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# Rapid Profiling of Marine Notches Using a Handheld Laser Distance Meter

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**ABSTRACT**

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A rapid, single-user profiling method for rocky shores is described. The Leica Disto D8 handheld laser distance meter measures distance up to 100 m and inclination in 360°. It automatically calculates horizontal distance and vertical elevation. Memory storage accommodates data for 30 measurement points, allowing easy plotting of shore profiles. This technique allows even inaccessible, dangerous, and overhanging cliff faces to be evaluated faithfully and within minutes. It is a major improvement over standard methods that often involve risky coasteering and climbing. Examples are given from marine notches in Thailand.

**ADDITIONAL INDEX WORDS:** *Rocky coast, active tectonics, Thailand.*

## INTRODUCTION

Sea cliffs and rocky shores represent approximately 75% of the world's coastline. Coastal planners and researchers interested in geomorphology often require measurements of the cross-shore topographic profile. Such profile is typically displayed as the elevation from a vertical datum as a function of cross-shore distance. This requirement—as worded by Puleo *et al.* (2008)—yielded a rich variety of methods used to survey beaches, from Emery's (1961) classic work to refinements by Krause (2004), Delgado and Lloyd (2004), and Andrade and Ferreira (2006), *etc.* Inexpensive methods of surveying rocky coasts by staff and spirit levels and by the can-and-tube method are described by Jones (1980) and are especially popular in student courses. All of these methods offer suitable measured profiles in reasonable time, but have significant drawbacks. They can only be applied to terrain accessible by walking and climbing and typically require the participation of at least two persons. This is a problem considering that many rocky coasts, especially those with marine notches and cliff collapse features, are far from being walkable; they might involve rock overhangs and steep slopes that demand a trained climber in the field team.

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The high-tech alternatives are using a total station (Denny amd Gaines, 2007) or terrestrial laser scanning (LIDAR) technology (*e.g.,* Rosser *et al.,* 2005). Both involve costly and bulky equipment and time-consuming setup, making them off limits to many researchers and impracticable for extensive work in remote locations.

Here we describe a method for rapid, single-user surveying of coasts—particularly those bearing marine notches—using a handheld laser distance meter. The technique reported here is being used for an ongoing study of marine notches along the Andaman coast of Thailand (Figure 1), where measuring notch dimension and elevation at a large number of sites is necessary for research on active tectonics (Figure 2).

## METHODS

We use a Leica Disto D8 laser distance meter, manufactured by Leica Geosystems (Heerbrugg, Switzerland). Its current price is approximately US$1200. The instrument is handheld (dimensions: 143.5 × 55 × 30 mm) and runs on two AA-size batteries. Total weight is 205 g. Among a variety of functions, the instrument measures distance and inclination angle between it and some point of interest. It automatically calculates vertical and horizontal projection of the inclined distance (Figure 3). Data can be stored for up to 30 measurement points and transferred to a computer. Stored data can be downloaded by Bluetooth® connection. We had no suitable receiver, so we recorded each data set manually in the field

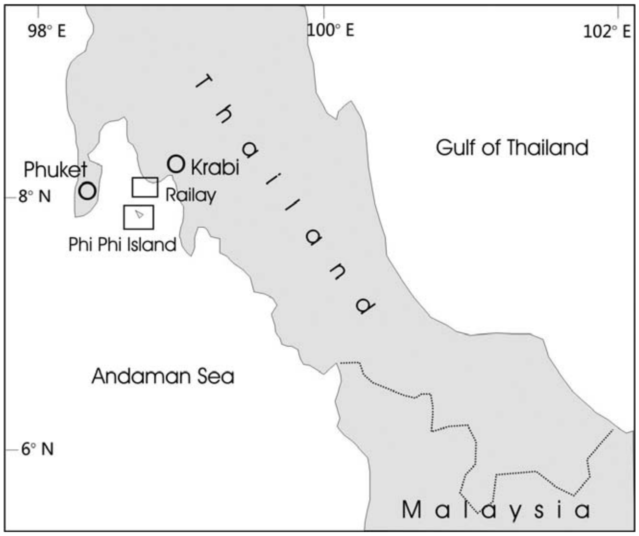


Figure 1. Location of the measurement sites along the Andaman coast of the Thai–Malay Peninsula.

