



Medieval Forewarning of the 2004 Indian Ocean Tsunami in Thailand

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Nature, Vol 455| 30 Oct. 2008| 1228-1231

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Abstract

- **Recent centuries provide no precedent for the 2004 Indian Ocean tsunami, either on the coasts it devastated or within its source area.**
- **Using sedimentary evidence for tsunamis, they identify probable precedents for the 2004 tsunami at a grassy beach-ridge plain 125 km north of Phuket.**
- **The 2004 tsunami, running 2 km across this plain, coated the ridges and intervening swales with a sheet of sand commonly 5–20 cm thick.**
- **The peaty soils of two marshy swales preserve the remains of several earlier sand sheets less than 2,800 years old.**
- **If responsible for the youngest of these pre-2004 sand sheets, the most recent full-size predecessor to the 2004 tsunami occurred about 550–700 years ago.**

Background

- **The term tsunami comes from the Japanese meaning harbor ("tsu", 津) and wave ("nami", 波).**
- **A tsunami is a series of waves created when a body of water, such as an ocean, is rapidly displaced.**
- **Due to the immense volumes of water and energy involved, the effects of a tsunami can be devastating.**

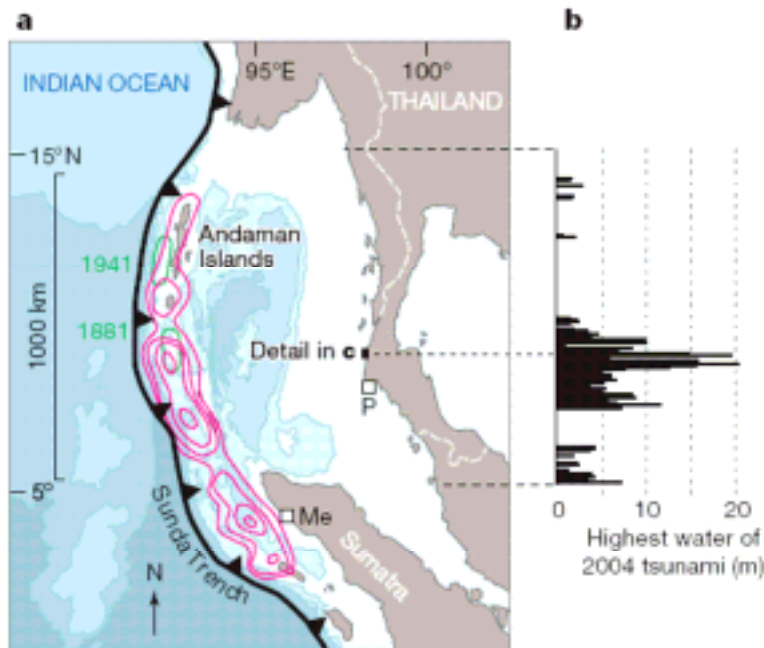
- **The potential to generate a tsunami:**

- **Earthquakes**
- **Mass movements above or below water**
- **Some volcanic eruptions**
- **Underwater explosions, landslides**
- **Underwater earthquakes**
- **Large asteroid impacts**
- **Detonation of nuclear weapons at sea**

