Expert Meeting on Tsunami Sources, Hazards, Risk and Uncertainties Associated with Vanuatu, San Cristobal and New Britain Subduction Zones

Background Information

1. Overview

1.1 Purpose

The Intergovernmental Oceanographic Commission (IOC) of UNESCO have agreed to support Member States of the Pacific Tsunami Warning and Mitigation System (PTWS) to better understand the uncertainties associated with several Pacific subduction zones. In response to a recommendation of the Task Team on Seismic Data Sharing in the Southwest Pacific at the 8th session of the Regional Working Group of the PTWS on Tsunami Warning and Mitigation for the Pacific Islands Countries and Territories (PICTs), it is proposed to hold an experts' meeting on the subduction systems from the western end of the New Britain Trench through the San Cristobal Trench to the southern section of the Vanuatu (New Hebrides) Trench. Several similar workshops have been held successfully covering tsunami sources in South and Central America, the South China Sea, and in the Tonga - Kermadec region of the Southwest Pacific. The purpose of expert's meetings is to quantify earthquake and tsunami sources, hazards and risks to support holistic risk management (readiness, response, reduction and recovery) and target suitable reduction projects.

Very large tsunamis associated with these subduction zones have the potential to cause widespread loss of life, and damage and disruption to multiple regions simultaneously. Many Southwest Pacific countries are exposed and vulnerable to destructive tsunamis with significant consequences. This meeting will aim to focus on the uncertainties of tsunami hazard associated with these subduction zones and propose ways of managing the risk.

1.2. Background

The study region is the plate boundary from the western end of the New Britain Trench, through the Cristobal Trench to the northern and southern sections of the Vanuatu Trench (see Figure 1), a length of around 4000 km. This is a little longer than the Tonga - Kermadec system to the east which is the other major plate boundary in this part of the Pacific. The tsunami potential of the identified subduction systems is not well understood, and there may be other non-subduction earthquakes and non-earthquake threats that have not been identified. All of these potential tsunami sources are significant threats to Southwest Pacific Member States. Many Southwest Pacific Islands have a long history of settlement in coastal locations, including their largest towns and cities; therefore, exposure to tsunami hazard is high. Tsunamis cannot be prevented, and warning times are variable from minutes to hours, depending on the settlement location and distance from the earthquake source along the subduction zones. What is less well known is the threat from non-seismic sources as was demonstrated by the Hunga Tonga - Hunga Ha'apai (HTHH) volcano-induced tsunami of January 2022 in the region further east of the study areas for this experts' meeting.

The plate margin in the study region is complex with high convergence rates and several microplates as well as accommodating the overall plate motion between the Pacific and Australian plates. The major structures include the New Britain subduction trench, a pronounced feature between the Bismarck Sea and the Solomon Sea, the Cristobal Trench southwest of the Solomon Islands, and the Vanuatu subduction system between Vanuatu and New Caledonia.

