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The Churia (Siwalik) Group of the Arung Khola Area, West Central Nepal

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CONTENTS

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Abstract

The uplift and erosion of the Himalayas has resulted in a vast pile of terrestrial sediments called the Siwalik Group deposited at the frontal deep of the mountains. The Churia (Siwalik) Group of the Arung Khola area in the Churia Hills was studied in 1982, 1984 and 1985. The Group is bounded by the Main Boundary Thrust in the north and Frontal Churia Thurst in the south. It consists of a north and south belt separated by the Central Churia Thrust. The group is divided into the Arung Khola Formation (2,100 m in thickness), Binai Khola Formation (2,800 m), Chitwan Formation (700 m) and Deorali Formation (450 m) in ascending order. As a whole, the group comprises a coarsening-upward sequence, reflecting the rising Himalayas. The paleomagnetic polarity stratigraphy of the Churia Group has been successfully established. Detailed mapping and sampling made it possible to draw a paleomagnetic iso-polarity zone map. Magnetostratigraphically the Al and Am Members of the Arung Khola Formation are correlated to Chron 10–15, the Au Member of the Formation to around Chron 9, the Binai Khola Formation to Chron 8-Gilbert Reversed Polarity Chron, and the Chitwan and Deorali Formations to Matuyama Reversed Polarity Chron. Lithostratigraphic nomenclature of "*Lower, Middle and Upper Siwaliks*" is different chronologically between the Siwalik Group of the type area in Pakistan and the Churia Group in Nepal. Sedimentation rate is calculated to be between 0.2 to 0.5 mm/yr in the Churia Group. Sedimentary studies have clarified the development of fluvial fan-river systems and their hinterlands. The Great Himalayas began their bigorous upheaval movements at about 10 Ma, which is reflected well in frequent intercalations of "*Pepper-and-Salt Sandstones*". Many freshwater molluscs have been discovered in the present area and were identified to the generic level. Most geologic structures of the present area are still active now, and are reflected well by geomorphologic features. Syn-sedimentary tectonic movement or syn-tectonic sedimentation characterises the Sub-Himalayan foothills, which may be interpreted by underthrusting of the Sub-Himalayan terrane against the Lesser Himalayan terrane.

1. Introduction

The rising Himalayas have been shedding vast piles of sediments to their southern front since the Neogene Period. These are collectively called the Siwalik

Group. In Nepalese Himalayas these are distributed in the most frontal hilly areas called the Churia Hills and the name of the Churia Group is given to them. The Siwalik Group is well-known because of the abundant mammalian fossils, especially early hominoids, and during the last 150 years many papers have been published on the Siwalik Group (PILGRIM, 1908 and 1934; COLBERT, 1935; and so on). Invaluable mammalian fossils have been known in the Siwalik Group, however, their nonmarine terrestrial sediments are lithologically changeable and lithostratigraphy of the group is quite difficult to establish. No successful correlation of the strata among separated fossil-bearing beds in the Siwalik Group has yet been done. It is said that abundant mammalian fossils obtained by village people or obtained by "*fossil-hunters*" have been left in laboratories or storerooms without stratigraphical information. It was not until the study by the collaborative studies among Peshawar Univ., Geological Survey of Pakistan, Darthmouth College, Yale University, Lamont-Doherty Geological Observatory, the University of Arizona and others published in 1982 (in *Paleogeogr., Paleocli., Paleoecol.*, vol. 37, *Special Issue*) that the occurrence of the Siwalik mammals could be closely examined. They studied the Siwalik Group in the Potwar Plateau in Pakistan, which there are well-known type localities of Siwalik faunas, such as the *Kamlial, Chinji, Nagri, Dhok Pathan and Tatrot faunas*, and paleomagnetic polarity stratigraphy was established by them for the first time at several type sections of the Siwalik faunas (OPDYKE and JOHNSON, D. D., 1982; JOHNSON, N. M. *et al.*, 1982; TAUXE and OPDYKE, 1982). Their paleomagnetic polarity stratigraphy was confirmed by Fission-Track dating of the volcanic ash layers intercalated in the same sequences (JOHNSON, G. D. *et al.*, 1982). Furthermore, the Middle and Upper Siwalik faunas were checked on the basis of the paleomagnetic polarity stratigraphy and biostratigraphic zonation of the Middle and Upper Siwaliks has been reestablished by BARRY *et al.* (1982). On the other hand, magnetostratigraphic study of the Upper Siwaliks near Pinjor in India was done by Azzaroli and Napoleone (1982).

As for the Churia Group, which belongs to the so-called Siwalik Group in Nepal, little has previously been known, not only stratigraphically but also paleontologically, although several contributions from the stratigraphic and paleontologic viewpoints have been reported (GLENNIE and ZIEGLER, 1964; ITIHARA *et al.*, 1972; SHARMA, 1973; WEST *et al.*, 1978 and 1982; YOSHIDA and ARITA. 1982; NAKAJIMA, 1982). As one of the themes of the project "*Study on the Crustal Movement in the Nepal Himalayas*" which was conducted by Prof. Koshiro KIZAKI of University of the Ryukyus, we decided to focus on the Churia Group of the Arung Khola area located between Butwal and Narayangarh in the Churia Hills (Fig. 1). Precise geologic mapping was performed in the preliminary survey in 1982, main survey in 1984 and supplementary survey in 1985.We attempted to independently establish the stratigraphy of the Churia Group in the surveyed area. The well-known stratigraphy and lithofacies of the Siwalik Group (*Lower Siwalik-Kamlial and Chinji, Middle Siwalik-Nagri and*

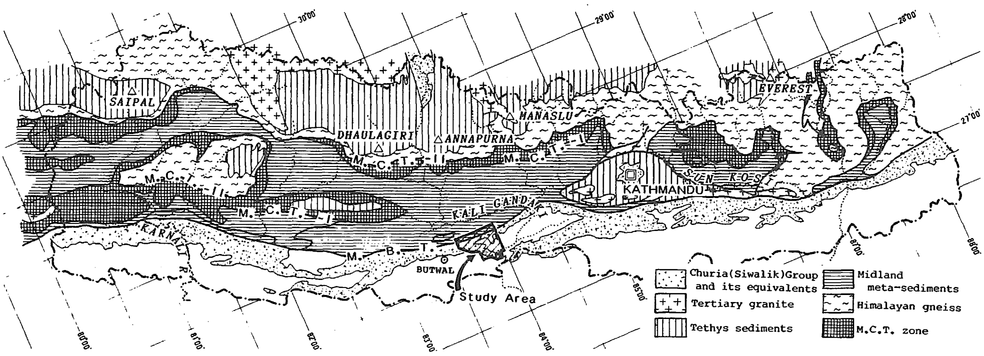

Fig. 1. Index map. Generalized geologic map of the Nepal Himalayas. Mainly based on unpublished data by the *Research Group for the Crustal Movement of the Nepal Himalayas* —CMH—, compiled by K. Kizaki *et al.*

Dhok Pathan, and *Upper Siwalik-Tatrot and Pinjor*) was not used in the area of this study, as the lithofacies are variable from area to area. We have surveyed the whole area of the sheet map of No. 63M/14 and the eastern adjoining area of 63M/10, of 1 inch/1 mile —Palhi Majhkhand and Palpa District— of which routes are collectively shown in Fig. 2. The geologic map and detailed columnar sections of the area (Appendix I, Figs. 1 and 2) are in the back pocket of this volume. Main route maps, mostly measured on foot in scale 1/5,000, are also given in the back pocket as Appendix I, Figs. 3, 4, 5, 6 and 7. We aimed, first, to establish the stratigraphy by precise field mapping, and secondly, to check it by paleomagnetic polarity stratigraphy. The sedimentology and paleontology was also studied. The field-data are described in detail in the present paper with some consideration on the correlation and sedimentary environments of the Siwalik Group. The geomorphologic description will be treated in a separate paper.

