more apatite form, and attract matrix, creating the final stone whose overall composition reflects the super saturation present in urine[7].

Apatite plays a key role in the formation of all kidney stones. The crystalline components of the urinary tract are CaC_2O_4, calcium phosphate, struvite, purine or cystine[9]. A majority of urinary stones are admixtures of two or more components, with the primary admixture being CaC_2O_4 and apatite[9]. Fermanor model studies have shown that calcium phosphate nidi are always formed initially and may subsequently become coated with CaC_2O_4 or other components[8].

From micromorphologic studies we show the sequence of steps that lead to the formation of the common human CaC_2O_4 urolith stone and this can be presented in four stages: (1) Formation of a nucleus or a plaque. (2) Uniform concentric rims of blood stain around the nucleus with multiple centres of growth bands. (3) Incremental growth bands of CaF_2 mixed with CaC_2O_4, and calcium phosphate in prominent growth direction forming papillae due to the probable availability of space leading into several papules. The individual growth bands can be ovoid, oblate or elongate, suggesting a driving force of a prominent growth direction and internal available space. (4) Development of radial cracks by the growing nucleus exerting pressure on the mineralized bands, thus resulting in the development of the cracks. Because of the compositional difference between the nucleus and the surrounding zones and the mineralized bands, the tiny papillae are more susceptible to deformation, and get dislocated along the radial cracks (Figure 2 *i*), eventually leading to a complete disruption and destruction of the individual septums, which float in the peripheral mineralized zone (Figure 2 *i*). These floating pieces possibly breakup into smaller pieces that are likely to cause excruciating pain to the kidney-stone patients.

This study is only a preliminary attempt at understanding the microstructure of kidney stones. Detailed research demands meticulous electron microscopic studies on the kidney stones, their chemistry, and the dietary habit and genetics of the patients.

1. Atmani, F., Glenton, P. A. and Khan, S. R., Identification of proteins extracted from calcium oxalate and calcium phosphate crystals induced in the urine forming subjects. *Urol. Res.*, 1998, **26**, 201–207.
2. Devuyst, O., Dahan, K. and Pirson, Y., Tamm–Horsfall protein or uromodulin: new ideas about an old molecule. *Nephrol. Dial. Transplant.*, 2005, **20**, 1290–1294.
3. Evan, A. P. *et al.*, Mechanism of formation of human calcium oxalate renal stones on Randall's plaque. *Anat. Rec.*, 2007, **290**, 1315–1323.
4. Giannosi, M. L., Mongelli, G. and Summa, V., The mineralogy and internal structure of kidney stones. *NDT Plus*, 2009, **2**, 418–419.
5. Hyacinth, P., Rajamohanan, K., Marickar, F. Y. M., Koshy, P. and Krishnamurthy, S., A study of ultra structure of urinary calculi by scanning electron microscopy. *Urol. Res.*, 1984, **12**, 227–230.
6. Kumar, N., Singh, P. and Kumar, S., Physical, X-ray diffraction and scanning electron microscopic studies of urolith. *Indian J. Biochem. Biophys.*, 2006, **43**, 226–232.
7. Kuo, R. L. *et al.*, Urine calcium and volume predict coverage of renal papilla by Randall's plaque. *Kidney Int.*, 2003, **64**, 2150–2154.
8. Leusmann, D. D. and Sabinski, F., Potential contribution of optional urease-positive bacteria to idiopathic urinary calcium stone formation. II. Microlith formation kinetics in a fermenter model of the urinary tract infected by optional urease-positive microorganisms. *Urol. Res.*, 1996, **24**, 73–78.
9. Mandel, N., Mechanism of stone formation. *Sem. Nephrol.*, 1996, **16**, 364–374.
10. Maragos, P., Sofou, A., Stamou, G. B., Tzouvaras, V., Papatheodorou, E. and Stamou, G. P., Image analysis of soil micromorphology: feature extraction, segmentation, and quality inference. *EURASIP J. Appl. Signal Process.*, 2004, **6**, 902–912.
11. Rez, P., Fong, H. and Sarikaya, M., Scanning electron microscopy and atomic force microscopy of the ring structures in human calcium oxalate urinary stones. *Microsc. Microanal.* (*Suppl. 2*), 2002, **8**, 746CD–747CD.
12. Parks, J. H., Coward, M. and Coe, F. L., Correspondence between stone composition and urine supersaturation in nephrolithiasis. *Kidney Int.*, 1997, **51**, 894–900.
13. Sai Satish, R., Ranjit, B., Ganesh, K. M., Rao, G. N. and Janardhana, C., A quantitative study on the chemical composition of renal stones and their fluoride content from Anantapur District, Andhra Pradesh, India. *Curr. Sci.*, 2008, **94**(1), 104–109.

