Sumatra Tsunami on 26 December 2004
Asian and Pacific Coasts 2005
September 4-8, 2005, Jeju, Korea

MEGA-TSUNAMI IN NORTHEASTERN TAIWAN AT LEAST 12,000 YEARS AGO

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ABSTRACT: ODP Site 1202 operated on the south slope of Okinawa Trough in 2001. It was discovered that the entire 410 mbsf terrigenous sediments were like that from the Taiwan's mountain. The analysis leaked out that the sedimentation rate was very high. Inspecting the tunnel construction of Snow Mountain in the Pei-I Freeway Project, its structure was found to be a fragile, complex geology. The worst problem was the large amount of artesian water, which was proved existing for 8 ka, indicating in there contained the underground reservoirs. The northern Snow Mountain was once a stratovolcano. At least 12,000 years ago, this volcano erupted and triggered a big landslide, which produced the sediments at Site 1202. The Lanyang River mouth was once at Suao habor, but it changed the river course after the big landslide. The landslide triggered mega-tsunami waves hundreds of meters high, this in turn caused a worldwide catastrophe.

KEYWORDS: Mega-tsunami, Underground reservoir, Worldwide catastrophe.

INTRODUCE: According to the outcome of ODP Site 1202 operation, the average sedimentation rate is the highest rates in the world. Where did the terrigenous sediments come from? Nobody can answer the question. Now we inspect the nearby mountain in Taiwan and find something in there that can answer the question.

1. The ODP Site 1202 is the place of highest sedimentation rates.

The Ocean Drilling Program (ODP) Site 1202 operated on the south slope of the Southern Okinawa Trough, the same position on the northern slope of the Ilan Sill, in April 2001 to obtain a high-resolution record of the history of the Kuroshio (Black) Current during the Quarternary.

Four holes were cored with the advanced hydraulic piston corer and extended core barrel at ODP Site 1202, the deepest of which is 410 m below seafloor (mbsf). The entire 410-m section discovered consists of rapidly deposited dark gray calcareous silty clay and sandy turbidites. Calcareous nannofossil and planktic foraminiferal occurring in the 410 meters long sequence drilled at ODP 1202 suggest that the sedimentary record is younger than 127 thousand years (ka) (Salisbury et al., 2002). If the age of the section is younger than 127 ka, as suggested by the absence of pink Globigerinoides ruber, then the sedimentation rate at the site was 325 cm per

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1,000 years (cm/kyr), But AMS ^{14}C dating of scaphopoda and planktic foraminifers picked from 10 depth levels down to 102 mbsf allows constructing a chronological framework for the last 24 ka (Wei, Cheng & Mii, 2003). The average sedimentation rate of the topmost 100 m of the record is about 420 cm/kyr. The oxygen isotope composite record of core at Site 1202 reveals the average sedimentation rate that is estimated at 500 cm/kyr (Wei, Mii & Huang, 2005). According to the global data of the world, the average sedimentation rate in the seabed estimates only 3-5 cm/kyr. There is one of the highest rates ever observed in the ocean basins of the entire world at Site 1202 (Figure 1).

