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FIELD GUIDE

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SIGNATURES OF 2004 SUMATRA-ANDAMAN AND PAST TRANSOCEANIC TSUNAMIS AND MEGA-SUBDUCTION ZONE EARTHQUAKES FROM ANDAMAN ISLAND

Javed N. Malik, Mahendrasinh S. Gadhavi and Santiswarup Sahoo

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Field Guide Book

INPRE-10

Signatures of 2004 Sumatra-Andaman and past transoceanic tsunamis and mega-subduction Zone Earthquakes from Andaman Island

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Team Leaders



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Prof. Javed H N Malik, at the Department of Earth Sciences, IIT Kanpur, is the foremost researcher in the fields of Active Fault Mapping, Paleoseismology, Paleo-tsunami and Archaeological studies in India. His work has led to identification of several new faults namely the Kangra Valley Fault; Taksal Fault, Pinjore Garden Fault, and Hajipur Fault in the Himalayan region. He was first to report active faults along the Kachchh Mainland and South Wagad from Gujarat. Also, identified evidence of several large-magnitude paleo-earthquakes that occurred in Himalaya during the historic period, and signatures of several mega-thrust earthquakes and associated seven transoceanic tsunamis from coastal stratigraphic records in Andaman. He is a recipient of National Geoscience Award in Disaster Management; S. S. Merh Award in Quaternary Geology; Young Muslim Scientist Award; B. B. Lal, Endowment Chair Professor for Archaeology (twice); Excellence in Teaching Award and is Fellow of Indian National Science Academy.



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Dr. Mahendrasinh Gadhavi is a geologist and academic specializing in structural geology, active tectonics, active fault mapping, and paleoseismology, with over two decades of field and research experience. His work has focused extensively on the Kachchh region and the Himalayan tectonic belt, contributing to several nationally funded active fault and seismic hazard investigations. He has substantial expertise in identifying and characterizing active faults through integrated geomorphic, structural, remote sensing, GIS, and field-based investigations. A key strength of his work is paleoseismic trench investigation and interpretation, including recognition of fault-related deformation, stratigraphic relationships, and earthquake-induced sedimentary and structural features preserved in trench exposures. His research contributes directly to understanding past earthquake chronology, fault segmentation, surface rupture, and seismic hazard assessment in India.

Abstract

The Andaman and Nicobar (A&N) Islands are located in highly active Seismic Zone V, with a historical record of moderate-to-large earthquakes (Mw 7.5–7.9). This tectonic framework provides an ideal setting for megathrust subduction zone earthquakes and transoceanic tsunamis. During the 2004 Sumatra–Andaman earthquake (Mw 9.3), the A&N coasts experienced significant coseismic subsidence and uplift. Along the east coast, Siri Vijaya Puram (formerly Port Blair) subsided by approximately 1 m, while Collinpur on the west coast subsided by about 0.5 m. Tsunami wave heights reached 3.0–3.5 m around Siri Vijaya Puram and 1.5–2.0 m near Collinpur, causing inland inundation up to 800 m. In the southern islands, Great Nicobar and Car Nicobar subsided by ~3 m and 1.2 m, respectively. Conversely, Shaheed Dweep (formerly Neil Island), located east of the Andaman Islands, recorded an uplift of roughly 0.5 m. This field excursion focuses on visiting key sites around Siri Vijaya Puram, including Mitthakhadi, Collinpur, Badabalu, and Kurmadera. The primary objective is to investigate nearshore coastal stratigraphy and geomorphic markers for evidence of paleo-earthquakes and paleo-tsunamis. Additionally, the itinerary includes a visit to Shaheed Dweep to observe its distinct, multiple marine terraces.

Preamble

The Andaman and Nicobar (A&N) islands, southeast of mainland India, are the Indian land masses closest to the epicenter of the 26 December 2004 Great Sumatra earthquake (Mw 9.3). They consist of a narrow-broken chain of about 572 picturesque islands, islets, and rocks extending along a general north-south direction between 14° N and 6.5° N latitude in the southeastern part of the Bay of Bengal (Fig. 1). Of these, only about 36 islands are inhabited. The islands are grouped into two sets, with the 10° N international shipping channel as the divider: islands north of 10° N latitude are called the Andaman Islands, and those in souths are called the Nicobar Islands. The North, Middle, South, and Little Andaman Islands are the most populated of the former islands; Car Nicobar, Great Nicobar, Katchaal, and Kamorta are the most populated of the latter islands. According to the 2001 census, the total population of the A&N islands is about 356,152; about 314,084 people live on the Andaman Islands, and about 42,068 live on the Nicobar Islands.

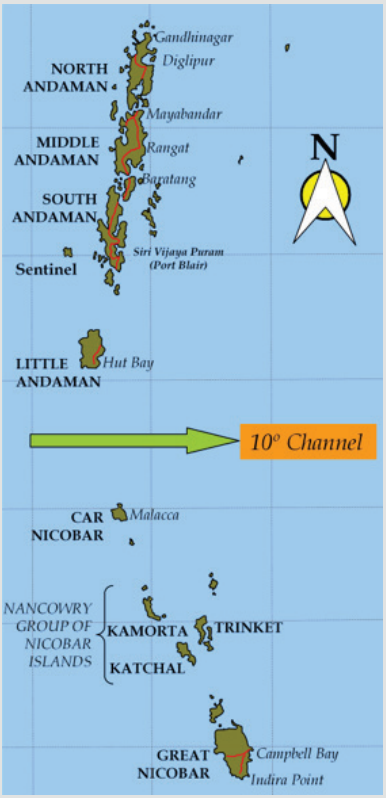


Fig. 1: The distribution of the Andaman and Nicobar Islands A&N Islands.

Research Problem and Global Context

The Sunda–Andaman subduction zone represents one of the most active convergent plate margins on Earth and has repeatedly generated great megathrust earthquakes and transoceanic tsunamis. The catastrophic 26 December 2004 Sumatra–Andaman earthquake (Mw 9.1–9.3) demonstrated the enormous destructive potential of this plate boundary, producing a rupture extending over ~1,300 km and generating one of the deadliest transoceanic tsunamis in recorded history. The event caused widespread loss of life across the Indian Ocean and produced remarkable coseismic uplift, subsidence, shoreline migration, and sediment redistribution throughout the Andaman and Nicobar Islands.

Despite the devastating consequences of the 2004 event, the recurrence behaviour of great earthquakes and tsunamis along the Sumatra–Andaman–Arakan subduction system remains poorly constrained. Instrumental and historical earthquake records extend back only a few centuries and are insufficient to characterize the recurrence intervals, rupture segmentation, magnitudes, and deformation patterns of infrequent but catastrophic megathrust earthquakes. Consequently, geological archives

preserving evidence of prehistoric earthquakes and tsunamis have become indispensable for reconstructing the long-term seismic history of this convergent margin.

The Andaman Islands occupy a unique tectonic position near the transition between the Sumatra, Andaman, and Arakan segments of the subduction zone. This strategic location enables preservation of multiple geological signatures of seismic deformation, including coseismic uplift and subsidence, tsunami deposits, liquefaction features, drowned forests, uplifted coral terraces, marine terraces, tidal notches, beach-ridge systems, and coastal marsh stratigraphy. Together, these geomorphic and sedimentary records provide one of the most complete natural laboratories worldwide for investigating the interactions between megathrust earthquakes, tsunamis, sea-level changes, and coastal landscape evolution.

Over the last two decades, multidisciplinary investigations combining geomorphology, sedimentology, stratigraphy, geochronology, micropalaeontology, and remote sensing have revealed evidence of several prehistoric tsunami and earthquake events predating the 2004 catastrophe. Geoslicer sections and trench investigations around Mitthakhadi and Collinpur have documented repeated episodes of coseismic subsidence, liquefaction, tsunami inundation, and coastal environmental change, while the rocky coasts of Kurmadera preserve multiple generations of tidal notches and wave-cut platforms that record repeated Quaternary land-level fluctuations. Likewise, the uplifted coral terraces of Shaheed Dweep (Neil Island) provide exceptional evidence of long-term tectonic uplift associated with repeated megathrust earthquakes. These geological archives significantly extend the regional earthquake history beyond historical records.

Regional Geology

4.1 Regional Geological Setting

The Andaman and Nicobar (A&N) Islands form the emergent part of the Sunda–Andaman island arc situated in the northeastern Indian Ocean. Extending for nearly 800 km in a north–south direction between approximately 6.5°N and 14°N (Fig. 2), the island chain represents the outer-arc high of an active convergent plate margin where the Indian Plate is being subducted beneath the Burma (Sunda) Microplate. This tectonic setting has produced one of the most seismically active regions of the world, characterized by active subduction, arc volcanism, crustal deformation, and repeated megathrust earthquakes. The islands occupy a strategic position between the Sumatra and Myanmar segments of the Sunda–Andaman subduction system and preserve exceptional records of active tectonics and coastal deformation.

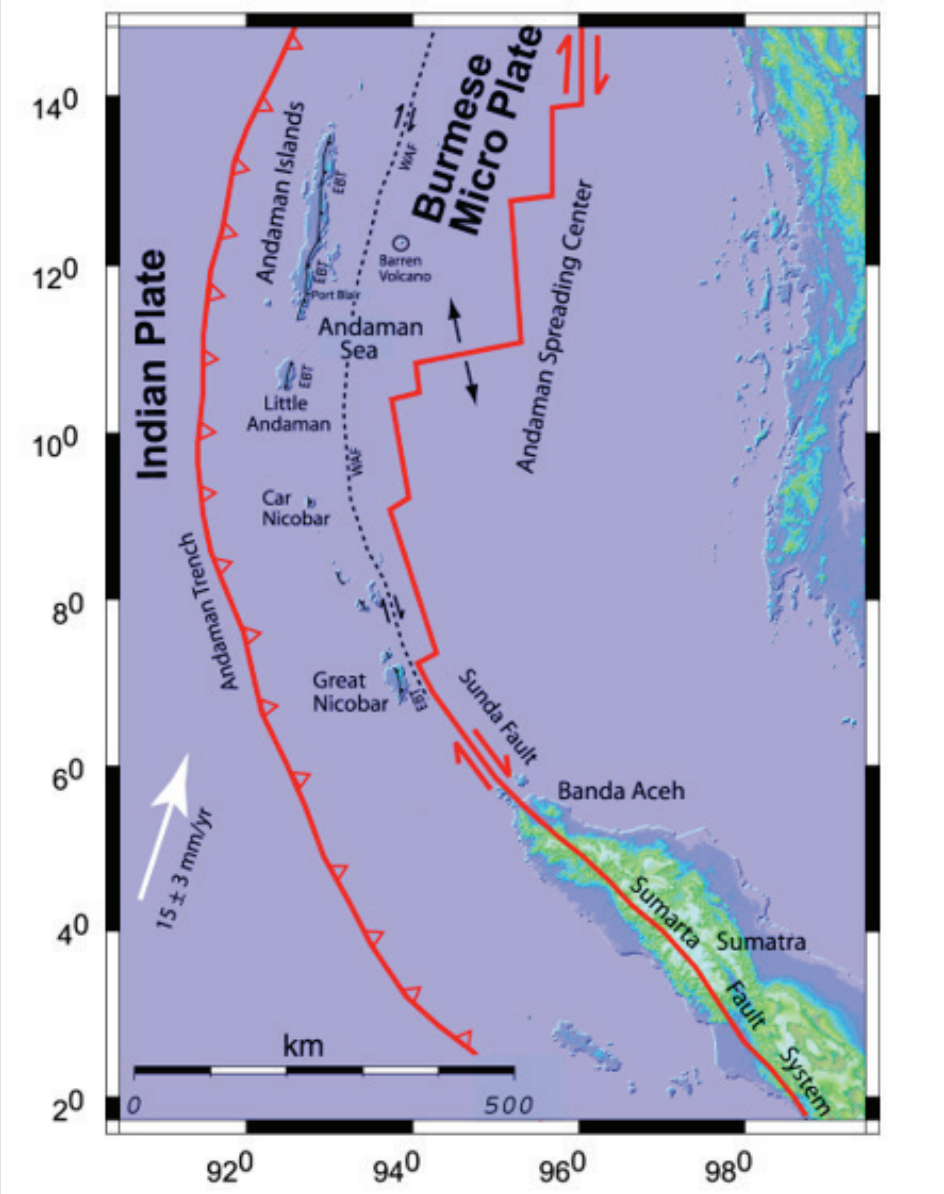


Fig. 2: Generalized tectonic map of the A&N islands and the adjacent region. The thick line with triangles marks the Andaman-Sunda trench the subduction zone between the Indian plate and the Burmese/Sunda plate. The thick line without triangles marks the Sumatra fault system and the Andaman spreading center. The white arrow shows the direction of the movement of the Indian plate.

4.2 Stratigraphy

The geology of the Andaman Islands comprises rocks ranging in age from the Cretaceous to the Recent. The eastern part of the islands is dominated by highly deformed ophiolitic complexes consisting of ultramafic rocks, volcanic sequences, pelagic sediments, and associated metamorphic rocks representing fragments of ancient oceanic lithosphere. These ophiolites are interpreted as remnants of the Neo-Tethyan oceanic crust that were emplaced during subduction and collision.

The western part of the islands is composed predominantly of an accretionary prism consisting of Eocene–Oligocene flysch sequences represented by sandstone, siltstone, shale, conglomerate, and deep-marine turbiditic deposits. These are overlain by Mio–Pliocene calcareous sediments and younger coastal deposits. Along the present coastline, unconsolidated Quaternary sediments comprising beach sands, beach-ridge complexes, tidal-flat deposits, mangrove peat, lagoonal mud, coral rubble, and tsunami deposits form the youngest sedimentary succession and preserve detailed evidence of repeated coastal deformation and tsunami inundation.

4.3 Structural Geology and Tectonics

The regional tectonic framework is governed by the ongoing convergence between the northeastward-moving Indian Plate and the Burma (Sunda) Microplate at a rate of approximately 5–6 cm/year. This convergence has resulted in the development of the Sunda–Andaman Trench, one of the world's major subduction zones.

Several major tectonic elements characterize the region:

• The Andaman–Sunda Trench, representing the active plate boundary and subduction interface.

• The Andaman Outer Arc Ridge, forming the emergent island chain.

• The Andaman Back-arc Basin, located east of the islands and associated with active seafloor spreading.

• The Andaman Spreading Centre, connecting southward with the Sumatra Fault System.

• The West Andaman Fault (WAF), a major right-lateral strike-slip fault extending along the island chain.

• The Eastern Boundary Thrust (EBT), separating the western accretionary prism from the eastern ophiolitic complex.

These structural elements accommodate partitioned deformation through thrusting, strike-slip faulting, crustal shortening, and back-arc extension, resulting in continuous modification of the regional landscape.

4.4 Geomorphology

The coastal landscape of the Andaman Islands reflects the combined influence of tectonic movements, sea-level fluctuations, tropical weathering, and marine processes. The coast exhibits remarkable geomorphic diversity, including rocky cliffs, wave-cut platforms, tidal notches, marine terraces, sandy beaches, beach-ridge–swale complexes, mangrove wetlands, lagoons, drowned forests, and coral reefs.

The western coast is generally characterized by rocky shorelines with uplifted coral platforms and marine terraces, whereas the eastern coast contains gently sloping coastal plains, estuaries, tidal flats, and mangrove ecosystems that are highly susceptible to coseismic subsidence and tsunami inundation.

Several geomorphic features visited during the excursion preserve evidence of repeated tectonic deformation:

- Dead forests formed due to coseismic subsidence.
- Beach-ridge and swale systems recording multiple tsunami events.
- Multiple generations of tidal notches indicating repeated uplift episodes.
- Marine terraces developed through successive tectonic uplift.
- Wave-cut platforms and emerged coral reefs documenting long-term land-level changes.

These geomorphic markers provide important constraints on the magnitude and recurrence of past megathrust earthquakes.

4.5 Quaternary Geology

The Quaternary succession of the Andaman Islands consists primarily of coastal and shallow marine sediments deposited under varying sea-level and tectonic conditions. These include beach sands, lagoonal silts, mangrove peat, estuarine clay, coral debris, beach-ridge deposits, and tsunami-generated sand sheets. Detailed trenching and geoslicer investigations at Mitthakhadi and Collinpur have revealed multiple sedimentary sequences recording repeated episodes of coseismic subsidence, liquefaction, tsunami inundation, and environmental change during the Late Holocene. Alternating peat layers and marine sediments, sharp erosional contacts, rip-up clasts, liquefaction structures, and tsunami sand layers demonstrate repeated transitions between terrestrial and marine environments caused by major earthquakes.

4.6 Seismotectonics

The Andaman and Nicobar Islands lie within Seismic Zone V, the highest seismic hazard category in India. The region experiences frequent moderate-to-large earthquakes generated by deformation along the Sunda–Andaman subduction interface, the West Andaman Fault, and associated crustal faults.

Historical records document several major earthquakes, including the events of 1679, 1762, 1847, 1881, 1941, and the 26 December 2004 Sumatra–Andaman earthquake, many of which generated destructive tsunamis affecting the Andaman and Nicobar Islands and the eastern coast of India. The 2004 megathrust earthquake produced approximately 1,300 km of coseismic rupture, resulting in differential uplift along the western coast and widespread subsidence along the eastern coast of the island chain.

Coseismic land-level changes reached approximately 1–1.2 m around Sri Vijaya Puram (Port Blair), 0.5 m around Collinpur, 1.5–2 m around Car Nicobar, and nearly 3 m near Indira Point in Great Nicobar. These vertical displacements profoundly altered coastal morphology through shoreline migration, inundation, emergence of coral reefs, and formation of drowned forests.

Flora, Fauna and Climate

5.1 Climate

The Andaman and Nicobar Islands experience a humid tropical maritime climate that is strongly influenced by the surrounding Bay of Bengal and Andaman Sea. The maritime setting moderates seasonal temperature variations, resulting in warm and humid conditions throughout the year. The climate is characterized by two principal seasons: a dry summer season extending from March to May and a rainy season associated with the southwest monsoon from May to September. The islands also receive significant rainfall during the northeast monsoon and occasional tropical cyclones between October and November. Annual rainfall averages approximately 3,000 mm, while the mean relative humidity remains around 79%. The mean maximum and minimum temperatures are approximately 30.2°C and 23.8°C, respectively.

The Andaman Sea exhibits a semi-diurnal tidal regime, with two high tides and two low tides of nearly equal amplitude occurring each day. The tidal range generally varies between 1.5 and 2.5 m, depending on season and local coastal morphology. These tidal fluctuations significantly influence coastal geomorphic processes, mangrove ecology, sediment transport, and marine biodiversity. During the field excursion, participants should expect warm temperatures, high humidity, and occasional rainfall; therefore, lightweight clothing, adequate hydration, sun protection, and rain gear are recommended.