ACKNOWLEDGEMENTS. We thank the Head, Department of Geology, University of Pune, Pune for providing facilities. We also thank DST and UGC, New Delhi for providing FIST and DRS (SAP) funds for infrastructure. The help rendered by Prof. N. R. Karmalkar in microscopic studies is acknowledged. S.S.K. thanks UGC, New Delhi for funds to carry out this work.

Received 2 February 2010; revised accepted 27 October 2010

Carbon storage and sequestration in bamboo-based smallholder homegardens of Barak Valley, Assam

Arun Jyoti Nath and Ashesh Kumar Das*

Department of Ecology and Environmental Science,
Assam University, Silchar 788 011, India

Smallholder farming systems throughout the world are believed to be potential sinks to remove atmospheric CO_2. Smallholder bamboo farming system in Barak Valley, Assam, which forms a part of the traditional homegarden system, holds promise in this respect. Occurrence of bamboo in all homesteads coupled with progressive increase in culm density over the years reflects its potential for carbon (C) storage. Hundred homegardens were selected from the study site and the total number of culms from all the different age classes per clump of *Bambusa cacharensis*, *Bambusa vulgaris* and *Bambusa balcooa* were recorded with their diameter at breast height. Harvest method was employed to estimate the aboveground biomass

---

*For correspondence. (e-mail: asheshdas684@hotmail.com)

and from biomass values C stock was determined. C estimate in aboveground vegetation in bamboo farming system ranged from 6.51 (2004) to 8.95 (2007) Mg ha^{-1} with 87%, 9% and 4% of the total C stored in culm, branch and leaf respectively. The rate of C sequestration was 1.20–1.46 Mg ha^{-1} yr^{-1}, with a mean of 1.32 Mg ha^{-1} yr^{-1}. In bamboo farming system under selective felling regime, although the C stock and sequestration was low compared to other agroforestry systems across the world, it represented a permanent stock. Harvesting of mature culms was balanced by C gain from new culms produced in the clump. Carbon assimilation ratio, an index to evaluate C sequestration potential per unit of C stock, exhibited bamboo farming as an efficient C sequester than other pure plantations or natural forests. Promotion of smallholder bamboo farming systems to reduce atmospheric greenhouse gas levels to receive certified emission reduction is recommended.

Keywords: Bamboo farming, carbon assimilation ratio, smallholder, homegarden.

HOMEGARDENING is the oldest land-use activity next only to shifting cultivation. It evolved through generations of gradual intensification of cropping in response to increasing human pressure and the corresponding shortage of arable lands[1]. Bamboo forms an important component of homegardens of Assam and the rural lives in Assam are intricately linked with these[2]. Under the traditional homegarden management, bamboo plantation development is integrated with other tree production systems for subsistence and commercial use[3]. Bamboo provides the villagers with a wide range of goods and services[2]. Selective felling is mainly practised in homegardens; the mature culms (> 2 years) which constitute about 15–30% of the total culms per clump are harvested each year[4].