2. General Geology of the Churia Group

The Churia Group is bounded by the Main Boundary Thrust (M. B. T.), the biggest Himalayan frontal fault still active now, to the north and by the Frontal Churia Thust (F. C. T.) to the south. The higher mountains of the Midland (Kali Gandaki) Supergroup occur in the north of the area and are comprised of Precambrian and Lower Paleozoic metasediments, mainly quartzites with subordinate slates and limestones (Sakai, 1985). The southern area, part of the Gangetic Alluvial Plain, is comprised of recent fluvial sediments.

The Churia Group of the surveyed area can be divided lithostratigraphically into four parts, and we named them the Arung Khola Formation, Binai Khola Formation, Chitwan Formation and Deorali Formation in ascending order, that is, in order of A, B, C and D in their capital letters. The Churia Group is distributed in the north and south belt separated by the Central Churia Thrust (C. C. T.). In the former belt the strata up to the middle part of the Binai Khola Formation are distributed, and in the latter the strata down to the upper part of the Arung Khola Formation are distributed. The generalized geologic map and columnar sections and their correlation to the Siwalik Group in the Potwar Plateau are briefly shown in Fig. 3.

On the basis of paleomagnetic polarity stratigraphy, which will be discussed in detail later, and if we take into consideration the Siwalik stratigraphy reestablished in the Potwar Plateau, the following correlation seems to be probable, that is, the Arung Khola Formation to the *Chinji-Nagri* zones, the Binai Khola Formation to the *Dhok Pathan-Tatrot* zones, and the Chitwan Formation to the *Pinjor* zone, respectively. The Deorali Formation may correspond to the *Boulder Conglomerates*.

The Arung Khola Formation consists of irregularly alternating beds of fine-grained sandstone and siltstone. This formation is characterised by frequent intercalations of variegated siltstones and coaly black siltstones. Plant remains and fossil-wood are sometimes contained in the latter. Sandstones are moderately indurated, mostly calcite-cemented, very poor in clay matrix, and belong to quartz arenites. Calcareous sandstones or sandy limestones are often intercalated in the middle part of the formation. The base of the formation in the north belt is cut by the C. C. T. and remains unknown. The total thickness of the formation attains to 2,300 m.

The Binai Khola Formation consists mainly of thick-bedded sandstones, and subordinately of siltstones and thin-bedded alternating beds of sandstone and siltstone. The formation is differentiated from the lower one in lacking in variegated siltstones. The upper part of the formation is accompanied by conglomerates, which increase gradually toward the top. The formation is characterised by frequent intercalations of white sandstone with black specks (mostly of biotite), shownig a *pepper-and-salt* appearance. Sandstones are less indurated, medium to sometimes coarse-grained. These are abundant in mica, rare in clay matrix, and calcite-cemented, belonging to lithic arenites. A gradual change of lithofacies from the underlying beds is observed, and it is likely that the formation conformably overlies the lower formation. The total thickness is about 2,800 m.

The Chitwan Formation is composed predominantly of gravel beds and subordinately of sand and silt layers. Gravels are mostly composed of quartzites of pebble to boulder size and seem to become larger toward the top. It conformably overlies the lower formation. The total thickness is 700 m.

The Deorali Formation is composed of disorganized boulder-conglomerate beds of mostly angular to subangular gravels. It is distributed locally in the northern margin of the south belt. Gravels are mostly derived from sandstones of the Churia Group. A gradual change of lithofacies from the Chitwan to the Deorali Formation is observed at Deorali. The total thickness is 450 m.

The Churia Group has a steeply inclined homoclinal structure in the North Belt.

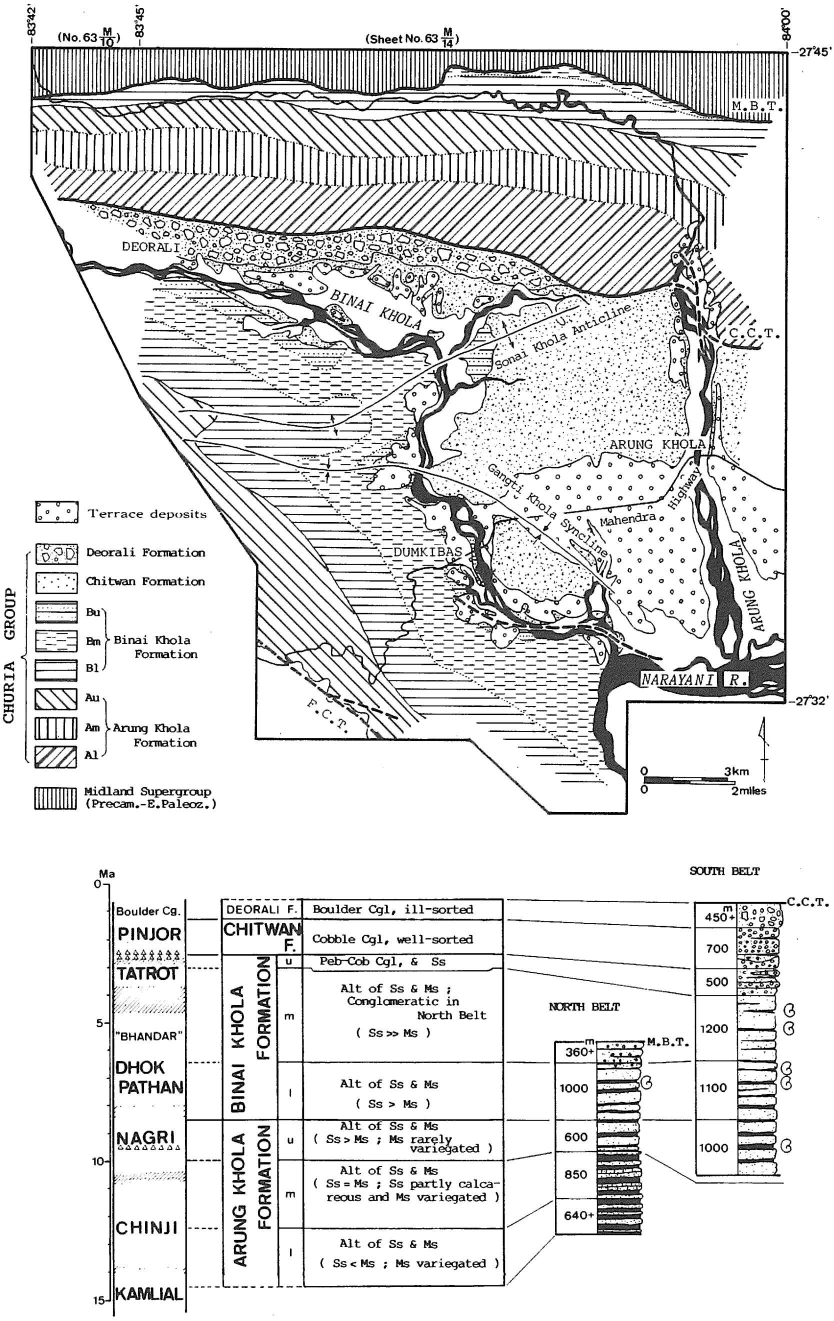

Fig. 3. Generalized geologic map and columnar sections of the Churia Group of the Arung Khola Area (the left column is based on OPDYKE *et al*, 1982 and JOHNSON *et al.*, 1985).

