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ANALYZE THE MECHANISM OF TSUNAMI BASED ON THE SCOPUS DATABASE

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ABSTRACT

The primary objective research is to obtain information from the Scopus database from 1972 to 2021 related to tsunamis from a mechanical perspective. The preliminary data get from the Scopus database considering that the Scopus indexed documents have gone through a rigorous review process and have credibility in publishing research results. 119 documents (years 1972-2021) get from Scopus data-based obtained based on the keyword Tsunami Mechanism. The VOSViewer application visualizes the research results related to the tsunami mechanism. Of all the papers, there are 80 of 119 documents in the form of articles on Tsunami Mechanisms from 1972 to 2021. Then, the scientist who studied the most tsunamis was Pararas-Carayannis, G., with seven documents. The author is in the first position of all written documents published in International Journals indexed by Scopus. The cities most affected by the tsunami were Japan. The affiliate most associated with tsunamis is The University of Tokyo in Japan. Earth and Planetary Sciences is the subject area in the first position with 77 documents. The keyword that appears the most is "tsunami" in 59 documents. The journal "Pure and Applied Geophysics" was the primary source. The implication of this research is to provide empirical evidence that research related to tsunami is still an exciting topic at present and in the future.

Keywords: *Bibliometric, Mechanism, Tsunami, Top 100 cited, VOSViewer.*

1. INTRODUCTION

A tsunami is one of the most hazardous disasters for humankind as displacing an enormous volume of water through sea waves. Annually, there are $4 billion (US$) in assets, and 60,000 people globally are affected by tsunami disasters (Bernard & Titov, 2015). The tsunami disaster negatively impacted the area it traversed, such as human casualties and economic losses, which increased 100 times over the last twenty years compared to the previous two decades (UNISDR, 2018). When this phenomenon occurs, the resulting disaster marked fatalities due to the increasing number of people living in coastal areas. Therefore, in the last few decades, research related to tsunamis has been growing, aiming to overcome the problem of tsunami disasters in the future (Jain et al., 2021).

Repeated or even a single tsunami occurrence has affected several countries such as India, Japan, Thailand, Turkey, and Indonesia. In history, three significant tsunamis occurred around the world, namely the 2004 Indian tsunami (Satake, 2014), the 2011 Tohoku tsunami (Pararas-Carayannis, 2014), and the 2018 Palu tsunami (Madlazim et al., 2020). The three tsunamis occurred without local institutions' warning or false warning, resulting in fatalities and considerable economic losses. The three tsunamis happened without any prior notice, or the warnings announced were false warnings, resulting in loss of life and substantial economic damage. Therefore, scientists and researchers conduct pre-and post-tsunami analyses of various tsunami events to obtain clues and solutions for future tsunami events. Several algorithms, methods, simulations, and modeling describe a tsunami event's occurrence, prediction, or impact. Various journals focus on discussing developments related to tsunami events, for example, Marine Geology which has produced articles that are very useful for future studies (Kuriyama et al., 2020; Grilli et al., 2021; Prizomwala et al., 2022). Another example is the Science of Tsunami Hazard, which has published articles related to various tsunami events worldwide (Mazova et al., 2020; Zaytsev et al., 2021; Toulkeridis et al., 2022).

Bibliometric analysis is a discipline that studies literature and science in a particular field quantitatively (Blümel & Schniedermann, 2020). The analysis provides a broad view of a specific area to identify research gaps. The gaps identified can provide a way to conduct probabilistic research and present particular results. Recently, several articles carried out the bibliometric analysis in tsunami research, namely Anil et al. (2010), who used the Scopus database from 1997 to 2008, then Jain et al. (2021) using the Scopus database and the Web of Science (WoS), followed by a state-of-the-art-study from 2004 to 2021. One of the powerful tools used to conduct bibliometric analysis studies is to use VOSViewer. The advantage of this tool is it makes it easier to interpret the data visually. In addition, this analysis has the advantage of analyzing the many scientific publications written on a particular topic. In bibliometric studies, researchers can use citation analysis to examine the level of systematic metrics (Suprapto et al., 2021)

Research Objective

The research aims to analyze the mechanism of tsunami based on the Scopus database from 1972 to 2021. Specifically, to obtain information related to:

1. Document type, source type, and authors in mechanism of tsunami research based on the Scopus database.
2. Country and affiliation in mechanism of tsunami research based on the Scopus database.

3. Keywords, sources title, and subject area in mechanism of tsunami research based on the Scopus database.
4. Subject area, SJR, and Citescore in mechanism of tsunami research based on the Scopus database.
5. Visualization by VOSViewer in mechanism of tsunami research based on the Scopus database.
6. Literature review of the top-cited paper in the mechanism of tsunami research based on the Scopus database.
7. Analyze the process of tsunami mechanism.

2. METHODS

This research is a desk study (Amarasinghe & Chandanie, 2020; Amarasinghe et al., 2019; Atkinson et al., 2018; Miller, 2015) that uses bibliometric analysis (Azad & Parvin, 2022; Nguyen, 2022; Liu et al., 2022; Maisonobe, 2022; Tang et al., 2022) and literature review (Makinoshima et al., 2020; Harahap & Huan, 2014; Gnoni et al., 2022; Kumar et al., 2022; Mina et al., 2022; Yang et al., 2022) focusing in the mechanism of tsunami. The primary objective research is to obtain information from the Scopus database from 1972 to 2021 related to tsunamis from a mechanical perspective. The main data of this research is from the Scopus database, considering that the Scopus indexed documents have gone through a rigorous review process and have credibility in the publication of research results. Briefly, the flow of this research described in Figure 1.