5.2 Flora

The Andaman and Nicobar Islands support one of the richest tropical forest ecosystems in the Indian subcontinent. Approximately 86% of the total land area is covered by dense forests comprising tropical evergreen, semi-evergreen, moist deciduous, littoral, and

mangrove vegetation. More than 2,200 species of plants have been recorded from the islands, of which nearly 200 species are endemic, while approximately 1,300 species are absent from mainland India. The forests are dominated by commercially important timber species such as Andaman Padauk (Pterocarpus dalbergioides), Gurjan (Dipterocarpus spp.), Marble Wood, and Silver Grey. Extensive mangrove forests occupy sheltered bays, estuaries, and tidal creeks, where they play a vital role in coastal stabilization, sediment trapping, carbon sequestration, and protection against storm surges and tsunami inundation. These coastal ecosystems also preserve valuable sedimentary archives used in paleoseismological and paleo-tsunami investigations.

5.3 Fauna

The islands harbour exceptionally rich terrestrial and marine biodiversity owing to their geographic isolation and tropical climate. Approximately 50 species of mammals have been reported, many of which are endemic to the archipelago. Notable terrestrial fauna includes the Andaman wild pig, Andaman masked palm civet, and populations of feral elephants introduced historically.

The islands are equally renowned for their rich avifauna, reptiles, amphibians, butterflies, and marine organisms. More than 225 butterfly species have been documented, together with a remarkable diversity of molluscan shells that have historically supported ornamental and handicraft industries.

The surrounding coral reefs, seagrass meadows, and mangrove ecosystems sustain diverse marine life, including reef-building (hermatypic) corals, non-reef-building (ahermatypic) corals, reef fishes, crustaceans, molluscs, sea turtles, and dugongs. These ecosystems are of immense ecological significance and contribute substantially to coastal productivity, fisheries, and tourism.

5.4 Indigenous Communities

The Andaman and Nicobar Islands are home to several Particularly Vulnerable Tribal Groups (PVTGs) that represent some of the oldest surviving indigenous communities in the world. These include the Great Andamanese, Jarawas, Onges, Sentinelese, and Shompens. Each community possesses a unique cultural identity and has adapted to the island environment over thousands of years.

Since this field excursion is confined to the Andaman Islands, participants may encounter regions associated with three indigenous groups:

• Jarawas, who inhabit the forests of South and Middle Andaman and continue to maintain a predominantly hunter-gatherer lifestyle under strict governmental protection (Fig. 3).

• Onges, who reside primarily on Little Andaman and practice a semi-nomadic lifestyle while receiving limited support for healthcare, education, and housing.

• Sentinelese, who inhabit North Sentinel Island and remain one of the world's last voluntarily isolated communities. The island is legally protected, and all external contact is strictly prohibited.



Fig. 3: Indigenous Tribes – the Jarawas from south and middle Andaman.

Participants are reminded that these indigenous communities are protected under Indian law. Respect for their cultural heritage, privacy, and legally restricted territories is essential throughout the field excursion.

Literature Review & Outstanding Issues

The Andaman and Nicobar Islands have attracted considerable scientific attention owing to their unique tectonic setting along the Sunda–Andaman subduction zone. Since the pioneering studies of Fitch (1970) and Curray et al. (1979), numerous investigations have focused on the tectonic evolution, structural framework, and geodynamics of the Andaman arc. Subsequent studies by Dasgupta and Mukhopadhyay (1992, 1993), Ortiz and Bilham (2003), Kayal et al. (2004), and the Geological Survey of India (2003) further established the region as an active convergent plate margin characterized by subduction, strike-slip faulting, back-arc spreading, and crustal deformation. These investigations provided the tectonic framework necessary for understanding the occurrence of large megathrust earthquakes and associated tsunamis.

The societal impact from tsunamis is extremely catastrophic. Two recent tsunamis triggered by 2004 Sumatra-Andaman (Mw 9.3) and 2011 Tohoku (Mw 9.1) mega- earthquakes along subduction zones have exhibited our poor understanding about their occurrences, characteristic wave patterns, and sediment transport (Satake et al., 2007; Goto et al., 2011; Malik et al., 2015). Reliable information pertaining to such events, which can be obtained from geological records, is crucial to minimize the consequent disaster. The Andaman and Nicobar Islands, and coastal areas along the Mainland India (as well as Indonesia and Thailand) are vulnerable to tsunamis generated from earthquakes originating from different sources that exist along the Sumatra Subduction Zone (SUSZ), Andaman Subduction Zone (ANSZ) and Arakan Subduction Zone (ARSZ) (Fig. 4a). Therefore, these are the best locations to study detailed aspects of tsunami events. The 26 December 2004 tsunamigenic earthquake [at 00:58:53 Universal Time; 06:28:53 a.m. Indian Standard Time] took more than 280,000 lives. A large coseismic rupture of ~1300 km (Ammon et al., 2005, Subarya et al., 2006; Malik et al., 2011) occurred along the SUSZ and ANSZ and resulted in dramatic land-level changes marked by prominent uplift and subsidence along the west and east coast of Andaman and Nicobar Islands (Fig. 4a, b) (Malik et al., 2005, 2011, 2015).

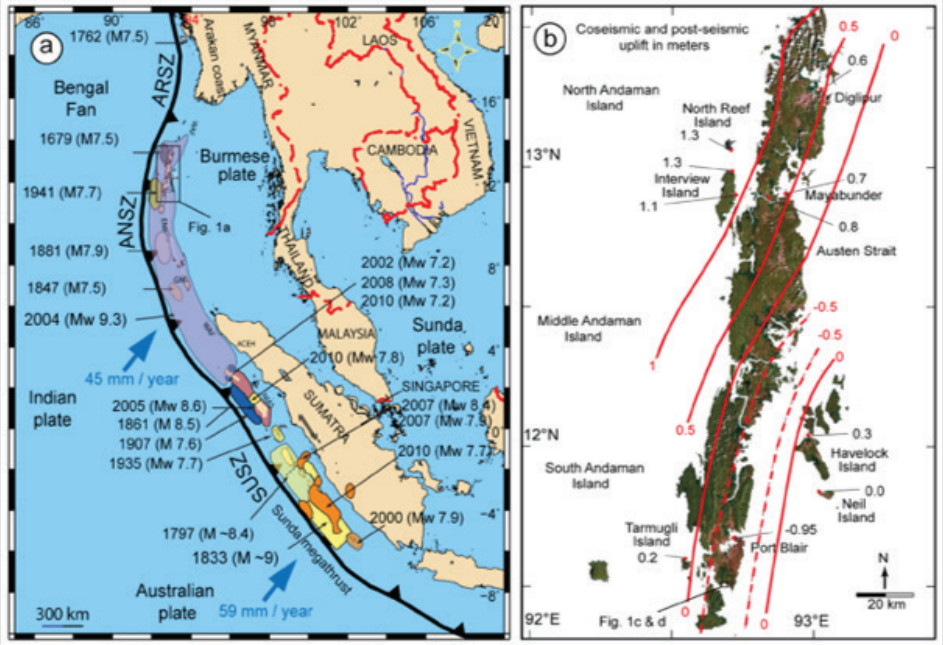


Fig. 4: (a) Regional tectonic map of Sumatra-Andaman region along with the extent of ruptures and earthquakes (with magnitude) occurring between AD1600–2004. The map was generated using Generic Mapping Tool (GMT). Fault lines, earthquake rupture areas, earthquakes listed with magnitude are adopted from Malik et al., 2015; Monecke et al., 2008; Meltzner et al.,2012. Sumatra Subduction Zone (SUSZ), Andaman Subduction Zone (ANSZ) and Arakan Subduction Zone (ARSZ). (b) Map of Andaman Islands showing areas of uplift and subsidence triggered by the 2004 event (after Malik et al., 2015).

Lack of comprehensive historical data poses a big challenge for a proper tsunami hazard evaluation for the Andaman and Nicobar Islands as well as the east coast of Mainland India. A poor understanding of such catastrophic events implies a huge risk associated with the failure of existing/upcoming nuclear power plants and life-line infrastructure near the densely populated coastal areas in India. Also, lesson learnt from the Tohoku earthquake and associated tsunami necessitates identification of tsunamis generated from local source(s) along the Andaman-Arakan or Sumatra segment. Even earthquakes with large magnitude should not be underestimated, which could be devastative as experienced during the recent 28 September 2018, Palu tsunami in Indonesia, produced by a Mw7.5 earthquake.

The 26 December 2004 Sumatra–Andaman earthquake and tsunami marked a major turning point in geological research within the Indian Ocean (Fig. 4a). Extensive field investigations documented widespread coseismic uplift, subsidence, shoreline migration, liquefaction, tsunami inundation, and coastal geomorphic changes throughout the Andaman and Nicobar Islands. Studies by Malik et al. (2005, 2011, 2015), Rajendran et al. (2007, 2011, 2013), Kayanne et al. (2007), and several other researchers established that the earthquake produced differential land-level changes across the island chain, with uplift dominating the western coasts and subsidence affecting large parts of the eastern coastline. These investigations also demonstrated the exceptional preservation of coseismic deformation and tsunami deposits in the coastal environment.

Earthquake-related ground shaking was observed all along these islands; however, the intensity of shaking was too low to expect significant liquefaction along the coastline of the A&N islands. Evidence of liquefaction was not available at most places on the ground surface, because the high-energy tsunami waves followed by shaking carried away large amounts of debris and topsoil and redeposited them in many regions along the coastline.

The Survey of India maintains a network of analog tide gauges along the coast of India at 26 major and significant ports (Fig. 5), including one each at Port Blair and Nancowry in the A&N islands. During the 26 December event, the Survey of India tide gauges at Port Blair, Nancowry Island, and Nagapattinam were inundated and thus provided no recording. The only record available from the A&N islands is from the digital gauge operated by the Integrated Center for Marine Area Management (ICMAM) in the Port Blair area. This record indicates a sharp change in the mean sea level of about 1.2 m after the earthquake (Figure 6).



Fig. 5: Location of tide gauges in India along the mainland coast and in the A&N islands (source: www.nio.org).

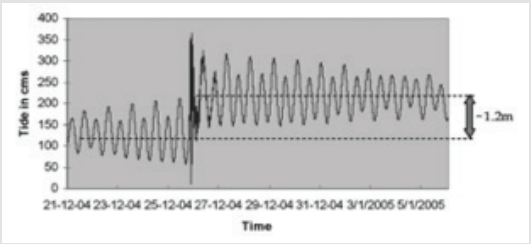


Fig. 6: Arrival of tsunami waves, indicated by a sudden rise in seawater level as recorded by the tide gauge at Chatam Island, South Andaman Island (source: ICMAM).

6.1 Main Andaman Islands

An aerial survey and field survey were carried out along the Main Andaman Islands (including the South, Middle, and North islands). The structure at Port Blair suffered minor damage caused by shaking. Evidence of lateral spreading causing landslip of the surficial soil on gentle slopes was observed at several locations. Of these, the most prominent lateral spreading was recorded at low-lying areas, such as at Sippyghat (Fig. 7a). Here the lateral spreading resulted in the development of extensional cracks as wide as 20–30 cm. Along with lateral spreading, inundation of land and waterlogging of up to 0.6 m in the low-lying areas were common. This was evidenced by the ~1–2 feet of water surrounding the houses in the Sippyghat area (Fig. 7b).

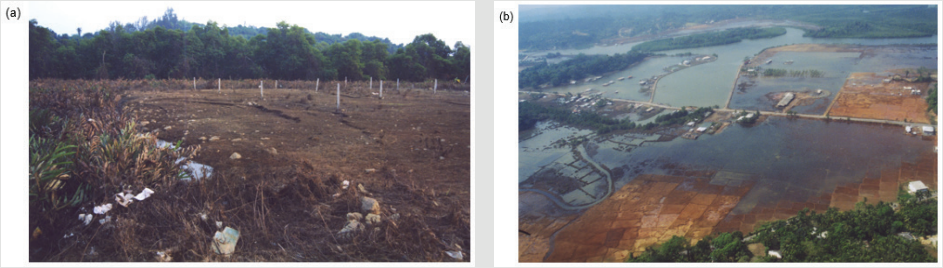


Fig. 7: (a) Extensional cracks in the Sippyghat area were caused by lateral spreading that was due to ground shaking. (b) inundation of land and waterlogging in the low-lying areas around Sippyghat, near Port Blair (photos: J. Malik).

Subsidence and tilting of houses and/or other buildings because of liquefaction was observed at several locations. At Haddow Jetty, a subsided two-story Police Barracks building marked by the rooftop seating at the ground level, as well as damage to the Passenger Hall, are evidence of liquefaction related to ground shaking. The jetty also sustained minor damage, and a portion of the jetty was washed away. Another inundation problem was observed in the bazaar area at Bamboo Flats near Port Blair (in South Andaman Island); after the 26th December earthquake, the water level rose by about 1.2 m above the normal high tide level, which is evident from the 0.3 m of water during high tide in the streetside shops along the shore (Fig. 8). The inundation of the areas around Sippyghat (Fig. 9) and Bamboo Flats is indicative of coseismic subsidence caused by the earthquake. Observations of tidal chart levels recorded by the Andaman and Lakshadweep Harbor Works suggest that, whereas a difference of 1.2 m was recorded on 26th December 2004, a steady difference of about 0.93 ± 0.30 m is obvious from 30th December 2004 to 8 January 2005.



Fig. 8: Subsidence caused the inundation of land in the bazaar area of Bamboo Flats (photos: J. Malik and D. Rai).



Fig. 9: Inundated single-story houses such as these suggest that the seawater level has gone up by about 1.0 m with respect to land in the Sippyghat area near Port Blair. Many areas are now flooded permanently because of land subsidence (photos: J. Malik).

An aerial survey via helicopter between Port Blair (South Andaman Island) and Betapur (North Andaman Island), along the east and west coasts of the Andaman Islands, revealed important evidence of landscape changes caused by the 26 December earthquake. The survey observations suggest that, in general, most of the area along the western coastline is marked by rocky cliffs, whereas the eastern coastline has a gentle slope. This rocky shoreline comprises stratified sedimentary rocks, with beds showing inclination toward the east. At several locations, the uplift of the smaller islands—namely, the Flat and Sentinel islands along the western coast—was very prominent (Figs. 10a, b). Remnants of uplifted coral heads (coral atoll) were noticed along the emerged shoreline of Flat Island. Uplifting of rocky platforms (terraces) was also observed along the western margin of the Andaman Islands. Apart from the uplift of the coastline, earthquake-induced landslides were also recorded along this rocky coastline whereas lateral spreading was more common along the eastern coast because of ground shaking around Betapur.

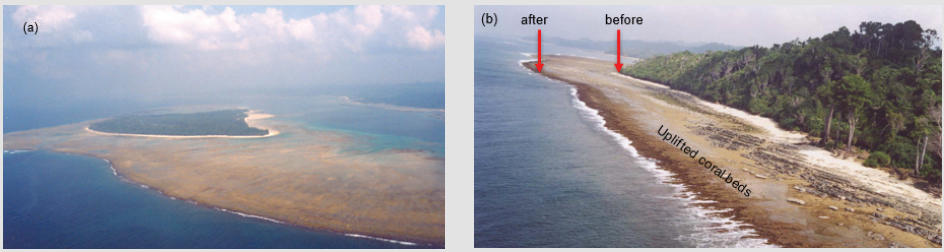


Fig. 10: (a) uplift of Flat Island along the western coast of Middle Andaman Island. (b) upthrow of the coral beds and rock strata caused by uplift on the western coast of Middle Andaman Island near Flat Island (photos: J. Malik).

Along with above observation and aerial+field surveys conducted along the Car Nicobar and the Great Nicobar Islands (not included in this field guide book), we inferred that the 26

December earthquake along the subduction zone resulted in the subsidence of the eastern coast by about 1.2 ± 0.2 m along Car Nicobar and Andaman Islands. However, the evidence of the submerged lighthouse at the southernmost tip of Great Nicobar Island by 3 m suggests that the islands closer to the subduction and to the epicenter experienced more relative subsidence than other islands in the north. Similar uplift and subsidence along the western and eastern coasts, respectively, caused by the 1881 Car Nicobar earthquake (Mw =7.9) have been recorded in the research literature (Ortiz and Bilham 2003).

Paleoseismological and paleo-tsunami studies have significantly expanded the understanding of prehistoric great earthquakes along the Sumatra–Andaman–Arakan subduction system. Sedimentary investigations at Mitthakhadi and Collinpur identified multiple tsunami sand sheets, liquefaction structures, abrupt environmental transitions, and repeated episodes of coseismic subsidence preserved within coastal marsh deposits. Geochronological studies based on radiocarbon dating suggest that several prehistoric earthquakes and tsunamis occurred prior to the 2004 event, including possible correlations with the historical earthquakes of A.D. 1679 and 1762. Comparable evidence of prehistoric tsunamis has also been reported from Sumatra, Thailand, Myanmar, and other parts of the eastern Indian Ocean, indicating that the subduction system has generated multiple transoceanic tsunami events during the Late Holocene.

The present field excursion addresses many of these unresolved issues by examining a suite of well-preserved geological archives distributed across the Andaman Islands. Field stops at Mitthakhadi, Collinpur, Kurmadera, Badabalu, and Shaheed Dweep (Fig. 11) demonstrate how coastal stratigraphy, geomorphic markers, geochronology, and modern land-level changes can be integrated to reconstruct the long-term history of megathrust earthquakes and transoceanic tsunamis. These observations provide valuable insights into earthquake recurrence, coastal deformation, and tsunami hazard, thereby contributing to improved understanding of one of the world's most active subduction systems.

6.2 Outstanding Scientific Questions

The field excursion is designed to address the following key research questions:

• What is the long-term recurrence interval of great megathrust subduction zone earthquakes and associated transoceanic tsunamis along the Sumatra–Andaman–Arakan subduction zone?

• How can the near shore coastal stratigraphy and geomorphic markers (e.g., beach-ridges, marine terraces, tidal notches) be integrated to distinguish far field and near field major/mega earthquakes, and associated tsunami events?

• Distinguish tsunami deposits from storm and other high-energy marine deposits?

• What were the magnitudes and spatial patterns of coseismic uplift and subsidence associated with prehistoric megathrust earthquakes?

• Can the geological records from the Andaman Islands be correlated with paleo-tsunami archives from Sumatra, Myanmar, Thailand, and other sectors of the Indian Ocean to reconstruct regional scenario?