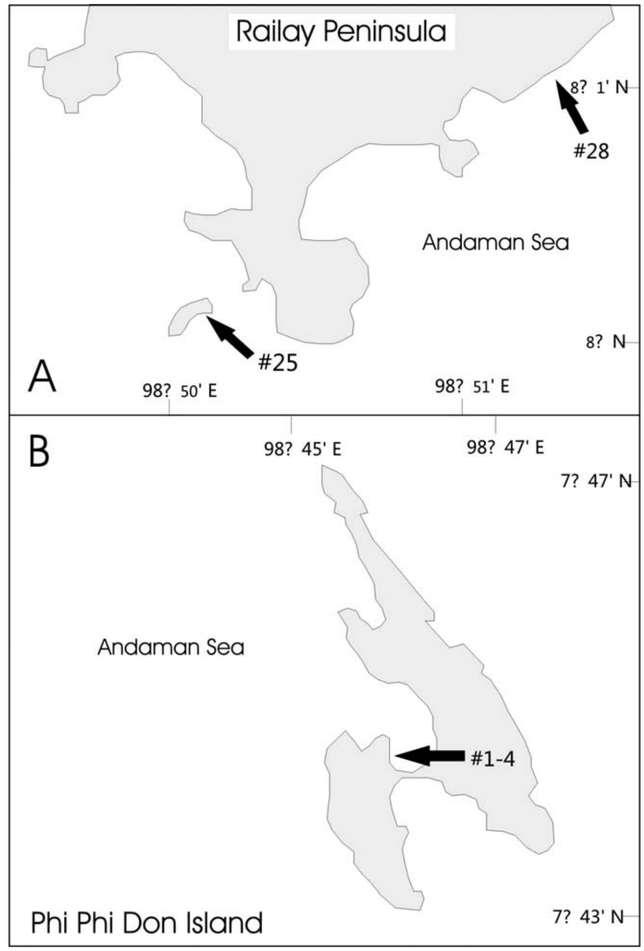


Figure 2. Location of the measurement sites. A. Railay Peninsula. B. Phi Phi Don Island. Arrows point at measured profiles.

notebook. Software can then be used to plot spatial relationships between measured points. In our case, we used Grapher software to draw the shapes of measured rock profiles.

This type of laser distance meter is capable of measuring angle in the vertical plane by a 360° tilt sensor. This capability allows measuring of the profile of a notch roof overhead, even if it extends behind the observer's standpoint. A built-in camera with 4× digital zoom and cross-hairs allows targeting of objects in very bright conditions (Figure 3). The instrument notifies the user of an error in case a biofilm coating, wet or exceedingly rough surface, surface at a low angle to the laser beam, or any other factor fails to provide a reflected beam of sufficient quality.

Measuring range for distance is from 0.05 m up to 200 m with a typical accuracy of ±1.0 mm. Inclination results are accurate to −0.1°/+0.2°. Being a handheld instrument, Leica Disto D8 provides these results as long as the unit is tilted less than 10° sideways. Values for distance are expressed in meters, feet, inches, or yards. The manufacturer recommends measuring on a vertical target plate over larger distances (>10 m). However, we measured distances of inaccessible objects up to 25 m in elevation.

The manufacturer also recommends using a tripod for precision measurements. For geological and geomorphological purposes the millimeter precision is rarely needed. Other kind of instruments, *e.g.,* microerosion meter and laser scanner (Swantesson *et al.*, 2006), can provide reliable results at these scales. We set our instrument to 0.01-m precision only. Instead of carrying a bulky tripod all day, the operator held the instrument tightly to his chest during measurement.