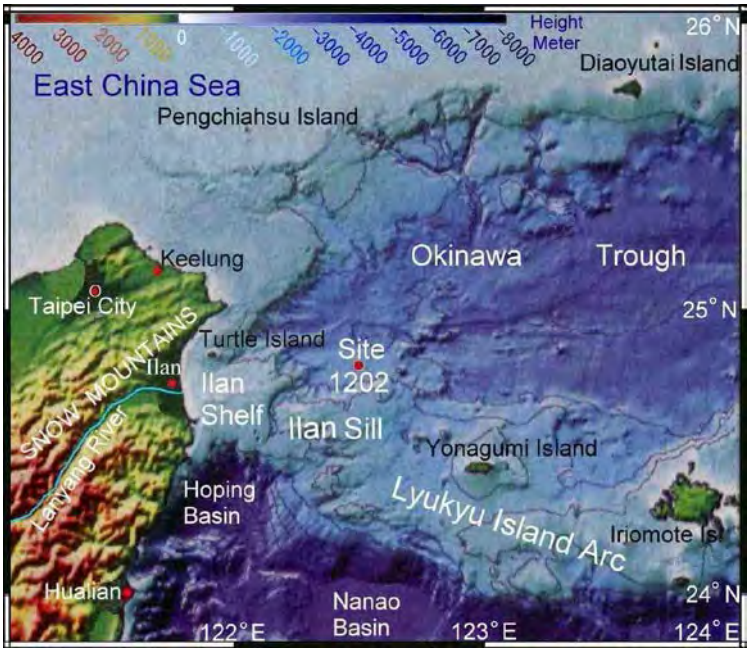

Figure 1. ODP Site 1202 is on the northern slope of the Ilan Sill. The Ilan Sill extends seaward from the Ilan Shelf and the Ilan Shelf is the seaward extension of the Ilan Plain on the northeastern coast of Taiwan.

2. The terrigenous sediment was supplied from Taiwan Island

Because of the relatively low biogenic content of the sediments in the Southern Okinawa Trough, which is an area of high sedimentation, this requires a large external terrigenous source. The enormous terrigenous sediment is recognized as being supplied from the East China Sea shelf and the island of Taiwan (Boggs, et al., 1979; Lou & Chen, 1996; Chen, Lo & Lin, 1992).

The one external source is the East China Sea shelf, which mainly comes from the largest river in China ── Yang-Tzu River. Despite the tremendous influx of sediment from the Yangtze Rivers, in terms of sediment supply, there is very little evidence of thick submarine fans and major slope deformation features on the Okinawa Trough in the East China Sea. Sequence stratigraphic analyses of seismic and high-resolution chirp sonar data provide that there is such a small volume of sediment reaching the Okinawa Trough (Miller, 2001). Yang-Tzu River is in the north more than 500 km far from Site 1202 and the Kuroshio Current flows northwards at high speed (2.7-3.6 km/hr), very width (150-200 km) and great depth (～1.0 km) (Fan, 1985; Yuan, et

al., 1998), so the sediments of Yang-Tzu River are obviously impossible to deposit in the Southern Okinawa Trough such a high sedimentation.

The other external source is on the island of Taiwan that is recognized as the Lanyang River, which is very near Site 1202. However, there is too little terrigenous sediment to supply, because the Lanyang River is an ordinary river and the silt content is obviously so low that it cannot supply the enormous amount of terrigenous sediments permanently at Site 1202.

It is very clear that the enormous terrigenous sediments at Site 1202 are deposited from neither Yang-Tzu River nor Lanyang River. Where did the terrigenous sediments, 410-m depth, come from? Nobody can answer the question. There is one clue to finding the truth that the large terrigenous sediments are deposited from low-grade metamorphic schist and marls found within these mountain ranges on the island of Taiwan (Salisbury, et al., 2002). We investigated the vicinal waters and the physiographic features, and found something in there.

3. The vicinal waters and physiographic features reveal the truth.

The Taiwan Island has been formed on the eastern edge of the Chinese continent by the collision between the Philippine Sea plate and the Eurasian plate (Suppe 1984; Teng 1990; Hsu & Sibuet, 1995) since 4 Million years (Ma) (Chi et al., 1981; Teng 1990; Lee & Lawver, 1994). This complicated tectonic structure is mainly due to the fact that the motion of the most northwestern portion of the Philippine Sea plate is impeded by the island. The sea floor off northeastern Taiwan features with three major physiographic units, which are the East China Sea continental shelf, the East China Sea continental slope and the southern Okinawa Trough and two less prominent topographic features of the Ilan Shelf and the Ilan Sill. The collision between the Philippine Sea plate and the Eurasian plate made the Crust in the northeastern Taiwan break and magma erupt to form with several volcanoes and volcanic islands. The wider East China Sea shelf is dotted with several volcanic islands related to the back-arc rifting of the southern Okinawa Trough (Teng et al.,1992).

