PALEOTSUNAMI STUDY in TAIWAN

Yoko OTA (NTU), Sept. 26, 2013

CONTENTS

1. Significance of paleotsunami

Key for the estimation of future tsunami

2. Indicators for paleotsunami (examples from overseas)

tsunami boulders *visible*

abrupt facies change of deposits *usually invisible*
need excavation

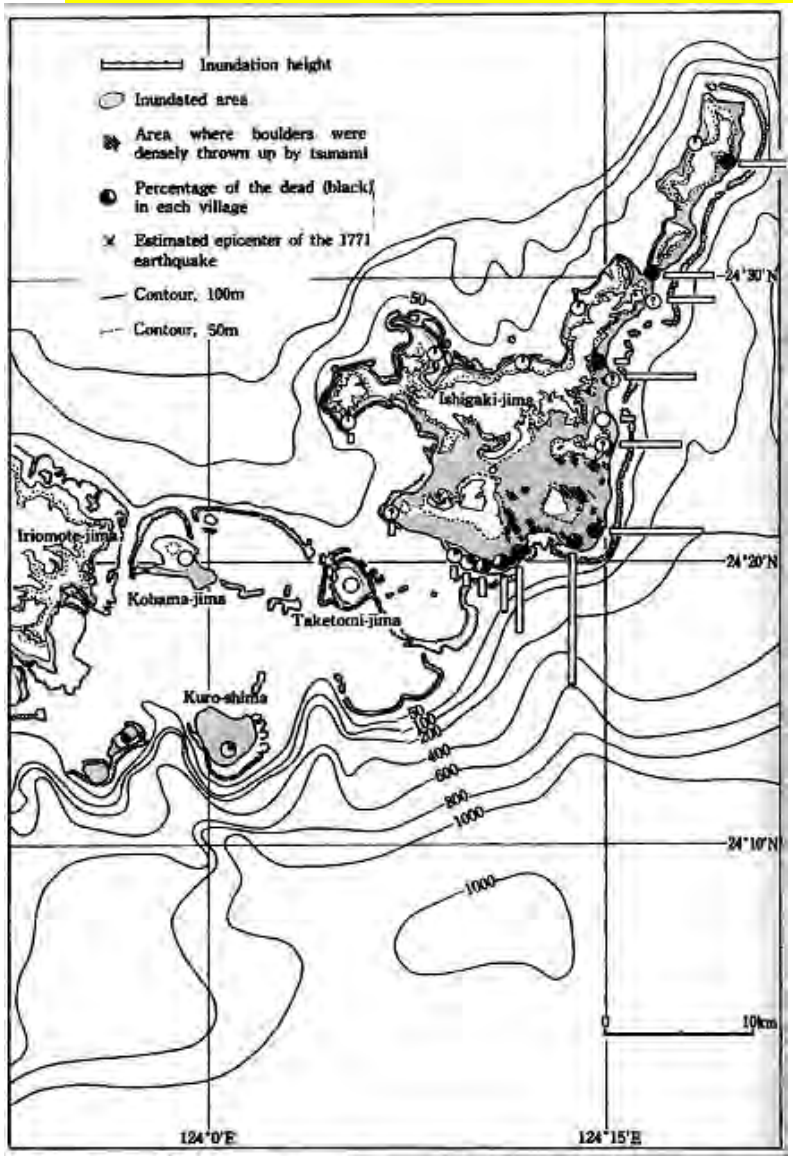
3. In Taiwan?

brief review

tsunami boulders	Hengchuan pen.
	Lanyu Island
	Green Island
facies change	Chenggong coast
	Heping Island

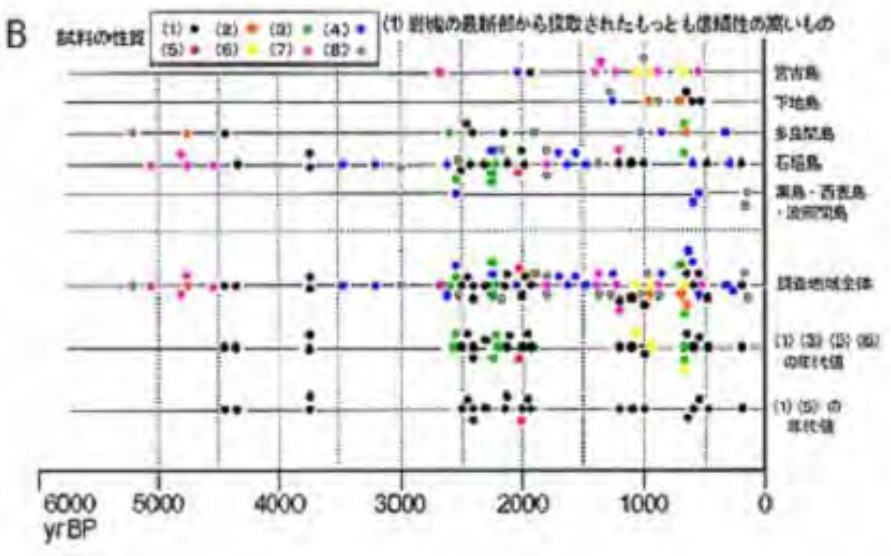
4. Future problems

2. Tsunami boulders and paleoearthquake in Ryukyu Islands.



1771 tsunami boulders, Ishigaki Is.
Compiled by Ota after Makino, 1968

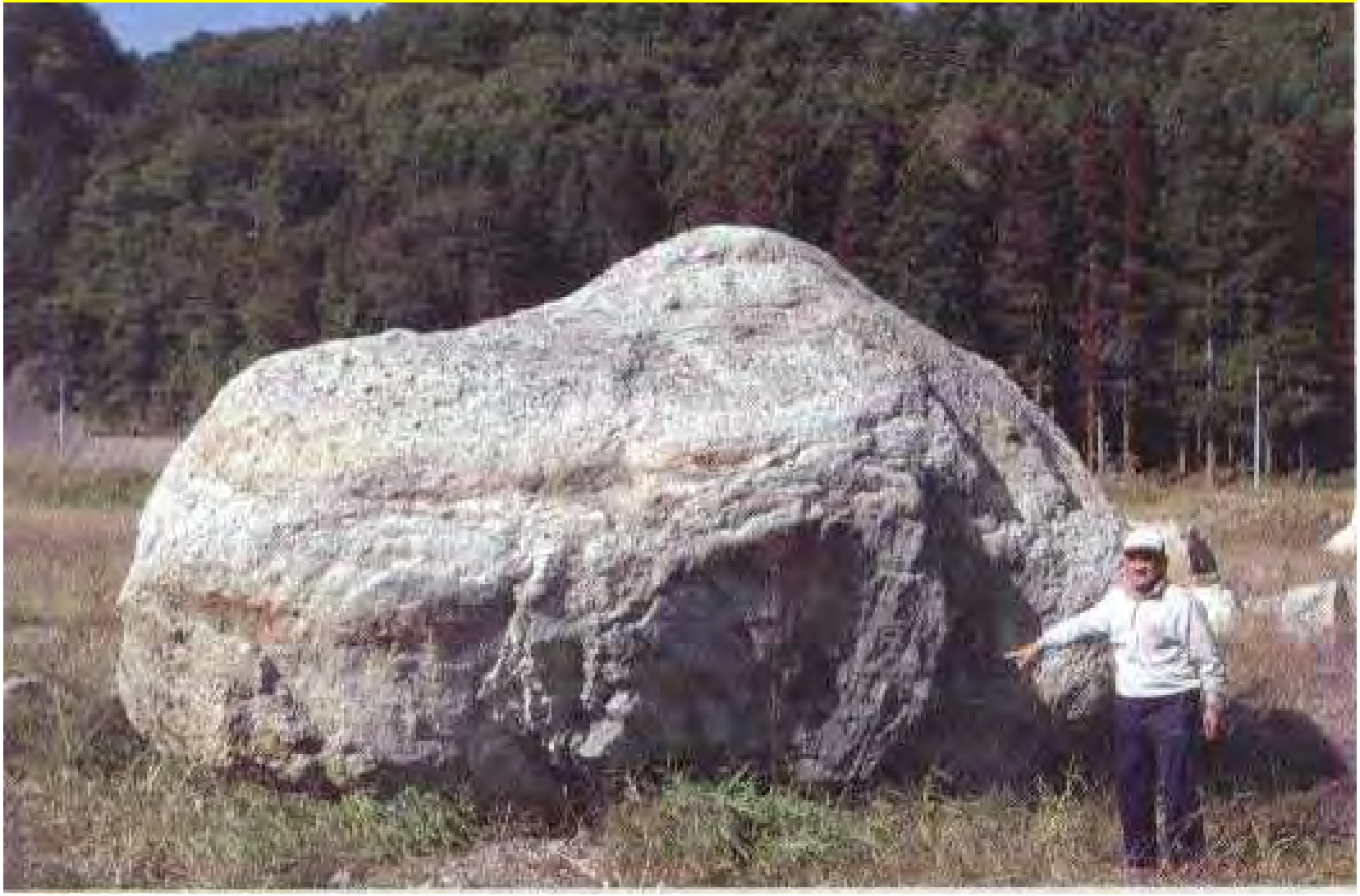
Tarama is.