Measurement follows a simple procedure. After measuring a reference point of a known elevation (*e.g.,* benchmark or the actual sea surface—time should be recorded), the height and horizontal distance from the instrument are displayed for each measurement point and stored in the built-in memory.

Problems may occur if the point measured is the sea surface. No reflection can be obtained from the water surface itself (and from similar shiny surfaces). When measuring to the reference point at sea surface, a partly submerged object, *e.g.,* waterline of a boat, will help. (The time of measurement should be recorded and referenced to the local tide chart.) In addition, measurement time can be extended up to 7 seconds, which usually helps when reflection is weak.

We successfully worked with the instrument in the tropics, exposing it to temperatures of up to 35°C and up to 80% humidity. The instrument is not waterproof, which is not a major drawback. The only limitation we found inconvenient is the maximum storage of 30 points. Improved memory with ability to store data for at least 100 measurement points would be more practical for geological applications.

## RESULTS

Three localities along the Andaman Sea coast of Thailand are briefly described here to illustrate practical advantages of the new method of seashore profiling. Most of the classical shore profiling techniques do not allow characterization of

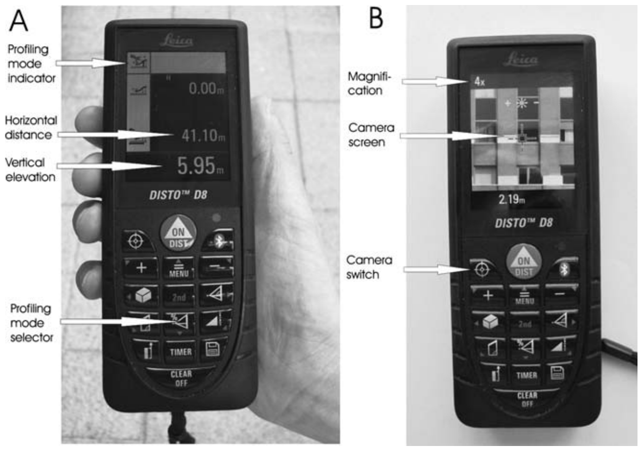


Figure 3. A. The Leica Disto D8 in profiling mode. Pressing the ON button measures horizontal distance and vertical elevation of the point. Data for up to 30 points can be stored in memory. B. The Leica Disto D8 in camera mode. The office building seen on the screen is *ca.* 130 m away. Aiming is with the cross-hairs on screen.

overhanging features. The Leica Disto D8 allows this, even if the overhanging portion of the cliff extends behind the instrument position.

To assess operator error on a simple surface we ran 10 profiles on a single building. Error in horizontal distance between the instrument and a series of points on a flat and vertical wall was used as an indicator of whether the operator can stand in the same position during the measurement and equaled ±2 cm only.

## Seashore Boulder Remeasured Four Times

Vertical profile of a seashore boulder of complex surface on Phi Phi Don Island was measured successively to learn about the reliability of the method: three times from the same position, one time from a relocated baseline (Figure 4). Measurement, writing the data in the field notebook, and recheck for 16 to 24 measured points took 6–8 minutes. A profile with 30 points requires less than 10 minutes of measuring and recording time.

## Double Marine Notch

Profile of a cliff NE of Railay bearing two marine notches was measured (Figure 5). Roof of the upper notch is 7 m above sea level. Normal access for profiling would be by ladder or by free climbing, but Leica Disto D8 made the process easy standing 12 m away from the cliff face.

