CHAPTER - 3
SOIL PROFILES

3.1. Introduction

Soil profile is a bi-dimensional vertical organization of soil horizons or layers of soil column displaying different degrees of weathering and a gradation from soil to parent rock. The horizons, more or less parallel to the ground surface, largely maintain uniform thickness and may be demarcated from the superjacent / subjacent ones by colour, texture, structure and mineralogy. Simonson (1959), Nahon (1991), Buol et al. (1997) and Birkeland (1999) have reviewed or discussed the mechanisms of formation of soil profiles. The term soil profile is often used in a pedologic sense, whereas, weathering profile is applied in a geologic context. The terms profile, soil profile and weathering profile are used interchangeably in this text.

Soil horizon refers to a layer of soil that is the product of, or is substantially modified by, pedogenic processes (Soil Survey Staff, 1975) Soil horizons are distinguishable from adjacent layers by a distinctive set of properties produced by the pedogenic processes. Volumes of past research amply vouche for the contrasting views on origin of layering in soils (e.g., Ruellan, 1971; Ollier and Pain, 1996; Tandarich et al. 2002). The significance of application of the concept of horizons in pedology, geomorphology, and paleopedology has been brought out by Ruhe, (1974), Johnson, 1990; Retallack, 1999; Schaetzl and Anderson, (2005). Surface and subsurface processes may destroy, create, enhance, or even obscure vertical contrast in soils (Phillips and Lorz, 2008).

Making of soil profile is a complex phenomenon as many processes with varying contributions lead to the formation of diverse variety of profiles. Sub-aerial addition to the surface, transformations within the soil column and upward/downward transfer and removal of components are the main processes involved. Humic components from decomposing organic matter, secondary minerals and other products due to weathering of primary minerals and changes in the physical property (especially bulk density) are the major factors that transform soil profiles.

Vertical transfer involves movement of ions and solids along with water. Dissolved ions (Fe, Al, Si, bases, bicarbonate, sulfate and chlorides) and organic compounds moving downward with infiltrating water under pull of gravity will precipitate at depth under favorable chemical conditions. Ions transferred to upper layers by capillary rise may be precipitated as salts in the upper part of the profile (e.g., calcrete). In respect of solids, translocation of clay is the most common phenomenon. Certain soil dwelling fauna (e.g. earthworms and termites) move the finer solids in any direction – a process termed bioturbation of soils (Birkeland, 1999). The loosing horizon is termed eluvial and the gaining one as illuvial.

3.2. Nomenclature

Ideally a soil profile should have six master horizons viz., O, A, E, B, C and R from surface to the bedrock. All the horizons may not be represented in soil profiles. Instead, horizon/s may be thin, underdeveloped or even absent in certain profiles. In this study, the USDA scheme (Soil Survey Staff, 1975) is used in identification and description of horizons (Appendix-V and VI), wherein the master horizons are denoted by upper case letters O, A, E, B, C, and R. Transitional horizons are represented by upper case letters AB, BA, BC, CB etc. For example, AB designates A-horizon grading to B-horizon without sharp break. Suffixing of lower case letters designate some specific characteristic or feature of the master horizon. For example, Bt stands for B-horizon with illuvial accumulation of silicate clays. Arabic numerals are used for further subdivision of master horizons. For example, A1 is used to indicate uppermost, darker part of A-horizon with larger presence of organic matter. Though excluded by the Soil Survey Staff, Gile et al. (1965) proposed 'K' to designate a horizon very enriched in calcrete, as an additional master horizon.

Laterite, almost ubiquitous in Kerala, represents B-horizon but excluded by the Soil Survey Staff, yet later added plinthite i.e. Bv horizon (Appendix III) to cover laterite. However laterite is retained in this study. Definitions and symbology of laterite sub-horizons, proposed by Aleva (1994), viz., vermiform laterite: BL1; mottled zone: BL2; blocky laterite: BL3 and lithomargic clay: BL4 is used in this study.

3.3. Soil Profiles in the Study Area

Sections exposed in new water wells or the ones under construction, wherever available, ideally offered opportunities for inspection, description and sampling. Appendix-II and III describe the list. For detailed examination, a set of 18 profiles in NB and 19 in TB, representing a variety of source rock types (viz., garnetiferous biotite gneiss (GBG), charnockite (CHK), khondalite (KHD), leptynite (LPT) and pyroxene granulite (PXG)), and the two physiographic domains (viz., HL and ML) have been selected (Appendix-VII & VIII).

In NB, among the 11 profiles in ML, 3 each are in garnetiferous biotite gneiss, charnockite and leptynite; one each in pyroxene granulite and khondalite. Of the 7 in HL, 4 are in garnetiferous biotite gneiss, 2 in khondalite and one in charnockite. In TB, among the 6 profiles in ML, 3 are in charnockite, 2 in garnetiferous biotite gneiss and one in pyroxene granulite. Out of 13 in HL, charnockite is the parent rock in 10 profiles and leptynite, garnetiferous biotite gneiss and pyroxene granulite each form the source rock.

Tables 3.1 and 3.2 (and Fig. 1.1 for NB and 1.2 of TB) list the sites of selected profiles and the thickness of horizons/sub-horizons in NB and TB, while Tables 3.3 and 3.4 summarizes data on physiographic details like, altitude, relative relief and slope of profile sites and measured thickness of master horizons viz., A, B, and C and depth to bedrock in NB and TB. Further, it needs to be noted that A-horizon is absent in 6 profiles in NB (viz., NB-16, NB-27 & NB-36 in ML and NB-10, NB-24 & NB-35 in HL) and B-horizon is missing in 3 profiles of HL in TB (i.e. TB-1&TB-10 in ML and TB-35 and TB-42). The E-horizon is either absent or very thin (<10 cm); wherever present, it is considered as part of A-horizon.

3.3.1. Horizons/sub-horizons in profiles

Horizons/sub-horizons identified in the weathering profiles in NB are A, AB, BA, BL1, BL2, BL3, BL4, BC, C1 and C2 (Table 3.1) and that in TB are A, ABk, B, Bk, K, BC, Ck1, Ck2, C1 and C2 (Table 3.2). The soil profiles and their horizons are represented and described in Appendix-VII (NB) and Appendix-VIII (TB).

