netic similarity with other Hindu caste populations. High rate of admixture with local caste populations and high extinction rate of Y-haplotype[2] might account for the apparent absence of YAP+ve lineages among Sunni Muslims. Shiya Muslims on the other hand, due to their less numbers, may have remained more culturally and genetically isolated within their communities. Under these conditions, ancestral Y haplogroups may have survived and persist till date. However, analysis of RPS4Y–'T' chromosome that occupies a high hierarchical position of haplogroup 'C' in the Y-binary tree[3], will provide a clear lineage, as Zerjal *et al.*[30] have reported that about 8% of males belonging to 16 different populations from Pacific to Caspian Sea show haplogroup 'C' lineage, often considered as genetic legacy of the Mongols.

The present study explores the presence of YAP+ve lineage in Shiya. Our study suggests that this could have been one of the founder lineages as the Shiites migrated into India, as revealed by the presence of YAP/M145/M203/SRY4064 lineage and its nearly similar frequency to those found among Middle Eastern populations, which are in all probability the source of Indian Muslim populations. Historians have demonstrated in the past that Shiya Muslims were less effective in converting other groups of people to their religion compared to Sunni Muslims.

Examination of additional diagnostic Y-specific haplogroups in the YAP–ve lineage as well as mt-DNA lineages may help further ascertaining the male-driven gene flow observed in the present study.

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Co-seismic and post-seismic displacements in Andaman and Nicobar Islands from GPS measurements

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We calculate the displacements of four sites in Andaman and Nicobar islands from Diglipur (13.16°N) to Car Nicobar (9.22°N), using GPS measurements made at these sites in September 2003 and repeated in February 2005, assuming that the inter-seismic displacements at all these sites can be represented by the 14 ± 2 mm/yr convergence between CARI near Port Blair and Bangalore, reported earlier on the basis of GPS measurements made by us between 1996 and 1999. Since the latest measurements were made after about a month of the great Sumatra event of 26 December 2004, and several moderate earthquake ruptures had since occurred adding to the co-seismic surface displacements, the values reported here also represent the contributions of aftershocks. Rigorous analysis of the two epoch GPS datasets from these sites yields precise displacement vectors, among which the one at Car Nicobar has the largest horizontal magnitude (6.49 ± 0.009 m to the WSW) with a significant 1.1 m subsidence. The horizontal displacement at Chatham Island near Port Blair is also similarly oriented, but smaller (3.53 ± 0.010 m) with reduced subsidence. Further northeast of Port Blair, the Havelock Island site shows an even smaller hori-

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zontal displacement (1.6 ± 0.013 m) to SW and nothing significant in the vertical while Diglipur, the northernmost Andaman site shows a much larger horizontal displacement (4.78 ± 0.008 m) to the SW, and a significant uplift of ~0.6 m. While these results are broadly consistent with the largely thrust component of earthquake fault slips reported by several workers on the basis of seismic fault mechanism studies, the southern components in the displacements of the northern sites require significant dextral slip contributions that may have been made by some of the moderate aftershocks or by slower ones or by aseismic strike-slip movements along the northern subduction boundary.

THE 26 December 2004 Sumatra–Andaman Island earthquake rupture ($M_w = 9.3$) and the associated tsunami caused widespread damage around the Indian shores, taking a heavy toll of life and property, it was also felt as far away as the American coasts. It is the largest earthquake to have rocked the globe in the past 40 years since the formulation and test of the theory of plate tectonics. The earthquake was caused by a mega thrust along which the eastern Indian Ocean slipped beneath the Indonesia–Andaman Islands of the Burma microplate (Figure 1 *a*), along a giant rupture that instantly (~3 min) (http://neic.usgs.gov/neis/poster/2004/20041226.html) broke a 600 × 50 km interface from Sumatra to Nicobar, and thereafter more haltingly right up to the northern Andaman.

The 200–400 km long Burma ribbon plate, squeezed between the Indian and Eurasian plates, extends from a zone of deformation in southern Burma, through the Andaman and Nicobar Islands to northern Sumatra. It is bounded on the west by the thrust-fault system that outcrops at the Sunda trench, and on the east by a zone of strike-slip faults and normal faults that pass east of the Andaman and Nicobar Islands.

