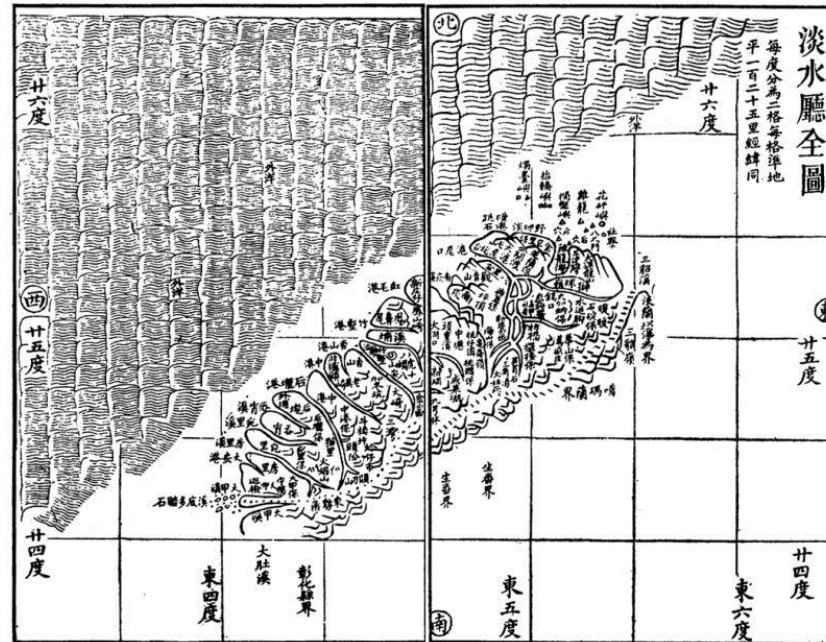


The 7th South China Sea Tsunami Workshop (SCSTW-7)

Review of the 1867 Keelung, Taiwan Earthquake and Tsunami



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Introduction

December 18, 1867, a disaster earthquake occurred in northern sea of Taiwan, and triggered a tsunami, hundreds of persons were killed and many houses were destroyed. Because of the age, lack of detailed literature data, for this limited understanding of the 1867 Keelung earthquake and tsunami.

This earthquake may be closely relative with the northeastern extending of Shanchiao fault. Earthquake and tsunami inflicted severe damage on the north coast, and impact of the entire Taipei area. There are many important constructions in this region, such as nuclear power plant. It is worth further study and discussion.

This study from the collection and collation of historical document to proceed, with assessing the reliability of data and the corresponding site locations. The use of GIS to build disaster spatial distribution. Simulated intensity map to evaluative source parameters.

Hsu(1983) Source materials on the history of natural disasters in Ching Taiwan

- 1、淡水廳志：(同治六年)冬十一月，地大震。……廿三日，雞籠頭、金包裏沿海，山傾地裂，海水暴漲，屋宇傾壞，溺數百人。 苗栗縣志(卷8，頁130)「祥異考」亦曰：「(同治六年)冬十一月，地大震。」

A big earthquake occurred, along the coast of Chi-lung-tou, Ching-bao-li, land slided and ground cracked, sea level rised violently, houses were destroyed, several hundred persons were drowned

- 2、淡水廳志：雞籠山以肖形名，同治六年地震崩缺。

Keelung mountain collapsed in 1867, renamed Kwei-lin.

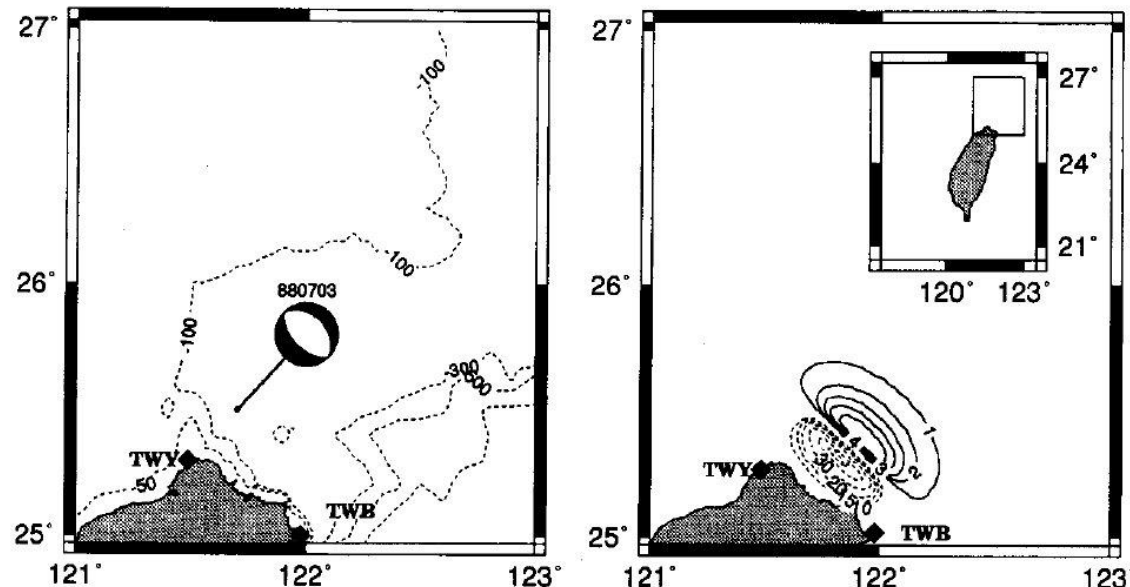
- 3、伊能嘉矩，大日本地名辭書續編/台灣/台北/士林街：同治六年之地震，(肆店)過半遭崩壞，邇來頽衰，已失其舊觀。

More than half of the town was destroy by the 1867 earthquake

- 4、Alvarez,Formosa一書云：「1867年12月18日，北部地震更烈，災害亦更大，基隆城全被破壞，港水以已退落淨盡，船隻被擱于沙灘上；不久，水又復回，來勢猛烈，船被衝出，魚亦隨之而去。沙灘上一切被沖走。原本建築良好之屋宇，亦被衝壞，土地被沙淹沒，金包裏地中出聲。水向上冒，高達四十尺；一部分土地沈入海中。基隆港內，有若干尺面積地方，其下落已較原來為深。此係據若干歐洲商人證實報告。」

This event is the only confirmed cause severe tsunami disaster. Due to lack of information, the causes of tsunami are inconsistent:

- **Volcanic eruptions cause tsunami :** (Yang et al.(1983), Taiwan Power Company, Atomic Energy Council) Volcano is located about 134 km northeast of Keelung
- **Earthquake and fault:** Hsu(1983), Tsai(1985)
- **Earthquake triggered undersea landslide caused tsunami :** Wu(2013)
- **Comprehensive earthquakes, landslides, volcanic eruptions and submarine topography:** Ma and Lee(1997)



**Collection and collation
of historical documents**

- Covering Taiwan and neighboring regions
- Chinese, Japanese, and other foreign

Data Reliability Analysis

- Data integrity and originality
- The credibility of the author and content

**Verification of names in
literature**

- Ancient names validation
- Ancient map and current map comparison

**Evaluated the corresponding
intensity and height of tsunami**

- Reference to the CWB intensity scale
- Consider geological and geographical data

Build spatial distribution

- Ancient map location (GIS)
- Converted into current map

Estimated source parameters

- Active faults, submarine topography, and other
- Epicenter, depth, magnitude

**Simulated intensity map to
evaluative source parameters**

- Empirical attenuation formula, intensity map
- compared with disasters distribution and simulated map

Procedure of data processing

Local version of literature

1, **The North China Herald and Market Report/January 8th, 1868:(北華捷報),**

2, 陳培桂(1871)/淡水廳志/卷四/賦役志/煤場：

陳培桂(1871)/淡水廳志/卷十二/物產考/礮案：

陳培桂(1871)/淡水廳志/卷十四/祥異考：

3, 沈茂蔭(1893)/苗栗縣志/卷八/祥異考：

4, **海關總稅務司署/ Reports on Trade at the Treaty Ports in 1881/ 第十七期附件/臺灣淡水部分/頁11-15：(謝毓壽和蔡美彪, 1987)**

一八六七年地震发生在十二月十八日，海水从基隆港倾泻而出，留下了一个干涸的泊位，但不几秒钟，带着两个浪头的海水又汹涌而回，淹没了舢板和人口。基隆、金包里及巴其那等城镇部分泡为废墟。淡水遭到严重破坏，好几百人死亡。

《1881年通商各关贸易报告》（英文） 第十七期 附件《台湾淡水部分》 页11—15

December 18, 1867, a earthquake occurred. Sea water rushed out from Keelung, leaving a dry berths, for a few seconds, with two tide waves while back, junk and people were submerged, Keelung, Ching-bao-li, and 巴其那 towns that its part soaked in water. Tamsui was severely damaged, several hundred people deaths.

THE North-China Herald.

AND MARKET REPORT.

Vol. II, No. 88. SHANGHAI, WEDNESDAY, JANUARY 8th, 1868. PAGE, THREE-12 P. ANNUAL.

NOTICES OF FIRMS.

NOTICE.
MR. CHARLES HOWARD-GARDNER has taken for his term, from the 1st of Dec. 1867, the office of the **REVENUE OFFICER** for the district of the **PORT OF SHANGHAI**, and will be in office on the 1st of Dec. 1867.

OLDFATHER & Co.
Messrs. 81, 83, 85, 87, 89, 91, 93, 95, 97, 99, 101, 103, 105, 107, 109, 111, 113, 115, 117, 119, 121, 123, 125, 127, 129, 131, 133, 135, 137, 139, 141, 143, 145, 147, 149, 151, 153, 155, 157, 159, 161, 163, 165, 167, 169, 171, 173, 175, 177, 179, 181, 183, 185, 187, 189, 191, 193, 195, 197, 199, 201, 203, 205, 207, 209, 211, 213, 215, 217, 219, 221, 223, 225, 227, 229, 231, 233, 235, 237, 239, 241, 243, 245, 247, 249, 251, 253, 255, 257, 259, 261, 263, 265, 267, 269, 271, 273, 275, 277, 279, 281, 283, 285, 287, 289, 291, 293, 295, 297, 299, 301, 303, 305, 307, 309, 311, 313, 315, 317, 319, 321, 323, 325, 327, 329, 331, 333, 335, 337, 339, 341, 343, 345, 347, 349, 351, 353, 355, 357, 359, 361, 363, 365, 367, 369, 371, 373, 375, 377, 379, 381, 383, 385, 387, 389, 391, 393, 395, 397, 399, 401, 403, 405, 407, 409, 411, 413, 415, 417, 419, 421, 423, 425, 427, 429, 431, 433, 435, 437, 439, 441, 443, 445, 447, 449, 451, 453, 455, 457, 459, 461, 463, 465, 467, 469, 471, 473, 475, 477, 479, 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Time: Tamsui 10:20, Keelung 09:45

TAMSUI.

The quiet town of Tamsui became the scene of much excitement on the morning of the 18th, in consequence of a terrible earthquake experienced at 10.20 A.M. No rumbling voice was previously heard; and the only intimation we had was a slight vibration at first, which drove us out of the house, until it increased so much as to make us stagger like drunken men. While we stood reeling about, prepared to see the house fall in, our attention was suddenly attracted to the next hill (upon which stands part of the town of Tamsui) by a loud crashing noise and a dense cloud of dust, which too truly indicated that many houses had been shaken down. The people were in a wild state of commotion, and rushed about bewildered, like ants. The scene on the hill was awful; villagers, apparently paralysed, stood looking at the debris of their homes, too frightened even to try and extricate the unfortunates who were buried alive beneath the ruins. The Foreign Customs officers immediately went to the scene of disaster, to render what little assistance they could in getting out the sufferers;—but it was a hopeless task. The mud walls of the native houses appeared to have fallen inwards and crumbled at once, and with the roof above debarred all chance of saving people alive. Hoes or spades could not be found, the people were too alarmed or indifferent to do any thing.

