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Article

Major and trace element compositions of Tertiary sedimentary successions in the NW and SE Bengal basin, Bangladesh

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Abstract

The Bengal basin in Bangladesh occupies the vast peripheral Himalayan foreland basin, and is divided into three geological provinces: 1) NW shelf (NWS); 2) the Northeastern foredeep (Surma basin); and 3) the southeastern Chittagong-Tripura Folded Belt (CTFB). These geological provinces contain sediments derived from the Himalaya and Proto-Himalaya that record the exhumation history of the Himalayan orogen. This study reports whole-rock major and trace element analyses of Paleogene and Neogene sediments from the NWS (n = 66) and Neogene sediments from the CTFB (n = 219). Both the NWS and the CTFB sample suites show marked compositional contrasts between sandstones and mudrocks, and systematic stratigraphic changes in composition. These geochemical variations are the end product of processes which include hydrodynamic sorting, weathering, diagenesis, and heavy mineral concentration, coupled with contrasting depositional environments related to Himalayan tectonics and climate change. The role of these factors in determining the geochemical variations will be evaluated further in future work, along with comparison with published data for geological province 2 (Surma basin), to explore the links between provenance, tectonism, and climate in the Himalaya-Bengal Basin depositional system.

Key words: Geochemistry, sandstone, mudstone, Bengal Basin, Bangladesh

Introduction

Geological processes and the erosion and deposition of sediments from nearby sources or orogens play an important role in crustal evolution. Erosion of Himalayan sediments and their deposition in the peripheral foreland basin has contributed significantly to changes in global geodynamics, climate and ocean geochemistry, as established in the literature (Raymo and Ruddiman, 1992; Richter e*t al.* 1992). The geochemical compositions of sediments respond to various tectonic, sedimentological, and climatic processes. Retention of the fingerprints of such processes is the basis of geochemical studies of sediments used to infer past geological environments. Geochemical compositions of sediments and their variations can be used to link provenance (Roser and Korsch, 1988; McLennan e*t al.* 1993), tectonic setting (Roser and Korsch, 1986), climate (Nesbitt and Young, 1982), and other earth surface processes operating at geological time scales. However, it remains a challenge to differentiate tectonically- and climatically-driven sedimentation, and the influence of these two primary factors on sedimentary environments and depositional patterns.

The Bengal basin fill is a record of Himalayan-derived sediments that can be used to infer the interaction of tectonism and climate. The Bengal basin began to receive sediments during the Oligocene period (38 Ma) (Najman e*t al.* 2008). The Bengal basin encompasses the northeastern part of the Indian subcontinent, and is located between the Indian Shield and the Indo-Burman Ranges (Fig. 1). It is divided into three geological provinces: i) Province 1, or the Northwest shelf (NWS); ii) Province 2, or the Northeastern foredeep (Surma basin); and iii) Province 3, the Chittagong Tripura Folded Belt (CTFB); each province varies in their facies and potential provenance (Reimann, 1993; Alam e*t al.* 2003; Najman, 2006). The Bengal basin thus occupies a vast region, and receives a large volume of sediments that may hold the key to resolving many basic problems, such as the geochemical variation of sediments in relation to Himalayan uplift and climate change. Understanding the effects of these processes helps in developing models of tectonic-climatic evolution in the regional context. The geochemical composition of sediments can also help identify past depositional environments.

Early work on the geochemical composition of sediments in the Bengal basin by Rahman and Faupl (2003) dealt with Neogene Surma Group sediments of the Surma basin (Province 2). Rahman and Suzuki (2007a, b) also inferred the provenance and tectonic setting of the Surma Group depositional basin. The Paleogene succession of the Bengal basin was studied by Najman e*t al.* (2008) to identify the provenance of the sediments. They found that significant contribution of sediments from the Himalaya began at 38 Ma, some 17 Ma earlier than previously thought. Stratigraphic and lithologic limitations of earlier work in the Surma basin (Rahman and Faupl 2003; Rahman and Suzuki (2007a, b) were addressed by Hossain e*t al.* (2010), who examined the geochemical compositions of both Paleogene and Neogene sandstones and mudrocks from the Surma

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succession (Province 2) to identify geochemical variations in the sediments in relation to provenance and weathering. However, Najman (2006) noted that amalgamation of datasets from more than one geological province for provenance studies could obscure regional details. To date, no geochemical studies have been carried out in Province 1 (NWS) or 3 (CTFB). Therefore, it is essential to study the geochemical composition of the sediments from each province individually.

In this paper, we present a geochemical database of sandstones and mudstones from the Paleogene and Neogene succession of Province 1 (NWS) and the Neogene succession of Province 3 (CTFB). This new geochemical data and previously published data from Province 2 (Hossain *et al.* 2010) will contribute to better understanding of the regional context of proto-Himalayan and Himalaya-derived sedimentation in the Bengal basin. This geochemical dataset will be interpreted and discussed in depth in future work to examine climatically and tectonically-induced sedimentation in relation to drifting of the Indian plate, and Himalayan uplift and climate change.

Geology of the Bengal Basin

Tectonic evolution

The tectonic evolution of the Bengal basin is related to the continent-continent collision of the Indian and Eurasian (Tibetan) plates, development of the Himalaya, and oblique subduction of oceanic crust beneath the Burmese plate, with associated development of an accretionary wedge (Alam e*t al.* 2003; Mukherjee e*t al.* 2009). India was part of Gondwana before collision of the Indian and Eurasian plates. The Gondwana supercontinent began to break up at ~126 Ma, and India started to move northward from the South Pole (Lindsay e*t al.* 1991). The Bengal basin started to form during that time, with rifting of the Indian plate from Antarctica and Australia. However, collision of the Indian and Asian plates took place during Eocene time (55 Ma) (Molnar and Tapponier, 1975). Recent work by Aitchison e*t al.* (2007) noted that soft collision started at the Eocene-Oligocene boundary (34 Ma ago). The Tethys Sea disappeared due to the collision between the Indian and Asian plates, and subsequent formation of the Himalaya fed sediments into the Bengal basin via gigantic river systems.

Stratigraphy

The stratigraphic successions of the NWS and CTFB are summarized in Table 1 (a, b). The depositional patterns and sedimentation within them are controlled by rise and fall of sea level, and uplift and subsidence of the source region and depositional basin, respectively (Alam e*t al.* 2003).

In the NWS the lowermost Jaintia Group (Paleocene-Late Eocene) is represented by the Tura Sandstone, Sylhet Limestone, and Kopili Shale, in ascending order. The Tura Sandstone Formation (Paleogene-E. Eocene) consists of poorly sorted sandstone, siltstone, mudstone, fossiliferous marl, and thin coal seams (Reimann, 1993; Uddin and Lundberg, 1999; Alam *et al*. 2003). The overlying Sylhet Limestone Formation (E.-M. Eocene) is composed of massive and compact limestone containing abundant foraminifera (Alam *et al*. 2003), and the Kopili Shale consists of thinly-bedded sandstone and shale (Uddin and Lundberg, 1999; Alam *et al*. 2003). The Barail Group of late Eocene to early Miocene age overlies the Jaintia Group, and is composed of interbedded sandstones and mudstones with high sand/mud ratio that were deposited in distal deltaic to marine environments (Alam *et al*. 2003; Najman *et al.* 2008). The Barail Group is succeeded by the Neogene Surma Group, which consists of sandstones, siltstones and mudstones deposited in a large deltaic system (Alam *et al.* 2003), followed by fluvial sandstones and mudstones of the Dupitila Group (Table 1).

The CTFB succession is all of Neogene age (Table 1b). The basal Surma Group is divided into the Bhuban and Bokabil Formations, in ascending order. Both consist of deltaic sandstones and mudrocks. In the CTFB the Surma Group is succeeded by the Tipam Group, which is subdivided into the Tipam Sandstone Formation and the overlying Girujan Clay Formation. The Tipam Group sediments consist of coarse grained sandstones, siltstones and mudstones that represent bedload-dominated braided fluvial and fluvial overbank deposits (Reimann, 1993; Alam *et al*. 2003). Tipam Group sediment are absent from the NWS, but also occur in Province 2. In the CTFB the Tipam Group is succeeded by the Dupitila Group, which consists of sandstones, siltstones, and mudstones that were laid down by a meandering river system (Johnson and Alam, 1991).

Sampling and Sample Preparation

Sample sites

This study presents whole-rock X-ray fluorescence (XRF) analyses of Paleogene and Neogene sandstones and mudrocks from Province 1 (NW shelf; n = 66) and Neogene sandstones and mudrocks from Province 3 (CTFB; n = 219). The samples were collected from both deep and shallow exploration boreholes, and also from outcrop (see Tables 2 and 3, respectively). The number of samples collected for each formation or group was determined by availability from drill core.

Samples from the NWS represent the Jaintia (n = 14), Barail (n = 6), Surma (n = 22) and Dupitila Groups (n = 24), in ascending order (Table 2). All samples were taken from drillcore. The Jaintia Group samples consist of 11 sandstones from the Tura Sandstone Formation, and three mudstones from the Kopili Shale; all of which were taken from the Bogra-2 well. Barail Group is represented by only six samples (one sandstone, five mudrocks), all of which were from the Singra-1 well. Surma Group samples (two sandstones, seven siltstones, 13 mudstones) were collected from the Bogra-2 and Singra-1 wells, whereas Dupitila Group samples (five sandstones, 13 siltstones, six mud-

Table 1. Stratigraphy, facies and depositional environments of (a) NW shelf (NWS; Province 1) and (b) CTFB (Province 3) of the Bengal basin in Bangladesh (modified from Reimann, 1993; Alam *et al.* 2003; Najman *et al.* 2008). Data are presented for the shaded formations.

(A) NW shelf (Province 1)				
Age	**Group**	**Formation**	**Lithology**	**Depositional environment**
Neogene	Dupitila	Dupitila	Sandstones, mudstones	Fluvial
Neogene	Surma	Surma	Sandstones, mudstones	Deltaic
L. Eocene-E. Miocene	Barail	Barail	Sandstones, minor mudstones	Deltaic
L. Eocene	Jaintia	Kopili Shale	Shales, minor limestone	Shallow marine
E. to M. Eocene		Sylhet Limestone	Limestone	Shallow marine
Paleocene-E. Eocene		Tura Sandstone	Quartz arenites	Shallow marine

(B) CTFB (Province 3)				
Age	**Group**	**Formation**	**Lithology**	**Depositional environment**
Neogene	Dupitila	Dupitila	Sandstones, mudstones	Meandering
Neogene	Tipam	Girujan Clay	Mudstones	Overbank
Neogene		Tipam Sandstone	Sandstones, mudstones	Braided
Neogene	Surma	Bokabil	Sandstones, mudstones	Deltaic
Neogene		Bhuban	Sandstones, mudstones	Deltaic

stones) were drawn from several wells (see Table 2).

The CTFB suite is much larger (n = 219), but spans only the Surma (n = 155), Tipam (n = 42) and Dupitila Groups (n = 22). The Surma samples are divided almost equally between the Bhuban (n = 80; 20 sandstones, 60 mudrocks) and the Bokabil Formations (n = 75; 14 sandstones, 64 mudrocks), collected from both drillcore and outcrop (Table 3, Fig. 1). Tipam Group samples represent the lowermost Tipam Sandstone Formation (n = 32; 16 sandstones, 16 mudrocks) and the Girujan Clay Formation (10 mudstones). Of these, five were taken from the Shahbajpur-1 well, and the remainder from outcrop (Fig. 1). The Dupitila Group samples (seven sandstones, 15 mudstones) were all collected from outcrop (Fig. 1).

Analytical procedures

Clean drill core and outcrop samples were chipped to < 1 cm using a manual splitter to remove any veins or thin weathering rinds. The chips were then repeatedly rinsed and soaked in deionized distilled water to remove dust and then dried in an oven at 110°C for 24 h. The dried chips were then crushed in a tungsten carbide ring mill, with mills time generally of 30-45 seconds, following the methodology of Roser e*t al.* (1998). Subsamples (10 g) of the pulps were placed in glass vials and returned to the oven at 110°C for > 24 h. Total loss on ignition (LOI) was subsequently determined gravimetrically by ignition for at least 2 h at 1020°C. The ignited samples from the LOI determination were hand-ground in an agate pestle and mortar, and returned to a 110 °C oven before preparation of glass fusion beads for the XRF analysis.

The XRF analysis was performed at Shimane University, using a Rigaku RIX 2000 spectrometer equipped with a Rh-anode X-ray tube. Major element and 14 trace element (Ba, Ce, Cr, Ga, Nb, Ni, Pb, Rb, Sc, Sr, Th, V, Y, Zr) abundances were determined from glass fusion beads prepared with an alkali flux (80% lithium tetraborate ($Li_2B_4O_7$) and 20% lithium metaborate ($LiBO_2$)), in a flux to sample ratio of 2:1 (Kimura and Yamada, 1996). Calibration and correction for spectral interferences followed the methodology of Kimura and Yamada (1996). Internal correction for intra-run drift was made using secondary calibration against ten Geological Survey of Japan standard rocks spanning the compositional range from gabbro (JGb-1) through to granite (JG-2).