While the main shock fault displacements and the northernmost extent of the rupture are still being debated, aftershocks suggest that it propagated 1300 km from an epicentral region at 3.3°N northwards[1]. Bilham *et al.*[2] estimate that reverse slip in the Nicobar Islands (7°N) was more than twice as much as the slip in the Andaman Islands (12°N). West southwestward over-thrusting of the eastern Indian Ocean lithosphere by the Andaman during the 26 December earthquake resulted in wide-spread adjustments in the elevation of the islands. Initial estimates[3] of the subsidence of the east coast of Car Nicobar (8°N) from oblique air photographs and shoreline damage are of the order of 1–2 m. Several observers in different parts of the islands[4] have also suggested various other figures.

The tectonic grain (Figure 1 *a*) of the Andaman and Nicobar Islands[5,6] is parallel to the plate boundary separating the Indian and Sunda plates east of the 90°E ridge. The Andaman–Nicobar ridge acts as a small tectonic plate bounded to the west by a subduction zone and to the east by strike-slip faults and spreading centres that extend northward to join the Saggang fault system in Burma. This plate has been referred to as the Burma microplate[7] or the Andaman plate[8], and its edges absorb part of the oblique convergence of 5.5 cm/yr between the Indian and Australian plates with respect to Eurasia. Three large historical earthquakes are known to have occurred[2] in 1847, 1881 and 1941, two of which at least produced modest tsunamis on the Indian coast[9]. Ortiz and Bilham[9] estimated the recurrence time for the 1881-type events to be 114–200 years on the basis of inferred GPS convergence rates[10] and inferred closure vectors.

GPS measurements (Figure 1) at Diglipur, Port Blair, Chatham Island, Havelock Island and Car Nicobar were first made in September 2003, jointly by C. P. Rajendran and Anil Earnest, CESS, Trivandrum and Souvik Banerjee, C-MMACS, Bangalore to pursue their respective research projects. After the 26 December 2004 Sumatra earthquake, we established eleven new sites (Figure 1) in January–February 2005, mostly in northern Andaman, and independently reoccupied four of the 2003 sites, excepting Port Blair. In both the field campaigns we used Trimble 5700 receivers with Zephyr antennas mounted on bipods except for Port Blair and Havelock, where screw-mounted tribachs were used to mount the antenna.

GPS data were processed using GAMIT/GLOBK software, along with the IGS stations: HYDE, IISC, NTUS, MALD, BAKO, COCO, DGAR, KUNM, WUHN, LHAS, KIT3, POL2 and SELE. Among these, only the last four were constrained to their ITRF coordinates and velocities with standard errors provided by IGS. Since the IGS stations located in the northern Indian Ocean (BAKO, COCO, DGAR, IISC, NTUS) were expected to have been disturbed during the earthquake, we constrain these stations loosely in our analysis along with the IGS sites KUNM and WUHN, so as to accommodate the effect of the earthquake. HYDE and MALD were not constrained as they are not in the ITRF 2000 solution. Coordinates of all the stations included in the analysis are estimated in ITRF00 reference frame, thereby obtaining the time series of their north, east and up coordinates. Figure 2 *a–d* gives the pre-seismic and post-seismic scatter in the north, east and up for the four stations with repeat measurements, which in turn yield the displacements suffered by them on account of the usual movement expressed by their inter-seismic rates plus those caused by the 26 December Sumatra rupture and post-seismic displacements. The CESS group has reported (http://www.seires.net/content/view/123/0/) horizontal shift, showing a southwestward movement for the islands from their preliminary estimates.