Two (we suppose opium smokers) on a bed, were got out, but dead. A woman who must have been cooking was got out alive, with her face fearfully burned; many more were severely wounded. The shock came from the N.E. towards the S.W. Houses fell in regular order, just as if artillery had been discharged at them. The loss of life at Tamsui is estimated at 80; but Pa-tai-en-na, a small town distant a few miles, suffered more, and it is reported 150 persons were killed. It was a most merciful dispensation of providence that the shock did not occur at night. During the day and following night, shocks were felt at intervals of an hour or so, the last being about 6.30 A.M. By persons residing at the sulphur pits, it is reported little motion was felt. The steam issuing from the pit seemed to lessen. The noisome smell so common at this place appeared much stronger on the 18th and following days. Houses on elevated sites suffered most.

At Keelung we learn the first shock was felt at 9.45 A.M., and lasted about thirty seconds. The earth cracked slightly in front of the Custom-house. A great portion of this town is down, burying numbers in the ruins. A cloud of vapour was seen to rise from the sea between Palm and Keelung islands, which was succeeded by the water of the harbour rushing out seawards, leaving it dry as far as Ruin Rock for some seconds. Everything was carried away with the receding water. The sea then returned in the shape of two large waves, swamping sampans and drowning

the people therein, and junks were carried away high and dry opposite Keelung. The harbour was in a state of agitation during the whole day; on the 20th it was hardly quiet. Instead of the water being clear as usual, it became yellow and muddy. Enormous quantities of fish were washed ashore and secured by the Chinese. The people appeared to exhibit the greatest indifference with regard to the fate of the sufferers, and would not assist in extricating them without a guarantee of some reward. When the water left the harbour, a man got down from a junk, but before he could reach the shore was overwhelmed by the returning water. Numerous coal boats were upset or sunk. An old wreck of a junk, deeply embedded for years in the sand, was washed high up on shore. Luckily no foreign vessels were

in port. Large stones were hurled from the hills at Keelung and near the sulphur pits. Natives report that a large opening has been made in the earth along the coast between this and Keelung. At 6.30 A.M., on the 20th a sudden shock drove us out of the house, and during the night two more were felt. The aneroid has been high; and the 18th was a splendidly clear day, as has been the case for weeks past. On the 19th it clouded up, and a little rain fell; the next day it was again clear. Chinese attribute these shocks to the unusual absence of rain. We are interested to know whether this was a local shock, or has been felt elsewhere. The great difference in the time given at Keelung and Tamsui may be explained by our having no accurate means of getting correct time. Often one person's watch is half an hour faster or slower than another.

Personal records and article

1,臺灣總督府臺北測候所(1899)地震年表：

★ 2,Davidson, J. W.(1903)/The island of Formosa, past and present (p. 187)

Davidson, J. W.(1903)/The island of Formosa, past and present (p. xxiii)

3,伊能嘉矩(1909)/大日本地名辭書續編(頁16)「台灣・台北・士林街」：(徐泓, 1983)

★ 4,岡本要八郎(1913)/同治年間に於ける金包里附近の地變：

★ 5,TMO(1914) The climate, typhoons, and earthquakes of the island of Formosa (Taiwan)：

6,Alvarez(1930),Formosa: (徐泓, 1983)

★ 7,Mackay(1895)/From Far Formosa(P.53)：

8,武者金吉(1951)/日本地震史料：許明光和李起彤(1996)

experienced in the island since the first days of the Dutch. That greater deposit of lava visible on the beach some twelve miles to the north east of Tamsui. It is reported on the authority of two foreigners who observed the phenomenon that, during the great earthquake of 1867, there was visible at sea, off **Bush Island**, Kelung, a column of water and steam which for a moment rose to a considerable height. The large quantity of **pumice stone** which has been washed upon the beach, and is sometimes seen floating at sea in the vicinity of Kelung, has given rise to the belief that there is possibly a submarine volcano off the port. but that it was the first movements that did the damage. In nineteen seconds after the first perceptible shock the damage was done and the town of

There are no records of any great destruction as the result of earthquakes. In 1867, during a severe earthquake, houses in **Kelung**, **Kinpori** (Kimpauli), **Banka** and other northern towns were destroyed, and some hundred persons were reported killed, and Kelung harbor was for a minute or so emptied of its water. It is difficult to account for this latter feature in any other way except as the result of some accompanying submarine convulsion.

swamped or dashed into the town with fearful speed, to work havoc among the few remaining houses left near the shore. Multitudes of fish were thrown upon the shore and promptly gathered by the populace. The earth opened in places and closed again. A large gorge was formed by the splitting of a mountain side through which now runs a stream of hot water from a volcanic pit abounding with sulphurous springs and geysers. Many other physical changes were noted, including the deepening by a few feet of the anchorage at Kelung. The loss of life was never known; it is extremely doubtful if there was any count made, but probably several hundreds perished. A calamity of this sort is doubly felt among a Chinese population, for there are none to give a helping hand in relieving the misery. The present case was

the great
water and
nice stone
vicinity of
the port.

c.	Total.
7	260
2	25
5	80
-	11
1	376

with 97.3
.1 respec
have ex-

Davidson, J. W.(1903)/The island of Formosa, past and present (p. 187)

Davidson, J. W.(1903)/The island of Formosa, past and present (p. xxiii)

lodes of quartz. It is difficult to estimate the quantity procured annually, although it must be considerable.

Great physical changes are continually taking place on the island. What was once a large and beautiful lake is now the fertile Bang-kah plain. Storms and freshets brought down vegetable matter from the mountains, and the bottom of the lake was gradually elevated. Meanwhile the waters were grinding and pressing against the spur that joined the Tai-tun and Quan-yin mountains, forming the lower bank of the lake. At some time a violent earthquake-shock rent this spur, and the waters rushed madly down to the sea, leaving behind a rich alluvial plain, and cutting what is now the channel of the Tamsui River.

Earthquakes are very common and do enormous damage.

In 1801 on one day four shocks were felt, and a month later two more. Years ago at Kelung rumbling sounds were heard, and the waters of the harbor receded until fish of all sizes were left wriggling and floundering in the mud and pools. Women and children rushed out to secure such rare and enticing prizes, but shrieks from the shore warned them of the return of the water. Back it came, furious as a charge of battle, overleaping its appointed bounds, and sweeping away all the houses in the low-lying land along the shore. The story of that tidal wave is handed down as one of the great catastrophes in

history. At Kin-pau-li, not many years ago, a shock was felt. Rice-fields suddenly sank three feet, and the sulphurous water rose and still covers the place. Sugar-cane is now cultivated in large tracts where boatmen plied their oars in 1872, and the waters of the Tamsui River glide over places where stood villages in which I preached the gospel twenty-three years ago. Changes are taking place, too, all along the shore. One might suppose that the hard rocks on the east coast would be able to resist all forces and influences. But no; tides and waves of the great Pacific tunnel, undermine, and wear away the bases of the

Mackay(1895)/From Far Formosa(P.53). Mackay arrived Taiwan in 1871. The descriptions of tsunami in Keelung are different with the other.

1867 December 18

10 a.m.

Extreme
North
Coast.

A violent earthquake occurred on the coast in the extreme north of the island, accompanied by a seismic tidal wave, which wrought great havoc on many buildings and caused a large loss of life. A foreign officer, who was stationed at the Keelung Custom House, at that time, reported this earthquake as follows:

"At Keelung some fifteen shocks were felt during the day, but it was the first movements that did the damage. In fifteen seconds after the first perceptible shock the damage was done and the town of Keelung was in ruins. The force of the earthquake may be judged when it is noted that the water of Keelung harbour ran out, leaving the bottom of the bay exposed. Fortunately there were no foreign vessels present, but the Chinese junks which were there, large and small, were in one second left dry on the bottom and in another caught by the huge returning wave to be either swamped or dashed into the town with fearful speed, to work havoc among the few remaining houses left near the shore. Multitudes of fish were thrown upon the shore and promptly gathered by the populace. The earth opened in places and closed again. A large gorge was formed by the splitting of a mountain side through which now runs a stream of hot water from a volcanic pit abounding with sulphurous springs and geysers. Many other physical changes were noted, including the deepening by a few feet of the anchorage at Keelung. The loss of life was never known; it is extremely doubtful if there was any count made, but probably several hundreds perished."

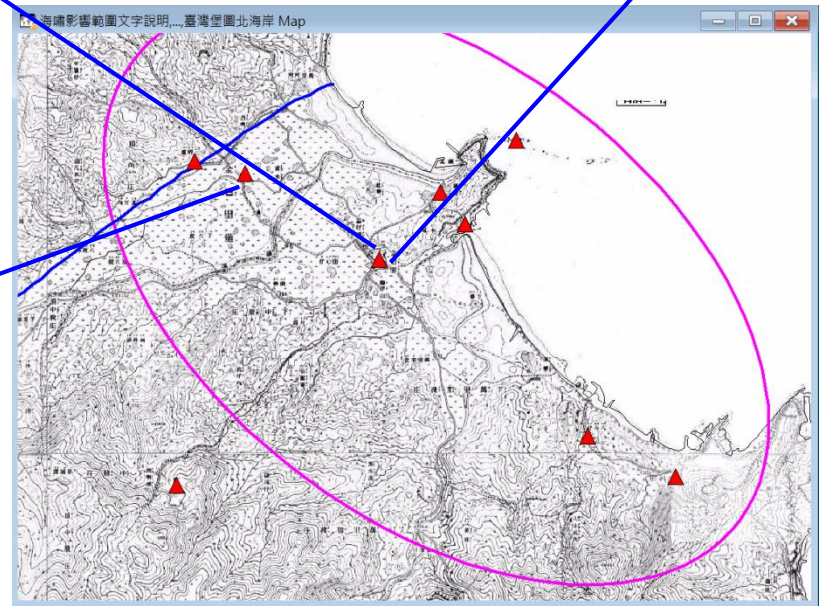
TMO(1914) The climate, typhoons, and earthquakes of the island of Formosa (Taiwan) (P.74)

Temple history and stele

- 1, 金包里慈護宮沿革：
- 2, 金山黃氏古厝/金山區公所：
金山芑豐居老厝：
- 3, 金山廣安宮：
- 4, 淡水清水祖師廟：
- 5, 基隆慶安宮沿革：
- 6, 基隆田寮河：
- 7, 台灣大百科全書/文化部臺灣知識的骨幹/磺嘴吼煙：
- 8, 新北市政府觀光旅遊局/基隆山：