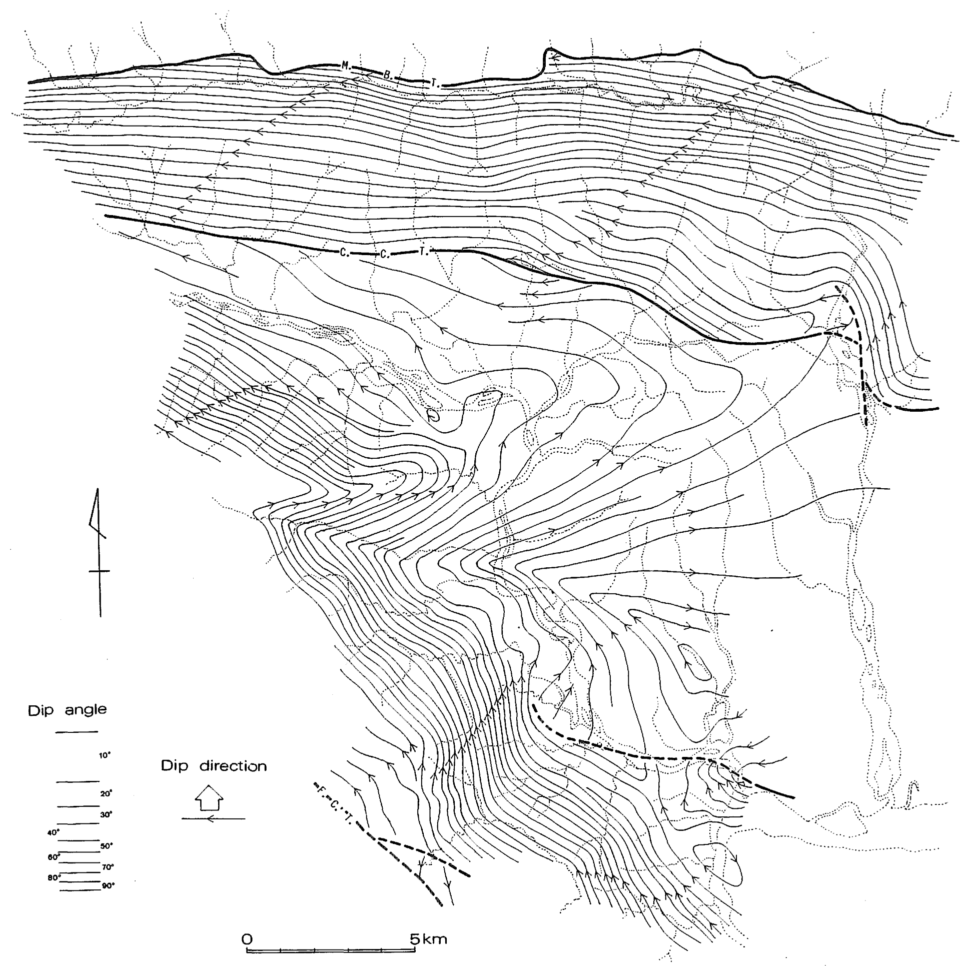

Fig. 4. Strike-line map of the Churia Group. M. B. T. *Main Boundary Thrust*, C. C. T. *Central Churia Thrust*, F. C. T. *Frontal Churia Thrust*

It becomes more steep toward the M. B. T. By contrast it has gently dipping and folded structures in the South Belt. It becomes rather gentle towards the northern C. C. T. and more steep toward the southern F. C. T.

The strike-line map of the surveyed area is shown in Fig. 4. The difference of the geologic structure between the both belts and that of age range (the South Belt contains more younger strata than the North Belt), may be reasonably explained by successive collision of the both belts into the Himalayas.

3. Stratigraphy of the Churia Group

A. *ARUNG KHOLA FORMATION*

The Arung Khola Formation is divided into the Lower (Al), Middle (Am) and Upper (Au) Members. It is distributed mainly in the North Belt, while only the Upper Member is distributed in the South Belt.

NORTH BELT

The Arung Khola Formation is widely distributed in middle to upper stream of the Arung Khola, and is well exposed. The mountainous area west and south of the Arung Khola is very difficult to approach except by several routes shown in Fig. 2. Strata near the M. B. T. are found to have suffered considerable disturbance.

Arung Khola Route (App. I, Fig. 3)

Lower Member (Al) is observed along the lower stream of the Arung Khola (App. I., Fig. 3, A), and is composed of alternating beds predominated by mudstone with subordinate sandstone. The latter usually 10 to 50 cm in thickness, and the former is 50 to 100 cm and is frequently variegated in reddish or purplish tint (Plate I–1). Current ripple cross-laminations are commonly developed in sandstones, and large-scale planar cross-beddings are sometimes observed at the upper part of the member. The beds are disturbed near the C. C. T.

Middle Member (Am) is continuously exposed along the Arung Khola (App. I, Fig. 3, B). It consists of sandstones and mudstones in roughly equal amounts, in beds

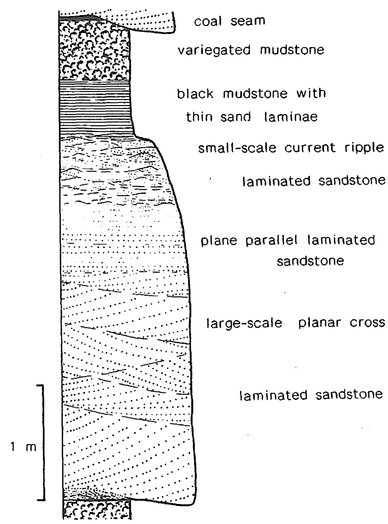

Fig. 5. A typical fining-upward sequence observed in the Am Member at the Arung Khola Route

usually 20 to 50 cm thick (Plate I–2, 3). Mudstone is often variegated as in the Al Member. Typical fining-upward sequences, which suggest the fluvial sedimentary cycles, are observed frequently throughout the member (Fig. 5). The upper half of each cycle, of which thickness varies from several to 10 m, consists of black mudstone with plant remains, variegated mudstone and, in some cases, coal seams, in ascending order. Thick composite sand bodies, which are composed of 2 or several sandstone beds, are sometimes observed. Fine calcareous sandstones are frequently intercalated, and comprise the E-W ridge of the surveyed area.

Upper Member (Au) is well exposed along the Arung Khola and the Dang Khola (App. I, Fig. 3, B and C). It is predominantly composed of sandstone with subordinate mudstone (Plate I–4). Sandstone beds are 1 to 2 meters thick and sometimes conglomeratic. Pepper-and-salt sandstones are often intercalated. Mudstones are sometimes variegated.

SOUTH BELT

The Upper Member of the Arung Khola Formation is well exposed along the Mahendra Highway crossing the Churia Hills. Exposure of the member is excellent along the Satbudn Nala. It is highly disturbed near the F. C. T. Compared with the same member in the north belt, it lacks intercalated pebble-bearing sandstones.

Mahendra Highway Route (App. I, Fig. 6)

Upper Member (Au) is exposed well along the road, although the strata are mostly dislocated and have suffered secondary disturbance. The member is composed of sandstones and mudstones in roughly equal amounts. Mudstones are often variegated. Beds are usually about 50 cm thick, sometimes in 1 to 2 meters (Plate I–5). Same horizons of the member are seen in repetition as the road is curved along the strike trend. Fining-upward sequences from large scale trough- or planar-cross bedded sandstones to variegated mudstones are commonly observed. They are mostly 10–15 m thick. Within the coarser-grained (sandy) part of a sequence, scouring surfaces are sometimes observable.

