# R E P O R T

## from
## a research journey to Sri Lanka


**by**

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## Mörner & Tooley to Sri Lanka March 12-19

We landed 04.00 in Colombo. No one was there to meet us. What to do. We had no address to go to, and we had no telephone number to ring; we were stuck. At about 5.30 a man suddenly turned up. Dr. Epitawatta. We were saved.

We went to the institute (PGIAR) of Kelaniya University. We had a meeting with Prof. Lakdysinghe. Our program was set up. The mission could start.

Monday 12

We inspected the sediment samples of Premathilake and discussed some issues in his recent Licentiate-thesis. Then we packed up the van and set off for his thesis area, the Horton Plains. We passed lovely scenarios. Made a stop in the botanical garden of Penadeniya. We arrived, just before dawn, at Nuwara Eliya where we spent the night. After dinner. I had a long talk with Premathilake about his thesis and about Horton Plains.

Tuesday 13

We set off for Horton Plains. We stopped in a pit with a very instructive section of weathered gneiss (Fig. 1). Here, we had our evidence of a long term weathering; probably some millions of years. The weathering was selective affecting the gneiss differentially all depending upon the internal gneiss structural composition. Primarily it the feldspar that weather, leaving the quartz intact.

Fig. 1. Gneiss weathering.

Fig. 2. The forest on the way to the Horton Plains.

We passed the forest (Fig. 2) and saw the tree ferns growing on the slope. They are a characteristic of rain forest, and were hence, very correctly, included in the total pollen count by Premathilake.


Fig. 3. Black soil on top of weathered gneiss. Red dot = C14-date ~7000 BP.

We passed the soil which had been radiocarbon dated; the base at 6970 ±80 BP (Fig. 3). Dating of soil is very problematic, because soil formation is an ongoing process, hence continually altering the apparent age of the soil. This has been well studied by others. This “soil” has rather the character of a soil-peat than a soil profile, however. The section need to be pollen analysed in order to validate the ages obtained.


Fig. 4. The swamp where Site 2 is located.

We passed the swamp where the core named Site 2 had been taken. It is very interesting – and important – that the sedimentation does not start, in this depression, until about 6600 BP. This is a point hat must be discussed in greater details. In Site 1, the sedimentation began with the improvements after the LGM local climatic conditions in Horton Plains. In Site 2, the onset of sedimentation began nearly 10,000 years later. Why? This question must be addressed and clarified. Can there be a correlation with the sand layer at ~2.5 m in Site 1 (despite some differences in radiocarbon age)?

Premathilake has a lot of data that need better presentation and discussion. Not least the sedimentary characteristics and sedimentary dynamics. It is utmost interest to discuss the absence of older interglacial deposits and the obviously quite heavy erosion at LGM- time. The erosion and deposition of eroded weathering products more or less barren of organic matter at LGM must be discussed and utilised in the comparison with the pollen information. Pollen say dry LGM. The erosion and redeposition of sediments seems to speak of, at least seasonally, heavy precipitation. The charcol presentation must not be in % of pollen sum but in a unit like grains per microscoping traverse, or so. Premathilake has a lot of core profiles and singular cores that are not discussed in the thesis. All this material is a great interest for the understanding of the sedimentary dynamics. The sand layer in Mid-Holocene time at Site 1 is of great interest. It must be discussed and put in a wider context. Can it be correlated with the base of Site 2 and the onset of peat formation in Fig. 5?

Premathilake is in the possession of a lot of data, which – we hope and propose – will be used in an extensive and penetrating description of the Horton Plains. This top-interesting area must be given the description it deserves. We need a new “chapter 1” in a Ph.D.-thesis that provides a monographic type presentation of the Horton Plains paleonvironment.

Fig. 5. Black soil on gravelly layer of down-slope redeposited weathering grains.

Fig. 6. Occasionally there is a “double” soil divided by a gravel layer. This is an ideal site for pollen analysis in order to decipher the chronology and paleoenvironment of the sequence.