金包里慈護宮沿革
同治六年十一月淡北
大地震，廟宇倒塌，
至同治十二年重建告
竣始見規模。

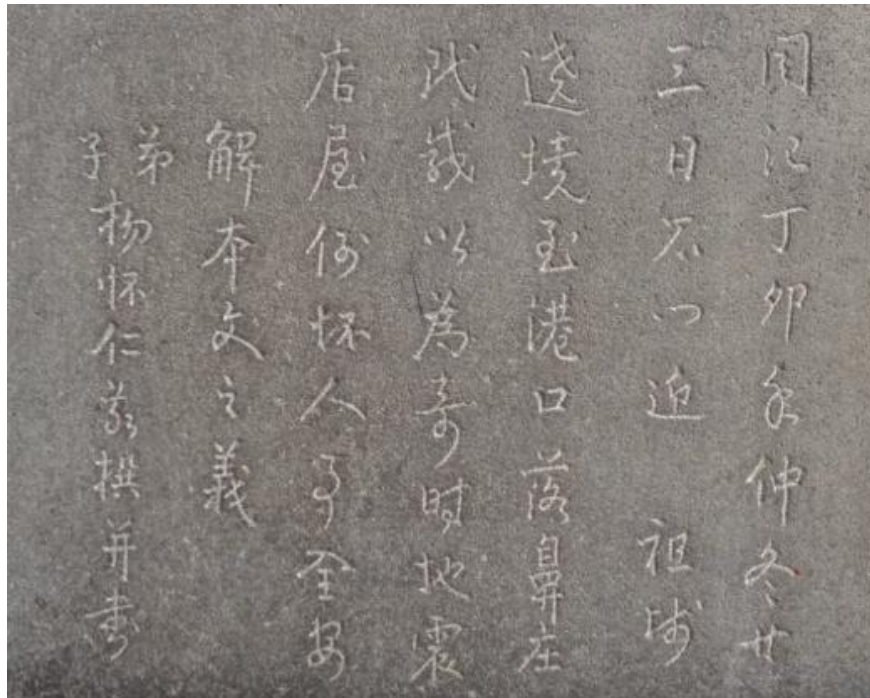
金包里慈護宮
<http://www.cihugong.com.tw/about.php>



interviews seniors 金山芑豐居老厝

淡水清水祖師廟

Shimen, north coast of Taiwan, plague occurred in 1867. Residents ask God to patrol and remove disasters(出巡消災). The god sedan arriving at the port, a sudden drop nose. All of residents rushed to the harbor. At that time a large earthquake occurred, the house collapsed, but no casualties. Thank God for prediction earthquake, a stele was set up at temple entrance, a wall murals produced to commemorated this event. 「祖德施石門昔日賑災禪佛力」 「聞記丁卯年仲冬廿三日石門迎 祖師繞境，至港口落鼻，庄民咸以為奇，時地震店屋倒壞人事安全 解本文之義弟子楊懷仁敬撰并書」



Keelung Custom House

Four River system of keelung

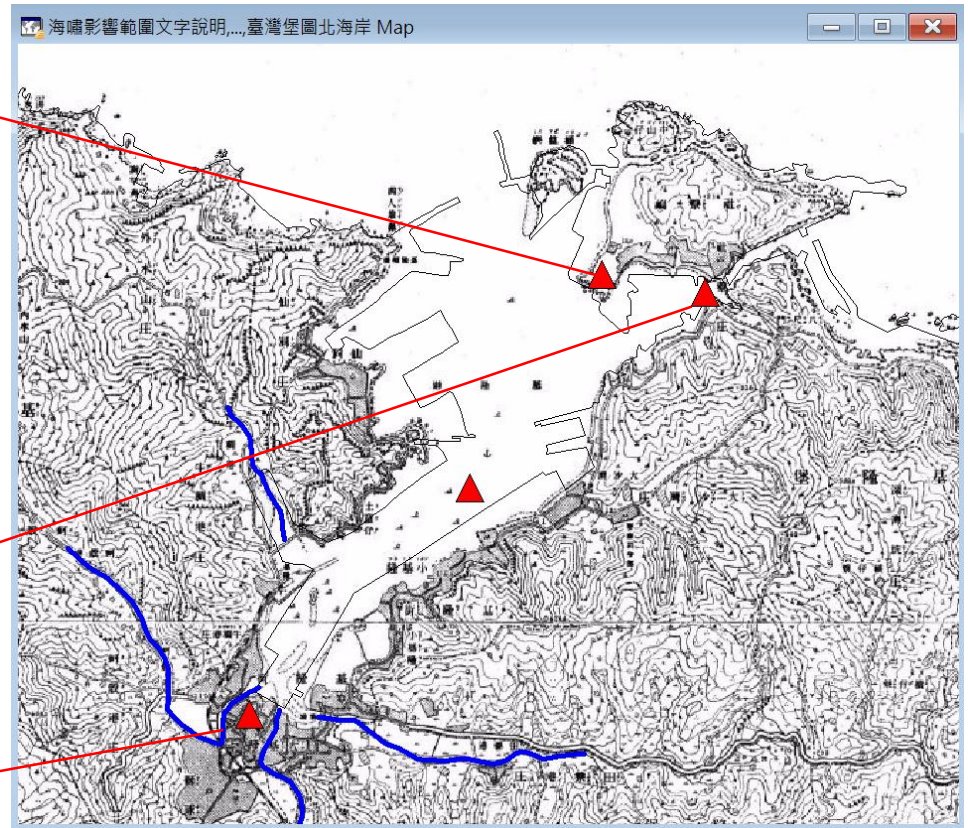
林振興(基隆殯葬所)所長 listen to his grandfather once described this history, four river water are sucked out and dried.

八尺門(基隆港務局莊耀輝副理)

The woman and child were swept away by the sea to pick up fish

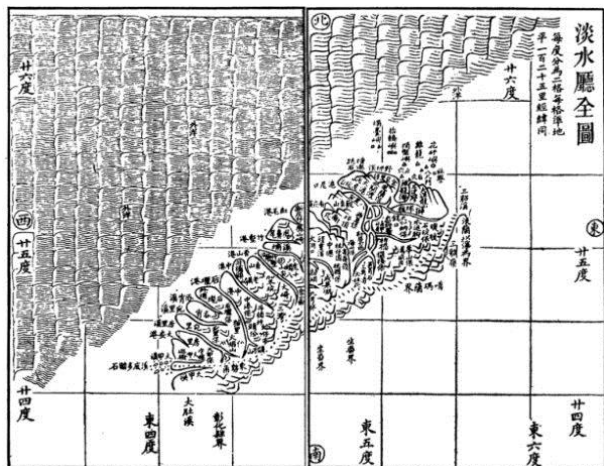
基隆慶安宮沿革

After 2004 South Asia tsunami. Folk legend, the tsunami in Keelung in 1867, Matsu apparitions(顯靈), the water is stopped front of the temple. Reference to the history of temple, and interviews seniors, are without this event. Chairman of the temple(童永) said that Matsu is God of sea, but never heard about Matsu apparitions in hundred years ago earthquake, there is not historical record.

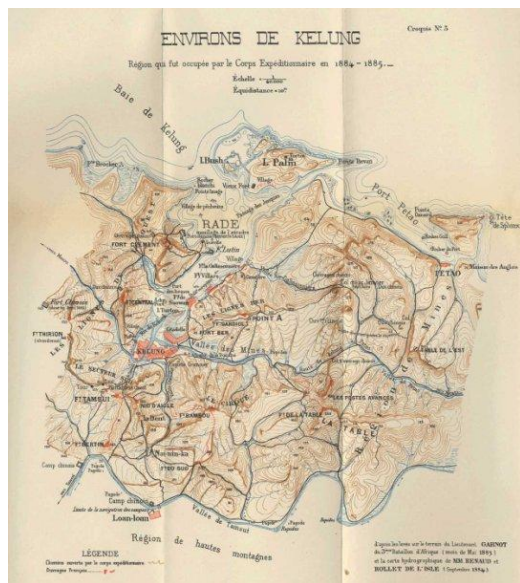


Verification of place names in historical documents

淡水廳全圖(陳培桂, 1871)

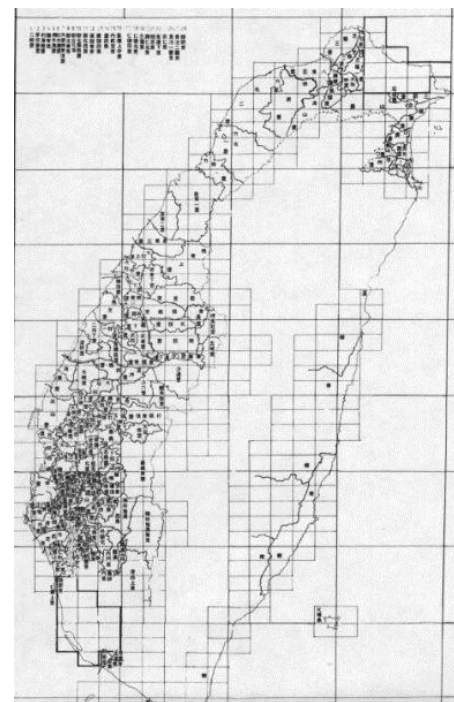


日人基隆築港(1899)前繪製的基隆港灣地圖



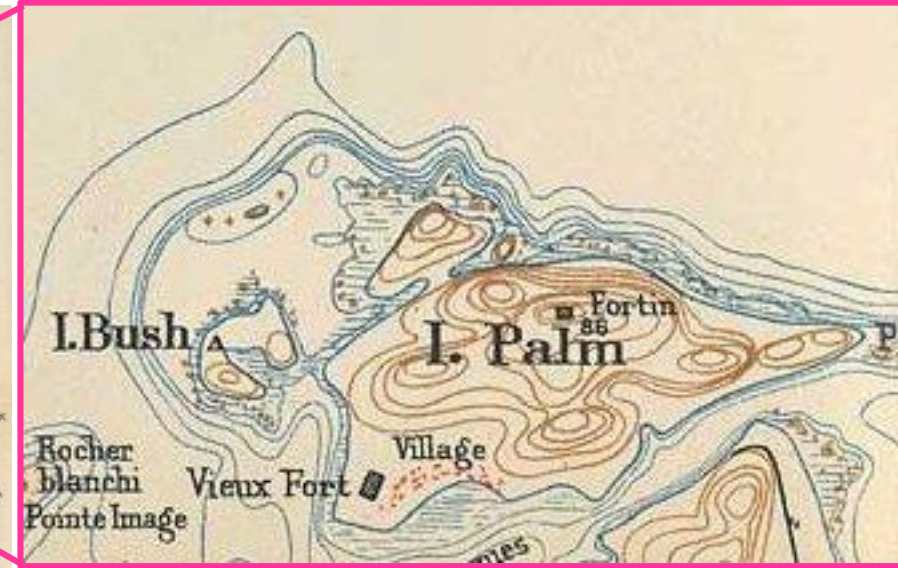
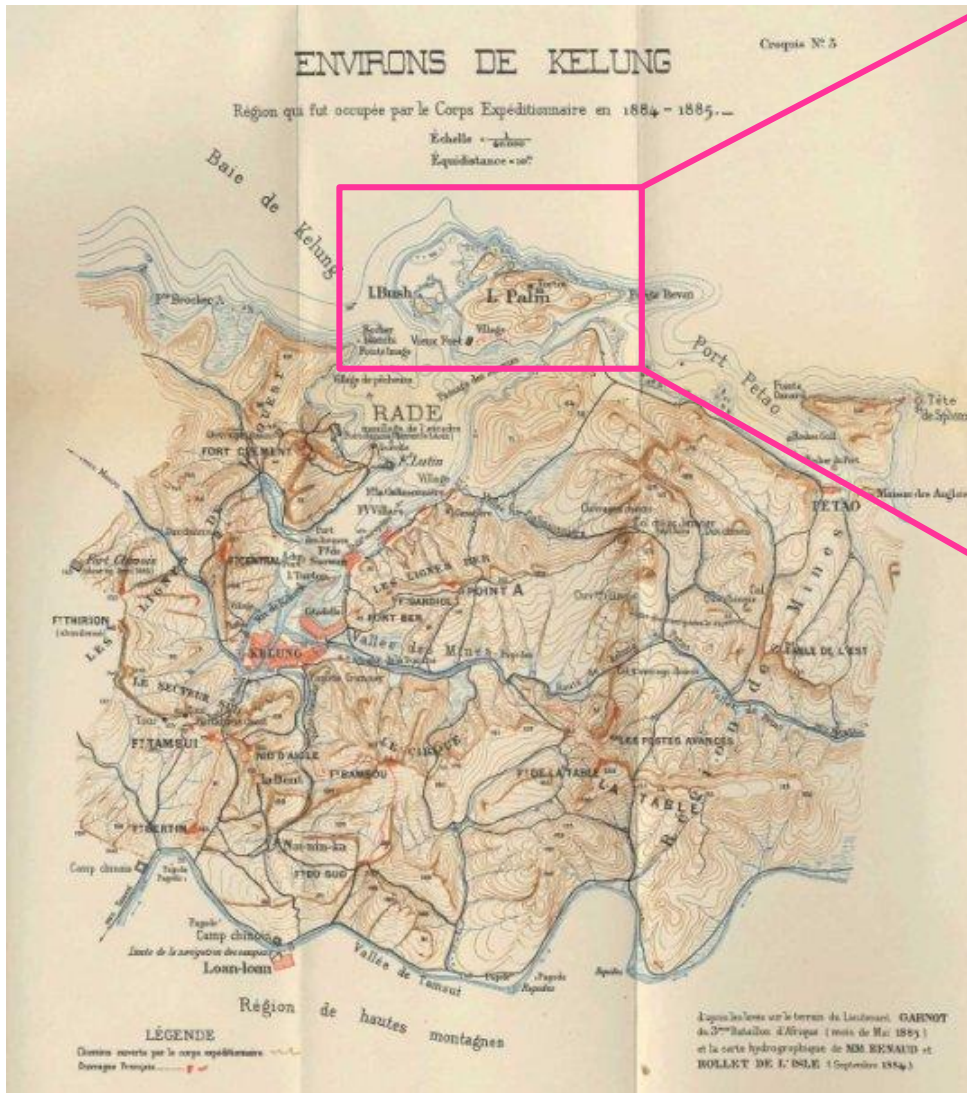
The maps were drawn when the French army attacked Taiwan during 1884-1885.