In order to obtain the co-seismic and later added displacement at these sites, we need to subtract from the above values their respective inter-seismic displacements, which are expected to be of the order of mm/yr. However we have knowledge of only one inter-seismic displacement rate (48.51 ± 2.1 mm/yr N38.5°E)[11] from earlier measurements at CARI. We assume this will be representative of those at all the other three sites, since these are in similar tectonic settings

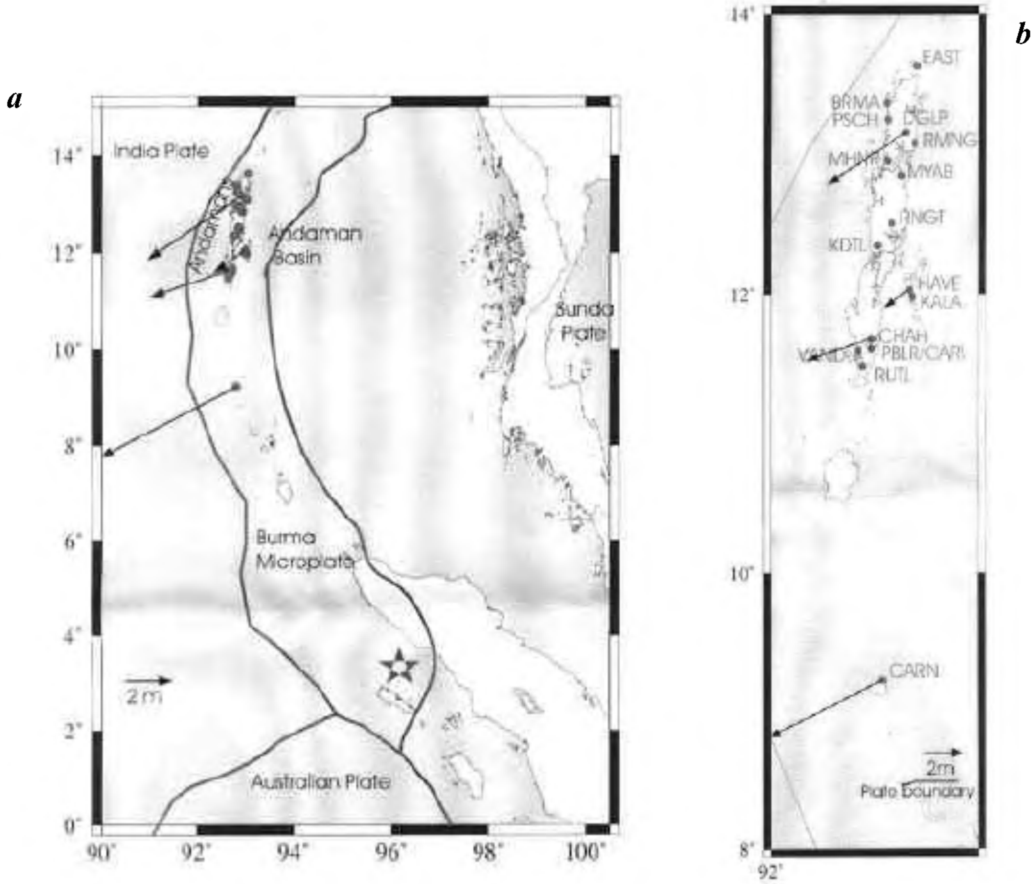


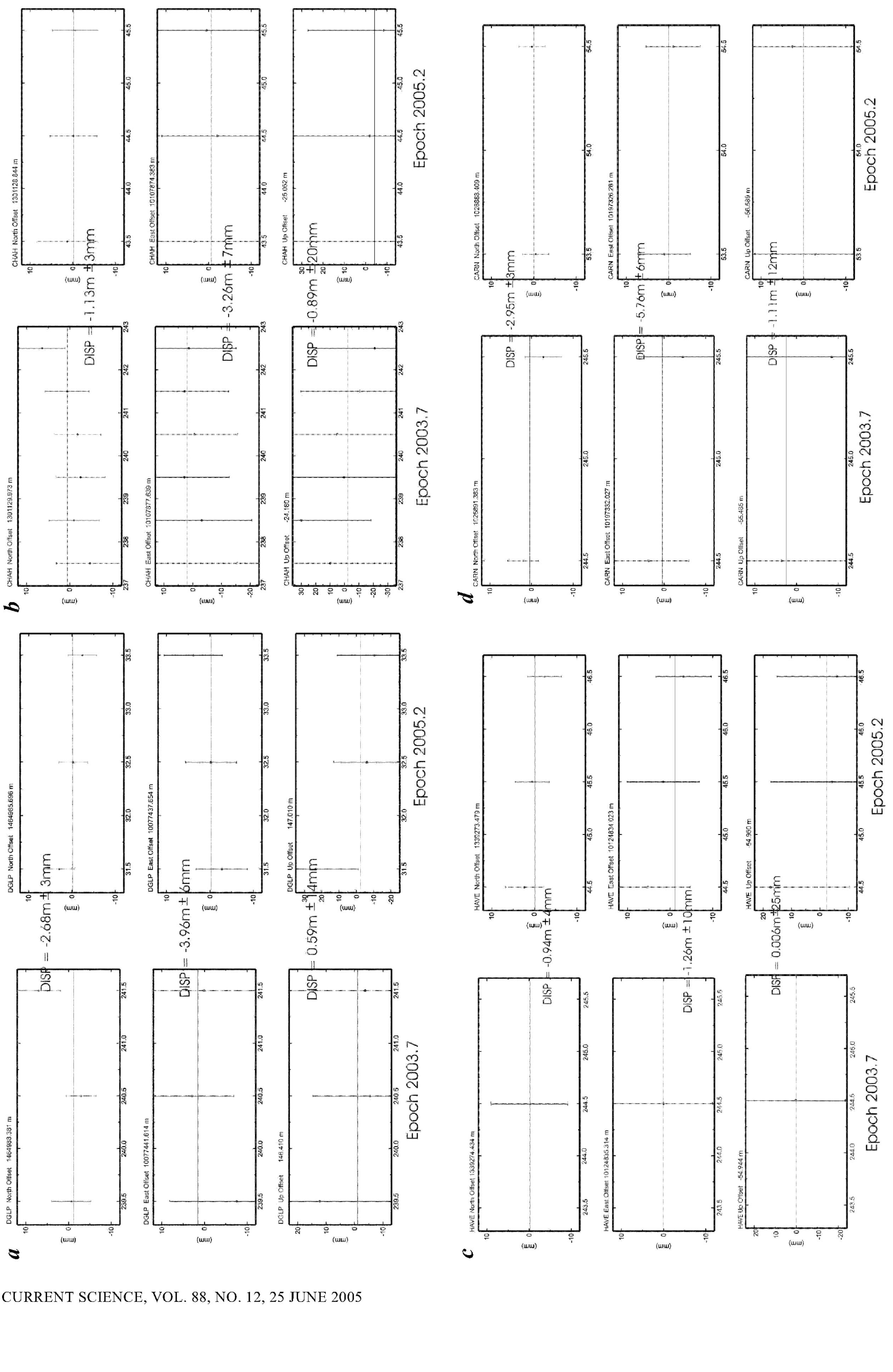
Figure 1. Co-seismic horizontal displacement vectors in Andaman. ***a***, Tectonic setting of the Andaman–Nicobar region. ***b***, Zoomed view of Andaman–Nicobar Islands with campaign sites and displacement vectors.

Table 1. Co-seismic displacements in Andaman–Nicobar Islands (2003.7 to 2005.2)

Site	Code	Latitude (°)	Longitude (°)	Displacement N (m)	Displacement E (m)	Displacement up (m)
Diglipur	DGPR	13.16	92.97	–2.68 ± 0.003	–3.96 ± 0.006	0.59 ± 0.014
Chatham Island	CHAH	11.69	92.72	–1.13 ± 0.003	–3.26 ± 0.007	–0.89 ± 0.020
Havelock Island	HAVE	12.03	92.99	–0.94 ± 0.004	–1.26 ± 0.010	0.006 ± 0.025
Car Nicobar	CARN	9.22	92.80	–2.95 ± 0.003	–5.76 ± 0.006	–1.11 ± 0.012

near the eastern edge of rupture in 2004. The displacements thus obtained at Diglipur, Chatham Island, Havelock and Car Nicobar Islands from epoch 2003.7 to 2005.2 along with their estimated errors are shown in Figures 1 and 2, and Table 1. The residual co-seismic displacements at all the four sites indicate motion to the west-southwest or southwest by varying amounts, the southern two sites having subsided and the northernmost at Diglipur uplifted.