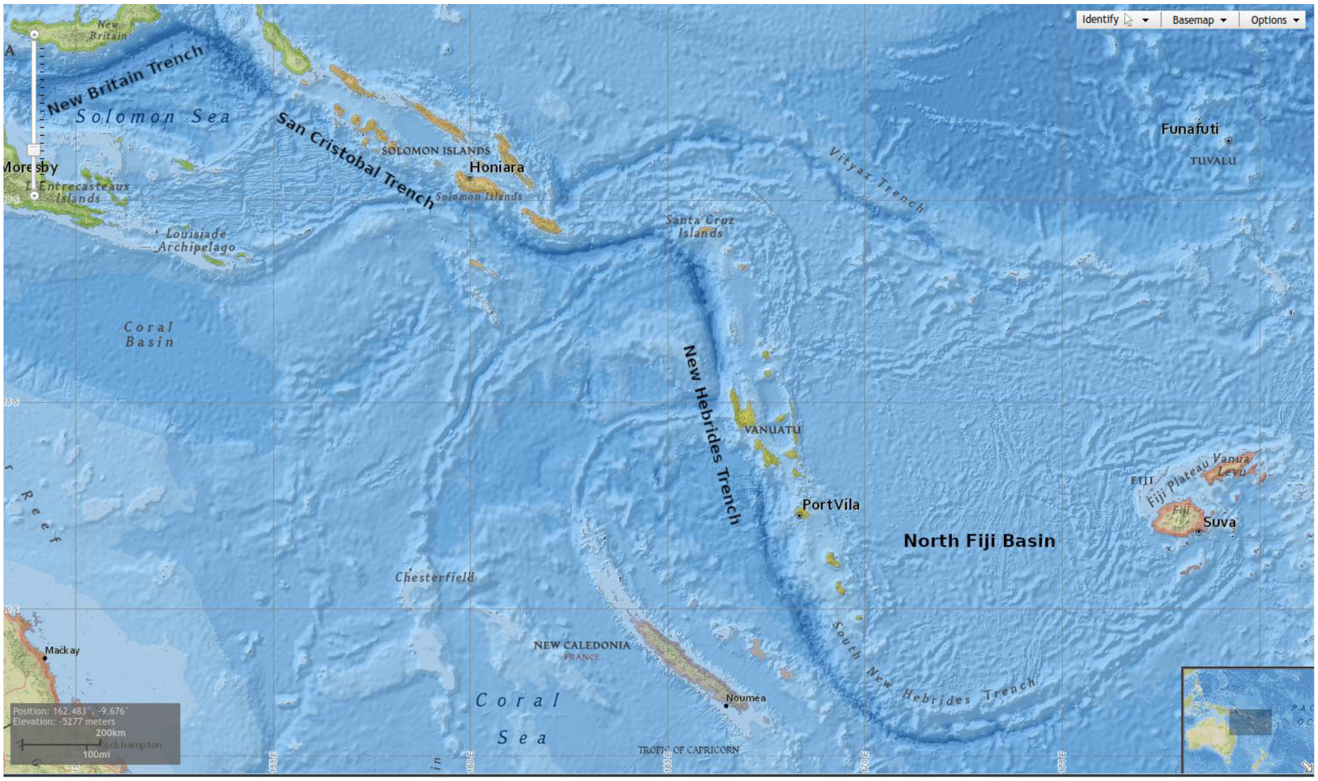

Figure 1: Map indicating the subduction systems of interest for the workshop., principally the New Britain Trench, San Cristobal Trench, and the northern and southern sections of the Vanuatu (New Hebrides) Trench.

2. Objectives and Outcomes

2.1 Objectives

The experts meeting will aim to deliver a number of outcomes to be summarized in an IOC Technical Report. Members of the experts meeting will be expected to endorse and support the report. The objectives are as follows:

- Use paleoseismology, historic event data, seismic studies and tsunami modelling in the Vanuatu and New Britain regions to develop a better understanding of the tsunami hazard and risk in the region. The maximum potential earthquake (M_{Max}) for the subduction zones and broader regions are to be considered and discussed.
- Discuss the uncertainties of the tsunami sources along the Vanuatu, San Cristobal and New Britain Subduction Zones. This will include maximum credible earthquake magnitude and rates of tsunamigenic events, to understand the most extreme consequences and risk management challenges, and from more likely, lower magnitude scenarios. Use real events from other regions to better define consequences.
- Investigate possible non-seismic tsunami sources in the Vanuatu, San Cristobal and New Britain subduction regions.
- Use this understanding of hazard, risk and uncertainty to define a number of Pacific and global community needs and actions. For example, identifying scientific research needs, evaluation of risk management programmes, informing priorities and investments to support risk management for at-risk Southwest Pacific countries and the broader Pacific.
- Identify and record gaps in knowledge or understanding of the Subduction Zone, and propose means for addressing or managing these.
- Consider the effects of slow subduction zone earthquakes and their influence on tsunami generation.
- Meet the agreed key objectives of ICG-PTWS (see attachment).

2.2 Key Scientific Questions

- Are there any non-subduction zone earthquake sources in the greater region?
- Segmentation on the subduction zones?
- MMax on the subduction zones or segments?
- Are there any non-earthquake sources of note (volcanic, landslides, etc)?