In the NB, A-horizon is present in 12 profiles only. The transitional horizon AB is present only in one profile (NB-31; thickness= 110.0 cm). Similarly the transitional horizon BA occurs only in NB-35 (thickness=50.0 cm). BL1 to BL4 are sub-horizons of laterite (Section 3.2), viz., BL1 (100.0 – 330.0 cm; N=12); BL2 (130 – 510.0 cm; N=12); BL3 (95.0 – 570.0 cm; N=3) and BL4 (150.0 – 290.0 cm; N=2), ideally

Table 3.1: Location and thickness of horizons/sub horizons in selected weathering profiles of Neyyar Basin (NB)

Sl. No.	Profile	Location	Thickness of Horizon / Sub horizon (cm)									
			A	AB	BA	BL1	BL2	BL3	BL4	BC	C1	C2
1.	NB 1	Panachamudu	100	--	--	115	165	--	--	--	70	--
2.	NB 2	Aruviode	15	--	--	165	290	--	--	--	--	230
3.	NB 7	Chempur	60	--	--	150	--	--	--	100	100	180
4.	NB 8	Muttilammudu	90	--	--	195	--	--	--	--	515	60
5.	NB 10	Chettikkunnu	--	--	--	200	--	--	--	--	330	--
6.	NB 12	Peruvila	60	--	--	230	--	570	--	--	120	--
7.	NB 16	Tattiyur	--	--	--	260	--	95	--	--	155	--
8.	***NB 19**	**Perumbazhuttur**	60	--	--	330	310	--	--	--	100	--
9.	NB 20	Perumbazhuttur	60	--	--	110	210	--	--	--	320	--
10.	***NB 24**	**Pantha**	--	--	--	100	130	--	--	--	120	--
11.	NB 27	Mariyapuram	--	--	--	--	225	--	--	--	405	870
12.	NB 30	Kottakkal	60	--	--	--	290	270	150	80	100	--
13.	NB 31	Valiyavila	150	110	--	--	510	--	--	--	780	--
14.	NB 32	Neyyar Dam	60	--	--	--	220	--	--	110	360	--
15.	***NB 35**	**Mlavetti**	--	--	50	--	170	--	--	--	160	--
16.	NB 36	Choliakonam	--	--	--	100	190	--	--	--	170	--
17.	NB 39	Karumkulam	150	--	--	--	100	--	290	--	800	100
18.	***NB 42**	**Idichakkaplamudu**	160	--	--	160	--	--	--	--	600	--

-- indicates absence of horizon/sub-horizon

* Profiles selected for textural, petrographic, mineralogic and chemical studies in addition to study of profile characteristics

Table 3.2: Location and thickness of horizons/sub-horizons in selected weathering profiles of Tambraparni Basin (TB)

Sl. No.	Profile	Location	Thickness of Horizon / Subhorizon (cm)									
			A	ABk	B	Bk	K	BC	Ck1	Ck2	C1	C2
1.	TB 1	NGO Colony	90	--	--	--		--	60	60	--	--
2.	TB 2	Sivandipatti	30	--	--	50	40	--	60	170	--	--
3.	TB 5	Ugandanpatti	60	--	--	30	40	--	50	320	--	--
4.	***TB 6**	**Cheranmahadevi**	30	--	--	--		15	--	--	75	120
5.	TB 7	Devarkulam	150	--	40	--		--	--	--	--	210
6.	TB 10	Kallampuli	80	50	--	--		--	55	40	--	--
7.	TB 12	Vadakku- Ariyanayakipuram	100	--	--	85		--	60	80	--	--
8.	TB 14	Marandai	20	--	45	--		--	--	--	285	1000
9.	TB 15	Marudamputtur	30	--	--	60		--	20	20	--	--
10.	TB 17	Nachiapuram	105	--	25	--		--	330	50	--	--
11.	TB 23	Pallakudi	50	--	--	*40*		--	--	--	*50*	*160*
12.	TB 24	Mel Ambur	50	--	--	130		--	40	--	--	--
13.	TB 25	Anjanadanarpatti	100	--	40	--		--	375	--	--	85
14.	TB 27	Pulavanur	90	--	--	90		--	290	--	--	--
15.	***TB 33**	**Kil Omanallur**	30	--	--	--		20	--	--	25	--
16.	*TB 35*	Rajapudukkudi	60	--	--	--		--	--	--	70	120
17.	***TB 38**	**Shencottah**	*100*	--	*250*	--		--	--	--	*75*	--
18.	TB 39	Idaikkal	110	--	--	--		*210*	--	--	*580*	--
19.	***TB 42**	**Vadakku- Konarkottai**	20	90	--	--		--	270	60	--	--

-- indicates absence of horizon/sub-horizon

* Profiles selected for textural, petrographic, mineralogic and chemical studies in addition to study of profile characteristics

Table 3.3: Physiographic attributes (altitude, slope, relative relief), nature of bedrock and thickness of master horizons and profiles in Neyyar Basin (NB).

Sl. No.	Profile	Altitude (m)	Physiographic domain	Slope (degrees)	Slope category	Relative relief (m)	Relative relief category	Bedrock	Thickness of Horizon / Sub-horizon (cm)			
									A	B	C	TOTAL
1.	NB 1	140	HL	8	G	40	LH	GBG	100	280	70	450
2.	NB 2	70	ML	4	G	20	R	KHD	15	455	230	700
3.	NB 7	80	HL	11	G	20	R	GBG	60	250	280	590
4.	NB 8	140	HL	11	G	60	LH	KHD	90	195	575	860
5.	NB10	100	HL	11	G	60	LH	KHD	--	200	330	530
6.	NB12	50	ML	2	VG	20	R	LPT	60	800	120	980
7.	NB16	60	ML	5	G	20	R	LPT	--	355	155	510
8.	NB19	60	ML	8	G	20	R	CHK	60	640	100	800
9.	NB20	60	ML	8	G	40	LH	PXG	60	320	320	700
10.	NB24	120	HL	18	S	120	H	CHK	--	230	120	350
11.	NB27	40	ML	2	VG	20	R	GBG	--	225	1275	1500
12.	NB30	60	ML	11	G	40	LH	CHK	60	790	100	950
13.	NB31	60	ML	8	G	20	R	LPT	260	510	780	1550
14.	NB32	80	HL	9	G	60	LH	GBG	60	330	360	750
15.	NB35	120	HL	12	G	80	LH	GBG	--	220	160	380
16.	NB36	40	ML	6	G	20	R	GBG	--	290	170	460
17.	NB39	50	ML	1	VG	20	R	CHK	150	390	900	1440
18.	NB42	20	ML	2	VG	20	R	GBG	160	160	600	920
								Mean	**95**	**368**	**369**	**801**

-- indicates horizons absent
ML- Midland; HL- Highland
VG - Very gentle slope; S - Steep slope; R – Rise; H- Hill
GBG-Garnetiferous biotite gneiss; CHK- Charnockite
LPT - Leptynite; PXG- Pyroxene granulite

Table 3.4: Physiographic attributes (altitude, slope, relative relief), nature of bedrock and thickness of master horizons and profiles in Tambraparni Basin (TB).