Field Transect

Day-1 (20th/21st January 2027; Thursday) Travel & Stay at SVP

- Delhi to Sri Vijaya Puram (SVP) (Port Blair) – Take mid-night flight reaching in morning
- 02:00 PM Visit around SVP (Port Blair)

Day-2 (22nd January 2027; Friday) Field visit & Stay at SVP

- 07:30 AM - 08:30 AM Break Fast
- 09:30 AM – Leave for fieldwork
- 10:00 AM – 06:00 PM Fieldwork around Mithakhadi, Collinpur (Geoslicing), and Khurmadera
- Night stay at SVP (Port Blair)

Day-3 (23rd January 2027; Saturday) Travel/Field visit & stay at Neil I.

- Take an early morning ferry to Neil Island
- 11:00 AM – 06:00 PM – Fieldwork around Sitapur, Ramnagar Beach and Lakshmanpur Beach

Day-4 (24th January 2027; Sunday) Field visit & stay at Neil I.

- 07:30 AM - 08:30 AM Break Fast
- 09:30 AM – Leave for fieldwork
- 10:00 AM – 01:00 PM - Fieldwork around Tango Beach and Bharatpur Beach
- 01:00 PM – 05:00 PM – Exploring Aquatic Life in Neil Island (self-sponsored)

Day-5 (25th January 2027; Monday) Travel/Field visit & stay at SVP

- 07:00 AM - 07:45 AM Break Fast
- Take morning ferry (~8:00 AM) to Sri Viyaya Puram (Port Blair)
- 12:30 PM – 04:30 PM – Leave for Fieldwork around Badabalu and ChidiyaTapu (Geoslicing)
- Free pass in evening – move around Sri Vijaya Puram (Port Blair)

Day-6 (26th January 2027; Tuesday) Travel

- Take flight to Lucknow

Maps showing route of travel destinations to be visited during the field excursion

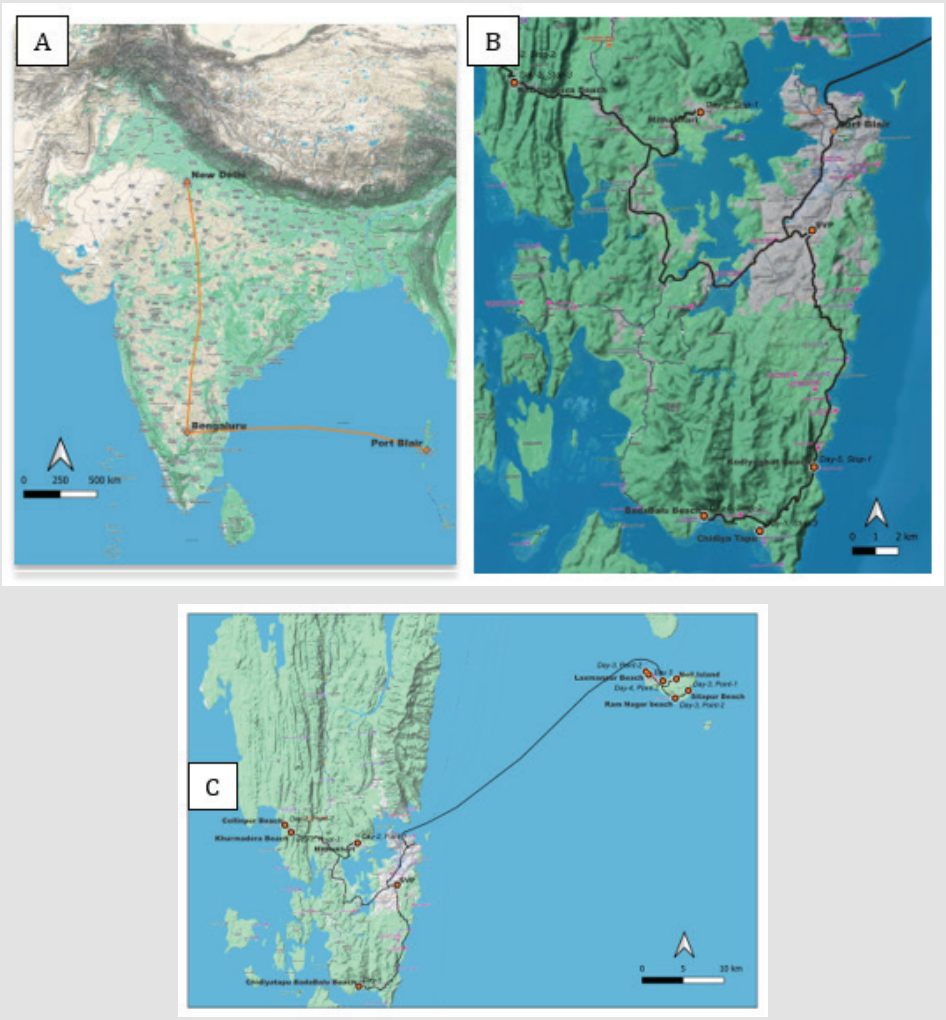


Fig. 11: A: Route map of field excursion during INQUA 2027. The trip starts from New Delhi (Indira Gandhi International Airport) to Sri Vijaya Puram (earlier name Port Blair) via Bengaluru on 20th January 2027. B: Map showing location of Stops during Day-2 and Day-5 around SVP (Port Blair), and C: Travel to Shaheed Dweep (earlier name Neil Island) to undertake excursion for Day-3 and Day-4.

Location(s) Description

Day 1: 20th-21st January 2027

We would take a mid-night flight from New Delhi (Indira Gandhi International Airport) to Sri Vijaya Puram (Port Blair) so as to reach in the morning of 21st January 2027. We expect to leave for a short visit around Port Blair after lunch to see the areas that were affected by the earthquake (subsidence) and tsunami Bamboo Flats, Sippyghat etc. We also propose to have a visit to the Anthropological Museum to know the culture/demography of the Andaman and Nicobar Islands (Fig. i). In evening we have a plan to take you to the historical Cellular Jail, also known as Kala Pani, means Black Water (a British colonial prison), which was affected by the earthquake of 1941 (Fig. ii).



Fig. i: A view of Anthropological Museum at Sri Vijaya Puram.



Fig. ii: A view of Cellular Jail at Sri Vijaya Puram.

Day 2: 22nd January 2027

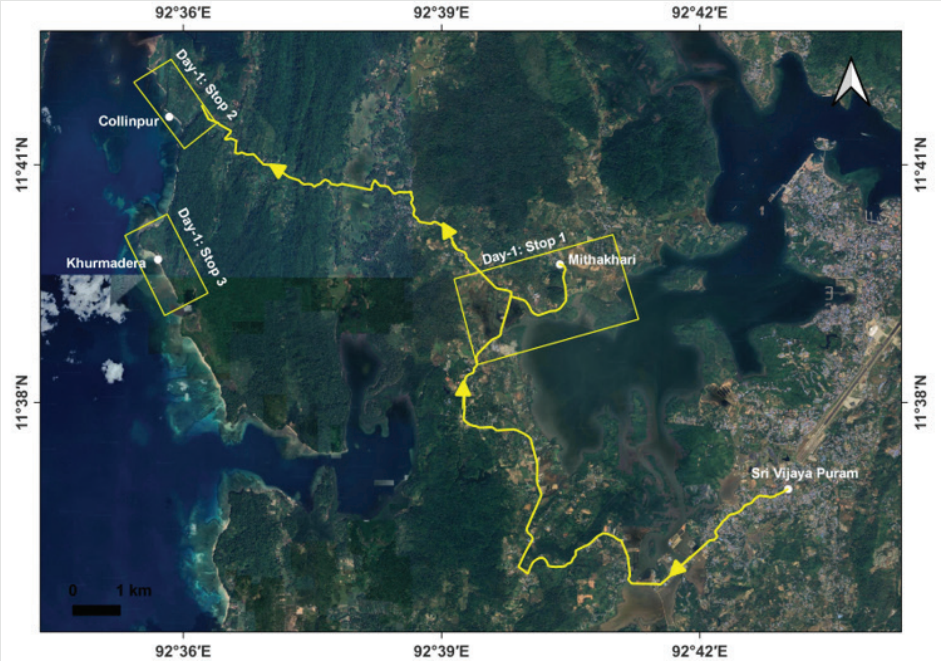


Fig 12. A route map showing the locations of Day-2. Stop-1 is the Mithakhadi area that experienced subsidence by ~1 m during 2004 Sumatra-Andaman earthquake causing inundation of the paddy fields and affected the residential areas as well. Stop-2: Collinpur – this site is located along the western coast of the Andaman Island, which also experienced subsidence. The area is marked by Beach-Ridge-Swal-Beach Ridge topography, ideal for the preservation of paleo-tsunami deposits. Stop-3: Khurmadera – a site along the western coast shows prominent sea-notches indicative of multiple events of uplift during geologic past.

Stop 1: Mitthakhadi and dead forest [11°39'40.59"N; 92°40'50.96"E]

On Day-1 we would visit Sites 1 and 2 to see the evidence of subsidence and possibly do some geoslicing (Figs. 11-13).

The 2004 earthquake at Port Blair was accompanied by moderate shaking and tectonic subsidence (Figs. 13a-e); however, no prominent liquefaction was reported, except the occurrence of lateral spreading at few places around Sippyghat (Malik and Murty, 2005; Singh et al., 2006) (Figs. 7-9). Subsidence of ~1 m caused inundation of the paddy field and several residential areas were affected (Malik and Murty, 2005) (Fig. 13e). The ensuing tsunami reached heights of 3.0–3.5 m near Port Blair; no significant tsunami deposit was reported. A few poorly constructed buildings experienced damage in Port Blair and adjoining areas, however, mostly the residential areas were affected due to inundation caused by subsidence (Figs. 8-9). The evidence of subsidence is well preserved in the Sippyghat area, which is

on-the-way to Mitthakhadi (Figs. 8, 9, 13e). Shallow coastal stratigraphy revealed at least two major earthquakes at Mitthakhadi (Figs. 13-15).

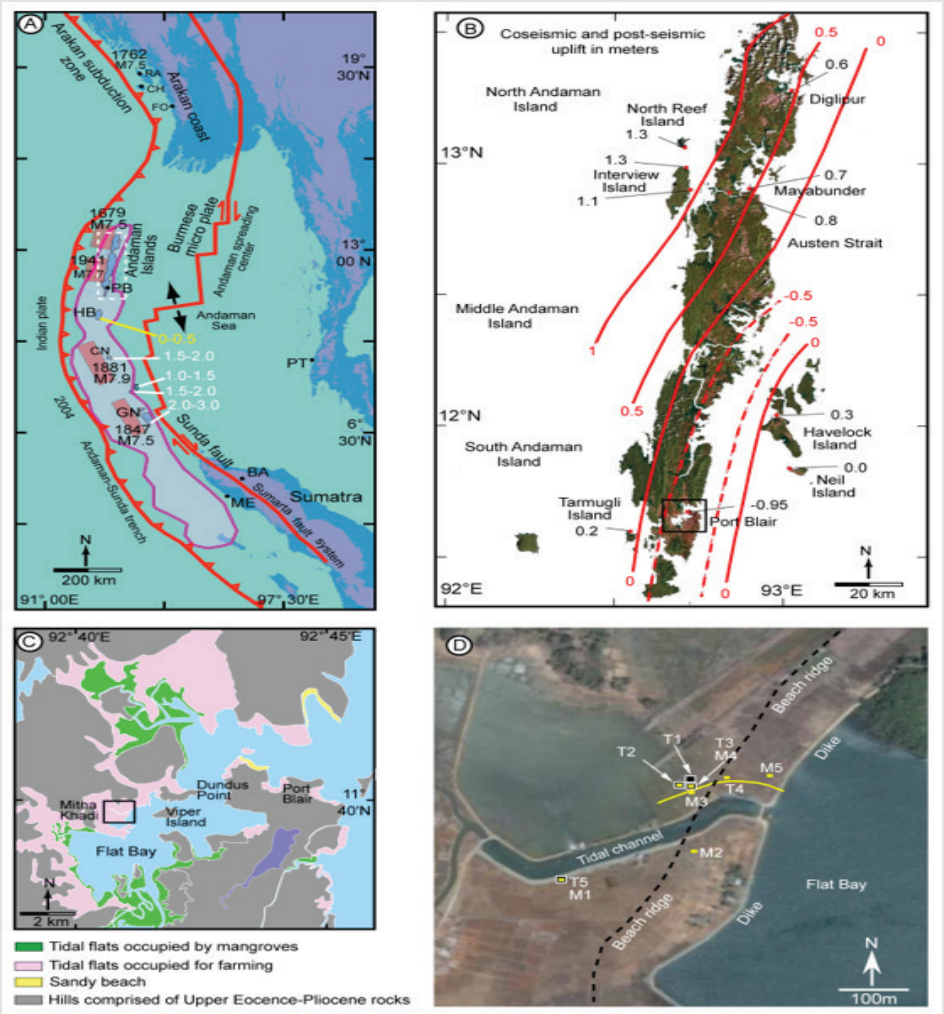


Fig. 13: A: Generalized plate tectonic map of Sumatra-Andaman and Arakan arc with past seismicity. Purple area marks source fault of A.D. 2004 Sumatra-Andaman earthquake (from Monecke et al., 2008). White box with broken line shows location of B. Yellow numbers indicate uplift and white shows subsidence during 2004 earthquake. RA-Ramree; CH-Cheduba; FO-Foul; PB-Port Blair; HB-Hut Bay; CN-Car Nicobar; GN-Great Nicobar; BA-Band Aceh; ME-Meulaboah; PT-Phra Thong. B: Map of Andaman Islands showing areas of uplift and subsidence triggered by 2004 event (after Kayanne et al., 2007). Black box shows location of C. C: Generalized geomorphic map of area around Port Blair and Flat Bay in South Andaman. Black box shows location of D. D: Google Earth™ image showing locations of trenches (T) and geoslice sampling (M) collected from 2005-2006 fieldwork. Yellow bold line-transect of total station profile. Black dotted line—location of beach ridge.



Fig. 13E: On the way to Mitthakhadi we will be stopping to see the dead forest – mainly the coconut plantation. Stop-1: A view of dead forest (coconut plantation). The trees died because of inundation caused by subsidence during 2004 Sumatra-Andaman earthquake.

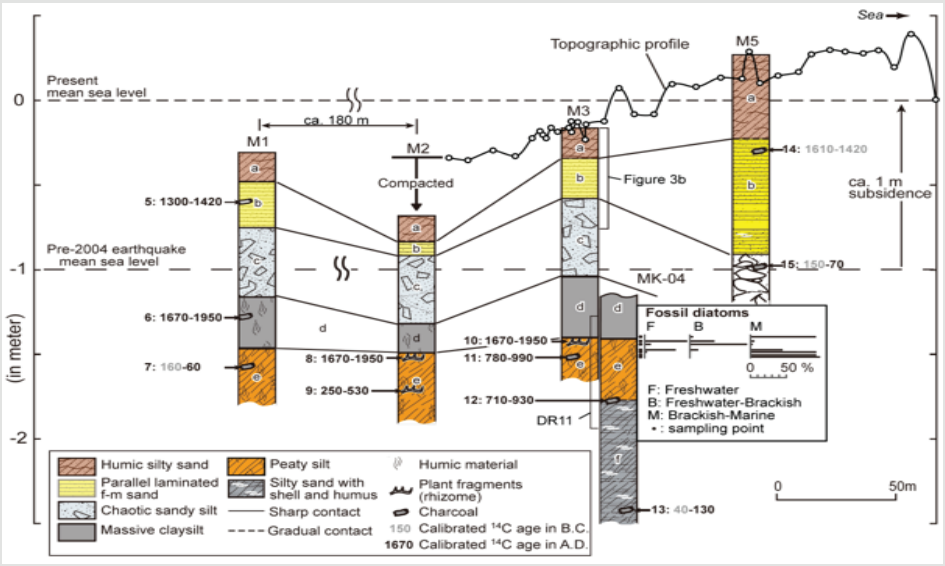


Fig. 14: Lithological sections collected by geoslicer at Mithakhadi site. Geoslices M1–M5 were collected to identify evidence of past earthquakes preserved in sediment record (see Fig. 16C-D for location).

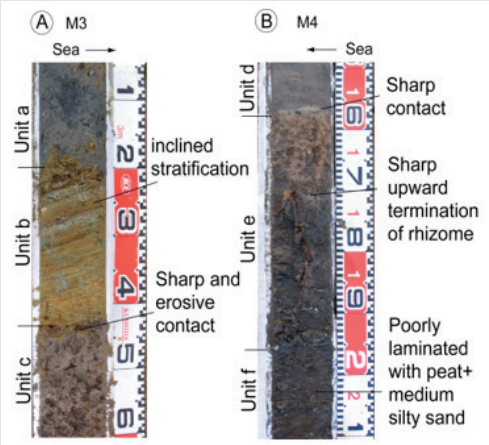


Fig. 15: Upper section of geoslicer M3 shows inclined stratification toward land and sharp to erosive contact with unit c. Unit b is interpreted as tsunami deposit. (For location, see Fig. 12d, column M3.) D: Close-up view of upper part of geoslice M4 (peel sample) showing prominent change in sedimentary facies from massive clay (unit d) and underlying peaty soil (unit e). (For location, see Fig. 12, column M4.) This change is well marked by sharp contact between units d and e. Sharp termination of rhizome was observed in unit e.

Paleoseismological Interpretation

We infer two paleoseismic events predating A.D. 2004 in the trench and geoslicer stratigraphy (Figs. 13c, d; 14; 15). Diatoms in the peaty layer (unit e) indicate a freshwater-brackish marshy environment at the top of the unit, whereas diatoms in the overlying silty clay layer (unit d) show a brackish-marine environment. A sharp contact between units d and e suggest a sudden submergence at the time of the contact (event I; older event) (Fig. 15). The chaotic nature and the dikes that probably fed it (unit c) indicate liquefaction, and the laminated unit b indicates an ensuing tsunami, both produced by event II. The radiocarbon (AMS) ages, obtained by dating charred material, rhizomes of vascular plants, and shell fragments, ranged from 60 to 3870 14C yr B.P. (Figs. 14-15). In situ rhizomes from the upper part of unit e from M2 and M3 gives an age of A.D. 1670–1950 (samples 8 and 10: Fig. 14). Because the detrital charred material from unit d gives an age of A.D. 1672–1950, the transition from unit e to unit d is well constrained as ca. 130 yr 14C B.P., which corresponds to calibrated ages of A.D. 1670 or later. Relatively older ages found in the younger stratigraphic units, for example A.D. 1300-1420 (sample 5; see Fig. 14) or 3220 ± 40 14C yr B.P. (sample 14 see Fig. 14) in unit b, or charred material dated as 150 B.C. to A.D. 70 (sample 15, Fig. 14), are considered as due to reworked material.