Satbudn Nala (App. I, Fig. 6)

Upper Member (Au) consists of rhythmic alternations of sandstone and mudstone in beds several tens cm to several meters thick. Mudstones are often variegated. Molluscan fossils were discovered at two adjacent horizons (F23a, b) in its lower part, with fragmented vertebrate bones. It is worthy to note that these horizons are stratigraphically equivalent to the *Sivapithecus* horizon reported by MUNTHE *et al.* (1983) in the Butwal area. We discovered many molluscan fossils form the bed just below the *Sivapithcus* horizon in that area. It is expected that the molluscan horizons in the both areas may be equivalent.

B. BINAI KHOLA FORMATION

The Binai Khola Formation is divided into the Lower (Bl), Middle (Bm) and Upper (Bu) Members. It is distributed mainly along the Binai Khola and its tributaries. Along the Arung Khola, only the Bl and the lower part of Bm Member are distributed

NORTH BELT

The Binai Khola Formation is characterized by thick-bedded sandstones of pepper-and-salt appearance and frequent intercalations of conglomerate. Along the Arung Khola route a gradual change from underlying Arung Khola Formation is observable. The Bl Member is well exposed along middle to upper stream of the Arung Khola, whereas the lower part of the Bm Member is partly distributed in the northeastern marginal area.

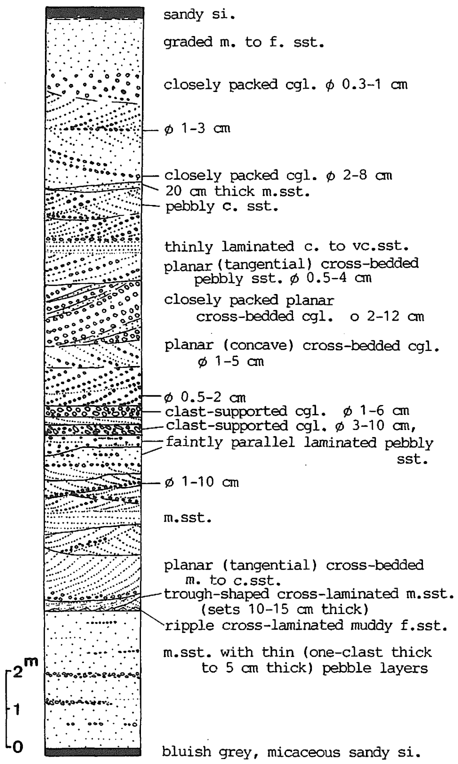

Fig. 6a. A fining-upward sequence consisting of composite cross-bedded sandstones. Bl Member at the Murali Khola. (Loc. is between M78 and M79, see App. I, Fig. 3.)

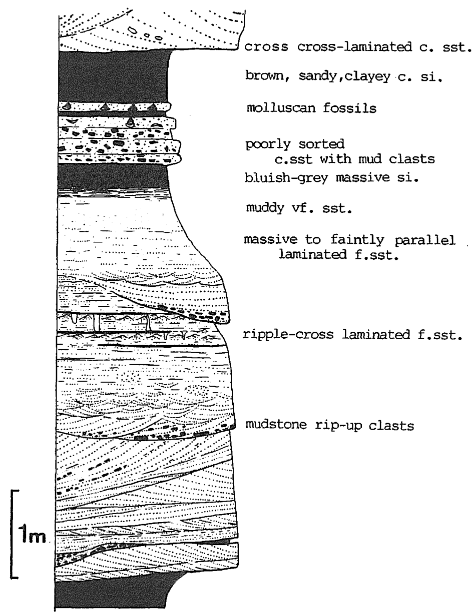

Fig. 6b. Typical fining-upward sequence of Bm Member at southern bank of the Binai Khola of Route 69. (Loc. is at F13, see App. I, Fig. 4)

Arung Khola Route (partly illustrated in App. I, Fig. 3)

Lower Member (Bl) is well exposed along middle to upper stream of the Arung Khola, where the general strike is subparallel to the stream, repeatedly exposing the member. It is characterized by pepper-and-salt sandstones, sometimes pebble-bearing, in beds several meters thick, alternating with subordinate siltstones (Plate II–1 to 6). Sandy limestones or calcareous sandstones are sometimes intercalated (Plate II–3). Pebbly sandstones are mostly planar cross-bedded (each set varies 0.5–2 m in thickness), and comprise thick composite sand bodies (Fig. 6a). Current-ripple laminations and cross-beddings are developed in most sandstone layers. Molluscan fossils were discovered in mudstone of 2 to 4 m thick at two localities of F11 (App. I, Fig. 3, E) and F12 (Fig. 8–⑥) of probably same horizon.

Middle Member (Bm) is limited in distribution to the Murali Khola and Dang Khola (App. I, Fig. 3, B and E) in the northeastern area. The member is characterized by gravel-bearing, pepper-and-salt sandstones and conglomerates. Siltstones of less than several meters thick are sometimes intercalated.

SOUTH BELT

The Binai Khola Formation is extensively distributed in the Binai Khola area and trends NW-SE. It conformably overlies the Arung Khola Formation. This relationship is observable in the Satbudn Nala. The formation is characterized and differentiated from the Arung Khola Formation by frequent intercalations of pepper-and-salt sandstones. The formation is moderately inclined throughout the area and a couple of anticline and syncline exsists in the central part, which are named the Sonai Khola Anticline and Gangti Khola Syncline, respectively. The formation is composed mainly of alternating beds of sandstone and siltstone. Sandstones become thicker and coarser and conglomeratic toward the top, comprising a coarsening-upward sequence. The formation is dominated by finer materials than that of the north belt and no remarkable conglomerates are developed in the Bl and Bm Members. The Binai Khola Formation is described by dividing the South Belt into the following three areas of the upper stream part (*Deorali area*), middle stream part (*Dumkibas area*) and lower stream part (*Mahendra Highway to Narayani River area*).

Deorali Area (App. I, Fig. 4)

The formation is well exposed in panoramic views in five routes of Nos. 28, 27, 32, 26 and 37. The Arung Khola Formation is distributed near the top of the mountain range, although its boundary with the Binai Khola Formation cannot be observed anywhere. The Bl Member, which is exposed in uppermost part of each valley, is often difficult to approach. It is composed of alternating beds of predominant sandstones and subordinate siltstones in beds several tens cm to several meters thick (Plate III–2, 3). They are rhythmically bedded, forming cuestas (Plate

III–1). The Bm Member is dominated by bedded sandstones 1 to several meters thick. Conglomerates are sometimes intercalated. It is also rhythmically bedded, forming cuestas. The Bu Member becomes more thick-bedded and coarser-grained with frequent intercalations of conglomerate (Plate III–4). Conglomerates are 5 to 25 m in thickness, and often show large-scale planar cross-beddings with lots of scouring surfaces. Thus, the entire Binai Khola Formation comprises a coarsening-upward sequence, although it is constituted from a lot of fining-upward sequences of several to several tens meters thick. In the Bl and Bm Members, the thickness of each fining-upward sequence is around 10 m. The coarse-grained lower half of these cycles are characterized by the presence of some truncation surfaces and by the fact that they are composed of 2 or more sandstone beds (Fig. 6b), unlike the fining-upward sequences in the Arung Khola Formation, of which sandy parts are composed of single sandstone bed. In the Bu Member, the thickness of each cycle attains more than 20 m. At the basal part of each cycle, mudstone blocks (30 to 100 cm in diameter) are contained along the scouring surfaces. The lower part of the cycle consists of planar cross-bedded pebbly sandstones (sets are 1 to 3 m thick), and they grade up into trough cross-laminated sandstones and the overlying black mudstones. Molluscan fossils were discovered in two horizons (F15 and 22 in the lower and F14 and 17 in the upper) of the Bl Member and in one horizon (F16) of the Bm Member.