Sl. No.	Profile	Altitude (m)	Physiographic domain	Slope (degrees)	Slope category	Relative relief (m)	Relative relief category	Bedrock	Thickness of Horizon / Sub-horizon (cm)			
									A	B	C	TOTAL (Depth to bedrock)
1.	TB 1	50	ML	<1	VG	<20	R	PXG	90	--	120	210
2.	TB 2	50	ML	<1	VG	<20	R	CHK	30	90	230	350
3.	TB 5	100	HL	<1	VG	<20	R	CHK	60	70	370	500
4.	TB 6	60	ML	<1	VG	<20	R	CHK	30	15	195	240
5.	TB 7	90	HL	1	VG	20	R	PXG	150	40	210	400
6.	TB 10	90	HL	<1	VG	<20	R	CHK	130	--	95	225
7.	TB 12	60	ML	<1	VG	<20	R	CHK	100	85	140	325
8.	TB 14	130	HL	1	VG	20	R	CHK	20	45	1285	1350
9.	TB 15	100	HL	1	VG	<20	R	CHK	30	60	40	130
10.	TB 17	110	HL	<1	VG	<20	R	CHK	105	25	380	510
11.	TB 23	90	HL	3	VG	20	R	CHK	50	40	210	300
12.	TB 24	90	HL	1	VG	<20	R	LPT	50	130	40	220
13.	TB 25	80	HL	<1	VG	<20	R	CHK	100	40	460	600
14.	TB 27	130	HL	1	VG	<20	R	CHK	90	90	290	470
15.	TB 33	50	ML	<1	VG	<20	R	GBG	30	20	25	75
16.	TB 35	50	ML	<1	VG	<20	R	GBG	60	--	190	250
17.	TB 38	280	HL	18	S	200	H	GBG	100	250	75	425
18.	TB 39	170	HL	<1	VG	<20	R	CHK	110	210	580	900
19.	TB 42	100	HL	<1	VG	<20	R	CHK	110	--	330	440
								Mean	**76**	**80**	**277**	**417**

-- indicates horizons absent
ML- Midland; HL- Highland
VG- Very gentle slope; S- Steep slope; R-Rise; H-Hill
GBG-Garnetiferous biotite gneiss; CHK- Charnockite
LPT - Leptynite; PXG- Pyroxene granulite

occurring in sequence. However, it is a rarity for all these sub-horizons to occur together in the same profile (Table 3.1).

The transition horizon BC is present in 3 profiles and thickness range is 80.0-110.0 cm (Table 3.1). Saprolite (C1) and saprock (C2) respectively are sub-horizons of C. Saprolite is present in all but one profile and thickness varies between 70.0 and 800.0 cm; but saprock is present in 5 profiles only (thickness= 60.0–870.0 cm). The tropical humid NB drives the weathering processes faster and hence saprolites are more prevalent in profiles of NB (in 17 out of 18) than saprocks (in 5 out of 18).

In the TB, A-horizon is present in all the soil profiles scrutinized. The ABk is a transitional horizon between A and B with pedogenic $CaCO_3$ accumulation. Here, $CaCO_3$ occurs as pore fillings or small nodules (dia. = 2-6mm) and is present only in 2 profiles (TB-10 & TB-42). B-horizon occurs in 5 profiles and Bk (i.e. B with pedogenic $CaCO_3$) accumulates as pore fillings/thin veins in 7 profiles (Table 3.2).

In many places in TB, subsoil carbonate buildup is in advanced stages of forming hard and thick (~ 1.0 m) accumulations (hardpan and laminar calcretes of Goudie, 1983), often enclosing soil and rock fragments. These calcrete zones are represented in 2 profiles in TB (i.e., TB-2 and TB-5; Table 3.2).

It is interesting to note that the thickness of B in TB-38, (a profile on the eastern side of the Western Ghats and enjoying a humid tropical climate) is 250 cm whereas other profiles in TB the thickness of B is relatively lower (25-130cm).

Both saprolite (C1) and saprock (C2) occur in TB. In some profiles the saprolite and/or saprock has the intergranular space filled with newly precipitated and variable amounts $CaCO_3$, as thin film or coating (< 2.0 mm) over the host grains enabling designation as Ck1and Ck2 respectively. Saprolites are more amenable to intergranular precipitation of $CaCO_3$ owing to their more weathered nature than saprocks.

3.3.2. Physiography-Profile Relationship

The inter-relationship between physiographic factors (viz., altitude, slope and relative relief) and thickness of soil horizons/ profiles in NB and TB are analyzed in the following section (Fig. 3.1-3.3).

3.3.2.1. Altitude vs. Thickness of Horizons

(i) A-Horizon

In NB (Table 3.3, 3.4 & 3.5) thickness of A-horizon in ML ranges between 15.0 and 260.0 cm. (mean = 103.0 cm; n = 8), whereas in the HL the values are between 60.0 and 100.0 cm (mean = 78.0 cm; n = 4). In TB, A-horizons in the ML spread between 30.0 and 100.0 cm. (mean=57.0 cm; n=6) and for HL corresponding values are 20.0 and 150.0 cm (mean = 85.0 cm; n=13).

The Figure 3.1 depicts several semi-log plots of altitude vs. soil horizon thickness and sum of thicknesses with fields of highland and midland. A-horizon is shown in Figure 3.1 (i). Here, the data points pertaining to either of the basins do show a near overlap or close proximity of poles, indicating a lack of clear cut variation between NB and TB. Though in NB mean thickness of A decreases with altitude, within TB there exists a positive trend i.e. mean thickness of A-horizon increases with increasing altitude.

(ii) B-Horizon

B-horizons in ML of NB show thicknesses range of 160.0 and 800.0 cm (mean= 449.0 cm; N=11), whereas in HL, it spans between 195.0 and 330.0 cm (mean= 244.0 cm; N=7). Thickness of B-horizons in the ML of TB, varies between 20.0 and 230.0 cm (mean= 53.0 cm; N= 4); in the HL the corresponding range is from 25.0 to 250.0 cm (mean= 91.0 cm; N= 11).

In NB the thickest B (800.0 cm) horizon has a leptynite parentage (NB-12) and occurs in a weathering profile sited in a very gently sloping rise in midland. In TB, the thickest B (250.0 cm) is developed over GBG, (TB-38) located in a steep hill in the highland. Distribution of poles in the plot suggests that the thicker B-horizons in NB

