the magma chamber at 90–100 kilometers (56–62 mi) is about 1,500 °C (2,730 °F) (Wikipedia, 2021l).

Suggested Magma Chamber at Tsunami Locality

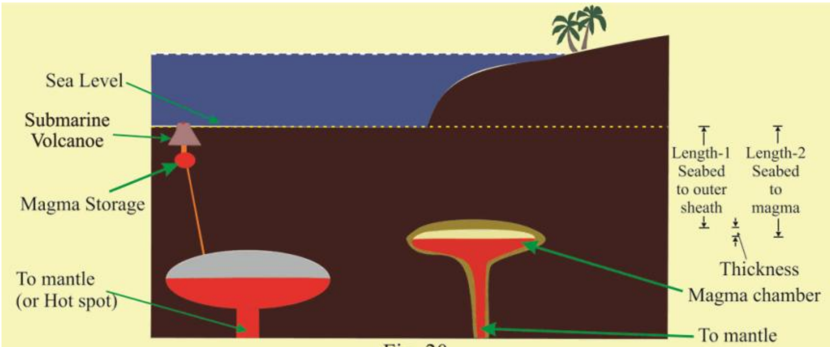

Fig. 20

Fig. 20. We suggested the existence of magma chamber or hotspots under seabed at areas, where earthquake-tsunami occurred, the volume of the chamber, liquid magma, its temperature and size of passage to mantle determine the magnitude of the tsunami and numbers of produced waves, also shown are the length-1 from seabed to outer sheath and length-2 to magma level.

F- The Proximity and Non-Proximity of Earthquake to Magma Chamber: The 2000, 2002, 2005, 2004, 2007a, 2007b Earthquake

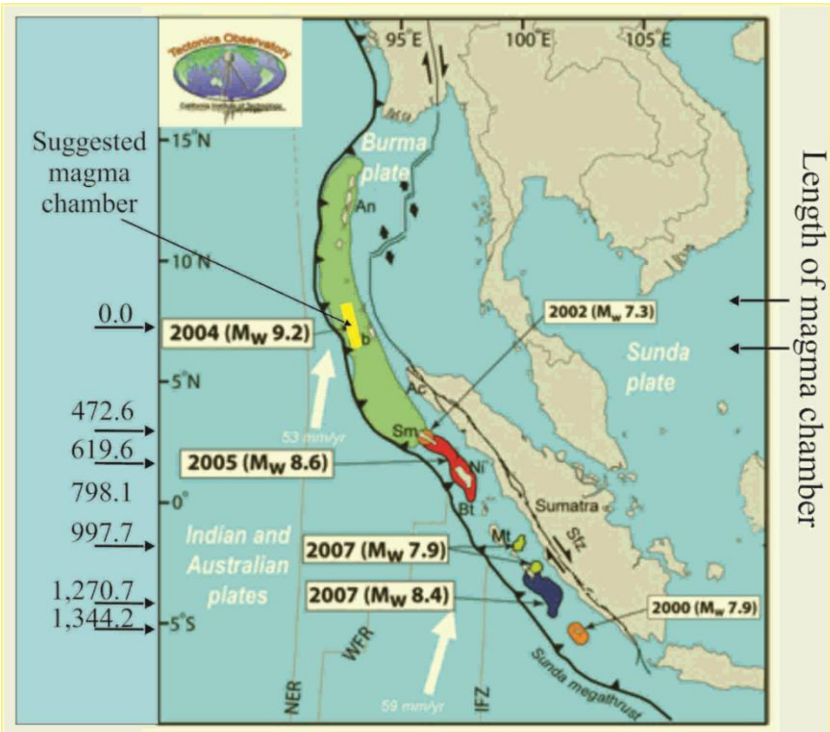

Fig. 21

Fig. 21. Map of the 2004 earthquake and tsunami (Tectonics Caltech.edu), we suggested the existence of deep magma storage in yellow color beneath 2004 tsunami. The distances between this chamber and five epicenters, are: **<u>2002</u>** (M_W 7.3) = 472.6 km, **<u>2005</u>** (M_W 8.6) =

619.6 km, **2007** (M_W 7.9) = 997.7 km, **2007** (M_W 8.4) = 1,270.7 km, and **2000** (M_W 7.9) = 1,344.2 km. These earthquakes failed to trigger tsunami because distances are great, the March 28, 2005 Mw = 8.6, its magnitude was high without major tsunami (Tang, L., et al. 2012), its 619.6 km from the chamber, it opened small crack and related small tsunami (Tectonics Caltech.edu), only 3 meters tsunami (Wikipedia, 2021w), thus magma chamber can only be accessible for large withdrawal when distance to magma chamber is short.

G- The Proximity of Earthquake To Magma Chamber and Recurrence of Tsunami: The 896, 1896, 2011 Earthquakes and Tsunamis