The west end of the southern Okinawa Trough is represented by the curvilinear isobaths at the greatest depths of about 2000 m. The trough is confined mainly by the East China Sea slope to the north and the slope off the Ryukyu volcanic islands. The Ilan Shelf is the seaward extension of the Ilan Plain on the northeastern coast of Taiwan. The shelf is fan-shaped and the width varies from about 10 km off the Lanyang River mouth to about 2 km near the seaside towns of Toucheng and Suao. The long and narrow Ilan Sill extends seaward from the Ilan Shelf and is between the Nanao Basin to the south and the back-arc basin of the Okinawa Trough to the north. This ridge is confined by the Ryukyu volcanic islands to the east and is narrower than the island chain of the Ryukyus. It is considered to be a part of the Ryukyu Arc which is segmented and submerged near Taiwan (Yu & Song, 1993).

There are many volcanoes existing in northeastern Taiwan and its vicinal waters, including northern Snow Mountain, which is the intersect place of Ryukyu volcanic arc and Luzon volcanic arc (Yu & Song, 1993). Turtle Island is a volcanic island, which is located at 55 km west of ODP Site 1202 and 15km east of Snow Mountain, has been formed from volcano erupting about 7,000 years ago. In this area was a capital site for the event that had been probably taken place during the last 5 Ma. In the vicinity of Turtle Island, there are about 60-70 volcanoes in the seabed and at least 11 submarine volcanoes that are still active (Lee, et al., 1998) and 30-40 nozzles of hot spring, including a biggest one in the world till now (Figure 2). In there, the marine life activity follows the lava flow, and the undersea water temperature reaches 140℃.The

live volcanic area is relatively large in the seabed.

There are several hot springs that still remain today, the two most famous are: Jiaoxi Spring on the east side of Snow Mountain, and Wulai Spring on the west side. This indicates the volcanoes of northern Snow Mountain have erupted many times in the past.

Figure 2. Near Turtle Island a nozzle of hot spring (4-m diameter and 10-m length) is the biggest in the world. (Natioal Sun Yat-Sen University Professor Chen, Chen-Tung Arthur provided.)

4. The eastern flank of the Snow Mountain looks as it has been cut out by the nature event

When driving a car from Taipei City toward Ilan City through Pei-I Highway, we must climb the slope over 50 kilometers of straight distance across the western area of Snow Mountain to the ridge. When reaching the point of the ridge, we can see the whole landscape that presents Lanyang Plain just beneath our feet. Here we find a sudden drop of about 600 meters. In order to reach Lanyang Plain, we must negotiate 9 sharp bends and l8 changes of direction. The terrain features are not as symmetric as the western area of the mountain, so we may imagine that the eastern flank of the mountain has been cut out by a natural event a long time ago (Fig. 3). What is the natural event? We must understand the characteristics of northern Snow Mountain.

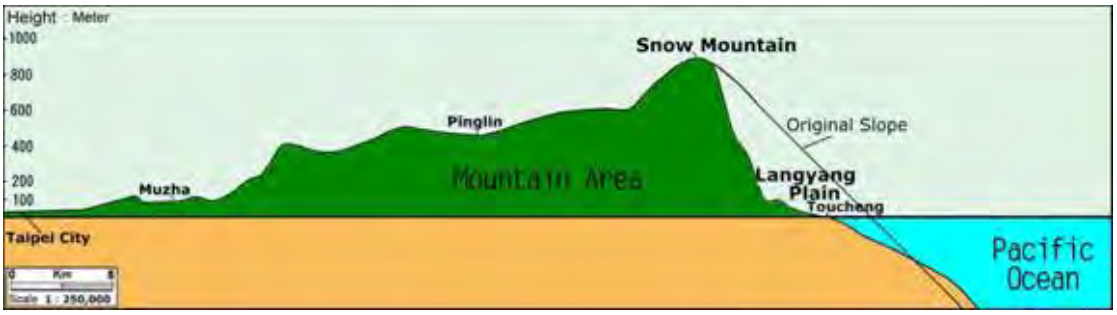

Figure 3. The profile from Taipei city to Toucheng around Pei-I Highway denotes maybe a landslide of Snow Mountain. The original eastern slope may be symmetric to the western slope.

5. The northern Snow Mountain is a fragile, complex geology

The northern Snow Mountain is located between Taipei County and Ilan County in Taiwan. It belongs to sedimentary rock with a little metamorphosis. The tunnel construction of Snow Mountain in Pei-I Freeway Project, which began in July 1991 and will be completed in December 2005, has 12.9 km in length and it is the longest tunnel in Southeast Asia. As the tunnel construction of Pei-I Freeway penetrated there, along the line of the tunnel was found very fragile, complex geology with many folds and faults.