Along the route No. 69, alternating beds of dominated by sandstone with minor mudstones of the Bm Member crop out along the southern bank of the Binai Khola with gently folded structures. Molluscan fossils were found at F13 site, of which horizon is upper than F16.

Dumkibas Area (App. I, Figs. 5 and 6)

The Binai Khola Formation is distributed in the areas of the Gangti Khola (No. 52), Ghagi Khola (No. 43) and Jimuri Khola (No. 44). Lithologically, it has same successions as seen in the above area. The formation is gently folded by the Sonai Khola Anticline and Gangti Khola Syncline.

Mahendra Highway to Narayani River Area (App. I, Figs. 6 and 7)

The Binai Khola Formation is well exposed along the Mahendra Highway. In the preveous paper (TOKUOKA and YOSHIDA, 1984), a fault contact between the Arung Khola and Binai Khola Formation was inferred from a disturbed zone near their boundary, however, a gradual change between them has become apparent in the Satbudn Nala. Pepper-and-salt sandstones become increasingly predominant above this boundary.

At the *Mahendra Highway* (App. I, Fig. 6), the Bl Member is composed of alternating beds of predominantly siltstone with subordinate sandstone (Plate IV–1), and the Bm Member of rhythmically alternating beds of sandstone and mudstone in equal amounts (Plate IV–2, 3). The Bu Member consists of predominant sandstones and subordinate siltstones with frequent intercalations of conglomerates (Plate IV–4, 5). Many fining-upward sequences of several to ten meters thick, are observed throughout the formation. The Bl and Bm Members are steeply inclined along the road, and are sometimes overturned. Molluscan fossils were found in the Bm Member (F18), this horizon is consistent with that in the Jimuri Khola (F19).

In the *Satbudn Nala* (App. I, Fig. 6), continuous exposure of the Au and Bl Members is observed and reveals a gradual change between them. The abundant influx of pepper-and-salt sandstones is assigned the boundary. The Bl Member is mostly composed of rhythmically alternating beds of sandstone and siltstone. Intercalated variegated siltstone is absent.

Along the *Narayani River and its tributaries* (App. I, Fig. 7; Nos. 45, 46, 48–51), the Binai Khola Formation are also distributed. The similar lithology is observable among these areas. Several minor and gently folded structures are found along lower stream of the Binai Khola and the Narayani River. Molluscan fossils occur in the Kedi Khola (F20) and the western bank of the Narayani River (F21) in the Bm Member, both occur in the same horizon. A peculiar occurrence of the latter (Plate VIII–1) reported by Tokuoka and Yoshida (1984) will be mentioned later.

C. CHITWAN FORMATION

The Chitwan Formation is named after the Chitwan Dun (*wide valley*) which is situated between E-W ridge in the North Belt and NW-SE ridge in the South Belt. The formation is distributed only in the South Belt, occupying an extensive area of the Chitwan Dun, where gently-dipping thick-bedded conglomerates form badlands (Plate V–2, 3). The formation consists mostly of semi-consolidated conglomerates and partly of gravel-bearing sandstones. Thin siltstone layers are intercalated. The total thickness is 700 m. The lower part is comprised mostly of pebble to cobble gravels, whereas the upper part is predominated in cobble and boulder gravels. Almost all gravels are rounded quartzites. A gradual change from the underlying Binai Khola Formation is observed at the Dumkibas area (App. I, Figs. 5 and 6) and along several routes in the Deorali area (App. I, Fig. 4). Along the Binai Khola and Arung Khola, these conglomerates are gently dipping and are unconformably overlain by terrace gravels (Plates IV–4 and V–4, 5).

At *No. 53 Nala*, where the Chitwan Formation dips moderately, a type columnar section was obtained (App. I, Fig. 6 and App. II, Fig. 15). It is composed mostly of conglomerates in beds of more than several meters thick. Sandstones and siltstones are sometimes intercalated, especially in its lower part. Its upper part cobble and boulder conglomerates predominate with very rare silty intercalations. A calcareous marker horizon is detected in middle part of the formation. It consists of the following beds in ascending order, *i.e.* 20 cm-bedded calcareous hard conglomerates (1 m thick), semi-consolidated conglomerate (1.7 m), 20 cm-bedded calcareous hard conglomerates (2.3 m), semi-consolidated conglomerate (3 m), and calcareous hard conglomerate (1.7 m). The hard horizon contains many limestone clasts in a calcareous matrix. This zone is resistant to weathering and is traceable northwestward, up to the entrance of the Gangti Khola (Plate III–5), and southwestward downstream of the Binai Khola (App. I, Fig. 1).

D. DEORALI FORMATION

The Deorali Formation is limited in distribution along the C. C. T. in northern margin of the South Belt. The Deorali Formation consists of very thick-bedded, disorganized and matrix-supported gravel beds, in which angular to subangular boulders are predominant. The bed-thickness sometimes exceeds several tens meters. Gravels are often larger than several meters. These beds are more resistant to weathering than Chitwan conglomerates, forming a continuous hilly ridge along its distribution (Plate VI–1). These conglomerates do not occur further eastward in the surveyed area. On the contrary it seems likely that these conglomerates extend further westward beyond the surveyed area.

The Deorali formation is well exposed along the valley north of Deorali, and dips gently northward (Plate VI–3, 4). A gradual change from the underlying Chitwan Formation is observed at the cliff north of Deorali (Fig. 7), where Chitwan type conglomerates (mostly of well-rounded quartzite gravels) alternate with Deorali type conglomerate (a mixture of well-rounded quartzites and angular to subangular sandstone boulders of Churia Group origin, Plate VI–5) in the lower twenty meters. These are replaced completely by Deorali-type boulder conglomerates in the upper part.

The total thickness of the formation attains to more than 450 m.

E. TERRACE DEPOSITS

River terrace deposits are widely developed in southeastern lowland (*Chitwan Dun*), and along the Binai Khola and Arung Khola. The higher and lower terraces are distinguished in the surveyed area. The higher one is developed in the southeastern area, of which exposures are observed at roadcuts along the Mahendra Highway. It consists of well rounded boulders with red-colored matrix and has a thickness of several meters. Usually red soil covers them. The lower terrace is developed in small areas along the Arung Khola and Binai Khola, and is composed of veneer gravel beds.

F. RECENT RIVER DEPOSITS

Along the Arung Khola and Binai Khola are distributed recent river gravels and sands, of which thickness is estimated to be less than ten meters. Most gravels are derived secondarily from the Chitwan conglomerates. It seems likely that both rivers are supplying only sandy and silty materials nowadays. Along the Narayani River only sandy deposits are present with rare gravels. Their thickness is assigned to be less than ten meters. In the external area south of the F. C. T. only sandy and muddy materials are found. Their thickness may exceed several hundred meters.