Example-1: The 869, 1896, 2011 Earthquakes and Tsunamis

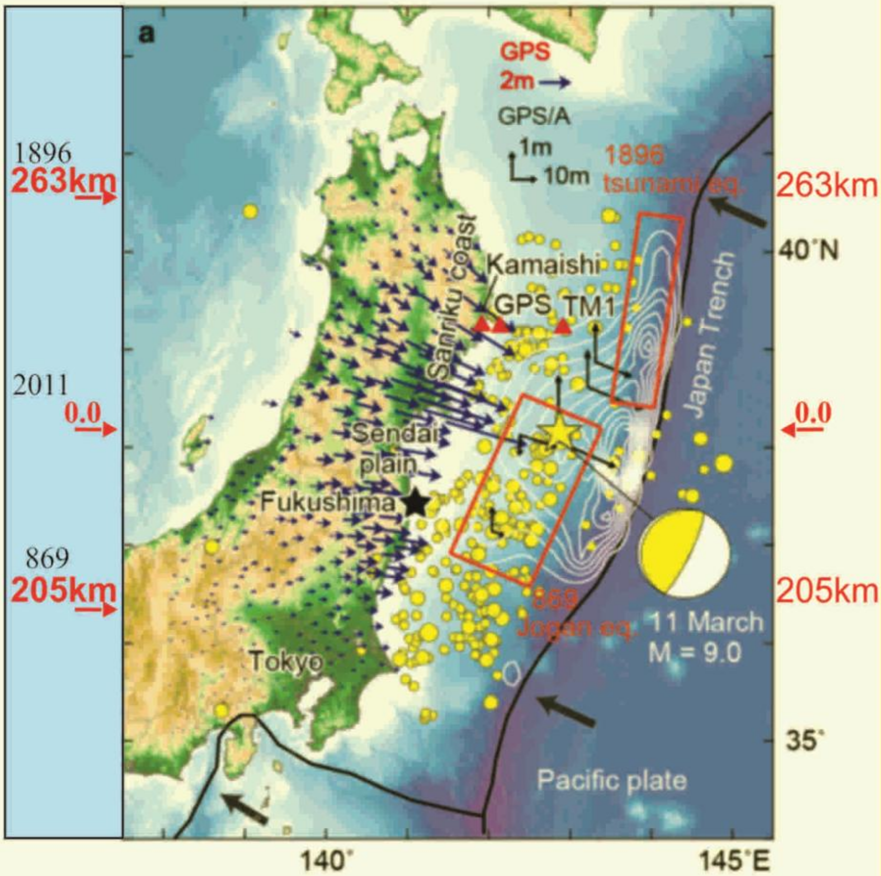

Fig. 22

Fig. 22. Since the link between large tsunamis than expected and earthquakes, thought important for disaster mitigation among others (Seno, 2002), it was realized that, the source of the 2011 earthquake appear to be a combination of the 1896 Sanriku "tsunami earthquake" and a Jogan type the size Mw = 8.3 to 8.4 (Satake, 2014). We derived distances between epicenters of Tōhoku, Sanriku and Jogan earthquakes and tsunami, for Tōhoku and Sanriku its 263 km and for Tohoku and Jogan its 205 km, both distances are smaller than in Fig. 21, therefore we suggested these tsunamis were generated from a common magma chamber, which will result in nearly the same magnitude of tsunami.

Example-2: Tsunami at Tori Shima, Japan, 1984

An earthquake with magnitude mb = 5.5, MS=5.5, occurred near Tori Shima, Japan, on June 13, 1984 at 31.448$^{\o}$ N, 140.036$^{\o}$ E, depth of 10 km, it generated tsunamis which are disproportionately large for the magnitude of the earthquake. At Hachijo Island, 150 km from the epicenter, tsunamis were visually observed with peak-to-peak amplitude of 130 to 150 cm (Kanamori et al., 1993). In this example, the depth of the magma chamber was shallow, and easily opened, allowed great amount of water to interact with magma and resulted in great tsunami wave.

The Sudden crake in Earth Sediment Created Huge Soundless Earthquake’s Tsunami: The case of May 1781 southwestern Taiwan coast.

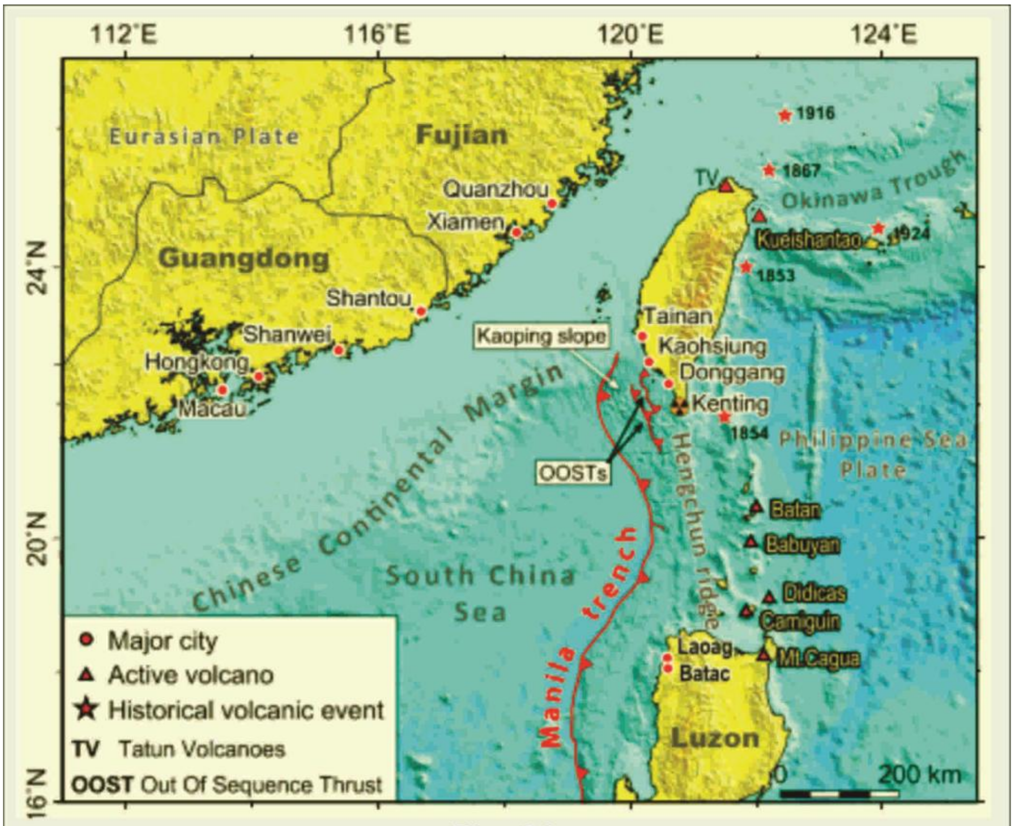

Fig. 23

Fig. 23. Example One: Donggang town and Bay in northeast South China Sea, the map shows marks of volcanoes and earthquakes (Li et al., 2015). In May 1781, in the current Dapeng Bay, the sea suddenly roared like thunder, and sea retreat quickly, exposing leaping fishes and shrimps, then an exceptionally large and localized tsunami waves occurred under clear skies and submerged all nearby villages, (Li et al., 2015). We liken that tsunami with the soundless eruption of Geyser in Yellowstone Park shown in Fig. 18 (Wikipedia, 2021b) and the above video, if a crake suddenly occurred in magma chamber such in Fig. 20, huge amount of water will enter the chamber, causing withdrawal and created tsunami without an

earthquake. The existence of foams on seas and oceans around the world could be interpreted from this perspective.

Example Two: The Papua New Guinea (PNG) tsunami of July 1998, was thought as caused by Submarine Mass Failure (SMF), due to the small magnitude of the earthquake 7.1, while the generated tsunami was 10-15 meters high (Tappin, et al,. 2008), But as explained, small magnitude of earthquakes can cause crake into large magma chamber produced huge steam and related tsunami waves, which can cause such devastations.