The west section of the tunnel mainly contains sandstone, graywacke and sandy shale. The quality of the rocks there is good to work with. This allows the construction process to run smoothly. But the east section of the tunnel mainly contains hard shale, Szuling sandstone and clastite, and 6 series of main faults and 2 synclines pass through there. One of the largest main fault estimates about 50 meters in length. The quality of rocks is so bad that the complex structure indicates the stratum is very easy to collapse (Lin, 2001).

The east section of the tunnel within the Snow Mountain is the weakest ─ Szuling sandstone, which contains fragments of laccolith, **Jianmo clay**[3], fault clay, fault breccia and high pressure layers of groundwater. There is a covered earth up to 720 m in thickness, average 350 m, above the tunnel. When excavating the tunnel, constructors used a Tunnel Boring Machine (TBM). The excavation caused collapses, often accompanied by earth flows. During the project a TBM was destroyed and buried.

In total there were 98 major collapses and 36 large artesian waters during the tunnel construction and 4 project schedules delayed. The worst problem of the tunnel construction was the largest artesian water in the world that yielded water up to a total of 650 l/s. Why were there so much artesian waters in the tunnel construction? The structure type of Snow Mountain revealed the truth.

6. There contains underground reservoirs

From the tunnel construction of Snow Mountain, we realize that the mountain is full of water. Much of the rain, which has fallen on the Snow Mountain, has been trapped inside it for several thousand years, because of its particular rock structure. We know that there are many folds and faults in the mountain and it was once a series of volcanoes. We can recognize that the deep of the Snow Mountain has two types of rock. One is very loose and permeable material, such as rubble and Szuling sandstone that the water can soak through from the surface, straight down to the laccoliths within the mountain. The other type of rock is the lava dyke which is formed by volcanic magma. As magma cooled and solidified, the dyke became a very hard, impermeable lava dyke. The water cannot penetrate through this rock and is trapped behind it. Therefore, there are many dykes within the mountain that act as a series of underground reservoirs.

7. The Illustration Data of Isotope Dating Groundwater

There are two isotope dating methods of ^{14}C and ^{3}H (Tritium) applied in the groundwater in the tunnel of Snow Mountain. Using Accelerator Mass Spectrometry ^{14}C isotope dating can figure

[3] **Jianmo clay** is a kind of mold siltstone, which can dissolve into water as sludge.

out the age and the source of the groundwater. Using ^{3}H isotope dating can determine if the old groundwater combines with new rainfall. The isotope dating groundwater in the tunnel was carried out, and then ^{3}H isotope dating sample of groundwater was surveyed by America National Miami University that determined a low limit of 0.1TU, where 1 TU indicates a T/H ratio of 10^{-18} (Taylor & Roether, 1982).

From June to December of 1999, the groundwater samples were taken from the tunnel of Snow Mountain, and analyzed in ^{14}C and ^{3}H as the following Table 1. The data of ^{14}C isotope dating showed that groundwater in the tunnel of Snow Mountain was about 8,000 years before present (yr BP). The 8,000 years old groundwater must have been deposited within the underground reservoirs.

Table 1. The Isotope Dating Data of Snow Mountain Guide Tunnel Around 30K in Pei-I Freeway. (Ministry of Transportation and Communication National Expressway Engineering Bureau provided)