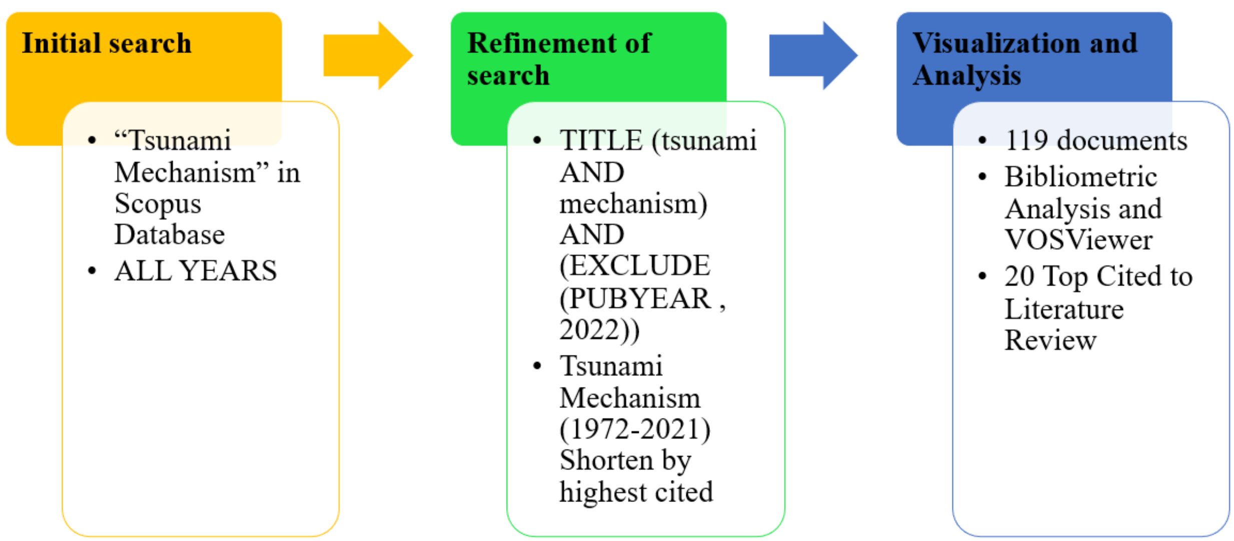


Figure 1. Flowchart research

Data from Scopus from 1972-2021 related to tsunamis from a mechanical perspective with the keyword "Mechanism Tsunami" was taken on March 01, 2022. For SJR data for each journal, it was taken from https://www.scimagojr.com/, and journal citescore data was taken from https://www.scopus.com/sources.uri

A total of 119 documents relevant to the mechanism of tsunami were visualized using VOSViewer. VOSViewer has proven to be effective for viewing profiles and research updates (Soegoto et al., 2022; Tamala et al., 2022; Nandiyanto, 2021; Chen et al., 2021; Sood et al., 2021).

3. RESULTS AND DISCUSSION

3A. Document Type, Source Type, and Authors

Table 1. Document type, source type, and authors in the mechanism of tsunami research

Document Type	**Total**	**Source Type**	**Total**
Article	80	Journal	89
Conference	26	Conference Proceeding	22
Book Chapter	5	Book	4
Review	4	Book Series	4
Erratum	3		
Note	1		
Authors			**Document**
Pararas-Carayannis, G.			7
Satake, K.			6
Løvholt, F., Tanaka, H., Udo, K.			4
Arikawa, T., Beppu, M., Harbitz, C.B., Ishikawa, N., Mano, A., Nistor, I., Nosov, M.A., Paris, R., Tatesawa, H., Tinti, S.			3
Armigliato, A., Chen, C., Esteban, M., Haugen, K.B., Iida, T., Imamura, F., Kanamori, H., Mazova, R.K., Mikami, T., Mota, D.F., Robertson, I., Sakellariou, D., Shibayama, T., Skachko, S.N., Takanashi, H., Tanioka, Y., Tappin, D.R., Tomita, T., Watts, P., Yalçiner, A.C., Yamamoto, Y.			2

Table 1 shows the top types of documents with 119 documents cited on tsunamis from 1972 to 2021. Of all the papers, there are 80 papers in the form of articles, 26 papers in conferences, five papers in book chapters, four papers indicating review, three papers included in the erratum, and one paper in the note. Then, in the "Authors" table, the scientist who studied the most tsunamis was

Pararas-Carayannis, G. with seven documents, followed by other researchers. The exciting thing isthat the documents discussing the most tsunamis are published in journals. It is in line with the "Authors" table, the author in the first position of all written documents published in International Journals indexed by Scopus.

3B. Country and Affiliation

Table 2. Country and Affiliation in the mechanism of tsunami research

Country	Doc.	Affiliation	Document
Japan	40	The University of Tokyo	11
United States	26	Tohoku University	9
Indonesia, United Kingdom	9	Tsunami Society International	6
China	8	Port and Airport Research Institute, Universitetet i Oslo, Norges Geotekniske Institutt, Alma Mater Studiorum Università di Bologna, Nizhny Novgorod State Technical University n.a. R.E. Alekseev	4
France, Russian Federation	7	Ministry of Education China, National Defense Academy of Japanö Middle East Technical University METU, Nanyang Technological University, CNRS Centre National de la Recherche Scientifique, Tokai University, Hohai University, Kyoto University, Kobe University, University of Hawaiʻi at Mānoa, Hokkaido University, Russian Academy of Sciences, University of Ottawa, Institut Teknologi Bandung, P.P.Shirshov Institute of Oceanology, Russian Academy of Sciences, Laboratoire Magmas et Volcans, Clermont-Ferrand	3
Norwaz	6	National Marine Environmental Forecasting Center, Applied Fluids Engineering, Inc., Bousai Consultant Co. Ltd., Nagoya University, Hellenic Centre for Marine Research, Japan Agency for Marine-Earth Science and Technology, Yale University, University of Rhode Island, University of Canterbury, British Geological Survey, Waseda University, National Institute of Advanced Industrial Science and Technology, National Central University, Universitas Gadjah Mada, University of Moratuwa, Universidade de Lisboa, Earth Observatory of Singapore, Université Clermont Auvergne	2

Table 2 discusses the cities and affiliations most associated with tsunamis. The cities most affected by the tsunami were Japan, and then in second place were Indonesia and the United Kingdom. It is very relevant because Japan is a country that has a very high level of seismicity. Therefore many earthquakes occur in Japan, with the result that tsunamis occur. In addition, one of the most powerful tsunamis in Japan was the 2011 Tohoku tsunami. Many researchers have discussed the tsunami's impact, mechanism, and source (Veszteg et al., 2014; Strusińska-Correia, 2017; Goto et al., 2021). Furthermore, the affiliate most associated with tsunamis is The University of Tokyo in Japan which is the country most associated with tsunamis.