臺灣堡圖1/20,000
(臨時臺灣土地調查局, 1904)



Palm island(棕櫚島), Bush Island

A cloud of vapour was seen to rise from the sea between Palm and Keelung islands(棕櫚島和基隆島之間的海面上有煙霧)，研判Palm Island(棕櫚島)應在基隆島附近



Palm Island : 和平島

Bush Island : 桶盤嶼

The maps were drawn when the French army attacked Taiwan during 1884-1885.

Ruin Rock

A cloud of vapour was seen to rise from the sea between Palm and Keelung islands, which was succeeded by the water of the harbour rushing out seawards, leaving it dry as far as Ruin Rock for some seconds. Everything was carried away with the receding water.

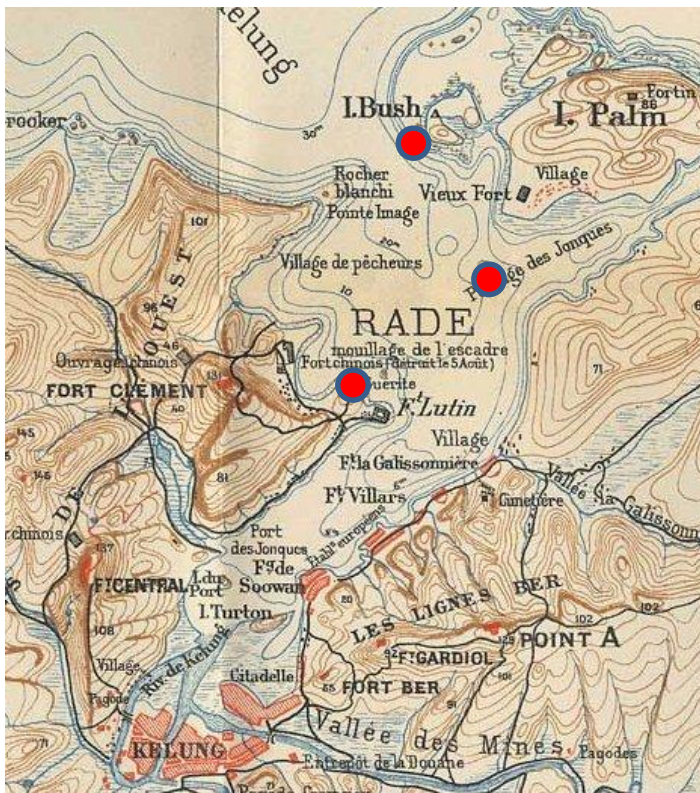
The North China Herald and Market Report/January 8th, 1868 (北華捷報)

上有一些裂縫。市鎮內大部分房屋震塌。有许多人被压在废墟下面。棕榈岛和基隆岛之间的海面上有烟雾。海港内的水涌向海外，致使远至閻王岩的地方有几秒钟成为无水地带，所有的东西都被退去的海水卷走了，然后海水又形成两个大浪涌回，将舢板

謝毓壽和蔡美彪(1987)

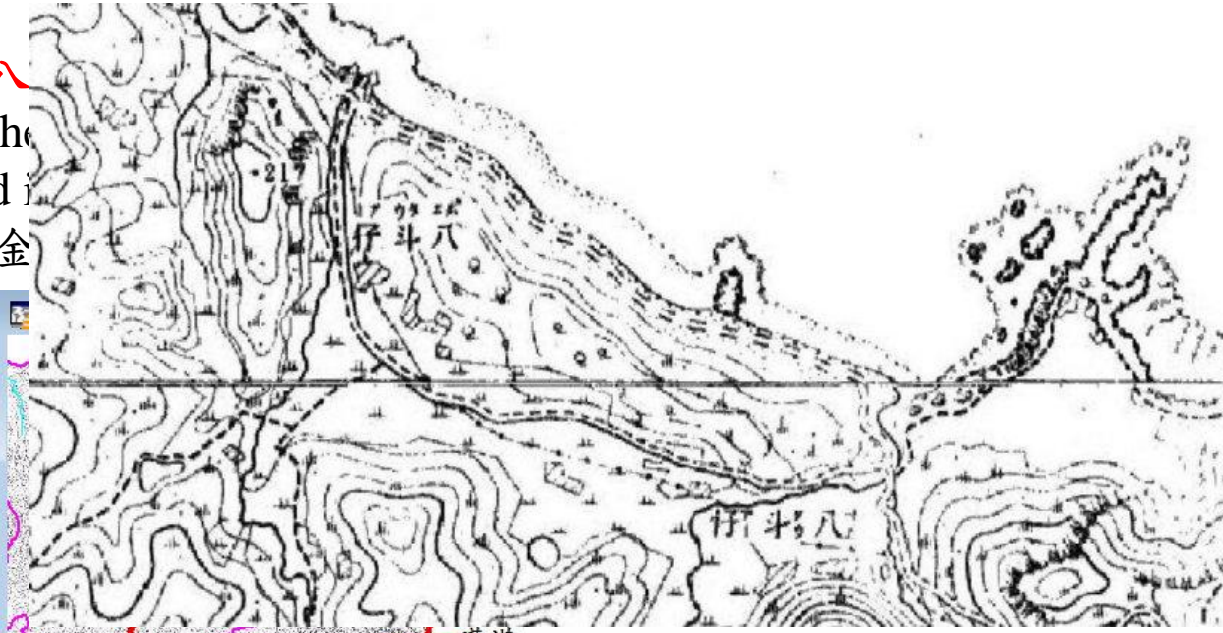
林明聖(2006)認為閻王岩就是現今野柳

**The outcome of discussions (with local archivist) :
Ruin Rock possible position:**



八斗仔 Nuclear Power plant

(岡本要八
water rush
immersed
八斗仔, 金)



仔 area

isaster less.



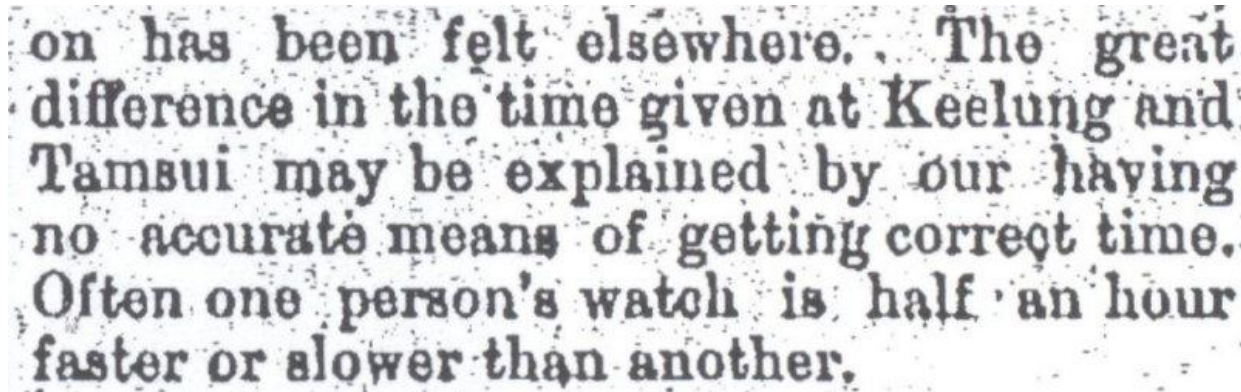
Earthquake occurrence time

Almost all of the data for the date of earthquake have consistent results :

December 18, 1867 (November 23, the 6th year of Tongzhi)

For the occurrence time of quake, there are 3 documents with further description.

1. Document of No. 8 (The North China Herald and Market Report/January 8, 1868): **Tamsui 10:20 AM., Keelung 09:45 AM.**



on has been felt elsewhere. . The great difference in the time given at Keelung and Tamsui may be explained by our having no accurate means of getting correct time. Often one person's watch is half an hour faster or slower than another.

2. Document of No. 13 (TMO, 1914): **North coast of Taiwan 10:00 AM.**
3. Document of No. 14 (岡本要八郎, 1913): **Kim-bao-li 10:00 AM.**

Based on the above information, estimate the occurrence time of quake is about 10:00 AM.