5. The Tsunami Mechanism

Panel 1: Networks of Magmas Under seabed

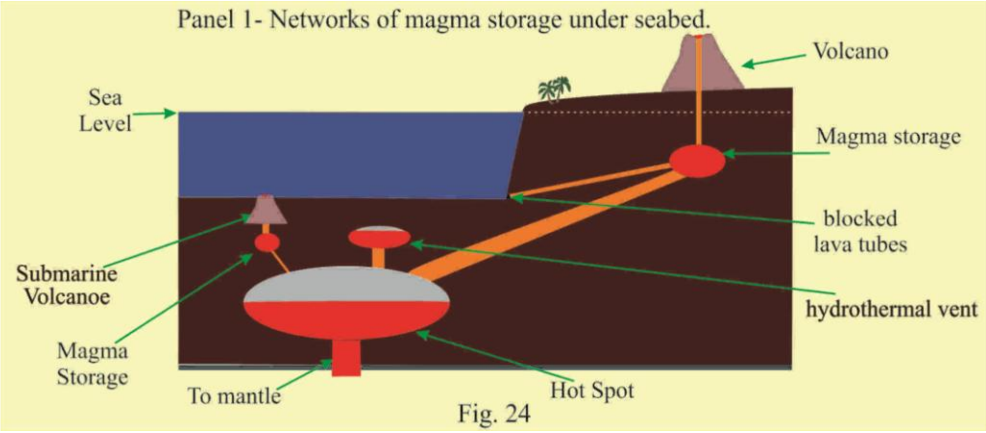

Fig. 24. Submarine volcanoes are in Earth's surface from which magma can erupt, many of them are located near areas of tectonic plate formation, known as mid-ocean ridges and Hydrothermal vents, they are sites of abundant biological activity (Wikipedia, 2021e); their numbers is estimated to be over one million, most are extinct, of which some 75,000 rise more than 1 km above the seabed (Wikipedia, 2021e), most of these are located in the depths of seas and oceans, although some in shallow water (Wikipedia, 2021e), the figure shows such networks (Wikipedia, 2021k), where network of magma storage and transport through the entire crust, with thickness ranging between 10 and 60 km (ANNEN et al., 2006) (Front Matter, 2017).

Panel 2: Earthquake Caused Crake on Seabed and Magma Storage.

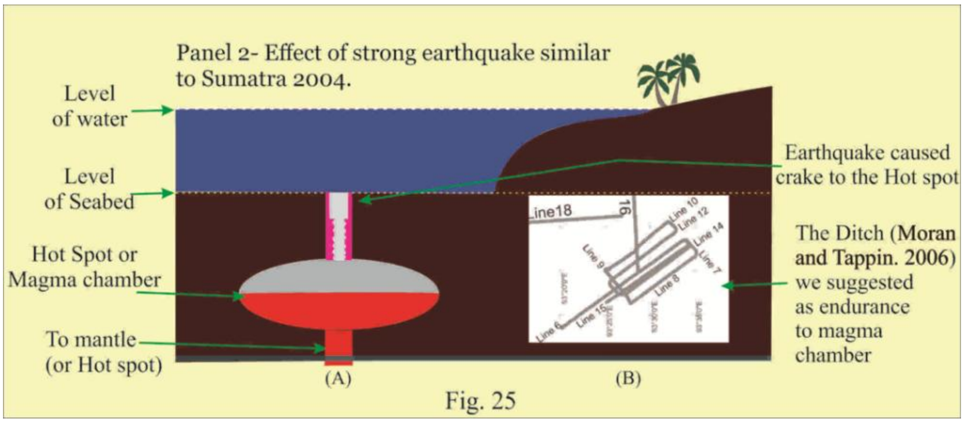

Fig. 25. Since 83% of tsunamis generated by earthquakes (Tang, L., et al. 2012), and as an oceanic trench several kilometers wide was discovered in the epicenter of 2004 Sumatra earthquake and tsunami (Knight, 2005), and the Tohoku earthquake in Japan in March 2011 generated worst tsunamis in Japan's history, its source approximately aligned with the Japan trench, around 2.5 km from the epicenter (Dettmer et al., 2016), thus an earthquake strike in Fig. 25, opened crake to the magma chamber in (A) while (B) shows ditch in epicenter of 2004 Sumatra earthquake-tsunami.

Panel 3: Sucking of the withdrawal Water.

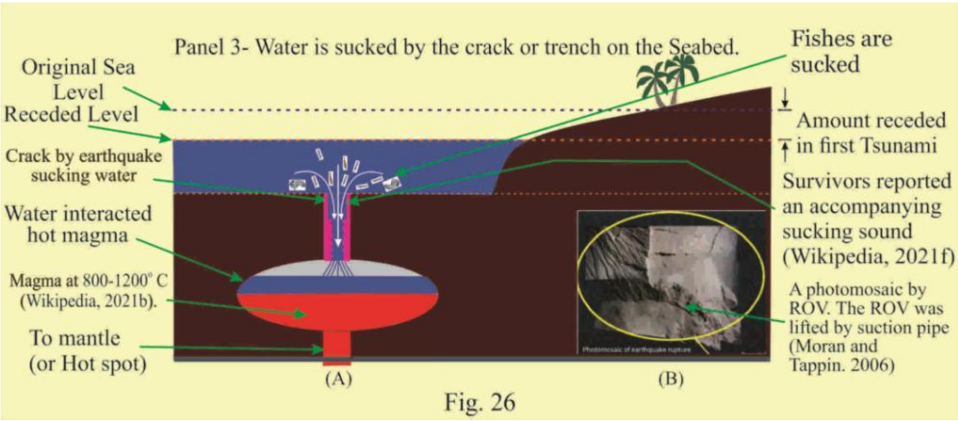

Fig. 26. Withdrawal water is filling the magma storage, such trench was discovered by HMS Scott on the seabed of 2004 Sumatra–Andaman earthquake (Wikipedia, 2021n), we suggested existence of magma storage under it, similar to Yellowstone's in Fig. 17 (*Smith*, 2018), when earthquake caused crake in it, this is at 0 hour in Fig. 5, it sucked water through the crack in (A) leading to the magma storage, survivors reported an accompanying sucking sound (Wikipedia, 2021a), this as sound travel several times faster in water (Johnson, 2018) (Sciencing.com), while in the report by SEATOS in May 2005, the trench (Ditch) (B) in the epicenter shows several freshly deformed soft rock features and no marine life, suggesting it was very recently formed (Moran, 2006) , and the spacing averaged in the profiles in Fig. 25 is 2 km; each profile was ~20 km long (Moran, 2006).

Panel 4: Tsunami = Amplification of water into steam by 1,700 times!