3C. Keywords, Sources Title, and Subject Area

Table 3. Keywords, sources title, and subject area in the mechanism of tsunami research

Keywords	Document	Subject Area	Document
Tsunami	59	Earth and Planetary Sciences	77
Tsunamis	56	Engineering	38
Earthquakes	28	Environmental Science	21
Coastal Engineering, Numerical Model	11	Physics and Astronomy	10
Earthquake	10	Social Sciences	6
Tsunami Generation	9	Energy	5
Bathymetry, Landslide, Pacific Ocean, Submarine Landslide	8	Mathematics, Multidisciplinary	4

Keywords are an essential part of a paper; with keywords, we can find out the words that most often appear and are discussed in a paper. Table 3 states that the keyword that appears the most is "tsunami" in 59 documents. Then the keywords "tsunamis" contained in 56 documents are followed by keywords associated with tsunamis such as Earthquakes, Tsunami Generation, Bathymetry, Landslide, Pacific Ocean, Submarine Landslide, etcetera. Furthermore, in Table 3, it can be seen that Earth and Planetary Sciences is the subject area in the first position with a total of 77 documents. It correlates with several journals discussing tsunamis with a subject area of Earth and Planetary Sciences, which can be confirmed on the https://www.scimagojr.com/ page.

3D. Subject Area, SJR, and Citescore

The journal "Pure and Applied Geophysics" was the primary source which published nine papers, followed by "Marine Geology," which published eight papers, and "Science of Tsunami Hazards" which published six papers. "Pure and Applied Geophysics" has a relatively high H-index value of 87 with an SJR of 0.72, while "Marine Geology" has a high H-index of 134 with an SJR of 1.24. Then in the third position, there is "Science of Tsunami Hazards," which has an H-index of 14 with an SJR of 0.24. The relationship between H-Index and SJR with the number of documents is related to citations from the journal. It is just that here, the H-Index and SJR cannot be used as the primary reference because the top 2 journals discuss tsunami-related issues and other topics such as earthquakes, fluid mechanics, and fluid geophysics. However, in the third position, namely "Science of Tsunami Hazards," this journal focuses on tsunamis, even though it has not a relatively high H-Index and SJR. Each volume published in this journal always discusses tsunamis.

Table 4. Subject area, SJR, and Citescore in the mechanism of tsunami research

Source Title	Doc.	SJR	H-index	Top Percentile	CiteScore
Pure and Applied Geophysics	9	0.72	87	64	3.5
Marine Geology	6	1.24	134	88	5.6
Science of Tsunami Hazards	6	0.24	14	58	2.4
Geophysical Research Letters	4	2.01	273	97	7.8
Natural Hazards	4	0.76	105	81	4.9
Physics of the Earth and Planetary Interiors	4	1.00	115	78	4.1
Journal of Coastal Research	3	0.25	90	26	0.8
Scientific Reports	3	1.24	213	93	7.1
China Ocean Engineering	2	0.40	25	50	1.8
Coastal Engineering Journal	2	0.99	40	73	3.9
Geotechnique	2	2.78	135	95	8.3
Journal of Asian Earth Sciences	2	1.32	125	90	6.0
Journal of Hydraulic Research	2	0.78	76	76	4.3
Natural Hazards and Earth System Sciences	2	1.12	99	87	5.8

Source Title	Doc.	SJR	H-index	Top Percentile	CiteScore
Proceedings of the International Offshore and Polar Engineering Conference	2	0.18	45	20	0.5

Proceedings of The Coastal Engineering Conference (7 documents) and Vestnik Moskovskogo Universita Ser 3 Fizika Astronomiya (2 documents) have been discontinued.

3F. Visualization by VOSViewer

There are 119 documents (years 1972-2021) from Scopus data-based obtained based on the keyword *Tsunami Mechanism*. The research results related to the tsunami mechanism are visualized using the VOSViewer application, which is presented in Figure 2.

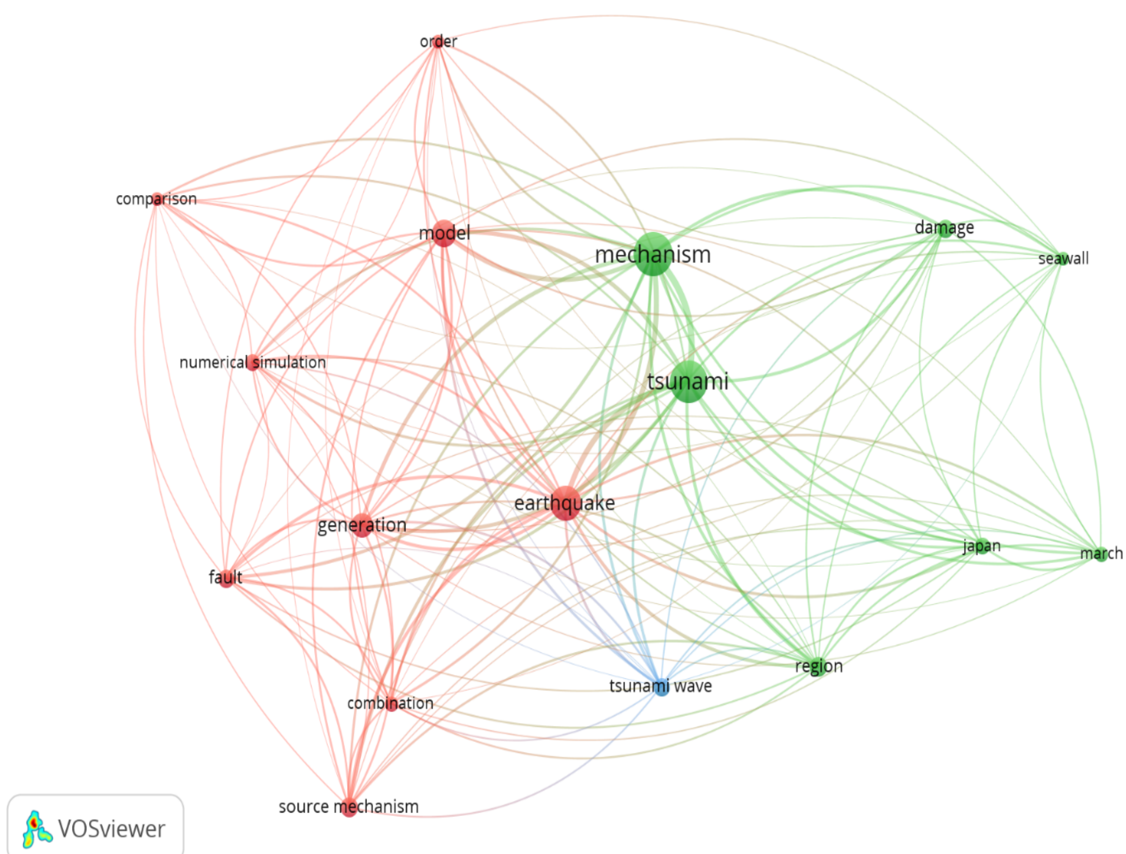


Figure 2. Networking visualizes of tsunami mechanism based on the Scopus database from 1972-2021 by VOSViewer