Along the trails, there are cut ditches which offer good and instructive section for the insight to the sedimentary dynamics. In Fig. 5, the change from down-hill movement of reworked material in the form of a gravel bed, quite abruptly is overlain by a peat. This records a drastic and rapid change in environmental conditions. When did this change take place? In the same ditch section, one occasionally find small depressions where there is a "double" soil (Fig. 6). The upper gravel bed obviously correlate with the top gravel in Fig. 5. Hence the lower peat predates the last phase of down hill movements. This means that we can identify 4 stages:

1. The upper peat, a period with dense vegetation.
2. The upper gravel unit, a period with little or no vegetation and heavy erosion.
3. The lower peat, an initial period with vegetation.'
4. The lower gravel unit, a period with little or no vegetation and heavy erosion.

Intuitively, one is tempted to suggest that Premathilake's Site 1 covers all 4 stages, whilst his Site 2 only covers the last 2 stages. The ditch section deserves more work.

We visited the scenic sites of "world's end" and "Baker Falls". A long, partly very beautiful, drive took as back to Colombo at 23.30. A long very interesting and wonderful day ended (not mentioning the writing up of the above text).

<u>Wednesday 14</u>

After a long waiting, our new guide, Dr. Adikari, turned up at 13.30 and we immediately set off for Tissamaharama where we arrived at 21.50 after a long and partly wild drive.

The frat plains west of Ratnapura caught our interest. Here sediment had been accumulating and piling up by alluvial processes. Here was a potential place of accumulation of all the sediments that had been eroded and gone on the Horton Plains. Hence, this area is a potential area for the recording of Last Interglacial, and older, deposits.

Dr. Adikari directed us to the book *Geology of Sri Lank*a by Cooray (1984, p. 136) and the discussion of the *Ratnapura Beds.* This gives a very good description of reworked and redeposited sediments. The fossil content is mixed but includes species suggesting Last Interglacial or even Mid-Pleistocene age. Obviously, we here have the missing beds from yesterday on the Horton Plaines. This cyclic sedimentation must, of course, also be recorded in the off-shore stratigraphy. This raises the interest of seismic profiling off the coast. The Ratnapura Beds should be subjected to modern pollen analysis.

<u>Thursday 15</u>

Early off for a full day studying sites along the coast between Kirinda and Tangalle.

<u>Site 1: Kirinda:</u> A coast dominated by a large number of core-stones, some of gigantic size. We identified 3 units:

(1) The present shore whith no real records of higher Holocene levels, except for one site where there are erosion and single deposition at about +2 m (this may, however, be due to lateral shore progradation).

(2) An old beach-rock at about ±0 m (Fig. 7). Age unknown.

(3) Erosion and shingle deposition (rounded weathered pebbles) at about +8 (10) m. This may be a Last Interglacial beach, if approved.

Fig. 7. Kirinda beach; beach-rock (green) and present sandy beach at the same level.

Passing the estuarine flat inland, we noted at somewhat higher depositional level by about 20-30 cm. As the outermost part is still wet and not overgrown, it seems to be very young. “Yes, it was more open water 30 years ago”, says Adikari. So, either sea level has fallen (like in the Maldives Islands) or the estuarine level has fallen due to decreased river discharge (the building of the Uda Walawe dam) or a combination of both. The higher estuarine plane continues over a wide area.

Site 2. Bundala Sanctuary: A back-lagoon, previously suffering bad flooding, has been opened to the sea by the digging of a channel through the coastal barrier. The walls of the channel must offer excellent sections for investigations. Adikari told us that artefacts and shells had been found, the shells being radiocarbon dated at 28 Ka. A 28 Ka shell date surely only represent a minimum age and the true age is likely to be the Last Interglacial. Therefore, it is significant that TL ages of a correlative sand bed gave around 70 Ka.

Along the route, we passed estuarine planes that seemed stepped with one plain at about +20-30 cm (Fig. 8) and another at about +50 cm.

Fig. 8. The estuarine plain goes up to +20-30 cm, and even up to +50 cm.

Site 3. Pallemalala (Bundala): A shell mound beneath 57 cm of silty estuarine clay. The shell mound is believed not to be a midden but a burial mound. This seems reasonable as so many people (some 20) are buried in the shell mound). Below the shells, there is estuarine mud. This may be taken to indicate a different paleogeographic setting as compared to today. The sea may have been much closer (~1 km now). The section (Fig. 9) was sampled by Tooley for pollen and microfossils.