Sampling Date	Sampling Location	^{14}C (yr BP)	^{3}H (TU)
1996/04/24	Guide Tunnel 39K+070	4850±80 $\delta^{13}C$＝-14.28‰	3.17±0.10TU
1997/06/23	Guide Tunnel 39K+070		2.38±0.14TU
l997/06/23	Guide Tunnel 39K+070		2.64±0.17TU
1997/06/23	Guide Tunnel 39K+150		0.87±0.17TU
1997/06/23	Guide Tunnel Tian-Chi stele (elevation 520m)		2.60±0.20TU
1997/06/23	Guide Tunnel 39K+178		0.64±0.16TU
1997/07/01	Guide Tunnel 39K+070	5500±100 $\delta^{13}C$＝-13.99‰	2.52±0.17TU
1997/07/01	Guide Tunnel 39K+079		2.86±0.17TU
1998/12/11	Guide Tunnel 38K+950	5140±80 $\delta^{13}C$＝-14.3‰	1.81±0.17TU
1999/06/07	Guide Tunnel 38K+902.4	5500±100 $\delta^{13}C$＝-14.0‰	1.20±0.20TU
1999/07/12	Guide Tunnel 29K+509.3	8450±50 $\delta^{13}C$＝-13.7‰	0.60±0.10TU
1999/10/31	Guide Tunnel 38K+476.2	5510±100	0.70±0.l0TU
1999/10/31	Guide Tunnel 29K+503	8600±130	0.60±0.10TU
1999/12/26	Guide Tunnel 38K+409.3	6950±180	1.60±0.70TU
1999/12/26	Guide Tunnel 29K+561.8	8230±110	0.90±0.20TU

8. Northern Snow Mountain was a kind of stratovolcano

According to the records of Pinglin village, there were more than 300 hectares of tea trees just above the tunnel, almost faded the half after digging the tunnel of Snow Mountain during the drought in 2003. In the preceding times the case did not happen that meant the old underground reservoirs of Snow Mountain were broken and flew away. So, there were a series of underground reservoirs inside the northern Snow Mountain that was proved.

Because the structure of the northern Snow Mountain is fragile, complex geology with many folds and faults and there are a series of underground reservoirs inside it that indicates it is a kind of stratovolcano, which is ease to collapse. Stratovolcano is constructed of alternating layers of pyroclastic and rock solidified from lava flows.

9. The nature event cut out the Snow Mountain was the landslide

According to the theoretical studies of stratovolcano (Johnson, 1987; Satake & Kato, 2001), we may conclude that the volcanoes of northern Snow Mountain erupted a long time ago and accompanied the vibrations of earthquakes; the magma upwelled from deep inside and reduced the strength of structure sufficiently and in turn heated the water of the underground reservoirs. When the water pressure rose it triggered the collapse of the underground dykes. As some underground reservoirs collapsed, the enormous volume of sandy clay and stone dropped into the Pacific Ocean and created a big landslide.

Its bulky sandy clay and stone sank into the sea and formed a large embayment, an indentation of beautiful arched coastline in Ilan County (Figure 3). From the view of physiographic features, the fan-shaped Ilan Shelf is the seaward extension of the Ilan Plain on the northeastern Taiwan coast and the long and narrow Ilan Sill extends seaward from the Ilan Shelf, too (Yu & Song, 1993). This means the terrigenous sediments of both all come from the landslide of Snow Mountain. It was proved by the outcome of ODP Site 1202.

10. A big landslide causes a mega-tsunami to destroy everything

On La Palma in the Canary Islands of the west of Africa that will erupt and cause to trigger collapse (Voight & Elsworth, 1992; Elsworth & Voight, 1996). The Cumbre Vieja volcano collapse models treat the resulting mega-tsunami as a shallow water wave and also produce initial leading mega-tsunami waves. For example, within two minutes after the postulated Cumbre Vieja collapse (up to 500 cubic kilometers in volume) begins, the model estimates a water dome 900 meters high on top of the monolithic slide block. After five minutes, and after traveling 50 km, on top of the now disintegrating block of material, the leading wave height drops to 500 meters. According to the model, after 8 hours mega-tsunami waves of up to 10-25 meters in height reach Florida of America and the Caribbean islands and invade into 20 km inside the shorelines (Ward & Day, 2001: Ward, 2001).

The conditions are similar to the Cumbre Vieja volcano, the enormous volume of the landslide in eastern flank of Snow Mountain, a rough estimate of about 480 km^3 (Area about 800 km^2 and average height about 600 m), will make a mega-tsunami. The wave height of the mega-tsunami in the waters of northeastern Taiwan may have been hundreds of meters and it became a big worldwide flood. Not only all the Ryukyu Islands and seafront of Taiwan Island, but also almost all the land around the Pacific Ocean was destroyed.