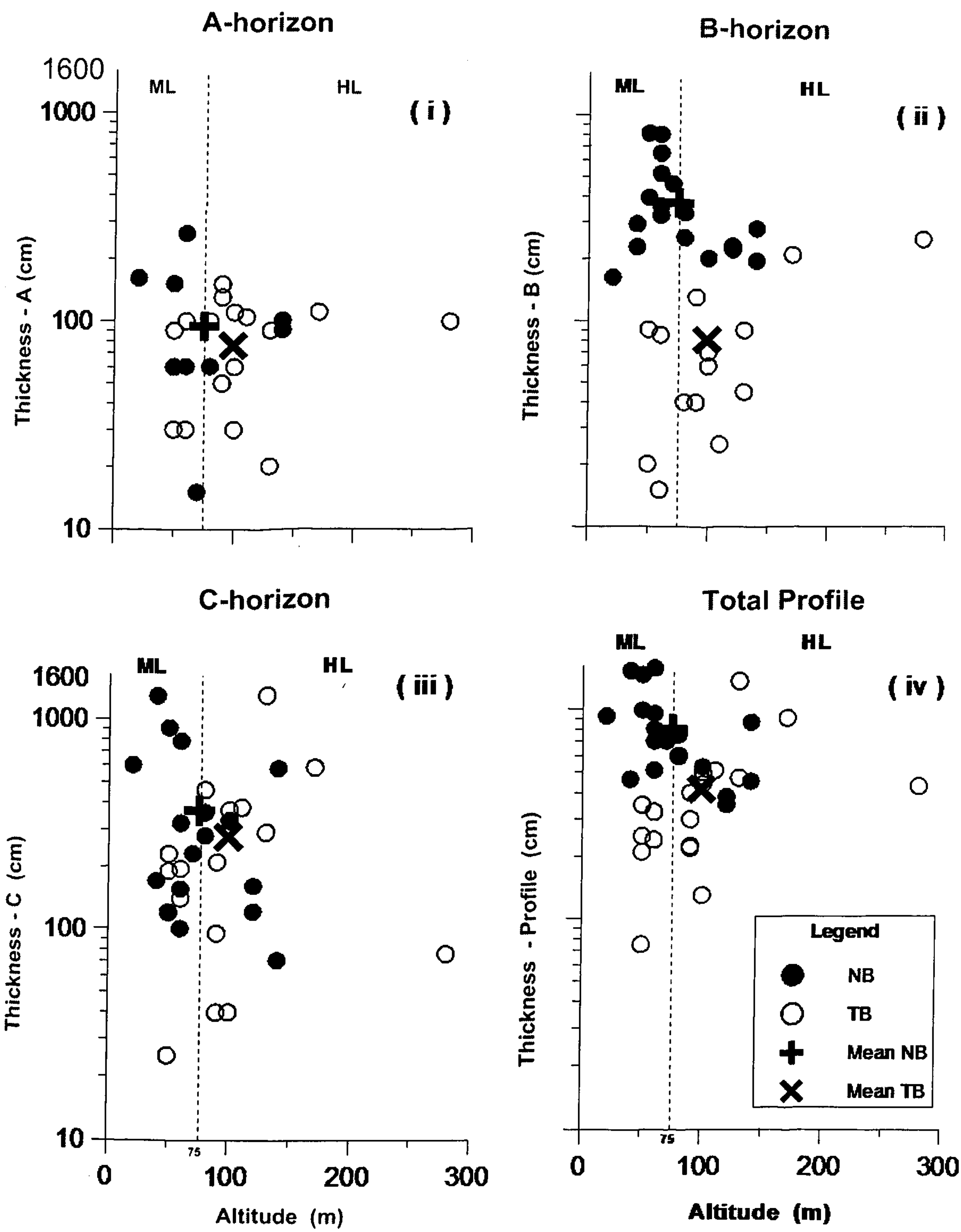

Fig. 3.1. Distribution of thicknesses of A, B and C horizons, and profiles with respect to the altitude of locations of weathering profiles in NB and TB. Discontinuous line demarcate midland (ML) and highland (HL). Note the separation of data poles of B horizons in NB and TB in (ii)

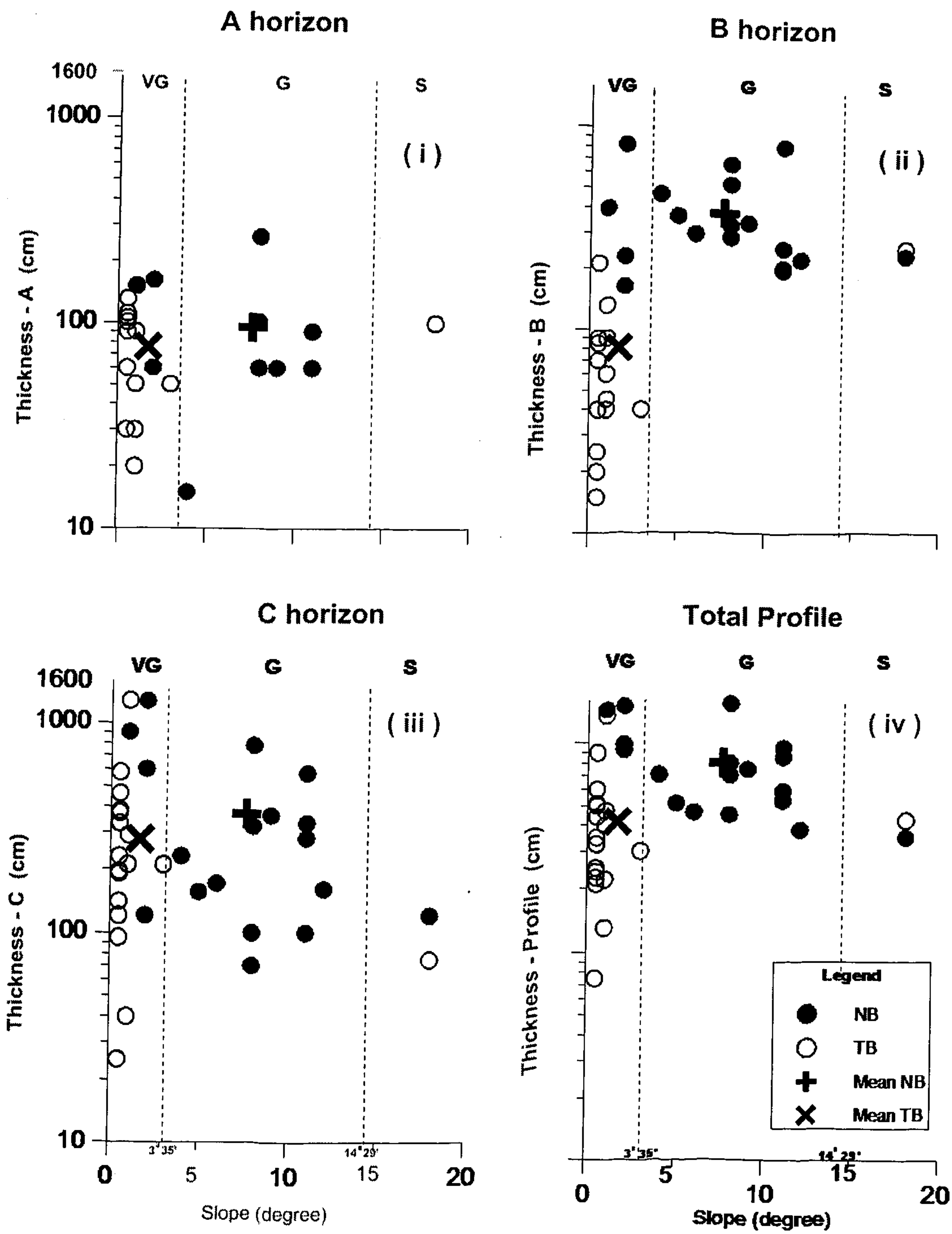

Fig. 3.2 Distribution of thicknesses of A, B and C horizons, and profiles with respect to the slope of locations of weathering profiles in NB and TB. Slope categories very gentle (VG), gentle (G) and steep (S).