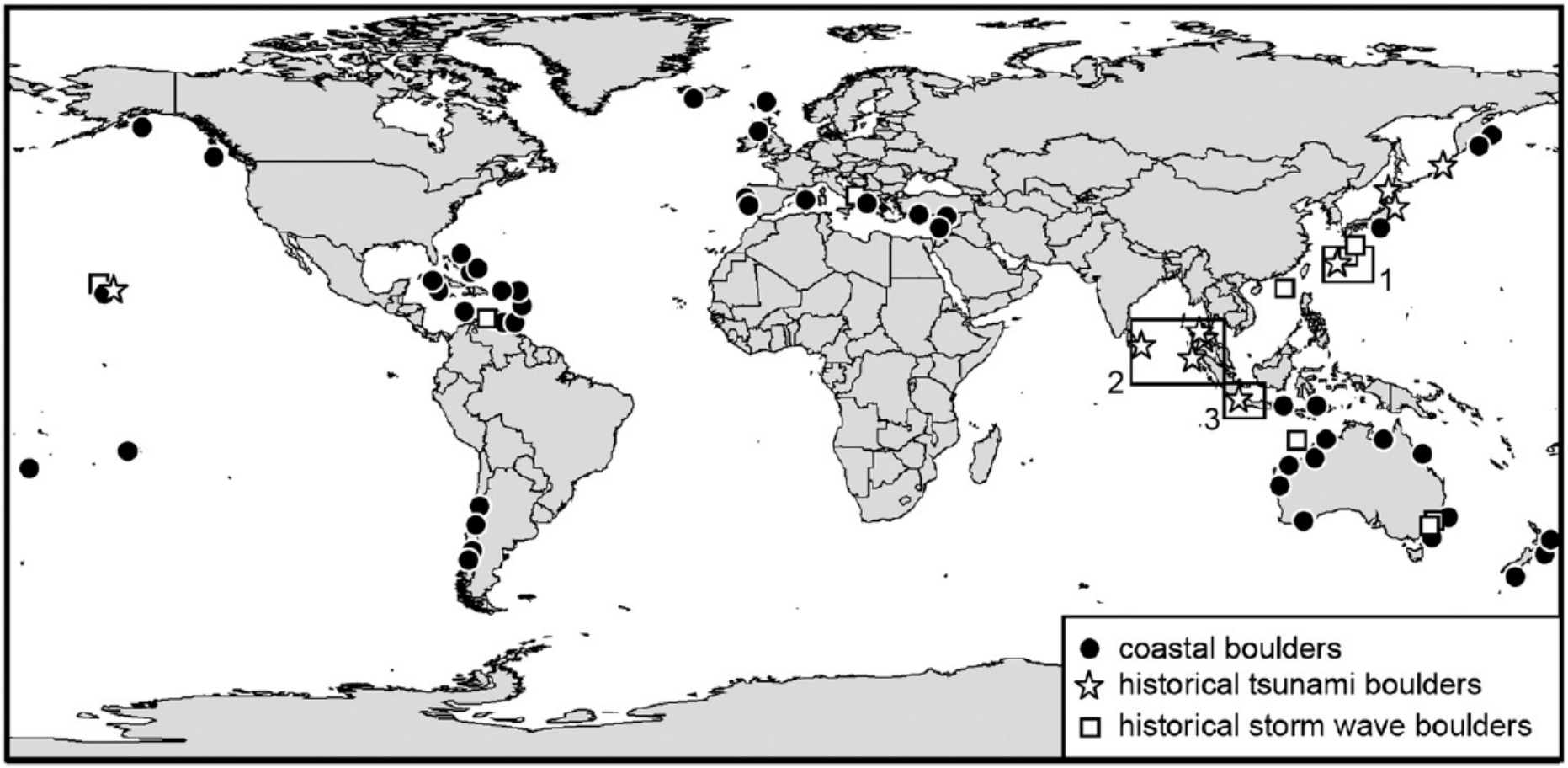


Timing f paleoearthquakes based on tsunami boulders (Kawana and Nakata,1994)

Tsunami boulder at Raga, by the 2011 Tohokuoki Eq.

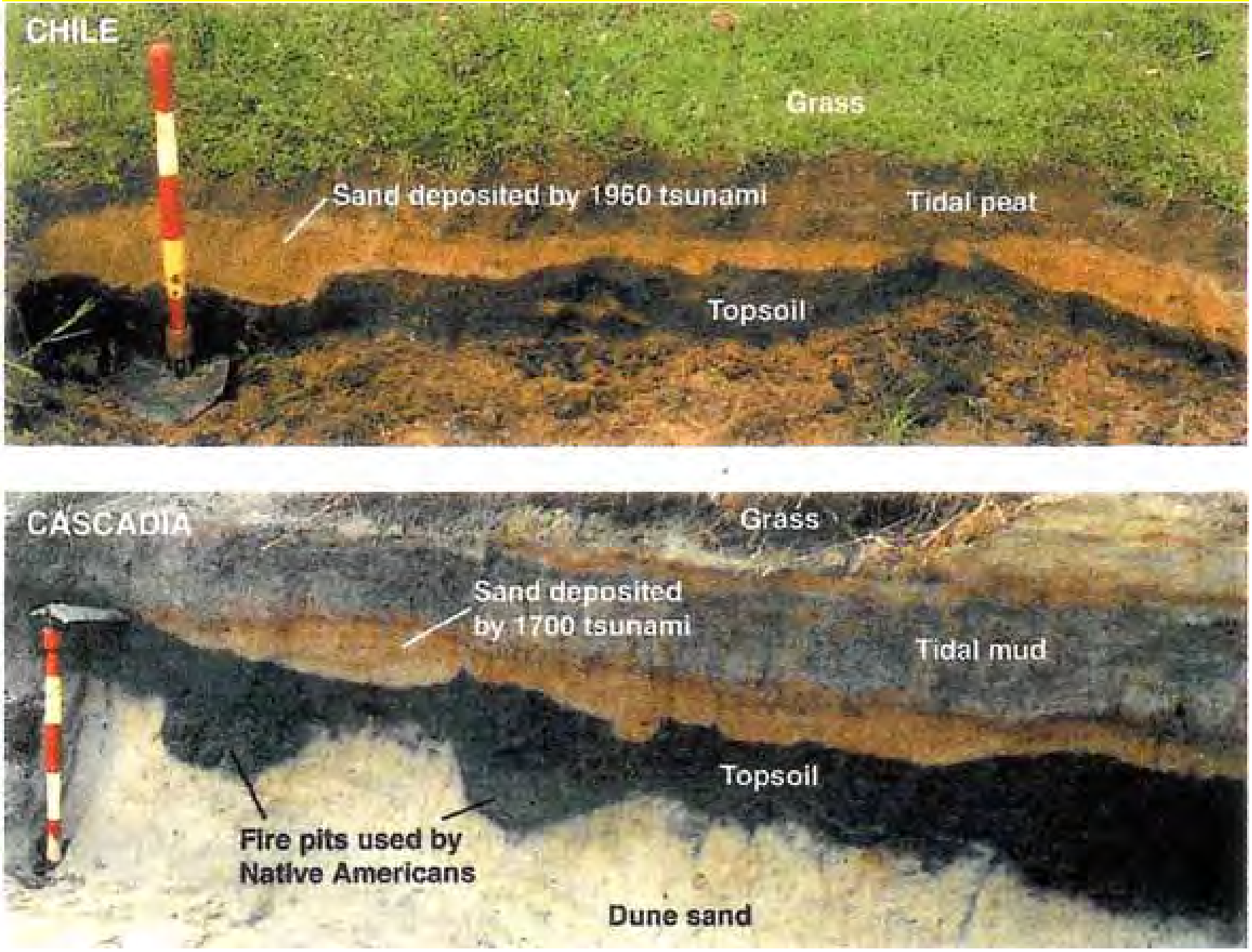
Tsunami boulders at Miyako by the 2011 Tohokuoki Eq. 600m from the coast



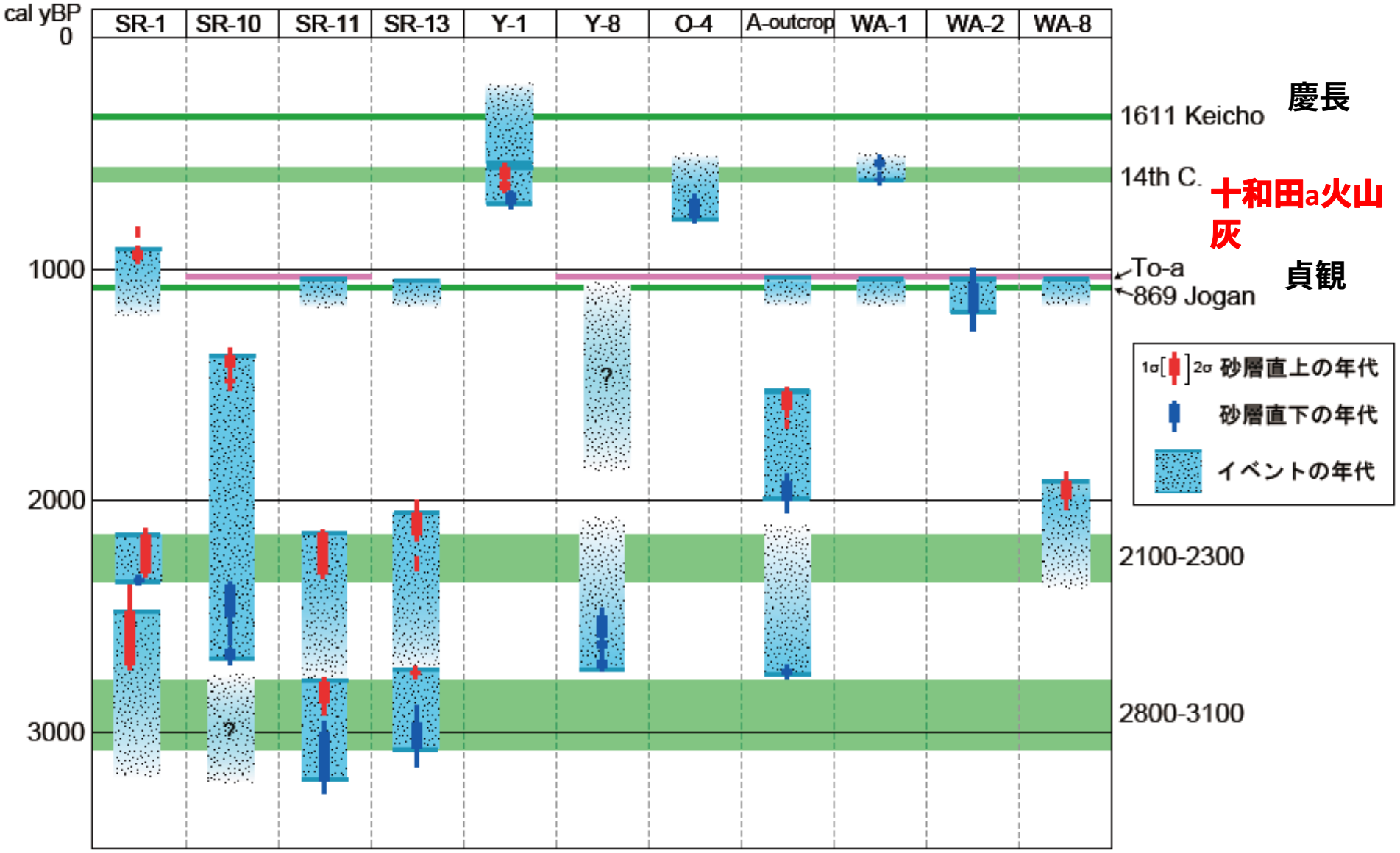


Distribution of tsunami boulders (Goto, 2010). No boulders from Taiwan

Abrupt facies change showing tsunami deposits (Atwater, 2005)



Repeated occurrence of paleotsunami in Ishinomaki Plain, Tohoku coast (Shishikura et al., 2007)



AD 869 Jogan tsunami deposits at Ishinomaki Plain

Aug. 27, 2013

3. Paleotsunami in Taiwan

Common questions on tsunami in Taiwan

1) Have tsunamis ever attacked the east coast of Taiwan ?

very negative when we started the work in 2009

2) How can we identify tsunami deposits?

3) How can we distinguish tsunami deposits and storm deposits?