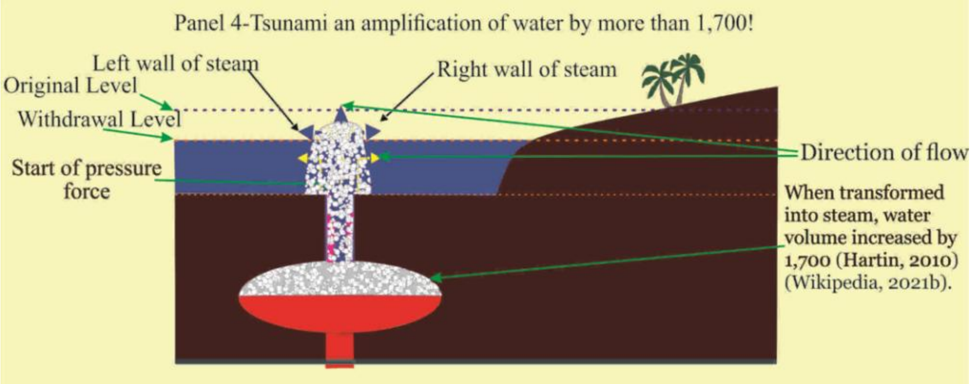

Fig. 27

Fig. 27. The withdrawal water interacted with magma in the chamber, if at 90–100 kilometers (56–62 mi) temperature is about 1,500 °C (2,730 °F) (Wikipedia, 2021l), while lava on earth is 800-1200^{o} C (Wikipedia, 2021b), we estimated magma at chamber at 1,200-1,500^{o} C, and since this is above the 367^{o} C (640 K) critical temperature, in which liquid and vapor phases are indistinguishable, and the substance is called a supercritical fluid (Wikipedia, 2021o), thus water immediately vaporized the resulted steam increased in volume by 1,700 times (Hartin, 2010), (Wikipedia, 2021b), this resulted in explosive power like the boilers in Figs. 10&11, this power raised the steam and water along the crakes upwards as shown.

Panel 5: The Force of the Pressure!

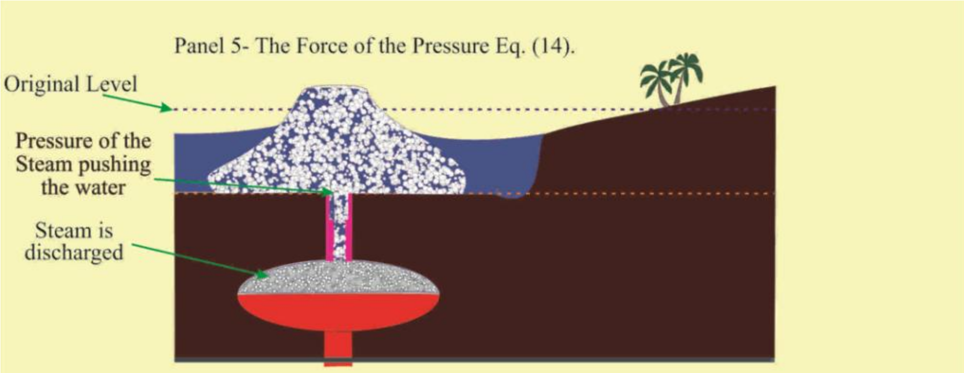

Fig. 28

Fig. 28. As steam push water through the entrance and rising the column of water through the ocean toward the surface, the steam/water will force its way on the four sides of the water while rising.

Panel 6: Maximum Force of Pressure = Maximum High = Maximum Tsunami Wave.

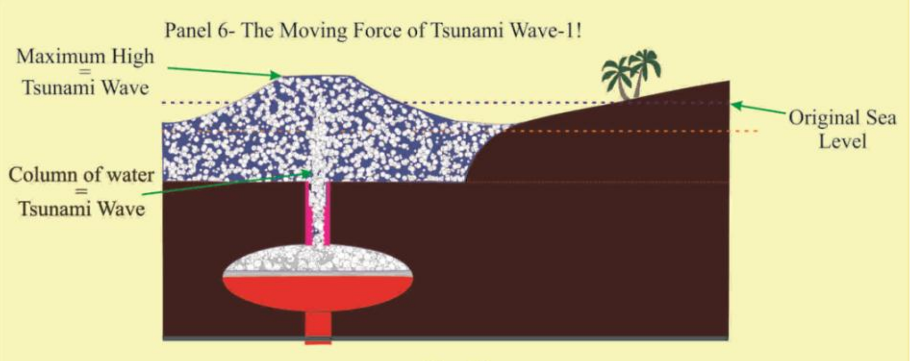

Fig. 29

Fig. 29. The steam pushed water upwards, it emerged from the seabed, and since tsunami waves travel outward in all directions as it originated (neamtic.ioc-unesco.org/), thus the direction of the water will be divided to the four sides in addition to the vertical one, while moving upwards, and the flow will be greatly along the width of the trench towards the beaches as shown in Fig. 6, indicating the start of tsunami wave, because the receded water is now raising very fast; the Maximum Force of Pressure = Maximum High = Tsunami Wave. The velocity of a tsunami wave can be calculated by obtaining the square root of the depth of the water in meters multiplied by the acceleration due to gravity (9,8 ms^2), it's given by (neamtic.ioc-unesco.org/)

$$V = \sqrt{h \times g} \qquad (2)$$

Where, h is the depth of the sea expressed in meters, g is the acceleration of gravity 9,8 m s^{-2}, and V is the velocity in m s^{-2}.

Panel 7: The Moving Force of Steam Pressure: Tsunami Wave!

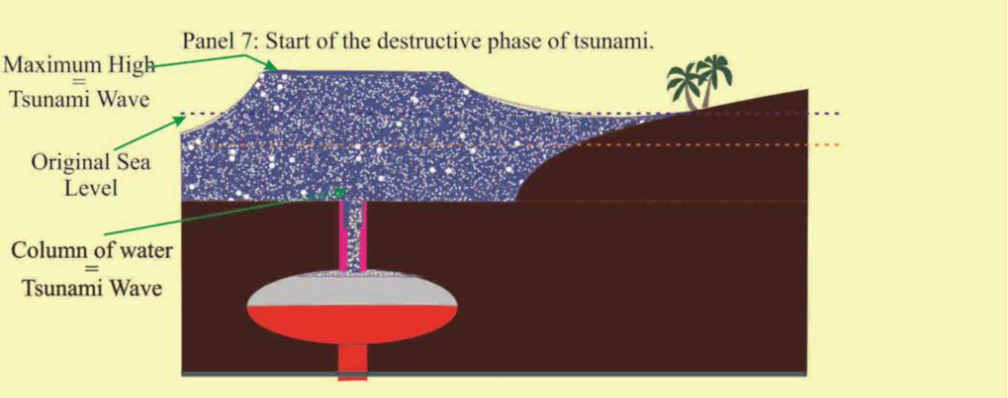

Fig. 30

Fig. 30. The moving force of the tsunami wave now reaching the coastline, where those at the beaches or enjoying the receded water in Fig. 4 (SMS Tsunamis, 2018), are shocked by the water coming with foams (Boxing Day Tsunami, 2004), because the extremely hot steam raised through the cool water of the ocean, its temperature coaled down and condensed forming the foams or bubbles.