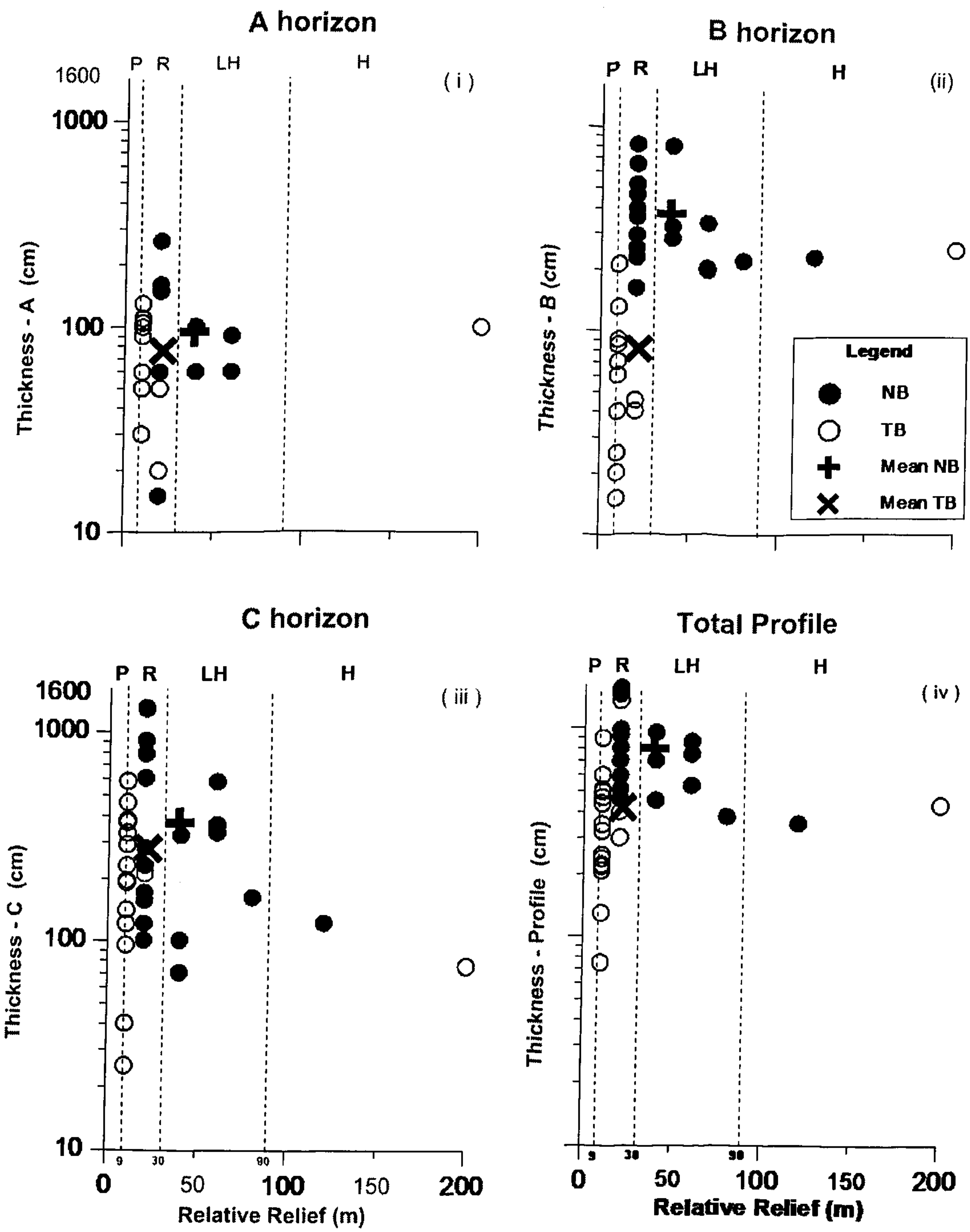

Fig. 3.3 Distribution of thicknesses of A, B and C horizons, and profiles with respect to the relative relief of locations of weathering profiles in NB and TB. Discontinuous line demarcate regions based on relative relief: Plain (P), Rises (R), Low Hills (LH) and Hills (H).

Table 3.5: Range in thickness (cm) and mean thickness (cm) of horizons in weathering profiles of midland (ML) and highland (HL) in NB and TB

Basin	Physiographic domain	A		B		C		Total Profile	
		Range (cm)	Mean	Range (cm)	Mean	Range (cm)	Mean	Range (cm)	Mean
NB	ML	15-260	103.0 (N=8)	160-800	449.0 (N=11)	100-1275	432.0 (N=11)	460-1550	955.0 (N=11)
	HL	60-100	78.0 (N=4)	195-330	244.0 (N=7)	70-575	271.0 (N=7)	350-860	559.0 (N=7)
TB	ML	30-100	57.0 (N=6)	20-230	53.0 (N=4)	25-230	277.0 (N=6)	75-350	242.0 (N=6)
	HL	20-150	85.0 (N=13)	25-250	91.0 (N=11)	40-1285	336.0 (N=13)	130-1350	498.0 (N=13)

(>400.0 cm) are in midland, whereas thicker ones in TB (>100.0 cm) are in the highland. Further, in NB, intra-basin-mean-thickness of B-horizon varies negatively with altitude, whereas in TB relation is positive.

Figure 3.1, a plot of altitude vs. thickness of B-horizons in NB and TB, is highly instructive in that it displays a marked separation of data poles between NB and TB warranting an explanation. Thicker B's in NB is a direct manifestation of rapid pedogenic weathering (i.e., strong weathering; Fig. 2.5.c) in this basin, owing to higher moisture content, in comparison with that of the slower rate in the TB (i.e., weak weathering; Fig. 2.5.c).

(iii) C-Horizon

Thickness of C-horizon (Table 3.3, 3.4 & 3.5) in the ML of NB varies from 100.0 to 1275.0 cm (mean=432.0; N=11). In HL, the corresponding variation is from 70.0 to 575.0 cm (mean=271.0 cm, N=7). In TB, the variability in thickness of this horizon is between 25.0 and 230.0 cm (mean=53.0 cm; N=4). The respective values for C in HL are 40.0 and 1285.0 cm (mean=336.0 cm; N=13).

In NB, the thickest C-horizon (1275.0 cm) has a GBG parent (NB-27) and the weathering profile is located in a very gently sloping rise in midland. In TB, the thickest C (1285.0 cm) is developed over charnockite (TB-14) in a very gently sloping rise in the highland. Moreover, thicker C's in NB are in midland, whereas in TB they are in the highland.

In Figure 3.1 (iii), an altitude vs. thickness plot seems to be an ineffective separator of the data poles.

(iv) Total Profile Thickness

Depth to bedrock (i.e. total profile thickness) is given in Table 3.3, 3.4 & 3.5 and Fig. 3.1 (iv). In the ML of NB the thickness of profiles vary between 460.0 to 1550.0 cm (mean=955.0; N=11), whereas in HL this range is between 350.0 cm and 860.0 cm (mean=559.0 cm; N=7). In respect of ML in TB, variation of thickness of total profile is between 75.0 and 350 cm (mean=242; N=6) and for those in HL the variation is between 130-1350.0 cm. (mean=498.0; N=13).

Among the soil profiles in NB, ones developed over leptynite (NB-31) are the thickest (1550.0 cm). This profile is located in a gently sloping rise in the midland. In TB, the thickest (1350.0 cm) profile has a charnockite parent rock (TB-14) and sits in a very gently sloping rise in the highland.