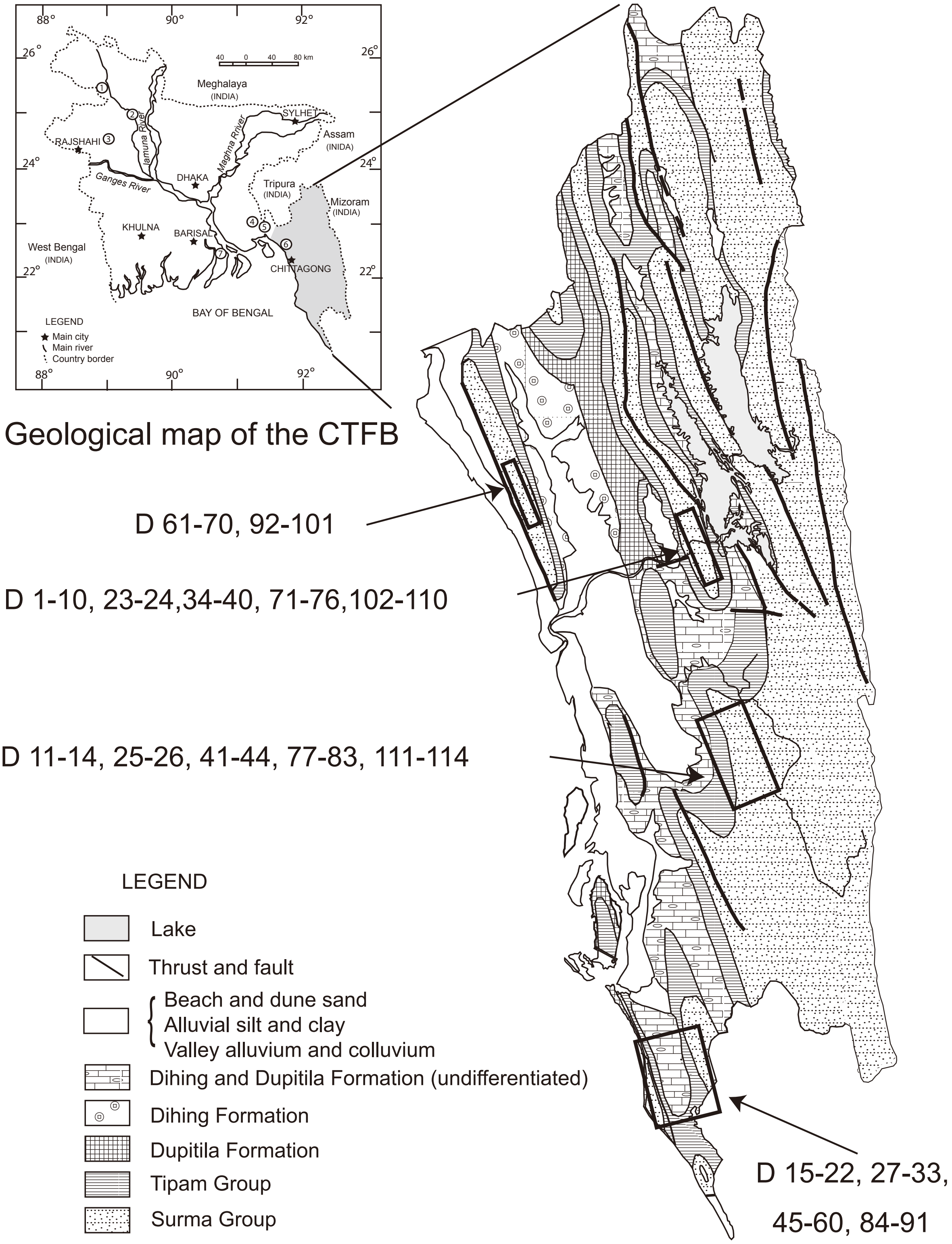

Fig 1. Map showing the location of drill hole and areas sampled in the NW shelf and CTFB, Bengal basin, Bangladesh. Drill hole No. (1) AS-13, 14, 27, 28, DOB-1, SOB-11/4, MS-13, 14, 15, 17, 19 (2) Bogra-2 (3) Singra-1 (4) Begumganj-2 (5) Feni-1 (6) Sitakund-5 and (7) Shahbajpur-1 (modified after Alam *et al.* 1990).

Results and Discussion

Major and trace elements analyses (anhydrous normalized basis) of the NWS and CTFB samples are listed in Tables 2 and 3, respectively. The normalizing factors used to adjust the major element data to 100% were also applied to the trace element data. The tabulated data can be corrected to a hydrous basis if desired, using the original "as analyzed" total (anhydrous), and the LOI values determined from the original hydrous powders.

NW shelf (NWS, Province 1)

Major elements

Major element abundances show significant variation within the NWS succession. Hydrodynamic separation of quartz and clay minerals during deposition strongly influences SiO_2 and Al_2O_3 contents, and hence largely controls the bulk composition of individual samples. Mean SiO_2 contents in sandstones are high in all formations, with an extreme average value of 97.16 wt% and very narrow range (96.03-97.96 wt%) in the Tura Sandstone Formation of the Jaintia Group, and 87.05 wt% for the single sandstone analyzed from the Barail Group. Average SiO_2 content in the two Surma Group sandstones analyzed is 83.73 wt%, rising to 89.64 wt% (86.34-92.60 wt%) for the Dupitila Group sandstones.

Average SiO_2 contents in the mudrocks show much wider variation. An average value of 61.40 wt% in the three Kopili Shale (Jaintia Group) samples analyzed is typical of shales, but disguises very low content (35.44 wt%) in one sample (DK-3) caused by abnormal Fe_2O_3 (35.01 wt%), and high SiO_2 (89.28 wt%) in another (DK-5; Table 2). Average SiO_2 content in the Barail mudrocks is also uniformly very high (90.28 wt%; range 83.40-94.61), well above the values typical of this lithotype (<~70 wt%). Average values fall to more normal values in the Surma (75.16 wt%) and Dupitila Groups (77.46 wt%). In these two groups the higher averages in the mudrocks are caused by significantly higher SiO_2 contents in siltstones versus mudstones. This is especially marked in the Dupitila samples, where SiO_2 contents in siltstones range from 80.40 to 88.31 wt%, slightly overlapping the range in sandstones (86.34-92.4 wt%), but well above that of companion mudstones (60.66-67.08 wt%), a range more typical of fine-grained sediments. These features indicate the NWS siltstones contain appreciable quantities of fine-grained quartz, and attest to the maturity and well-sorted nature of the NWS sediments in general.

As expected from hydrodynamic sorting, Al_2O_3 is the next most abundant major element in all formations. Average content in the Tura sandstones is only 1.29 wt%, rising to 6.47 wt% in the single Barail sandstone, 8.33 wt% in the Surma Group, before falling to 6.57 wt% in the Dupitila sandstones. Mudrock averages show the opposite pattern, falling from 12.30 wt% in the Kopili Shale to 5.18 wt% in the Barail Group, returning to higher values more typical of fine-grained sediments of 13.88 wt% in the Surma Group, and falling slightly to 11.62 wt% in the Dupitila Group.

Due to the covariations of SiO_2 and Al_2O_3, Surma Group sediments thus tend to have higher contents of TiO_2, Fe_2O_3, MnO, MgO, Na_2O and P_2O_5 than underlying Barail and overlying Dupitila equivalents. Tura Sandstone exhibits remarkably low Na_2O and K_2O contents, with Na_2O below theoretical lower limit of detection (0.10 wt%) in all except one sample, and maximum K_2O of only 0.11 wt%. CaO contents are also very low in all Tura sandstones, with all < 1 wt% (Table 3), and in most mudrocks. Average CaO in the Kopili Shale (4.06 wt%) is biased by one high value (11.67 wt% in DK-3), and falls to 0.09 wt% in Barail mudrocks and 0.43 wt% in the Surma Group, before rising to 2.40 wt% in the Dupitila Group. However, Dupitila siltstones have much lower CaO contents (range 0.04-0.92 wt%) than their companion mudstones (5.97-7.87 wt%). The high abundances in these mudstones are also accompanied by relatively high LOI values (9.27-10.15 wt%), indicative of presence of authigenic $CaCO_3$. In general, LOI values are low (< 5 wt%) in most of the NWS samples. However, higher LOI values (5-15 wt%) are seen in the Kopili Shale (11.51-14.07 wt%) and in many Surma mudrocks, where they appear to be associated with high Fe_2O_3 or Al_2O_3 contents, rather than CaO. This implies influence in these samples of other diagenetic phases, such as Fe oxy-hydroxides, siderite, or hydrous clays.

Overall the major element data for the NWS samples thus show marked fractionation between sandstones, siltstones, and mudstones; very high maturity, as indicated by high SiO_2 contents; severe depletion in mobile elements such as Na_2O, K_2O, and CaO; and irregularities in the distribution of fluid-mobile elements. These features indicate their bulk chemistry has been strongly influenced by factors other than source composition, including sorting, weathering, and diagenesis.

Trace elements

The effects of hydrodynamic sorting are seen clearly in the NWS trace element data, with average abundances in the mudstones in each group almost always greater than in companion mudstones. This is true for all trace elements analyzed in the Dupitila and Jaintia Groups, with concentrations in the mudrocks generally more than double those in the sandstones. In the Surma Group samples average contents in the mudrocks are higher for all except Ba, which is marginally higher (average 289 ppm) in the average of the two sandstones analyzed than in the 233 ppm mean from 20 mudrocks. The single sandstone analyzed in the Barail Group has higher Ba, Ga, Pb, Rb and Sr than the mudstone average (n = 6), but this contrast may not be significant.

The effects of quartz dilution are clearly seen in the Tura Sandstone samples, which are characterized by lower trace element abundances than all other sandstones. In the Tura sandstones average contents of all elements except Ba (80

Table 2. Whole rock major (wt%) and trace element (ppm) analyses of sandstones and mudrocks from the NW Shelf (Province 1), Bangladesh.
Index: SaNR-sample number; Lith-lithology; total iron as Fe_2O_3; LOI-Loss on ignition. Note that data are tabulated on an *anhydrous normalized* basis. The normalizing factors were applied to both the major and trace element data. Original anhydrous analysis total (Total*) and LOI data are included to allow recalculation to a hydrous basis if desired.
Lithology codes: c sst - coarse sandstone; m sst - medium sandstone; f sst - fine sandstone; zst -siltstone; mst - mudstone.