2.3 Outcomes

As a minimum, the following outcomes will be developed as a result of the scientist experts meeting:

- Develop an IOC Technical Report summarizing the meeting and its findings.
- Provide recommendations for consideration by the ICG-PTWS WG1, WG2, PICT-WG, and Pacific Region Member States.
- Suggest further research to support the understanding of these subduction systems and any other potential sources in the regions, and the response and reduction initiatives for affected Southwest Pacific countries.

3. Meeting Components

Topics to be covered in the meeting are as follows:

- Earthquake and other historical tsunamigenic events associated with the Vanuatu, San Cristabol and New Britain regions.
- Possible future tsunamigenic earthquake sources associated with the Vanuatu, San Cristobal and New Britain regions as constrained by current seismological understanding.
- Possible non-seismic tsunami sources (e.g. volcanic and landslides).
- Tsunami modelling (inputs may be required to run the models during the meeting).
- Risk based scenario assessments.
- Paleoseismological and paleotsunami studies.
- Digital Elevation Modelling and bathymetry – requirements, gaps, existing data (including bathymetric modelling).
- Emergency management expertise – risk reduction initiatives.
- Technology and detection networks eg seismic and Global Navigation Satellite Systems (GNSS)

4. Tectonic Setting and Previous Work

The aim of this section is to provide an overview rather than a comprehensive summary of the tectonic setting in the regions of interest and some of the resources available to aid discussion. As outlined in the background section above, the region of interest is very complex tectonically. Basically, it is made up of a series of trenches and subduction systems (Figure 2) taking up the motion between the Pacific and Australian plates on this major section of the Pacific Ring of Fire. The plate motion rates vary from around 50 mm a year in the southern section of the Vanuatu Trench to over 100 mm a year on the northern San Cristobal (Solomon Islands) section of the plate boundary and the New Britain Trench.

The earthquake activity is high on all parts of the plate boundary in the region of interest, with over 230 earthquakes of M 7 or above recorded since 1900 (Figure 3) in the National Earthquake Information Centre catalogue (USGS). Five of these earthquakes have been over M 8, including the 2007 Gizo and 2013 Lata (Solomon Islands) earthquakes in the San Cristobal region. In the 1900s M 8+ earthquakes occurred in the New Britain region in 1906 (near Lae, Papua New Guinea) and in 1971 (near Panguna, Papua New Guinea) and in the Vanuatu region in 1920 (near Isangel, Vanuatu).