Homegarden bamboos can be significant sinks of atmospheric carbon (C) due to their fast growth and high productivity[5]. Finding low-cost methods to sequester C is emerging as a major international policy goal in the context of global climate change[5]. The United Nations Framework Convention on Climate Change defines C sequestration as the process of removing C from the atmosphere and depositing it in a reservoir. The role of agroforestry systems across the world has been prioritized in C sequestration[6], whereas bamboos in particular remain unexplored. Bamboos form the imperative component of the agrosilvicultural system in North East India and have an important influence on the C balance of the ecosystem through assimilating atmospheric CO_2 (ref. 7). Bamboos have socio-economic and ecological value and their management can provide benefits on a local, national and global level through livelihood, economic and environmental security for many millions of rural people[5]. Only a few studies have demonstrated the potential of bamboos in C storage and as C sinks[8–11]. Therefore, understanding of C storage and sequestration potential of bamboos is crucial to evaluate their role in homegardens in environmental and economical sustainability. This communication aims to describe the potential of bamboo-based smallholder homegardens in C stock management and C mitigation through sequestration.

The study was conducted in Irongmara and Dargakona villages, Cachar District, Barak Valley, North East India (24°41′N, 92°45′E), where bamboo occurs in all homegardens. Although seven bamboo species were found in the study area, the highest frequency of occurrence was observed for *Bambusa cacharensis* R. Majumder (Betua), followed by *B. vulgaris* Schrad. ex Wendl. (Jai borua) and *B. balcooa* Roxb. (Sil borua)[2]. Since 85–90% of the total growing stock of bamboo in the homegardens was contributed by these three species, C stock and sequestration were determined for these species. Homegarden size in the villages ranged from 0.07 to 1.67 ha, with an average[2] of 0.28 ha. Communities like Mala, Maal and Pashi dominated the study area. The climate of the study site is sub-tropical warm and humid with average rainfall of 2226 mm, most of which is received during the southwest monsoon season (May–September). Average maximum and minimum temperatures were 30.5°C and 20.3°C respectively.

One hundred homegardens were selected from the study site through simple random sampling, representing 10% of the total household. Since a majority of the homegarden owners were smallholders, sampling was done mostly for smallholders. The soil was acidic, sandy loam to sandy clay loam in texture with 35.48–40.26% water-holding capacity. Soil organic carbon, N, P and K were 0.89–1.13%, 0.14–0.21%, 27–34 Mg kg^{-1} and 54–62 Mg kg^{-1} respectively[12].

Data were collected from 2004 to 2007. Average number of clumps of *B. cacharensis*, *B. vulgaris* and *B. balcooa* per homegarden was 3.84, 1.50 and 1.07 respectively[2]. All the clumps of the three species from the 100 selected homegardens were enumerated for the present study. The total number of culms from all the different age classes per clump for the three species in each homegarden was recorded with their diameter at breast height (DBH). The number of new culms produced was recorded from 2005 to 2007. DBH of new culms was recorded in November each year when the culm growth stabilized. Biomass was determined by harvesting randomly selected culms of different sizes. Depending on the culm size, nine diameter classes for *B. cacharensis* and ten different girth classes for *B. vulgaris* and *B. balcooa* were recognized representing the whole diameter range, and from each diameter class three culms for *B. cacharensis* and two culms for *B. vulgaris* and *B. balcooa* were harvested from all the four age classes. After harvesting, the culms were divided into leaf, branch and culm component and their fresh weights were taken in the field. A sub-sample of each component was oven-dried at 70°C to constant weight. Culm, branch and leaf dry weights were calculated using the moisture content. Sub-samples of culm, branch and leaf were ground in a Wiley mill. A total of 50% of the ash-free mass was taken as the C content. The ash content was determined by igniting 1 g of powdered sample at 550°C for 6 h in a muffle furnace. Aboveground C stock was determined by summing the C in leaf, branch and the woody components for three species per homegarden, and then computed on hectare basis.