The two paleoseismological events are significantly different in terms of age and paleo-seismological characteristics. Event I occurred ca. A.D. 1670 or later, based on the calibrated radiocarbon ages of in situ plant material and detrital charcoal from the peaty layer. Event II, with liquefaction and a tsunami, occurred after event I. While event I has no evidence for strong ground motions and was associated with clear geological evidence of sudden subsidence, event II was associated with strong ground shaking and a tsunami. The A.D. 2004 event was not accompanied by strong shaking, but did involve a tsunami and subsidence.

We estimate that the amount of subsidence during event I was as much as 1 m. The peaty unit e was deposited in a marshy environment, whereas unit d, with a sharp bottom contact, was deposited in a deeper (probably marine) environment. This height range is approximated by the difference in habitats of diatom species. The dominant diatom species show that the environment was a freshwater or slightly brackish water marsh before the event, while two of marine taxa (Diploneis suborbicularis and Tryblionella cocconeiformis) suggest that it became marine between high and mean tides (Kosugi, 1987) after the event. As the present tidal range is 2 m, we approximate the amplitude of submergence to be as much as 1 m.

Event I may be correlated with an earthquake on 28 January 1679, among the large earthquakes known from written records in India. The 1679 earthquake was widely felt in the regions from Arakan (Burma), Bengal (Bangladesh), and along the eastern coast of India along Coromandal and Madras (now known as Chennai) (Iyengar et al., 1999), indicating that it was large magnitude (M ~7.5). It is ambiguous whether this earthquake generated any tsunami around the southern Andaman area (Rajendran et al., 2008).

Event II may be related to a large earthquake on 2 April 1762 in Arakan, as reported in historical records from the coastal region of Myanmar (Cummins, 2007). It has been suggested that this earthquake resulted in uplift of ~3–7 m along the coasts of Ramree, Cheduba, and Foul Islands, located offshore of the Arakan coast of Myanmar (Aung et al., 2008). However, there is no written record of a tsunami.

Studies of tsunami deposits in Thailand have revealed tsunami sand layers dated as ca. 550–700 14C yr B.P. (ca. A.D. 1300–1450; Jankaew et al., 2008; Fujino et al., 2009). From the sediment stratigraphy, it is suggested that this event was similar to the 2004 Sumatra-Andaman earthquake, and no such event has occurred since then. Also, evidence of past earthquakes, ca. A.D. 1640–1950, has been reported from Aceh, northwestern Sumatra, and another after A.D. 780–990 (Monecke et al., 2008). Event I in Port Blair may be correlated with penultimate tsunami in Sumatra, but not in Thailand. Event I and the A.D. 2004 earthquake had similar effects in Port Blair; however, their sources may be different because they produced different tsunami effects in Thailand.

While no evidence of coseismic land-level change associated with event II was found, it is possible that the area underwent either coseismic or postseismic uplift. If the uplift was not coseismic, it must have been transient in the postseismic period. It did not continue during the entire interseismic period, because the tide gauge data at Port Blair indicates subsidence at a rate of 2.2 mm/yr since A.D. 1916. The reasons to envisage the uplift are (1) the area after event I was under subtidal conditions, as indicated by unit d, and (2) the area was ~1 m above mean sea level before the 2004 Sumatra-Andaman earthquake, as suggested from the uppermost unit a and the subsidence of 1 m during the 2004 earthquake. Thus, it is inferred that the area underwent subsidence of ~1 m during event I, and possibly an uplift of ~1 m between event I and 2004, either coseismic with event II or during the postseismic period, then subsided by ~1 m in 2004. It is also suggested that the uplift could have been the result of slip in the deeper part of the subducting plate farther east-ward, resulting in a different pattern of deformation compared to event I and the 2004 Sumatra-Andaman earthquake. Slip along the deeper section might have resulted in uplift of the area around Port Blair and subsidence farther east.

Stop 2: Collinpur [11°41'40.21"N; 92°35'53.62"E]

The Collinpur site is located along the west coast of the southern Andaman Island, which also experienced subsidence, is marked by Beach-Ridge-Swal-Beach Ridge topography, ideal for the preservation of paleo-tsunami deposits (Figs. 12; 16a-b; 17a-b and 18a-g).

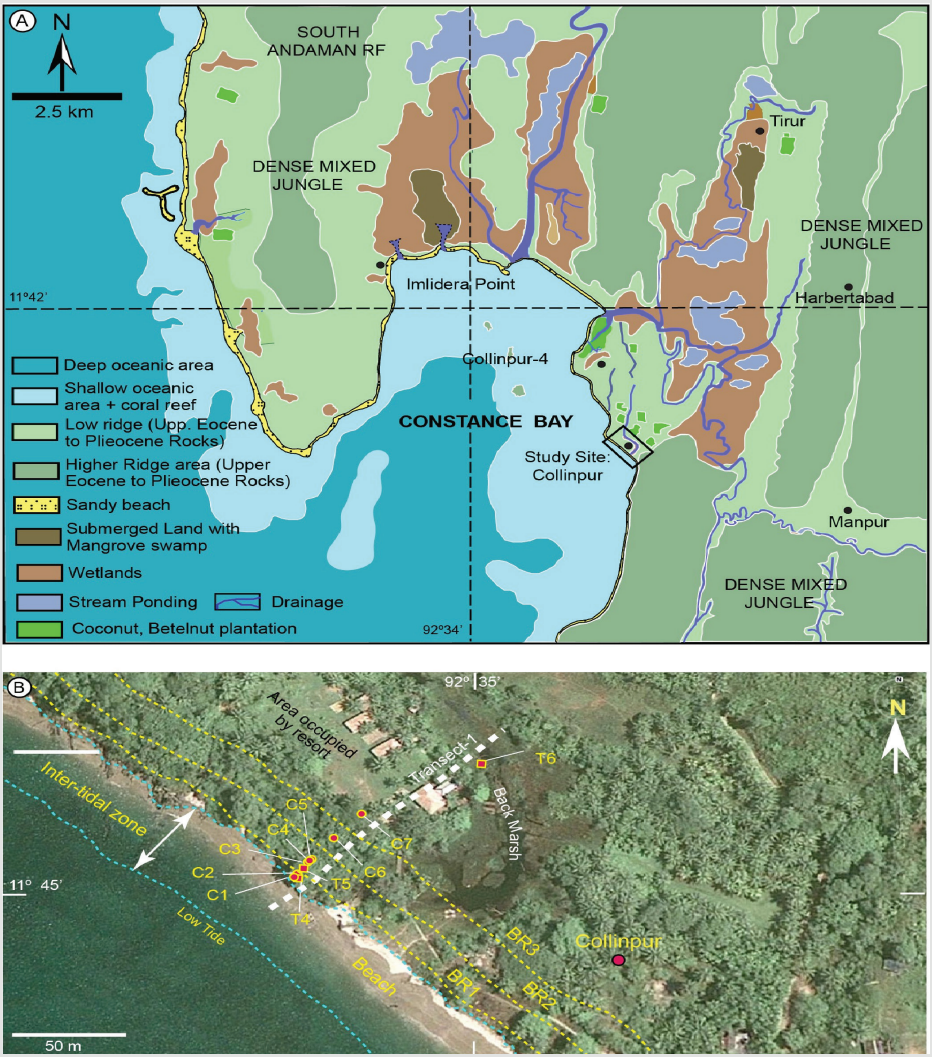


Fig. 16: (A) Geomorphic map of the area around Collinpur and Constance Bay and neighboring areas along the west coast of South Andaman Island, (B) Coastal topography marked on Google image of the area along Collinpur, Site-2. Geoslice location along NE–SW transects are indicated by C1 to C8, and trenches by T4 to T6. Beach ridges are marked by BR1 to BR3.

In total 08 geoslices and 03 shallow trenches were used to identify the past record of mega- & large- magnitude earthquakes as well as associated tsunamis (Fig. 16b). Geoslices collected clearly revealed preserved older large-&-transoceanic tsunamis and evidence of large/mega-thrust subduction zone earthquake.

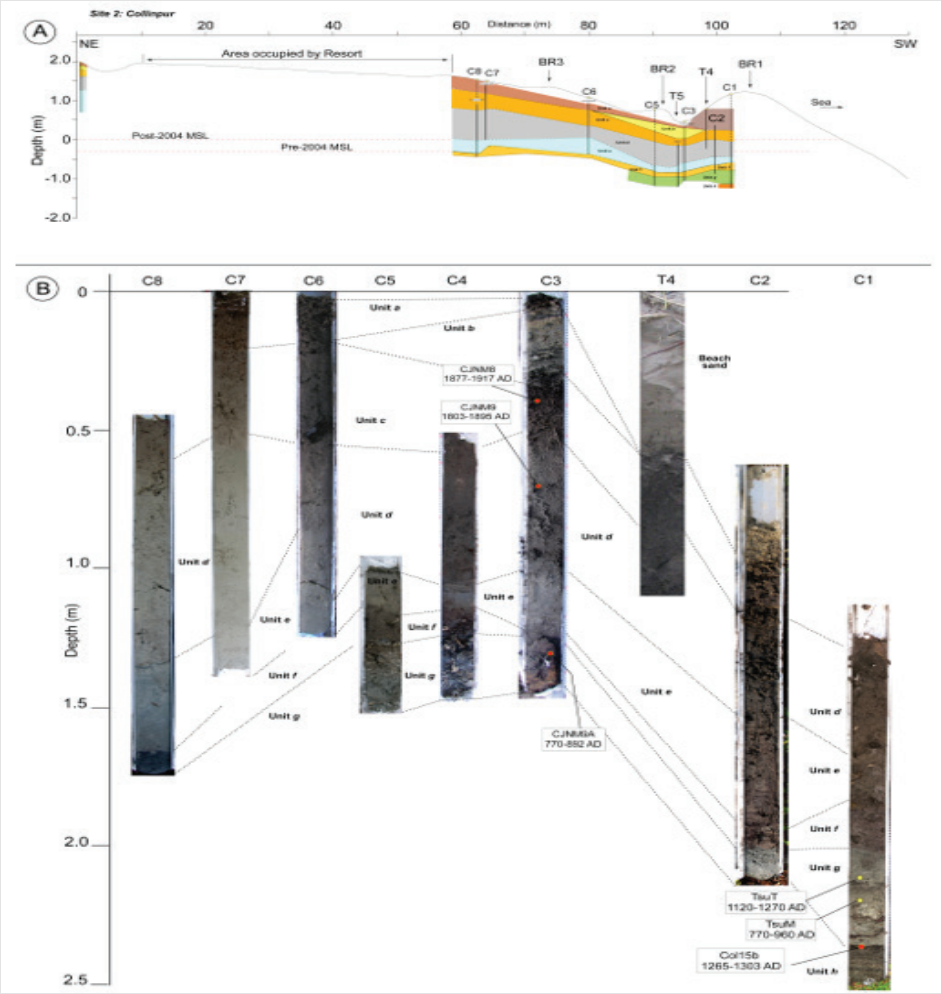


Fig. 17: (a) NE–SW transect across the coast at Site-2, with topographic profile and location of trench and geoslices sections collected. The area is marked by beach ridge-swale-beach ridge topography. Sediment stratigraphic data from eight geoslice C1–C8, and three trench sections (T4-T6) were collected (refer Figs. 16B, 2 A and C for location). For deeper sediment stratigraphy geoslice sections C1 and C2 were collected from base of T4 excavated at the back-limb of BR1, and C4 and C5 from T5 excavated in a swale between BR1 and BR2; (b) Geoslice and trench sections showing correlation between various sedimentary units (total eight units, Unit a-youngest and Unit h-oldest). The sections are placed with respect to horizontal, vertical scale represents depth from surface.

Based on the grain size, sedimentary structures and the nature of the contact (erosional or depositional) with under- and over-lying sedimentary units, the entire sediment succession is classified into 08 units (Unit a- youngest and Unit h- oldest) (Figs. 17-19).

Unit h was found in geoslice C1 at a depth of 2.34 m (Figs. 16a-b, 17a-b, and 19a). Here this unit shows a sharp contact with overlying Unit g. It is marked by poor lamination of silty-sand and peat layers, and is also devoid of any shell fragments (Figs. 17a-b and 19a). We interpret that this probably was a back-marsh that remained isolated from tidal waters, but was inundated during exceptional higher high tides. the Unit g was observed in geoslices C1, C2, C3, C4 and C5. In C1 it is found at a depth of 2.0 m on the back-limb of beach ridge, BR1 (Fig. 17a-b). This unit is 30 cm thick and comprised medium to coarse sand along with broken shell fragments (Figs. 17b and 19a, c and d).

Variation in grain size, gradation and sedimentary structures enabled identification of four sub-units in Unit g in geoslice C1 (Fig. 19a). Sub-unit W1 (2.33–2.27 m), comprised of medium to fine sand layer with broken shell fragments in the bottom part is capped by a thin layer (~ 1.5 cm) of plant debris (Fig. 19a). A few fragments of plants and rip-up clasts were also seen within this sand layer. This sub-unit is marked by a sharp and erosional contact with underlying Unit h (Fig. 19a). Overlying sub-unit W2 (2.27–2.21 m), also depicted a similar depositional pattern, with plant debris on the top that got deposited from suspension fallout due to a stage of water stagnation between two successive waves (Bondevik et al., 1997; Fujiwara, 2007; Fujiwara and Kamataki, 2007). Sub-unit W3 (2.21–2.09 m), shows normal grading marked by fining upward sequence. Basal portion at 2.2 m depth is comprised of medium-coarse sand along with comparatively larger fragments of broken shells as observed in other sub-units W1 and W2. Further in the upper part of the section at 2.1 m the unit was marked by a thin layer of ~ 3.0 cm with prominent laminations (Fig. 19a). Sub-unit W4 (2.09–1.99 m) shows inverse grading with medium to coarse sand with broken shell fragments near the top (Figs. 17b and 19a). Four sub-units (W1–W4) within 30 cm thick Unit g, had sharp erosive contact, normal and reverse gradation, rip-up clasts, scattered plant fragments as well as plant debris are indicative of deposition by multiple tsunami waves.

Such multiple-bed tsunami deposits have been reported from locations around the world, e.g., coastal lakes of western Norway, USA (Bondevik et al., 1997); Boso Peninsula, Japan (Fujiwara and Kamataki, 2007); Miura Peninsula, Japan (Shimazaki et al., 2011). It has been suggested that the vertical stacking by multiple layers usually develop due to long wave-length as well as wave period. Such cycles of sub-units cannot be deposited by storm waves with a shorter wave periods (Fujiwara and Kamataki, 2007). In Unit g alternate layers of coarse sand, shell fragments and plant debris, partial lamination in upper part suggested deposition under varied energy conditions. Coarse sand including shell fragments and plant debris were deposited by the incoming wave (run-up) and the return (backwash) wave respectively (Figs. 17b and 19a).

The Unit g was also found from swale between BR1 and BR2 in geoslice sections C4 and C5 at a depth of 1.3 m (Figs. 17a-b; 18a-b and 19c-d). Here this unit is about 20 cm thick comprising comparatively coarser deposits made up of poorly sorted, angular to sub-rounded assorted clasts of coral, shells, sandstone etc., and with coarse sand as matrix (Figs. 17b and 19c-d). In section C3 at 1.2 m depth a tree log at same stratigraphic level was observed. Variation in

grain size (i.e., coarse sand in geoslice C1 and gravelly deposit in geoslices C4 and C5) in Unit g towards land suggested lateral facies variation during single tsunami event and during this event the tree log was uprooted and transported by the tsunami wave (Figs. 17b and 19b).

Unit f is present in geoslices C1, C2, C4, C5, and C8 at depth of 1.2–1.8 m with variable thickness ranging from 15–20 cm (Fig. 17a-b). It is marked by a sharp contact with underlying Unit g. Formation of peaty soil suggested that the area was isolated from the ocean and remained at or above the mean sea level. Peats can also accumulate below the mean sea level if the site is inland and isolated from the oceanic waters. As the stratigraphic sections in this study were proximal to ocean, we considered that the peat was formed due to a land-level change.



Fig. 18: (a) A view of present beach and two beach ridges (BR1 and BR2) at Site 2; (b) Photo showing location of BR1, BR2 and BR3 and shallow inter-ridge swales; (c) mapping conducted across beach ridge-swale-beach ridge; (d) trench T4 excavated on the back-limb of BR1 for collecting geoslice section from deeper part, (e) a view of back-marsh located behind BR3, connected through a small tidal inlet. The tidal channel gets connected with sea during heavy rain in the uplands; (f) Exposed section in Trench-T5 excavated in a swale between BR1 and BR2. Deeper geoslice section C4 and C5 were collected from this trench. (g) Exposed section in Trench-T6. Thin layer of fine sand overlying unit c (peaty soil) represents the inland extension of 2004 tsunami deposit (Unit b).

Unit e made up of massive silt to silty-clay was observed in all geoslices its thickness ranges from 10–25 cm (Fig. 17a-b, 18f-g, 19b-d). This unit shows a gradual to sharp contact with the underlying Unit f, with no prominent sedimentary structures (Figs. 17b, 19b-d). Finer sediments, silt to silty-clay could be deposited under fluvial or estuarine environment or during filling up of a basin. In the present study area the possibilities of having contribution from fluvial or estuarine environment is very meagre.