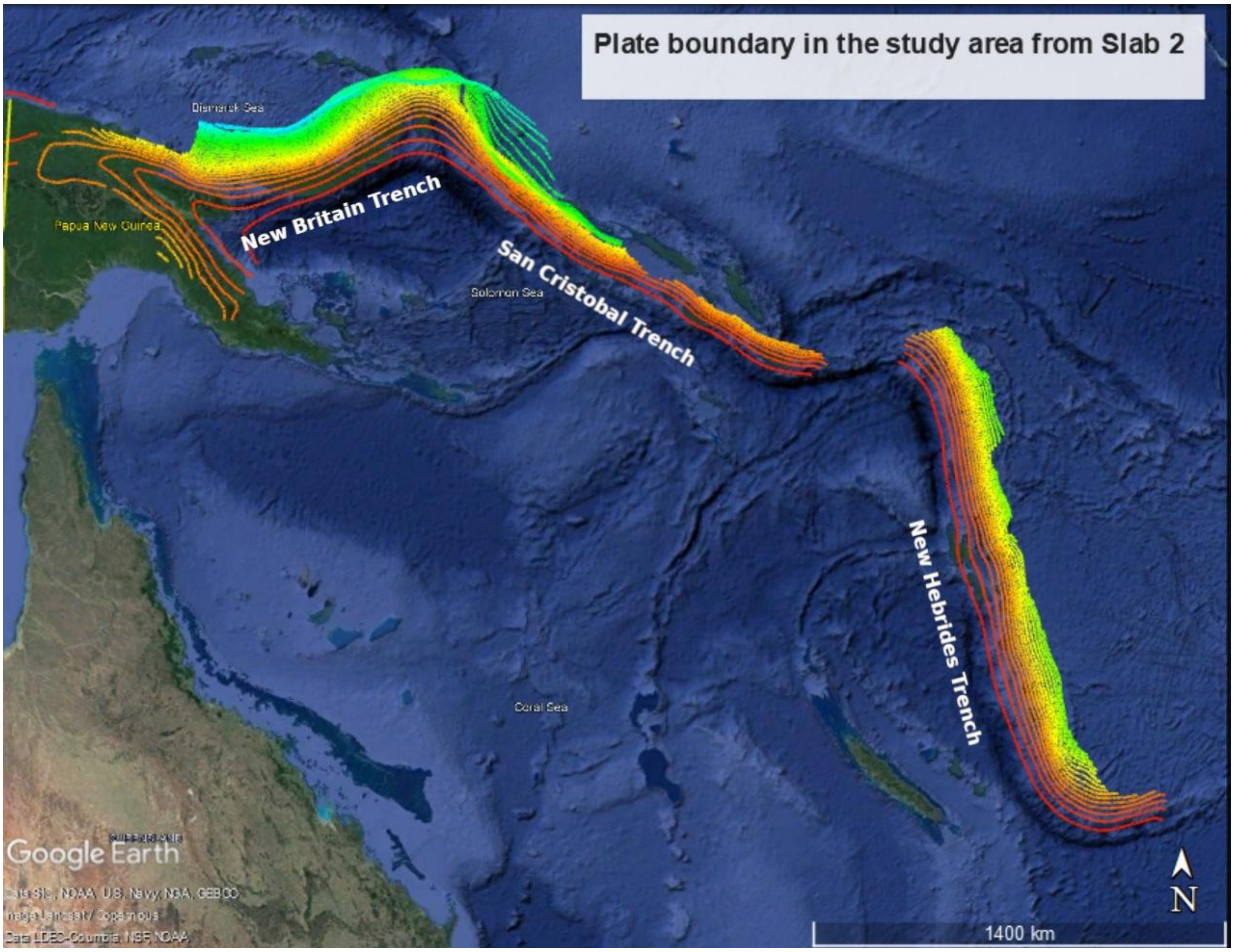

Figure 2: The plate boundary in the study region from Slab 2 (Hayes, 2018) showing coloured contours with depth (reds, through yellows, greens, blues with depth). The region of interest is from the west of the New Britain Trench in the north, through the San Cristobal Trench west of the Solomon Islands to the Northern and Southern sections of the Vanuatu (New Hebrides Trench) further south between New Caledonia and Vanuatu.

4.1 The New Britain Trench

The current plate configuration has evolved over time from the collision of the Indian, Australian and Pacific Plates. Micro-plates evolved to accommodate the relative motions of the three plates - including the Solomon Sea Plate, and the North and South Bismarck Plates. After the arrival of the Ontong-Java Plateau, the Australian Plate subducted under the Pacific Plate at the New Britain Trench.

The New Britain Trench region frequently experiences large earthquakes; this subduction zone is one of the most seismically active regions of the world. Deep earthquakes (depth greater than 300 km) are reasonably common as well; several M 6.5+ earthquakes have occurred over the past 40 years, including a M 6.8 event in June 1995. Because of their great depths, none are known to have caused damage. In some locations the Australia slab in the region is seismically active to depths of greater than 400 km.