The Figure 3.1 (iv), makes it clear that majority of the profiles in NB are relatively thicker than those of TB. The mean thickness vs. altitude plot also suggests a tendency for profiles in NB to decrease with altitude, while converse rules in TB.

3.3.2.2. Slope vs. Thickness of Horizons

In this section (Figure 3.2-i-iv), slope vs. thickness of specific horizons and slope vs. sum of thicknesses of horizons are examined. The bounding lines between very gently sloping (range= 0° - 3°35' of Fairbridge, 1968), gently sloping (range= 3°36' - 14°29') and steeply sloping types (range= 14°30' - 34°40') are drawn in the figure. Slopes <1° has been assigned a value of 0.5° to enable plotting. In all the plots, data poles of TB lie close to and spread along the length of the Y-axis.

In NB, among the 18 profiles in ML, 4 (NB-12, NB-27, NB-39 and NB-42) are under very gently sloping category with a small range for the slope (1-2°). i.e., these locations are nearly flat. The next 13 profiles are in the gently sloping type with slope values varying from 4 to 12°· One profile (NB-24) lies in the steeply sloping category with a slope of 18° (Table 3.2). In TB, among the 19 locations all but one belongs to gently sloping type with slopes $\leq$ 3°. Only one location (TB-38) is in the steeply sloping terrain (slope= 18°).

(i) A-Horizon

In NB, mean thickness of A-horizons in very gently sloping terrain is higher (i.e., 60.0 – 160.0 cm; mean=123.0 cm; N=3) than those of gently sloping type (15.0-260.0 cm, mean = 85.0; N=9). Among the 19 weathering profiles in TB, all except one are in the very gently sloping category. The A-horizons in these profiles have a range of thickness from 20.0-150.0 cm (mean= 75.0 cm; N=18). The A-horizon is not represented at all (i.e., NB 24) in steep terrain of NB. In TB the only weathering profile in steep terrain is TB-38, and has a 100.0 cm thick A-horizon (Table 3.3, 3.4 and 3.5).

The spread of poles in Figure 3.2 (i) do not show any causality between thickness and slope of land, and is suggestive of the modifications the land surface underwent as a result of extrinsic causes.

(ii) B-Horizon

In the gently sloping terrain in NB, profiles tend to develop thinner B-horizons (mean= 372.0 cm; N=13) relative to very gently sloping tract (mean= 394.0 cm; N=4). The B-horizon in profile NB-24 set in the steep terrain is 230.0 cm thick. In TB, B-horizons in very gently sloping terrain have a thickness of 15.0 – 210.0 cm. (mean= 69.0 cm; N=14); B in a lone profile in the steep terrain (TB-38) is 250.0 cm thick.

Figure 3.2 (ii), plot of slope vs. thickness of all B-horizons in both the basins do show a broader spread along the Y direction (up to 800.0 cm). The poles of NB and TB stand demarcated. In NB the thickness of B-horizon tend to decrease with slope. Due to the low slope values of profiles in TB, from the plot of slope vs. thickness no meaningful inferences could be made.

iii. C-Horizon

Thickness of C-horizons, in the very gently sloping terrains, in NB, shows larger values (120.0-1275.0 cm; mean = 724.0; N=4) vs. those in gently sloping terrain (70.0-780.0; mean=279.0 cm; N=13). C-horizon in the profile NB-24 sitting in a steep slope is 120.0 cm thick. In TB, C-horizons are relatively thinner in very gently sloping tracts (25.0-1285.0 cm; mean=288.0 cm; N=18). C in the singular profile in the steep terrain (TB-38) is 75.0 cm thick.

In Figure 3.2 (iii) a plot of data, NB and TB distinctly apart. Thickness of C-horizons in profiles in NB tends decrease with slope, while such an inference is difficult to reach for the C of TB.

(iv) Total Profile Thickness

Measured profiles in very gently sloping tracts in NB are notably thicker (range= 920.0-1500.0 cm; mean=1210.0 cm; N=4) than those in gently sloping segments (380.0-1550.0 cm; mean=710.0 cm; N=13). In TB, in very gently sloping swaths, the range of thickness of the profiles and mean values are 75.0-1350.0 cm and 416.0 cm (N=18) respectively. Like in the case of B and C-horizons, plot of thickness of profiles also shows clear demarcation between NB and TB. Thickness of profiles in NB tends to decrease with slope - a joint contribution of B and C-horizons. As poles of profiles in TB are restricted to a narrow range, a generalization is not possible in this case.

3.3.2.3. Relative Relief vs. Thickness of Horizons

In NB, 10 profiles fall in the category of rises and 7 under low hills. Only one profile, NB 24, in HL belongs to hill. In TB, among the 19 profiles, all but one belongs to the rise and one (TB-38) belong to the hill terrain (). The plot of relative relief vs. thickness (Fig. 3.3 i-iv), more or less mimics the plot of slope vs. thickness. Thicker horizons and profiles (> 400.0 cm) are associated with terrains of lower relative relief (< 20.0 m). From the distribution of poles (Fig.3.3 ii, iii and iv), it can be inferred that thickness of B, C and the thickness of the profile tend to decrease with relative relief.

3.3.3. Lithologic Control on Soil Horizons

The control of bedrock, if any, on the thickness of A, B and C-horizons of profiles in NB and TB, has also been examined. Thickness of horizons (in %) in the soil profiles in ML and HL in either of the basins is given in Table 3.6. Distribution of thickness of A, B and C-horizons among profiles is variable.

In the ML of NB, charnockite gives thicker B (NB-30; 83%) followed by leptynite (NB-12; 82%). But in the case of C-horizon in ML of NB, the thickest one is noticed over GBG (85%) in NB-27, followed by NB-42 on GBG (65%). In the HL of NB, thickest B-horizon (66%) is formed in a profile on charnockite (NB-24), followed by one on GBG (62%) in NB-1. Here, thickest C is found in two profiles (NB-8 & NB-10) over khondalite (67% and 62% respectively), followed by one on GBG (48%) i.e. NB-42 (Table 3.6).

In ML of TB, the thickest B-horizon (27%) found in the profile over GBG (TB-33); second to this is profiles in TB-12, developed over charnockite, where B-horizon contributes to 26% of the total profile thickness.

Table 3.6: Bed rock-wise thickness (in %) of A, B and C horizons in profiles of highland and midland of Neyyar and Tambraparni basins.