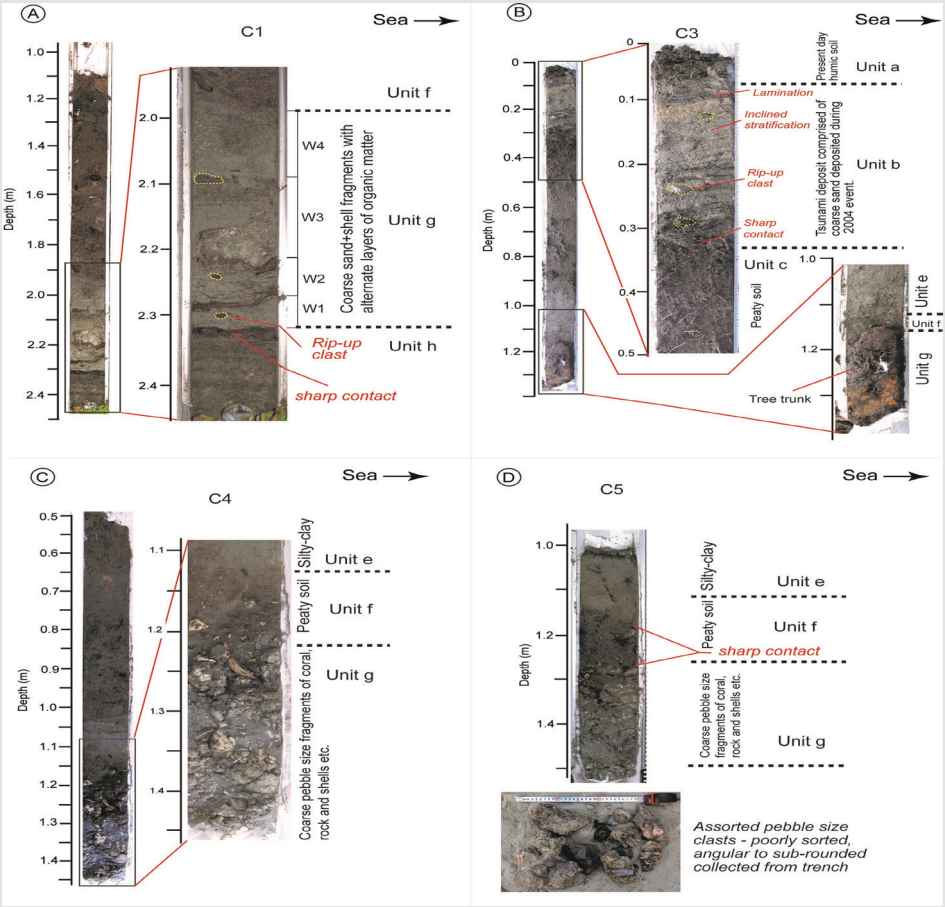


Fig. 19: (a) Close-up of tsunami deposit identified from the base of C1 geoslice at Site 2. The 30 cm thick deposit was found at a depth of 2 m below the surface along the back-limb of the beach ridge (BR1). The Unit g marks sharp-erosive contact with underlying peaty soil (Unit h). Rip-up clasts in the deposit are marked by yellow dotted circles. (b) Unit b - 2004 tsunami deposit from geoslice section C3. The 20 cm thick yellowish coarse sand shows sharp contact with underlying peaty soil (Unit c), inclined stratification towards land and lamination at the top. Yellow dotted circles marks scattered rip-up clasts. A close-up of uprooted tree trunk in tsunami deposit. (c) Coarser deposit– Unit g from geoslice C4 at a depth of 1 m below the surface. Unit g comprised of pebbles size fragments of coral, rock and shells. (d) Unit g from geoslice section C5 is marked by coarser (pebble) assorted clasts of coral, shell, rocks etc. A sharp contact is marked between Units e and f, as well as between Units f and g.

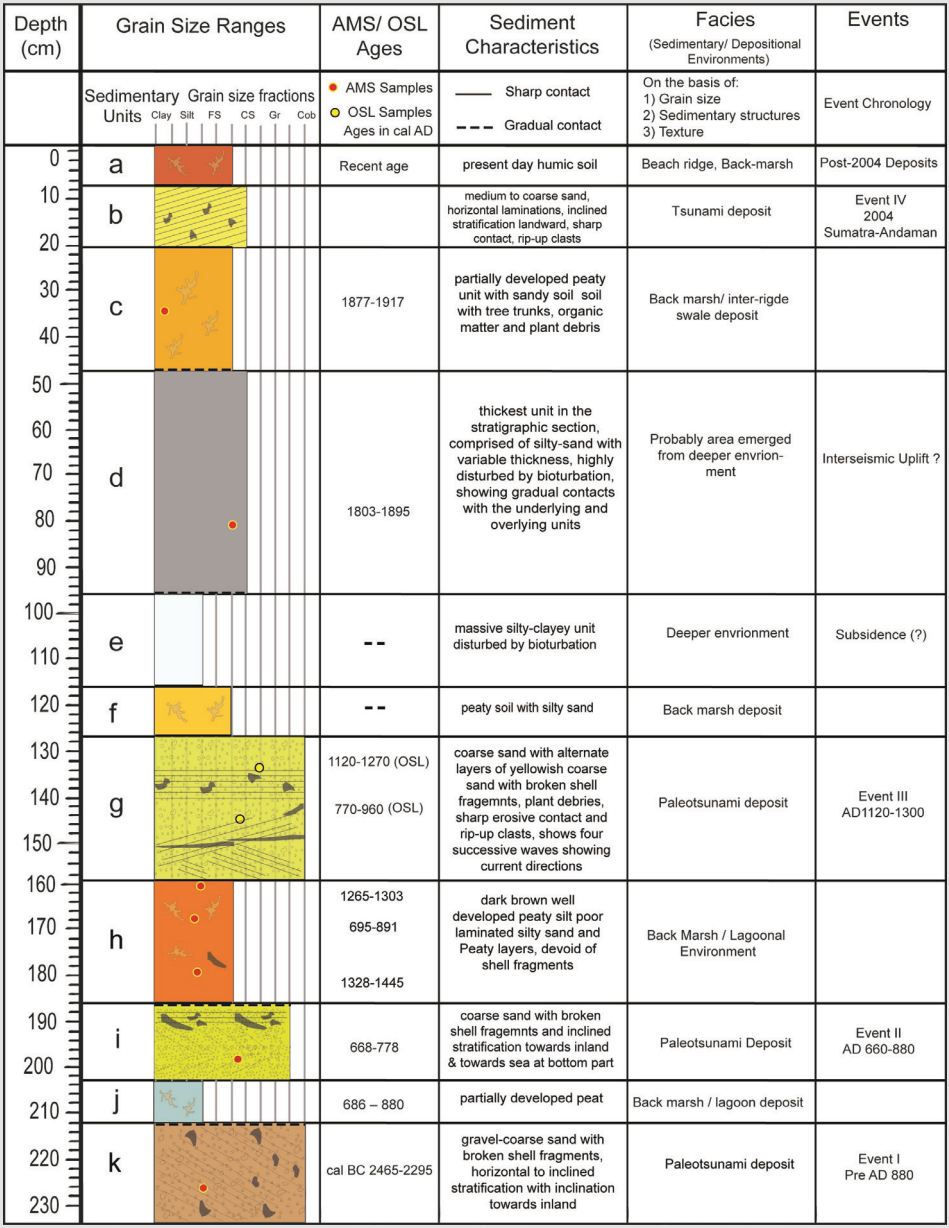


Fig. 20: A composite litho-section based on the exposed sedimentary units. Note units I, j, and k were exposed in deeper sections from adjacent site of Collinpur-4 located not of this site.

In geoslice sections C5 and C8 this unit shows sharp contact with underlying Unit f suggested sudden changes, probably indicative of land-level change associated with coseismic subsidence. Hence, we inferred that the finer sediments probably were deposited under calm subaqueous environment. Similar finer deposits marked by sharp contact with underlying unit from Mitha Khari at Port Blair has been attributed to sudden land-level change and inferred as deposition under deeper environment (Malik et al., 2011).

Towards the top a comparatively coarse Unit d made-up of silty-sand with variable thickness was observed in all geoslices (Figs. 17a-b). It shows a gradual contact with underlying Unit e, and variable thickness ranging from 30–60 cm (Figs. 17a-b). The deposition could be related to a normal basin filling process, which could be attributed to beach-ridge deposition. This was overlain by a weak to well-developed peaty sandy soil (Unit c). Unit c was observed (Figs. 17a-b; 18f-g and 19b), with a variable thickness that increases landwards (Figs. 17a-b). Silty-sand along with well-developed overlying peaty soil indicated a change in environment; probably the area emerged above tidal levels.

Unit b is a medium to coarse sand unit was only found in swale between BR1 and BR2 (Figs. 17a-b; 18f-g and 19b). Unit b is marked by inclined stratification dipping towards land, rip-up clasts and lamination in the upper part (Figs. 17b; 18f-g and 19b). Thickness of the unit was about 20 cm near the shore and reduced to about 5 cm inland (Figs. 17a-b; 18e, g and 19b). A thin layer of fine sand was observed from trench-T6 located in the back-marsh area (Figs. 16b; 17a-b, 18g). We surmise that this sand unit (Unit b) was deposited during recent tsunami event associated with 2004 Sumatra–Andaman earthquake. The area experienced subsidence by about 50 cm during 2004 event as inferred from field evidence (Kayanne et al., 2007) and confirmed from the interviews of residents (Malik et al., 2006). The area is in process of developing a new peaty soil (Unit a) as identified from the swale as well as from back-marsh (Figs. 17a-b and 18a-g). The composite stratigraphy of these units are summarized in Fig. 20.

Stop 3: Kurmadera [11°40'2.47"N; 92°35'37.91"E]

The Kurmadera site is located along the west coast of the southern Andaman Island (Figs. 12 and 21). The site is located vertically below the Collinpur Village (Site-2) in its southward extent. Similar to Site-1 and Site-2, this area also experienced subsidence and remain submerged after the 2004 earthquake. The land area behind the beach ridge is sloping inland and has been used for coconut and betelnut plantations. The area is characterized by wide beach, prominent sea-notches and rocky platform (Fig. 21).

Our investigations at Kurmadera suggest that the area witnessed multiple episodes of uplift and subsidence, which is clearly reflected in the morphology of its landscape (Figs. 27a-b, 28a-b, and 29a-b). Here we observed relicts of the previous rocky landscape in form of large notches and cliffs, which had survived long-term erosion due to past land level changes in the region.

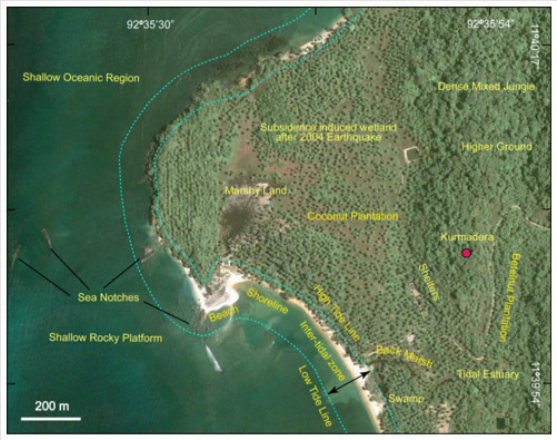


Fig. 21: Coastal topography and major geomorphology around Kurmadera are marked in the area; Inter-tidal zone and the MSL are bounded by sky blue dashed lines (Date of image: 8/2011).

We observed at least 04 sea-notches of variable height ranging from 50-150 cm formed (Fig. 22a-b). Among these notches N1, N2 and N3 are more-or-less of similar height (Fig. 22a-b). We see a relicts of wave-cut-platforms associated with N2, N3 and N4 sea-notches (Fig. 22b). These notches probably indicate multiple episodes of upliftment during recent geological past. We have not dated these notches, hence unable to connect to any of the past events.

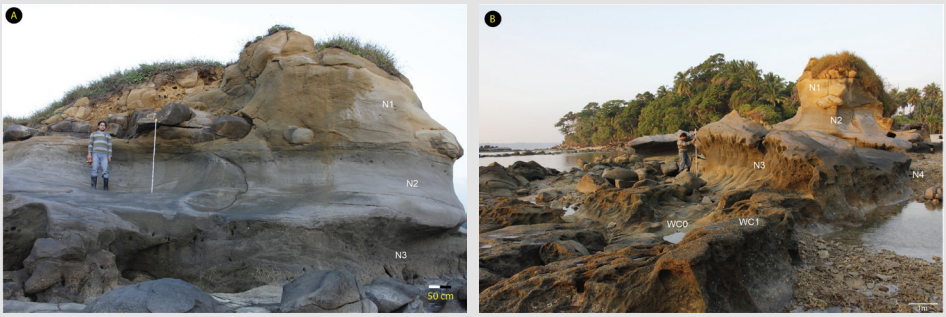


Fig. 22: (a) Three levels of large paleo-notches facing towards sea observed at Site-1; Sea notches of Level-1, 2 and 3 represent the three major episodes of uplift; (b) Sea notch of Level-3 and present day tidal notches in Kurmadera formed before and after the 2004 earthquake, respectively; High Water Level (HWL) is marked on the notches; Active minor notches are under tidal influence and so are unstable, i.e., sensitive to minor sea level and land level changes.

Day 3: 23rd January 2027

We would visit to a Shaheed Dweep (Neil Island) located northeast of the main Andaman Island. To reach Shaheed Dweep we would take an early morning ferry which will take ~1.5 hours to reach there (Fig. iii). After having break-fast and refreshing ourselves we would undertake a field around the island to see the multiple marine terraces and sea-notches (Fig. 23).

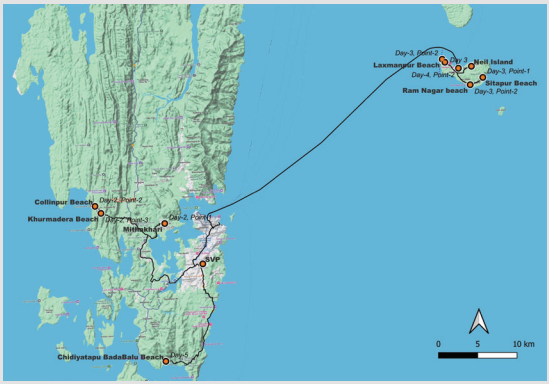


Fig. iii: Route between Port Blair and Neil Island.

Stop 1: Sitapur Beach

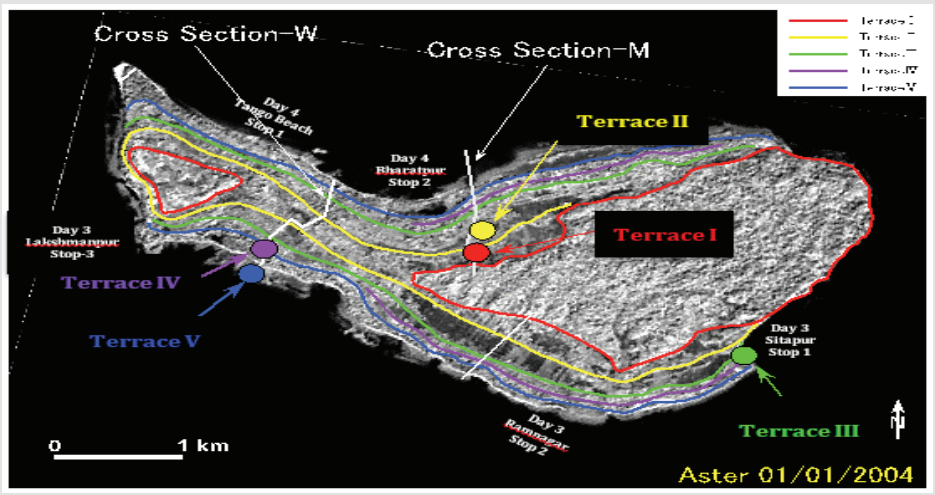


Fig. 23: Aster Image showing a view of Shaheed Dweep (Neil Island) with multiple marine terraces (Terrace I to V) with typical step like coastal geometry as seen extended on north and south of the island. Distribution of terraces are marked by continuous color lines and circles marks the location of prominent exposures of terraces around the island. Topographic profiles collected are indicated as Cross section-W (collected in the western portion of the island) and Cross section-M (collected in the middle portion of the island).

The island is made up of coral/coral debris. The overall morphology of the island exhibits step like topography representing different level of terraces from Terrace I (older higher) to Terrace V (youngest), exotic beaches, and a few places marked by prominent multiple sea-notches (Figs. 23-38).

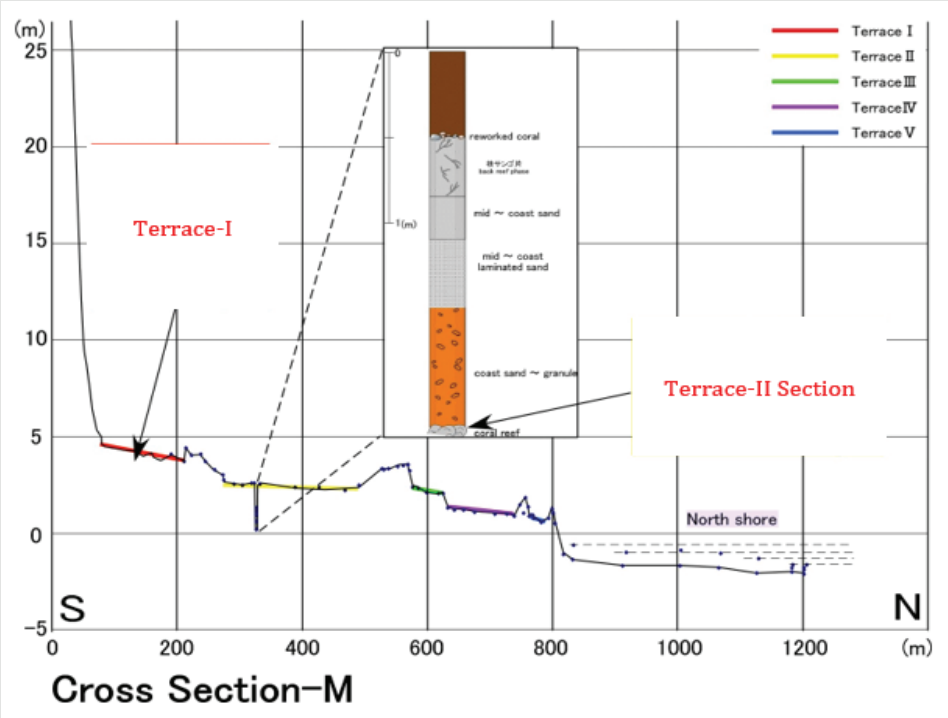


Fig. 24: Topographic profile showing the higher Terrace-1 and Terrace-2 in the central portion of the Neil Island.

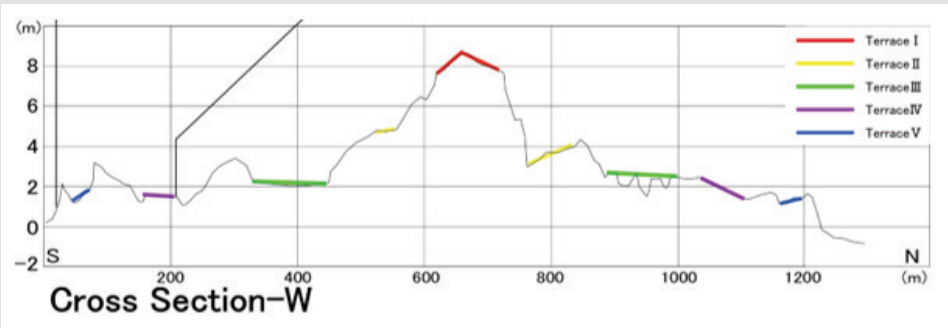


Fig. 25: Topographic profile showing distribution/relative height of the terraces (I to V) across the middle portion of the island.