SaNr	Depth (m)	Well	Lith	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI	Total*
Dupitila Group																													
Dupitila Formation																													
DD-01	901	Singra-1	mst	66.39	0.70	13.30	5.02	0.09	3.37	6.27	1.40	3.32	0.14	503	85	62	17	16	28	23	154	12.1	126	20.0	89	31	297	9.39	99.39
DD-02	901.5	Singra-1	mst	60.66	0.73	16.35	6.76	0.11	3.72	5.97	1.24	4.32	0.14	668	82	89	22	17	35	32	193	14.1	136	20.7	115	33	200	10.15	99.44
DD-04	902.5	Singra-1	mst	66.67	0.71	13.06	5.11	0.09	3.33	6.25	1.35	3.30	0.14	534	93	64	16	16	29	26	151	12.8	128	20.8	88	33	337	9.27	99.24
DD-05	903	Singra-1	mst	63.91	0.71	14.38	6.08	0.11	3.52	6.28	1.23	3.64	0.14	588	86	78	18	17	33	26	168	14.2	133	20.6	104	33	257	9.84	99.43
DD-06	903.5	Singra-1	mst	63.59	0.72	15.04	5.46	0.08	3.61	6.26	1.24	3.86	0.13	589	83	73	20	17	32	26	177	14.1	130	19.6	100	31	238	10.02	99.49
DD-07	16	AS-3	zst	80.40	0.32	10.98	2.50	0.04	0.91	0.86	1.60	2.32	0.06	363	54	27	12	9	11	23	131	6.7	88	13.5	37	24	151	1.34	99.77
DD-08	24	AS-5	zst	82.87	0.26	9.79	1.98	0.04	0.71	0.92	1.52	1.87	0.04	330	45	29	12	6	10	19	93	4.1	114	10.3	33	16	130	1.30	100.40
DD-09	64	AS-14	zst	80.80	0.36	11.13	2.99	0.02	0.71	0.56	0.97	2.43	0.03	409	48	38	13	9	18	21	120	5.1	90	9.7	44	14	138	3.21	100.22
DD-10	118	AS-27	zst	84.64	0.57	13.54	0.48	0.01	0.21	0.14	0.18	0.22	0.03	447	53	102	15	22	5	8	17	11.7	28	12.5	73	23	287	5.04	99.60
DD-11	127	AS-28	zst	88.31	0.34	11.04	0.05	0.01	0.15	0.04	0.01	0.03	0.01	449	81	57	12	18	0	26	10	9.1	10	6.7	45	14	185	3.94	99.91
DD-12	14-16	DOB-1	f sst	88.37	0.15	7.18	1.21	0.01	0.36	0.18	0.46	2.04	0.03	334	41	13	8	4	4	22	107	3.2	42	7.8	16	11	117	1.18	100.54
DD-13	32-34	DOB-1	m sst	86.34	0.19	8.03	1.43	0.02	0.41	0.65	1.07	1.83	0.03	304	42	26	9	5	7	18	87	2.0	97	8.8	22	15	98	1.18	100.25
DD-14	62-64	DOB-1	m sst	89.84	0.17	6.25	1.09	0.01	0.32	0.27	0.62	1.42	0.02	211	33	14	7	5	7	15	75	2.4	49	9.3	14	13	98	1.09	101.18
DD-15	96-98	DOB-1	m sst	91.27	0.12	5.27	0.90	0.01	0.27	0.20	0.34	1.62	0.02	241	28	11	6	4	3	15	81	2.0	45	5.2	2	8	86	0.90	99.69
DD-16	126-128	DOB-1	m sst	92.40	0.28	6.11	0.79	0.01	0.20	0.10	0.01	0.11	0.02	11	47	36	8	10	5	19	15	4.1	26	8.0	29	19	257	2.35	99.29
DD-17	14-16	SOB-11/4	mst	67.08	0.58	14.22	4.93	0.05	1.34	7.87	1.04	2.81	0.08	469	103	67	17	13	33	88	165	13.2	110	27.9	70	34	254	9.11	98.94
DD-18	82-84	SOB-11/4	zst	85.38	0.30	8.26	2.88	0.04	0.46	0.44	0.56	1.64	0.05	292	72	46	10	7	18	23	89	3.5	62	10.7	49	19	150	2.49	100.07
DD-19	88-90	SOB-11/4	zst	83.01	0.34	9.72	2.67	0.03	0.57	0.79	0.81	2.00	0.04	335	52	32	11	8	17	23	108	6.2	75	11.7	41	20	157	2.98	99.97
DD-20	108-110	SOB-11/4	zst	83.98	0.34	9.31	2.41	0.03	0.52	0.53	0.85	1.98	0.04	319	52	24	12	8	13	23	104	4.4	78	11.4	38	18	149	2.53	99.94
DD-21	62	MS-13	zst	85.35	0.22	8.30	2.49	0.01	0.44	0.59	0.88	1.67	0.05	296	48	21	10	6	10	17	85	6.1	84	10.8	26	17	106	1.95	99.36
DD-22	68	MS-14	zst	81.40	0.36	10.78	2.89	0.02	0.58	0.71	1.06	2.16	0.04	385	56	36	10	9	16	20	106	6.9	103	11.4	44	17	146	2.91	99.12
DD-23	73	MS-15	zst	82.89	0.27	10.18	2.27	0.01	0.54	0.59	1.05	2.17	0.03	373	39	36	11	7	12	19	105	4.3	95	7.7	35	15	117	2.56	99.39
DD-24	77	MS-17	zst	81.22	0.37	11.28	3.39	0.04	0.63	0.04	0.68	2.32	0.04	392	49	36	11	9	15	21	127	7.0	71	11.9	41	19	160	3.55	100.24
DD-25	88	MS-19	zst	83.21	0.31	10.19	2.61	0.03	0.42	0.43	0.74	2.02	0.04	327	48	26	11	7	11	20	100	8.1	78	10.0	41	17	131	2.88	99.39
Surma Group																													
DS-01	1300	Singra-1	mst	65.23	0.81	17.31	6.82	0.11	2.83	1.70	1.34	3.70	0.14	540	80	106	22	18	55	31	174	15.7	112	17.8	126	32	196	6.55	99.87
DS-02	1801	Singra-1	mst	74.76	1.24	14.38	5.60	0.03	1.02	0.20	0.91	1.77	0.09	271	112	142	16	26	51	22	96	13.6	132	19.3	145	37	480	6.33	99.56
DS-03	1802	Singra-1	mst	79.06	1.03	11.38	5.07	0.05	0.88	0.25	0.80	1.39	0.08	223	107	118	14	22	37	18	76	10.0	104	15.1	105	32	549	4.57	99.17
DS-05	1804	Singra-1	mst	74.30	1.25	14.71	5.74	0.03	1.01	0.24	0.87	1.75	0.10	279	123	144	18	26	51	22	95	13.0	135	18.0	142	37	566	6.40	99.73
DS-06	1600	Bogra-2	mst	85.62	1.01	8.69	3.47	0.01	0.50	0.12	0.09	0.45	0.03	91	97	128	10	23	25	17	38	7.8	85	11.1	114	24	535	4.29	99.79
DS-07	1602	Bogra-2	f sst	84.87	0.32	7.80	2.70	0.06	0.77	0.60	1.39	1.43	0.05	273	45	28	8	6	22	15	61	3.1	117	6.6	36	15	100	1.53	99.73
DS-08	1603	Bogra-2	f sst	82.59	0.43	8.86	3.44	0.05	0.94	0.63	1.44	1.57	0.07	305	60	61	10	9	23	18	68	8.1	120	10.4	54	21	177	1.78	99.33
DS-09	1604	Bogra-2	mst	82.35	1.02	8.20	6.75	0.12	0.69	0.27	0.08	0.43	0.08	99	107	135	10	23	34	17	35	10.8	88	12.2	124	30	713	5.22	99.55
DS-10	1606	Bogra-2	mst	61.32	0.89	18.99	7.73	0.13	3.42	2.00	1.18	4.20	0.15	550	78	130	26	20	70	34	195	18.6	124	19.7	139	34	190	7.86	99.88
DS-11	1608	Bogra-2	mst	67.06	1.42	17.72	10.39	0.12	1.20	0.45	0.34	1.15	0.15	192	121	170	22	32	66	29	79	20.9	188	20.2	226	39	361	9.72	100.53
DS-12	1723-1724	Bogra-2	zst	85.71	1.00	7.72	4.29	0.01	0.55	0.22	0.09	0.39	0.03	97	115	144	8	23	27	16	33	8.9	74	13.5	110	28	704	4.37	99.28
DS-13	1723-1724	Bogra-2	mst	68.05	1.29	16.87	8.45	0.20	1.52	0.53	0.36	2.55	0.18	310	131	156	22	28	56	18	134	17.9	179	21.6	172	42	495	10.52	99.40
DS-15	1724-1725	Bogra-2	zst	74.35	1.40	16.68	3.81	0.03	1.02	0.14	0.35	2.11	0.10	241	134	159	22	30	48	9	116	14.4	152	19.7	162	41	469	9.89	99.32

Table 2 (ctd). Whole rock major (wt%) and trace element (ppm) analyses of sandstones and mudrocks from the NW Shelf (Province 1), Bangladesh.

SaNr	Depth (m)	Well	Lith	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI	Total*
Surma Group ctd)																													
DS-16	1725-1726	Bogra-2	mst	70.64	1.49	19.10	4.47	0.06	1.19	0.18	0.38	2.37	0.10	274	145	166	24	32	70	4	129	16.1	198	24.0	202	43	410	15.71	99.27
DS-17	1725-1726	Bogra-2	zst	70.64	1.71	17.86	6.13	0.08	0.98	0.29	0.40	1.81	0.11	240	142	183	24	37	47	21	107	18.7	200	21.5	196	44	457	9.76	99.77
DS-18	1726-1727	Bogra-2	mst	68.01	1.59	20.41	5.28	0.09	1.31	0.28	0.32	2.58	0.12	285	142	176	26	35	61	10	142	17.2	187	24.9	198	47	385	12.02	99.66
DS-19	1726-1727	Bogra-2	zst	85.49	1.00	7.88	4.33	0.04	0.55	0.16	0.11	0.39	0.04	77	104	143	10	23	24	16	34	9.9	79	12.2	108	26	708	4.18	99.49
DS-20	1727-1728	Bogra-2	mst	69.11	1.26	17.38	7.21	0.11	1.39	0.42	0.35	2.58	0.18	310	119	164	20	28	64	21	140	18.3	180	23.1	175	39	384	9.96	99.35
DS-21	1727-1728	Bogra-2	zst	79.85	1.45	12.57	4.30	0.01	0.69	0.10	0.21	0.80	0.04	140	130	189	17	32	47	24	61	10.3	133	17.9	169	30	636	6.09	99.17
DS-22	1728-1729	Bogra-2	mst	59.40	1.14	16.06	16.59	0.39	2.28	0.98	0.37	2.49	0.31	297	103	133	17	26	53	26	123	16.0	197	20.9	170	42	275	13.16	99.13
DS-23	1728-1729	Bogra-2	zst	91.05	0.21	7.46	0.53	0.01	0.23	0.07	0.06	0.37	0.03	64	51	30	3	6	6	6	20	2.0	23	5.4	22	10	292	7.51	99.75
DS-24	1729-1730	Bogra-2	zst	91.16	0.39	6.24	1.11	0.01	0.28	0.07	0.19	0.51	0.04	75	69	40	5	9	8	8	29	3.4	39	9.4	50	14	319	3.96	100.34
Barail Group																													
DB-1	2001	Singra-1	m sst	87.05	0.34	6.47	2.37	0.04	0.60	0.74	1.10	1.25	0.05	719	45	40	6	6	11	13	49	5.4	122	9.6	40	18	118	6.08	100.37
DB-2	2002	Singra-1	mst	83.40	1.29	8.55	5.48	0.01	0.61	0.07	0.20	0.36	0.03	92	175	188	10	28	31	21	30	10.5	88	19.4	154	38	1157	5.30	100.67
DB-4	2002.5	Singra-1	zst	89.83	0.78	5.79	2.93	0.01	0.40	0.07	0.07	0.11	0.02	42	106	94	2	18	16	10	14	5.3	37	11.5	71	23	878	3.39	99.60
DB-5	2003	Singra-1	zst	94.25	0.69	2.86	1.62	0.01	0.30	0.12	0.01	0.10	0.04	54	101	84	3	16	8	9	13	0.4	36	8.6	43	22	793	1.75	99.09
DB-6	2004	Singra-1	zst	94.61	0.65	2.65	1.58	0.02	0.30	0.08	0.01	0.08	0.02	46	102	82	1	15	8	8	13	3.4	32	9.6	46	21	757	1.60	99.06
DB-7	2004.5	Singra-1	mst	89.28	0.83	6.03	2.99	0.01	0.44	0.10	0.08	0.21	0.03	68	93	98	6	19	18	12	20	5.1	48	8.5	74	24	668	3.13	99.54
Jaintia Group																													
Kopili Shale Formation																													
DK-3	1765	Bogra-2	mst	35.44	0.74	8.76	35.01	0.84	6.55	11.67	0.34	0.53	0.13	134	158	154	9	13	70	28	27	25.8	403	30.4	546	51	522	13.59	95.52
DK-4	1766	Bogra-2	mst	59.49	1.80	22.12	11.60	0.08	2.09	0.40	0.42	1.92	0.08	213	156	188	27	38	68	32	109	23.1	229	25.0	252	36	523	14.07	99.63
DK-5	1767	Bogra-2	mst	89.28	0.83	6.03	2.99	0.01	0.44	0.10	0.08	0.21	0.03	68	93	98	6	19	18	12	20	5.1	48	8.5	74	24	668	11.51	96.13
Tura Sandstone Formation																													
DC-1	1991-1992	Bogra-2	c sst	97.74	0.05	0.79	0.68	0.01	0.18	0.52	0.01	0.01	0.01	71	19	1	0	2	1	6	3	0.6	13	0.7	5	4	81	1.71	100.12
DC-2	1991-1992	Bogra-2	m sst	97.47	0.07	0.96	0.84	0.01	0.17	0.46	0.01	0.01	0.01	71	17	3	1	3	1	2	3	2.0	13	2.0	6	4	91	2.44	100.49
DC-3	1992-1993	Bogra-2	m sst	97.12	0.13	1.51	0.67	0.01	0.18	0.35	0.01	0.01	0.01	80	29	2	1	4	1	4	5	2.0	13	2.6	10	7	164	2.58	100.71
DC-4	1992-1993	Bogra-2	m sst	97.37	0.09	0.96	0.74	0.01	0.18	0.62	0.01	0.01	0.01	93	16	1	1	3	2	4	2	0.5	16	1.8	5	5	110	1.99	99.10
DC-6	1994-1995	Bogra-2	m sst	96.03	0.15	2.29	0.87	0.01	0.18	0.34	0.06	0.06	0.01	52	23	4	3	4	4	4	5	1.2	15	3.9	1	7	120	3.31	98.84
DC-8	1994-1995	Bogra-2	c sst	97.96	0.13	0.77	0.39	0.01	0.18	0.54	0.01	0.01	0.01	104	29	1	1	3	1	4	4	0.8	15	2.7	0	9	204	1.24	97.54
DC-9	1995-1996	Bogra-2	f sst	96.48	0.23	1.62	1.13	0.01	0.17	0.34	0.01	0.01	0.01	67	28	5	1	5	0	8	6	0.8	14	3.2	14	8	188	3.60	101.02
DC-10	1995-1996	Bogra-2	c sst	97.58	0.07	0.95	0.61	0.01	0.18	0.56	0.01	0.01	0.01	88	18	1	0	3	1	5	4	1.1	15	1.6	5	4	79	2.16	100.58
DC-11	1996-1997	Bogra-2	m sst	97.07	0.10	1.37	0.53	0.01	0.17	0.45	0.19	0.10	0.01	98	33	2	1	3	1	5	8	2.0	16	2.1	6	8	242	1.79	100.51
DC-12	1996-1997	Bogra-2	m sst	97.27	0.26	1.08	0.84	0.01	0.16	0.36	0.01	0.01	0.01	76	31	5	1	5	1	6	4	1.9	13	2.8	11	9	199	2.92	100.61
DC-13	1997-1998	Bogra-2	f sst	96.65	0.13	1.88	0.71	0.01	0.16	0.32	0.01	0.11	0.01	78	34	6	1	4	1	6	9	2.0	16	2.5	6	8	260	3.08	100.83