Profile	Bedrock	Thickness of horizon (%)		
		A	B	C
		Neyyar Basin		
Midland profiles				
NB 27	GBG	0.00	15.00	85.00
NB 36	GBG	0.00	63.04	36.96
NB 42	GBG	17.39	17.39	65.22
NB 19	CHK	7.50	80.00	12.50
NB 30	CHK	6.32	83.16	10.53
NB 39	CHK	10.42	27.08	62.50
NB 20	PXG	8.57	45.71	45.71
NB 12	LPT	6.12	81.63	12.24
NB 16	LPT	0.00	69.61	30.39
NB 31	LPT	16.77	32.90	50.32
NB 2	KHD	2.14	65.00	32.86
Highland profiles				
NB 1	GBG	22.22	62.22	15.56
NB 7	GBG	10.17	42.37	47.46
NB 32	GBG	8.00	44.00	48.00
NB 35	GBG	0.00	57.89	42.11
NB 8	KHD	10.47	22.67	66.86
NB 10	KHD	0.00	37.74	62.26
NB 24	CHK	0.00	65.71	34.29
		Tambraparni Basin		
Midland profiles				
TB 33	GBG	40.00	26.67	33.33
TB 35	GBG	24.00	0.00	76.00
TB 2	CHK	8.57	25.71	65.71
TB 6	CHK	12.50	6.25	81.25
TB 12	CHK	30.77	26.15	43.08
TB 1	PXG	42.86	0.00	57.14
Highland profiles				
TB 38	GBG	23.53	58.82	17.65
TB 24	LPT	22.73	59.09	18.18
TB 5	CHK	12.00	14.00	74.00
TB 10	CHK	57.78	0.00	42.22
TB 14	CHK	1.48	3.33	95.19
TB 15	CHK	23.08	46.15	30.77
TB 17	CHK	20.59	4.90	74.51
TB 23	CHK	16.67	13.33	70.00
TB 25	CHK	16.67	6.67	76.67
TB 27	CHK	19.15	19.15	61.70
TB 39	CHK	12.22	23.33	64.44
TB 42	CHK	25.00	0.00	75.00
TB 7	PXG	37.50	10.00	52.50

Table 3.7: Bed rock-wise average thickness (in %) of A, B and C horizons in profiles of highland and midland, Neyyar and Tambraparni basins.

Bedrock	Average thickness of horizon (%)		
	A	B	C
	Neyyar Basin		
Midland profiles			
GBG	5.56	23.44	71.01
CHK	8.46	57.05	34.48
LPT	10.53	54.77	34.70
KHD	2.14	65.00	32.86
PXG	8.57	45.71	45.71
Highland profiles			
GBG	10.14	49.77	40.09
CHK	0.00	65.71	34.29
KHD	6.47	28.42	65.11
	Tambraparni Basin		
Midland profiles			
GBG	27.69	6.15	66.15
CHK	17.49	20.77	61.75
PXG	42.86	0.00	57.14
Highland profiles			
GBG	23.53	58.82	17.65
CHK	14.84	10.69	74.47
PXG	37.50	10.00	52.50
LPT	22.73	59.09	18.18

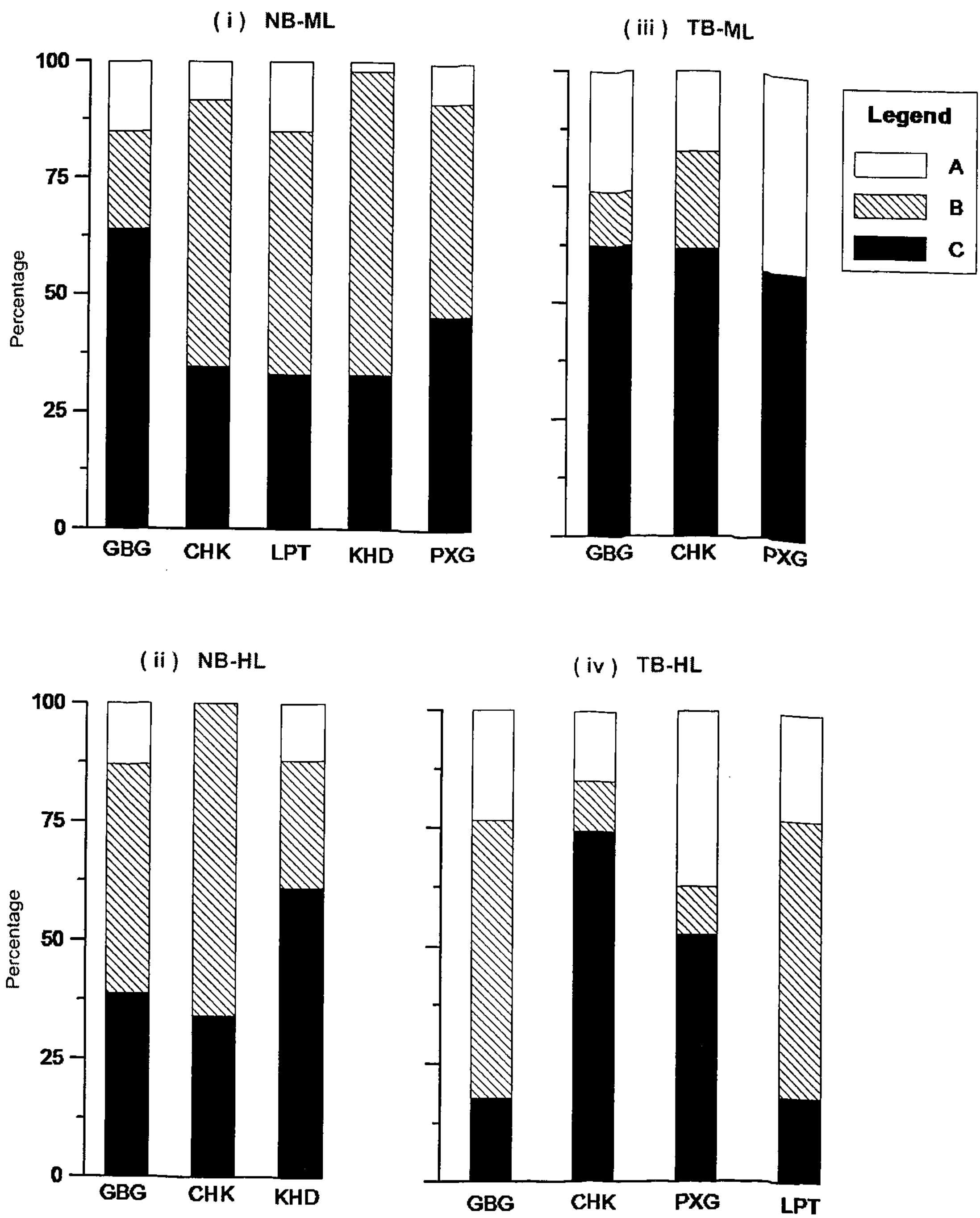

Fig. 3.4 Mean thickness (%) of A, B and C horizons in profiles developed over specific bedrock types in the midland and highland of NB and TB. GBG - garnetiferous biotite gneiss, CHK - charnockite, KHD - khondalite, PXG - pyroxene granulite and LPT - leptynite.

Average thickness of A, B and C-horizons in profiles in NB and TB developed over various rock types (GBG, CHK, LPT, KHD and PXG) is given in Table 3.7 and Figure 3.4. The data poles suggest that development of horizons in profiles is not bedrock specific.

3.4. Discussion

Development of soil profile is a complex process, as many factors and processes with varying intensity lead to the formation of diverse profiles (Nahon, 1991; Buol et. al. 1997). The foregoing sections dealt with the difference in the thickness of soil horizons developed in NB and TB.