Observations on the map using VOSViewer obtained four different clusters consisting of 17 keywords, as shown in Figure 2. The first red cluster contains nine items such as earthquake, generation, combination, source mechanism, fault, numerical simulation, comparison, order, and model. The second green cluster contains six items: Tsunami, mechanism, damage, seawall, region, japan, and march. The blue cluster only consists of 1 item, namely the tsunami wave.

3G. Literature Review of Top Cited Paper

Table 5. Literature review of 20 top-cited in the mechanism of tsunami research

Name (Year)	Finding / Results
Kanamori, H. (1972)	With different periods, the 1946 Aleutian and 1896 Sanriku earthquakes produced similar seismic wave excitations. The weak zone is possible due to friction heating at the interface between the oceanic and continental lithosphere.
Tappin, D.R., Watts, P., McMurtry, G.M., Lafoy, Y., Matsumoto, T. (2001)	In the Sissano offshore area, it produces movement along a plane with limited lateral boundaries that mostly dip-slips to the north.
Wang, X., Liu, P.L.-F. (2006)	Using numerical results, the rupture velocity and slip duration from the rupture zone up to 1300 km are still relatively shorter when compared to the propagation and time scale.
Harbitz, C.B., Løvholt, F., Pedersen, G., Masson, D.G. (2006)	Bathymetry, slide permeability, the velocity of rock slide impact on water bodies, and rock slide frontal area are factors that determine rock slides and the resulting tsunami.
Satake, K. (1994)	A comparison of the distribution of tsunami heights shows that the estimated fault length is 250 km, slightly longer than the aftershock area. Around shallow faults, it is possible to have less stiffness than standard underthrust faults.
Abe, K. (1973)	The tectonic deformation of the submarine slump and large landslides generates a tsunami. The tsunami in the Nankaido earthquake of 1946 was caused by a source deformation greater than the seismic waves.

Name (Year)	Finding / Results
Papadopoulos, G.A., Gràcia, E., Urgeles, R., (...), Novikova, T., Papageorgiou, A. (2014)	The characterization of the seismic landslide tsunami source is very effective using numerical modeling as well as empirical discrimination criteria. Interdisciplinary research efforts on tsunamis are needed in terms of tsunami generation.
Paris, R., Switzer, A.D., Belousova, M., (...), Whelley, P.L., Ulvrova, M. (2014).	The abundance of potentially tsunamigenic volcanoes puts the region's rapidly developing beaches at risk. Strategies in dealing with future events using scientific investigations are very important.
Nomanbhoy, N., Satake, K. (1995).	The largest tsunami waves and the largest pressure changes were caused by the same event. The mechanism for tsunami generation is still poorly understood.
Yolsal, S., Taymaz, T., Yalçiner, A.C. (2007).	An important component in the tsunami wave simulation is a high-resolution bathymetric map based on a simulation study.
Haugen, K.B., Løvholt, F., Harbitz, C.B. (2005)	The small fraction of the surface elevation can be increased for small-time lags behind the avalanche, which is in accordance with the results of retrogressive avalanche analysis.
Kato, F., Suwa, Y., Watanabe, K., Hatogai, S. (2012)	There are eight factors that caused the failure of the coastal embankment in the Great East Japan Earthquake. These factors refer to the structure of the seawall, parapet, and armor.
Tinti, S., Armigliato, A., Manucci, A., (...), Yalçiner, A.C., Altinok, Y. (2006).	A very stable slump before the earthquake was demonstrated through a stability analysis using the concept of boundary balance.
Paris, R. (2015).	Difficulties in integrating and harmonizing sources in numerical models and probabilistic tsunami hazard maps are caused by the diversity of waves in terms of amplitude, period, shape, dispersion, etc.
Satake, K. (1985)	Slips and faults can be prevented by tsunami simulation for the topography. The fault is divided into two segments in the area of the aftershock and tsunami recording.
Satake, K., Tanioka, Y. (2003)	Not only splay faults or submarine slumps but a seismological fault model is also needed to reproduce the waveforms of far-field tsunamis.

Name (Year)	Finding / Results
Ma, S. (2012)	Shallow fault subsidence causes a significant inelastic uplift of the seabed. Shallow subduction zone deformation is affected by changes in pore pressure in the overriding wedge.
Wright, S.G., Rathje, E.M. (2003)	Changes in soil shear strength and slope stability over time are produced by excess pore water pressure due to earthquakes.
Witter, R.C., Kelsey, H.M., Hemphill-Haley, E. (2001)	The setting of washovers on the Oregon coast in the sand deposition mechanism is a potential cause of the storm-wave runup and long-distance tsunamis.
Huang, Z., Zhao, D. (2013)	The huge tsunami occurred because the Okhotsk plate was shot out toward the Japan Trench caused by most of the pressure being released in a short time and the plate interface became separated after the Mw 9.0 earthquake.