Stop-1 [11°49'13.06"N; 93° 3'41.83"E]

To understand the distribution of terraces we would focus along the southern coast of the NI, starting from Sitapur Beach located in the southeast corner of the island (Fig. 23). While moving towards the Sitapur Beach we would be seeing Terrace-II and III along the village road marked by prominent undulations (Figs. 23-26). Also, we would be able to see the higher terrace (Terrace-I) located northside along the village road (Figs. 23, 27). The Sitapur coast exhibits wide beach with wave-cut platform and a marine terrace (Terrace-III) comprised of corals/coral debris (Figs. 23; 28-29).



Fig. 26: Undulation along the village road showing the location of Terrace-II and Terrace III.



Fig. 27: A view of higher terrace (Terrace-I) located northside along the village road.



Fig. 28: A view of Sitapur Beach along the southwestern coast of Neil Island. The area also shows present-day wave cut platform and beach (top) along with uplifted marine terrace (Terrace-III).



Fig. 29: Field photos showing present-day wave cut platform and beach (top) along with uplifted marine terrace (Terrace-III) comprised of died corals/coral debris (bottom).

Stop-2 [11°48'52.67"N; 93° 2'44.75"E]

The Ramnagar Beach is located along the southern coast of the NI (Fig. 23). While moving towards the Ramnagar coast from the village road (Terrace-III) we will come across Terrace-IV and Terrace-V further south of the beach area (Figs. 23, 30-31).



Fig. 30: A view of Terrace-IV while moving towards the Ramnagar Beach from north to southern coast.



Fig. 31: A view of Terrace-V near the Ramnagar Beach.

Further south of Ramnagar Beach the area is marked by flat eroded bed comprised of corals (Fig. 32). This wave-cut platform observed on either side of the island coast – could be suggestive of another younger terrace.



Fig. 32: A view of Terrace-V near the Ramnagar Beach and present-day wave-cut platform in the foreground.

Stop-3 [11°49'55.55"N; 93° 0'50.40"E]

On the way to Lakshmanpur Beach we would see the exposed coral atoll (dead) representing the Terrace-IV (Figs. 23, 33a-b). Lakshmanpur coast showcase a natural-rocky-bridge with multiple sea-notches, indicative of past sea-levels in the Indian Ocean (Figs. 23, 34).



Fig. 33a-b: Terrace-IV along the southwestern coast of Neil Island. Refer Cross-section-W profile marked in Fig. 25.



Fig. 34: Prominent multiple sea-notches (04 level) at Lakshmanpur along the southwestern coast of the Neil Island.

Day 4: 24th January 2027

Stop-1 [11°50'38.63"N; 93° 1'8.15"E]

We would visit Tango Beach along the northwestern coast of the Neil Island (Figs. 23; 25; 35a-b; 36. This portion of the coast exhibits exotic beach with present wave-cut platform made-up of corals (exposed in the low-tide) to its north, and a raised surface to its south representing the Terrace-V (Figs. 23, 35a-b).



Fig. 35a: A view of Terrace-V (west of Tango Beach) along the northwestern coast of the Neil Island.



Fig. 35b: Terrace-III looking south from Tango-Beach.

Further, moving towards west near Lakshmanpur Beach No. 1 [11°50'49.17"N; 93° 0'56.46"E] we would see the prominent change in elevation indicating the Terrace-V and Terrace-III (Figs. 35a-b; 36).



Fig. 36: A view of Terrace-III (west of Tango Beach) along the northwestern coast of the Neil Island near Laxmanpur Beach.

Stop-2 [11°50'10.90"N; 93° 1'59.76"E]

The Bharatpur Beach is in the middle-narrow zone along the northern coast of the Neil Island (Fig. 23). While moving down north from the village road we will come across the Terrace-II (village road) and Terrace-III surface (Figs. 23, 37). Further north towards beach we would see Terrace-V (Fig. 38).



Fig. 37: A view of Terrace-III and Terrace-II on the way to village road from Bharatpur Beach.



Fig. 38: A view of the Bharatpur Beach with Terrace-V.

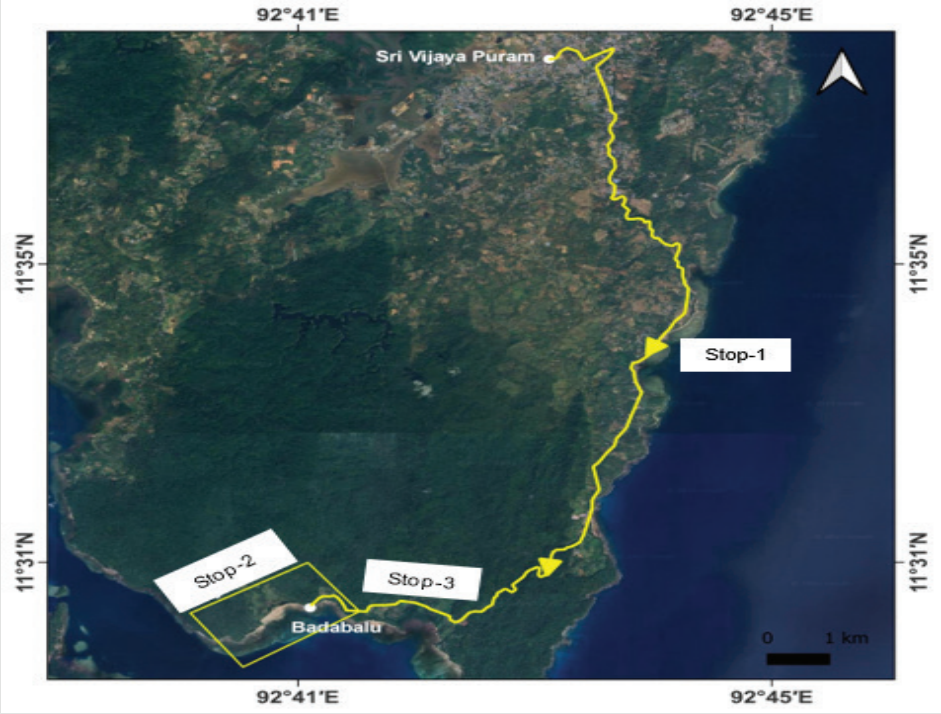


Fig. 39: A route map showing the location of Day-5. Stop-1: Near Bunker Beach showing the evidence of subsidence caused by 2004 Sumatra-Andaman earthquake. Stop-2: the Badabalu Beach, which also experienced subsidence by 40-45 cm causing shifting of beach towards inland and local inundation of the area and Stop-3: Chiyatapu Beach.

The ENE-WSW striking Badabalu beach along the south coast of Andaman is a famous tourist destination (Fig. 39). The Badabalu area was severely affected by the 2004 tsunami (Sumatra-Andaman earthquake) and experienced a coseismic subsidence of ~40–45 cm (Figs. 40a-b; 41a-h). Google Earth images from 2004 to 2014 clearly exhibit the pre- and post-seismic changes in coastal geomorphology (Figs. 47a–h and 48a-b). According to the survivors, the Badabalu area experienced ~4 m high tsunami waves, with run-up up to 0.8–1.0 km from the coast. Coseismic subsidence resulted into a landward shifting of the beach by 35–50 m (Figs. 41a–h and 42a-b).

Stop-1 [11°33'36.13"N; 92°43'46.31"E]

On the way to Badabalu/Chidiyatapu we will see the evidence of land-level change along the east coast of the southern Andaman Island. The area was subsided by ~0.5m, well-marked by the damaged seawall, which was later reconstructed at a higher level (Figs. 39, 43a). Submergence of the area by ~3 m (indicated by watermark) during the 2004 tsunami near Chidiyatapu (Fig. 43b). The tsunami height was about 3-3.5 m. To avoid inundation the local residents have reconstructed their houses on the reclaimed elevated areas (Fig. 43c).

Stop-2 [92°43'46.31"E; 92°40'35.20"E]

Landward migration of the beach also caused inundation of the area and formation of beach ridge, back-marsh inland, and dead forest along the coastline (Fig. 44). Local residents artificially filled the area by 0.7–0.8 m, shifted their houses to the higher ground, and elevated the coastal roads to avoid inundation around residential area and agricultural fields during high-tides. We propose to undertake geoslicing at 1-2 locations to showcase the signatures of paleo-tsunami and land-level change preserved in shallow stratigraphy (Figs. 40a-b).

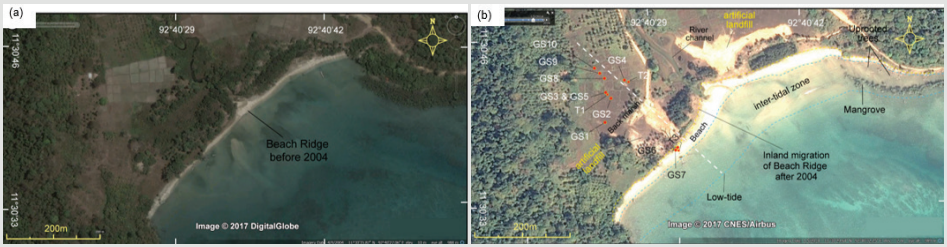


Fig. 40: (a) Google image of the area around Badabalu (Stop-3) along the south coast of Andaman showing intact beach, beach-ridge and back-marsh before the 2004 event. The image was taken on 09 April 2004 (Map data: Google, DigitalGlobe). (b) Google image showing the effect of the 2004 Sumatra-Andaman earthquake. The land subsidence was ~40-45 cm, resulted in inundation and erosion of coastline, as well as inland migration of beach, beach-ridge and back-marsh. The image was taken on 01 May 2014 (Map data: Google, CNES/Airbus). White dashed line marks the WNW-ESE striking transect along which topographic profile, as well as stratigraphic sections, were collected. Geoslice locations are indicated as GS1 to GS10 and trenches as T1 to T3.

01 May 2014 (Map data: Google, CNES/Airbus). White dashed line marks the WNW-ESE striking transect along which topographic profile, as well as stratigraphic sections, were collected. Geoslice locations are indicated as GS1 to GS10 and trenches as T1 to T3.



Fig. 41(a-h): Google Earth images showing changes in the landscape along the south coast of Andaman Island at Badabalu caused by 2004 Sumatra-Andaman earthquake. We interpreted pre- and post-earthquake images from April 2004 to May 2014. The land subsidence was ~40-45cm, which resulted in inundation and erosion of the coastline as well as inland migration of beach and beach-ridge. Figs. 45a-g: DigitalGlobe is the data provider, and 45h: the data provider is CNES/Airbus.

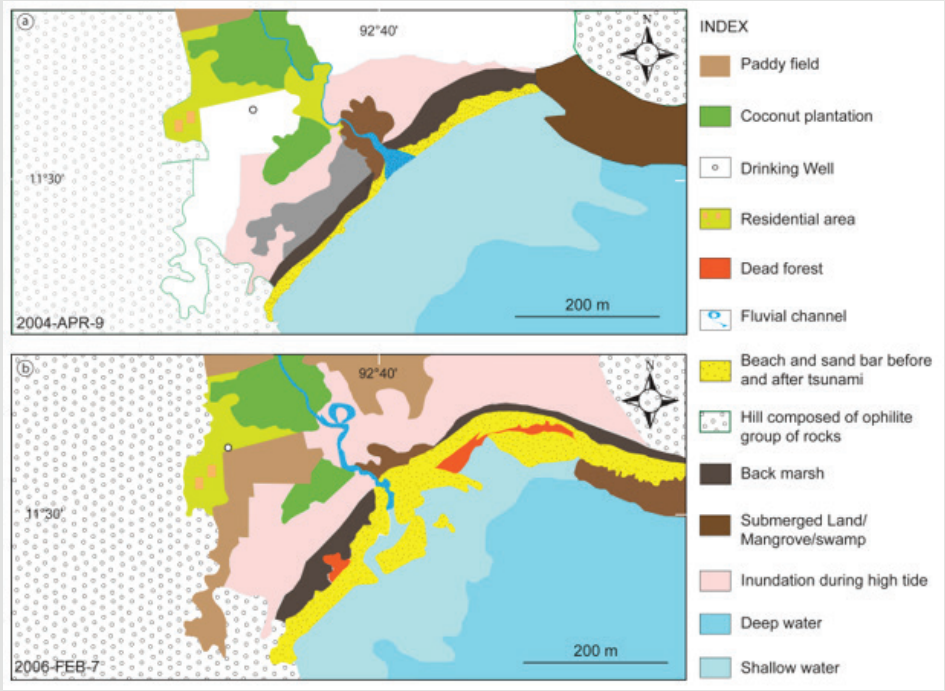


Fig. 42: (a) Generalized geomorphic map showing the distribution of coastal landforms around Badabalu during April 2009, based on onformation extracted from Google Earth image. (b) Map showing prominent geomorphic changes caused by 2004 Sumatra-Andaman earthquake and tsunami. Landform information extracted from Google Earth image taken on 07 April 2006. Coseismic subsidence resulted in the landward shifting of beach by 35-50 m, causing inundation and formation of beach-ridge as well as back-marsh inland. The land-level change also affected the stream debouching into the bay. The stream had a well-marked 3-6m wide meandering channel before the 2004 earthquake. Morphology of the channel changed from meandering to straight, also marked by the formation of an Ox-bow lake and widening of channel up to 8-14m.

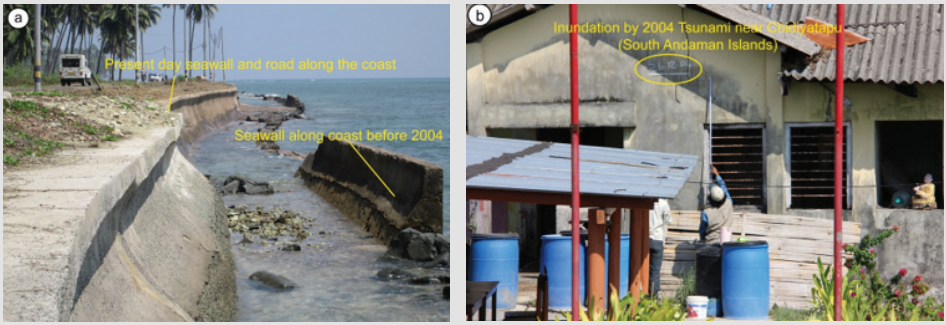


Fig. 43: Stop-1: (a) Field photograph showing a damaged seawall due to 0.5m subsidence along the southeast coast of Andaman Island during the 2004 Sumatra-Andaman earthquake, which was later reconstructed at a higher level. The photo was taken on the way to Chidiyatapu. (b) Submergence of the area by ~3 m (indicated by watermark) during the 2004 tsunami near Chidiyatapu. The tsunami height was about 3-3.5 m. (c) Reconstructed local house on the reclaimed elevated areas to avoid inundation during high tide. Photo near Chidiyatapu along the south coast of Andaman.





Fig. 44: Stop-2: (a) Formation of dead forest due to the intrusion of saline water and regular inundation resulted due to subsidence along the southern coast of Andaman Island. (b) Landward migration of beach and beach-ridge observed at Badabalu. The coastline is subjected to coastal erosion due to subsidence and tsunami. (Photos looking east at Badabalu beach). (c) Artificial land-fill by local residents to prevent waterlogging and inundation from high-tide near Badabalu (Photo looking south). (d) The fill was up to 0.75-1.0 m along the south coast of Andaman Islands at Badabalu (Photo looking south).

Google Earth images (pre and post 2004 earthquake) were used to identify the location that experienced land-level change and having a shoreline configuration with beach-ridge-swale topography, which are ideal for the preservation tsunami deposits (Figs. 40a-b; 41a-h). A detailed topographic survey using Total Station was conducted transverse to the shoreline along the WNW-ESE transect (Figs. 40b; 45a-b). We looked for the signatures of paleo-earthquakes and paleo-tsunamis from shallow stratigraphy at Badabalu (Figs. 40a-b; 45a-b). The area is marked by typical beach ridge-swale-beach ridge topography, with a distinct back-marsh (Figs. 45a-b). Such geomorphic setting is considered to be an ideal site for the preservation of tsunami deposits. We excavated three 1-1.5m deep trenches (T1-T3; Fig. 45a) and obtained 10 geoslices (GS1-GS10) 1.5-3m deep along a WNW-ESE transect normal to the coastline (Figs. 45a-b).

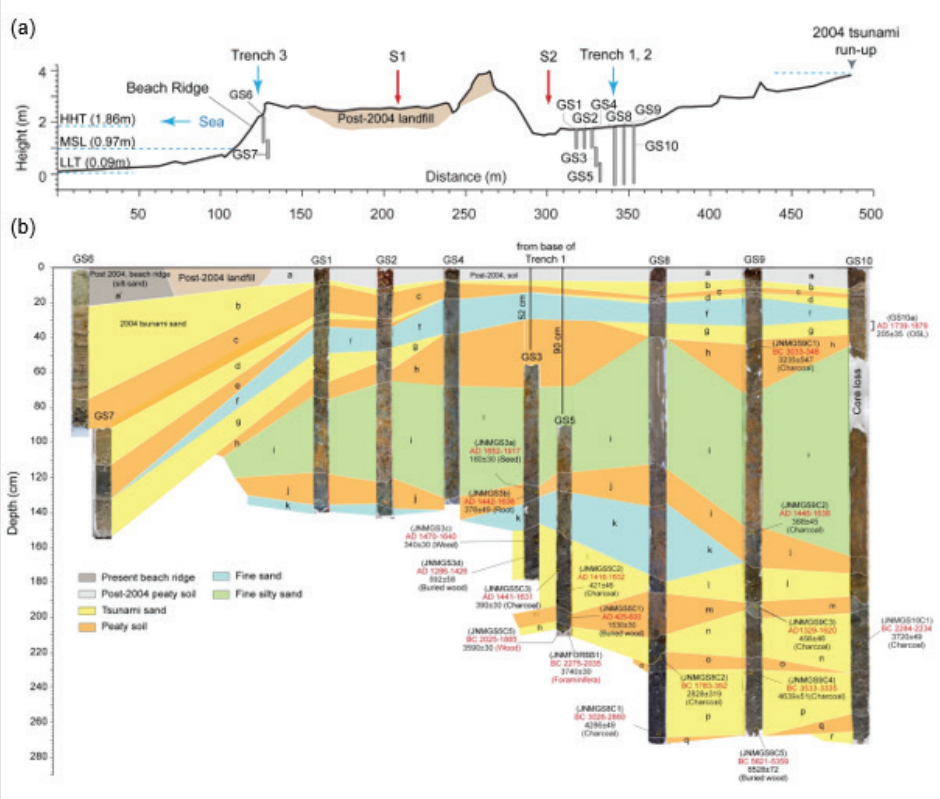


Fig. 45: Stop-2: (a) Topographic profile collected along WNW-ESE transect (refer Fig. 44b for location). Locations of geoslices and trenches for shallow stratigraphic record are marked along the profile. The area shows beach ridge-swale-beach ridge topography. The middle portion of the profile shows artificial fill by local residents to prevent inundation. LLT – lower low tide, MSL – mean sea level and HHT – higher high tide. (b) Geoslice and trench sections placed with respect to horizontal. The vertical scale represents depth from the surface. The distribution of all exposed sedimentary lithounits was correlated. Based on the sedimentary characteristics the exposed units were classified into total 19 units, from the youngest Unit-a' to the oldest Unit-r). In total seven tsunami deposits (including 2004 tsunami) were identified from the exposed stratigraphic sequence ranging in depth from 160-270cm. Units b, d, g, l, n, p and r represent tsunami deposits marked by yellow colour.