Replies

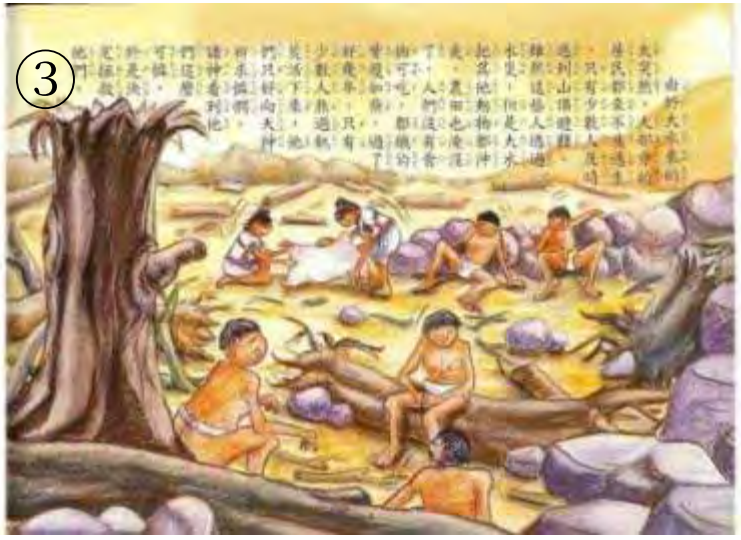
1)Yes, there are some evidences of paleotsunami

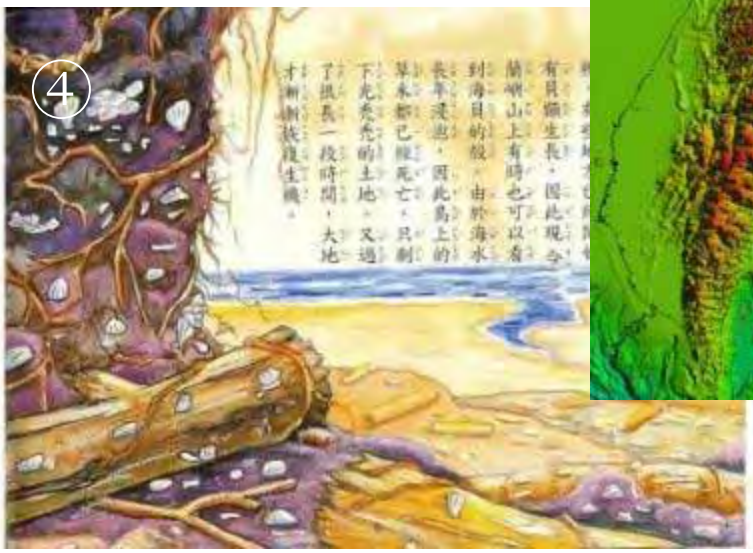
2)Yes, we have some criteria

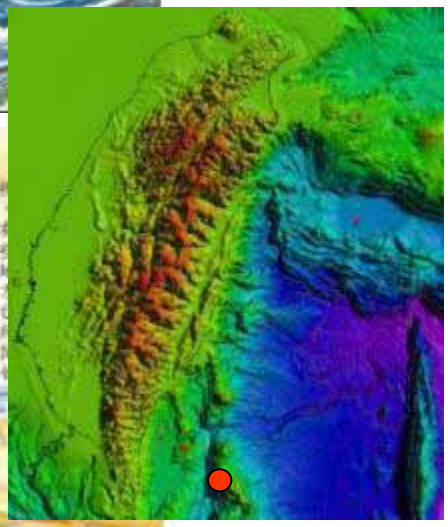
3)Yes, but not easy

This presentation includes these topics based on recent works

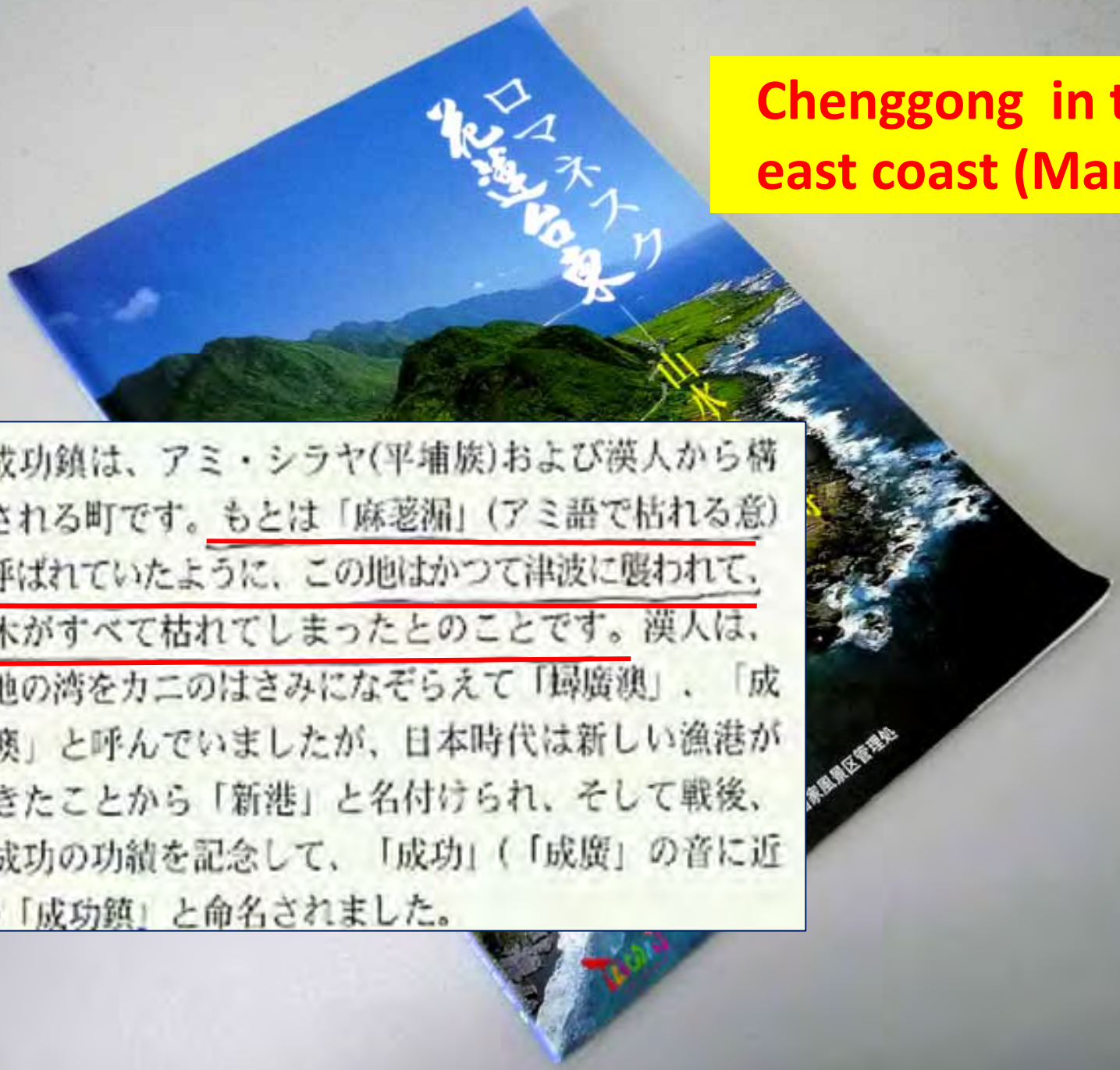
How about folklore on tsunami handed down among the natives?







Chenggong in the east coast (Mararoa



成功鎮は、アミ・シラヤ(平埔族)および漢人から構成される町です。もとは「麻荖漏」(アミ語で枯れる意)と呼ばれていたように、この地はかつて津波に襲われて、草木がすべて枯れてしまったとのことです。漢人は、当地の湾をカニのはさみになぞらえて「歸廣澳」、「成廣澳」と呼んでいましたが、日本時代は新しい漁港ができたことから「新港」と名付けられ、そして戦後、鄭成功の功績を記念して、「成功」(「成廣」の音に近い)「成功鎮」と命名されました。

Stories from other areas

Examples

Honping (豐浜) coast; Village people moved to inland from the coast because of coastal disasters (ca. six generations ago)

紅頭 (Lanyu Island) Story about sudden sea level rise

Further investigation are necessary

Tsunami or storm?

Timing ?

Brief summary of paleotsunami study based on geological evidence on the east coast of Taiwan

2009-2010 Excavation by handauger and geoslicer at Chenngong terrace (Matta et al.,2011, Ota et al., 2011, 2012; submitted)

2009 Observation of probable tsunami boulders at east Hengchun Peninsula (Matta et al., 2013, Ota et al., 2013)

2011 Preliminary observation of tsunami boulders at Green Island

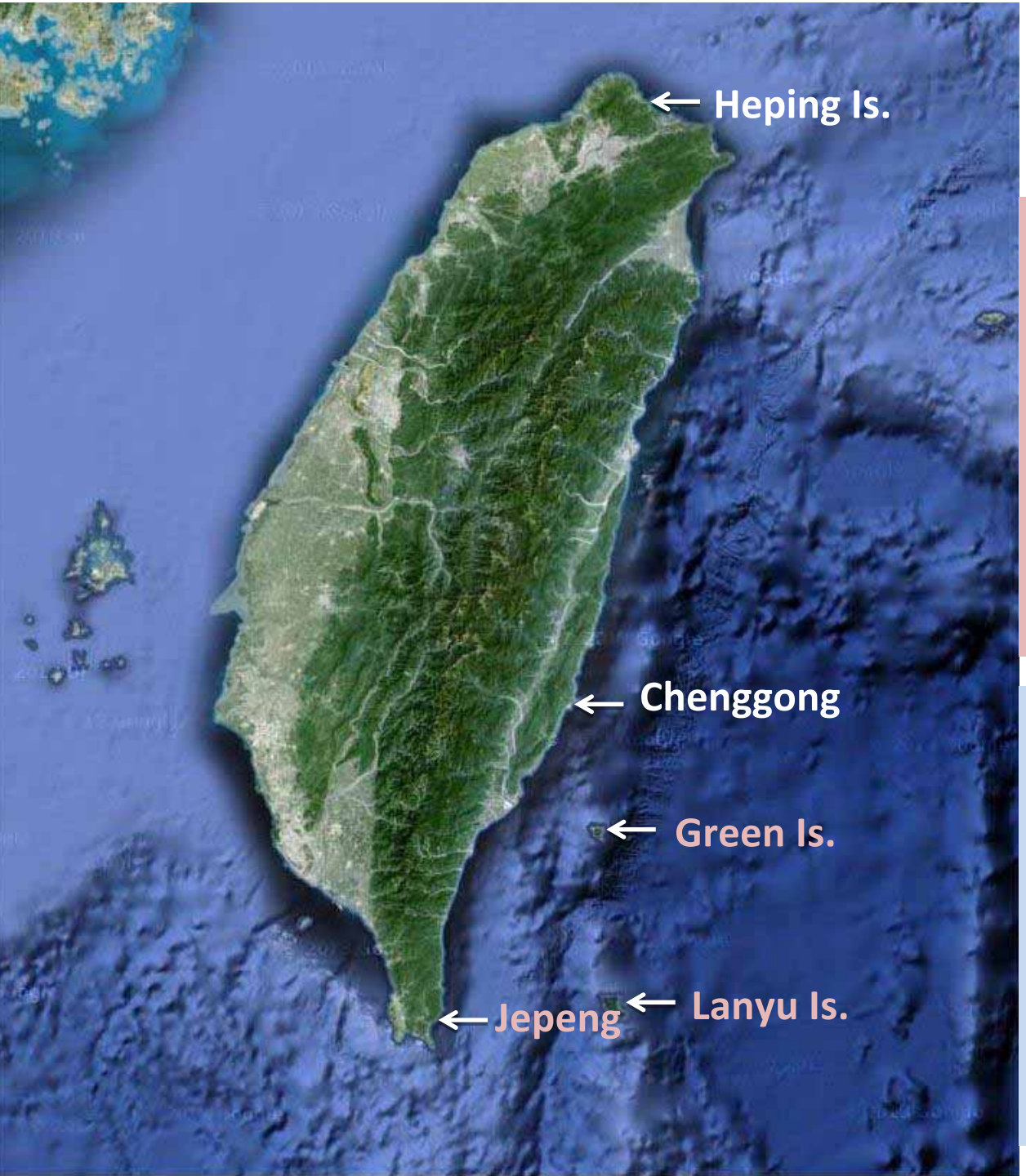
(These works are by Matta, Ota, Ando, and others)