3H. Analyze the Mechanism of Tsunami

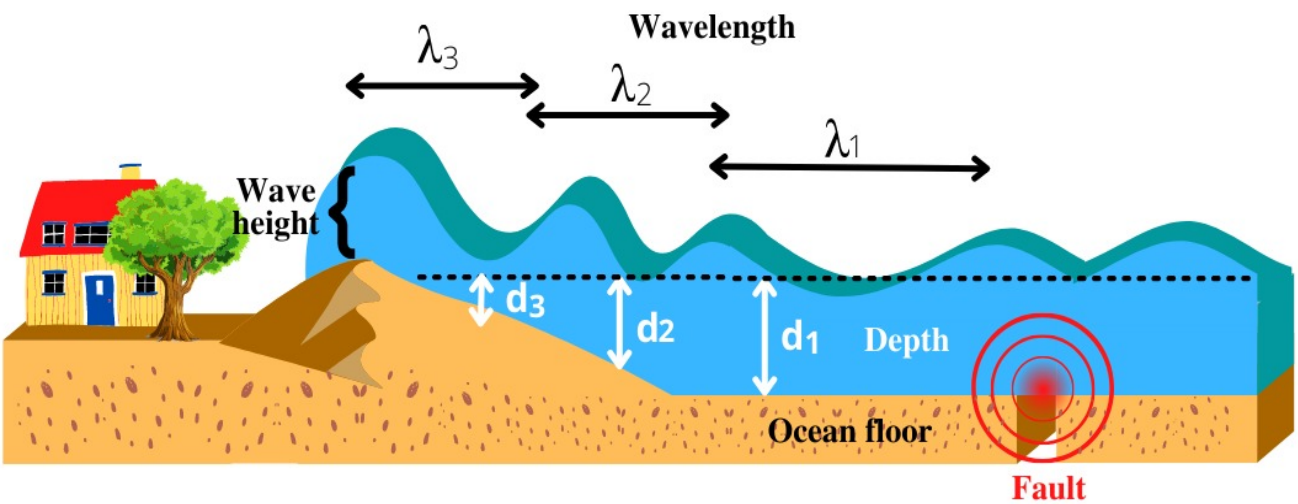
Tsunamis are waves caused by the impulsive movement of ocean disturbances between tides and swell waves in the gravitational spectrum of water waves (Haugen et al., 2005). When the seabed experiences vertical motion in the Earth's crust, the balance of the water surface is disturbed due to the sudden rise or fall of the seabed. A tsunami is a very large ocean wave triggered by an underwater earthquake, volcanic activity, or landslide as a large-scale disturbance (Yolsal, 2007). In addition, tsunamis can also be caused by collisions between extraterrestrial objects and the sea.

Earthquakes that occur below sea level occur due to the meeting of two Earth's plates colliding with each other. When the two plates collide, and there is an up and down fault pattern, it will cause a big wave. When the plate moves vertically, this will trigger the water above it to form waves in all directions, including towards the mainland, which will cause a tsunami. This is what happens for water to regain its balance on top of the colliding plates and change its position. The rupture dynamics of shallow subduction zone earthquakes and their tsunami genesis are influenced by dynamic pore pressure changes in the overriding wedge above the shallow subduction plate interface (Ma, 2012).

Tsunamis caused by submarine landslides are characterized by volume and shear mass dynamics, as well as water depth (Harbitz et al., 2006). Tsunamic submarine landslides and landslides that occur on land are caused by the same thing, namely due to the accumulation of sand, which has a critical angle and is getting thinner day by day, causing collapse. In geomorphology, this is called the "angle of repose". The critical angle of the seabed at the tip is the most vulnerable. If the slope of this critical angle is in the path of the earthquake and there is a small disturbing vibration, it is certain that landslides will occur frequently. Plate movements will cause underwater landslides that can trigger powerful waves. The effects of a tsunami caused by submarine sediment avalanches can be greater than those in subduction zones.

Volcanic activity is a triggering factor for tsunamis, especially from volcanoes located near or under the sea. Volcanic activity generally causes the lip of the volcano to rise or fall, which then triggers large waves similar to a tsunami under the sea. Tsunamis generated by volcanic eruptions are difficult to predict. Its characteristics are the existence of waves that have a short period and greater dispersion than the tsunami generated by an earthquake (Paris et al., 2014). Volcanic tsunamis are generated by underwater explosions, pyroclastic flows, volcanic-tectonic earthquakes, unstable slopes, shock waves, and collapsing calderas (Paris, 2015).

Tsunami waves are mechanical waves that have a propagation speed proportional to the density of the propagation medium. Tsunami waves are classified as transverse waves whose vibration direction is perpendicular to their propagation. In addition, tsunami waves also include longitudinal waves whose vibration direction is parallel to their propagation. An illustration of the tsunami



mechanism is shown in Figure 3.

(Source: authors)

Figure 3. Illustration of the tsunami mechanism

A tsunami will vibrate harmoniously when it is in an area where the sea surface is very deep with a large wavelength and speed. The energy of a tsunami wave is always constant so that when a wave enters a shallow area, its wavelength and speed will be smaller while its amplitude will be larger. This process can be formulated as follows:

$$v = \lambda \,.\, f$$

We know that $\omega = 2\pi f$ and $k = \dfrac{2\pi}{\lambda}$. So we can write :

$$v = \frac{\omega}{k}$$

Where : $\omega = \sqrt{gk \tanh(kd)}$

$$v = \frac{\sqrt{gk\tanh(kd)}}{\sqrt{k^2}}$$

$$v = \sqrt{\frac{g}{k}\tanh(kd)}$$

$$v = \sqrt{g\frac{\lambda}{2\pi}\tanh\left(2\pi\frac{d}{\lambda}\right)}$$

The hyperbolic tangent function has the following limits:

$$\tanh\left(2\pi\frac{d}{\lambda}\right) \approx \left(2\pi\frac{d}{\lambda}\right) \quad \text{for small } 2\pi\frac{d}{\lambda}$$

$$\tanh\left(2\pi\frac{d}{\lambda}\right) \approx 1 \quad \text{for large } 2\pi\frac{d}{\lambda}$$

So that the velocity value can be formulated as :

$$v \approx \sqrt{g\frac{\lambda}{2\pi}} \quad \text{for deep water}$$

$$v \approx \sqrt{gd} \quad \text{for shallow water}$$

Where v is the speed of the wave, g is the acceleration due to gravity, and d is the depth of the sea surface. This is what causes tsunami waves to have a very large height. The long wave or shallow water approach is applicable when the wavelength is longer than the water depth (Satake & Tanioka, 2003). The success of the tsunami propagation simulation and the accurate prediction of the arrival time of tsunamis occurring at different locations depending on the correct estimation of the fault plane mechanism (Wang & Liu, 2006). Tsunami data can be interpreted in terms of the volume V_T of water displaced at the tsunami source. This volume is equal to the volume of the seabed displaced if a shallow fault causes a base displacement, given by Kanamori. (1972), it can be written as :

$$V_T \approx (D_0 \sin\delta \sin\lambda) S$$

where D_0 is the dislocation, δ is the dip angle, λ is the slip angle, and S is the area of the fault plane. If the seismic moment M is equal to $\mu S D_0$, we can write :

$$V_T \approx S D_0 \sin\delta \sin\lambda$$

$$V_T \approx \frac{M}{\mu}\sin\delta\sin\lambda$$
$$M = \frac{\mu V_T}{\sin\delta\sin\lambda}$$