ppm), Ce (25 ppm), Sr (14 ppm) and Zr (158 ppm) are < 10 ppm. Among the mudrocks, average contents of Ce, Cr, Ni, Sc, Sr, Th, V, and Y in the Kopili Shale mudstones are greater than equivalents in the Barail, Surma and Dupitila Groups, suggesting differing provenance. Another feature of the mudrock analyses is the relatively high concentrations of several elements (Ce, Y, Zr) that are typically found in resistant heavy minerals such as monazite, apatite and zircon, especially in the Jaintia, Barail, and Surma Groups. For example, average Zr concentrations in the mudrocks in these three groups are 571, 851, and 456 ppm, respectively, well above the 190 ppm value in average upper continental crust (UCC; Taylor and McLennan, 1985). This suggests significant zircon concentration in the NWS mudrocks. Conversely, average concentrations of more mobile trace elements (Ba, Sr) are significantly lower in both sandstones and mudrocks within groups than in UCC (550 and 350 ppm, respectively). In clastic sediments both elements are typically associated with feldspars, and values in the NWS lower than UCC thus suggest significant loss during weathering or diagenesis.

The above features indicate that the trace element abundances in the NWS sediments have also been influenced by sorting, weathering, diagenesis, and heavy mineral concentration, and hence do not directly reflect original source rock compositions.

CTFB (Province 3)

Major elements

As in the NWS suite, the CTFB sandstones analyzed here have higher concentrations of SiO_2 and lower concentrations of Al_2O_3 than the mudstones. Average SiO_2 contents increase stratigraphically upward. SiO_2 contents of the sandstones range from 59.33-80.15 wt% (mean 74.21 wt%) in the Bhuban Formation, 71.97-83.06 wt% (mean 77.39 wt%) in the Bokabil Formation, 60.31-86.84 wt% (mean 80.71 wt%) in the Tipam Sandstone Formation, and 77.36-95.49 wt% (mean 85.60 wt%) for the Dupitila Formation. Lowest SiO_2 in some samples, e.g. D-92, D-94 and D-109 (Bhuban) and D-42 (Tipam) are due to high CaO contents from authigenic $CaCO_3$ cements. Average SiO_2 contents in the mudrocks are similar in the Bhuban (67.55 wt%), Bokabil (67.77 wt%), Tipam (71.01 wt%) and Girujan Clay (69.60 wt%) Formations. However, average SiO_2 increases slightly in the Dupitila mudrocks (74.56 wt%), due to unusually high concentrations (80.19-92.32 wt%) in four siltstones.

Al_2O_3 concentrations in the Girujan Clay mudrocks tend to be a little higher than in equivalents in the other formations, with a range of 14.90-19.79 wt% (mean 16.98 wt%), compared to 10.56-20.37 wt% (mean 16.06 wt%) in Bhuban mudrocks, 9.64-19.79 wt% (mean, 16.24 wt%) in Bokabil mudrocks, 10.02-19.79 wt% (mean, 14.65 wt%) in Tipam Sandstone Formation mudrocks and 4.40-18.55 wt% (mean, 14.15 wt%) in the Dupitila Formation. Average concentrations of Al_2O_3 in the mudrocks are 44% (Bhuban) to 80% (Dupitila) greater than in the sandstones within each formation, with relative enrichment increasing stratigraphically upward.

Average concentrations of the remaining major elements are naturally constrained by the sum of the SiO_2 and Al_2O_3 contents. The next most abundant oxides are Fe_2O_3 and K_2O, with ranges of averages by lithotype and formation of 2.36-6.53 and 1.47-3.16 wt%, respectively. Average Fe_2O_3 content in the sandstones falls progressively from 4.63 wt% in the Bhuban Formation through to 2.36 in the Bhuban Formation, whereas mudrocks averages fall at a lower rate, from 6.53 wt% to 4.64 wt% respectively. This reflects a steady rise in relative enrichment between average mudrock and sandstone of 1.41 times (Bhuban), through 1.54 (Bokabil) and 1.61 (Tipam Sandstone), to 2.36 times in the Dupitila Formation. This suggests increasing fractionation between sandstone and mudrock end-members stratigraphically upward, as a result of improved sorting. The same pattern is observed for K_2O, with the mudstone to sandstone enrichment factor increasing from 1.42 (Bhuban) through to 1.69 (Dupitila).

The most notable feature of the remaining major elements is the low levels of the mobile oxides CaO and Na_2O. Average CaO content in the sandstones falls from 3.91 wt% (Bhuban), through 1.76 wt% (Bokabil), to 2.16 wt% (Tipam Sandstone), to 0.68 wt% in the Dupitila Formation. Comparable averages for the mudrocks are 1.96, 1.72, 1.47 and 0.85 wt%, respectively, and that in Girujan Clay mudrocks is even lower (mean 0.48 wt%, range 0.26-0.85 wt%). Sandstone Na_2O contents are also low, averaging 1.16 wt% (Bhuban), 1.23 wt% (Bokabil), 0.89 wt% (Tipam) and 0.76 wt% (Dupitila); mudrock averages are lower still, falling steadily from 1.10 wt% in the Bhuban Formation to 0.86 wt% in the Dupitila. With the exception of a few samples enriched in CaO from carbonate cements, CaO and Na_2O contents in the CTFB sediments are considerably less than in UCC (4.2 and 3.9 wt% respectively; Taylor and McLennan, 1985). This points to considerable modification of bulk sediment compositions from the source to the depocenter. Moreover, the consistent trend towards lower abundances of these elements with stratigraphic position points to progressive modification with time.

The remaining major elements (TiO_2, MnO, MgO, P_2O_5) all share a common feature in greater abundances in the mudrocks than in the sandstones, with average enrichment factors ranging from 1.11 to 2.04. Furthermore, abundances in both sandstones and mudrocks generally decrease stratigraphically upwards, in response to increased SiO_2 content. This again points to progressive change of modifying factors with time.

Trace elements

The CTFB trace element data also show marked fractionation between sandstones and mudrocks. Within each formation almost all elements are enriched in the

Table 3. Whole rock major (wt%) and trace element (ppm) analyses of sandstones and mudrocks from the CTFB (Province 3), Bangladesh.
Index: SaNR-sample number; Lith-lithology; total iron as Fe2O3; LOI-Loss on ignition. Note that data are tabulated on an *anhydrous normalized* basis. The normalizing factors were applied to both the major and trace element data. Original anhydrous analysis total (Total*) and LOI data are included to allow recalculation to a hydrous basis if desired.
Lithology codes: c sst-coarse-grained sandstone; m sst-medium sandstone; f sst-fine and very fine grained sandstone; zst -siltstone; mst-mudstone. OC-outcrop sample; see Fig. 1 for locations.

SaNr	Depth (m)	Well	Lith	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI	Total*
Dupitila Group																													
Dupitila Formation																													
D-01	OC		mst	72.64	0.68	14.25	4.25	0.06	1.68	1.56	1.73	2.99	0.15	435	84	74	16	15	31	27	133	10.7	163	20.2	92	32	315	2.31	100.14
D-02	OC		zst	68.20	0.74	15.78	5.75	0.08	2.62	1.66	1.51	3.52	0.14	485	83	83	19	17	44	32	162	12.0	137	19.9	104	34	217	3.82	100.10
D-03	OC		zst	67.03	0.76	15.78	6.03	0.09	2.66	2.50	1.62	3.39	0.15	473	79	94	16	16	48	32	165	14.1	173	22.3	108	33	214	4.11	98.88
D-04	OC		zst	66.75	0.77	17.34	6.18	0.07	2.35	1.21	1.50	3.67	0.14	523	79	98	21	18	46	37	190	16.1	142	21.1	114	35	194	3.38	100.54
D-05	OC		mst	64.89	0.77	17.39	6.32	0.08	2.77	2.56	1.46	3.61	0.15	522	78	97	21	17	44	42	182	17.0	156	20.8	118	33	190	4.79	101.73
D-06	OC		zst	75.63	0.70	12.86	4.79	0.05	1.37	1.02	1.08	2.41	0.08	399	73	107	15	15	42	18	131	10.8	129	14.2	93	30	280	2.74	100.49
D-07	OC		zst	72.04	0.79	14.65	5.95	0.07	1.64	0.91	1.10	2.74	0.11	446	75	113	14	16	57	23	145	12.5	130	18.3	107	32	239	3.30	99.48
D-08	OC		m sst	77.92	0.61	11.03	3.91	0.06	1.31	1.32	1.50	2.23	0.10	371	80	81	9	13	46	20	114	9.2	138	17.8	72	36	303	1.67	99.65
D-09	OC		f sst	77.36	0.53	11.14	4.15	0.06	1.65	1.24	1.44	2.34	0.08	373	51	73	12	12	40	17	122	9.4	137	11.4	74	22	194	1.75	100.09
D-10	OC		m sst	80.66	0.51	10.14	3.26	0.05	0.84	1.25	1.32	1.90	0.06	349	71	68	8	11	23	16	87	8.1	157	16.9	63	25	205	1.47	99.14
D-11	OC		mst	77.92	0.77	13.68	4.36	0.03	0.84	0.11	0.23	2.04	0.02	360	88	102	15	16	68	18	123	13.7	53	14.4	97	45	283	3.74	100.63
D-12	OC		f sst	83.08	0.45	9.31	3.13	0.06	0.67	0.80	0.77	1.71	0.03	322	72	69	10	11	16	16	81	8.9	106	18.0	55	24	203	1.82	100.06
D-13	OC		mst	68.74	0.92	18.55	5.44	0.14	1.71	0.72	0.62	3.12	0.04	481	91	132	22	19	52	27	160	19.1	119	22.5	150	42	223	4.70	99.22
D-14	OC		zst	80.28	0.77	12.23	3.10	0.02	0.99	0.07	0.58	1.96	0.01	366	74	109	14	15	69	15	111	8.9	54	13.2	80	32	298	2.99	100.56
D-15	OC		zst	92.32	0.40	4.40	1.24	0.02	0.25	0.10	0.34	0.95	0.00	171	78	71	3	9	10	14	48	2.7	30	13.4	26	13	288	1.21	98.34
D-16	OC		m sst	95.49	0.08	2.76	0.49	0.01	0.19	0.05	0.13	0.80	0.01	146	33	8	3	4	4	11	42	0.6	25	2.1	6	8	59	0.78	98.58
D-17	OC		zst	76.19	0.98	17.11	2.67	0.01	0.59	0.05	0.24	2.14	0.01	322	106	163	19	19	28	21	111	16.3	53	18.6	132	41	316	4.61	99.85
D-18	OC		zst	85.83	0.56	10.49	1.76	0.01	0.32	0.04	0.10	0.89	0.00	152	60	93	13	11	15	13	61	9.9	27	13.9	73	16	311	3.36	100.25
D-19	OC		m sst	91.34	0.31	6.30	0.64	0.01	0.22	0.05	0.14	0.99	0.01	184	54	44	4	7	6	15	51	5.8	28	10.1	28	14	172	1.84	98.51
D-20	OC		m sst	93.33	0.32	4.48	0.92	0.01	0.20	0.04	0.04	0.66	0.01	127	37	36	5	8	4	11	37	1.6	20	8.6	19	10	185	1.37	97.62
D-21	OC		zst	80.19	0.73	10.42	5.93	0.02	0.47	0.07	0.23	1.92	0.02	366	97	102	9	14	33	23	127	10.1	44	20.2	83	32	494	3.19	99.00
D-22	OC		mst	69.78	0.89	17.32	5.80	0.05	2.02	0.23	0.57	3.26	0.07	497	111	118	22	19	92	30	175	15.6	77	17.3	127	57	206	4.34	100.26
Tipam Group																													
Girujan Clay Formation																													
D-23	OC		mst	62.80	0.92	19.46	8.11	0.11	2.65	0.85	1.20	3.73	0.16	511	85	158	21	18	84	37	187	20.9	132	21.2	159	35	175	5.05	99.58
D-24	OC		mst	63.05	0.92	19.79	7.99	0.12	2.52	0.68	1.14	3.63	0.16	508	82	147	25	18	76	37	185	20.1	126	18.5	158	35	172	5.09	100.68
D-25	OC		mst	63.48	0.95	19.47	7.58	0.07	2.89	0.66	1.08	3.71	0.12	519	83	175	25	19	107	37	190	21.3	113	20.3	160	36	178	4.83	100.15
D-26	OC		mst	69.40	0.89	16.37	6.09	0.06	1.98	0.81	1.16	3.13	0.11	480	84	155	17	17	84	28	160	15.5	122	19.7	133	33	215	3.71	99.16
D-27	OC		mst	73.32	0.83	15.32	4.71	0.04	1.71	0.29	1.04	2.68	0.05	382	83	122	18	16	62	23	144	13.4	83	16.4	117	30	257	3.99	100.45
D-29	OC		mst	73.94	0.85	15.69	3.98	0.03	1.50	0.29	1.01	2.67	0.04	379	85	126	19	17	53	22	140	16.5	86	15.6	111	29	290	3.91	100.49
D-30	OC		mst	74.34	0.83	15.06	4.28	0.03	1.46	0.30	1.01	2.64	0.06	372	91	123	15	17	58	22	138	16.9	84	19.2	113	31	322	3.72	99.33
D-31	OC		mst	73.70	0.81	14.90	5.24	0.04	1.50	0.26	0.97	2.51	0.06	374	81	123	18	16	59	24	137	15.8	85	15.6	117	31	281	3.58	100.58
D-32	OC		mst	70.52	0.89	16.81	6.24	0.04	1.72	0.26	0.73	2.76	0.03	390	97	154	17	17	78	28	142	19.9	87	21.6	150	36	351	4.41	99.32
D-33	OC		mst	71.40	0.89	16.99	5.33	0.09	1.51	0.39	0.76	2.62	0.03	387	108	153	20	17	78	32	139	19.2	98	18.6	137	37	346	3.48	100.84
Tipam Sandstone Formation																													
D-34	OC		f sst	81.43	0.46	9.76	3.08	0.05	0.79	0.96	1.34	2.08	0.06	361	56	59	8	11	28	18	100	6.1	142	13.4	52	20	175	1.58	98.54
D-35	OC		mst	65.26	0.96	19.79	6.44	0.05	2.46	0.52	0.91	3.50	0.11	496	82	140	26	19	98	36	180	20.4	115	20.1	156	37	198	4.84	100.74
D-36	OC		m sst	80.82	0.48	9.54	3.67	0.07	0.94	1.11	1.42	1.88	0.06	328	72	62	11	10	22	16	90	7.7	147	13.1	57	23	201	1.29	99.80
D-37	OC		f sst	78.54	0.55	10.72	4.03	0.05	1.20	0.99	1.58	2.25	0.09	383	64	65	11	13	33	20	117	9.8	143	13.0	62	24	214	1.63	99.17