2012 Test pit observation of Holocene deposits on Heping Island (Chung et al., 2012 and in press)

2013 Start of three years project, supported by Academia Sinica; Lanyu Island, Green Island (Ota, Shue and others)

2013 Workshop on paleotsunami (Yen, supported by NSC)

2013 Tsunami project by NSC (led by Yen)



PALEOTSUNAMI STUDY SITE

Tsunami boulders

Jepeng (Matta et al.2013),

Green Island (Ota et al., under working)

Lanyu Island (Ota et al. under working)

Facies change of deposits

Chenggong coast (Matta et al., submitted)

Heping Island (Chung et al., accepted)

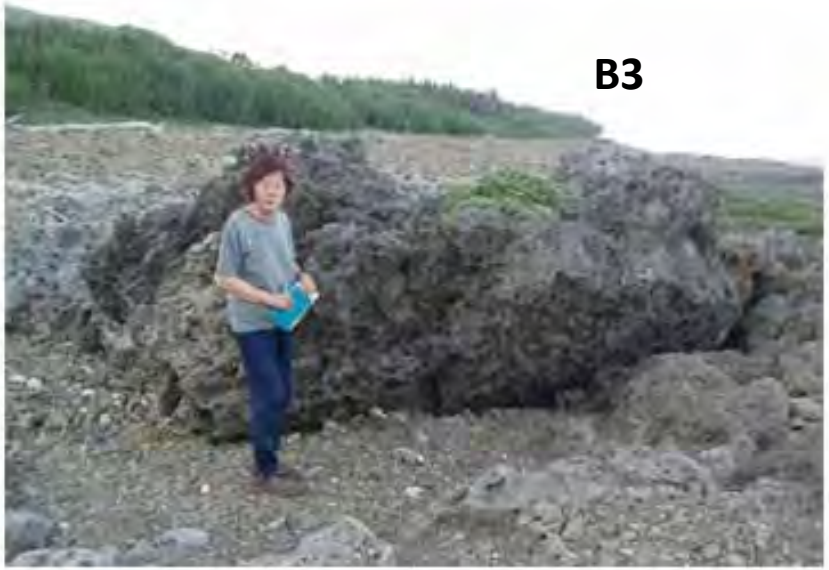
Jepeng area

Location of the observed sites

Coral boulders are found from three sites B1,B2, B3 on Holocene coral terrace.

Tsunami boulders in Henchung Peninsula

Three tsunami boulders



Size of coral boulders

	Maximum diameter	Height above the terrace	Distance from the shoreline
B1	**5.5 m**	**1.4-2.2** m	**76.5m**
B2	**4.2**	**3.6**	**48.4**
B3	**5.5**	**1.2-1.6**	**ca. 30**

How we regard the boulders are tsunami origin ?

1.Boulders are composed of corals with overturn structure
2. No coral limestone on the mountains

Then,
1.Coral boulders should be transported from by wave
2. When?
3. How? Tsunami or storm?

Radiocarbon ages from the coral terrace and boulders

Sample occurrence	Sample no.	Lab no.	14C age yr BP	Cal yr BP
in situ coral	20051015-4	NTU-4457	5270 ± 50	**5320-5220**
in situ coral	950702-08	NTU-4575	5160 ± 49	**5220-5120**
coral boulder (B1)	J-1	NTU-5331	4530 ± 50	**4860-4570**
coral boulder (B2)	J-2	NTU-5365	5000 ± 50	**5490-5250**
coral boulder (B2)	J-3	NTU-5338	4570 ± 50	**4910-4620**

Summary and problems

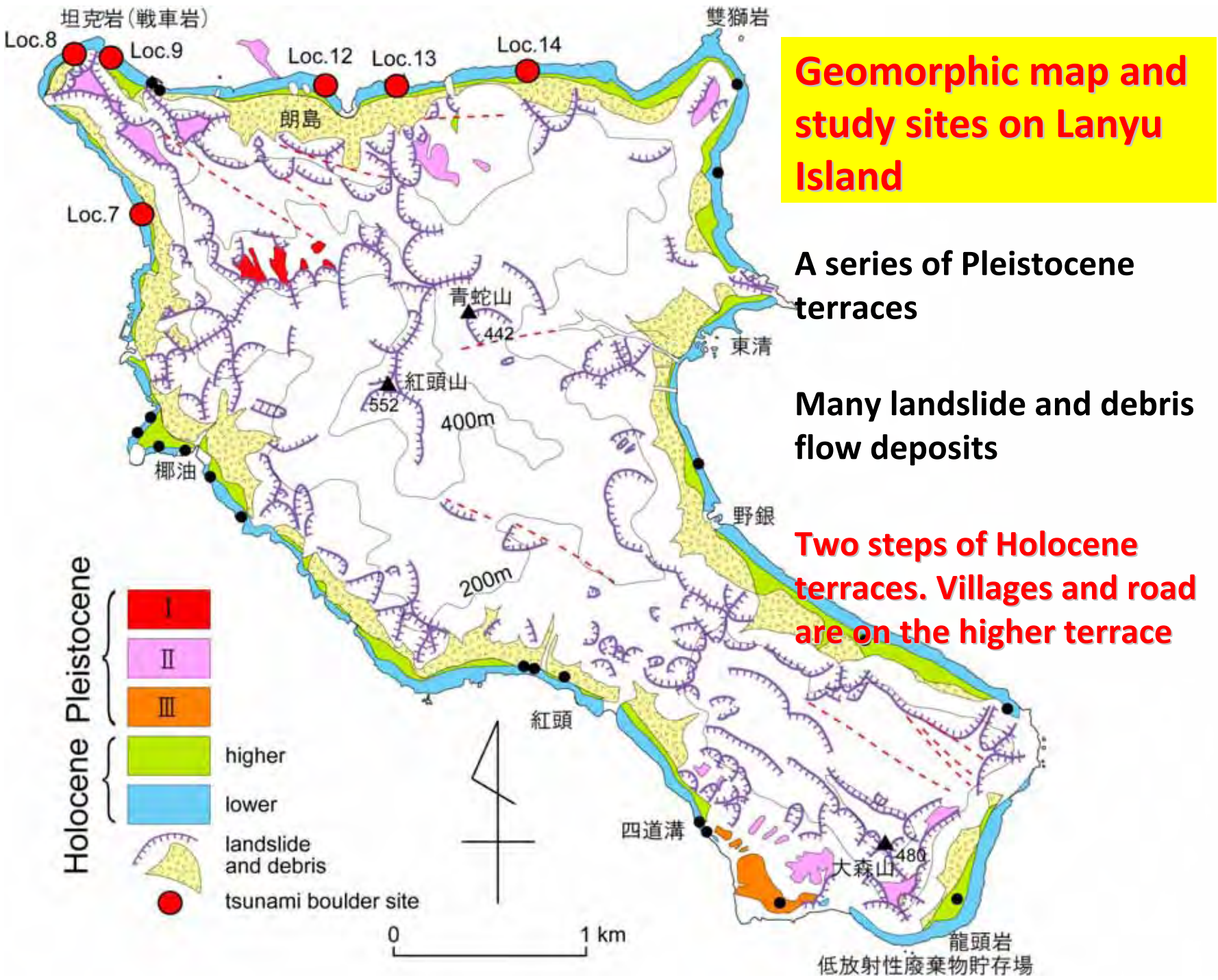
Three radiocarbon ages of coral boulders are nearly the same as the underlying Holocene corals ; ca. 5000 yr BP

Corals boulders are broken from the coral terrace and transported by tsunami waves

Tsunami waves arrived at ca. 5m above sea level

Timing of the estimated tsunami is unknown, but only once during the last 5000 yrs

This is the first site for paleotsunami boulders . Presence of tsunami boulders at any other place?



Geomorphic map and study sites on Lanyu Island

A series of Pleistocene terraces

Many landslide and debris flow deposits

Two steps of Holocene terraces. Villages and road are on the higher terrace

Summary from Lanyu Island

27 sites were investigated on the coast of Lanyu Island

Probable tsunami boulders are found at six sites, mostly located on the northern coast; Origin?

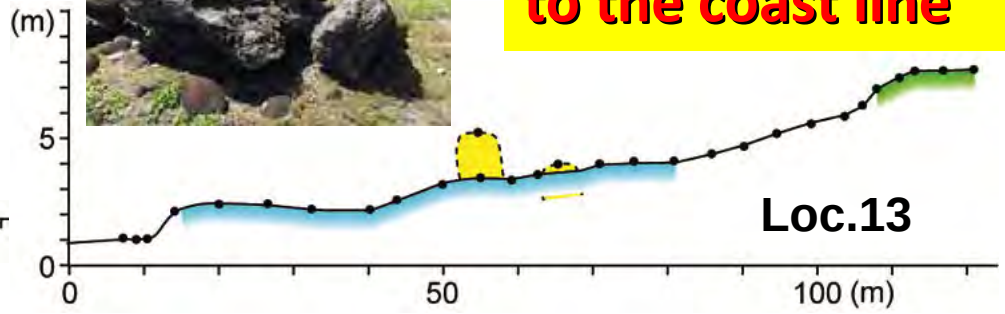
How can we identified the tsunami origin? How we can distinguish tsunami boulders from storm origin?

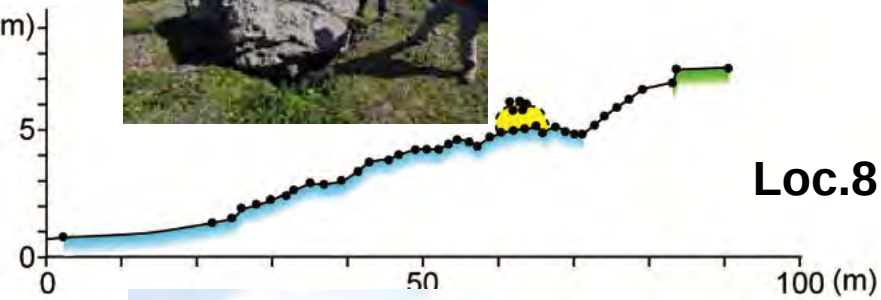
1) Larger size: usually larger size than ca. 2m across

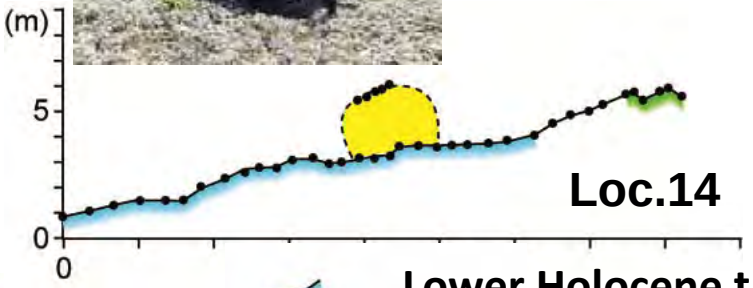
2) Many volcanic boulders are reworked from debris flow deposits

3) Some recrystallized limestone blocks are reworked from older higher terraces

Tsunami boulders and profiles normal to the coast line







Lower Holocene t.
Higher Holocene t
Coral boulders.