Regression models were fitted linking the C stock of different culm components with DBH as the independent variable for the three species. The best fitting model was selected based on highest value of coefficient of determination R^2 and lowest value of standard error of estimate E (ref. 13).

The C sequestration for the period 2004 (C_1)–2005 (C_2), 2005 (C_3)–2006 (C_4), and 2006 (C_5)–2007 (C_6) was calculated as $\Delta C_1 = (C_2–C_1)$, $\Delta C_2 = (C_4–C_3)$ and $\Delta C_3 = (C_6–C_5)$.

The equation for the C sequestration is

$$\Delta C_s = (C_n - C_{n-1}) + L,$$

where C_n is the C stock for the nth year, C_{n-1} is the C stock of the year preceding the nth year and L is the total litter production during the period.

Litter production was studied from the bamboo-dominated sites of ten homegardens by laying ten permanent litter traps (prepared with bamboo frame) of 50 cm × 50 cm size in each homegarden. Monthly estimation of litterfall was made by collecting the litter and sorting it into (i) leaf litter, (ii) sheath litter and (iii) branch litter. The litter so collected was oven-dried at 70°C to constant weight. Monthly component-wise litterfall values were summed to obtain the total annual litter production.

Consistent increase in the total number of bamboo culms in the homegarden over the study year was observed (Table 1). *B. cacharensis* represented 56% of the total growing stock of bamboo in the sampled homegarden. The corresponding value for *B. vulgaris* was 26% and for *B. balcooa* was 18% (Table 1).

Estimates of C content in culm components exhibited higher proportions in woody component (50–52%) than in branch (47–48%) and leaf (41–43%) for the three species. There was an apparent trend in the increase in C estimates of the leaves, branches and culm components from 2004 to 2007. Total C stock of bamboo in homegardens over the period with 95% confidence interval is given in Table 2. Proportion of C stock analysis among the species revealed that 36–38%, 34–36% and 28–30% was contributed by *B. cacharensis*, *B. vulgaris* and *B. balcooa* respectively. C partitioning among the aboveground vegetation components exhibited that 4% was stored in leaf, whereas branch and culm stored 9% and 87% respectively. Total litter production (Figure 1) varied from 868 to 1125 kg ha^{-1} yr^{-1}, with a mean of 1032 kg ha^{-1} yr^{-1}. Leaf litter contributed 57% of the total annual litterfall. The corresponding value for sheath and branch litter was 38% and 5%. C content determined for leaf, sheath and branch components of litter was 45, 47 and 52% respectively. Conversion of litter component with their respective C contents showed annual C production through leaf, sheath and branch litter as 0.27, 0.19 and 0.04 Mg ha^{-1} yr^{-1} respectively. The rate of C sequestration was 1.20–1.46 Mg ha^{-1} yr^{-1}, with a mean of 1.32 Mg ha^{-1} yr^{-1} (Table 3). C production through aboveground biomass increment from new culm production and litterfall contributed 62% and 38% respectively of total C sequestered annually.

The consistent increase in aboveground C stock might result from the increase in culm density. New culm production successively over the years increased the culm density. The farmers in the study area felled fewer culms per clump than produced. Irrespective of higher culm density of *B. cacharensis* in homegarden biomass, C stock was almost the same for the three species, which can be explained by the greater culm size and height of *B. vulgaris* and *B. balcooa* than *B. cacharensis*. C storage in the aboveground biomass ranging from 21.69 to 76.55 Mg ha^{-1} in a grove of pure bamboo plantation in Barak Valley has been reported[7]. Estimated C stock of 4.87 and 14.62 Mg ha^{-1} in agricultural and agroforestry systems respectively, in the terai zone of West Bengal has been reported[14]. C stock in agroforestry practices has been estimated as 9, 21, 50, and 63 Mg C ha^{-1} in semiarid, subhumid, humid and temperate regions respectively[15]. Biomass C stock ranged from 0.7 to 54.0 Mg C ha^{-1} in traditional and improved agroforestry systems in the West African Sahel[16]. Since bamboo is one of the components in multistrata mixed species homegardening system, bamboo farming system in homegardens had relatively smaller C stock than other agroforestry systems. In bamboo, the C sequestration potential is determined by the new culms produced annually. Under the farmers' management system new culms are not felled and hence almost all C sequestrated through them can be assumed as a net gain. Harvest of products, particularly in single-objective plantations, has a negative impact on the