Linear shallow wave theory can explain the tsunami propagation process. The shallow water equation in a spherical coordinate system related to transient seafloor motion, given by Wang & Liu (2006), can be expressed as :

$$\frac{\partial h}{\partial t} + \frac{\partial \xi}{\partial t} + \frac{1}{R\cos\varphi}\left[\frac{\partial P}{\partial \psi} + \frac{\partial}{\partial \varphi}(\cos\varphi Q)\right] = 0$$

$$\frac{\partial \xi}{\partial t} + \frac{1}{Rcos\varphi}\left[\frac{\partial P}{\partial \psi} + \frac{\partial}{\partial \varphi}(\cos\varphi Q)\right] = -\frac{\partial h}{\partial t}$$

$$\frac{\partial P}{\partial t} + \frac{gh}{Rcos\varphi}\frac{\partial \zeta}{\partial \psi} - fQ = 0$$

$$\frac{\partial (hu)}{\partial t} + \frac{gh}{Rcos\varphi}\frac{\partial \zeta}{\partial \psi} - f(hv) = 0$$

$$\frac{\partial Q}{\partial t} + \frac{gh}{R}\frac{\partial \zeta}{\partial \varphi} + fP = 0$$

$$\frac{\partial (hv)}{\partial t} + \frac{gh}{R}\frac{\partial \zeta}{\partial \varphi} + f(hu) = 0$$

Where P and Q represent the volume flux ($P = hu$ and $Q = hv$, where u and v are the mean depth velocity in the latitude and longitude directions); h is the water depth; is the free surface elevation; (ψ, φ) indicate the longitude and latitude of the Earth; R is the radius of the Earth, and f represents the Coriolis force coefficient.

4. CONCLUSION

119 documents (years 1972-2021) from Scopus data-based were obtained based on the keyword Tsunami Mechanism. Of all the papers, there are 80 of 119 documents in the form of articles on Tsunami Mechanism from 1972 to 2021. Then, the scientist who studied the most tsunamis was Pararas-Carayannis, G., with seven documents. The author is in the first position of all written

documents published in International Journals indexed by Scopus. The cities most affected by the tsunami were Japan. Affiliate most associated with tsunamis is The University of Tokyo in Japan. Earth and Planetary Sciences is the subject area in the first position with 77 documents. The keyword that appears the most is "tsunami" in 59 documents. The journal "Pure and Applied Geophysics" was the primary source. The relationship between H-Index and SJR with the number of documents is related to citations from the journal. It is just that here, the H-Index and SJR cannot be used as the primary reference because the top 2 journals discuss tsunami-related issues and other topics such as earthquakes, fluid mechanics, and fluid geophysics. However, in the third position, namely "Science of Tsunami Hazards," this journal focuses on tsunamis, even though it has not a relatively high H-Index and SJR. Each volume published in this journal always discusses tsunamis. Observations on the map using VOSViewer obtained four different clusters consisting of 17 keywords. The first red cluster contains nine items such as earthquake, generation, combination, source mechanism, fault, numerical simulation, comparison, order, and model. The second green cluster contains six items: Tsunami, mechanism, damage, seawall, region, japan, and march. The blue cluster only consists of 1 item, namely the tsunami wave. Analysis of top-cited paper in mechanism of tsunami research based on the Scopus database (attachment). The implication of this research is to provide empirical evidence that research related to Tsunami is still an exciting topic at present and in the future. The limitation of this research is that it only uses the Scopus database. Further research needs to be supplemented with Google Scholar and Web of Science data access. In addition, further research following up on the findings of the VOSViewer and visualization, including current and future research trends, will be an exciting topic.

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Attachment 1

Analysis of top-cited paper in mechanism of tsunami research based on the Scopus database

No	Name	Journal Identities	Title	Cited	SJR	H-index	Percentile	CiteScore
1	Kanamori, H. (1972)	1972 Physics of the Earth and Planetary Interiors 6(5), pp. 346-359	Mechanism of tsunami earthquakes	610	1.1 (Q1)	115	78th	4.1
2	Tappin, D.R., Watts, P., McMurtry, G.M., Lafoy, Y., Matsumoto, T.	2001 Marine Geology 175(1-4), pp. 1-23	The Sissano, Papua New Guinea tsunami of July 1998 - Offshore evidence on the source mechanism	285	1.24 (Q1)	134	88th	5.6
3	Wang, X., Liu, P.L.-F	2006 Journal of Hydraulic Research 44(2), pp. 147-154	An analysis of 2004 Sumatra earthquake fault plane mechanisms and Indian Ocean tsunami	186	0.67 (Q2)	76	76th	4.3
4	Harbitz, C.B., Løvholt, F., Pedersen, G., Masson, D.G.	2006 Norsk Geologisk Tidsskrift 86(3), pp. 255-264	Mechanisms of tsunami generation by submarine landslides: A short review	162	0.67 (Q2)	43	70th	3.2
5	Satake, K.	1994 Geophysical Research Letters 21(23), pp. 2519-2522	Mechanism of the 1992 Nicaragua Tsunami Earthquake	128	2.01 (Q1)	273	97th	7.8
6	Abe, K	1973 Physics of the Earth and Planetary Interiors 7(2), pp. 143-153	Tsunami and mechanism of great earthquakes	103	1.1 (Q1)	115	78th	4.1
7	Papadopoulos, G.A., Gràcia, E., Urgeles, R., (...), Novikova, T., Papageorgiou, A	2014 Marine Geology 354, pp. 81-109	Historical and pre-historical tsunamis in the Mediterranean and its connected seas: Geological signatures, generation mechanisms and coastal impacts	95	1.24 (Q1)	134	88th	5.6