Coral boulders are on the lower terrace

Size of coral boulders and height of terraces

Location	Base of boulder (m)	Boulder size (m)		Terrace height (m)	
		w	h	inner margin of blue t.	outer margin of green t.
Loc.7	3.5	5.4	2.6	4.5	
Loc.8	5.0	2.7	1.5	5.0	7.5
Loc.9	4.0	4.0	2.0	5.0	8.0
Loc.12		3.8	1.2		
Loc.13	2.5	2.8	1.7	3.0	6.8
Loc.14	2.5	6.8	3.5	3.0	5.0

TENTATIVE SUMMARIES from LANYU ISLAND

Coral boulders at six sites, on the lower Holocene terrace > 5 m above sea level on the northern coast. Location of tsunami genetic earthquake?

Measurement of profiles normal to the coast line (Total station) and measurement of size. Boulders are composed of coral limestone , 3-5 m across.

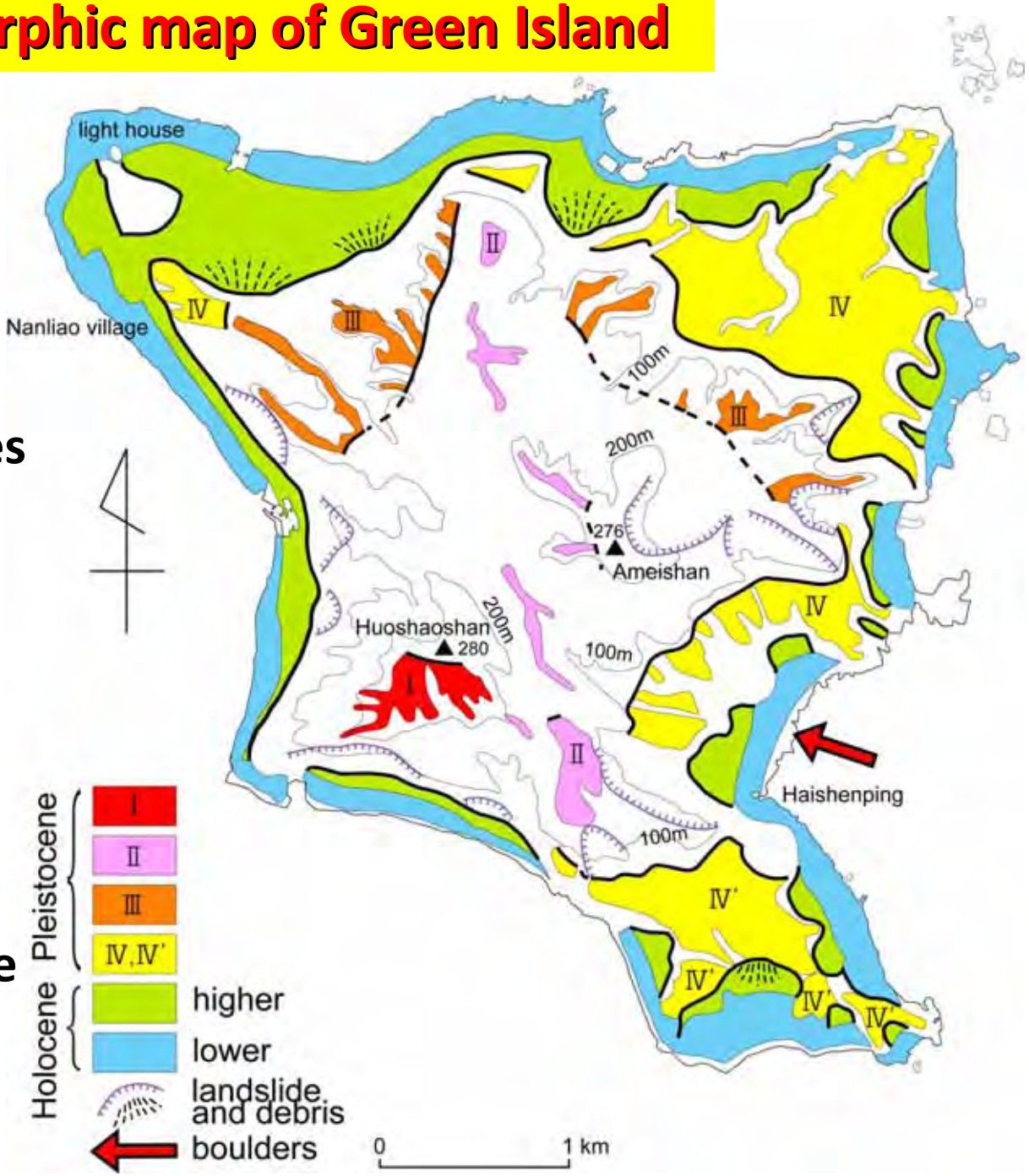
Sampling of attached corals and U-series dating; Age of attached corals does not represent the time of tsunami. How can we know the timing of tsunami: single event or multiple events?

Inundation tsunami height should be higher than the boulder height, probably reaching up to higher Holocene terrace where the most of settlements are located

Geomorphic map of Green Island

A series of marine terraces and two steps of Holocene terraces

Probable tsunami boulders are only at one site



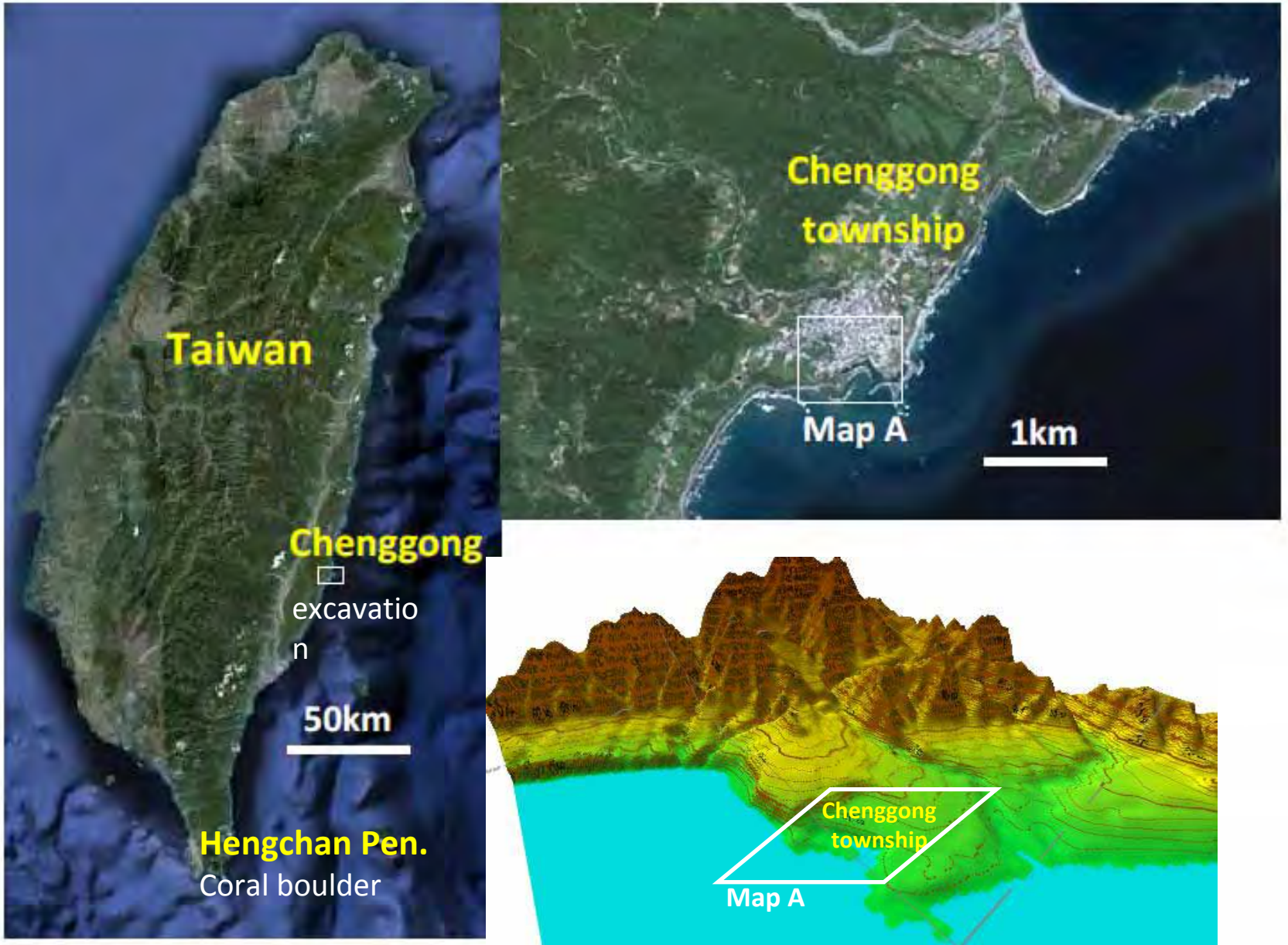
Boulders on the east coast of Green Island