- **The 2004 Indian Ocean tsunami:**

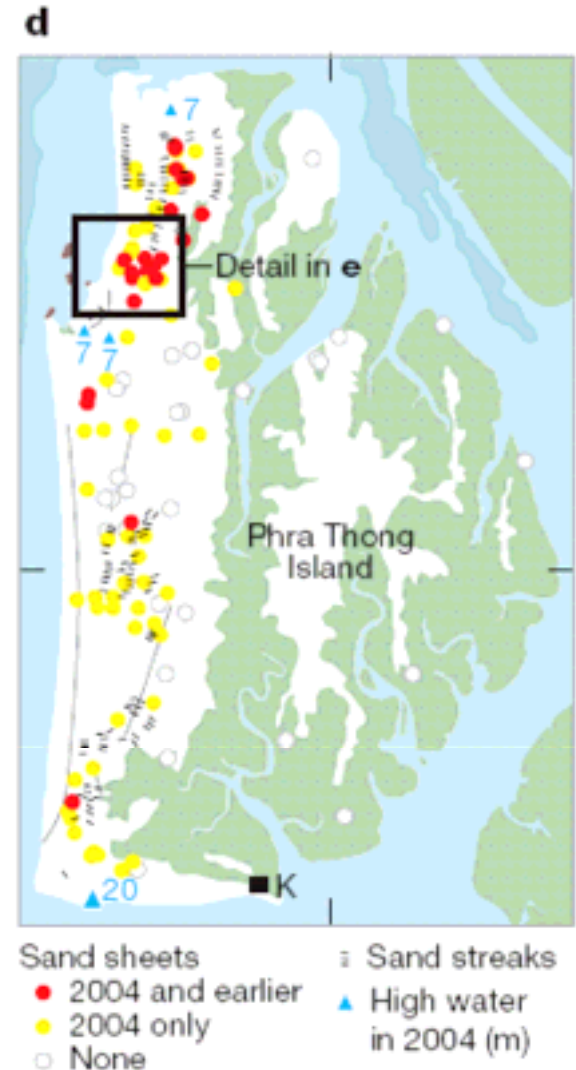
- Associated with an earthquake of **magnitude 9.2**
- Resulted from a **fault rupture 1,500km long** that expended centuries' worth of plate convergence.
- Claimed nearly all of its victims on shores that had gone **200 years** or more without a tsunami disaster.
- The earthquake **defied a Sumatra–Andaman catalogue** that contains no nineteenth-century or twentieth-century earthquake larger than magnitude 7.9

- Rose **20m above sea level** on Phra Thong Island
- Coated most of the island's **western half** with a sheet of sand
- Ran more than **2km inland across** a Holocene plain

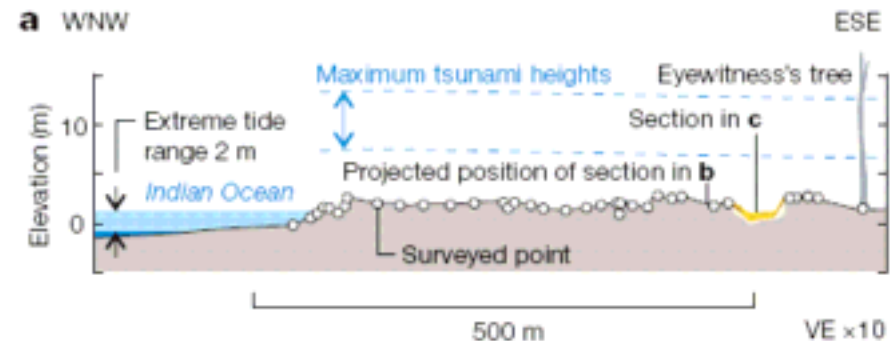
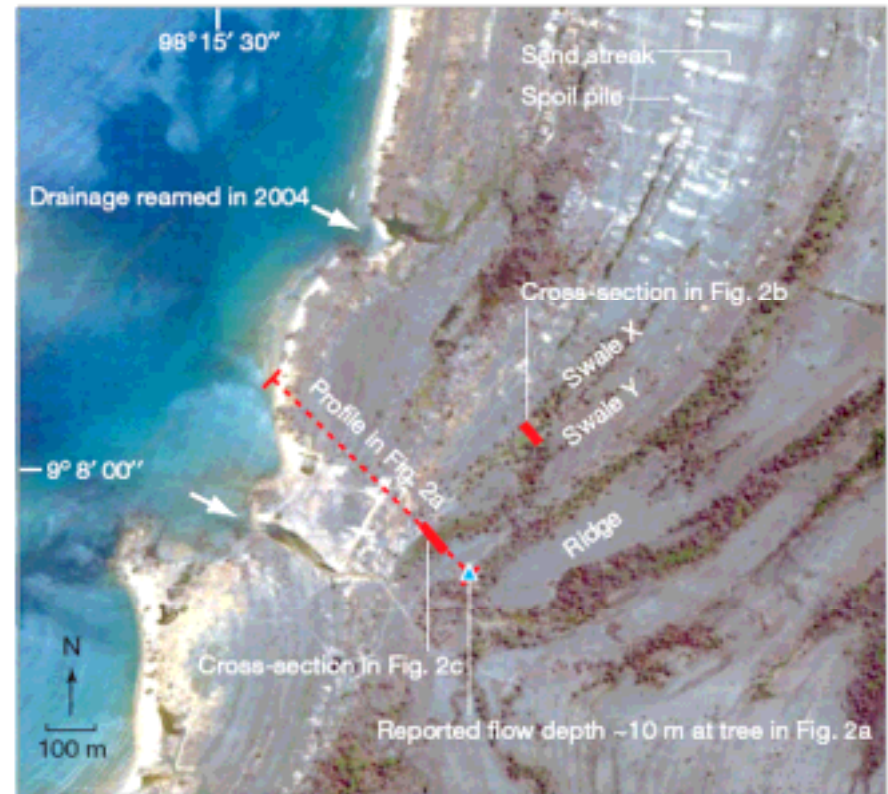