Tide

Reference the tide table of 2013(CWB, 2013)

Keelung (Lunar calendar November 23) neap tide

January 4, 2013 (Lunar calendar November 23)

潮時	潮高(中等潮位)	潮高(最低潮位)	高低潮
01:42	2	100	H
07:25	-44	55	L
14:54	22	120	H
21:13	-40	59	L

45.5 cm
65.5 cm → 10:00 (-21.4/77.6)
63.5 cm

December 25, 2013(Lunar calendar November 23)

Ebb to Rising tide

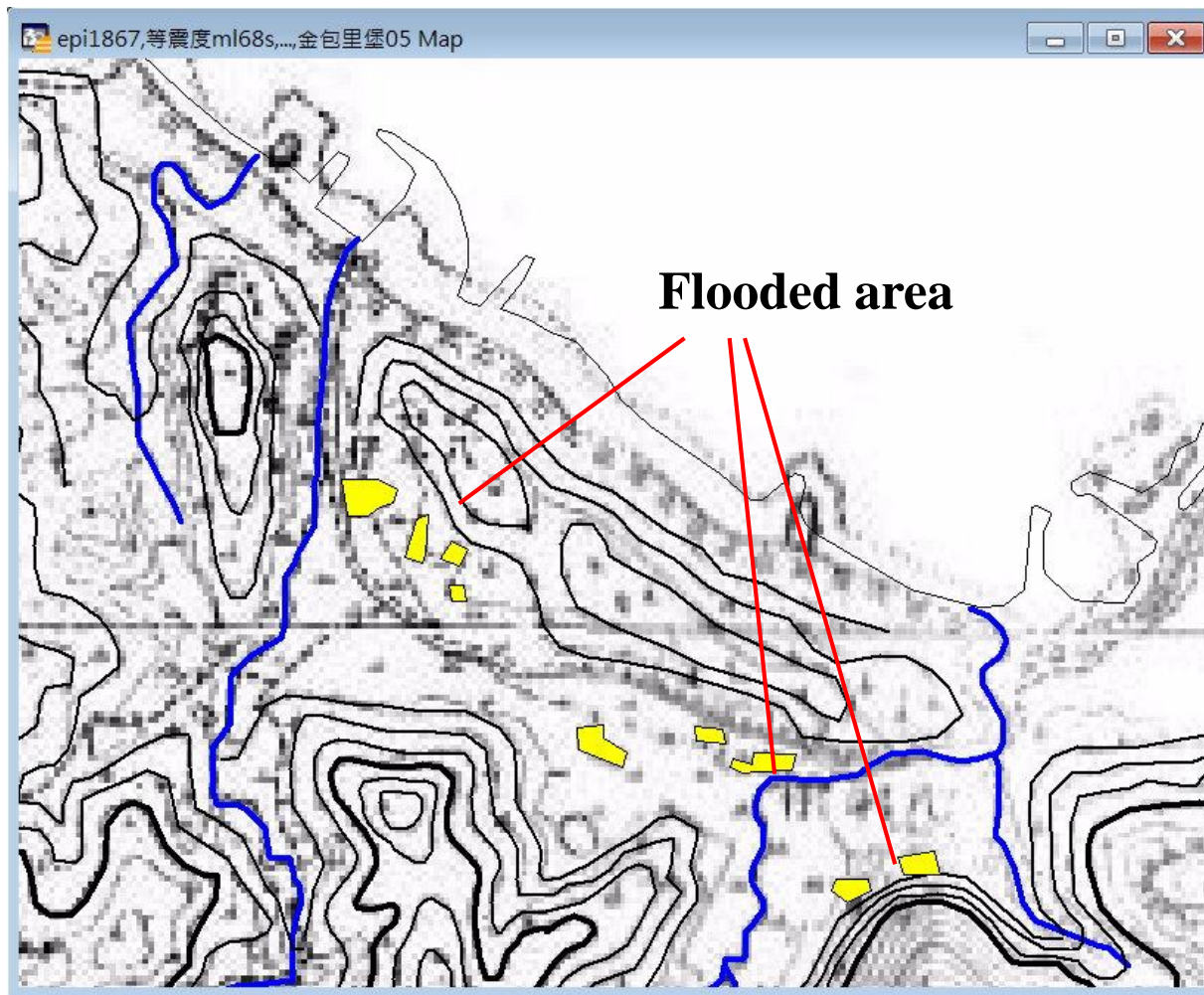
潮時	潮高(中等潮位)	潮高(最低潮位)	高低潮
02:29	-1	97	H
08:13	-37	61	L
15:38	23	121	H
22:07	-35	63	L

36.0 cm
60.0 cm → 10:00 (-22.6/75.4)
58.0 cm

中等潮位：以當地當年中等潮位為基準

最低潮位：以當年最低潮位為基準

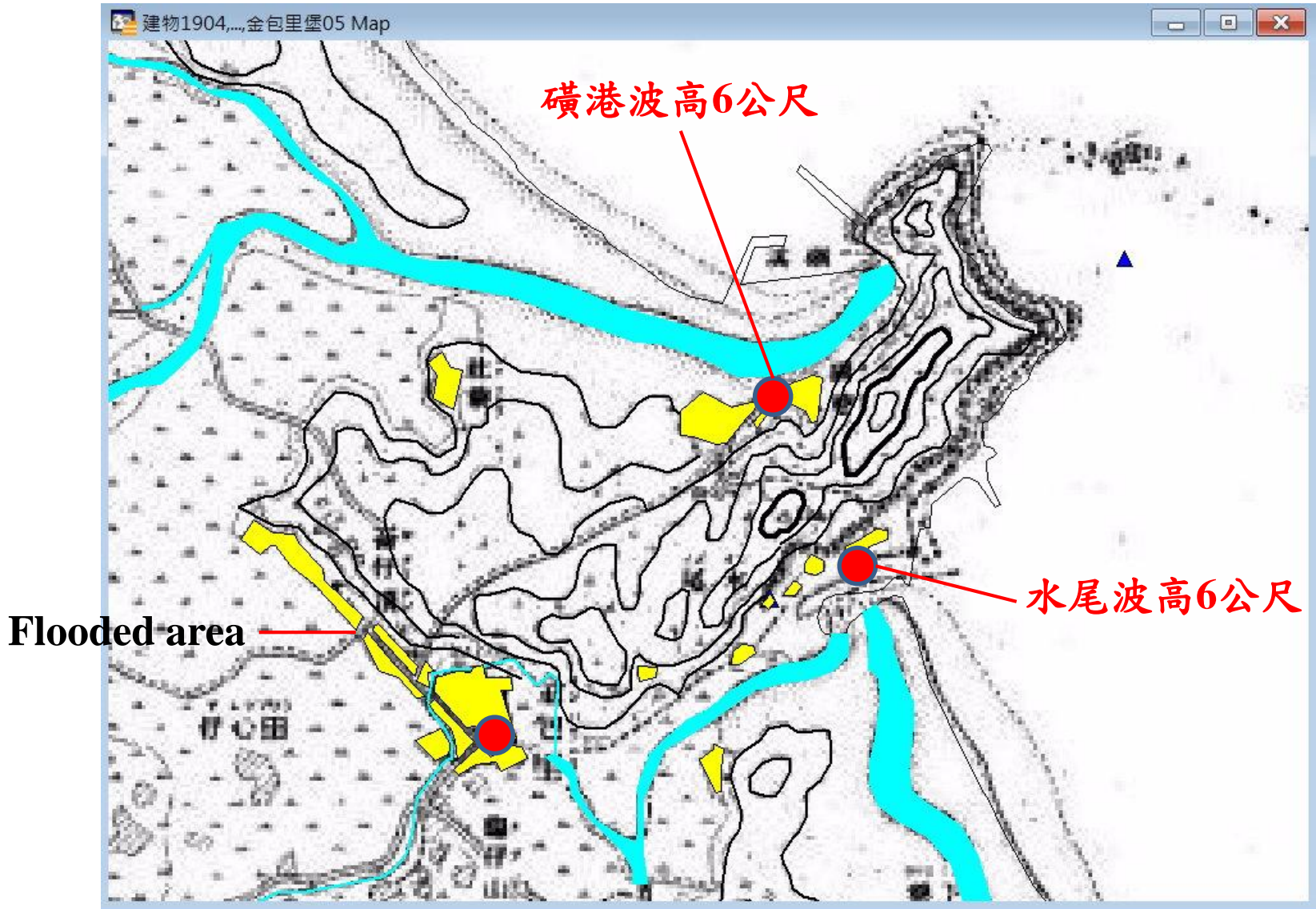
We assume that there are no major changes in topography in between 1867-1904. The 1904 map using as a basis for estimating the elevation of sea water traced back.



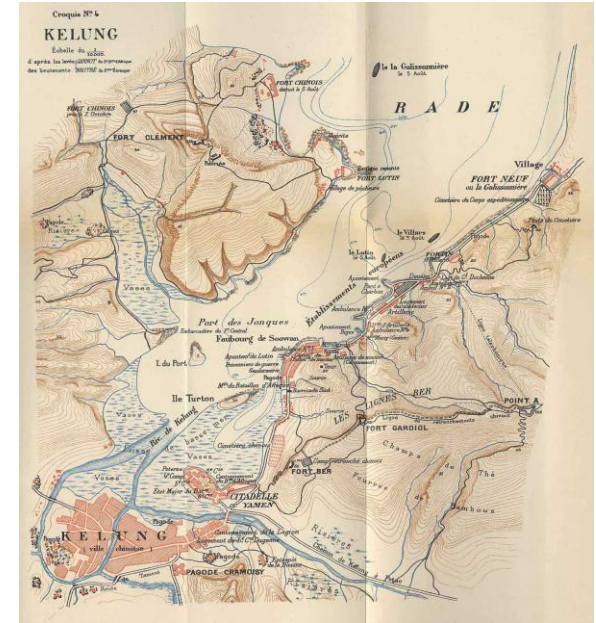
Contour
50 feet = 15.2 m
200 feet = 60.8 m

— 50 feet
— 200 feet

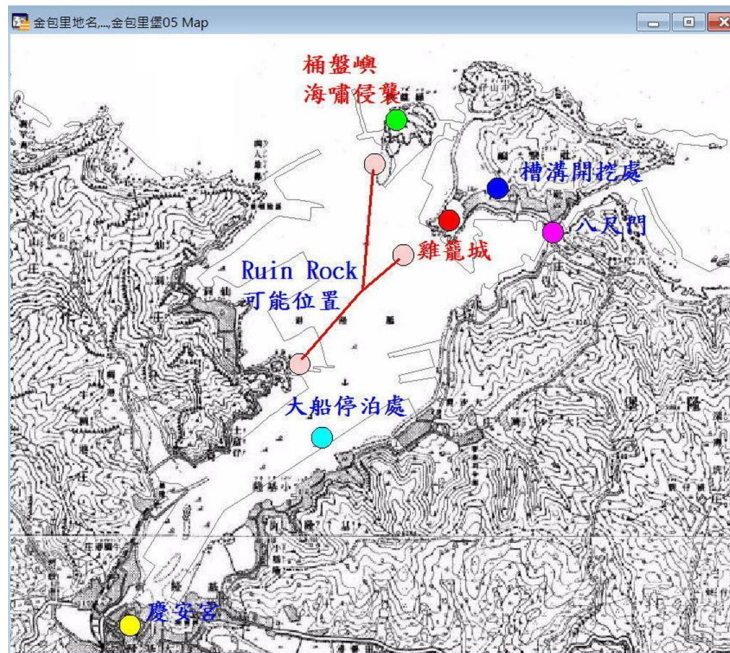
Along the river, the sea water traced back to Pa-tao-chi area with elevation about 15.2 m.



Along the river, the sea water traced back to Ching-bao-li, elevation about 15 m.