No	Name	Journal Identities	Title	Cited	SJR	H-index	Percentile	CiteScore
8	Paris, R., Switzer, A.D., Belousova, M., (...), Whelley, P.L., Ulvrova, M.	2014 Natural Hazards 70(1), pp. 447-470	Volcanic tsunami: A review of source mechanisms, past events and hazards in Southeast Asia (Indonesia, Philippines, Papua New Guinea)	72	0.76 (Q1)	105	81st	4.9
9	Nomanbhoy, N., Satake, K.	1995 Geophysical Research Letters 22(4), pp. 509-512	Generation mechanism of tsunamis from the 1883 Krakatau Eruption	70	2.01 (Q1)	273	97th	7.8
10	Yolsal, S., Taymaz, T., Yalçiner, A.C.	2007 Geological Society Special Publication 291, pp. 201-230	Understanding tsunamis, potential source regions and tsunami-prone mechanisms in the Eastern Mediterranean	59	0.67 (Q1)	132	90th	5.4
11	Haugen, K.B., Løvholt, F., Harbitz, C.B.	2005 Marine and Petroleum Geology 22(1-2 SPEC. ISS.), pp. 209-217	Fundamental mechanisms for tsunami generation by submarine mass flows in idealized geometries	59	1.34 (Q1)	116	96th	6.7
12	Kato, F., Suwa, Y., Watanabe, K., Hatogai, S.	2012 Proceedings of the Coastal Engineering Conference 53 No.3 (2012)	Mechanisms of coastal dike failure induced by the Great East Japan Earthquake Tsunami	53	1.56 (Q1)	110	98th	8.3
13	Tinti, S., Armigliato, A., Manucci, A., (...), Yalçiner, A.C., Altinok, Y.	2006 Marine Geology 225(1-4), pp. 311-330	The generating mechanisms of the August 17, 1999 İzmit bay (Turkey) tsunami: Regional (tectonic) and local (mass instabilities) causes	50	1.24 (Q1)	134	88th	5.6
14	Paris, R.	2015 Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 373(2053),20140380	Source mechanisms of volcanic tsunamis	48	1.07 (Q1)	169	98th	6.9

No	Name	Journal Identities	Title	Cited	SJR	H-index	Percentile	CiteScore
15	Satake, K.	1985 Physics of the Earth and Planetary Interiors 37(4), pp. 249-260	The mechanism of the 1983 Japan Sea earthquake as inferred from long-period surface waves and tsunamis	48	1.1 (Q1)	115	78th	4.1
16	Satake, K., Tanioka, Y.	2003 Pure and Applied Geophysics 160(10-11), pp. 2087-2118	The July 1998 Papua New Guinea earthquake: Mechanism and quantification of unusual tsunami generation	47	0.72 (Q2)	87	64th	3.5
17	Ma, S	2012 Geophysical Research Letters 39(11),L11310	A self-consistent mechanism for slow dynamic deformation and large tsunami generation for earthquakes in the shallow subduction zone	46	2.01 (Q1)	273	97th	7.8
18	Wright, S.G., Rathje, E.M.	2003 Pure and Applied Geophysics 160(10-11), pp. 1865-1877	Triggering mechanisms of slope instability and their relationship to earthquakes and tsunamis	46	0.72 (Q2)	87	64th	3.5
19	Witter, R.C., Kelsey, H.M., Hemphill-Haley, E.	2001 Journal of Coastal Research 17(3), pp. 563-583	Pacific storms, El Niño and tsunamis: Competing mechanisms for sand deposition in a coastal marsh marsh, Euchre Creek, Oregon	42	0.25 (Q3)	90	26th	0.8
20	Huang, Z., Zhao, D.	2013 Journal of Asian Earth Sciences 70-71, pp. 160-168	Mechanism of the 2011 tohoku-oki earthquake (Mw 9.0) and tsunami: Insight from seismic tomography	41	1.32 (Q1)	125	90th	6.0
21	Ma, K.-F., Kanamori, H., Satake, K.	1999 Journal of Geophysical Research: Solid Earth 104(B6),1999JB900073, pp. 13153-13167	Mechanism of the 1975 Kalapana, Hawaii, earthquake inferred from tsunami data	40	1.98 (Q1)	232	91st	6.5

No	Name	Journal Identities	Title	Cited	SJR	H-index	Percentile	CiteScore
22	Papazachos, B.C., Dimitriu, P.P.	1991 Natural Hazards 4(2-3), pp. 161-170	Tsunamis in and near Greece and their relation to the earthquake focal mechanisms	36	0.76 (Q1)	105	81st	4.9
23	Pelayo, A.M., Wiens, D.A.	1990 Geophysical Research Letters 17(6), pp. 661-664	The November 20,1960 Peru Tsunami Earthquake: Source mechanism of a slow event	34	2.01 (Q1)	273	97th	7.8
24	Jayaratne, M.P.R., Premaratne, B., Adewale, A., (...), Esteban, M., Nistor, I.	2016 Coastal Engineering Journal 58(4),1640017	Failure mechanisms and local scour at coastal structures induced by Tsunami	31	0.99 (Q1)	40	73rd	3.9
25	Yeh, H., Mason, H.B.	2014 Geotechnique 64(2), pp. 131-143	Sediment response to tsunami loading: Mechanisms and estimates	30	2.78 (Q1)	135	95th	8.3
26	Rahiman, T.I.H., Pettinga, J.R., Watts, P.	2007 Marine Geology 237(1-2), pp. 55-70	The source mechanism and numerical modelling of the 1953 Suva tsunami, Fiji	30	1.24 (Q1)	134	88th	5.6
27	Yamamoto, Y., Takanashi, H., Hettiarachchi, S., Samarawickrama, S.	2006 Coastal Engineering Journal 48(2), pp. 117-145	Verification of the destruction mechanism of structures in Sri Lanka and Thailand due to the Indian Ocean tsunami	28	0.99 (Q1)	40	73rd	3.9
28	Gunawan, E., Meilano, I., Abidin, H.Z., Hanifa, N.R., Susilo	2016 Journal of Asian Earth Sciences 117, pp. 64-72	Investigation of the best coseismic fault model of the 2006 Java tsunami earthquake based on mechanisms of postseismic deformation	27	1.32 (Q1)	125	90th	6.0