## Overhanging Cliff

Amalgamated notches on Rang Nok Island at Railay having overhanging portions emerging up to 8 m from the sea were

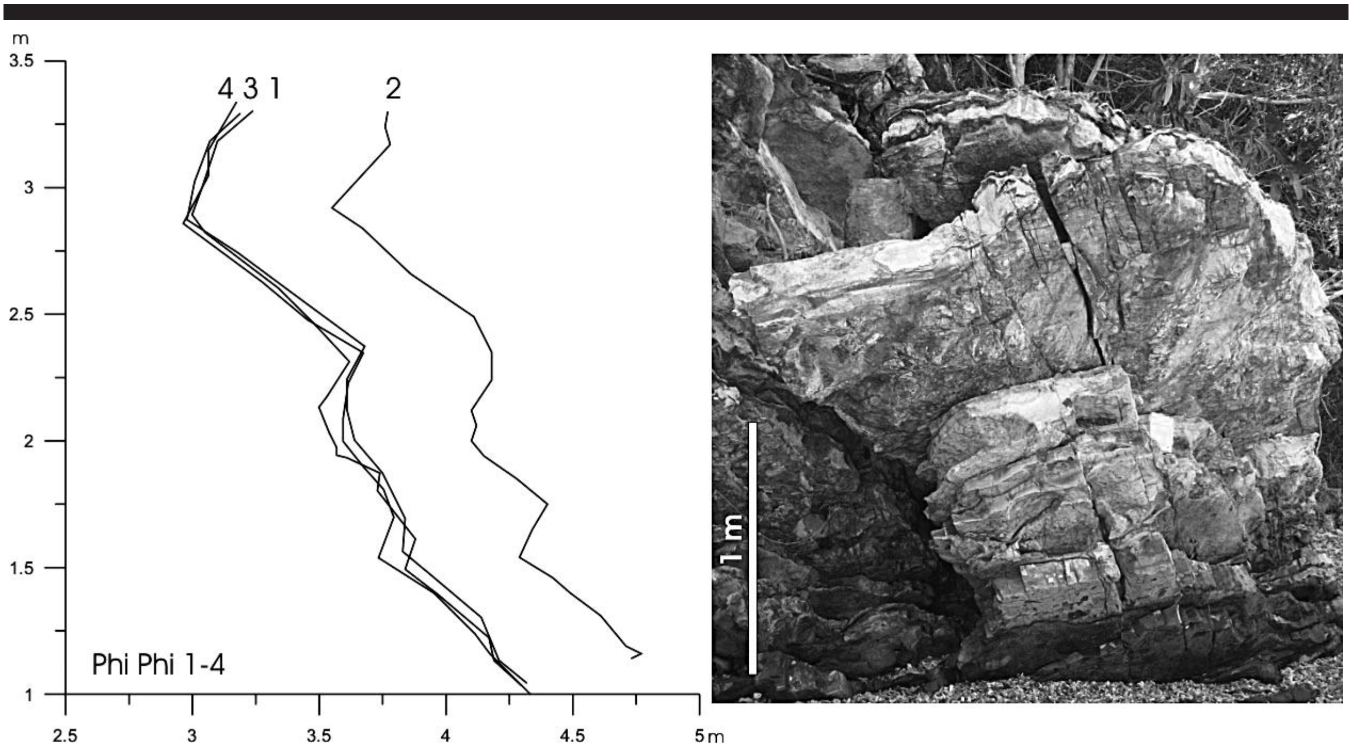


Figure 4. Coastal rock at low tide, remeasured by handheld laser distance meter Leica Disto D8 four times. Measurements 1 to 3 show the minimal error of the method. The curve on the right is displaced by 0.5 m due to a different baseline. However, details of the surface are convincingly similar, assuring us that the method provides reproducible results. Profiles were drawn by Grapher software. Profile #PhiPhi_1 to PhiPhi_4. Phi Phi Don Island, northern bay, western side, Krabi province, Thailand. Photo by M.K., #7713. Site at 7°44′31.1″ N, 98°45′57.3″ E. Scale bar 1 m.