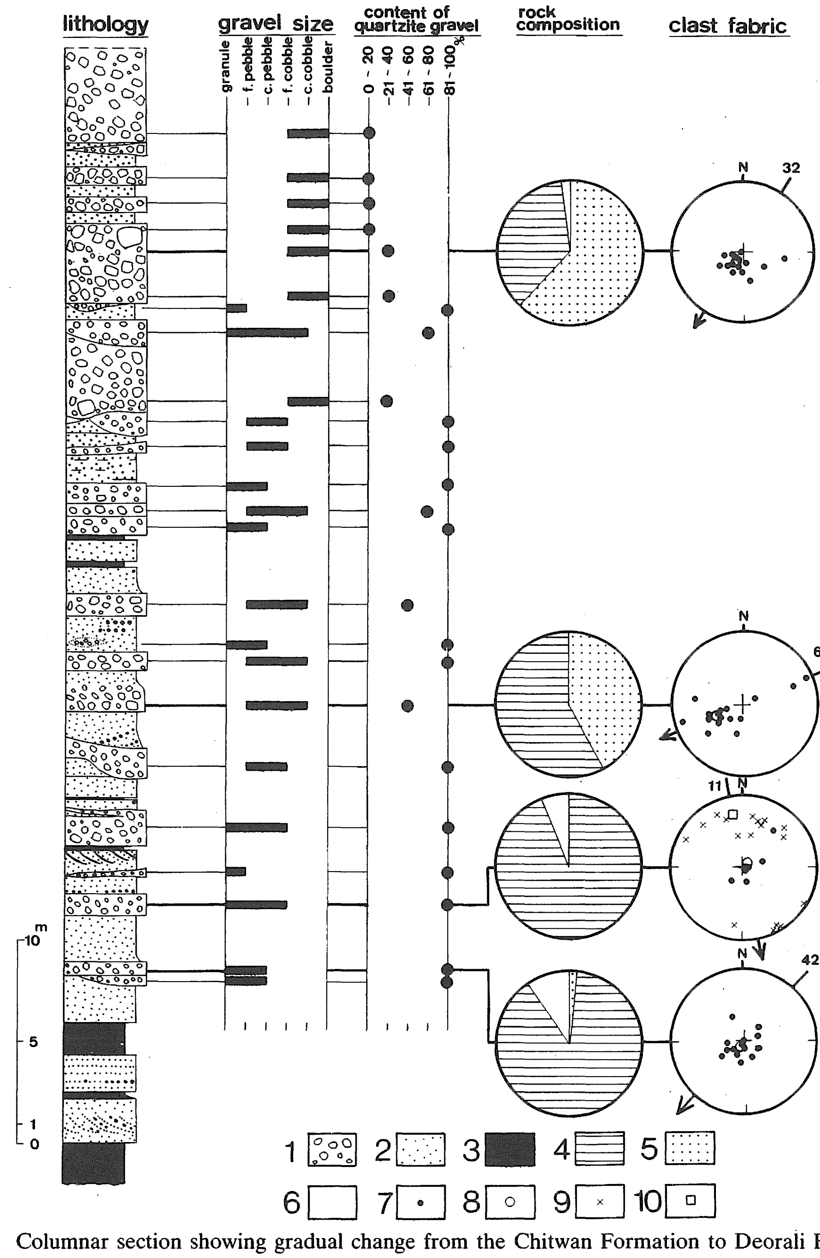

Fig. 7. Columnar section showing gradual change from the Chitwan Formation to Deorali Formation, and composition and fabric of the Deorali conglomerates. The first influx of disorganized conglomerate bearing gravels of Churia sandstones themself marks the base of the Deorali Formation. Arrows in the right column indicate mean direction of clast-fabric. 1. conglomerate, 2. sandstone, 3. mudstone and/or siltstone, 4. quartzite gravels, 5. sandstone gravels derived from the Churia Group, 6. other gravels supplied probably from the Midland Supergroup, 7. poles of ab-planes of gravels, 8. vector mean for poles of ab-planes of gravels, 9. a-axes of gravels, 10. vector mean for a-axes of gravels

4. Geologic Structure

A. *MAIN BOUNDARY THRUST*

The Main Boundary Thrust (M. B. T.) has been assigned as a tectonic contact between the Midland metasediments and the Siwalik Group. We use here the term "*Main Boundary Thrust*" instead of "*Main Boundary Fault*" as the boundary is essentially a thrust between underthrusting Sub-Himalayan terrane against the Lesser Himalayan terrane. The M. B. T. is well-known from aerophotographic survey as one of the biggest thrust systems bounding the Himalayan Fronts, however, little is known about its exact appearance in the field. We traced it throughout the surveyed area, the results of which are shown collectively in Fig. 8. The M. B. T. was checked at the valley given their numbers. It is usually concealed under thick debris, however, we could point out its exact localities at several valleys.

In most places the M. B. T. is of high-angle fault dipping northward, and is of low-angle thrust in Nos. 10 and 17 valleys. The latters seem to be of creeped high-angle fault near the surface. Crush zones exist along both sides of the M. B. T. Usually northern Midland Supergroup have been sufferred through more severe and extensive deformation than the southern Churia Group. The disturbed zone in the former is several tens meters, and that in the latter is less than several meters. The M. B. T. is assinged to be a low-angle thrust at greater depth.

B. *STRUCTURE OF THE CHURIA GROUP*

The Churia Group in the surveyed area is divided tectonically into the North and South Belts separated by the C. C. T. In the North Belt the group forms a homoclinal structure dipping at a high-angle to the north, whereas in the South Belt it has gently folded structures accompanied by some faults. The strike-line map of the Churia Group is shown in Fig. 4.

NORTH BELT

The strata trend in E-W, dipping 40° to 70° northward. In the area east of the Arung Khola, the Arung Khola Formation has NW-SE trend. This change in strike is probably related to the presence of an inferred fault along the Arung Khola. The strata dip more steeply toward the M. B. T. as clearly shown in Fig. 4, thus disproving the isoclinal foldings inferred by Tokuoka and Yoshida (1984).

SOUTH BELT

Compaired with the North Belt, the South Belt has a gently inclined structure, although it has steeply dipping structures in the southwestern part along the F. C. T. The Sonai Khola Anticline and Gangti Khola Syncline are the most important folds in the South Belt, both of which have been clarified by precise geologic mapping. As shown in Fig. 4. it is recognized that the strata become gentle toward C. C. T.

Sonai Khola Anticline has NE-SW axis, plunging northeastward. Around the Sonai Khola area the Chitwan Formation is gently dipping and sometimes flat, however, it is likely that the anticline reaches the C. C. T.

Gangti Khola Syncline has WSW-ENE axis, plunging eastward. In the Binai Khola, we can observe its axial part, which is represented by sharp bending of the hard calcareous horizon in the Chitwan Formation (App. I, Fig. 5 and Plate III–5). The syncline is asymmetrical and its southern wing dips more steeply than the northern one. Its southeastern extention occurs beneath the terrace. The Chitwan F. along the synclinal axis is steeply dipping in the hilly area east of the Binai Khola.

Central Churia Thrust (C. C. T.) trends E-W. It is clearly manifested in geomorphology, indicating its active nature (Plate VI–2). The Deorali Formation in the South Belt is overthrust by the Arung Khola Formation of the North Belt, although the thrust plane is not exposed. Most angular to subangular boulders in the Deorali Formation must have been derived from adjacent tectonic highs.

Frontal Churia Thrust (F. C. T.) bounds the southern limit of the Churia Group. The strata exposed at the entrance of the Satbudn Nala is highly disturbed and dislocated by this thrust. Although it is completely concealed beneath the alluvial plain, it is assigned one of the biggest thrust systems in the Frontal Himalayas.