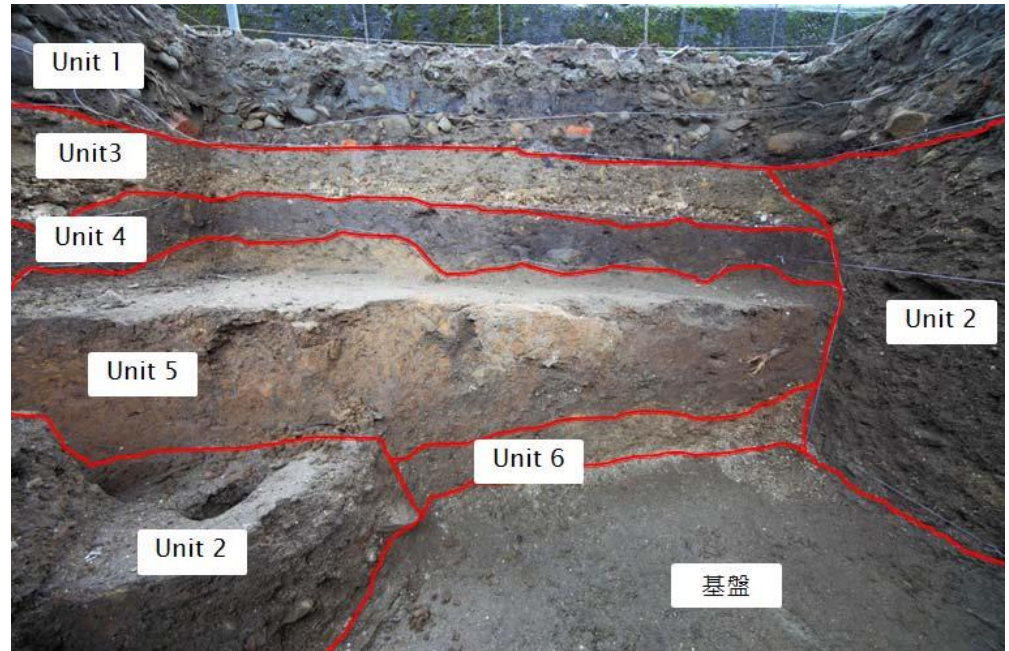
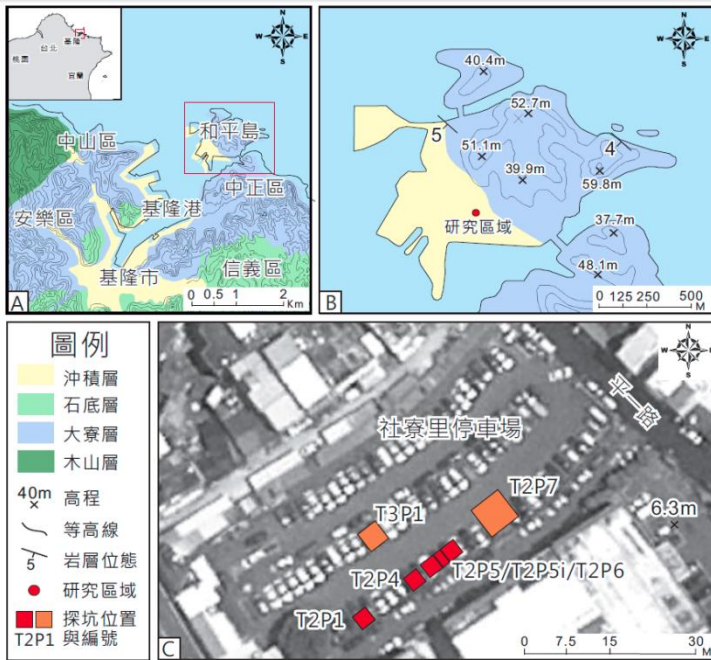


慶安宮 At low tide, there are 1-1.5 km away from the sea. May not be flooded.

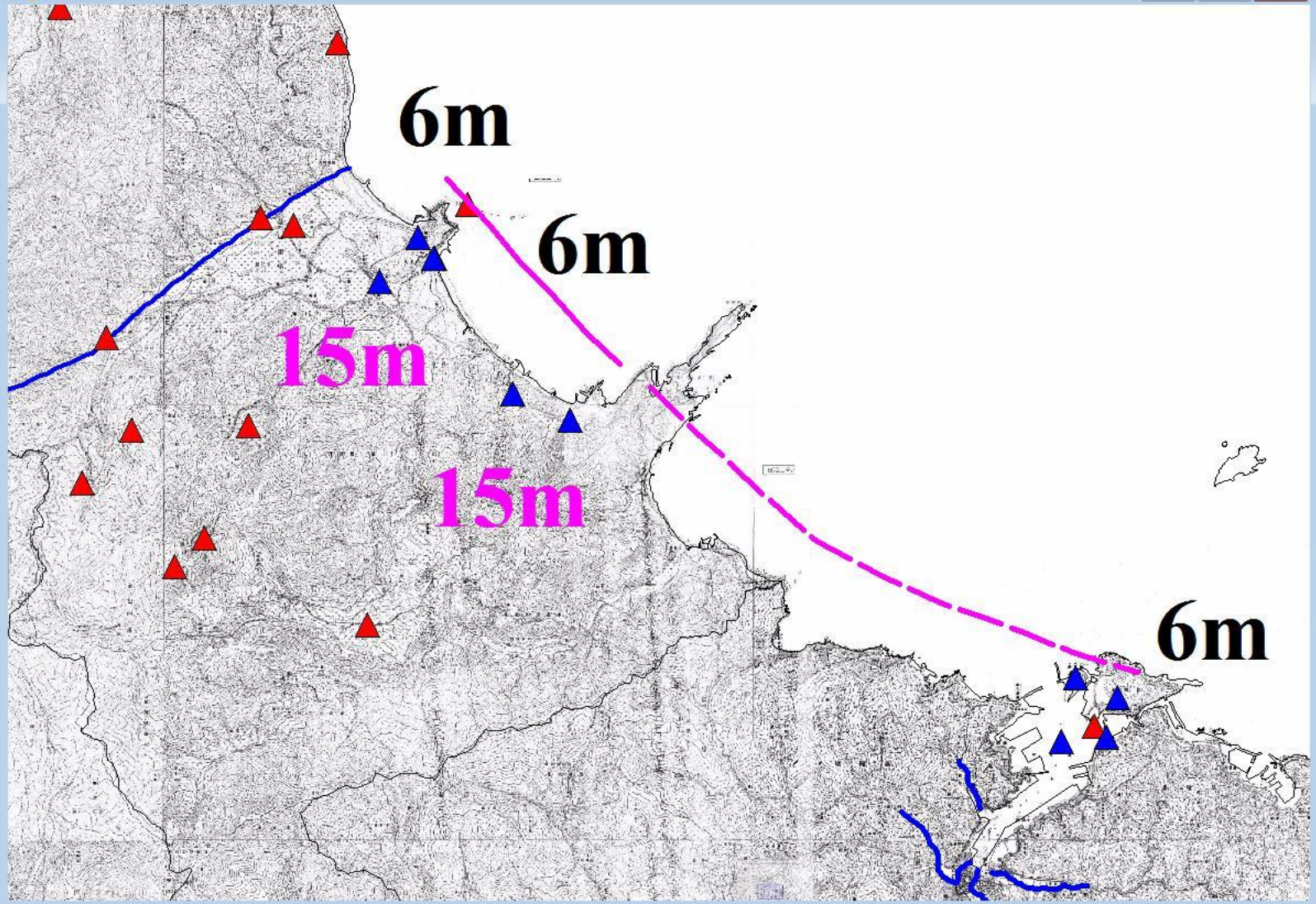


- 桶盤嶼(Bush Island) 海嘯侵襲處
- 雞籠城 海關位置
- 地調所槽溝開挖處
- 八尺門，海嘯侵襲死傷嚴重
- Ruin Rock可能處，海底乾涸位置
- 大船停泊處可能位置，地震後加深
- 慶安宮，可能沒有淹水

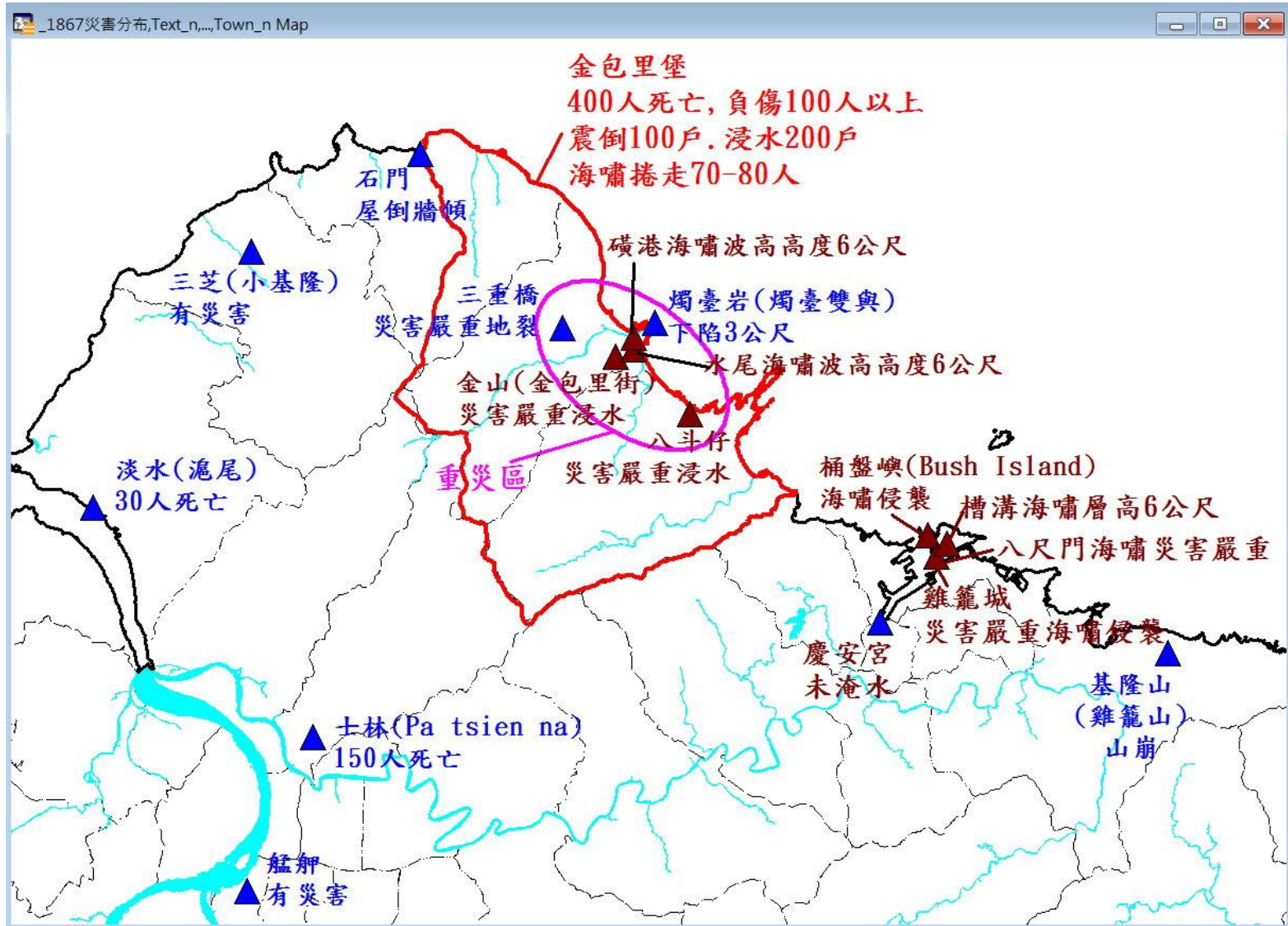
Preliminary study of the Tsunami deposits in archeological trench, Heping Island, Keelung (Chung et al., 2013)



Unit 3 : the tsunami deposits, gravelly sandstone, thickness : 5-15 cm
The direction of flow : NW—SE, several time
The elevation of the top of unit 3 is about 6 m