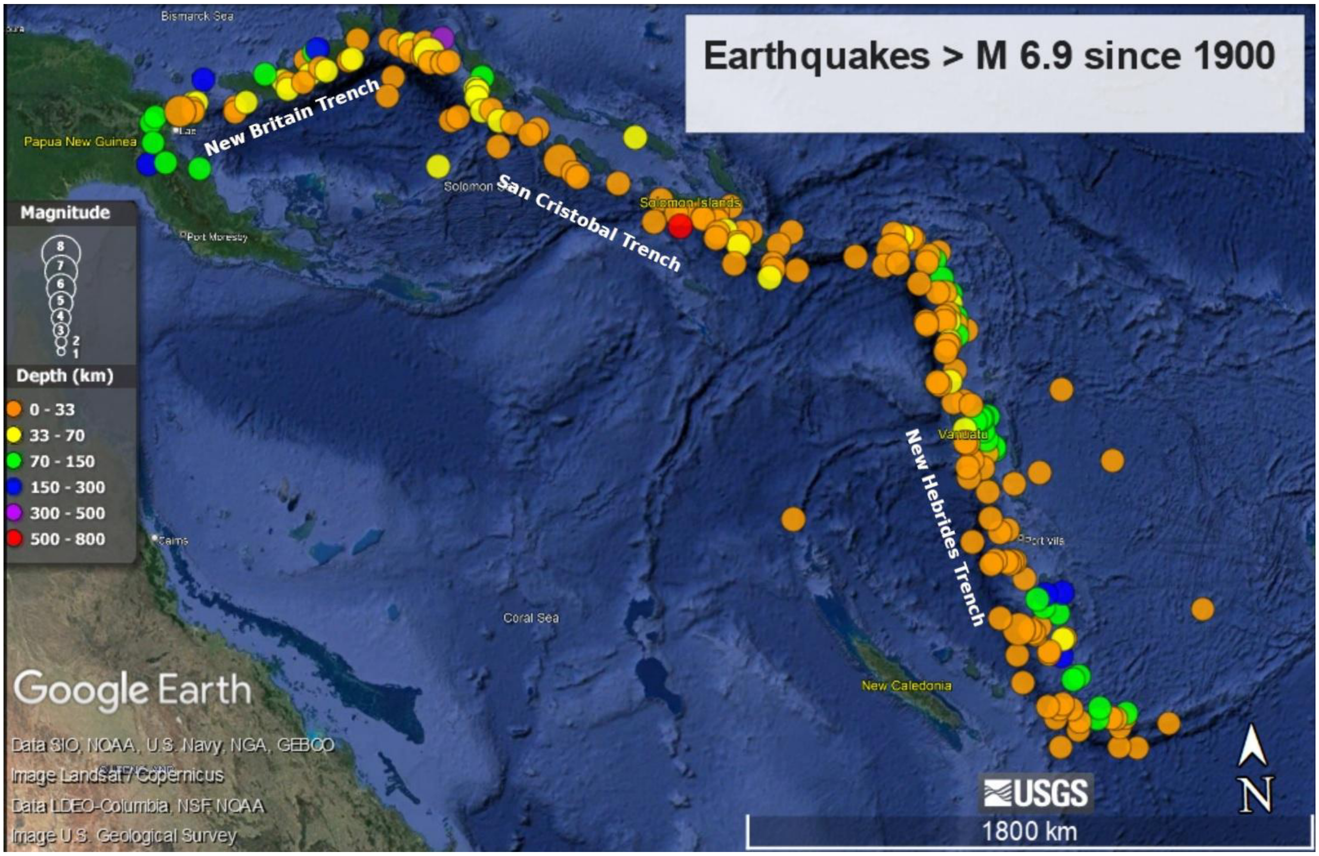

Figure 3: Earthquakes in the region of interest M 7 or greater since 1900, colour-coded for depth (as indicated) with the size based on magnitude as indicated.

4.2 The Cristobal Trench

San Cristobal Trench is a subduction zone in Southeast Solomon Islands, between the New Britain and Vanuatu Trench systems. In fact many authors include the San Cristobal Trench in the general tectonics of the New Britain and Vanuatu regions. It is a segment of a convergent plate boundary formed by the subduction of the Solomon Sea plate eastwards beneath the Pacific plate. The trench runs east-west from Santa Cruz Islands to Makira Island. The trench reaches a depth of over 8000m. The region has produced many large earthquakes, including M 8 events in 2007 and 2013 causing tsunamis, and a series of two just below M 8 in 2016.

4.3 The Vanuatu Trench

The Vanuatu subduction system is the major tectonic feature in the plate boundary zone between the Tonga–Fiji region and the Solomon Islands and is accompanied by a complex series of rifts and transform faults in the North Fiji Basin (eg Power, et al., 2012). Vanuatu straddles the plate boundary zone with New Caledonia to the South-west and Vanuatu and Fiji to the north-east. All Southwest Pacific Member States (countries and territories; PICTs) in the region are at risk from this subduction system and the resulting hazards, as are more distant Member States such as New Zealand (Power, et al., 2012). In this region the Australian Plate subducts north-eastward beneath Vanuatu and transforms to a complex series of rifts in the North Fiji Basin. GPS velocities indicate that rapid clockwise rotation of the Vanuatu Arc is the primary tectonic control on the kinematics of back-arc deformation in the North Fiji Basin, particularly in areas of active rifting in the Errom- ango and Futuna Troughs (Calmant et al., 2003; Pelletier et al., 1998).