All exposed stratigraphic sections studied were perpendicular to the shoreline. Lithounits in the exposed sections were classified based on their sedimentological characteristics in the field (e.g., color, grain size, contacts etc.)(Figs. 40b; 45a-b; 46a-d; 47a-d; 48a-e).

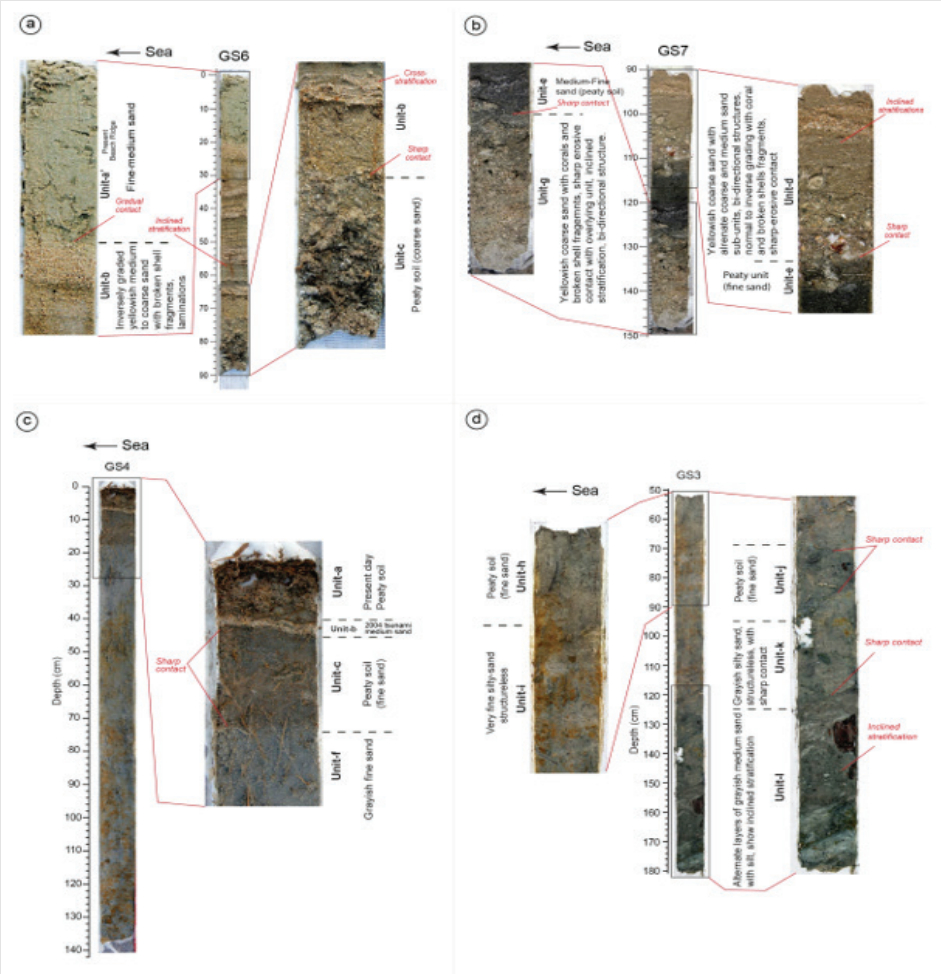


Fig. 46: (a) Close-up view of 2004 tsunami deposit (Unit-b) and underlying peaty soil (Unit-c) exposed in GS6. Unit-b is marked by inversely graded yellowish medium-coarse sand with broken shells. It also shows prominent laminations, and a sharp contact with underlying unit (Unit-c). (b) Close-up view of Units d, e and g exposed in GS7. Unit-d (paleo-tsunami) comprises coarse to medium sand with fine gravel clasts and broken shell fragments. It shows bi-directional structure with normal to inverse grading and a sharp contact with underlying peaty unit (Unit-e). Unit-g also comprises coarse to medium sand with broken shell and coral fragments. It shows inverse grading and bi-directional structure. (c) In GS4, the upper portion of the stratigraphy shows a thin layer of medium sand representing 2004 tsunami sandwiched between pre-(Unit-c) and post- (Unit-a) 2004 event peaty soils. Unit-b shows sharp contacts with underlying (Unit-c) and overlying (Unit-a) units. Unit-c also marks a sharp contact with underlying fine sand Unit-f. (d) Close-up view of geoslice GS3 collected from the base of T1-trench. The stratigraphy in the upper portion shows Unit-i with a gradual contact with overlying peat (Unit-h). Lower portion exhibits well-preserved paleo-tsunami deposit (Unit-l) with a sharp contact with Unit-k. Unit-l is ~30 cm thick medium sand-silt comprised of broken shells and coral fragment and rip-up clasts of plant material. It shows prominent inclined stratification. Unit-k comprised of silty sand also shows sharp contact with overlying peat (Unit-j). Refer Fig. 40b and 45a-b for location.

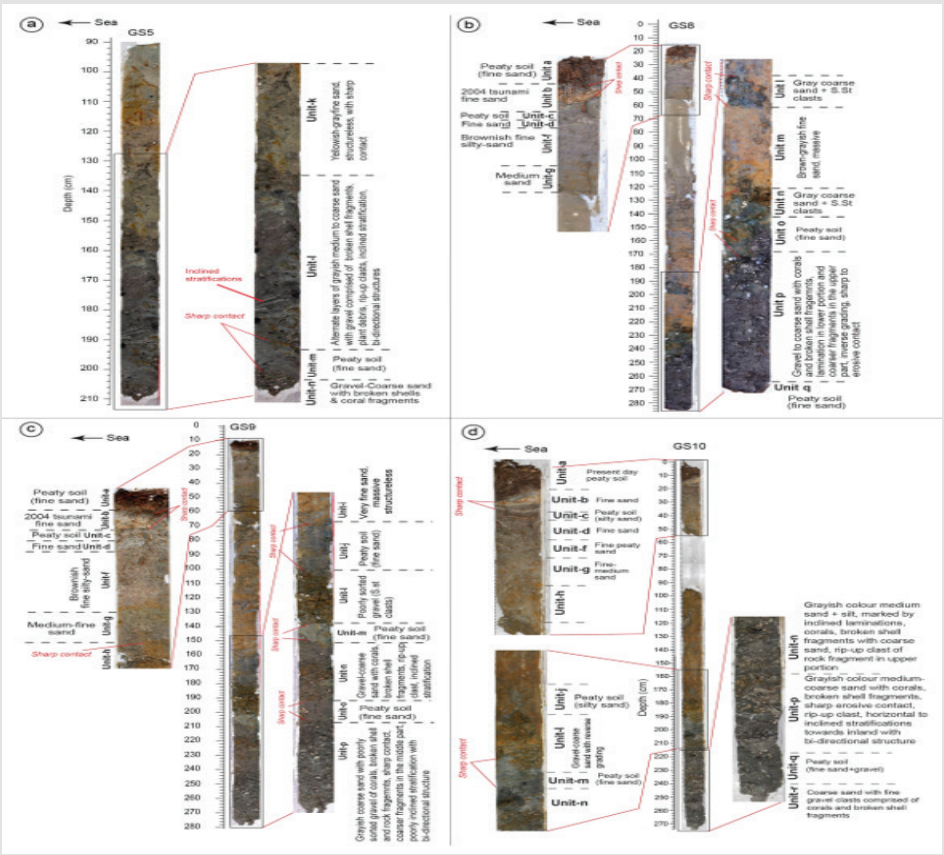


Fig. 47: (a) The GS5 geoslice was collected from further deeper portion of the trench T1. About 40-45 cm thick paleo-tsunami deposit (Unit-l) comprises of alternate layers of medium to coarse sand with broken shell fragments, plant debris, rip-up clasts, and shows bi-directional structure. It shows sharp contacts with overlying Unit-k and underlying Unit-m. (b) GS8 displays a thin layer of 2004 tsunami (Unit-b) with a sharp contact with overlying and underlying peaty units. This inland section also shows a very thin lens of Unit-d (fine sand) and Unit-g (medium-fine sand). Unit-l is greyish coarse sand with gravel (sandstone) clasts. It shows sharp contact with Unit-m. Unit-P is thickest and comprise of gravel to coarse sand along with broken shells and coral fragments. (c) Geoslice GS9 exhibits Units-b, d, g, l, n and p – indicative of tsunami deposits. Unit-b shows sharp contacts with underlying and overlying units. Units d and g comprise of medium-fine sand are paleo-tsunami deposits, marking sharp contacts with underlying units. Units l, n and p represent paleo-tsunami deposits, separated by peaty units m and o. Unit p consist of coarse sand and gravel clasts, broken coral and shell fragments, and shows sharp contact with the overlying Unit-o. Unit-n made-up of coarse sand with inclined stratification shows sharp contact with the overlying and underlying units (Units m and o). (d) The GS10 geoslice collected from back-marsh shows thin medium sand layer of 2004 tsunami sandwiched between peaty soils pre- (Unit-a) and post- (Unit-c) 2004 event with sharp contacts. Unit-l comprises of sandstone clasts (gravel) and coarse sand showing a gradual contact with the overlying Unit-j and a sharp contact with the underlying Unit-m. Units n and p are paleo-tsunamis sharing the same contact. Unit-o is missing in this section. Unit-n is a medium sand unit showing inclined laminations, rip-up clasts and broken shell and coral fragments. Unit-p is medium-coarse sand with coarser fragments of coral clasts and broken shells with bi-directional structures. Unit-p shows sharp contacts with underlying Unit-q (peaty soil) and overlying paleo-tsunami (Unit-n). Unit-r comprise coarse sand with fine gravel clasts (Unit-r) occurs at a depth of ~270cm. Refer Fig. 40b and 45a-b for location.

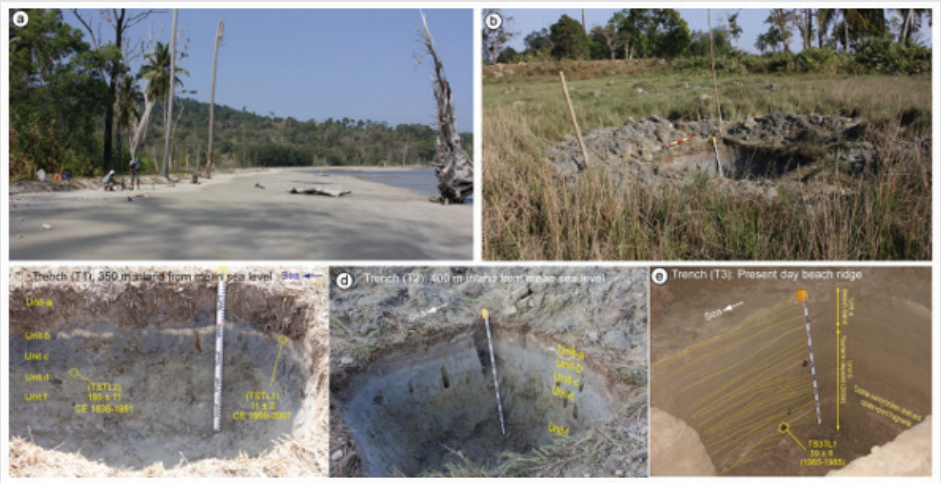


Fig. 48: (a) Geoslice section collected from the present-day beach at Badabalu. Sampling was carried out keeping in mind that the present-day beach area was occupied by a back-marsh before 2004. Please refer Figure 4a-b for location. (b) E-W oriented trenches (T2& T3) excavated behind the present-day beach-ridge in the back-marsh area at Badabalu. Please refer Figure 4a-b for location. (c) T1 and T2 trenches exposed along a transect behind the beach ridge in the back-marsh area. The near-surface stratigraphic section reveals present day peaty soil and discontinuous sand layers of 2004 tsunami deposit. Please refer Figure 4a-b for location. (d) E-W oriented trench (T3) excavated on the present-day beach. (e) The lower portion of T3 trench shows a thick 2004 tsunami deposit comprised of coarse to medium sand with bi-directional structures capped by fine sand of present-day beach at Badabalu. Please refer Fig. 40b and 45a-b for location.

The study from Badabalu revealed evidence of at least seven tsunami events in the last 8000 years (Figs. 45b; 46a-d; 47a-d; 48a-e and 49). To bracket the events several 14C AMS and OSL ages were obtained from various geoslicers and trenches (Figs. 45-48). These events were bracketed based on their modelled calendar ages. The Event-I (Unit-b), having an OSL age of CE 1999–2007, represents the 2004 Sumatra-Andaman tsunami. Event II (Unit-d) occurred around CE 1838–1883, after CE 1747–1850 and before CE 1999–2007. We correlate this event with the 1881 (Mw 7.9) Car Nicobar earthquake, which was felt over much of India and parts of Burma as well as in the Bay of Bengal (Ortiz and Bilham 2003). This was a local event that occurred along the Andaman segment, generated 0.8 m high tsunami, resulted in an uplift of 10–60 cm at Car Nicobar (Ortiz and Bilham 2003) but did not have a widespread effect. Event-III (Unit-g) took place around CE 1747–1850, after CE 1649–1787 and before CE 1838–1833, and correlates with an earthquake of CE 1762 (Mw7.5). This event occurred along the Arakan Subduction Zone that caused uplift of ~3–7 m along the coasts of Ramree, Cheduba, and Foul Islands, located offshore of the Arakan coast of Myanmar (Aung et al., 2008) and also generated a tsunami (Cummins et al., 2007). Signatures of liquefaction and tsunami deposit were also reported from Mitha-Khadi around Port Blair in Andaman Island (Malik et al., 2011). However, no clear evidence of land-level change was found at the present study site. This suggest that Andaman was at the southern tip of this rupture. Event-IV (Unit-j) occurred after CE 1463–1581 and before CE 1747–1850. The event correlates with the historic earthquake of CE 1679, which was felt around Arakan (Burma), Bangladesh, Chennai,

and areas adjoining Indian Ocean (Iyengar et al., 1999).This event may also be correlated with: (i) the event occurred along the Andaman Segment, that accompanied land-subsidence during CE 1600 from Mitha-Khadi near Port Blair (Malik et al., 2011) (ii) a tsunami event of CE 1640–1950 reported from Sumatra (Monecke et al., 2008), and/or (iii) with a tsunami event of CE 1530–1730 (380 ± 50 cal. BP) from Thailand (Cummins et al., 2007). Considering its wide-spread effect we suggest that this event was triggered along the Andaman Segment and was comparatively larger than CE 1881 (Event II), inflicting wider effect in the Indian Ocean. Event V (Unit-l) occurred after CE 1305–1420 and before CE 1510–1632, which correlates with the CE 1300–1400 tsunami reported from Phra Thong, Thailand (Jankaew et al., 2008; Fujino et al., 2009; Prendergast et al., 2012) and CE 1290–1400 tsunami from Aceh, Indonesia (Monecke et al., 2008). This event may also be correlated with the CE 1120–1300 tsunami event reported from the west coast of Andaman (Malik et al., 2015) and with turbidites found from Sumatra (T3: 630 ± 110 cal. BP; CE 1159–1480) (Patton et al., 2015). Also, signatures of subsidence and tsunami deposit during CE 1040–1495 have been reported from the south Andaman, as well as an uplift from Hut Bay and north Andaman (Jankaew et al., 2008; Fujino et al., 2009). This was a mega earthquake sourced locally along the Andaman segment and resulted in a transoceanic tsunami (Malik et al., 2015). Event VI (Unit-n) occurred after BCE 2660–2100 and before CE 428–600. Further considering the youngest age of detrital charcoal from Unit-n (BCE 2024–1885), we suggest that Event VI occurred after BCE 2024–1885. This event may be correlated with turbidites observed in a core (T26: 3720 ± 340; BCE 3095–1290) from Sumatra (Patton et al., 2015) and also with the tsunami of BCE 2000–3000 reported from Peraliya, Sir Lanka (Jackson et al., 2014; Dahanayake et al., 2008). We infer that Event VI was a local event produced by Andaman Segment, generated a tsunami that reached the eastern coast of India and Sri Lanka. Event VII (Unit-p) was after BCE 3086–2758 and before BCE 2661–2100, during BCE 2966–2286. Due to a wider age bracket it is difficult to correlate this event with a particular event reported from other adjoining areas in the Indian Ocean. Nevertheless, it may be correlated with the BCE 2810–3200 (4760–5150 cal. BP) tsunami reported from Karagan Lagoon, southeast Sri Lanka (Jackson et al., 2014; Dahanayake et al., 2008), and also with turbidites reported from Sumatra (T27: 3900 ± 190 cal. BP; BCE 2892–1895) (Patton et al., 2015). Since we do not have any lower limit bracketing Event VIII, we suggest that Event VIII (Unit-r) occurred before BCE 5612–5323. This event can be correlated with turbidite identified from Sumatra during (T43: 6600 ± 140 cal. BP; BCE 5786–5301)14, and with the BCE 5374–5579 (7324–7529 cal. BP) tsunami event reported from Indonesia (Rubin et al., 2017). Because we found this tsunami deposit in only one geoslice, it is difficult to ascertain if this was a local (Andaman segment) or a distant sourced event.

Based on the stratigraphic record, OSL and 14C AMS ages, and modelled ages in OxCal, we observed a considerable depositional gap for almost 2000 year between 3700 and 1500 years BP. This discontinuous stratigraphic record could be attributed to erosion due to one of the possibilities: (a) coseismic uplift or gradual uplift during inter-seismic period along the up-dip portion of the subducting plate or upper plate fault. But no upper plate fault from this region has been reported; (b) Relative Sea Level (RSL) fall which accelerated erosion of the stratigraphic sequence. The chronology of the beach ridges and reconstruction of complex pattern of shoreline progradation and erosion from Phra Thong, Thailand suggest a short episode of local erosion between 4000 and 3800 yr BP, could be attributed to climate

change, impact of a tsunami or tropical cyclone (Brill et al., 2015). Further, Brill et al. 2015, also reported a signature of sea-level fall and shoreline progradation from Phra Thong with decreased rate of <1 m/year during 3300–3500 yr BP. Dura et al., 2016, reported an incomplete record of subduction zone earthquakes in coastal stratigraphy from the coast of Sumatra, because the late Holocene (last 4 ka) RSL or sea-level fall facilitated erosion and restricting preservation of lithounits. Following these arguments, we suggest that erosion was accelerated due to RSL fall at ~3500 BP in Andaman and Nicobar Islands. The continuous stratigraphic sequence from 1500 years BP till present is attributed to a gradual RSL rise, which remained within the tidal frame of 1–2 m in the Andaman region.