Panel 8: Start of the destructive phase of tsunami.

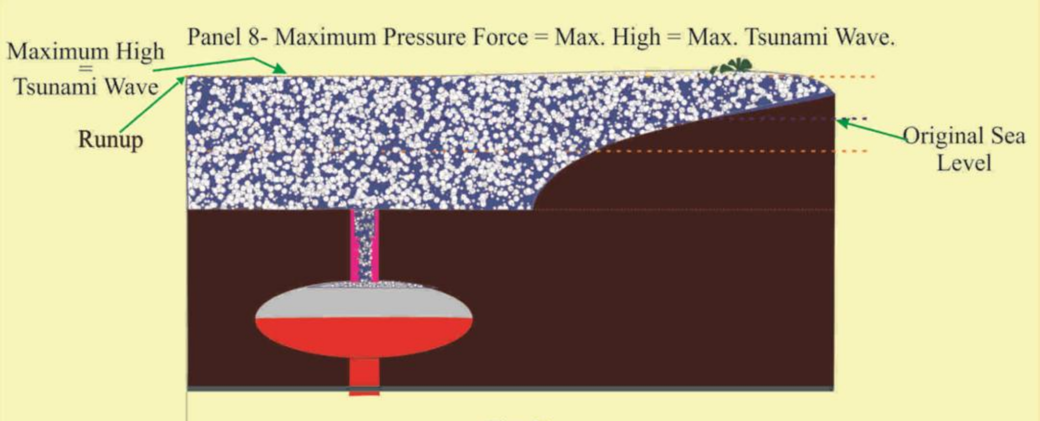

Fig. 31

Fig. 31. The first wave of tsunami in a series could reach the beach in few minutes (neamtic.ioc-unesco.org/), as shown it depends on many factors; this is the start of the destructive phase of tsunami, when tsunami exceeds the normal sea level. The flow depths of 2004 tsunami, along the northern shores of Banda Aceh varied from 6 to 12 m, inundated the coastal plain up to 5 km inland, the west coast, flow depths were generally on the order of 15–25 m along the shores with extreme runup up to 35 m to the south of Lhok Nga. The two large waves followed the first in Fig. 5 (Sasaki et al., 2011), in Ulee Lheue in Banda Aceh, the tsunami height was 6 m (20 ft) at Ulee Lheue to 8 km (5.0 mi) in the north-east, inundation was observed to extend 3–4 km (1.9–2.5 mi) inland throughout the city (Wikipedia, 2021n), as the steam condensed, water start returning to normal sea level.

Panel 9: The end of First wave; the start of the second great water withdrawal!

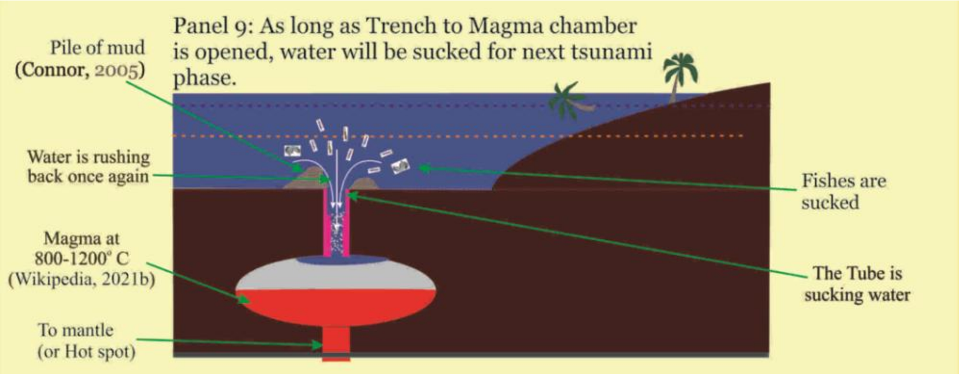

Fig. 32

Fig. 32. Although we illustrated the first wave as strong, but as in Fig. 5, second withdrawal and tsunami was the greatest (Sasaki et al., 2011), it start immediately after the end of the first wave, which reach the maximum inundation and runup, the water stat receding and enter the magma chamber again, as depicted in plate-3, Fig. 26; HMS Scott's couldn't detect any wildlife around the epicenter for nearly eight days (Wilson, 2004), this means all animals were sucked into the magma chamber, while geologists Dr Tim Henstock said: "There are features which we would think are something like the Grand Canyon would looks, "*you can*

see huge piles of mud maybe a few hundred meters thick"; "*there's a lot of evidence of activity at the subduction zone*" (Connor, 2005), it's the reason we included fishes and different species entering the chamber in this figure, while the piles of mud, are dumped by the outburst of the of steam, or by the incoming water, or both are possible.

Panel 10: Huge water is sucked in second withdrawal, with sea wildlife!

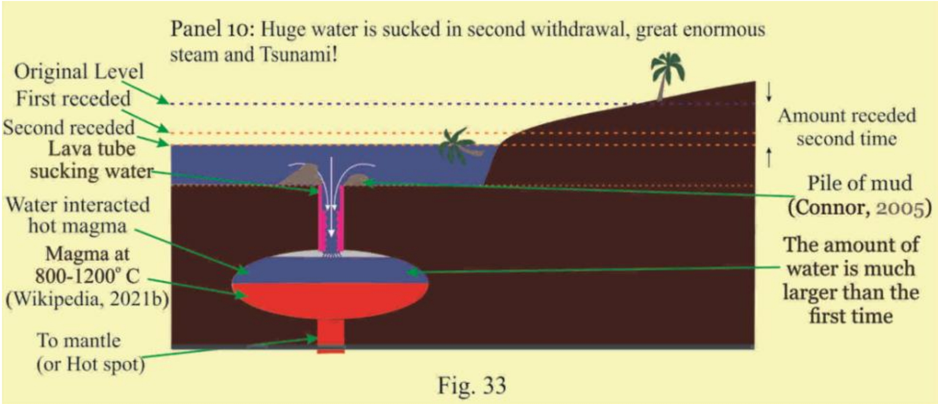

Fig. 33. The receded water reached minimum sea level, and maximum exposure of the beach at great distance, one of the palm tree was carried to the sea, the chamber is full once again with the water, great interactions are taken place, it will resulted in huge steam and pressure inside the chamber, which will resulted in great force of pressure, that will forced the still incoming water out of the chamber, raised as column of water and forming the second tsunami wave, the cycle will continue as long as the crake is open, and only stopes when its either closed, the 30 plus waves in 2004 shown in Fig. 5 may means the temperature is continually renewal by tunnels from mantle boundary with outer core.