Table 3 (ctd). Whole rock major (wt%) and trace element (ppm) analyses of sandstones and mudrocks from the CTFB (Province 3), Bangladesh.

SaNr	Depth (m)	Well	Lith	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI	Total*
Tipam Group (ctd)																													
Tipam Sandstone Formation (ctd)																													
D-38	OC		zst	68.43	0.85	16.03	7.22	0.10	2.25	0.73	1.17	3.08	0.13	484	80	117	20	17	60	32	163	15.8	107	18.4	126	34	234	3.86	99.92
D-39	OC		mst	68.11	0.67	10.48	4.93	0.37	1.82	10.07	1.27	2.16	0.13	342	70	89	8	14	42	18	103	12.1	267	18.2	82	31	261	9.08	98.35
D-40	OC		zst	70.08	0.92	14.82	6.36	0.08	2.23	1.29	1.25	2.81	0.16	437	111	143	18	18	59	23	146	14.8	112	21.7	128	39	459	3.87	99.84
D-41	OC		zst	69.57	0.86	15.64	6.18	0.08	2.36	1.06	1.23	2.91	0.11	439	84	104	19	17	52	26	148	13.5	128	17.1	132	33	226	3.74	99.75
D-42	OC		m sst	60.31	0.42	7.49	2.98	0.61	1.75	23.89	0.95	1.53	0.07	224	51	108	1	8	143	12	63	8.0	188	18.3	54	27	166	15.57	96.53
D-43	OC		f sst	77.57	0.55	10.62	5.77	0.09	1.29	0.64	1.19	2.19	0.10	346	50	72	13	12	52	18	127	9.5	115	10.1	94	22	181	2.26	99.30
D-44	OC		zst	80.97	0.51	10.02	3.74	0.05	0.91	0.75	1.14	1.87	0.04	349	61	68	6	11	35	17	95	8.1	135	16.7	73	21	199	1.64	98.65
D-45	OC		m sst	79.11	0.55	11.09	4.81	0.07	1.04	0.59	0.72	1.97	0.06	327	76	81	12	12	36	25	106	11.3	100	14.8	92	30	290	2.36	99.62
D-46	OC		m sst	83.52	0.48	8.47	3.20	0.06	0.72	0.87	0.94	1.69	0.05	292	82	65	4	10	21	23	85	9.3	112	20.2	67	26	339	1.18	98.43
D-47	OC		f sst	83.16	0.46	8.94	3.46	0.07	0.86	0.60	0.68	1.69	0.09	289	61	69	10	10	31	19	89	7.6	96	12.3	60	22	235	1.53	99.57
D-48	OC		f sst	83.10	0.45	8.87	3.37	0.05	0.80	0.73	0.76	1.80	0.06	308	69	61	6	10	26	21	91	8.1	107	16.2	67	24	284	1.37	98.29
D-49	OC		zst	72.24	0.85	15.91	5.49	0.06	1.59	0.39	0.61	2.80	0.06	411	86	119	19	17	59	25	155	16.6	96	17.2	136	34	265	3.50	99.41
D-50	OC		f sst	86.84	0.31	6.84	2.66	0.05	0.59	0.63	0.57	1.47	0.03	256	47	38	3	8	18	22	72	4.6	92	14.2	47	19	167	0.99	98.61
D-51	OC		f sst	81.72	0.44	9.48	3.67	0.07	0.87	0.85	0.98	1.87	0.05	322	64	52	11	10	24	22	98	6.3	117	12.4	72	23	201	1.83	99.39
D-52	OC		zst	78.90	0.64	10.83	4.62	0.13	1.17	0.74	0.87	2.00	0.10	330	90	95	7	13	32	17	110	11.2	102	20.4	87	31	399	2.51	98.59
D-53	OC		zst	75.80	0.74	13.69	4.78	0.04	1.37	0.46	0.70	2.34	0.08	359	80	113	16	14	49	17	127	13.7	93	14.9	114	32	286	3.03	99.83
D-54	OC		m sst	85.26	0.20	7.82	2.65	0.06	0.57	0.78	0.96	1.65	0.05	301	38	24	3	5	15	21	79	5.7	116	12.3	51	15	88	1.12	98.20
D-55	OC		f sst	78.28	0.65	11.49	5.07	0.06	1.19	0.51	0.68	2.00	0.09	325	84	91	13	13	42	18	111	8.0	94	14.6	96	30	319	2.45	99.30
D-56	OC		m sst	85.03	0.28	8.14	3.03	0.04	0.63	0.54	0.55	1.73	0.03	311	67	29	9	8	20	30	86	7.3	100	12.2	55	26	194	1.28	99.50
D-57	OC		m sst	85.91	0.34	7.93	2.72	0.04	0.57	0.46	0.43	1.57	0.03	283	61	49	8	8	24	24	78	5.5	85	12.0	63	20	177	1.45	99.51
D-58	OC		f sst	80.78	0.50	11.06	3.88	0.05	0.85	0.42	0.46	1.97	0.03	372	66	50	13	11	34	21	109	7.6	87	12.7	73	24	194	2.58	99.98
D-59	OC		zst	76.90	0.65	10.59	5.70	0.08	1.33	1.25	0.87	2.52	0.10	369	69	79	14	13	46	22	132	8.4	135	13.5	107	26	226	1.97	88.18
D-60	OC		zst	79.63	0.53	10.44	3.59	0.06	0.88	1.45	1.32	2.01	0.08	338	81	70	6	11	24	18	99	8.3	165	20.4	83	26	295	1.25	99.49
DR 64	998-999	Shahbajpur-1	mst	66.46	0.84	17.16	6.84	0.11	2.56	0.97	1.30	3.44	0.14	516	83	111	22	18	61	30	184	16.5	138	19.7	128	33	202	5.37	99.20
DR 65	1000-1001	Shahbajpur-1	mst	65.05	0.83	17.66	7.31	0.11	2.65	0.94	1.19	3.58	0.14	529	77	115	21	17	62	31	191	17.7	140	20.5	134	34	194	5.36	98.82
DR 66	1001-1002	Shahbajpur-1	zst	66.06	0.84	17.59	6.70	0.10	2.52	0.90	1.20	3.59	0.13	529	84	112	21	18	61	34	189	15.9	139	20.2	133	33	178	4.93	99.01
DR 67	1004-1005	Shahbajpur-1	zst	65.79	0.86	17.28	6.84	0.10	2.52	0.94	1.19	3.52	0.14	537	89	112	21	18	64	34	188	17.1	136	21.1	137	34	209	5.22	98.57
DR 68	1005-1006	Shahbajpur-1	zst	66.93	0.78	16.45	6.73	0.10	2.43	0.98	1.35	3.33	0.14	495	81	106	20	16	58	30	178	14.7	143	18.9	125	31	194	5.11	98.62
Surma Group																													
Bokabil Formation																													
D-61	OC		f sst	77.46	0.67	11.85	4.80	0.07	1.21	0.72	0.98	2.14	0.10	386	79	101	14	13	41	20	111	9.8	127	14.8	102	28	286	2.34	100.24
D-62	OC		zst	76.58	0.70	12.06	5.10	0.05	1.40	0.76	0.95	2.28	0.12	398	79	90	9	14	48	19	120	10.2	122	19.3	110	28	274	2.29	98.96
D-63	OC		zst	83.12	0.37	9.64	2.81	0.03	0.67	0.53	0.87	1.93	0.04	369	46	43	10	7	28	18	92	4.1	134	9.3	51	17	130	1.59	99.88
D-64	OC		mst	74.37	0.69	13.82	5.91	0.04	1.38	0.54	0.69	2.46	0.10	399	79	112	12	14	51	24	125	14.8	130	19.7	112	38	211	3.08	99.21
D-65	OC		mst	63.61	0.96	18.80	7.44	0.06	3.24	1.34	0.78	3.62	0.15	490	84	143	24	19	78	34	179	21.7	111	20.0	171	38	201	3.12	100.30
D-66	OC		zst	73.04	0.84	13.92	5.77	0.11	1.63	0.76	1.10	2.69	0.14	425	88	110	12	16	54	23	141	12.9	114	22.7	127	33	297	2.87	98.90
D-67	OC		mst	71.35	0.83	14.50	5.84	0.08	2.14	1.22	1.20	2.70	0.14	428	87	103	18	16	51	22	140	14.0	137	17.3	126	33	266	3.39	99.73
D-68	OC		m sst	79.48	0.54	10.62	3.83	0.06	0.99	1.07	1.21	2.13	0.08	378	68	64	7	11	32	20	111	8.0	152	18.1	78	23	219	1.47	98.67
D-69	OC		zst	69.44	0.83	15.82	6.86	0.12	1.92	0.84	1.08	2.94	0.15	469	73	110	20	16	61	26	159	12.9	135	15.6	140	32	208	3.57	100.16
D-70	OC		mst	64.60	0.98	19.05	8.47	0.11	2.42	0.65	0.41	3.16	0.16	464	90	170	16	19	92	34	198	21.7	107	27.4	188	37	201	5.32	98.57
D-71	OC		zst	69.21	0.86	15.55	6.69	0.06	2.49	1.07	1.00	2.92	0.15	448	83	138	20	16	63	24	152	16.8	114	16.7	133	35	251	4.21	100.12
D-72	OC		zst	79.64	0.64	10.42	4.24	0.05	1.08	0.65	1.12	2.06	0.11	379	85	97	3	12	37	17	105	7.7	122	22.6	93	26	329	1.93	99.50
D-73	OC		mst	72.01	0.85	14.46	6.13	0.07	1.88	0.63	1.14	2.69	0.14	435	86	117	17	17	55	22	141	13.1	116	16.7	127	34	296	2.99	100.31
D-74	OC		mst	63.85	0.94	18.70	7.70	0.07	3.00	0.95	1.17	3.49	0.13	518	85	139	16	18	74	32	172	19.2	127	26.5	173	34	184	5.07	99.57
D-75	OC		f sst	78.00	0.63	11.38	4.19	0.04	1.36	0.90	1.33	2.06	0.10	361	81	85	13	13	45	20	106	7.4	134	15.8	87	25	274	1.76	100.32
D-76	OC		f sst	73.75	0.76	12.72	5.16	0.05	2.09	1.56	1.34	2.43	0.14	407	87	100	15	15	46	18	118	15.4	134	17.4	114	33	341	3.05	99.94

Table 3 (ctd). Whole rock major (wt%) and trace element (ppm) analyses of sandstones and mudrocks from the CTFB (Province 3), Bangladesh.