The lower portion of the stratigraphic section comprising Units l to r reveals stacked sequence of peaty units (wetland soils; Units m, o and q) and tsunami deposits. The Unit-k comprising fine-medium silty-sand suggests basin-fill under sub-tidal condition followed by a gradual uplift during inter-seismic period. The peaty soil (Unit-j) indicates the formation of wetland soil at or above mean sea-level. This was followed by a coseismic subsidence, and a long-term post-seismic subsidence is well justified by the presence of a 75 cm thick very fine sand (Unit-i). The presence of Unit-h (peaty soil) suggests that the area was at or above mean sea-level. We infer that the area emerged from deeper environment (sub-tidal) around this time.

The upper portion of the stratigraphic section, Unit-b marks the 2004 tsunami, Units d and g represents tsunamis during the recent historic time. Unit-f with fine sand suggests that the area was under the influence of sub-tidal environment, whereas Units e and c (peaty soils) indicate that the area was at or above mean sea-level. Possibly the area experienced subsidence during these earthquakes and recovered during post-seismic period, which eventually facilitated the formation of wetland soils and vegetation growth. The area remained submerged for substantially longer span during inter-seismic period as indicated by a thick fine silty-sand (Unit-i). A long-term inter-seismic subsidence implies a huge strain accumulation. However, couple of large magnitude earthquakes viz. CE 1881, with a rupture near Car Nicobar in the mid-segment of Andaman, and CE 1762, ruptured along the Arakan Subduction Zone, partially released the long-term accumulated strain after CE 1679 event. The CE 1679 event was a local event having its rupture along the Andaman Island. Hence, we conclude that the Andaman Segment has enough accumulated strain to trigger a mega-tsunamigenic subduction zone earthquake in near future. A 2000 years stratigraphic gap add to the uncertainty associated with the estimation of the recurrence of tsunamigenic earthquakes. However, 1500 years of continuous sequence suggests a recurrence of 420–750 years for a mega-earthquakes along subduction zone like the 660–880 CE3, 1300–1400 CE and the 2004 Sumatra Andaman earthquake having different source. A shorter interval of 80–120 years is inferred for the large earthquakes like 1679, 1762 and 1881 CE.

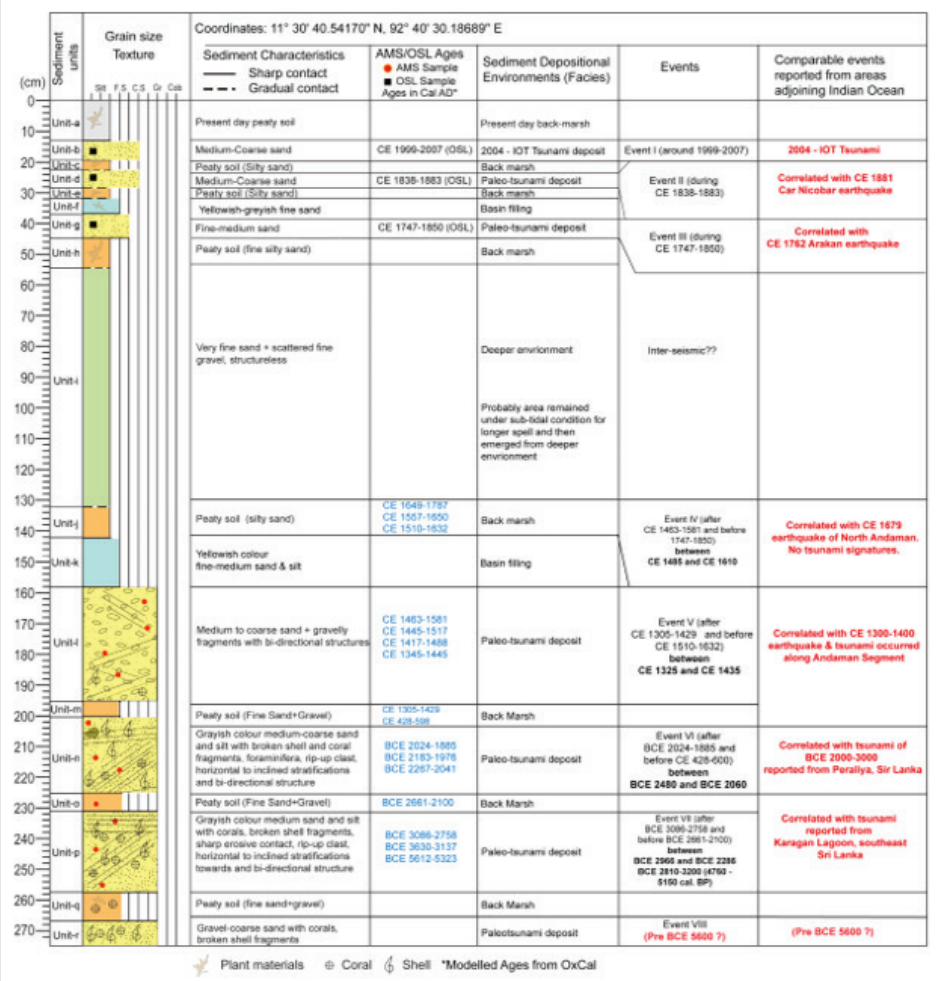


Figure 49: Composite stratigraphic-section constructed using the litho-sections obtained from geoslices and trenches at Badabalu, south coast of Andaman Island.

Stop-3 [11°30'20.92"N; 92°42'3.38"E]

Visit to Chiyatapu Beach and return back to Sri Vijaya Puram (Port Blair).

Day 6: 26th January 2027

Take flight from Sri Vijaya Puram (Port Blair) to Lucknow (via Kolkata).

Geoheritage, Archaeology, Culture and Natural Heritage

The Andaman and Nicobar Islands possess exceptional geoheritage, ecological diversity, archaeological significance, and cultural heritage, making them one of the most remarkable island systems in the Indian Ocean. Besides preserving outstanding geological records of active subduction, repeated megathrust earthquakes, and transoceanic tsunamis, the islands also contain unique tropical ecosystems, colonial monuments, indigenous cultures, and protected marine environments. These natural and cultural assets collectively enhance the scientific value of the present field excursion.

10.1 Geoheritage of the Andaman Islands

The Andaman Islands constitute one of the world's finest natural laboratories for studying active plate tectonics and coastal geomorphic evolution. The landscape preserves numerous geomorphic markers generated by repeated episodes of tectonic uplift, subsidence, sea-level fluctuations, and tsunami inundation. Among the most significant geoheritage features are:

- Multiple marine terraces preserved on Shaheed Dweep (Neil Island).
- Fossil and uplifted coral reefs.
- Tidal notches recording successive Quaternary uplift events.
- Wave-cut platforms and coastal cliffs.
- Beach-ridge–swale complexes.
- Drowned forests formed by coseismic subsidence.
- Paleo-tsunami deposits preserved within coastal marshes and beach-ridge systems.
- Liquefaction structures and evidence of repeated coseismic land-level changes.

These geological archives provide invaluable records for reconstructing Late Quaternary coastal evolution, paleoseismic history, and recurrence of megathrust earthquakes along the Sunda–Andaman subduction zone. The field excursion visits several of these internationally significant geoheritage sites, including Mitthakhadi, Collinpur, Kurmadera, Badabalu, and Shaheed Dweep.

10.2 Archaeological and Historical Heritage

10.2.1 Cellular Jail (Kala Pani)

The Cellular Jail, located in Sri Vijaya Puram (formerly Port Blair), is one of India's most important colonial monuments and a National Memorial. Constructed by the British between 1896 and 1906, the prison was used to incarcerate Indian freedom fighters during the colonial period. Its distinctive radial architecture originally consisted of seven wings extending from a central watchtower.

Apart from its historical significance, the Cellular Jail also preserves evidence of regional seismicity. The structure experienced damage during the 1941 Andaman earthquake, making it an important example of the interaction between natural hazards and built heritage. During the field excursion, participants will visit the Cellular Jail to appreciate both its historical importance and its relevance to earthquake engineering and disaster resilience.

10.2.2 Anthropological Museum

The Anthropological Museum in Sri Vijaya Puram provides valuable insight into the indigenous communities of the Andaman and Nicobar Islands. The museum exhibits traditional tools, weapons, ornaments, housing styles, clothing, photographs, and ethnographic information documenting the lifestyles and cultural evolution of the island tribes.

A visit to the museum offers participants an opportunity to understand the long-standing relationship between indigenous communities and the island environment, complementing the geological perspective of the field excursion.

10.3 Indigenous Communities and Cultural Heritage

The Andaman and Nicobar Islands are home to several Particularly Vulnerable Tribal Groups (PVTGs), representing some of the oldest surviving indigenous communities in the world. These include:

- Great Andamanese
- Jarawas
- Onges
- Sentinelese
- Shompens

The present excursion is confined to the Andaman Islands, where the principal indigenous groups include the Jarawas, Onges, and Sentinelese. These communities have maintained distinct cultural traditions and possess extensive ecological knowledge developed through long-term adaptation to the island environment.

The Jarawas continue to practice a predominantly hunter-gatherer lifestyle in the forests of South and Middle Andaman under strict legal protection. The Onges inhabit Little Andaman and maintain a semi-nomadic lifestyle, while the Sentinelese remain voluntarily isolated on North Sentinel Island and are protected under Indian law.

Participants are requested to respect all regulations concerning indigenous territories. Direct interaction, photography, or any disturbance of tribal communities is strictly prohibited.

10.4 Mahatma Gandhi Marine National Park

The Mahatma Gandhi Marine National Park, located near Wandoor on the southwestern coast of South Andaman Island, is one of India's most important marine protected areas. Established to conserve the rich biodiversity of the Andaman Sea, the park comprises numerous small islands, coral reefs, mangrove forests, seagrass meadows, and tropical marine ecosystems.

The park supports an exceptional diversity of marine organisms, including reef-building corals, fishes, sea turtles, dugongs, molluscs, echinoderms, and crustaceans. These ecosystems play a crucial role in coastal protection by reducing wave energy during storms and tsunamis while also preserving valuable records of sea-level change and tectonic uplift.

Although the field excursion does not include detailed scientific investigations within the Marine National Park, participants may appreciate its significance as an outstanding example of the close relationship between marine biodiversity, coastal geomorphology, and active tectonic processes.

10.5 Regional Culture

The Andaman Islands represent a unique cultural landscape shaped by indigenous traditions, colonial history, and migration from various parts of mainland India. The present population comprises people from diverse linguistic and cultural backgrounds, including communities originating from Bengal, Tamil Nadu, Andhra Pradesh, Kerala, Punjab, and northern India.

Fishing, agriculture, coconut and arecanut cultivation, forestry, and tourism constitute the principal livelihoods of the local population. The multicultural society is reflected in its festivals, cuisine, architecture, and traditional crafts, while maintaining strong links with the surrounding marine environment.

The islands have also emerged as an important centre for ecotourism and geotourism, where visitors can experience tropical rainforests, coral reefs, pristine beaches, mangrove ecosystems, and spectacular coastal geomorphology alongside their rich historical heritage.

10.6 Geoheritage Conservation

Many of the geological sites visited during this excursion preserve fragile evidence of past earthquakes, tsunamis, and coastal evolution that cannot be replaced once disturbed. Participants are therefore requested to follow responsible field practices by avoiding unnecessary disturbance of sediment exposures, coral terraces, tidal notches, beach ridges, and mangrove ecosystems. Conservation of these natural archives is essential for future scientific investigations and for improving our understanding of megathrust earthquakes and tsunami hazards in the Indian Ocean.

Local Conveniences



Figure A: Hospitals nearby Port Blair Airport.



Figure B: Police Stations nearby Port Blair Airport

11.1 Where to Shop in Andaman: Best Souvenirs, Apparel, and Markets:

Shopping in the Andaman and Nicobar Islands offers a mix of authentic souvenirs, apparel, and essentials.

• Sagarika Emporium (Port Blair & Havelock) for handicrafts,

• Ramolon for boutique items.

• Cellular Jail's shop for historic memorabilia,

• Aberdeen Bazaar and Goenka in Port Blair are great for apparel.

• Auraa in Port Blair is a go-to spot for handpicked home-enhancing products.

Bargaining is common in local markets and keeping receipts for shell or coral items is advisable. Many shops prefer cash, so carrying some is recommended.

11.2 Help with stolen passport:

1. Report to Local Authorities: Visit the nearest police station and file an FIR (First Information Report) for the lost/stolen passport. Get a copy of the FIR, as it is required for further procedures.

2. Inform the Workshop Organizers: Notify the INQUA workshop coordinators or local hosts about the situation. They might assist in contacting local authorities or embassies.

3. Getting a New Passport or Travel Document- Since there is no foreign embassy in the Andaman Islands, students should contact their country's embassy in New Delhi, Chennai, or Kolkata.

4. Arrange Temporary Identification: Use a digital copy of the passport (if available) or any other ID (student ID, driver's license, etc).

Conclusion

The Andaman Islands are among the most significant natural laboratories for investigating active subduction-zone processes, megathrust earthquakes, transoceanic tsunamis, and Quaternary coastal evolution. Situated along the Sunda–Andaman convergent plate margin, the islands preserve an exceptional combination of geomorphic, sedimentological, and stratigraphic records that document repeated episodes of tectonic uplift, coseismic subsidence, tsunami inundation, and long-term landscape evolution. These geological archives provide invaluable insights into the recurrence and characteristics of great earthquakes that cannot be obtained solely from historical or instrumental records.

The field excursion integrates observations from a diverse range of geological settings, including drowned forests, beach-ridge–swale systems, paleo-tsunami deposits, liquefaction features, marine terraces, uplifted coral reefs, wave-cut platforms, and tidal notches. Detailed investigations at Mitthakhadi, Collinpur, Kurmadera, Badabalu, and Shaheed Dweep demonstrate how coastal geomorphology, sedimentology, geochronology, and paleoseismology can be combined to reconstruct the long-term history of megathrust earthquakes and associated tsunamis along the Sumatra–Andaman subduction zone. These field examples illustrate the response of coastal environments to repeated tectonic deformation and highlight the preservation potential of geological evidence for reconstructing prehistoric catastrophic events.

Beyond its geological significance, the excursion also highlights the close relationship between active tectonics, tropical ecosystems, indigenous cultures, and historical heritage. Visits to the Anthropological Museum and Cellular Jail, together with observations of the unique coastal landscapes and marine ecosystems, provide participants with an integrated understanding of how geological processes have influenced both the natural environment and human history in the Andaman Islands.

The observations made during this excursion contribute directly to improving our understanding of earthquake recurrence, coseismic land-level changes, tsunami generation, and coastal evolution in one of the world's most active subduction systems. Such knowledge is fundamental for refining paleoseismic models, improving probabilistic seismic and tsunami hazard assessments, and strengthening disaster preparedness for densely populated coastal regions throughout the Indian Ocean. Consequently, the Andaman Islands continue to serve as an internationally important field laboratory for advancing research in tectonic geomorphology, paleoseismology, paleo-tsunami studies, Quaternary geology, and coastal hazard assessment.

References

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- https://www.and.nic.in/andaman/tribes.php
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- https://www.go2andaman.com/

Annexure

Field Excursion Guidelines: Do's and Don'ts

To ensure the safety of all participants and to promote responsible scientific field practices, all participants are requested to adhere to the following guidelines throughout the field excursions.

Keep a valid passport (for international participants) or a government-issued photo ID (for Indian participants) with you at all times during the field excursion.

Do's	Don'ts
1. Follow the instructions of the excursion leaders, coordinators, and local authorities at all times.	1. Do not collect rocks, fossils, archaeological artefacts, biological specimens, or any other materials without prior authorization.
2. Remain with the group and inform the excursion leader before leaving the designated route.	2. Do not damage, deface, or remove material from geological outcrops, caves, monuments, heritage structures, or other natural features.
3. Wear appropriate field attire, including sturdy closed-toe footwear, full-length trousers, a hat or cap, and weather-appropriate clothing.	3. Do not wander alone or separate from the excursion group without informing the field leaders.
4. Carry sufficient drinking water, personal medications, sunscreen, insect repellent, and other essential field supplies.	4. Do not climb unstable slopes, cliffs, rock formations, or enter hazardous areas unless specifically instructed or supervised.
5. Keep a valid photo identification and your excursion registration details with you during travel.	5. Do not swim or enter rivers, lakes, lagoons, or coastal waters unless expressly authorized by the excursion leaders.
6. Respect local customs, religious sites, cultural heritage, and private property.	6. Do not consume alcohol, recreational drugs, or engage in unsafe or irresponsible behaviour during the excursion.
7. Follow the Leave No Trace principles by carrying back all waste and helping to keep field sites clean.	7. Do not operate drones or other restricted equipment without obtaining the necessary permissions.
8. Use designated trails and approved observation areas to minimise environmental disturbance.	8. Do not photograph restricted installations, sensitive locations, or local residents without prior permission.
9. Observe geological, ecological, archaeological, and cultural features carefully without causing any damage.	

10. Record field observations systematically and collect samples only with prior permission from the excursion leaders and the relevant authorities.

11. Exercise caution near cliffs, riverbanks, caves, unstable slopes, road cuts, and other potentially hazardous terrain.

12. Respect wildlife by maintaining a safe distance from animals, birds, reptiles, insects, and their habitats.

13. Immediately report any illness, injury, emergency, or hazardous situation to the excursion organizers.

14. Be prepared for changing weather conditions and comply with all safety advisories issued by the excursion leaders.

9. Do not create excessive noise or disturb local communities, religious activities, wildlife, or natural habitats.

10. Do not leave valuables unattended or rely solely on mobile phone connectivity in remote areas.

11. Do not undertake any activity that may compromise your safety, the safety of fellow participants, or the conservation of the area's geological, ecological, archaeological, or cultural heritage.

Disclaimer

Participation in the field excursions is entirely at the participant's own risk. While the Organising Committee and excursion leaders will make every reasonable effort to ensure participant safety and provide appropriate guidance, they shall not be held responsible for any personal injury, illness, loss of personal belongings, property damage, delays, or unforeseen incidents arising during travel or field activities. Participants are expected to act responsibly, follow all instructions issued by the excursion leaders, and comply with applicable local laws and regulations throughout the excursion.













Scan for
Field Guide Book

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