5. Sedimentary characteristics

The Siwalik Group is well known as one of the great fluvial sedimentary bodies in the world. The group reflects a continuous record of fluvial sedimentation since the Neogene Period with well-preserved records of vertebrate fauna. However, it is so changeable in lithofacies that regional correlation of the group has been quite difficult to ascertain. After the establishment of paleomagnetic polarity stratigraphy in the Potwar Plateau, the Siwalik Group has been attracting much attention from sedimentologists of the world. The stratigraphy and geologic structure of the Churia Group in the surveyed area has become apparent on the basis of detailed field mapping with the aid of paleomagnetic polarity stratigraphy. Our sedimentologic results can offer invaluable key for the interpretation of the ancient river systems and sedimentary basin of the Siwalik Group.

A. SEDIMENTARY SEQUENCES

The Churia Group in the surveyed area is assigned as a whole to form a coarsening-upward sequence, attaining to 6,000 m in thickness. This coarsening-upward sequence is composed of numerous fining-upward sequences, of which thickness ranges from several to several tens meters. These fining-upward sequences are safely assinged to be of fluvial origin, judging from the vertical sequence of sedimentary structures (Figs. 5 and 6a, b). NAKAJIMA (1982) described the fining-upward sequences in the area about 60 km west of Butwal. He concluded that these were not fluvial or alluvial fan deposits as insisted by GLENNIE and ZIEGLER (1964) and BANERJEE and BANERJEE (1982), but coastal deposits of a big freshwater basin, mainly based on thickly developed lignite beds at the top of each sequence, and the lack of land indicators. However, judging from poor development of lignite beds, presence of mud-cracks and rain-drops and frequent development of lag deposits at the base of each sequence (Plate VIII, Fig. 1), it is probable that the sediments of the study area were deposited by fluvial processes. These fining-upward fluvial cycles are probably the results of lateral migration of river-channels and/or sandy lobes on the alluvial fan. It is worthy to note that the thickness of each cycle increases upward in the stratigraphic succession. The coarser-grained part at the lower half of each cycle becomes thicker and coarser. This fact and the general coarsening-upward trend of the Churia Group suggest the uprift of the Himalayas and consequent prograding of the fan-river systems developed at the frontal foothill of the Himalayas. Johnson *et al.* (1985) reported the fining-upward sequences in the Potwar Plateau, which are around 1,000 m in scale. In the present area, neither fining-upward sequences nor coarsening-upward sequences of same scale can be recognized.

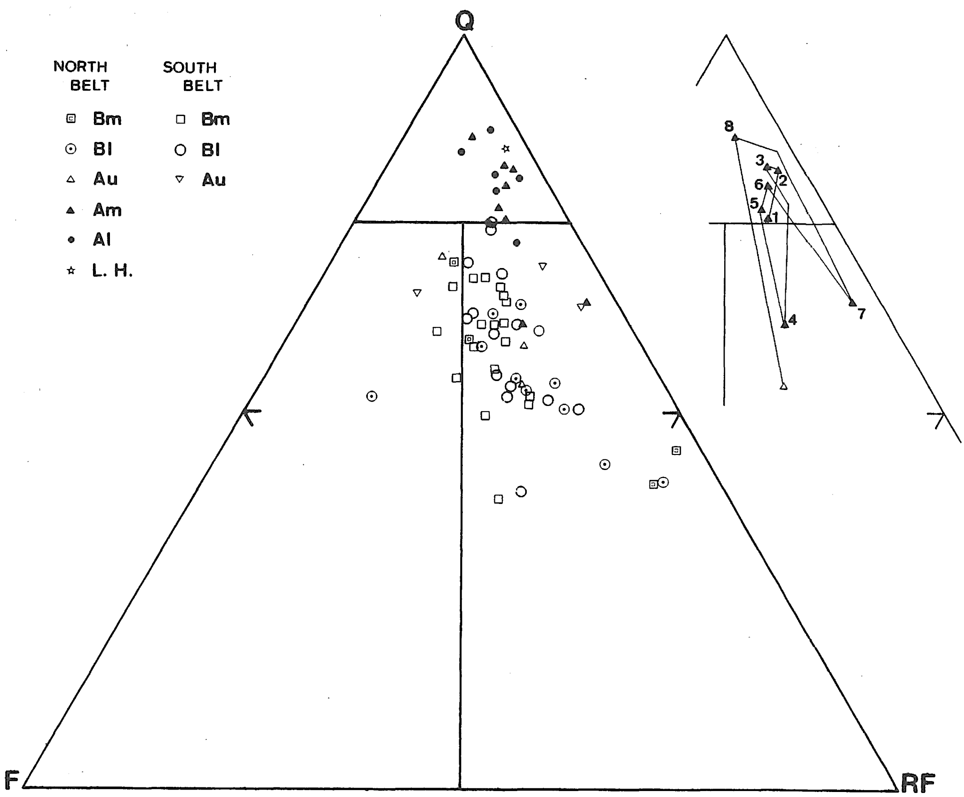

Fig. 9. Q (*quartz*) – F (*feldspars*) – RF (*rock fragments*) diagram of sandstones of the Churia Group. A star symbol indicates the quartzite of the Midland Supergroup (Precambrian-Lower Paleozoic) at the Murali Khola. In the additional figure of upper right successive compositional changes of Am sandstones in the north belt are traced from 1 to 8 in ascending order.

B. SANDSTONE PETROGRAPHY

Specimens were obtained from massive sandstones thicker than one meter, and thin sections were observed and point-counted under the microscope by K. HISATOMI. Forty-seven specimens of the Arung Khola Formation and twenty-one specimens of the Binai Khola Formation were studied. Semi-consolidated Chitwan and Deorali sandstones were not checked. The results are shown in Figs. 9, 10, 11, and Table 1.

Sandstone of the Churia Group belong mostly to lithic arenite or quartz arenite. Clay matrix is very rare and calcite cement is rich in most specimens. Sandstones are divisible into two groups. One is of the Al and Am Members, and the other is of the Au, Bl and Bm Members. The former is dominated in quartz (60 to 90% of total grains) and poor in rock-fragments (4 to 30%), belonging to quartz arenite. The latter is comparatively poor in quartz (35 to 70%) and rich in rock-fragments (12 to 50%), belonging mostly to lithic arenite.

Sandstones of Al and Am Members are characterized by dominant quartz, 60 to 90% of the total grains. Among quartz grains, polycrystalline quartz occupies 11 to 25% of the total. Feldspars range between 3 and 12% and are mostly K-feldspar. Rock-fragments comprise less than 20%, and are derived from sedimentary, granitic, schistose and gneissose rocks. Mica is very rare. These sandstones are quite similar in composition to those of the Midland Supergroup, one of which is included in Fig. 9. It is worthy to note that several sandstones are similar in composition to the other group mentioned below. These are intercalated intermittently within the members.