SaNr	Depth (m)	Well	Lith	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI	Total*
Surma Group (ctd)																													
Bokabil Formation (ctd)																													
D-77	OC		mst	66.30	0.87	17.51	7.01	0.11	2.48	1.07	1.04	3.46	0.16	481	83	120	16	18	61	32	177	17.5	138	24.5	154	34	195	4.36	98.84
D-78	OC		zst	71.03	0.78	14.91	5.73	0.08	2.04	1.07	1.36	2.84	0.16	428	80	96	18	16	48	24	148	13.8	138	16.9	120	32	230	3.32	100.10
D-79	OC		f sst	76.69	0.62	12.39	4.26	0.05	1.14	0.84	1.50	2.38	0.12	378	72	71	5	13	31	20	125	7.0	141	20.9	86	26	218	1.92	100.06
D-80	OC		mst	72.62	0.79	14.40	5.71	0.07	1.90	0.71	1.15	2.53	0.12	424	76	106	16	15	51	20	129	13.8	115	15.0	114	28	238	3.10	100.72
D-81	OC		f sst	77.12	0.66	12.09	4.30	0.07	1.27	0.83	1.38	2.15	0.13	359	97	91	13	14	35	19	110	7.5	132	18.0	87	30	374	1.93	100.62
D-82	OC		zst	71.15	0.78	15.58	5.93	0.06	1.59	0.71	1.18	2.86	0.15	445	86	101	13	16	47	28	146	14.9	134	22.5	124	33	238	2.95	99.55
D-83	OC		mst	67.62	0.84	17.45	6.46	0.08	2.23	0.80	1.22	3.16	0.15	465	82	113	21	17	55	28	162	15.0	127	18.3	145	34	208	3.84	101.23
D-84	OC		mst	69.49	0.93	16.74	6.88	0.12	1.97	0.44	0.49	2.84	0.09	406	88	154	20	17	76	29	153	17.6	131	18.1	151	36	242	4.41	99.77
D-85	OC		zst	71.04	0.88	15.80	6.64	0.14	1.85	0.36	0.51	2.69	0.09	387	87	136	18	17	73	27	147	17.1	122	17.0	149	33	249	6.76	99.92
D-86	OC		mst	65.56	0.99	18.94	7.74	0.14	2.54	0.40	0.30	3.31	0.09	434	91	152	23	18	94	37	176	21.6	114	19.1	183	37	213	5.40	99.45
D-87	OC		zst	69.80	0.95	17.04	6.30	0.05	2.09	0.31	0.51	2.88	0.08	403	91	131	20	18	80	28	155	16.3	107	18.3	156	36	258	4.44	99.96
D-88	OC		mst	67.46	0.87	17.14	6.64	0.09	2.43	1.01	0.98	3.26	0.13	456	84	127	20	18	64	31	170	19.8	141	20.3	151	34	213	3.74	99.93
D-89	OC		mst	69.82	0.84	15.69	6.07	0.07	2.09	0.93	1.24	3.13	0.12	458	88	108	13	16	55	28	159	13.7	142	25.0	136	33	210	3.32	98.78
D-90	OC		mst	69.47	0.83	15.97	6.40	0.11	2.17	0.83	1.07	3.00	0.13	453	83	115	19	16	66	26	161	18.7	133	17.7	130	35	232	3.19	99.63
D-91	OC		zst	46.57	0.68	11.47	5.64	1.05	2.06	29.76	0.22	2.40	0.15	295	67	87	13	13	44	15	111	8.4	167	16.0	97	32	153	20.14	97.95
DR 37	2499-2500	Feni-1	mst	70.38	0.75	14.67	5.73	0.11	2.22	2.06	1.15	2.78	0.15	419	81	107	18	16	52	25	143	13.1	143	17.3	102	32	223	5.16	99.13
DR 38	2500-2501	Feni-1	zst	66.80	0.88	17.06	6.87	0.10	2.56	0.97	1.24	3.34	0.17	482	93	113	21	18	59	30	170	16.0	139	20.3	133	37	239	4.82	98.59
DR 39	2501-2502	Feni-1	zst	65.55	0.89	17.93	7.17	0.11	2.64	1.05	1.12	3.39	0.16	478	82	130	23	17	77	33	176	17.5	142	18.7	139	35	199	5.26	98.73
DR 40	2502-2503	Feni-1	mst	67.17	0.82	17.23	6.66	0.10	2.33	1.00	0.92	3.64	0.13	556	86	106	22	17	49	32	172	16.3	105	17.5	133	34	248	4.86	98.34
DR 41	2503-2504	Feni-1	mst	63.14	0.92	19.34	7.82	0.12	2.84	0.76	1.26	3.66	0.15	491	86	150	24	18	83	34	185	18.8	140	19.4	159	34	178	5.56	98.99
DR 42	2504-2505	Feni-1	mst	65.18	0.89	18.19	7.25	0.11	2.64	0.92	1.25	3.42	0.15	480	82	124	23	18	79	33	176	17.1	143	18.9	145	32	188	5.28	99.03
DR 43	2505-2506	Feni-1	mst	67.06	0.85	16.80	6.57	0.09	2.58	1.32	1.29	3.29	0.14	471	92	117	21	17	59	30	167	14.7	133	19.3	122	33	242	5.04	99.33
DR 44	2506-2507	Feni-1	mst	64.06	0.94	18.95	7.30	0.10	2.75	0.76	1.41	3.59	0.15	490	84	145	25	19	81	35	183	17.8	140	20.0	154	31	196	5.35	98.96
DR 45	2634-2635	Feni-1	zst	67.29	0.84	16.53	6.76	0.12	2.45	1.19	1.44	3.21	0.17	467	95	122	20	17	60	31	166	16.1	145	20.4	124	35	242	4.84	99.07
DR 46	2635-2636	Feni-1	mst	66.09	0.89	17.32	7.01	0.10	2.61	1.01	1.40	3.41	0.17	486	94	120	22	18	64	33	171	16.6	137	20.8	133	34	255	4.99	98.48
DR 47	2636-2637	Feni-1	m sst	81.73	0.52	9.41	3.23	0.04	0.98	0.68	1.36	1.96	0.09	428	64	61	10	11	27	22	91	4.2	121	14.4	49	19	247	1.69	99.20
DR 48	2637-2638	Feni-1	f sst	83.06	0.54	8.22	3.27	0.04	1.34	1.01	0.78	1.66	0.08	303	85	91	10	12	24	16	86	4.8	58	13.5	43	25	379	2.87	99.14
DR 49	2638-2639	Feni-1	mst	62.67	1.01	19.65	7.96	0.08	3.01	0.67	1.01	3.81	0.13	486	90	145	24	20	83	32	197	21.7	134	20.4	163	36	205	5.46	99.21
DR 50	2734-2735	Feni-1	mst	65.36	0.88	18.03	7.14	0.10	2.70	0.89	1.22	3.55	0.15	500	86	122	22	18	65	31	182	18.9	141	20.4	133	34	196	5.09	99.16
DR 51	2735-2736	Feni-1	mst	64.30	0.93	18.74	7.33	0.09	2.81	0.83	1.15	3.67	0.15	509	91	134	24	19	68	34	189	18.8	141	21.2	147	35	211	4.98	99.25
DR 69	1794-1795	Shahbajpur-1	f sst	71.97	0.72	13.03	5.34	0.07	2.29	2.37	1.29	2.80	0.12	488	74	74	16	16	40	22	151	11.2	135	16.7	93	29	247	4.32	98.61
DR 70	1795-1796	Shahbajpur-1	mst	68.99	0.83	15.45	6.62	0.05	2.62	1.03	1.21	3.07	0.13	482	79	110	19	17	71	28	161	15.5	136	17.5	123	30	223	4.18	99.10
DR 71	1796-1797	Shahbajpur-1	m sst	76.45	0.70	10.88	4.09	0.06	1.71	2.31	1.47	2.18	0.14	394	100	64	12	14	29	16	115	8.0	145	19.9	74	34	382	3.31	98.74
DR 72	1797-1798	Shahbajpur-1	m sst	76.32	0.68	10.95	4.14	0.06	1.71	2.22	1.58	2.20	0.14	397	89	59	14	14	28	19	116	8.9	143	16.4	79	32	351	3.25	98.98
DR 73	1799-1800	Shahbajpur-1	zst	68.05	0.81	15.31	6.30	0.08	2.69	2.04	1.35	3.24	0.12	526	88	91	19	17	47	24	170	15.0	148	20.7	111	33	262	5.23	98.46
DR 74	1801-1802	Shahbajpur-1	zst	71.82	0.73	12.87	5.58	0.07	2.39	2.32	1.34	2.77	0.12	469	75	77	15	16	40	25	150	13.2	137	16.9	95	29	278	4.45	98.44
DR 75	2011-2012	Shahbajpur-1	zst	69.67	0.83	14.39	5.90	0.06	2.49	2.08	1.55	2.89	0.15	486	87	93	18	17	48	21	146	13.0	143	18.8	104	33	256	4.59	98.64
DR 76	2012-2013	Shahbajpur-1	zst	69.14	0.82	14.85	5.91	0.06	2.45	2.02	1.65	2.95	0.15	474	88	95	18	17	49	29	150	15.6	146	19.8	113	34	280	4.64	98.96
DR 77	2013-2014	Shahbajpur-1	zst	67.39	0.87	15.86	6.44	0.06	2.64	1.93	1.48	3.18	0.15	509	87	95	19	18	53	29	160	14.3	147	21.1	130	34	260	5.02	98.66
DR 78	2014-2015	Shahbajpur-1	zst	70.01	0.83	14.32	5.80	0.06	2.41	2.09	1.48	2.85	0.14	471	95	98	16	17	46	22	144	14.1	144	21.0	116	34	316	4.55	98.94
DR 79	2016-2017	Shahbajpur-1	zst	68.06	0.84	15.26	6.49	0.06	2.62	2.01	1.47	3.06	0.14	497	90	101	17	17	52	26	155	13.4	143	20.8	115	34	263	4.93	98.82
DR 80	2289-2290	Shahbajpur-1	zst	65.71	0.84	16.49	6.62	0.08	2.71	2.61	1.14	3.64	0.15	567	84	96	19	19	47	34	189	15.9	123	22.3	122	34	223	5.86	98.67
DR 81	2292-2293	Shahbajpur-1	zst	65.61	0.85	15.99	6.26	0.09	2.73	3.59	1.12	3.61	0.14	565	88	92	18	19	45	32	187	16.7	123	24.1	117	33	233	6.58	98.18
DR 82	2293-2294	Shahbajpur-1	f sst	72.97	0.70	12.63	5.04	0.07	2.17	2.32	1.29	2.71	0.11	465	74	69	15	15	39	22	148	11.2	134	15.8	84	27	240	4.09	98.99
DR 83	2295-2296	Shahbajpur-1	mst	66.22	0.82	15.59	6.18	0.09	2.65	3.60	1.17	3.52	0.15	544	83	94	18	18	46	33	184	15.3	124	21.9	124	35	244	6.34	98.48
DR 94	373-374	Sitakund -5	zst	64.67	0.89	17.83	7.15	0.11	2.91	1.58	1.16	3.56	0.16	521	87	136	23	19	79	39	178	17.0	143	19.6	149	34	206	5.96	98.79
DR 95	374-375	Sitakund -5	mst	70.38	0.78	14.40	6.17	0.12	2.39	1.76	1.02	2.81	0.17	459	86	110	15	16	64	29	142	17.2	134	20.5	105	34	276	5.22	98.77
DR 96	375-376	Sitakund -5	zst	67.92	0.86	15.74	6.28	0.12	2.62	2.19	1.01	3.12	0.15	481	79	126	20	18	69	32	157	15.7	147	18.8	121	31	214	5.86	98.04

Table 3 (ctd). Whole rock major (wt%) and trace element (ppm) analyses of sandstones and mudrocks from the CTFB (Province 3), Bangladesh.