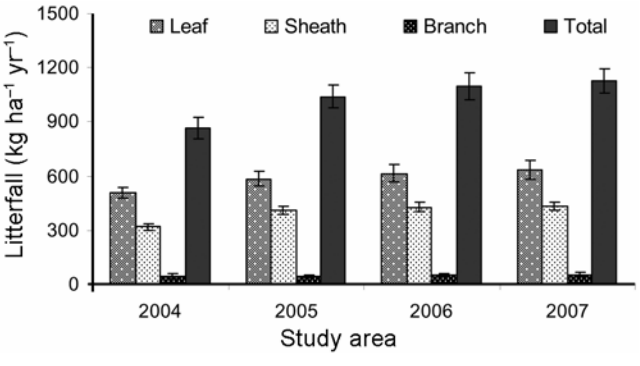

Figure 1. Litterfall in bamboo-based smallholder homegardens in Barak Valley, Assam.

Table 1. Culm density (no. ha^{-1}) of three species in bamboo-based smallholder homegardens in Barak valley, Assam

	Bambusa cacharensis	*Bambusa vulgaris*	*Bambusa balcooa*	Total
2004	487 ± 43	235 ± 26	152 ± 23	874 ± 58
2005	510 ± 65	248 ± 30	167 ± 21	925 ± 74
2006	598 ± 41	278 ± 31	186 ± 20	1062 ± 68
2007	642 ± 45	306 ± 27	212 ± 21	1160 ± 62

Values are mean ± SE.

Table 2. C estimates (Mg ha^{-1}) in aboveground biomass components in bamboo-based smallholder homegardens in Barak Valley, Assam

Species and component	2004	2005	2006	2007
B. cacharensis				
Leaf	0.09	0.10	0.12	0.13
Branch	0.19	0.21	0.24	0.26
Culm	2.14	2.32	2.69	2.94
Total	2.43	2.63	3.05	3.33
B. vulgaris				
Leaf	0.09	0.09	0.10	0.11
Branch	0.27	0.28	0.31	0.35
Culm	1.89	2.26	2.27	2.51
Total	2.24	2.63	2.69	2.97
B. balcooa				
Leaf	0.05	0.06	0.07	0.08
Branch	0.17	0.18	0.20	0.23
Culm	1.62	1.84	2.02	2.34
Total	1.84	2.08	2.29	2.65
Grand total	6.51	7.34	8.03	8.95
Total with 95% confidence limit	6.51 ± 0.68	7.34 ± 0.77	8.03 ± 0.84	8.95 ± 0.93

Table 3. C sequestration (Mg ha^{-1} yr^{-1}) in bamboo-based smallholder homegardens in Barak Valley, Assam

	2004–2005	2005–2006	2006–2007
C gain through new culms produced	0.83	0.69	0.93
C production through litterfall	0.48	0.51	0.53
Total C sequestration	1.31	1.20	1.46

C stock of the system and raises concerns of ‘permanence’[17], and the problem holds in long-term C storage for the farmers’ deliberate management system of clear felling of bamboo clumps for commercial purposes, as observed in bamboo groves of NE India[5]. It is worth noting that in homegardens under selective felling system although the C stock is low, nonetheless it represents a permanent stock, as C export through harvesting of mature culms is balanced by C gain from new culms produced in the clump. Long rotation systems such as agroforests and homegardens can sequester sizeable quantities of C in plant biomass and in long-lasting wood products[18], besides having other secondary environmental benefits[19] and improvement of social situation of local communities[20].