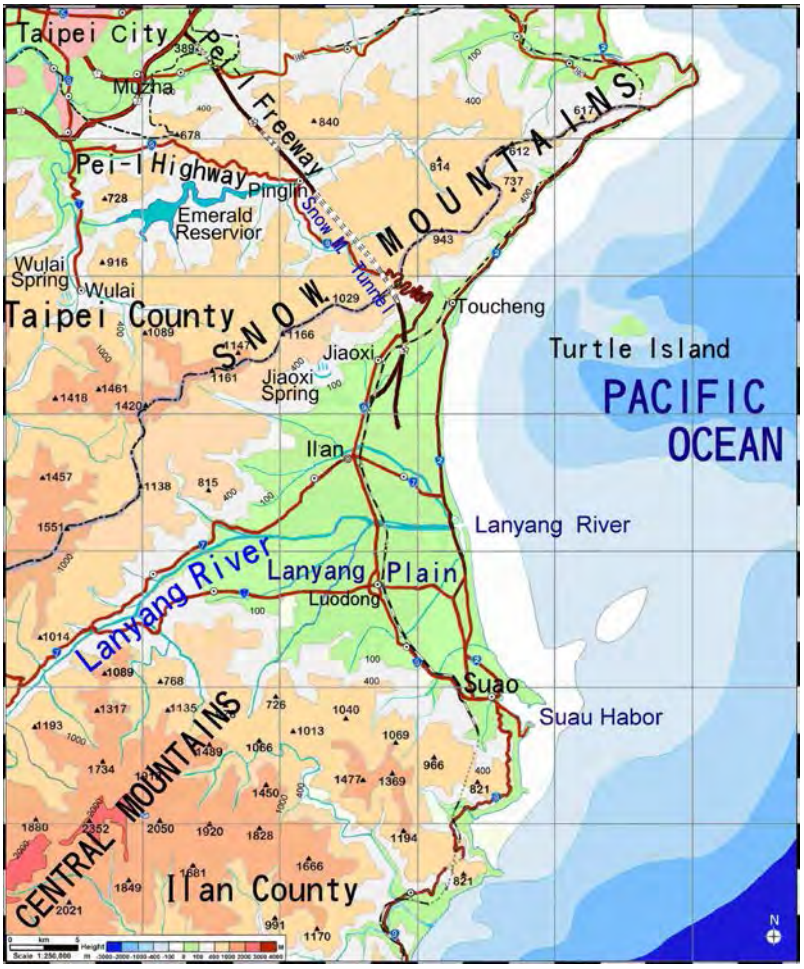

Figure 3. The map of northeastern Taiwan shows that there is an indentation of beautiful arched coastline and the Suao Harbor should be once the Lanyang River mouth.

11. The landslide of Snow Mountain changed the river course of Lanyang River

According to the map of Taiwan (Figure 3), the seashore line and the contour lines beneath the sea level near the Lanyang River mouth are very straight and smooth, and that indicates there is a new river mouth, but the Suao harbor is different. There are the prominent embankments and all the contour lines bulge out from the Suao harbor at the influence of Kuroshio Current northwards. During the last glacial period, more than 12,000 years ago, the sea level was 120 m below the present's (Fairbanks, 1989). There were many sand bars near the Suao harbor including an elliptic sand bar about more than 2.5 km long, indicating that the Lanyang River, the longest river of the Lanyang Plain, had flowed out from Suao harbor since long time ago. This is a proof that the Lanyang River changed the river course after a big landslide, which was the collapse of the northern Snow Mountain. As the enormous volume of earth sank into the ocean, there was no obstruction and the river course didn't need to make a turn to Suao harbor any more. Therefore, it flowed directly into the ocean to run a new one as the present.

12. The mega-tsunami occurred at least 12,000 years ago.

The first people to appear in Japan were Minatokawajin on the island of Okinawa 18,000 years ago. Later, all of the mankind's remnants were extinct for a span of 10,000 years, and then 6,670 years ago the historical culture remnants appeared again (Kimura, 1991). From the legend, all of them were destroyed after an immense flood. The people around the Pacific Rim, including Taiwan aborigines, had a legend that their ancestors survived after a big flood or a terrible tsunami. This means a mega-tsunami in the waters of northeastern Taiwan happened at least 18,000 years ago. This time interval is conformed by 410-m terrigenous sediments at ODP Site 1202.