SaNr	Depth (m)	Well	Lith	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI	Total*
Surma Group (ctd)																													
Bokabil Formation (ctd)																													
DR 97	376-377	Sitakund -5	mst	61.69	0.97	19.79	7.80	0.10	3.16	1.37	0.97	4.01	0.14	553	90	161	22	19	92	36	202	19.0	150	24.3	161	33	193	6.66	97.82
DR 98	612-613	Sitakund -5	mst	64.82	0.94	16.91	6.95	0.08	2.99	2.68	1.07	3.44	0.13	494	94	125	21	18	69	32	168	17.3	141	20.6	149	32	246	6.58	97.96
DR 99	975-976	Sitakund -5	m sst	78.55	0.53	7.76	3.72	0.12	1.09	5.90	0.78	1.49	0.07	360	69	106	8	10	39	19	68	7.2	393	14.9	49	23	285	5.93	98.14
DR 100	976-977	Sitakund -5	m sst	79.96	0.47	9.18	4.22	0.06	1.47	1.86	0.92	1.79	0.07	378	58	94	11	10	64	24	84	8.1	172	10.1	51	18	170	3.49	98.75
DR 101	1096-1097	Sitakund -5	mst	67.34	0.93	17.37	6.76	0.06	2.38	0.64	0.99	3.42	0.11	594	96	137	21	18	68	31	174	17.4	148	21.5	138	35	274	5.07	98.17
DR 102	1097-1098	Sitakund -5	mst	68.02	0.89	16.73	6.55	0.07	2.29	0.79	1.25	3.31	0.11	600	86	127	21	17	69	30	164	18.6	159	18.8	141	30	233	5.00	97.85
DR 103	1098-1099	Sitakund -5	mst	65.68	0.94	18.28	7.08	0.07	2.52	0.71	0.97	3.66	0.11	626	90	139	22	19	77	31	186	18.0	150	22.7	147	31	262	5.40	98.08
DR 104	1099-1100	Sitakund -5	mst	63.15	0.97	19.24	7.93	0.08	2.77	0.68	1.11	3.96	0.11	659	92	155	25	20	78	27	198	21.3	141	20.4	173	34	218	5.57	98.05
DR 105	1543-1544	Sitakund -5	mst	63.18	0.95	18.41	7.59	0.11	3.08	1.65	1.20	3.67	0.17	523	87	152	21	19	87	34	183	20.1	143	23.1	158	37	200	6.52	98.22
DR 109	1936-1937	Sitakund -5	mst	66.56	0.82	16.42	6.37	0.14	2.60	2.55	1.03	3.36	0.14	864	78	133	21	16	71	30	167	16.3	155	17.5	120	31	201	5.97	97.40
DR 110	1937-1938	Sitakund -5	mst	66.43	0.85	17.26	6.40	0.09	2.70	1.45	1.22	3.45	0.14	608	79	133	20	17	76	30	177	17.5	137	21.0	136	30	213	5.74	98.58
Bhuban Formation																													
D-92	OC		f sst	61.15	0.62	8.88	4.06	0.82	2.20	19.57	0.67	1.89	0.13	307	66	73	9	12	31	16	84	8.1	29	15.6	68	28	279	15.32	98.06
D-93	OC		mst	75.64	0.73	10.75	4.07	0.06	2.30	2.95	1.08	2.27	0.14	393	89	88	13	15	34	18	106	10.7	115	18.0	92	27	382	4.76	98.75
D-94	OC		f sst	59.33	0.70	9.05	4.32	0.89	2.47	20.49	0.57	2.02	0.16	339	79	74	10	14	30	13	91	9.0	210	18.0	78	30	357	15.70	98.05
D-95	OC		zst	61.33	0.88	18.86	8.33	0.08	2.80	3.09	0.55	3.93	0.16	560	84	150	24	18	74	33	195	19.3	12	21.6	163	36	178	6.65	99.20
D-96	OC		zst	65.13	0.87	17.02	7.17	0.13	2.56	2.85	0.78	3.32	0.17	481	84	129	21	17	71	31	166	19.6	126	19.5	144	36	226	5.85	99.44
D-97	OC		zst	63.21	0.96	19.82	8.05	0.15	2.49	0.60	0.68	3.87	0.17	533	91	144	26	20	89	37	202	21.1	115	21.5	177	38	187	4.62	99.33
D-98	OC		mst	67.88	0.83	14.96	6.15	0.14	2.30	3.76	0.93	2.90	0.15	454	85	110	18	17	62	27	147	18.7	123	18.9	133	35	251	5.91	98.96
D-99	OC		mst	66.27	0.92	16.93	6.32	0.08	2.41	2.86	0.80	3.25	0.15	460	92	135	21	18	62	33	163	19.4	117	19.5	147	36	240	5.65	99.44
D-100	OC		f sst	78.98	0.63	10.76	4.08	0.08	1.42	0.91	0.97	2.06	0.11	385	77	91	12	12	37	18	104	10.1	99	15.6	88	27	318	2.54	99.38
D-101	OC		mst	70.20	0.79	14.09	5.63	0.20	2.05	3.20	0.91	2.79	0.13	438	92	107	17	15	54	24	141	14.1	128	17.8	121	35	270	2.60	98.67
D-102	OC		f sst	75.44	0.66	11.83	6.32	0.09	1.53	0.64	0.92	2.48	0.09	444	66	83	16	14	66	26	135	12.9	113	12.8	110	26	223	5.22	99.37
D-103	OC		zst	68.66	0.90	16.19	6.53	0.05	2.46	1.10	0.94	3.03	0.14	459	81	126	19	18	62	26	155	17.8	113	19.0	148	33	248	4.38	99.47
D-104	OC		zst	72.82	0.81	14.35	5.85	0.06	1.66	0.59	1.06	2.65	0.13	431	77	112	17	16	53	22	137	15.0	108	17.8	127	32	273	2.99	99.68
D-105	OC		f sst	77.16	0.69	11.60	4.38	0.05	1.72	1.09	0.98	2.21	0.13	384	79	93	13	14	37	21	113	12.0	103	15.8	96	30	299	2.99	99.13
D-106	OC		mst	80.32	0.61	10.56	3.40	0.03	0.96	0.68	1.22	2.12	0.10	387	80	71	11	12	29	19	107	8.2	121	16.3	76	25	320	3.52	99.42
D-107	OC		f sst	71.86	0.77	14.89	6.09	0.04	1.74	0.69	1.00	2.81	0.11	449	74	97	19	15	51	24	145	17.6	112	16.8	134	30	216	1.75	99.68
D-108	OC		mst	73.43	0.77	13.32	5.39	0.06	2.08	1.15	1.15	2.49	0.14	410	83	100	16	15	45	21	127	16.5	107	16.2	120	33	263	3.24	99.73
D-109	OC		f sst	68.24	0.58	8.43	3.44	0.68	1.34	14.55	0.87	1.78	0.09	296	72	75	9	11	28	17	81	9.2	347	15.1	67	27	326	11.12	98.25
D-110	OC		zst	67.93	0.65	10.75	4.81	0.58	1.88	10.35	0.83	2.12	0.11	337	72	91	12	13	42	16	104	12.3	261	14.3	90	30	257	9.25	98.69
D-111	OC		zst	71.15	0.80	14.79	5.68	0.08	2.12	1.08	1.38	2.76	0.14	439	85	101	18	17	48	23	141	15.9	137	16.7	126	34	254	3.35	99.00
D-112	OC		zst	72.14	0.80	14.22	5.66	0.08	1.95	1.10	1.26	2.63	0.17	437	94	113	16	16	45	24	135	14.8	145	19.2	124	36	298	3.23	99.54
D-113	OC		zst	73.47	0.87	15.85	5.60	0.04	1.30	0.04	0.09	2.63	0.09	515	117	94	18	17	55	34	137	14.4	76	20.6	130	38	360	4.15	99.29
D-114	OC		mst	66.95	0.86	17.13	7.03	0.13	2.25	1.11	1.10	3.26	0.18	483	87	108	20	17	56	31	167	17.8	138	21.5	143	36	227	4.31	98.99
DR 13	3033-3034	Begumganj-1	f sst	73.88	0.64	11.73	4.71	0.20	1.98	3.14	1.25	2.32	0.15	389	73	76	15	13	39	23	115	12.8	172	15.4	77	29	265	4.65	98.47
DR 14	3034-3035	Begumganj-1	zst	64.65	0.94	19.11	7.65	0.07	3.16	1.21	1.16	1.88	0.15	551	83	126	25	19	67	38	195	22.5	150	19.4	153	32	183	5.44	98.37
DR 15	3035-3036	Begumganj-1	mst	65.17	0.96	17.49	7.33	0.06	2.96	1.09	1.25	3.53	0.16	513	88	129	23	19	70	32	178	20.8	140	20.2	149	36	236	5.08	98.38
DR 16	3036-3037	Begumganj-1	zst	64.04	0.90	18.33	7.31	0.07	3.03	1.21	1.19	3.75	0.16	554	79	126	23	19	65	40	186	19.5	140	18.9	142	33	186	5.57	98.86
DR 17	3037-3038	Begumganj-1	zst	64.77	0.85	16.23	6.83	0.25	2.78	3.63	1.16	3.30	0.19	474	78	111	20	17	62	33	164	16.2	185	17.5	122	32	193	6.66	98.16
DR 18	3047-3048	Begumganj-1	mst	66.51	0.92	16.49	6.84	0.08	2.92	1.52	1.25	3.31	0.16	512	86	119	21	18	60	35	165	17.4	135	19.0	128	33	250	5.25	98.92
DR 19	3048-3049	Begumganj-1	f sst	70.83	0.76	13.67	6.14	0.09	2.54	1.81	1.30	2.70	0.15	496	76	97	17	16	49	30	137	11.3	131	15.2	107	26	238	4.70	99.09
DR 20	3049-3050	Begumganj-1	mst	63.53	0.94	18.70	7.43	0.09	3.03	1.22	1.14	3.77	0.14	511	82	130	24	19	72	38	187	19.8	140	19.8	153	30	193	5.55	98.83
DR 21	3050-3051	Begumganj-1	mst	63.22	0.97	18.59	7.68	0.08	3.12	1.25	1.14	3.80	0.16	521	81	125	24	19	67	41	186	20.6	140	20.0	144	31	208	5.44	98.43
DR 22	3476-3477	Begumganj-1	f sst	74.48	0.61	10.26	4.21	0.10	1.79	5.22	1.17	2.02	0.13	348	76	72	13	13	41	18	100	9.8	172	14.1	61	27	298	6.06	98.46
DR 23	3477-3478	Begumganj-1	mst	64.58	0.97	17.46	7.08	0.06	2.99	1.91	1.19	3.63	0.13	535	100	124	23	20	70	33	177	16.9	127	20.4	144	33	274	5.75	98.49
DR 24	3478-3479	Begumganj-1	mst	67.31	0.90	15.60	6.33	0.06	2.75	2.46	1.23	3.20	0.15	494	107	114	20	19	59	32	157	15.5	128	19.8	118	35	301	5.71	98.71

Table 3 (ctd). Whole rock major (wt%) and trace element (ppm) analyses of sandstones and mudrocks from the CTFB (Province 3), Bangladesh.