Analysis of carbon assimilation ratio from the published data[14] on pure plantation of *Dalbergia sissoo* (11.11%) and *Terminalia arjuna* (12.07%) and natural forest of *Shorea robusta* (3.34%), revealed greater potentiality under cost-effective small-scale bamboo farming system in the study area (16–20%). Therefore, large-scale bamboo plantation development as a part of agroforestry expansion practices or land-use intensification using degraded land may provide the greatest potential C storage sink.

1. Kumar, B. M. and Nair, P. K. R., The enigma of tropical homegardens. *Agrofor. Syst.*, 2004, **61**, 135–152.
2. Nath, A. J. and Das, A. K., Bamboo resources in the homegardens of Assam: a case study from Barak Valley. *J. Trop. Agric.*, 2008, **46**, 46–49.

3. Peyre, A., Guidal, A., Wiersum, K. F. and Bongers, F., Dynamics of homegarden structure and function in Kerala, India. *Agrofor.. Syst.*, 2006, **66**, 101–115.
4. Nath, A. J., Das, G. and Das, A. K., Population structure and culm production of bamboos under traditional harvest regimes in Assam, Northeastern India. *J. Bamboo Rattan*, 2006, **5**, 79–88.
5. Nath, A. J., Das, G. and Das, A. K., Above ground biomass, production and carbon sequestration in farmer managed village bamboo grove in Assam, northeast India. *J. Am. Bamboo Soc.*, 2008, **21**, 32–40.
6. Nair, P. K. R., Mohan Kumar, B. M. and Nair, V. D., Agroforestry as a strategy for carbon sequestration. *J. Plant Nutr. Soil Sci.*, 2009, **172**, 10–23.
7. Nath, A. J. and Das, A. K., Carbon pool and carbon sequestration potential of village bamboos in the agroforestry system of Northeast India. In International Tropical Ecology Congress, Abstract. HNB Garhwal University, Uttarakhand and International Society for Tropical Ecology, Varanasi, 2–5 December 2007, p. 159.
8. Isagi, Y., Kawahara, T., Kamo, K. and Lto, H., Net production and carbon cycling in bamboo *Phyllostachys pubescens* stand. *Plant Ecol.*, 1997, **130**, 41–52.
9. Das, D. K. and Chaturvedi, O. P., *Bambusa bambos* (L.) Voss plantation in eastern India: I. Culm recruitment, dry matter dynamics and carbon flux. *J. Bamboo Rattan*, 2006, **5**, 47–59.
10. Kiyono, Y. *et al.*, Predicting chronosequential changes in carbon stocks of pachymorph bamboo communities in slash-and-burn agricultural fallow, northern Lao People's Democratic Republic. *J. For. Res.*, 2007, **12**, 371–383.
11. Kumar, B. M., Sudheesh, K. G. and Rajesh, G., Standing stock of thorny bamboo [*Bambusa bambos* (L.) Voss] in the homegardens of Thrissur, Kerala. *J. Trop. Argic.*, 2005, **43**(1–2), 51–56.
12. Nath, A. J., Studies on the ecology and management of bamboos in traditional homegardens of Barak Valley, North East India. Ph D thesis, Assam University, Silchar, 2008.
13. Nath, A. J., Das, G. and Das, A. K., Aboveground standing biomass and carbon storage in village bamboos in North East India. *Biomass Bioenergy*, 2009, **33**, 1188–1196.
14. Koul, D. N. and Panwar, P., Prioritizing land-management options for carbon sequestration potential. *Curr. Sci.*, 2008, **95**, 658–663.
15. Montagnini, F. and Nair, P. K. R., Carbon sequestration: An underexploited environmental benefit of agroforestry systems. *Agrofor. Syst.*, 2004, **61**, 281–295.
16. Takimoto, A., Nair, P. K. R. and Nair, V., Carbon stock and sequestration potential of traditional and improved agroforestry systems in the West African Sahel. *Agric. Ecosyst. Environ.*, 2008, **125**, 159–166.
17. Roshetko, J. M., Lasco, R. D. and Angeles, M. D., Smallholder agroforestry systems for carbon storage. *Mitig. Adapt. Strat. Global Change*, 2007, **12**, 219–242.
18. Albrecht, A. and Kandji, S. T., Carbon sequestration in tropical agroforestry systems. *Agric. Ecosyst. Environ.*, 2003, **99**, 15–27.
19. Pandey, D. N., Carbon sequestration in agroforestry systems. *Climate Policy*, 2002, **2**, 367–377.
20. Rootzen, J. M., Berndes, G., Ravindranath, N. H., Somashekar, H. I., Murthy, I. K., Sudha, P. and Ostwald, M., Carbon sequestration versus bioenergy: A case study from South India exploring the relative land-use efficiency of two options for climate change mitigation. *Biomass Bioenergy*, 2010, **34**, 116–123.