Stratigraphy & Chronology analysis

- Digged **more than 150 sites** of pits and augering holes into ridges and swales to seek pre-2004 sand sheets at Phra Thong .
- Found **20 sites content pre-2004** sand interbedded with the peaty soils of **swales that hold standing water** most of the year
- **Didn't find pre-2004** sand beds in the **quartzsand soils** of the ridges or in the **slightly organic soils** of swales that are merely damp.

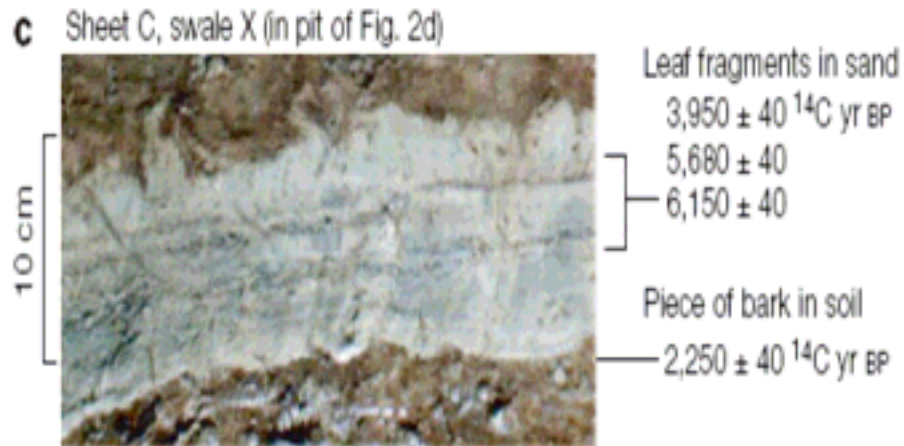
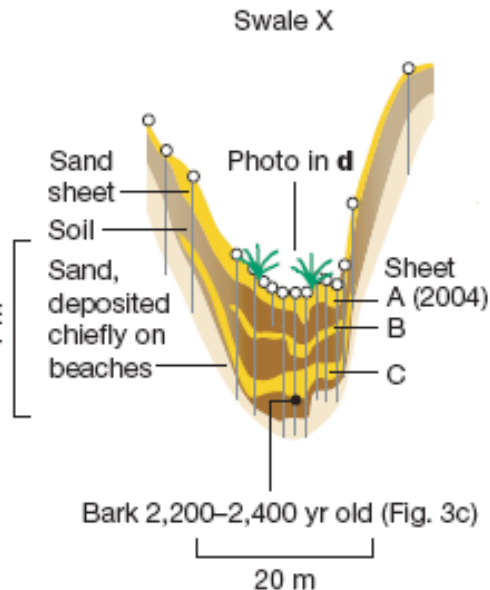


- Traced pre-2004 beds across each of **two marshy swales** near a place where the 2004 tsunami flowed about 10m.
- These swales formed about **2,500 years ago**.
- The more westerly of **the swales (X)** postdates its neighbour (Y).
- Assembled **stratigraphic cross-sections** from correlated **pits, auger borings and a trench**.