SaNr	Depth (m)	Well	Lith	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI	Total*
Surma Group (ctd)																													
Bhuban Formation																													
DR 25	3479-3480	Begumganj-1	zst	67.32	0.89	16.90	7.36	0.09	2.37	0.64	1.38	2.89	0.17	470	87	126	21	17	74	30	150	17.4	159	16.5	135	36	225	4.26	99.17
DR 26	3480-3481	Begumganj-1	zst	59.98	1.05	20.37	8.06	0.06	3.43	1.38	1.11	4.41	0.14	583	99	148	27	22	80	38	211	23.9	132	22.2	171	34	230	6.03	98.93
DR 27	3523-3524	Begumganj-1	mst	63.47	0.93	19.50	7.11	0.09	2.76	0.97	1.16	3.88	0.14	529	87	134	25	19	71	35	194	18.7	136	19.2	147	32	197	5.42	99.14
DR 28	3524-3525	Begumganj-1	mst	64.74	0.92	17.73	7.38	0.14	2.70	1.63	1.13	3.49	0.17	496	91	122	22	19	71	32	174	17.7	145	18.5	137	35	202	5.79	99.16
DR 29	3525-3526	Begumganj-1	mst	64.24	0.83	15.13	5.93	0.26	2.59	6.55	1.15	3.19	0.13	455	81	106	20	18	57	29	155	15.6	161	17.5	116	32	229	8.37	98.60
DR 30	3526-3527	Begumganj-1	zst	63.62	0.88	17.13	6.83	0.10	2.89	3.43	1.38	3.60	0.14	525	90	117	23	18	65	33	177	14.9	146	19.4	123	34	206	6.67	98.91
DR 31	3527-3528	Begumganj-1	mst	64.64	0.86	16.61	6.68	0.10	2.76	3.53	1.22	3.47	0.13	500	82	112	21	18	66	37	171	17.0	149	18.7	120	33	209	6.64	98.59
DR 32	3660-3661	Begumganj-1	mst	68.83	0.87	15.83	6.57	0.09	2.45	0.97	1.22	3.03	0.15	480	84	111	20	18	58	27	155	15.9	121	17.8	119	31	243	4.55	98.80
DR 33	3661-3662	Begumganj-1	mst	66.08	0.97	17.07	7.27	0.09	2.75	0.98	1.23	3.41	0.15	591	89	128	23	19	64	35	172	15.2	124	19.1	141	32	241	4.91	98.74
DR 34	3662-3663	Begumganj-1	zst	71.28	0.81	14.46	6.06	0.10	2.18	1.04	1.20	2.72	0.15	474	81	102	17	16	52	27	139	13.1	120	17.1	106	32	253	4.05	99.00
DR 35	3663-3664	Begumganj-1	mst	67.52	0.90	16.45	6.94	0.09	2.58	0.96	1.21	3.22	0.14	486	83	113	21	18	60	29	163	17.7	124	18.4	133	31	238	4.58	98.80
DR 36	3664-3665	Begumganj-1	f sst	78.23	0.62	10.66	4.32	0.09	1.52	1.32	1.24	1.85	0.15	337	77	69	12	12	35	21	94	8.2	114	14.0	67	30	277	3.29	98.98
DR 52	2842-2843	Feni-1	zst	69.20	0.83	15.59	6.24	0.10	2.39	1.40	1.07	3.03	0.15	451	90	107	19	17	56	28	157	14.1	134	19.8	126	35	267	4.83	99.12
DR 53	2843-2844	Feni-1	zst	69.51	0.79	15.42	5.98	0.09	2.33	1.66	1.11	2.95	0.15	559	85	108	19	16	56	30	150	14.2	138	18.9	111	33	240	5.03	98.66
DR 54	2844-2845	Feni-1	mst	68.03	0.86	16.40	6.39	0.08	2.47	1.26	1.14	3.21	0.15	479	95	119	20	17	58	30	164	15.2	133	20.6	117	33	256	4.87	98.47
DR 55	2845-2846	Feni-1	zst	63.87	0.91	18.80	7.33	0.09	2.84	1.17	1.09	3.75	0.16	537	87	135	24	19	72	34	187	20.7	137	20.4	156	34	198	5.59	98.60
DR 56	2846-2847	Feni-1	mst	65.07	0.91	18.18	7.03	0.10	2.80	1.09	1.13	3.54	0.16	502	87	120	23	19	70	31	182	20.0	137	20.1	157	35	204	5.33	98.96
DR 57	2847-2848	Feni-1	mst	64.83	0.90	17.83	7.34	0.12	2.87	1.24	1.17	3.55	0.16	509	83	123	22	18	69	30	183	16.8	138	20.0	151	35	201	5.54	98.75
DR 58	2848-2849	Feni-1	mst	65.11	0.89	17.63	7.27	0.13	2.84	1.45	0.99	3.51	0.16	501	84	132	21	18	68	31	182	19.0	140	19.5	146	34	202	5.48	98.83
DR 59	2852-2853	Feni-1	zst	67.62	0.84	16.59	6.51	0.09	2.54	1.26	1.13	3.25	0.15	495	85	108	20	18	60	31	165	17.4	133	19.7	132	34	218	4.96	98.94
DR 60	2853-2854	Feni-1	zst	63.45	0.82	14.37	6.05	0.36	2.41	8.45	0.97	2.96	0.17	504	88	100	17	17	52	25	147	11.6	162	19.4	104	36	294	9.54	98.37
DR 61	2854-2855	Feni-1	mst	70.86	0.83	14.53	5.82	0.08	2.31	1.58	1.11	2.72	0.16	440	91	104	18	17	48	26	139	12.4	130	20.1	115	35	293	4.65	98.89
DR 62	2913-2914	Feni-1	zst	65.29	0.97	18.26	7.26	0.07	2.62	0.75	1.00	3.66	0.13	549	93	126	23	20	71	33	185	17.6	126	21.6	143	35	249	4.99	98.65
DR 63	2914-2915	Feni-1	mst	74.76	0.73	12.81	4.99	0.05	1.81	0.94	1.26	2.53	0.13	443	86	75	15	15	39	22	128	10.2	107	17.6	89	31	307	3.46	99.07
DR 84	3014-3015	Shahbajpur-1	f sst	76.53	0.70	11.91	4.52	0.05	1.65	0.88	1.29	2.36	0.11	425	91	102	13	15	44	24	119	8.7	136	21.9	90	28	381	2.81	98.78
DR 85	3016-3017	Shahbajpur-1	f sst	79.05	0.62	10.42	4.01	0.04	1.52	0.89	1.34	2.01	0.11	391	77	86	11	12	35	21	99	8.0	129	17.2	60	27	320	2.40	99.27
DR 86	3017-3018	Shahbajpur-1	zst	67.64	0.87	15.92	7.18	0.05	2.84	0.88	1.31	3.18	0.13	499	89	109	20	18	63	25	165	13.8	131	18.9	127	32	269	4.24	98.88
DR 87	3018-3019	Shahbajpur-1	m sst	77.56	0.58	11.08	4.33	0.05	1.60	0.89	1.50	2.31	0.11	417	76	56	10	14	32	21	117	9.9	122	17.5	63	23	288	2.49	98.69
DR 88	3018-3019	Shahbajpur-1	zst	74.16	0.67	12.87	5.38	0.05	2.11	0.85	1.28	2.52	0.11	427	75	89	14	14	52	27	130	12.3	131	17.5	93	29	249	3.12	98.82
DR 89	3019-3020	Shahbajpur-1	f sst	76.12	0.70	11.84	4.77	0.05	1.85	0.98	1.29	2.28	0.12	400	88	99	12	15	43	22	118	10.8	130	20.7	93	29	315	2.86	99.27
DR 90	3020-3021	Shahbajpur-1	f sst	72.17	0.75	13.70	5.92	0.05	2.31	0.97	1.29	2.71	0.13	446	87	105	15	15	52	24	140	11.9	134	19.4	98	31	290	3.74	98.79
DR 91	3021-3022	Shahbajpur-1	mst	72.38	0.75	13.43	5.81	0.05	2.33	1.13	1.35	2.65	0.13	446	84	95	14	16	48	22	140	12.0	122	17.9	97	31	272	3.62	98.54
DR 92	3402-3403	Shahbajpur-1	f sst	77.28	0.58	11.05	4.44	0.05	1.72	0.96	1.57	2.25	0.11	410	65	69	13	13	32	24	111	9.5	120	13.4	67	22	253	2.84	98.58
DR 93	3408-3409	Shahbajpur-1	f sst	77.57	0.57	10.96	4.21	0.04	1.67	1.03	1.57	2.25	0.11	422	68	57	10	13	32	18	113	8.3	120	16.7	65	22	258	2.62	98.78
DR 111	2490-2491	Sitakund -5	mst	63.88	0.95	18.26	7.35	0.11	3.03	1.64	1.02	3.61	0.15	508	91	145	24	19	86	34	177	19.2	139	19.8	156	35	206	6.10	98.19
DR 112	2494-2495	Sitakund -5	zst	67.92	0.83	14.38	6.17	0.19	2.58	3.87	1.09	2.81	0.16	446	89	123	14	17	64	26	140	14.4	168	23.3	113	35	283	6.78	98.22
DR 113	2495-2496	Sitakund -5	mst	66.44	0.90	16.74	6.64	0.10	2.84	1.79	1.07	3.33	0.15	501	92	126	21	18	76	30	163	16.2	130	19.5	144	33	208	5.94	97.54
DR 114	2496-2497	Sitakund -5	mst	65.19	0.92	17.42	7.04	0.11	2.96	1.76	1.00	3.44	0.15	512	93	139	18	19	80	34	173	16.3	134	23.9	149	33	214	6.22	97.75
DR 115	2648-2649	Sitakund -5	mst	67.17	0.87	15.68	6.64	0.07	3.04	2.02	1.12	3.27	0.12	610	88	135	19	18	71	26	162	15.8	139	19.0	128	30	242	5.81	97.61
DR 116	2649-2650	Sitakund -5	mst	68.72	0.84	14.70	6.51	0.07	2.95	1.90	1.17	3.02	0.12	555	81	122	18	18	64	25	150	14.9	126	18.1	114	30	262	5.51	97.94
DR 117	2650-2651	Sitakund -5	mst	69.84	0.82	14.13	6.12	0.07	2.84	1.99	1.24	2.82	0.12	490	90	117	18	17	58	23	140	11.5	122	18.4	105	32	283	5.37	98.66
DR 118	2651-2652	Sitakund -5	zst	71.07	0.76	13.48	6.04	0.07	2.70	1.84	1.18	2.75	0.11	591	83	111	17	16	59	23	138	11.7	119	16.2	97	28	267	4.99	98.53
DR 119	2793-2794	Sitakund -5	zst	68.80	0.87	15.23	6.49	0.06	2.63	1.37	1.26	3.16	0.14	551	88	116	19	18	57	27	158	15.4	118	17.9	118	31	277	4.94	98.54
DR 120	2794-2795	Sitakund -5	m sst	78.28	0.58	10.30	4.61	0.05	1.74	1.03	1.21	2.09	0.10	410	72	73	12	11	41	26	106	8.8	95	14.1	60	25	265	3.17	98.56
DR 121	2795-2796	Sitakund -5	m sst	80.15	0.54	9.69	3.75	0.04	1.47	1.06	1.21	1.99	0.10	516	70	66	11	11	31	20	96	8.6	98	14.5	47	24	276	2.86	98.46

mudrocks, with enrichment factors generally greater than 1.25, with a maximum of 2.30 for Ni in the Dupitila Formation. The exceptions are Sr in the Bhuban Formation, which is fractionally enriched in the sandstone average (134 ppm) compared to the mudrocks (132 ppm); and Zr, which is clearly enriched in the sandstones in both the Bhuban (287 ppm) and Bokabil (287 ppm) Formations relative to their mudrocks (245 and 232 ppm, respectively).

As for most of the major elements, trace element abundances in both the sandstones and the mudrocks tend to decrease from the Bhuban through to the Dupitila Formations due to quartz dilution, although the decrease is not always regular. Strontium shows the least change, falling from an average of 134 ppm in Bhuban sandstones through to 88 ppm in Dupitila sandstones; for the equivalent mudrocks contents fall from 132 ppm to 99 ppm, respectively. Strontium also shows the least contrast between the mudrocks and the sandstones, with enrichment factors of 0.99 to 1.13 throughout the succession. Furthermore, concentrations of Sr in all CTFB samples are considerably lower than in UCC (350 ppm; Taylor and McLennan, 1985), suggesting significant loss of this mobile element. This is also the case for Ba, with average contents by lithology and formation ranging from 267 to 486 ppm, well below the UCC value of 550 ppm (Taylor and McLennan, 1985). Contents of less mobile trace elements (Ce. Cr, Nb, Sc, Sr, Th, V, Y, Zr) are close to or are greater than UCC values, indicating they have not been affected by the processes which reduced Sr and Ba abundances.

Conclusions

Geochemical compositions of Paleogene and Neogene mudstones and sandstones from Province 1 (NWS) and Province 3 (CTFB) in Bangladesh show significant and systematic variations, between both formations and groups, and between lithotypes. These variations reflect the operation of several processes, among which hydrodynamic sorting, source change, weathering, and preferential heavy mineral concentration are likely to be significant. These systematic variations may hold potential keys to resolve the exhumation history of the Himalaya in relation to tectonic and climatic factors. Detailed interpretation of the geochemical variations in the NWS and CTFB in the light of tectonic and climate factors will be made in future work, along with comparison and correlation with published data for Province 2 (Surma Basin), in an effort to improve understanding of Himalayan erosion in a regional context.

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