Boulders are volcanic rocks; maximum size is 2 x 6m

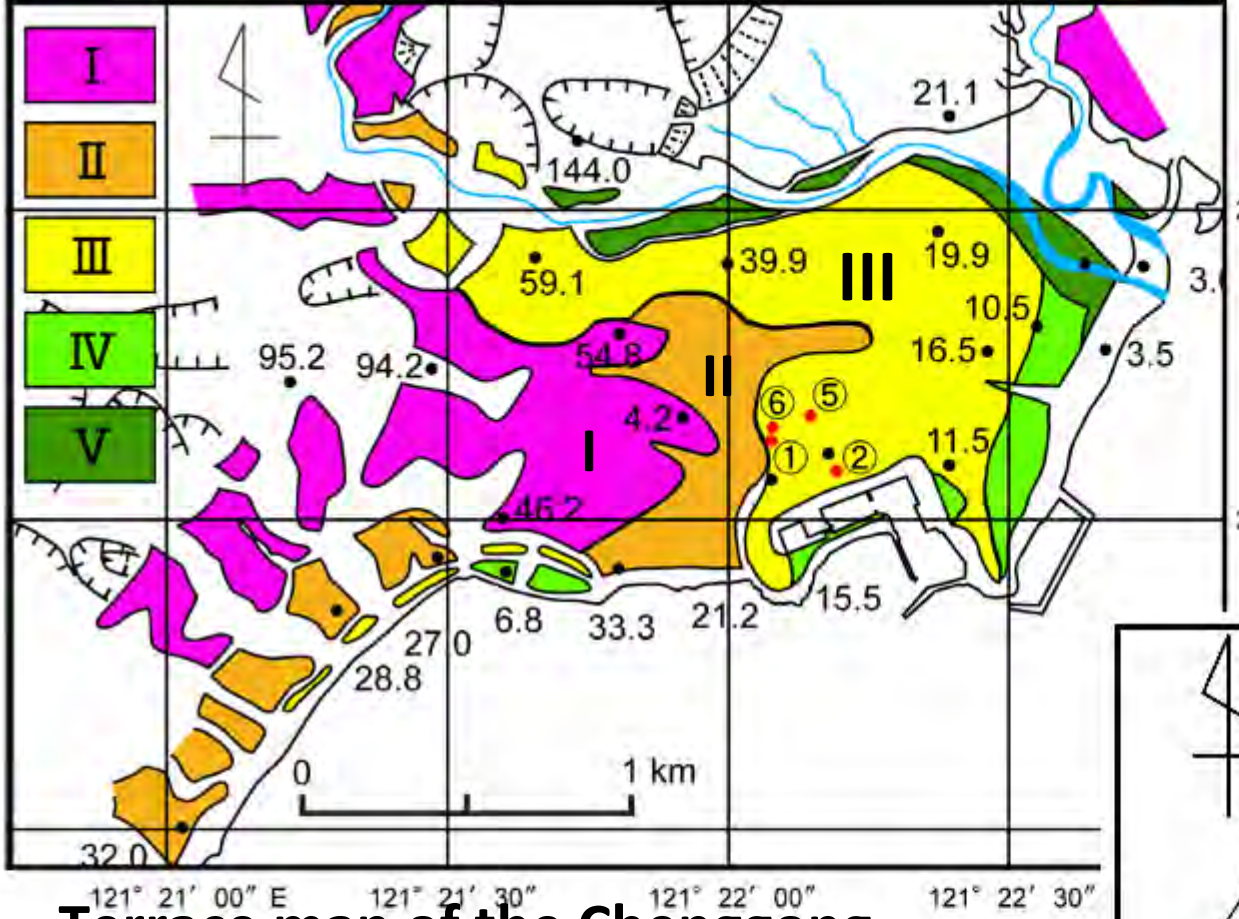
Probably tsunami origin

Tsunami warning board and route for evacuation at the front of town office, Green Island

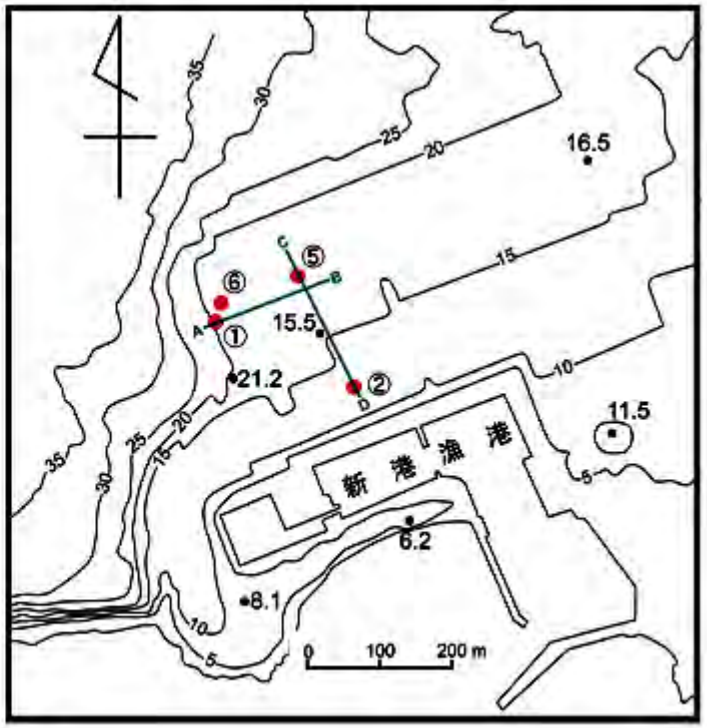
July, 2013



The Chenggong coast is fringed by a series of Holocene marine terraces. Excavation sites are located on the terrace at ca. 15-20 m. asl.



①, ②, ④, &⑥ are the excavation sites



Terrace map of the Chenggong area. Five steps of Holocene marine terrace, I to V, are present, recording rapid uplift of this coast. Four excavation sites are on the Terrace III, where Chenggong town is located.

Excavation by Geoslicer

Core obtained by Geoslicer

Terrestrial deposits

Sand with brackish shell

Terrestrial marshy deposits

Land surface

Facies observation and sampling (every 5 cm)

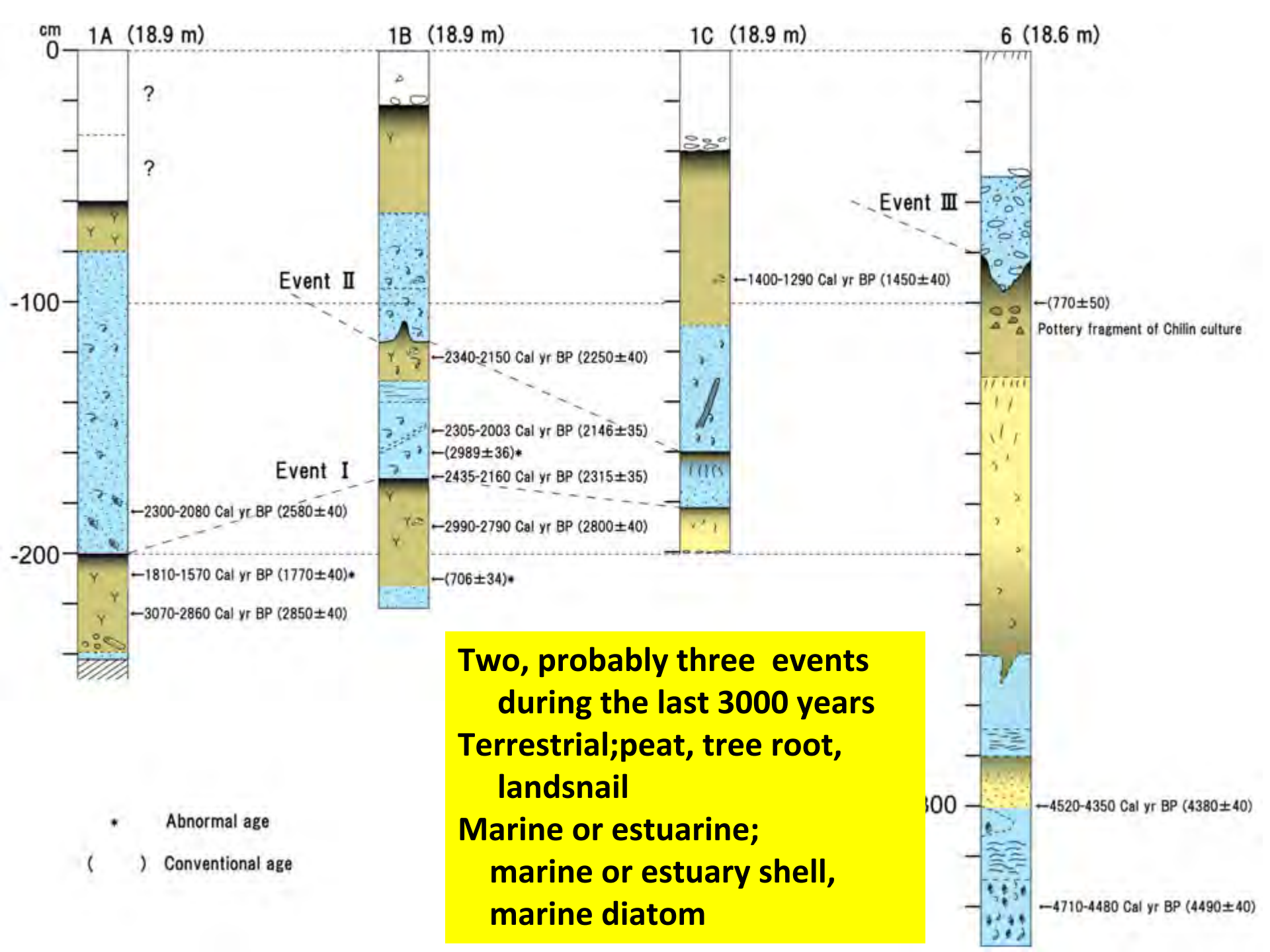
Facies observation and description (in site and laboratory by Ota, Schwitzer, Matta)

Radicarbon dating (total 17 samples, 15 are by AMS, 7 samples are by Dr Burr)

Identification of shells (by Dr Chen, and Shea, CGS)

Identification of archeological crafts (by Dr Liu (Academia Sinica)

Diatom analysis (by Nishikawa)



Two, probably three events during the last 3000 years

Terrestrial;peat, tree root, landsnail

Marine or estuarine; marine or estuary shell, marine diatom

Possible tsunami deposits at site 1 and 6.

Only beach deposits at site 2 and 5

Preservation of tsunami deposits is very local

Too limited number for excavation sites

No micro relief remains corresponding to different facies of deposits

Summary and problems

Three abrupt facies changes from terrestrial to marine at 2 sites during the last 3000 years at Chenggong area

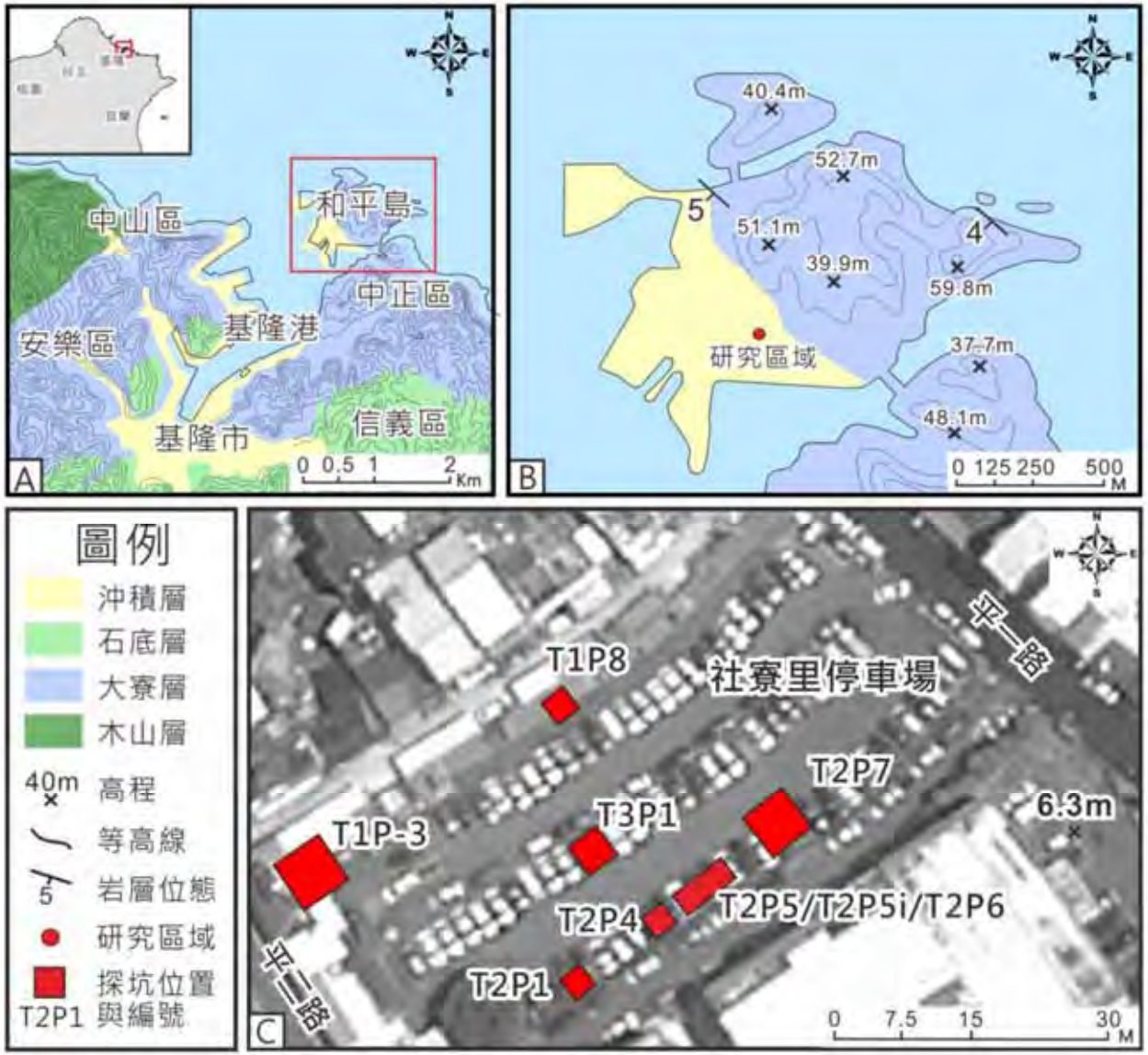
These events are probably caused by tsunamis