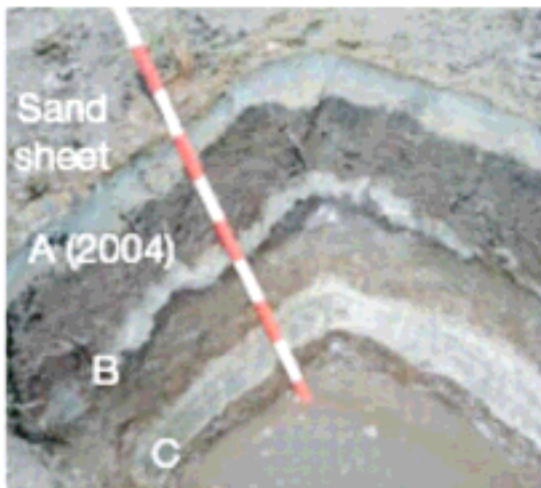


Swale X

- **Sheet C** is commonly **10 cm thick**
- **Coarse to very coarse sand** forms a discontinuous basal layer
- The rest of sheet C consists of **very fine sand and coarse silt** that contains horizontal leaf fragments
- The entire sheet formed after **2,200–2,400 years ago**
- Leaf fragments ages exceed the bark age by thousands of years

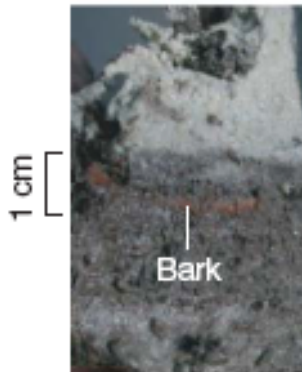


- **Sheet B**, commonly **5 cm thick**, typically fines upwards from **fine sand to sandy silt**
- It conformably overlies **peaty soil** that contains a horizon of **bark** fragments in its **uppermost 1 cm**
- Three fragments yielded ages **between 530 ± 40 and 570 ± 40**
- Sheet B was deposited about **550–700 years ago**



Stripes on ruler, 10 cm

Sheet B, swale X (in pit of Fig. 2d)