No	Name	Journal Identities	Title	Cited	SJR	H-index	Percentile	CiteScore
29	Pararas-Carayannis, G.	2010 Science of Tsunami Hazards 29(2), pp. 96-126	The earthquake and tsunami of February 27 2010 in Chile - evaluation of source mechanism and of near and far-field tsunami effects	27	0.24 (Q3)	14	58th	2.4
30	Costa, P.J.M., Andrade, C., Cascalho, J., (...), Paris, R., Dawson, S	2015 Holocene 25(5), pp. 795-809	Onshore tsunami sediment transport mechanisms inferred from heavy mineral assemblages	23	1.01 (Q1)	117	96th	4.7
31	Pelinovsky, E., Talipova, T., Kurkin, A., Kharif, C.	2001 Natural Hazards and Earth System Sciences 1(4), pp. 243-250	Nonlinear mechanism of tsunami wave generation by atmospheric disturbances	21	1.12 (Q1)	99	87th	5.8
32	Webster, J.M., George, N.P.J., Beaman, R.J., (...), Abbey, E.A., Daniell, J.J.	2016 Marine Geology 371, pp. 120-129	Submarine landslides on the Great Barrier Reef shelf edge and upper slope: A mechanism for generating tsunamis on the north-east Australian coast?	19	1.24 (Q1)	134	88th	5.6
33	Pararas-Carayannis, G.	2014 Pure and Applied Geophysics 171(12), pp. 3257-3278	The Great Tohoku-Oki Earthquake and Tsunami of March 11, 2011 in Japan: A Critical Review and Evaluation of the Tsunami Source Mechanism	19	0.72 (Q2)	87	64th	3.5
34	Imamura, F., Hashi, K.	2003 Pure and Applied Geophysics 160(10-11), pp. 2071-2086	Re-examination of the source mechanism of the 1998 Papua New Guinea earthquake and tsunami	19	0.72 (Q2)	87	64th	3.5

No	Name	Journal Identities	Title	Cited	SJR	H-index	Percentile	CiteScore
35	Fukao, Y., Sandanbata, O., Sugioka, H., (...), Watada, S., Satake, K.	2018 Science Advances 4(4),eaao0219	Mechanism of the 2015 volcanic tsunami earthquake near torishima, Japan	17	5.93 (Q1)	146	97th	16.6
36	Kaabouben, F., Brahim, A.I., Toto, E., (...), Soares, P., Luis, J.F.	2008 Journal of Seismology 12(4), pp. 575-583	On the focal mechanism of the 26.05.1975 North Atlantic event contribution from tsunami modeling	17	0.52 (Q2)	55	56th	2.7
37	Hagala, R., Llinares, C., Mota, D.F.	2017 Physical Review Letters 118(10),101301	Cosmic Tsunamis in Modified Gravity: Disruption of Screening Mechanisms from Scalar Waves	15	3.69 (Q1)	673	95th	15.2
38	Nosov, M.A., Skachko, S.N.	2001 Natural Hazards and Earth System Sciences 1(4), pp. 251-253	Nonlinear tsunami generation mechanism	13	1.12 (Q1)	99	87th	5.8
39	Huang, Z., Wu, T.-R., Chen, T.-Y., Sim, S.Y.	2013 Journal of Hydro-Environment Research 7(2), pp. 113-123	A possible mechanism of destruction of coastal trees by tsunamis: Ahydrodynamic study on effects of coastal steep hills	12	0.68 (Q2)	38	80th	4.7
40	Williams, D.M.	2010 Irish Journal of Earth Sciences 28, pp. 13-23	Mechanisms of wave transport of megaclasts on elevated cliff-top platforms: Examples from western Ireland relevant to the storm-wave versus tsunami controversy	12	0.16 (Q4)	11	30th	0.9
41	Zengaffinen, T., Løvholt, F., Pedersen, G.K., Muhari, A.	2020 Pure and Applied Geophysics 177(6), pp. 2493-2516	Modelling 2018 Anak Krakatoa Flank Collapse and Tsunami: Effect of Landslide Failure Mechanism and Dynamics on Tsunami Generation	10	0.72 (Q2)	87	64th	3.5

No	Name	Journal Identities	Title	Cited	SJR	H-index	Percentile	CiteScore
42	Sakellariou, D., Rousakis, G., Nomikou, P., (...), Carey, S., Sigurdsson, H.	2012 Proceedings of the International Offshore and Polar Engineering Conference pp. 61-67	Tsunami triggering mechanisms associated with the 17th cent. BC Minoan eruption of thera Volcano, Greece	10	0.18	45	20th	0.5
43	Tonini, R., Armigliato, A., Tinti, S.	2011 Pure and Applied Geophysics 168(6-7), pp. 1113-1123	The September 29 2009 Samoa Islands Tsunami: Simulations based on the first focal mechanism solutions and implications on Tsunami early warning strategies	10	0.72 (Q2)	87	64th	3.5
44	Haugen, K.B., Løvholt, F., Harbitz, C.B.	2005 Marine and Petroleum Geology 22(1):209-217	Fundamental mechanisms for tsunami generation by submarine mass flows in idealised geometries (Book Chapter)	10	1.34 (Q1)	116	96th	6.7
45	Schambach, L., Grilli, S.T., Tappin, D.R.	2021 Frontiers in Earth Science 8,598839	New High-Resolution Modeling of the 2018 Palu Tsunami, Based on Supershear Earthquake Mechanisms and Mapped Coastal Landslides, Supports a Dual Source	9	1.1 (Q1)	30	74th	3.3
46	Latcharote, P., Suppasri, A., Yamashita, A., (...), Kai, Y., Imamura, F.	2017 Frontiers in Built Environment 3,16	Possible failure mechanism of buildings overturned during the 2011 great east Japan tsunami in the town of Onagawa	9	0.51 (Q2)	18	77th	2.6
47	von Huene, R., Miller, J.J., Klaeschen, D., Dartnell, P.	2016 Pure and Applied Geophysics 173(12), pp. 4189-4201	A Possible Source Mechanism of the 1946 Unimak Alaska Far-Field Tsunami: Uplift of the Mid-Slope Terrace Above a Splay Fault Zone	9	0.72 (Q2)	87	64th	3.5