Fig. 9. The Pallemala shell mound and covering estuarine clay sampled by Tooley (red dots).

Site 4. Kalamatiya: shell bank beneath estuarine silt. Here people have been "mining" for shells and cut a very large number of pits up to 2-3 m deep. The first pit we visited had a very odd stratigraphy. Something was wrong; mans digging and refilling, or some geological severe disturbance. One structure looked very much like liquefaction venting and lateral mushrooming. In an other pit we found a sequence that seemed representative (Fig. 10).

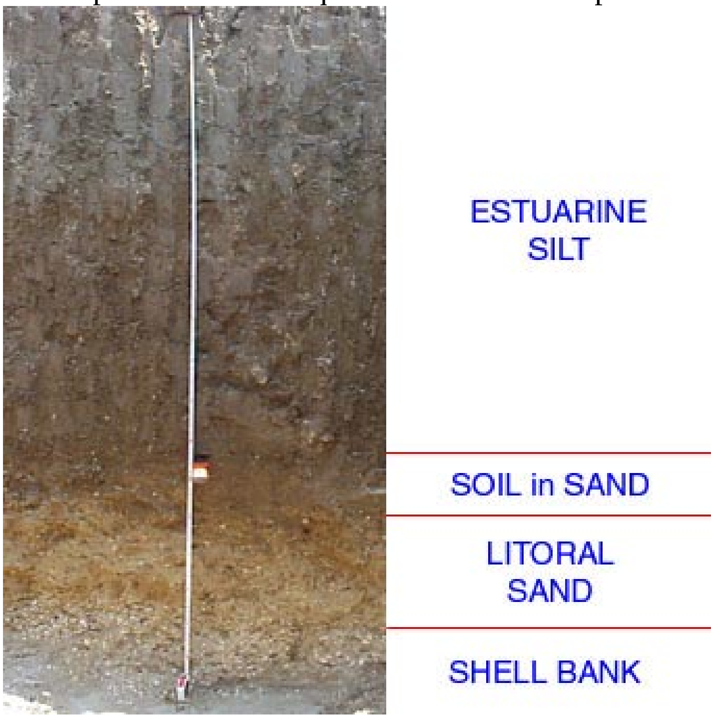


Fig. 10. The complete Kalamatiya section sampled by Tooley.

The following sequence was recorded and sampled at every 10 cm interval (Fig. 10).

| | |
|---|---|
| 0-114 cm | estuarine silt (maybe mangrove silt) |
| 114-131 cm | humic sand, interpreted as a land surface soil |
| 131-156 cm | brown sand interpreted as beach sand |
| 156-180 cm | shell-bank in sand |
| below | zone with artefacts, bones and charcoal; a habitated land surface |

This sequence was sampled by Tooley for pollen and microfossils. By measuring to ground water level, which we assumed approximated mean sea level reasonably well, we obtained:

The shell bank need a sea level higher by about +0.8 m

The soil (sand) need a land surface above about +1.0 m

The estuarine silt need a water table +2.0-2.2 m (fluvio-estuarine above mean sea level)

Whilst the Fig. 10 section was being sampled, Mörner investigated other pits (Fig. 11) which exhibited something very surprising; evidence of liquefaction and venting of liquefied material – in this case: sand, shells and humus (with sorting according to density). A white sand becomes liquefied (now structureless) and tries to vent through the covering silt. The silt deforms and sink down (where sand flows away). The shells, being lighter, float on the sand, pressing on at the base of the silt. The soil, still lighter, floats, too, and vents. The silt deforms and may even fragment into silt "pebbles". The liquefaction was induced by an earthquake.

Fig. 11. The pit exhibiting liquefaction and venting structures of a paleoseismic event. The white sand (not present in Fig. 10) is the main liquefaction bed (therefore it is now structureless). It tries to vent through the estuarine silt. The shells and humus floats on the sand and vent into the silt.

Figs. 12 and 13 shows close-ups of the liquefaction/venting structures. Liquefaction is a sort of phase change; from solid sand to fluidized sand. This fluidization change – liquefaction – is brought about by ground shaking; i.e. an earthquake of a magnitude, not less than 6.5 (6.0) on the Richter scale. The present paleoseismic event occurred after the deposition of the silt.