According to the outcome of ODP Site 1202 (Wei, Cheng & Mii, 2003), from the terrigenous sediments the depletion of heavy oxygen isotope began at about 17 ka, and persisted until 8 ka. C/N ratio and $CaCO_3$ content of the bulk sediments in the smaller than 63 micron fraction suggest that the site did not reach to today's hemi-pelagic condition until 10 ka. In contrast, terrestrial source contributed significantly during the period of 25 ka to 11 ka. A reversal of oxygen isotopic values to more positive values suggests a local registration of the Younger Dryas at 11.6-11.1 ka. Those time intervals coincide with the mega-tsunami between 18,000 and 11,000 years ago. Those time intervals coincide with the mega-tsunami between 18,000 and 10,000 years ago. This comes to a conclusion: at least 12,000 years ago, a mega-tsuna1mi occurred in northeastern Taiwan, and then caused a worldwide catastrophe.

Acknowledgements

We are grateful to Dr. Tsai, Tseng-Chang of Culture University, Graduate School History Institute for constructive criticisms and helpful comments.

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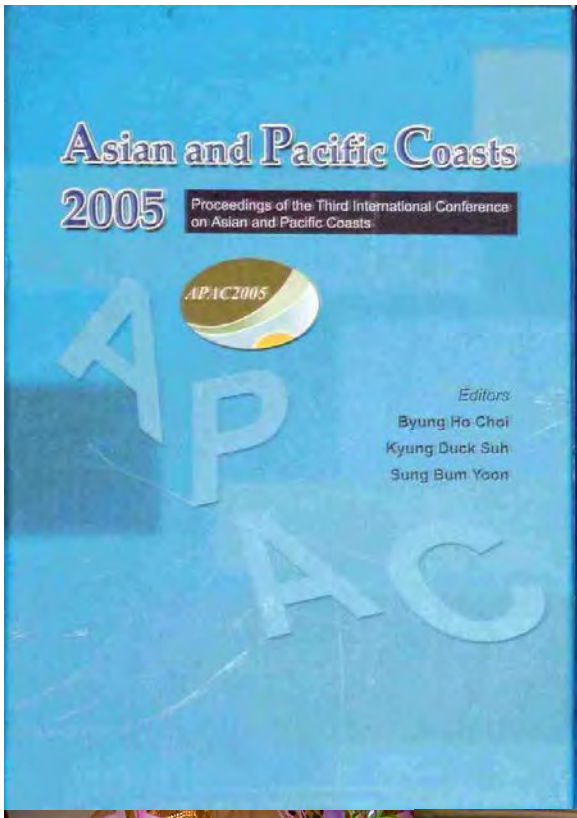
Asian and Pacific Coasts
2005
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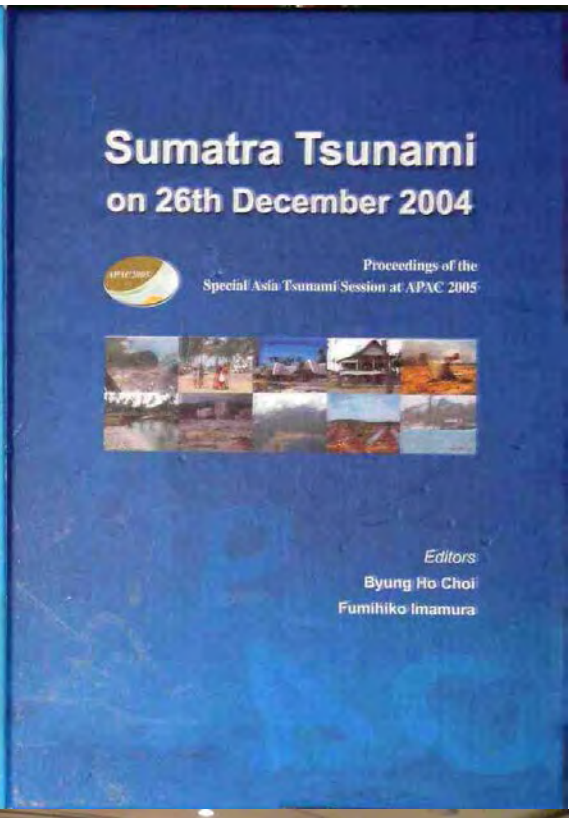
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