The southeastern termination of active subduction at the Vanuatu Trench is uncertain, but based on seismicity, subduction is likely to terminate somewhere within 5 degrees longitude of 169°E (around 300 km south of Aneityum, Vanuatu's southern-most island; and around 300 km east of Noumea, New Caledonia). Where the active subduction is taking place at the southern Vanuatu Trench is key to understanding the tsunami hazard posed by earthquakes on this section of the Vanuatu subduction zone. Large subduction thrust earthquakes on the east–west trending portion of the southern Vanuatu subduction margin could trigger tsunamis that impact PICT countries in the Southwest Pacific and New Zealand. GPS data from the Matthew and Hunter Islands indicate that up to 5 cm/year of convergence is occurring on the east–west striking portion of the southern Vanuatu Trench (Calmant et al., 2003), indicating that active subduction is occurring on the southern segment of the Trench, but the Matthew Hunter Fracture Zone becomes dominated by strike-slip deformation further east (Power, et al. 2012).

The Vanuatu Arc region of the Australia/ Vanuatu plate boundary experiences numerous strong earthquakes. In the past quarter century, the 1,000-kilometer section of the Vanuatu Trench centred near the epicentre of the largest earthquake in the region since 1900 (the 1920 M 8.1 earthquake located around 100 km west-southwest of Isangel, Vanuatu) has produced 19 earthquakes of M 7+. The largest was a M 7.7 earthquake near the southern end of this section (249 km East of Vao, New Caledonia) in May 1995.

4.4 Tsunami Hazard Studies and other Resources

Several New Zealand focused studies have identified the regions of interest for the proposed workshop as potential sources of large tsunami. Power et al., 2012 concentrates on the likely impacts on New Zealand from the South Vanuatu Trench and Kermadec subduction systems. Although this paper focuses on the potential New Zealand impact, the results are relevant to the rest of the Southwest Pacific. Various other New Zealand tsunami hazard reports also discuss the subduction systems in the area of interest for the proposed workshop, particularly the Southern Vanuatu Trench. The 2013 update of the New Zealand tsunami hazard (Power, et al., 2013) also identifies the South Vanuatu Trench as being an important potential hazard in the Southwest Pacific Region.

The 2018 report (Power, 2018) commissioned by New Zealand's emergency management agency (NEMA) into the siting of tsunameters (DART 4Gs in this case) included a scientific evaluation of the tsunami sources threatening New Zealand and its Southwest Pacific neighbours. This concluded that the Tonga - Kermadec subduction systems and the Hikurangi Margin (off the east coast of New Zealand) were the highest priority for New Zealand. However, the south Vanuatu Trench (east of New Caledonia) was also a priority for both New Zealand and the Southwest Pacific. In the end the New Zealand Government funded a network of 12 DART 4Gs, three of which cover at least part of the plate margin which is the focus of the proposed workshop, and the network is now operational.

As well as the New Zealand hazards reports, there have been several recent studies that have provided tsunami hazard assessments in the region. For example, Fakhruddin et al., 2021 provides probabilistic tsunami hazard and exposure assessments for the Pacific island's country of Fiji, and Johnson, et al., 2021 provide probabilistic seismic hazard assessments for several Pacific Islands countries.

A 2015 study of a doublet of earthquakes that year contains useful estimates of the tsunamigenic potential of the New Britain trench (Heidarzadeh, et al., 2015). A recent paper detailed a case study of the Matthews Island M 7.7 earthquake of February 2021 (Roger, et al, 2022) in the transition zone at the southern end of the Vanuatu system provided insight into the tsunami potential of higher magnitude earthquakes in the region.

The GEM Faulted Earth Subduction Interface Characterisation Project (Berryman, et al., 2015) provided estimates of the parameters of all major subduction systems on the planet and is a useful reference for comparison with other estimates. Likewise, the SLAB2 characterisation of subduction zone geometries (Hayes, et al., 2018) is another important source of information (see Figure 2).

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