Fig. 12. The liquefied sand tries to vent upwards (red arrow). The shells float on the sand and are pressed against the base of the silt and vent in a wedge upwards. The humus is floating, too, here compressed into a layer, including “pebbles” of silt, between the sand and the silt.

Fig. 13. The whole silt bed is floating on the liquefied sand (hence the undulating boundary) and shells have vented into the silt along a thin channel.

Site 5. Ussangoda: Bauxite laterite weathering and old volcanic ash beds. We looked for signs of higher sea levels. There are no indications present in this section of any higher Holocene level (at the most +0.5 m). Nor are there signs of any Last Interglacial level. In the water outside, there are coral reefs. Hence this is a good site for off-shore studies.

Fig. 14. Ussangoda. Red lateritic bauxite weathering above an old lithified volcanic ash bed.

We ended this day at 19.00. We were all very satisfied after a splendid day. We had found the first – to our knowledge – evidence of paleoseismic events in Sri Lanka. We had take two important sequences of samples. We had learned a lot about former sea level changes. The Kalamatiya area cries for a separate investigation. The estuarine plains are ideal for coring.

Friday 16

At 08.30 we left for Colombo driving along the coast for a general impression of the coastal structures. We saw extensive beach-rock beds at about present sea level or just below. It would be interesting to know their age. In general, we saw no clear evidence of higher Holocene sea levels (that means not higher than 0.5 m, or so). Nor did we see any traces of a higher Last Interglacial level. As we just drove-by, much better studies are required, especial estuarine and back-barrier coring an micropaleontological studies.

Site 6, Gadawaya: A Buddha temple from about 200 AD which had collapsed, the roof falling in (Fig. 15), the entrance stepping stones being displaced in various directions, and erected stones besides being tilted over in various directions (Fig. 16). The site is being excavated by support from the Bonn University. We must ask us why and when was the temple destroyed. We find it very tempting to advocate a paleoseismic event causing all the deformations recorded (Figs. 15-16) and we think of our findings yesterday at Kalamatiya.

Fig. 15. Godawaya. The roof of the temple has fallen down (covering a graining stone).

Fig. 16. Godawaya. The stones are tilted in different directions. It is tempting to think in terms of a paleoseismic event, and a possible correlation with the event recorded at Kalamatiya.

At 15.50 we arrived in Colombo and at 16.00 started our university lectures. Some 20 persons attended the meeting. Prof. Lakdysinghe introduced the speakers.

Mörner: Sea Level Changes

Tooley: Storm Surge Signatures

We discussed mutual scientific problems and in particular the interaction of sea level changes, climate, changes in oceanic and atmospheric circulation (the monsoonal regime), archaeology and the new finding of paleoseismic events. We also discussed the proposed sea level changes in the future. Both speakers gave strong arguments against any disastrous future flooding scenarios. The speakers were warmly thanked by Prof. Dahanayake. Another good day ended.

Saturday 17

This day was spent at the PGIAR institute. Somadeva introduced us to his studies of the changes in habitation in the coastal plain of Kirindioya–Tissamaharama area. We were both impressed by the amount and sharpness of collected data, the reconstructions offered and the interpretations given. The interaction between flood plain evolution and habitation is striking. We have to consider the building up of sedimentary cover in response to time, sea level changes, precipitation and sediment transport down the plain.

22 samples have already been taken from two sites – Bundala and Kalamatiya – for paleoenvironmental reconstructions employing pollen, diatoms and foraminiferal analyses. Whilst these analyses will provide information about the environmental conditions that prevailed at these sites they are not associated directly with habitation sites or with the paleo-hydrology of the Kirindioya floodplain. A two-pronged strategy is essential:

1.Samples are required from a site where in situ sherds, artefacts and charcoal associated with human habitation have been recovered. It is preferable that samples for paleoenvironmental reconstructions are taken from the same units with cultural remains and at the same time as the archaeological excavation.

2. Water-logged sites need to be identified in the floodplain of the Kirindioya particularly with in situ organic material from which pollen and other microfossils can be extracted. The analytical results will provide data on the regional vegetational history of the floodplain, changes in water quality (fresh to brackish and marine) and discharge conditions. Conclusions can be drawn about climatic phases affecting the coastal plain and therefore habitability, sea level changes and vegetation.

