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Some Thoughts on The Risk of Natural Disasters in Ryukyu Archipelago

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Ryukyu Archipelago



Ryukyu Archipelago is situated on the Ryukyu Arc and consists of a chain of islands for a length of 1300 km between Kyushu Island of Japan and Taiwan. The main islands are Amami-Oshima, Okinawa, Miyako, Ishigaki, Iriomote and Yonaguni from north to south

Natural Disasters

- •Earthquake
- •Tsunami
- Geotechnical Disasters
 - (Slope failure, Liquefaction, Debris flow, sinkholes)
- •Typhoon, Tornadoes, Torrential rains

TECTONICS

Ryukyu arc is considered to be a convergent plate margin where the Philippine Sea plate is subducting beneath the Eurasian plate

The arc is a rifting fragment of continental crust and it is oriented NE-SW direction and the convergence rate between the Philippine sea plate and the Eurasia plate varies from 5 to 7 cm/yr.



CRUSTAL DEFORMATIONS



In the region, the Philippine Sea plate moves towards WNW with respect to the interior of the Eurasia plate, having a relative velocity of approximately 60 mm/yr. This figure shows the crustal deformations measured from GPS network of GEONET of Japan

1958 Ishigaki Earthquake, Toppled Block wall (from JMA)

Earthquake Risk

Past Seismicity of Ryukyu Archipelago



It is almost unknown compared to other regions of Japan



• $3 < M \le 4$ • $4 < M \le 5$ • $5 < M \le 6$ • $6 < M \le 7$ $1 < 7 < M \le 8$ The region is very seismically active and there are more than 5 large events having a magnitude greater than 7. It is not an aseismic region



Seismicity on vertical cross section A-A'

As seen from the figure, the Philippine Sea plate subducts beneath the Okinawa plate-let with an inclination of about 30-35 degrees. On the west side, the seismic activity in Okinawa trough is also clearly seen.

Research on Active Faults are not sufficient compared other regions of Japan _____



図Ⅲ8-7-1 沖縄島の地質図

Okinawa Main Island

Miyako Island

Kisaki

NIED



Estimation of Magnitude of Past Earthquakes from geological evidences and archaeological remains



Aydan (2012, 2018)

Segmentation and anticipated seismic parameters of mega earthquakes





Archeological Evidences of Past Earthquakes in Okinawa Island

1) Minami-Uebaru Fault (Offset 10m)



2) Toppled rock block in Nakagusuku Castle remains about 400 years ago





修復前 修復後 Estimated Maximum Acceleration > 0.7g

Intra-plate Earthquake: Mw8.1

Inter-plate earthquake: Mw9.1

3) Taira-Bridge: Bridge and well & settlement

Deformation and damage to remains by an earthquake several hundreds

p: 76.00 d: 178.00 i: 114.00

 $M_W = ?$



Damage to Karstic caves can be used for inferring past earthquakes



Original idea by Gilli

1771 Meiwa Earthquake



Tsunami run-up height in Ishigaki, Miyako and Tarama Island Values are incompatible with an earthquake of Magnitude 7.4



Ishigaki Cave

(b)





Karstic Cave in the area of New Ishigaki Airport

C Cave





2005 Off-Sumatra Earthquake (Nias Island) Mw 8.5) Tögindrawa





Tögindrawa

Tögindrawa



Layers of sedimentation of stalactites and stalagmites



Estimationg of seismic characteristics from stalactites and stalagmites



Crustal Deformation (2005 Off-Sumatra Earthquake (Nias Island)





Pier

Estimation from corals: Sumatra



TSUNAMI

POSSIBILITY OF TSUNAMI IN RYUKYU ARCHIPELAGO



The tsunami by the 1771 Meiwa earthquake is well documented. However, the other tsunamis are fundamentally unknown

New Ishigaki Airport

Tsunami boulders and deposits observed on rock cuts of Ryukyu Limestone Formation

Tsunami Boulder

Tsunami deposits

Tsunami Boulders





Tsunami Boulder in Ohama district of Ishigaki Island.

The ages of the coral fossils on some tsunami boulders in the vicinity of Ishigaki and were determined by Goto et al [14] and they identified several periods: about 200, 500, 1000, 2000, and 2500 years ago on the tsunami boulders.

Geometrical Parameters of Major Tsunami Boulders in Ryukyu Archipelago



Location	Elevation	Height	Length	Width	Distance to the cliff
	(m)	(m)	(m)	(m)	(m)
Miyako-Hennazaki	20	4	6.8	4.5	21
Shimoji	12.5	9.0	16	14	43
Okinawa-Kasakanja	12	3	7.5	5	34
Ishigaki-Ohama	8.0	5.9	12	11	96



The largest tsunami boulder exist in Shimoji Island

Investigation of tsunami boulders through drones





Estimation of Magnitude of Mega Earthquakes



Location	Mw (Lower Bound)	Mw (Upper Bound)
Miyako-Hennazaki	9.5	9.7
Shimoji	9.0	9.5
Okinawa-Kasakanca	9.0	9.2
Ishigaki-Ohama	8.6	9.1

See Aydan and Tokashiki (2018) for details

Geotechnical Disasters

Slope failure & Debris flow Sinkholes, Liquefaction

Cliff Failures



Kyanmisaki Shore

Kita-Uebaru Landslide and Debris Flow



Evaluation of Causes of Kita-Uebaru Landslide & Debris Flow



Sinkholes

2009 L'Aquila Earthquake, Italy

From Ginowan City

Ground Liquefaction

Recently many artificial landfills

Damage to Katsuren Castle Remains by the 2010 Off the Okinawa Island

Locations of major damages

Historical structures may be damaged

Many Piloti Structures

Regional seismic coefficient is 0.7,

Which is the lowest in Japan. Kumamoto was 0.8.

Retrofitting is necessary

Infra structures should be retrofitted

Typhoons(Hurricanes) and Tornadoes

Increase in Size and Originates more northward

Alley of Typhoons

Strong wind, heavy rain and floods

Structural Damage-1

Structural Damage-2

Monitoring of the effects of typhoon on a apartment (2014 July 8)

CONCLUSIONS

Some of conclusions from this study are as follow:

1) The risk of mega-earthquakes and mega-tsunamis is quite high in Ryukyu Archipelago despite the common belief that the Okinawa Prefecture is an seismic region. The mega-earthquakes up to Magnitude 9.7 is possible in view of the tsunami boulders distributed over the Ryukyu Archipelago while the segmentation of the Ryukyu trench implies risk of mega-earthquakes with a magnitude greater than 9.5.

2) The risk geotechnical natural disasters in Ryukyu Archipelago is landslides in Shimajiri formation and, cliff failures and sinkholes in Ryukyu limestone formation.

3) The Ryukyu Archipelago is also known as the "Typhoon Alley". The risk of natural disasters due to typhoons is quite high. The global warming is expected to increase the risk of super-scale typhoons in Ryukyu Archipelago. This may also result in the modification of design wind loads on structures in Japan.

Fault outcrop appeared in 2016 Kumamoto earthquake

THANK YOU FOR YOUR ATTENTION