Phases of Tsunami:

- Immediately after earthquake, the sea recedes slightly.
- Water is amplified in magma chamber.
- Small tsunami wave follows.
- As the steam condensed, water returned to normal level.
- Large amount of sea recedes for one-two kilometers.
- Great amount of water is transformed into steam in magma chamber.
- Great tsunami wave follows with great force.
- As the steam condensed, water returned to normal level.
- The sea recedes for second or third times, followed each time by tsunami wave.
- Finally when the trench is closed, water return to normality.

ⓄⓄⓄⓄⓄⓄⓄ

The destructive town of Banda Aceah

Boxing Day Tsunami Banda Aceh 1 of 4

https://www.youtube.com/watch?v=HVc4GH5Oduw

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'TSUNAMI-LIKE WAVES' Hit Village in Indonesia (Tidal Bore) | Kampar River (Sumatra)

https://www.youtube.com/watch?v=pKd0PCI6Sx4

ↀↀↀↀↀↀↀ

Why the Indian Ocean Tsunami Was So Deadly
https://www.youtube.com/watch?v=oMhVHM6WwWQ

ↀↀↀↀↀↀↀ

An earthquake with magnitude 7.4 struck eastern Indonesia today December 14, 2021 at 0320 GMT in the Flores Sea, it triggered tsunami warning, the warning was lifted two hours after the earthquake (Suroyo and Da Costa, 2021), because the tsunami didn't materialized. Therefore and as explained in section 4-G, this earthquake and many others strong earthquakes, showed the importance of knowing the locations of magma storages and the magnitude which can possible crake seabed and trigger tsunami wave, which can help raising levels of awareness and interventions; and although the area is fare from Sumatra magna storage, but there could be another storage as the area is near Papua New Guinea which had history of tsunami (Heidarzadeh et al., 2015) with devastated results (Tappin, et al,. 2008).

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6. Energy of Tsunami & Conclusion
   A- Deriving the Amplified Volume of the Tsunami Wave

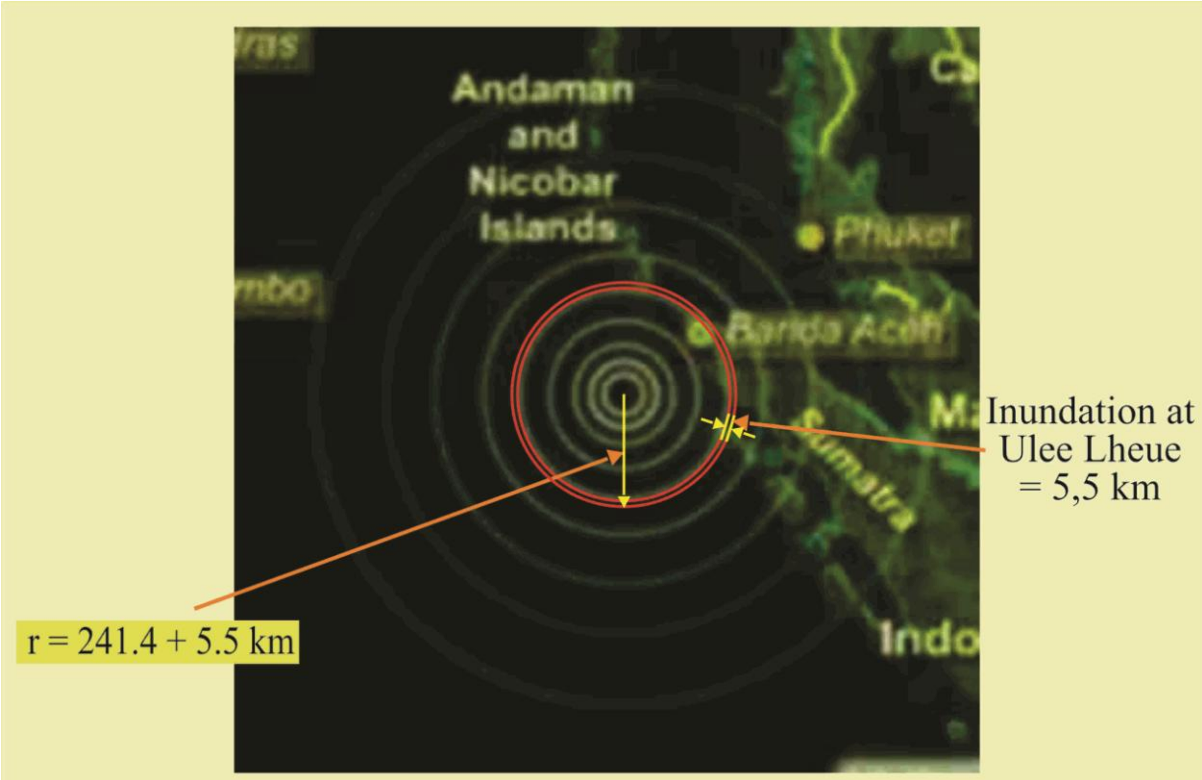

Fig. 34

Fig. 34. The Epicenter map of 2004 Sumatra–Andaman earthquake tsunami (Reuter, 2004) with inundation of 5,5 km at Ulee Lheue (Prasetya et al., 2011), tsunami wave represented by the circular area having radius from the epicenter to Ulee Lheue + inundation, this multiplied by the run up (h) gives the volume of the tsunami wave, as in Fig. 34, thus tsunami wave is given by

$$V_{TW} = \pi\, r^2\, h_S \qquad (3)$$

Where, r is the radius from epicenter to Ulee Lheue town plus the inundation distance 5.5 km, since the distance from the epicenter to Ulee Lheue 241.4 (150 miles) (TOBITA et al., 2006), inundation distance is 5.5 km, r = 241.4 + 5.5 = 246.9 km, height = 20 & 30 meters the results in Table. 2.

Table. 2. Volume of Tsunami Wave

Data	Amount of water in area covered by inundation distance r at Ulee Lheue = 1.5959e+11 m^2	
Tsunami height in m	20	30
Volume of Tsunami wave m^3	3.8302e+12	5.7453e+12

Table 2

Fig. 35. The Tsunami wave as derived from Eq. (3), the volume of water derived from the areas covered by circle in Fig. 34, from epicenter to the inundation distance 5.5 km after Ulee

Lheue beach its 246.9 km (150 miles) (TOBITA et al., 2006), then multiplied by 20&30 gives the amplified water.