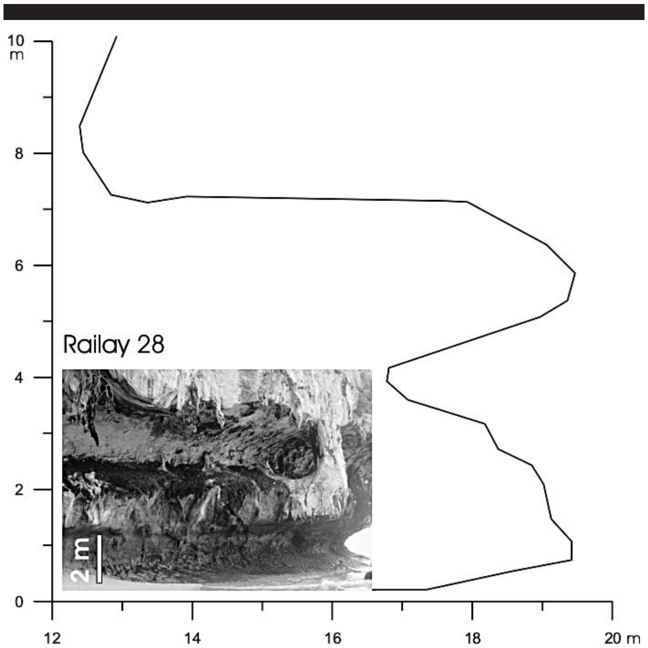


Figure 5. Double notch, 7 m high, top portion is inaccessible. ESE-facing cliff. Fetch of waves 20 km. Profile #Railay_28. Railay NE, Krabi, Thailand. Photo: M. K., #0867. Site at 8°01′17.0″ N, 98°51′21.0″ E. Scale bar 2 m.

profiled at low tide (Figure 6). Here an accurate record of the shape (strictly to scale) is extremely important, because elevation and subsidence history is coded in subtle inflection points of the notch system.

## DISCUSSION

### Why Measure Notches?

Marine notches are grooves formed in bedrock of rocky coasts, particularly in limestone. They develop parallel to sea level by a combination of physical and biological abrasion and biological and chemical dissolution (*e.g.,* Focke, 1978; Kázmér and Taboroši, 2012; Neumann, 1966; Pirazzoli *et al.*, 1994; Pirazzoli, Laborel, and Stiros, 1996; Taboroši and Kázmér, 2012). Marine notches will form in the tidal zone under quiet and moderate conditions, whereas wave-stressed coasts usually lack them, wave undercutting and cliff collapse being faster than notch formation (Sunamura, 1992; Trenhaile, 1987). They are frequently used to assist investigations of relative sea-level change in tectonically active regions (Kershaw and Guo, 2001).

In addition to elevations, the shapes of notches also bear much importance. Pirazzoli (1986, his fig. 4) shows nine scenarios where various notch shapes—including complex multiple notches—record the story of gradual and stepwise changes in relative sea level. He called attention to the importance of recording the detailed shape of any notch, if it