In NB, thickest A-horizon (260.0 cm) is observed in profile NB-31- over a leptynite parent, in midland (site elev. = 60.0 m), with a gentle slope (8°). Then again, thickest B-horizon (800.0 cm), NB-12 on leptynite, is in the ML (elev. = 50.0 m). Here, the terrain has very gentle slope (2°) and is a 'rise'. In respect of C, the thickest one (1275.0 cm) is at NB-27, in the midland at 40.0 m, and at very gentle slope (2°). In NB, the thickest profile (1550.0 cm) is NB-31, which also hosts the thickest A-horizon.

In TB, thickness of A-horizon is 150.0 cm in profile TB-7 located in highland (elev. = 90.0 m). Here slope is very gentle (1°) and hence the profile is in a 'rise'. Highest thickness (i.e., 250.0 cm) for B-horizon is noted in TB-38. This profile in the highland at an elevation of 280.0 m attains a slope of 18° and relative relief of 200 m. and hence is in the category of hill. Profile TB-14, hosting the thickest C-horizon (=1285.0 cm) has total thickness of 1350.0 cm, and is located in the highland at an altitude of 130.0 m. Here slope is very gentle (1^0) and relative relief is 20.0 m.

The role of various physiographic attributes like altitude, slope and relief, and bed rock types and climate in controlling the thickness of horizons in NB and TB warrants explanation. Generally in NB, plot of altitude vs. thickness (Fig. 3.1) shows an association of thicker soil horizons/profiles (>500 cm) commonplace with midland. Such a relationship is not exhibited by soil horizons and profiles in TB. In Figures 3.1 (i) and (iii), data points do not suggest any meaningful control or functional relationship between horizon thickness and profile site elevation.

Yet, for the B-horizon, inter-basin difference of thickness is clearly brought out in Figure 3.1 (ii). Here, data poles of NB and TB lie relatively well segregated. Most of the B-horizons in NB are relatively thicker (160-800 cm) than those of TB (< 250 cm). Similarly, in Figure 3.1 (iv) of altitude vs. profile thickness, data poles for NB and TB grouped basin-wise and lie mostly apart across a thickness of ~450 cm. Hence, it may be inferred that the thickness of B – the horizon of illuviation – is reflective of degree of weathering and profile development in the basins.

Judging from the aforesaid data on thickness of A, B and C-horizons, it is inferred that the type of bedrock does not play any decisive role in the thickness of horizons. Despite the petrologic differences, the chief lithologies in the basins do show a great deal of petro-physical similarities, especially in respect of the gross structures at the outcrop level. Foliation, fractures and joints with variable distribution and spacing across the lithologies make the latter behave in a similar fashion geo-hydrologically and hence the efficiency of supply of moisture - the chief agent of rock alteration - to the various litho-structural domains. The basis for inter-basin dissimilarities in distribution of thickness therefore must be a factor unrelated to the lithologies.

Thicker soil profiles are associated with gentler slopes and hence gentler slopes favour thickness of profiles. This is evidently due to (i) lesser surface erosion whereby A-horizon is preserved and (ii) lesser groundwater gradient that favour wider fluctuation of water table and downward progression of weathering front at A/B, B/C and C/R interfaces.

Organic activity plays a significant role in development of soil profiles only in forest areas where undisturbed and/or substantial accumulation of humus matter occurs. Profile locations in NB and TB are located either in residential plots or small farms with seasonal short term crops where contribution of organic matter to soil, and hence profile development, is negligible. Both NB and TB are part of Southern Granulite Terrain of Precambrian shield that has remained stable and subjected to weathering for several millions of years. Therefore, 'time' factor is similar in these basins.

It follows that climate plays the pivotal role in development of soil horizons and soil profiles in NB and TB. Climate has a direct relationship to intensity of weathering

(White and Blum, 1995). Tropical humid conditions in NB favour 'strong weathering', whereas semi-arid climate in TB inflict 'weak weathering'. Further, laterite is a typical product of weathering under tropical humid conditions (McFarlane, 1976) and therefore its absence in soil profiles of TB is a signature to the influence of climate on weathering.

The difference in pathways of weathering between humid and semi-arid terrains across the Western Ghats has been established by the variance in clay mineralogy (Deepthy and Balakrishnan, 2005). It is suggested that inter-basinal difference in climate may be established by variance in thickness of soil profiles and its constituent horizons (especially B-horizons) also.

3.5. Summary

1. The charted characteristics of weathering profiles developed in the NB (18) and TB (19) clearly reflect and are under the influence of altitude, slope, relief, lithology and climate.

2. Among the 18 profiles in NB, 11 are located in ML and 7 in HL, whereas in TB 6 are in ML and 13 in HL.

3. The profiles are developed on bedrocks like garnetiferous biotite gneiss, charnockite, khondalite, leptynite and pyroxene granulite.

4. Soil horizons present in the profiles of NB are A, AB, BA, BL1, BL2, BL3, BL4, BC, C1 and C2. Similarly, those recorded in the TB are A, ABk, B, Bk, K, Ck1, Ck2, C1 and C2.

5. Laterite (B-horizon) typical of tropical humid climate is present in all weathering profiles in NB. In TB, laterite is missing; instead calcrete (indicator of semi-aridity is ubiquitous either as cement, pore filling or veins in B-horizon (Bk) and C-horizon (Ck1 & Ck2) or discrete zone with a horizon name, K.

6. Profiles in ML of NB (mean thickness in ML are A=130.0 cm; B = 449.0 cm; C = 432.0 cm), are relatively thicker in comparison with HL (A = 78.0 cm; B = 244.0 cm; C = 271.0 cm). On the contrary, TB shows a mean thickness of (A=57.0 cm;

B=53.0 cm; C=277.0 cm) in ML, while horizons in HL (A=85.0 cm; B=91.0 cm; C=336.0 cm) are thicker than that of ML.

7. It is also obvious that between the basins, horizons in NB are thicker than those in TB. Mean thickness of A, B and C-horizons of NB are 95.0 cm, 368.0 cm and 369.0 cm, while in in TB the corresponding values are 76.0 cm, 80.0 cm and 277.0 cm respectively. Further, between NB and TB, profiles in NB are thicker (mean = 801.0 cm) than those of TB (mean = 417.0cm).

8. Between-basin-difference is best expressed in the thickness of B-horizons, which is differentiated clearly in Fig. 3.1.

9. Thickness of profiles in NB shows a negative correlation with altitude, whereas, that of TB show a positive correlation with altitude.

10. Influence or dictate of slope on thickness of horizons and profiles are obvious, in that NB has thicker horizons and profiles associated with gentler slopes. Comparable data for TB in this respect is unavailable.

11. The control of RR on thickness of horizons and weathering profiles is well displayed in NB. Horizons and profiles tend to be thicker in locations of low relief. Data in TB is not available for comparison.

12. Comparison of the thickness in NB and TB indicate that type of bedrock has no decisive role in the thickness of horizons. Further, no common trend can be made out relating thickness of profiles to nature of bedrock.

13. Inter-basin difference in the thickness of horizons and weathering profiles between NB and TB is a robust signature of differing climate (i.e., tropical humid vs. semi-arid) and hence processes.

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