ACKNOWLEDGEMENTS. We thank the two anonymous reviewers for their valuable comments. This work was supported by a research grant from the G.B. Pant Institute of Himalayan Environment and Development, Almora.

Received 10 August 2009; revised accepted 11 November 2010

Using MASW to map depth to bedrock underneath Dehradun fan deposits in NW Himalaya

A. K. Mahajan* and Nitesh Rai

Wadia Institute of Himalayan Geology, 33, GMS Road,
Dehradun 248 001, India

Dun Valley is an intermontane valley located within the Siwalik foreland basin in Garhwal Himalaya. With the evolution of Dun Valley, Dun gravels and post-Siwalik formations were deposited in this valley in the form of fan deposits. Earlier information on the thickness of Dun gravels in the Dehradun fan and bedrock depth level was based on stratigraphy studies and estimated to be 600 m. Later, based on tube-well boring and field observations, the thickness of the Dun gravels has been revised to 100–300 m. In the present communication, shear wave velocity (V_s) field has been calculated using multichannel analysis of surface waves (MASW), surveyed using 4.5 Hz frequency geophones with Elastometer-aided weight drop hammer as a source. This enabled us to map the thickness of the Dun gravels and the depth to bedrock underneath the Dehradun fan deposits as 35 m in the northern flank of the syncline, 140 m in the centre of the broad syncline and 90 m in the southern flank of the syncline below the ground surface. The Middle Siwalik sandstone and Upper Siwalik conglomerates bedrock have been assigned a shear wave velocity of ~750–800 m/s and ~950–1000 m/s respectively, after running a seismic profile directly on the respective bedrock exposed along the river sections. Based on 1D and 2D V_s profiles from north to south, a model of cross-section showing depth of bedrock/thickness of the Dun gravels has been presented. Different litho units of the Dehradun fan defined by earlier researchers have been validated with V_s. Each unit, i.e. units A–C, has been assigned V_s as 700–850, 500–700 and < 500 m/s respectively.

Keywords: Bedrock, fan deposits, multichannel analysis, shear wave velocity, surface waves.

A NUMBER of intermontane broad open synclinal valleys or Dun basins dominate the morphotectonic features of the Sub-Himalaya, e.g. Ropar–Pinjor Dun and Dun Valley in NW Himalaya[1]. These basins are formed on the large-scale synclines of Siwalik strata and are separated from the Lesser Himalaya to the north by the Main Boundary Thrust (MBT) and Mohand Thrust (MFT)[2,3] to the south (Figure 1). A major part of Dun Valley is covered by three fans, from west to east the Donga, Dehradun and Bhogpur fans, deposited by streams following the topography produced by the activity of MBT[4,5]. Due to

---

*For correspondence. (e-mail: akmahajan@rediffmail.com)