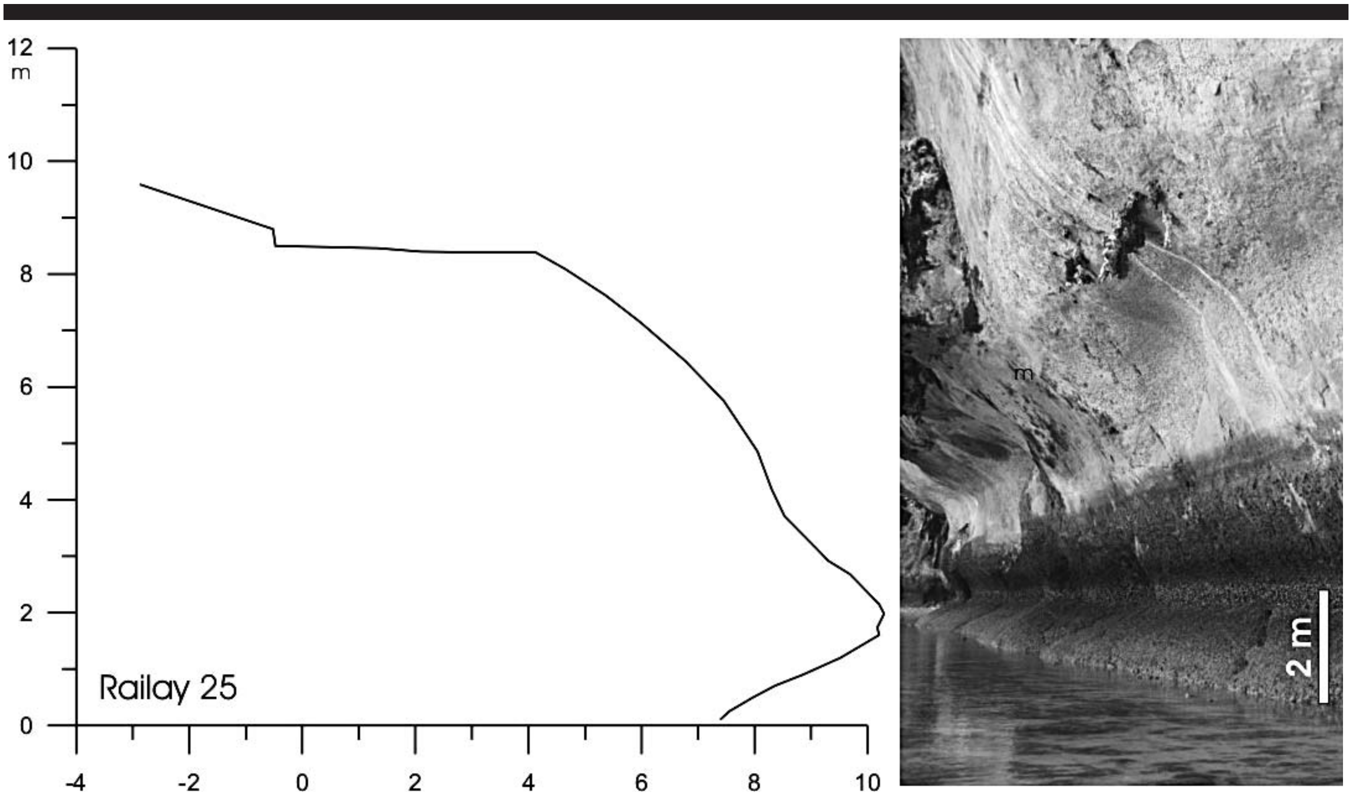


Figure 6. Amalgamated double notch. Site inaccessible for direct contact measurement. Operator is standing on underwater top of coral reef. Overhanging roof extends behind available standpoint. High tide mark at 2.5-m elevation. Active notch and spray zone covered by dark cyanobacterial film. The uplifted, inactive notch (only the roof is preserved) extends up to 8 m elevation, capped by overhanging calcareous tufa. SSE-facing cliff. Fetch of waves >250 km. Profile #Railay_25. Rang Nok Island in Phra Nang Bay, Railay, Krabi, Thailand. Photo: M. Kázmér, #0823. Site at 8°00′16.2″ N, 98°50′11.1″ E. Scale bar 2 m.

Table 1. *Pirazzoli (1986) parameters of the measured notches.*

| Parameters | Railay #25 Lower (Amalgamated Notches) | Railay #25 Upper (Amalgamated Notches) | Railay #28 Lower | Railay #28 Upper |
|---|---|---|---|---|
| Elevation of notch vertex above mean sea level (m) | 0.8 | No vertex | −0.35 | 4.6 |
| Height of notch between edge of roof and edge of floor (m) | 4 | ~4.3 | 2.3 | 2.5 |
| Depth of notch between dripline and vertex (m) | 2 | ~4 | 3 | 7 |
| Dip of rock face (m) | Slightly overhanging | Slightly overhanging | Vertical | Vertical |

is to provide data for minor rises and falls of the sea level. Nevertheless, detailed measurements are rarely the case. In much of the literature, illustrations show a "model" marine notch, possibly made by freehand sketching (*e.g.,* Morhange *et al.,* 2006; Nunn *et al.,* 2002; Pirazzoli *et al.,* 1991).