We continued the discussions with Premathilake, Somadeva and Adikari. Somadeya and Adikari stressed the importance of phytholite studies in cross-sections including both more elevated areas and flood plain pits. We all agreed in this. We visited the impressive library of PGIAR. Finally, Premathilake introduced us the his undergraduate class and asked us for communications.

Mörner talked about sea level and related problems

Tooley talked about the importance of paleoenvironmental studies

Some 25 students attended. The presentations were followed by discussions. One of the students, Wijesinghe, introduced us to the old legend of a major sea level flooding some 2200 years ago. The possibility of ground radar studies of coastal plain areas was discussed.

From the topographic maps, we saw that there was an excellent paleo-shoreline recorded in the –10 fathom contour. Obviously, we here have an ideal site for off-shore investigations by diving and sediment coring.

In the evening, we had dinner with Dr. Katupotha. We discussed sea level changes and coastal evolution. His coral reef sites in SE Sri Lanka must, in one way or the other, be incorporated in the integrated history of the coastal evolution and settlement dynamics.

We also touched upon the question of an international symposium in SE Sri Lanka right after our big international sea level meeting in the Maldives in March 2003. And so we ended another splendid day in Sri Lanka (which happened to be the birthday of the author).

Sunday 18

This day was devoted to an excursion to the coastal zone north of Colombo up to a point north of Puttalam. Dr. Epitawatta was our leader, assisted by Premathilake. Start 08.30 back 21.00. We discussed the immigration of species like coco-nuts, bananas and chilli, which was said to remain unknown, and chances to trace them by palynological studies.

Site 8, Dekovita (near Elakanda): A sequence of beach barriers and back-barrier swamps which southwards are said to connect with erosional steps in a slop. The back-barrier swamps are likely to offer good stratigraphic records for pollen analysis and micropaleontology. Off the present beach there is a beach-rock. Around Madampe (and Chilaw), there is an extensive back-barrier swamp, ideal for coring.

Site 9. Mundalama: An old beach-barrier rises high over the out plain and lagoon (Fig. 17). On the back-barrier side, there is an elevated estuarine plain. Here, is an ideal area for a levelled and cored profile of the Mid-Holocene sea level high stand. Shortly north, an other shore flat extends outside the beach which now is much lower in elevation. The corresponding high Holocene sea level may be in the order of +2 m, or so.

Fig. 17. Mundalama. View from the in land beach-barrier out over the present lagoonal area with bordering back-barrier flats, and the present beach-barrier in the distance.

We followed the inner beaches and plains from assumed Mid-Holocene time towards the north. The entire coastal zone from Colombo to Kalpitiya is dominated by beaches and beach-barriers built up by long-shore drift from the south towards the north.

Site 9, Puttalan Limestone Quarry: The limestone is said to be of Miocene age. If so, I would guess it is about 10 Ma old. The surface is very heavily affected by dissolution. The disolution surface is seen both as filled depressions in the quarry walls (Fig. 18), and in a 3D cleaning so the surface stands out in full relief (Fig. 19). The leached depression are filled by a chocolate-brow silt and clay. A similar bed, up to 10 m thick, is covering the entire quarry. It is the weathering products, but it seems to have accumulated by wind (loess fractions). The Miocene beds consist of calciarenite, glauconite clay-silt-sand and limestone with marine fossils.

Just outside the quarry, we found a hanging grey silt bed that seems to represent a younger estuarine back-barrier plain. The elevation seems to be in the order of +20-30 m, and it may hence – preliminary and hypothetically – represent the 2.9 Ma sea level high stand. A lower plain, with weathered surface, might be our Last Interglacial shore-plain. All this is nothing but speculations until the area has been levelled, sampled and dated. We just point out the area as a potential target for further studies.

Fig. 18. The Quarry wall, a covering, probably short distance wind blown, chocolate-brown silt-clay (above), a strongly weathered limestone surface, and the Miocene beds.

Fig. 19. The cleaned 3D surface of the weathered limestone surface.

By this we ended our last day – this time – in Sri Lanka. We thanked our hosts for a most perfect time in terms of scientific achievements and overwhelming hospitality.