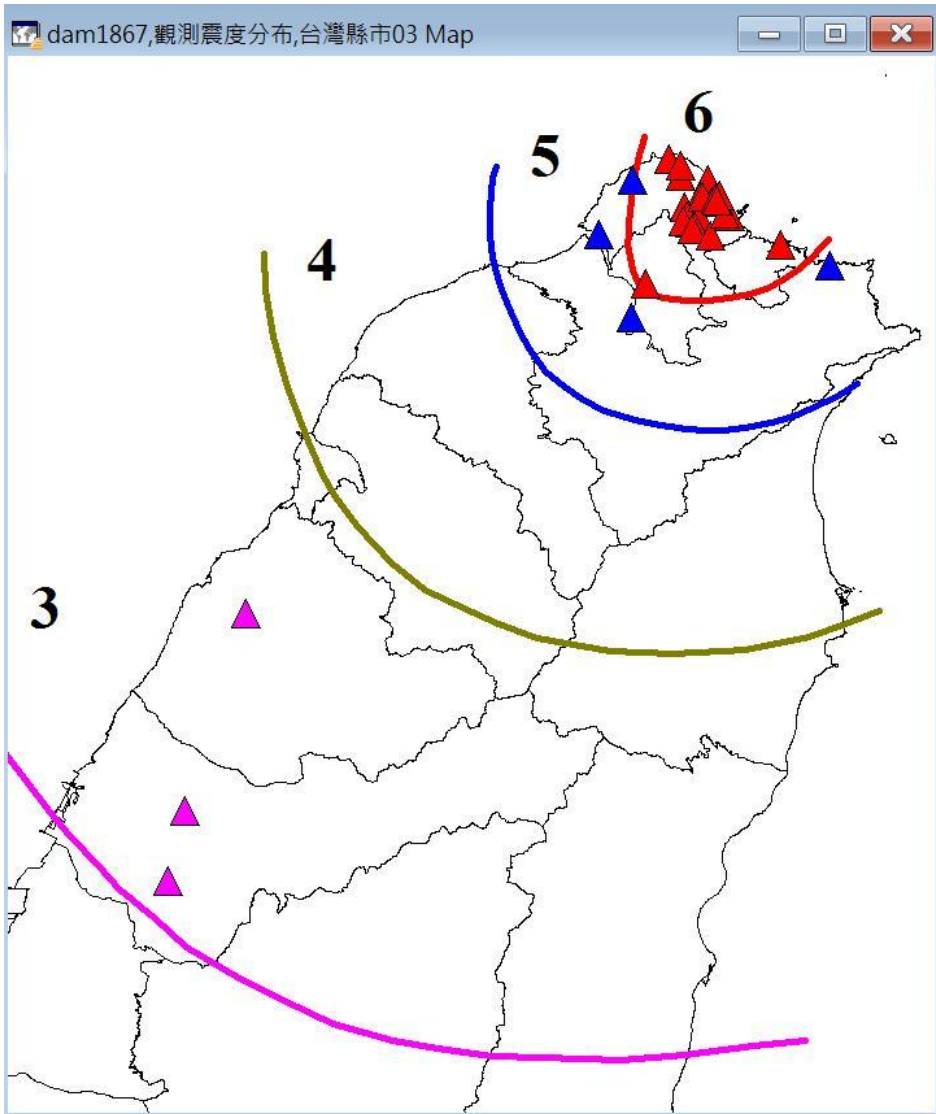
More than 580 death.



Evaluated the corresponding intensity (crustal deformation and tsunamis)

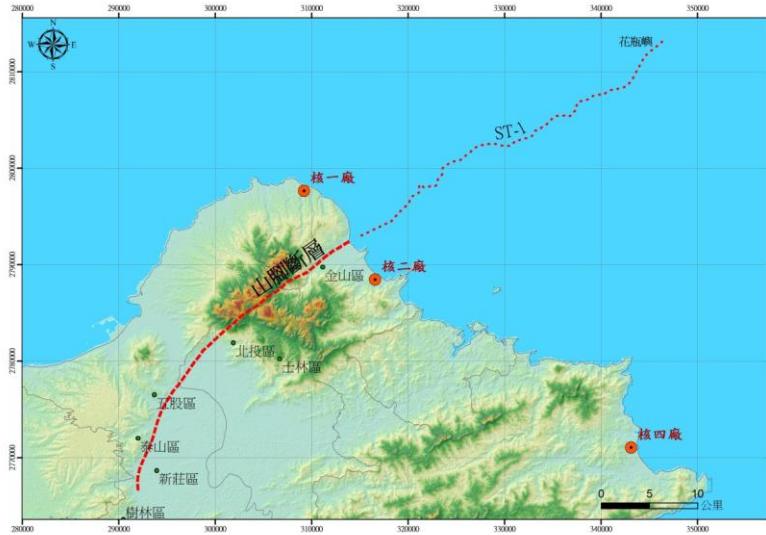
CWB intensity scale

震度分級	地動加速度 範圍	人的感受	屋內情形	屋外情形
0 無感	0.8gal以下	人無感覺。		
1 微震	0.8~2.5gal	人靜止時可感覺微小搖晃。		
2 輕震	2.5~8.0gal	大多數的人可感到搖晃， 睡眠中的人有部分會醒來。	電燈等懸掛物有小搖晃。 房屋震動，碗盤門窗發出 聲音，懸掛物搖擺。	靜止的汽車輕輕搖晃，類 似卡車經過，但歷時很短。 靜止的汽車明顯搖動，電 線略有搖晃。
3 弱震	8~25gal	幾乎所有的人都感覺搖晃， 有的人會有恐懼感。	房屋搖動甚烈，底座不穩	汽車駕駛人略微有感，電 線明顯搖晃，步行中的人 也感到搖晃。
4 中震	25~80gal	有相當程度的恐懼感，部分 的人會尋求躲避的地方，睡 眠中的人幾乎都會驚醒。	物品傾倒，較重傢俱移動， 可能有輕微災害。	
5 強震	80~250gal	大多數人會感到驚嚇恐慌。	部分牆壁產生裂痕，重傢 俱可能翻倒。	汽車駕駛人明顯感覺地震 ，有些牌坊煙囪傾倒。
6 烈震	250~400gal	搖晃劇烈以致站立困難。	部分建築物受損，重傢俱 翻倒，門窗扭曲變形。	汽車駕駛人開車困難，出 現噴沙噴泥現象。
7 劇震	400gal以上	搖晃劇烈以致無法依意 志行動。	部分建築物受損嚴重或倒 塌，幾乎所有傢俱都大幅 移位或摔落地面。	山崩地裂，鐵軌彎曲， 地下管線破壞。

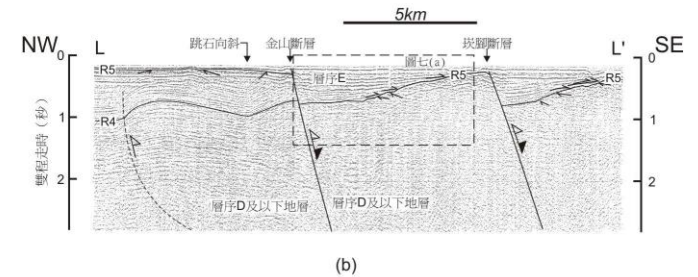
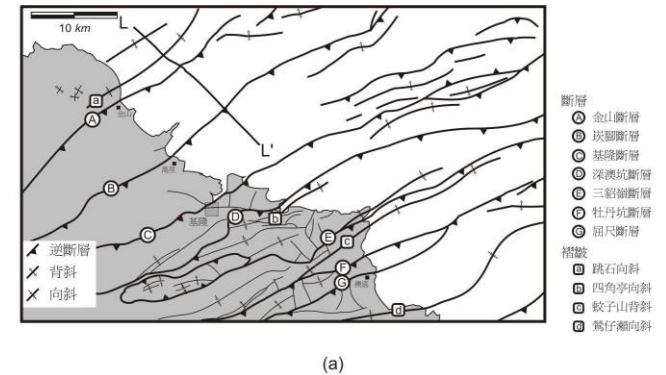


Location	Intensity
淡水 Tanshui	5
士林 Shih-lin	6
磺港 Huang-kang	6
水尾 Shu-wei	6
金山 Jinshan	6
八斗仔 Pataozu	6
三界壇 Shanjetain	6
跳石	6
磺溪頭 Huang-shi-tou	6
三重橋 Shan	6
硫黃山 Sulphur mountain	6
庚子坪頂	6
死磺坪 Shi-huang-ping	6
大坪 Taping	6
阿里磅 Alipan	6
磺嘴 Huangjei	6
三芝 Shanzhi	5
石門 Shimen	6
基隆 Keelung	6
基隆山 Keelung moutain	5
苗栗 Mioli	3
豐原 Fennyuan	1
台中 Taichung	3
浙江象山 Shansan	1

Estimated source parameters



Distribution of the Shanchiao fault
(Central Geological Survey, MOEA)



Strike: N60E
dip: more than 62 (Xiao, 1998)
Rake: -90

By the Geodetic Survey results show that the Shanchiao fault on both sides of the horizontal displacement did not significantly change, but the hanging wall subsidence obvious trend .

Considering tsunami was generated, the epicenter should be offshore, widespread landslides, epicenter is not too far from the coast. (Tsai, 1986)

Simulated intensity map to evaluative source parameters

Wells and Coppersmith (1994) fault length vs. magnitude

Normal fault

$$M_W = 4.86 + 1.32 \text{ Log(SRL)} \pm 0.34 \quad (5.2 < M_W < 7.3)$$

$$M_W = 4.34 + 1.54 \text{ Log(RLD)} \pm 0.31 \quad (5.2 < M_W < 7.3)$$

$$\text{Log(RW)} = -1.140 + 0.350 M_W \pm 0.12 \quad (5.2 < M_W < 7.3)$$

Cheng et al.(2011) M_L - M_W relationship

$$M_L = 5.115 \ln(M_W) - 3.131 \pm 0.379 \quad (M_L \geq 5.5)$$

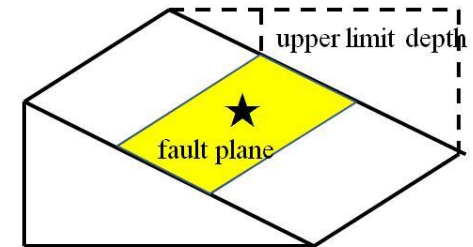
Length	Surface rupture(SRL)			Subsurface rupture(RLD)		
	RW	M_W	M_L	RW	M_W	M_L
30 km	17.4	6.8	6.7	14.8	6.6	6.5
40 km	20.4	7.0	6.8	17.4	6.8	6.7
50 km	22.1	7.1	6.9	20.4	7.0	6.8