The wave reached to ca. 15 m above present sea level, but actually to several meters above sea level considering the high uplift rate

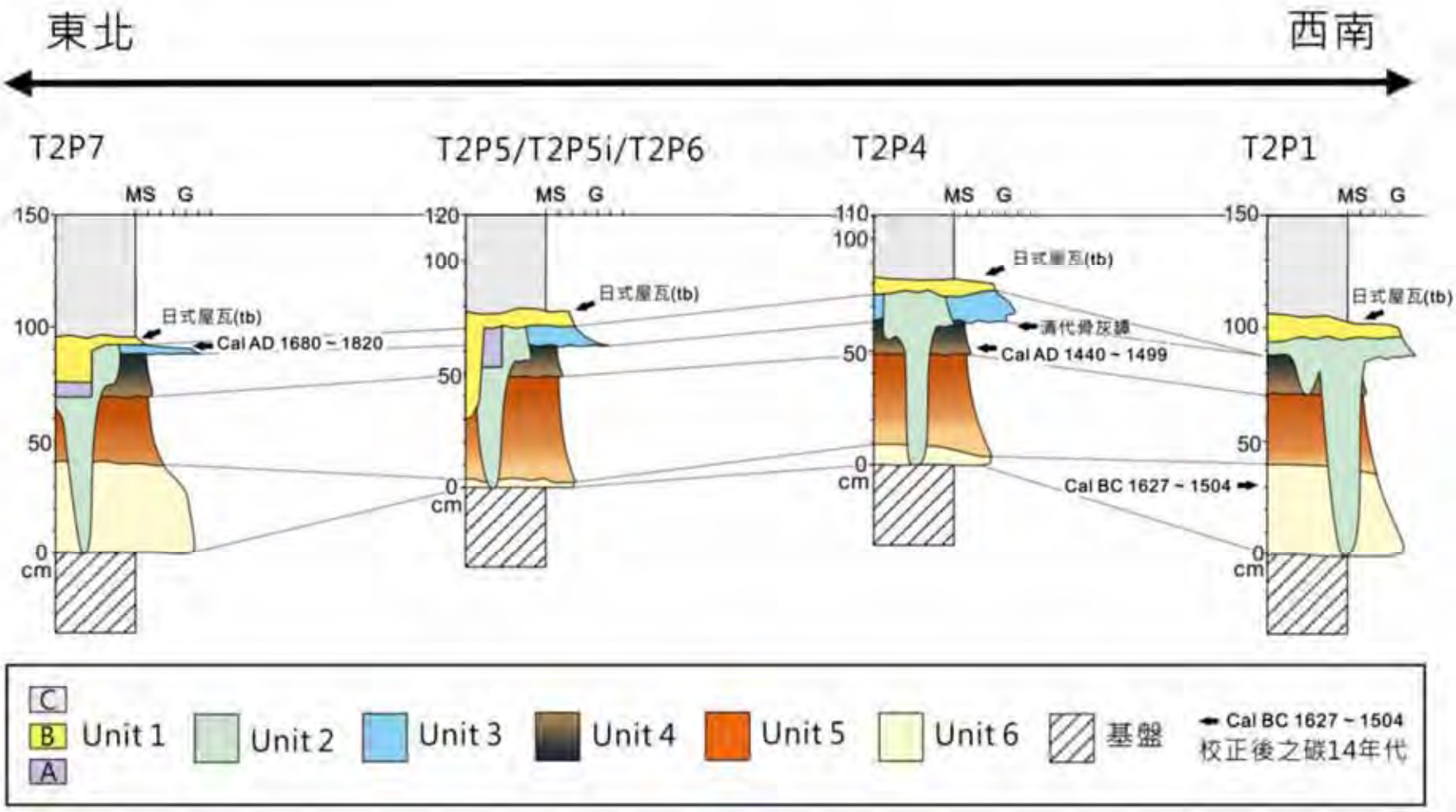
Many unsolved problems for estimation of aleoearthquake (for example;)

- # Number and exact age of events,
- # Confirmation of tsunami origin
- # Areal extent of distribution of probable tsunami deposits
- # Inundation height

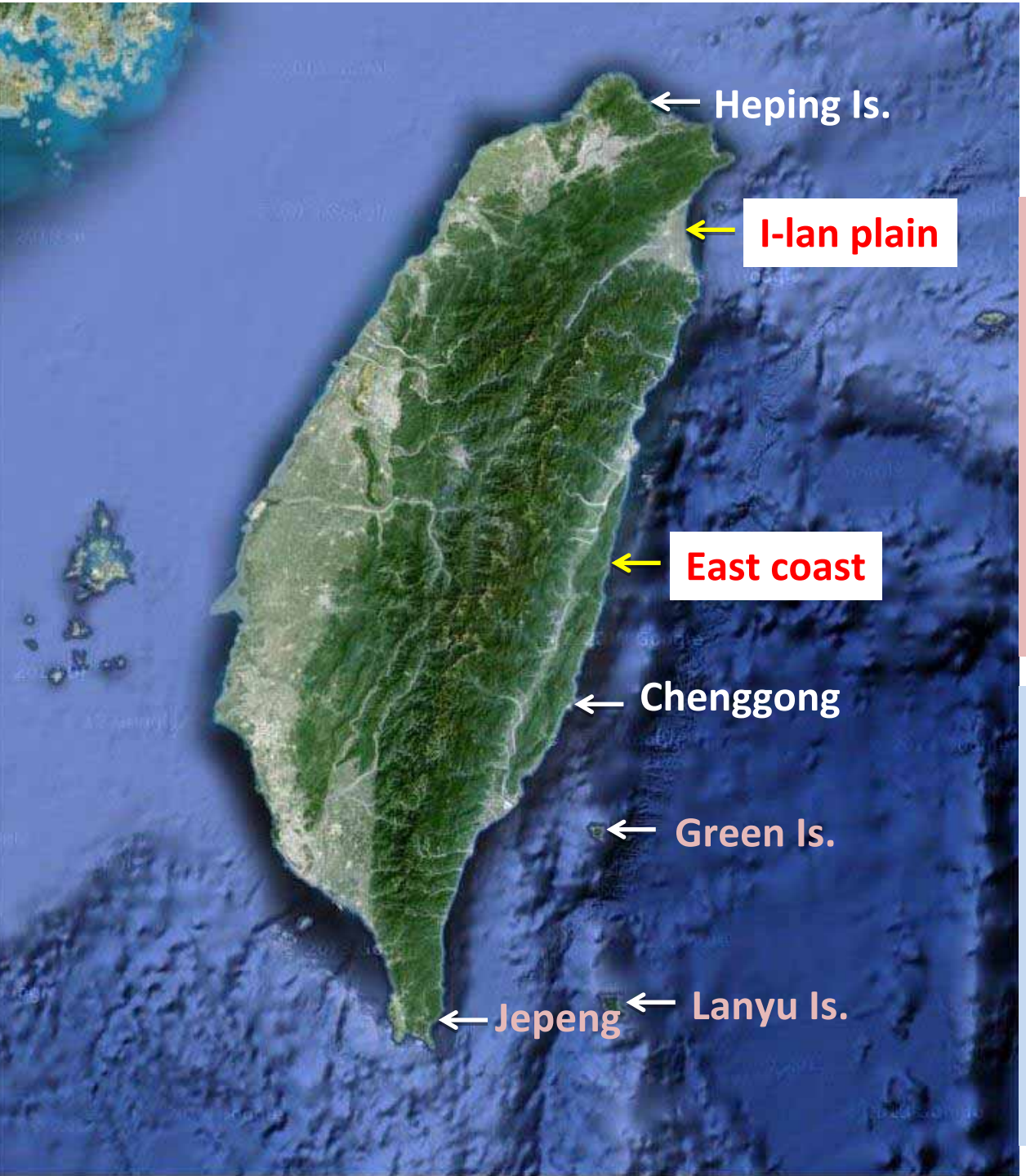
Location of archeological test pits, Heping Island
Finding of high-energy event deposits (Chung et al. accepted)



Correlation and result of 14C ages: Unit 3 containing marine overlies the Quing Dinasty cultural layer (Chung et al, accepted).



Unit 3 represents extreame storm or tsunami event. If unit 3 was tsunami, it possible the 1867 Keelung tsunami.



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Tsunami boulders

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Green Island (Ota et al., under working)

Lanyu Island (Ota et al. under working)

Facies change of deposits

Chenggong coast (Matta et al., submitted)

Heping Island (Chung et al., accepted)

4. Summary and Future works

1)Summary

Probable geological evidences for paleotsunami are found at several locations on the east coast of Taiwan.

Tsunami boulders at Jepeng, Lanyu Island, Green Island

Facies change at Chenggong coast and Heping Island

2) Towards the future stuides

*Areal extent attacked by tsunami, and location and magnitude
of tsunamigenetic earthquakes

Increase the study sites: We have only spot data

*Timing of tsunami, single event or multiple event ?

Accurate dating of sediment

Does attached corals represent the timing of tsunami?

*Estimation of inundation height

How high above the presence of tsunami boulder or above facies change height?