The displacement at Car Nicobar has the largest magnitude of 6.49 m ± 0.009 m, with a significant 1.1 m subsidence, as expected from slip solutions of the main Sumatra rupture that terminated around 9°N. Further, the displacement vector is almost normal to the subduction boundary here, which also conforms with the almost pure thrust movement required by fault plane solutions[1,2] (http://neic.usgs.gov/neis/poster/2004/20041226.html). The horizontal displacement further north at Chatham Island near Port Blair is also broadly similar albeit smaller (3.45 m ± 0.009 m), with reduced subsidence of 0.9 m, corroborating the smaller signal expected from the reduced slip on the Sumatra rupture northward along the Andaman. Further northeast of Port Blair, the Havelock Island site shows an even smaller horizontal displacement to SW (1.6 m ± 0.013 m) and nothing significant in the vertical, indicating a transition zone between the uplift on the western shores of Andaman Islands and subsidence on the eastern shores. Diglipur, the northernmost Andaman site shows a much larger horizontal displacement (4.78 m ± 0.008 m) to SW, with a significant uplift of ~0.6 m. Unfortunately, at Havelock station we have only one day data for epoch 2003.7.



North, east and up offset with errors and co -seismic displacement at Diglipur station (*a*) Chatham Island station (*b*) Havelock station (*c*) and Car Nicobar station (*d*) from e pochs 2003.7 ements.

GPS-derived displacements (Table 1), while broadly conforming to the implications of reverse fault slips obtained from seismic data[2–4,12] (~15 m beneath Car Nicobar decreasing to half as much further north), are approximately parallel to the relative plate velocity between the Indian and Burma plates. However, while the surface displacement vectors at Car Nicobar and at Chatham Island are normal to the subduction boundary along this segment coinciding with the almost pure thrust mechanism of the main Sumatra and its extended rupture, those at Havelock and Diglipur are oblique requiring additional dextral strike-slip components, which could have been contributed by strike-slip ruptures or possibly aseismic strike-slip movements on the rupture plane.

While we are unable to quantify the separate contributions of co-seismic and post-seismic slip to our observed displacement vectors, we note that the positions were changing during the post-seismic measurements by 5 to 10 mm in several days. In summary, GPS measurements give a motion of the order of metres of Andaman Islands towards Bangalore in the southwest direction and also precise quantification of co-seismic displacements necessary to constrain the subsurface processes associated with the earthquake.

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Changes in groundwater regime at Neill Island (South Andaman) due to earthquake and tsunami of 26 December 2004

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The earthquake and tsunami of 26 December 2004 have caused vast devastation to human life and property. It has been severe in the Andaman and Nicobar Islands, particularly the Nicobar Islands. The earthquake has caused subsidence of land at some places and up-liftment at other places in many islands. Groundwater, which is only source of drinking water at some of the tiny islands, has been affected due to tsunami. Neill Island is one such island in South Andaman. Results of hydrogeological investigation before and after the earthquake and tsunami of 26 December 2004 are presented here.

THE recent earthquake and tsunami of 26 December 2004 have caused severe destruction to human life and livelihood in the Andaman and Nicobar Islands. These islands have been receiving a series of aftershocks after the events. Thousands of people have died and several have gone missing. The earthquake and tsunami had major effects in parts of Car-Nicobar Islands. Many parts of the Middle and North Andaman have also suffered. Several places have submerged and many have been up-lifted. Houses have been completely washed away and many RCC structures have collapsed. Mud volcano has been activated in South Andaman (Bartang). In order to assess the effect of the earthquake and tsunami on Neill Island, particularly on the groundwater regime, a detailed investigation has been carried out.

The Neill Island lies in the South Andaman, about 32 km east of Port Blair and is part of Ritchie's Archipelago. It lies in the southern-most part of the Archipelago (Figure 1)

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