Base of sheet B

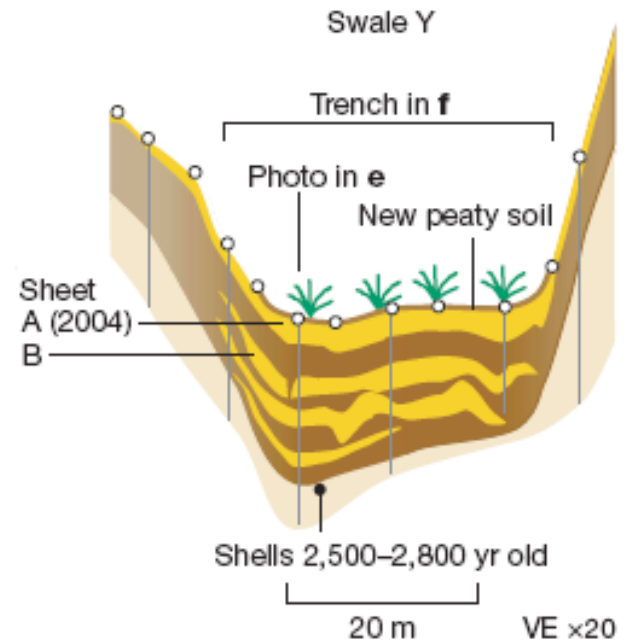
Pulled apart

Bark shed from *Pandanus* tree and preserved in soil

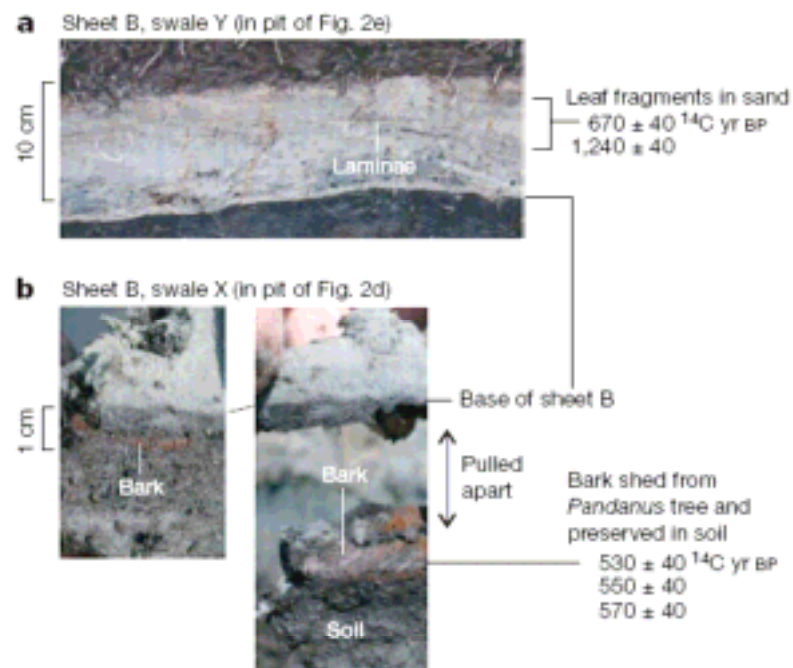
530 ± 40 ^{14}C yr BP
 550 ± 40
 570 ± 40

•Swale Y

- **Three** pre-2004 sand sheets
- All are **similar in thickness** to 2004
- All were **formed after 2,500–2,800** years ago marked by shells
- The **lowest two** sheets, otherwise undated and thus left uncorrelated with swale X, consist **very fine to fine sand**
- They **lack sedimentary structures**, probably because of bioturbation that blurs their contacts with the soils beneath.



- The **highest** pre-2004 sheet (B) retains a sharp base and tabular shape that extend the **full length of the trench** .
- This sheet fines upwards from basal **fine or medium** sand to parallel-laminated **very fine** sand that **abounds in leaf fragments** .
- It probably **correlates with sheet B of swale X**
 - each is the youngest pre-2004 sand sheet in its swale
 - the leaf fragments in swale Y yielded ages too young for correlation with sheet C

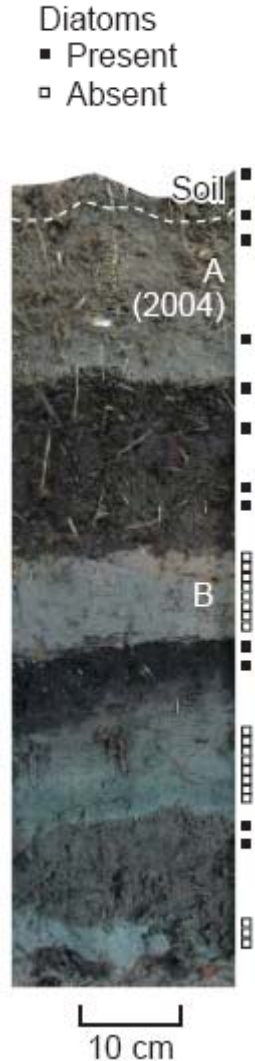


• diatom sediment

- Although the 2004 sand sheet abounds in brackish and marine diatoms, the earlier sand sheets in swales X and Y lack diatoms of any kind
- Marine and brackish-water diatoms aid in identifying tsunami deposits on temperate shores
- Perhaps their opaline silica valves do not last long in tropical warmth; in experiments, the dissolution of diatoms increases with temperature



swales X



swales Y

• Preservation is also a problem for the sand sheets:

➤ The pre-2004 sheets:

- **distinct and sharply** bounded where the swale soil is **peaty**
- **blurred** by gradational contacts where the soil is just **slightly organic**
- **totally absent** in the sandy soils of **beach-ridge crests**

➤ The 2004 tsunami deposit is already headed towards this fate:

- **in wet swales** it has a protective **cap of** organic matter as much as **5 cm thick**
- **on ridge crests** it **lacks any cover** other than ejecta from burrows that tap the underlying sandy soil.

- **The source of pre-2004 sand sheets**

- Although sand sheets can record **intense storms**, the **geographic setting (less than 10 ° from the Equator)** **limits** Phra Thong's exposure to such storms.
- Scores of **twentieth-century cyclones** originated in Indian Ocean waters to its west, but all these **moved towards India, Bangladesh or Myanmar** without producing a known storm surge in Thailand.
- **Tropical cyclones** do strike Thailand from its **Pacific side**. However, such a storm **loses strength** during its overland crossing to the Indian Ocean

- Phra Thong's **setting** also **disfavours** sand-sheet deposition by **river or wind**.
- **Tidal inlets separate** the island from the nearest rivers.
- **Aeolian dunes obscure little**, if any, of the island's delicate striping by beach ridges and swales.

- **Chronology provides three further reasons to ascribe the pre-2004 sand sheets to tsunamis:**

- **First, the middle Holocene ages of the leaf fragments from sheet C imply scour into long-buried deposits beneath tidal inlets.**
- **The 2004 tsunami showed capacity for such scour by knocking down mangroves along an inner part of the inlet that bounds Phra Thong Island on the south.**

➤ **Second**, the sand sheets represent **infrequent events**:

- The soil between **sheets C and B** spans **1,500–1,850 years**
- The interval between **sheet B and the 2004 tsunami** lasted nearly **550–700 years**
- These time intervals are in the broad range of deductive estimates for the **recurrence of giant earthquakes** in the Sumatra–Andaman source region of the 2004 tsunami.

➤ **Third**, sheet B, if little younger than AD 1300–1450, may correlate with tsunami and earthquake **evidence elsewhere**.

- The **youngest widespread** pre-2004 sand sheet on a beach-ridge plain at **Meulaboh, Sumatra** overlies plant detritus dated to **AD 1290–1400**.
- **Two coral fragments** on a marine terrace in the **Andaman Islands** gave ages in the range **AD 1200–1650**.
- **However**, in accounts from Ibn Battuta (journey, AD 1325–1354) and the great Ming armadas (voyages, AD 1405–1433), there was **no written evidence** for a sheet-B tsunami on Sumatran and SriLankan shores that the 2004 tsunami would overrun.

- **What tsunami sources might Phra Thong's pre-2004 sand sheets represent?**
 - **Too little is known** about the sheets' landward extent on the island, let alone their potential correlates on other Indian Ocean shores, to **require full-size predecessors** to the 2004 Sumatra–Andaman earthquake.
 - The sheets probably required **ruptures larger than that of 1881**, which crested **less than 1 m high**
 - The pre-2004 sheets may also require Sunda Trench **earthquakes larger than magnitude 8.5**

Result: Sand sheets of Phra Thong Island thus forewarn of infrequent catastrophe.

- They are already providing public officials and coastal residents with tangible evidence that the 2004 tsunami was not the first of its kind.
- Tsunamis without precedent in written history may threaten Indian Ocean shores that face other parts of the Sunda Trench and the Makran subduction zone.

- **It can be hoped that natural warnings from recent geological history will help avert surprises from these additional tsunami sources.**
- **Still to be determined:**
 - **Whether centuries dependably separate such outsize tsunamis of Sumatra–Andaman source**
 - **Whether these recur often enough to dominate Thailand's probabilistic tsunami hazard.**

THANK YOU!