Pirazzoli (1986) suggested recording notch shape by measuring (1) the elevation of the deepest part of the notch—the vertex—above sea level or another datum; (2) the height of the notch between the edge of the floor to the edge of the roof; and (3) depth of the notch between the drip line and the vertex. The dip of the rock face should also be provided. (See Table 1 for the Pirazzoli parameters for the measured notches.) In case of complex shapes, Pirazzoli (1986: 377) recommends that the profiles be measured in detail, but provides no instructions on how this should be done. Table 1 contains these parameters for the notches we measured.

### Where to Measure Notches?

For the purpose of investigation of active tectonics, notches should be measured in areas where there is a change in lateral consistency: elevation changes of the vertex, floor and roof height, notch depth (the Pirazzoli parameters), and any major change in notch cross-section. Naturally, measurements should be done where there is no topographic shading, *i.e.,* the full cross-section is within line of sight. This requirement is especially important for elevated notches located high above the surveyor.

### Lithology and Environment

The measured rocky coasts are along the Andaman coast of Thailand, in the wider region of Phuket. All sites are exposures of hard, clear limestone—occasionally with chert bands—of Permian age. The open ocean is about 50 km to the southwest; islands and rocks of an archipelago protect the coasts from winds and waves. The sea along the coast is generally shallower than 10 m. Neap tide range is 0.9 m, spring tide range is 2.5 m.

### Notches

At least two levels of notches were observed. The lower one is active, the higher one is supposed to have been formed during the last interglacial. The considerably older age of the upper notch is indicated by frequent infill by tufaceous speleothem-like deposits.

The relative size and proximity of the two notches is variable, even in locations of Railay east (#25, Figure 5) and Railay west (#28, Figure 6), which are a mere 3 km apart. The top of the upper notch is 7 m above low tide in the east and 8.5 m above low tide in the west. The top of the lower notches is exposed even during spring high tide, indicating minor differential uplift during the Holocene. Further studies are in progress to systematically measure the elevation of the notches above sea level along the Andaman coast, and to delineate distinct units of uplift and subsidence.

### Comparison with Other Methods

The tape and rod method (*e.g.,* Kershaw and Guo, 2001 their figure 2C; Pirazzoli, 1986) is the traditional way of measuring marine notches. The laser distance meter seems to be superior in profiling overhanging and inaccessible sites, up to a distance and elevation of 20–30 m, depending on light and reflectance conditions. However, it is probably inferior in profiling erosional platforms, beaches, and any other feature lying at low angle to the handheld laser beam.

For erosion rate studies, we think that laser scanning (*e.g.,* Gómez-Pujol and Fornós, 2010; Gómez-Pujol, Fornós, and Swantesson, 2006) is superior to our method. The accuracy of handheld field equipment cannot compete with a stabilized instrument on tripod.

The advantage of the Leica Disto D8 is in its small size, light weight, and easy operation. We consider it a truly excellent tool for the needs of the field geologist. The instrument is easy to carry all day, needs no setup time, consumes little battery power, and allowed M.K. to measure tens of profiles per day, while walking several kilometres along the coast, more often than not wading in the sea up to waist depth.

## CONCLUSIONS

A single-user method to profile coastal cliffs, especially those with marine notches, is described. The Leica Disto D8 laser distance meter instrument provides the necessary accuracy, even in places where direct access is difficult, unfeasible, or dangerous. This method offers a sound, reproducible way of examining vertical distribution patterns of morphology and biology of rocky coasts, leading to results to be used in studies of coastal erosion and past sea-level changes. To the best of our knowledge, this is the first attempt to provide exact, reproducible measurements of marine notches.

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