Energy of Tsunami Wave

The Enthalpy (H), is the product of Mass (M) in a system and Specific Enthalpy (h), its

$$H = M \times h \tag{4}$$

While specific Enthalpy (h), is summation of internal energy (U) and Product of Absolute Pressure (P) and Specific Volume (V).

$$h = U + (P \times V) \tag{5}$$

The Specific Enthalpy of Super Heated Steam can be calculated from the regular equation.

$$h_s = h_g + C_p\,(T_s - T_f) \tag{6}$$

C_p - Specific Heat of Steam at Constant Pressure, which can be considered as 1.860 KJ/Kg.°C, Ts - Temperature of super heated Steam, T_f - Saturation temperature i.e., 100°C (Kalva, 20016).

When water enter the chamber it's instantly transformed into steam, and increased in volume by 1,700 times at standard temperature and pressure (Hartin, 2010) (Wikipedia, 2021b); it's suggested that only small percentage of the withdrawal water transformed into steam when interacted with magma in the magma chamber, this dynamic amount is by

$$D_A = \frac{R \times W}{\mathrm{I} \times A} V \tag{7}$$

Where, R is the runup in m, W is the withdrawal in m, I is the inundation distance in m, A is the amplification factor 1,700 times, V is the volume of the receded water given in Table. 1, in m^3 and the dynamic amount D_A is the water interacted with the magma to cause the amplification as unit. If R = 4.25 m and 20 m, W= 8 m, I = 4,000 m, A = 1,700, and V = 5.576e+11 m^3 and 1.574e+12m^3 therefore the amount of water D_A = 2.788e+6 m^3 and 2.2221e+7 m^3.

In the formula of ideal gas (OpenStax, 2012), the volume is given by (Hartin, 2010)

$$V = R_U \left(n \frac{T}{P}\right) \tag{8}$$

Where, R_U is the ideal or universal gas constant is 8.3145 J/K mol, the Boiling Point of Water at Atmospheric Pressure = 100° C (373.15 K). Atmospheric Pressure = 101,325 Pa and the Density of Water at 20° C (293.15 K) = 1,000,000 g/m^3.

The expansion ratio of steam using the Ideal Gas Law, can provide solution for the change in volume when water is vaporized to steam, the Ideal Gas Law can be used to determine the amplification ratio of steam, where the relationship between the initial and final conditions to set them equal (Hartin, 2010)

$$\frac{P_1 V_1}{P_2 V_2} = \frac{n_1 R_u T_1}{n_2 R_u T_2} \tag{9}$$

Where, P is Pressure (Pa), V is Volume (m^3), T is the Temperature (K), n is the Moles, Ru is the Universal Gas Constant (8.3145 J/mol K), subscript of 1 refers to initial conditions where the upper layer consists of hot smoke and air and subscript of 2 refers to conditions at (later).

As water is vaporized at its boiling point and the absolute temperature of the resulted steam is increased its volume increases, arranging Eq. (9) and multiplied result in 403.238 to give amplification by 1,700, it's given by

$$V_2 = \frac{T_2 V_1}{T_1} \times 403.238 \qquad (10)$$

But what does an increase in the volume of gas means? Since pressure (P), mass (m), and the acceleration due to gravity (g), are related by P = F/A = (m*g)/A, where A is surface area, thus the atmospheric pressure is proportional to the weight per unit area of the atmospheric mass above that location (Wikipedia, 2021d), expressed as

$$P = \frac{F}{A} = \frac{mg}{A} \qquad (11)$$

Where, g is gravitational acceleration on earth 9.80665 m/s^2, inlet area of trench A = 1.6e+8 m^2, therefore, in unit terms, the pressure is given by

$$P = \frac{F}{A}\frac{N}{A}, \frac{N}{m^2} \qquad (12)$$

But the ideal gas law in Eq. (8) gives pressure by

$$P = n\frac{R_U\,T}{V}, Pa, or\ \frac{N}{A} \qquad (13)$$

From Eq. (12) and Eq. (13), the pressure is

$$P = \frac{F}{A} = n\frac{R_U\,T}{V}, Pa, \frac{N}{m^2} \qquad (14)$$

Multiplying each part by volume V, we get

$$PV = \frac{FV}{A} = nR_U\,T, Pam^3, \frac{Nm^3}{m^2}, Nm \quad (15)$$

Analyzing the volume of gas, where Eq. (15) illustrated the change in the unit of force (N/A-N/m^2) in Eq. (14) to the unit of work (N.m) or unit of energy in Eq. (15), this product let us questioned the product PV and relate steam at 169.90° C with energies in Wikipedia (Wikipedia, 2021p), it's our view that the product PV expressed the energy of steam, it's the energy which exploded the boiler of the trains in Figs. 10&11, and the formula can expressed the energy of Tsunami, and it's given by

$$E = PV = \frac{FV}{A} = nR_U\,T, (Nm)J \qquad (16)$$

Where, R_U is the ideal or universal gas constant is 8.3145 J/K mol, the Boiling Point of Water at Atmospheric Pressure = 1200° C (1473.15 K). Atmospheric Pressure = 101,325 Pa and the Density of Water at 20° C (293.15 K) = 1,000,000 g/m^3, 1 mole of water is 18 grams. Given volume of tsunami water is 5.5853e+11 m^3 and 1.574e+12 m^3, changing to kg gives 5.5853e+14 kg and 1.574e+15 kg, is 5.5853e+17 g /18 = 3.1029e+16 mol and 1.574e+18/18 = 8.7444e+16 mol, using these in Eq. (16), the results are in the last columns in Table. 3.

Table 3.

Parameters	1	2	3	4	Tsunami 4,25 m	Tsunami 12 m
T (F)	337.80	379.50	395.60	406.00	2,192	2,192
T (C)	169.90	193.10	202.00	207.80	1,200	1,200
P (psi)	160.00	200.00	250.00	300.00	3.4231e+7	9.6473e+7
V (m^3)	489.95	445.48	372.81	319.60	5.585e+11	1.574e+12
nRT (Nm^2) J	78,392	89,097	93,204	95,880	3.8006e+20	1.0710e+21
PV (W) J	78,392	89,096	93,203	95,880	1.9118e+19	1.5185e+20

Table 3.

Fig. 35. Table. 3. The four columns give temperatures of Steam at four different pressures and volumes, the product of pressure and volume by obtaining nRT using the RHS of Eq. (16) is gives the unit of work done, the last two columns for tsunami using the two volume of water and related data in both Eq. (11) and Eq. (16).