Jean et al.(2006):

$$Y(g)=0.00284e^{1.73306M}[R+0.09994\exp(0.77185M)]^{-2.06392}$$

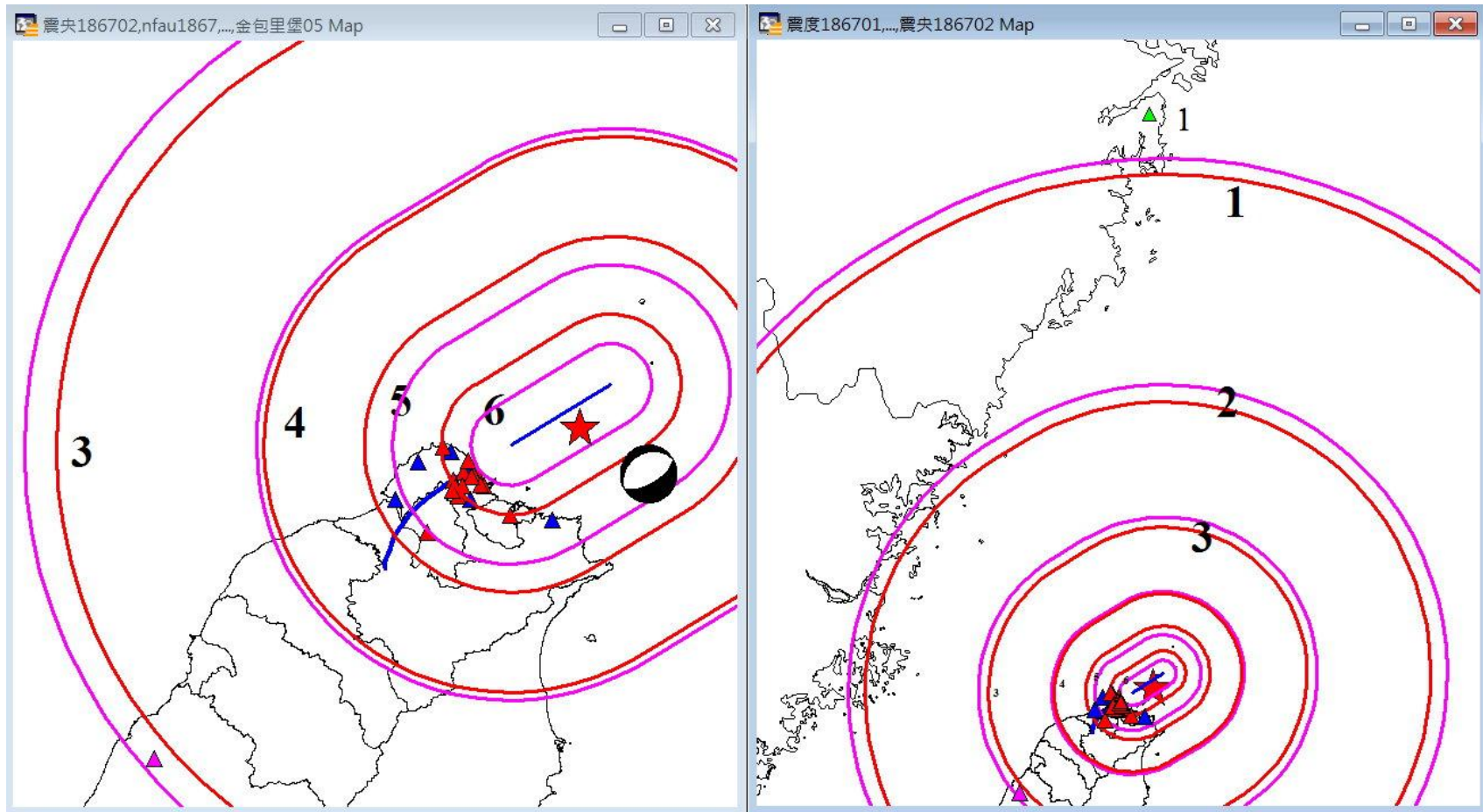
Shin(1998):(CWB):

$$PGA = 12.44 \times \exp(1.31 \times M_L) \times r^{-1.837}$$



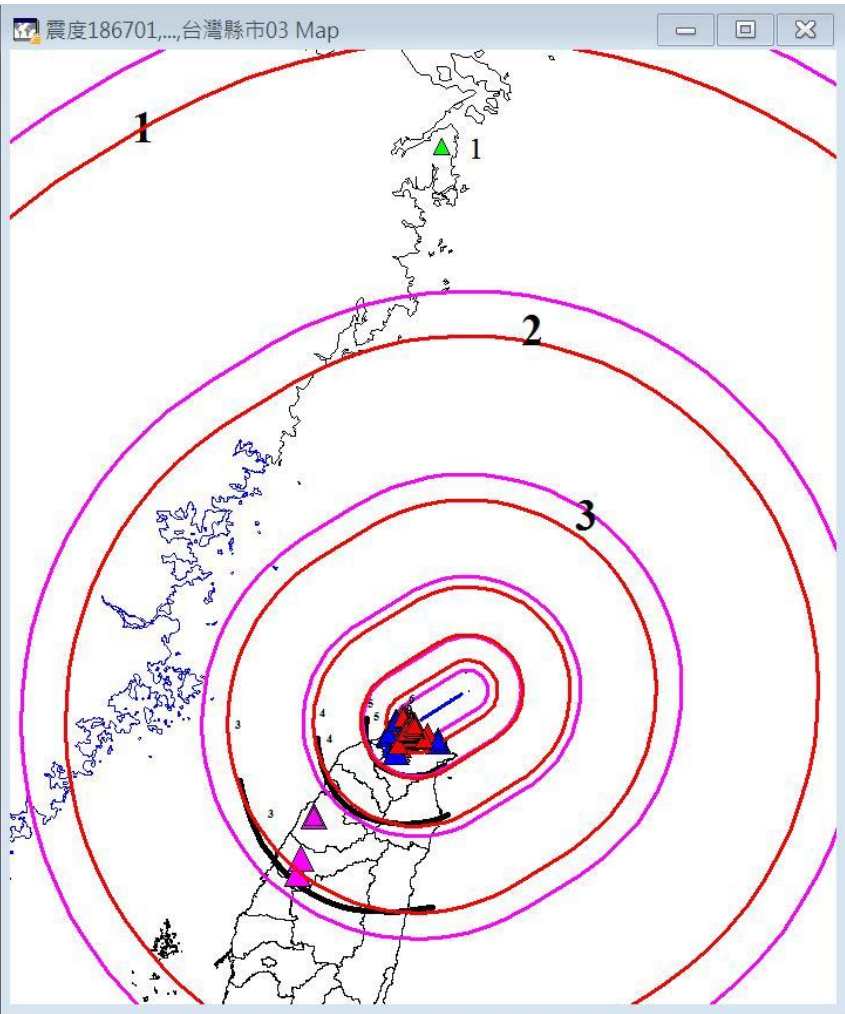
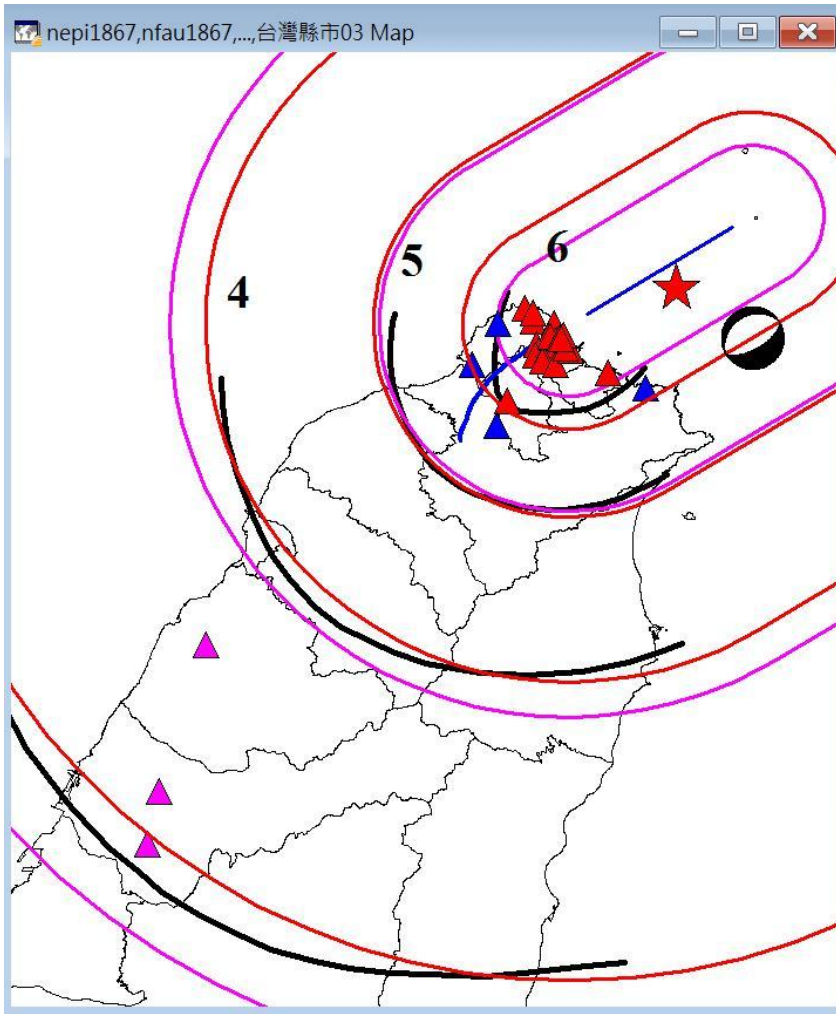
Mag	7 (0.4g)	6 (0.25g)	5 (0.08g)	4 (0.025g)	3 (0.008g)	2 (0.0025g)	1 (0.0008g)	Upper limit deph
6.7(Jean)	17.0	21.8	40.0	74.4	136.5	253.9	466.2	0 km
6.7(Shin)	7.6	14.1	37.5	79.1	150.4	277.6	495.2	0 km
6.8(Jean)	18.2	23.4	42.9	79.7	146.4	272.3	499.9	0 km
6.8(Shin)	8.4	15.5	40.9	86.2	163.7	302.1	538.7	0 km
6.9(Jean)	19.5	25.0	46.0	85.5	157.0	292.0	536.1	0 km
6.9(Shin)	9.3	17.0	44.6	93.9	178.2	328.7	586.0	0 km

Mag	7 (0.4g)	6 (0.25g)	5 (0.08g)	4 (0.025g)	3 (0.008g)	2 (0.0025g)	1 (0.0008g)	Upper limit deph
6.5(Jean)	13.9	18.3	38.4	64.5	118.6	220.7	405.4	10 km
6.5(Shin)	3.8	10.6	31.1	66.5	126.9	234.4	418.4	10 km
6.7(Jean)	16.2	21.2	39.7	74.2	136.4	253.8	466.2	10 km
6.7(Shin)	5.8	13.2	37.1	79.0	150.3	277.6	495.1	10 km
6.8(Jean)	17.5	22.8	42.6	79.6	146.3	272.2	500.0	10 km
6.8(Shin)	6.8	14.6	40.6	86.1	163.7	302.0	538.6	10 km



— Jean et al.(2006)

— Shin (1998) Fault length:30 km(subsurface rupture) , $M_W=6.6$, $M_L=6.5$
 25.34N, 121.91E, Depth=15 km (60, 62, -90)



- **Jean et al.(2006)** Fault length:40 km(surface rupture) , $M_W=7.0$, $M_L=6.8$
- **Shin, 1998** 25.34N, 121.91E, Depth=10 km (60, 62, -90)

Preliminary results

- The 1867 Keelung earthquake is closely relative with the northeastern extending of Shanchiao fault. The epicenter of the Keelung earthquake is : 25.34°N , 121.91°E , Depth=10 km, magnitude $M_{\text{W}}=7.0$, $M_{\text{L}}=6.8$, fault length about 40 km, possible fault-plane : (60, 62, -90)
- Earthquake triggered a tsunami, water rushed Huangkan (磺港) and Shuwei(水尾), wave height about 6 m. The results are consistency with trench at Heping Island.
- Along river, the sea water traced back to 金山 and 八斗仔 area with elevation about 15 m.