Important areas to be studied

Densely populated coast

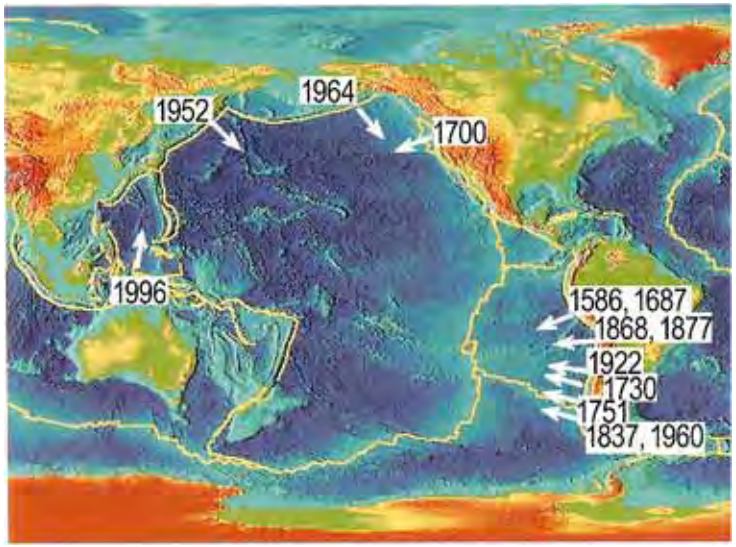
The coast near critical facilities

The coast facing probable large earthquake

Proposed area:for example

Ilan plain, east coast the Coastal Range, northeastern coast

Foreign tsunamis recorded in Japan

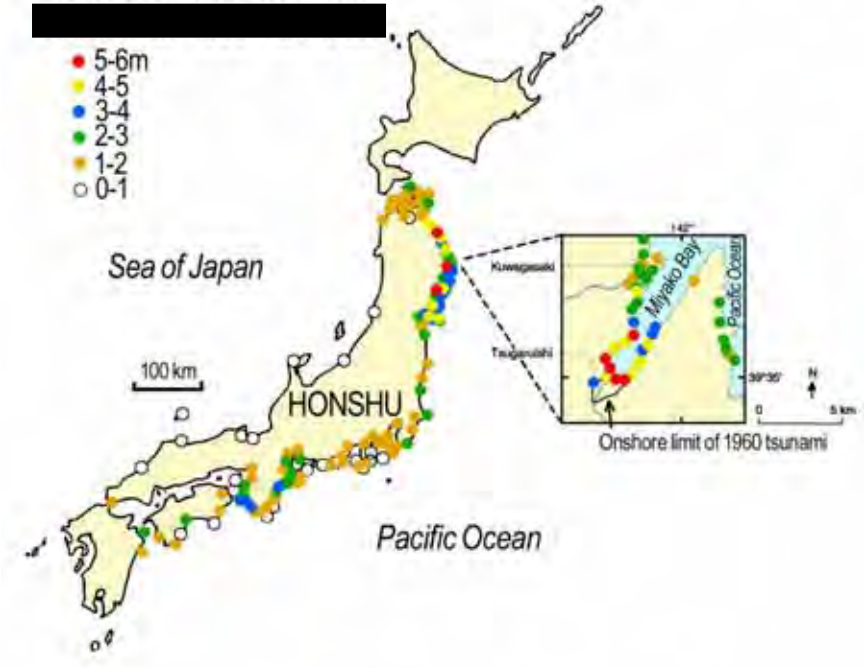


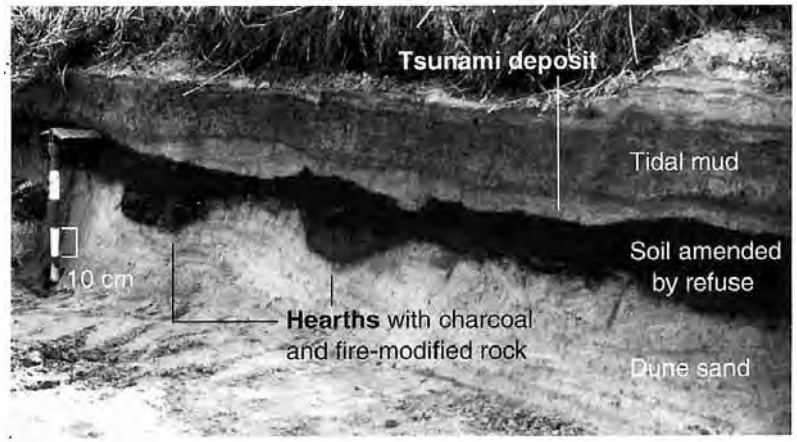
Recorded sites of 1700 tsunami

1700 Tsunami from Cascade (Atwater *et al*., 2005)

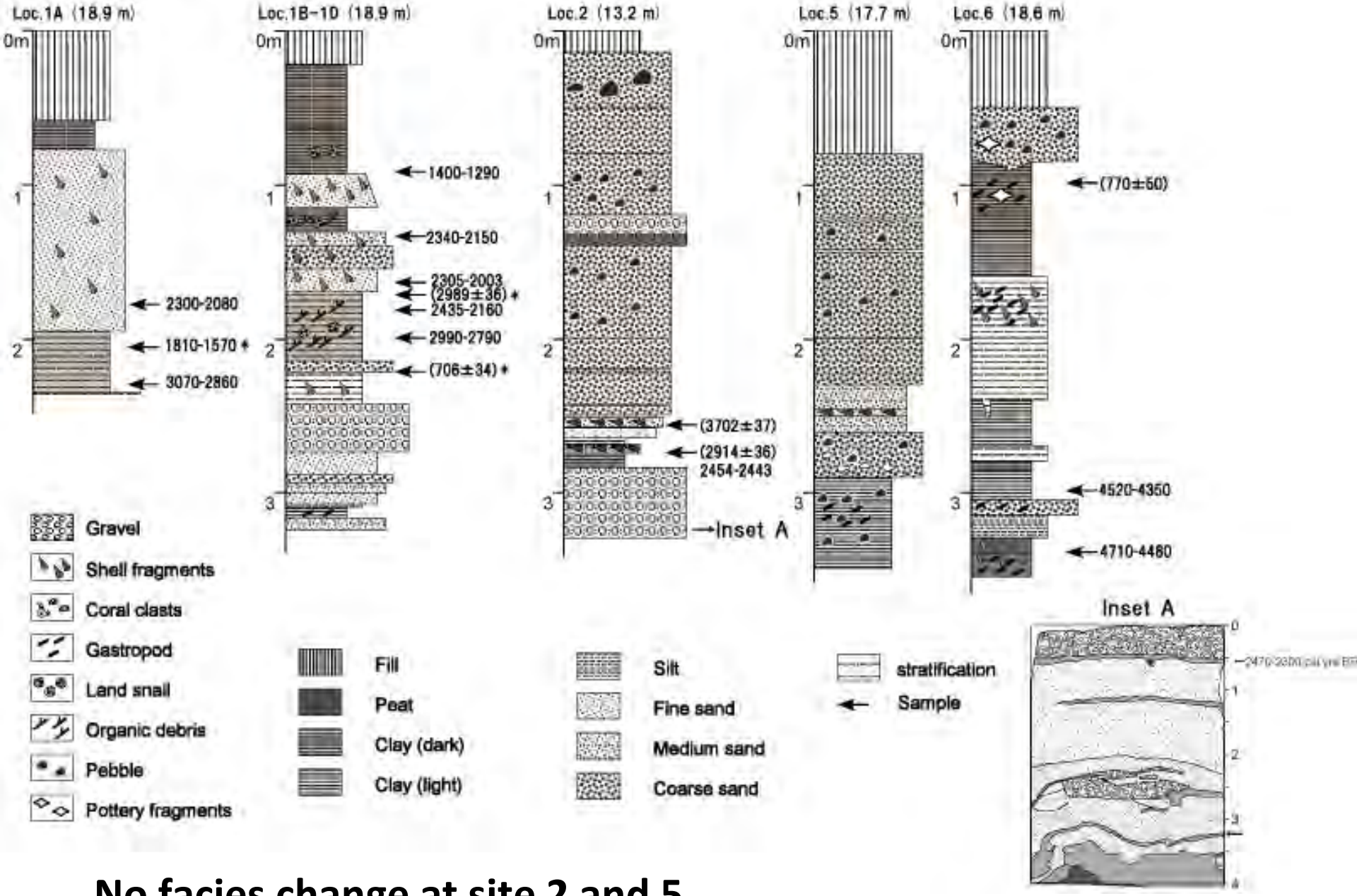
Documents on 1700 orphan Tsunami

Height of 1960 Chilean tsunami





Tsunami deposits in 1700 at Salmon R.



No facies change at site 2 and 5

Excavation sites for paleotsunami study in Ishinomaki Plain (Shishikura et al., 2009)

A series of beach ridges and interridge lowlands

Simplified Columnar Section

Height of terrace	Year of tsunami
18m	A.D. 1160-1297
5 to 10m	BC390-AD660
0 to 4m	B.C.1040-840

Assuming uplift rate 4-6 mm/y

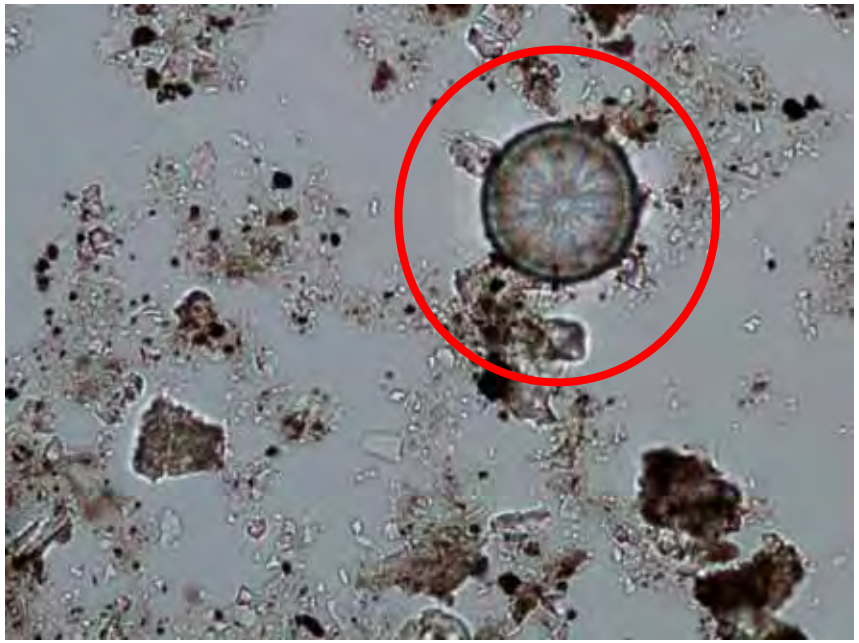
Marine diatoms

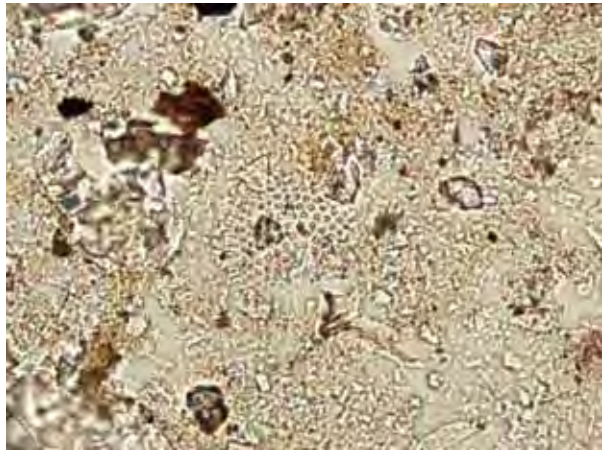
Chilin Culture pottery

Land snail

Land snail

Marine diatoms from a layer above the Chilin (**麒麟**) archeological layer





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