Water is vaporized in the upper layer (Hartin, 2010), such as the magma chamber, thus from Eq. (11), the pressure is given by

$$P = m\frac{V}{At} \qquad (17)$$

Since the velocity given by Eq. (2), is due to the rush of water from inside the storage, and this rush due to the force of pressure inside the magma chamber, therefore substituting velocity V in Eq. (17) with the RHS of Eq. (2), we got

$$P = \frac{m\sqrt{gh}}{At} \qquad (18)$$

If the depth of the Sea like Sumatra is 5,000 meters, the depth of magma storage is 30,000 meters-40,000, the width of Tsunami (length of the trench) is around twenty kilometers, 20,000 m, width of the trench is 4 × 2,000 (Moran, 2006), therefore area (A) in Eq. (17) is 1.6e+8 m^2, for the velocity we use the depth = 5,000 m in Eq. (2), the velocity is = 221.36 ms^{-1}.Using data obtained in Table 1, and the dynamic volume of water D = 5.86995e+10 m^3 of gas, in Eq. (17) the pressure is derived both withdrawal and given in Table. 4.

Since the magnitude of the force of Tsunami at beach, which allow tsunami to penetrate deep inside the land, or the inundation distance (d_I), therefore using Eq. (11), we can established the energy of tsunami at the beach as the force multiplied by the inundation distance (d_I).

$$W = Fd_I = PAd_I = mgd_I \qquad (19)$$

Where, W is the work by the tsunami wave in Joules.

Since 4,186 joules of energy is required to raise the temperature of one kilogram of water by one degree Celsius (Wikipedia, 2021q), and Specific Latent Heats (SLH) of vaporization of water is 2264.705 kJ/kg (Wikipedia, 2021q), if this is multiplied in total mass and critical temperature of water 373.946^{o} C, then we get the Internal energy (U), the result is inserted in Table 4. While inserting critical temperature of water 373.946^{o} C, with other data in Eq. (5), we get the Specific Enthalpy of Super Heated Steam = 3.213432e+6, all tabulated in Table 4.

No	Parameter	Percentage of Receded Water		Total Receded Water	
1	Amount Receded m	4.25	12	4.25	12
2	Volume-1 Recede	4.6036e+11	1.574e+12	5.5853e+11	1.574e+12
3	Volume-2 Reduced (D_A) Eq. (10)	2.788e+6	2.2221e+7		
4	Amount of water in Kg	2.788e+9	2.2221e+10	5.5853e+14	1.574e+15
5	Volume-1 Eq. (16) N/A	4.7396e+9	1.0752e+11	9.4949e+14	7.6163e+15
6	Pressure Eq. (23) N/A	3.857198e+3	3.0743e+4	7.727e+8	2.1776e+9
7	Work = (VP) J	1.8281e+13	3.3055e+15	7.3367e+23	1.6585e+25
8	Internal energy (U)	2.3611e+15	2.5784e+16	4.7300e+20	1.097e+21
9	Specific Enthalpy h Eq. (6)	4.7405e+15	3.0165e+16	7.3414e+23	8.0115e+24
10	Enthalpy (H) Eq. (5)	1.3216e+25	1.8624e+27	4.1004e+38	2.1054e+40
11	Energy Eq. (25) J	2.4686e+18	2.6711e+19	4.9453e+23	1.1475e+24

Table 4

Fig. 36. Table 4. The characteristics of the interaction between the receded water and the magma in the magma chamber in columns 3&4 using Eq. (7), while 5&6 gives the estimated withdrawal water without change. Row No 1 is amount of withdrawal, No 2 the volume in m^3, No 3 reduced amount for column 3&4, No 4 amount in kg, No 5 volume using Eq. (10), No 6 pressure using Eq. (17), No 7 work (PV) in J, No 8 the Internal energy (U), No 9 h using Eq. (5), No 10 H using Eq. (4), No 11, Energy inundation as distance d travelled by the force using Eq. (19), the inlet of the chamber = 1.6e+8 m^2.

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Videos of the 2004 Sumatra and the 2011 Japanese earthquakes and Tsunamis:

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Boxing Day Tsunami 2004 Indonesia:

https://www.youtube.com/watch?v=s4IpGX6uFpc&fs=1&modestbranding=1&rel=0&showinfo=0

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Boxing Day Tsunami 2004 Sri Lanka:

https://www.youtube.com/watch?v=HCq7YFlytSQ&fs=1&modestbranding=1&rel=0&showinfo=0&fs=1&modestbranding=1&rel=0&showinfo=0

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Boxing Day Tsunami 2004 Thailand:

https://www.youtube.com/watch?v=G6lq3l_eZS8&fs=1&modestbranding=1&rel=0&showinfo=0

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Boxing Day Tsunami 2004 Koh Lanta | Phi Phi:

https://www.youtube.com/watch?v=HCq7YFlytSQ&fs=1&modestbranding=1&rel=0&showinfo=0

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THE SCARIEST IMAGES OF THE TSUNAMI IN JAPAN

https://youtu.be/HAjF20yph90

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Tsunami in Kesennuma city, ascending the Okawa river:

https://www.youtube.com/watch?v=P8qFi74k2UE&fs=1&modestbranding=1&rel=0&showinfo=0

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As the above six videos shows the 2004/2011 Sumatra and Japan Tsunamis, their effects and characteristics which supposed to be depicted by our model, while the next video shows 3D Simulation of Tsunami, based on the current theory, for comparison.

ↀↀↀↀↀↀↀ

The Formation of Tsunami (3D Simulation), based on the current theory of Tsunami. Dec 26, 2011

https://www.youtube.com/watch?v=SlwZzbGh7Cw&fs=1&modestbranding=1&rel=0&showinfo=0

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7. Conclusion

The repetitive narration linking tsunamis phenomenon with earthquakes and withdrawals of water which amplified when returning back as tsunami wave flooding coastal areas, this is studied with topographical structure of these areas, while reviewing the distribution of magmas networks from mantle outer core boundary (MCB) to hotspots and magma storages, where we suggested the existence of magma storages in areas where earthquake-tsunamis occurred, such as Sumatra, Japan, Nicaragua, and Mentawai trenches and Hawaii islands,;

thus when earthquakes strike these areas and in the vicinity of the magma chamber and caused a crake in the seabed leading to these chambers, water will flow into the chamber, interacted with the highly hot magma, this resulted in the transformation of water into steam, its volume increased by 1,700 times, this will create the force of pressure, which will push water and steam out of the chamber, and start the tsunami wave, approaching beaches with foams, which's a condensed steams, flooding the coastal areas, and causing great destructions; the cycles of withdrawal and amplification of tsunami waves can repeated itself several times as shown in Fig. 6, until the crake to the chamber is closed, ending the cycle of tsunami earthquake, this suggestion answered questions related to its relations to magnitudes of earthquakes, conditions for occurrence or non-occurrence near to each others, quantity of withdrawal water and magnitude of tsunami wave, with ideas that can created a good base for tsunami knowledge and studies which will help in the creation of protective measure against this natural destructive force.

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