Sandstones of Au, Bl and Bm Members are characterized by predominant rock-fragments and micas, the total of which ranges from 20 to 53%. Rock-fragments are composed mainly of schistose, gneissose and granitic rocks, in which biotite-

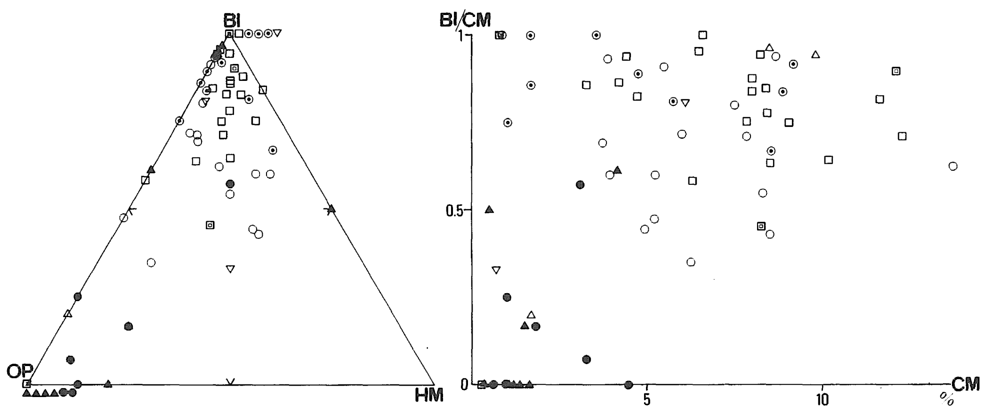

Fig. 10. BI (*biotite*) —OP(*opaque minerals*) —HM(*heavy minerals*) diagram (*left*) and a diagram (*right*) showing the relation between BI/CM(*biotite+opaques+heavy minerals*) and CM . Symbols are as given in Fig. 9.

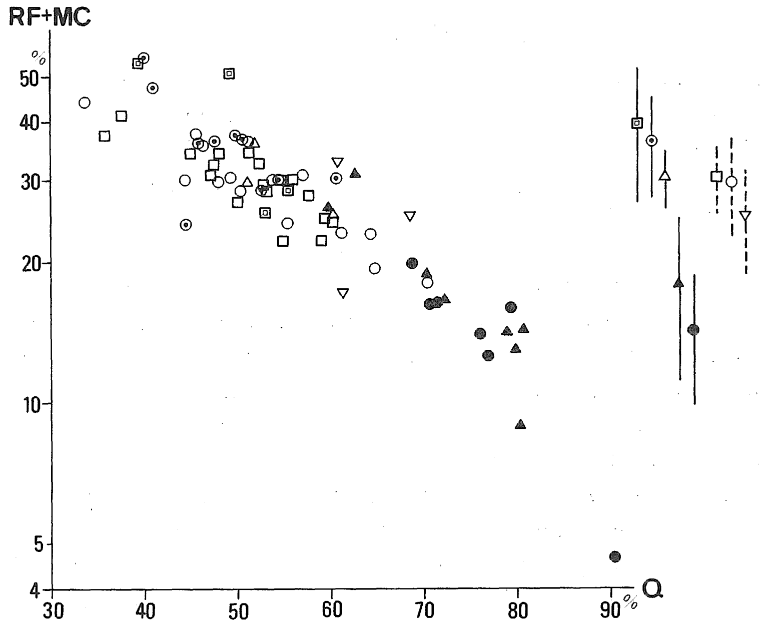

Fig. 11. A diagram showing the relation between RF(*rock fragments*) +MC(*micas*) and Q(*quartz*) of sandstones of the Churia Grouop (Percentage means their amounts to total grains). Illustrations in right are mean values in each member and their standard deviation. Symbols are as given in Fig. 9.

Table 1. Compositional properties of sandstones of the Churia Group (Abbreviations are same as Figs. 9, 10 and 11)

		MQ	PQ	TQ	PL	KF	TF	RF	MC	RF+MC	HM	OP	CI
NORTH BELT	Bm (4)	35.64	12.48	48.11	1.91	7.60	9.50	32.53	7.00	39.52	0.59	0.83	5.34
	Bl (10)	36.82	11.83	48.64	1.58	12.29	13.87	28.60	7.21	36.23	0.37	0.35	4.59
	Au (3)	41.54	12.80	54.34	1.64	12.34	13.98	21.14	9.14	30.28	0.00	0.73	6.66
	Am (8)	52.80	20.10	72.90	0.53	5.41	5.94	16.90	1.06	17.95	0.09	0.99	1.47
	Al (7)	60.78	15.57	76.35	1.07	4.85	5.92	12.31	1.95	14.26	0.25	1.56	2.17
SOUTH BELT	Bm (18)	41.96	9.30	51.26	1.46	13.66	15.12	20.63	9.57	30.20	0.68	0.85	7.51
	Bl (15)	44.14	8.85	52.99	1.60	11.52	13.13	22.09	7.62	29.47	0.88	1.39	6.61
	Au (3)	46.98	16.59	63.57	0.94	9.17	10.11	21.90	3.09	24.99	0.15	0.39	2.53

quartz schist and muscovite-quartz schist are predominant. The total amount of rock-fragments and micas increase upward, as shown in Fig. 10. Feldspars range between 10 and 20%, and are more common in these members than in the above ones. They are mostly of K-feldspars (microcline and perthite). Calcite-cement occupies more than 30% of the total volume. Samples were obtained from the North and South Belts, and no essential difference are found between them. A minor difference is that sandstones of the North Belt are rich in rock-fragments and less abundant in quartz than those of the South Belt. This may be explained by their relative positions to the source area. KRYNINE (1937) reported about sandstone petrography of the Siwalik Group for the first time and pointed out the abundance in rock fragments of metamorphic rocks.

Pepper-and-Salt sandstones characterize the Binai Khola Formation. Their abundant influx can determine the base of the formation, although similar sandstones are also intercalated in the Au Member. Black grains of "*pepper*" are mostly biotite, and rarely opaque and some heavy minerals. Their total amount is less than 14%. Micas are dominant in them, occupying 50 to 95%, and are succeeded by opaque minerals of less than 4% (Fig. 10). Grains of garnet, zircon and rarely kyanite are present, although these minerals are very rare. JOHNSON *et al.* (1985) reported that the proportion of hornblende grains in sandstones increase rapidly in the Middle Siwalik of the Potwar Basin and that it was supplied from the Mt. Nanga Parbat region. In the present case the dominant increase of biotite may reflect the upheaval of schistose, gneissose and granitic rocks in the Himalayan Range located behind the Churia Hills.

C. PALEOCURRENT ANALYSIS

Many paleocurrent data were obtained in the Churia Group. These are sole-markings, cross-bedding and ripple-marks and clast-fabrics of conglomerates. The data are collectively shown in Figs. 12–a and 12–b. Typical sole-markings are shown in Plate VII–3, 4 and 5. It is of no doubt that almost all terrigenous materials have been supplied southwards from the Himalayan side. In the Arung Khola Formation, however, there is not so much data, the paleocurrent from the north is dominant, whereas in the Binai Khola Formation, predominant paleocurrent system from NNE to SSW can be observed. In the Chitwan Formation, which is mostly composed of gravel beds and rare in data, the paleocurrent system is inferred to have been changeable. It is inferred that the upheaval of the Midland had occurred and that the mountain- and river-systems of the Himalayas have been essentially accomplished at that time. The Deorali Formation is assigned to be fault-scarf deposits in front of the C. C. T., and is known to have been derived from the north.

D. OTHER SEDIMENTARY FEATURES

Well preserved mud-cracks occur on the bottom surfaces of sandstone layers of the Bl Member (Plates II–5 and VII–1). Mud-cracks in the Al Member and rain-drops on the top of a laminated siltstone bed of the Bm Member along the Narayani River were reported (TOKUOKA and YOSHIDA, 1982; Plate VII–2). These data offer fruitful keys for paleogeographic reconstruction of the Churia Group.

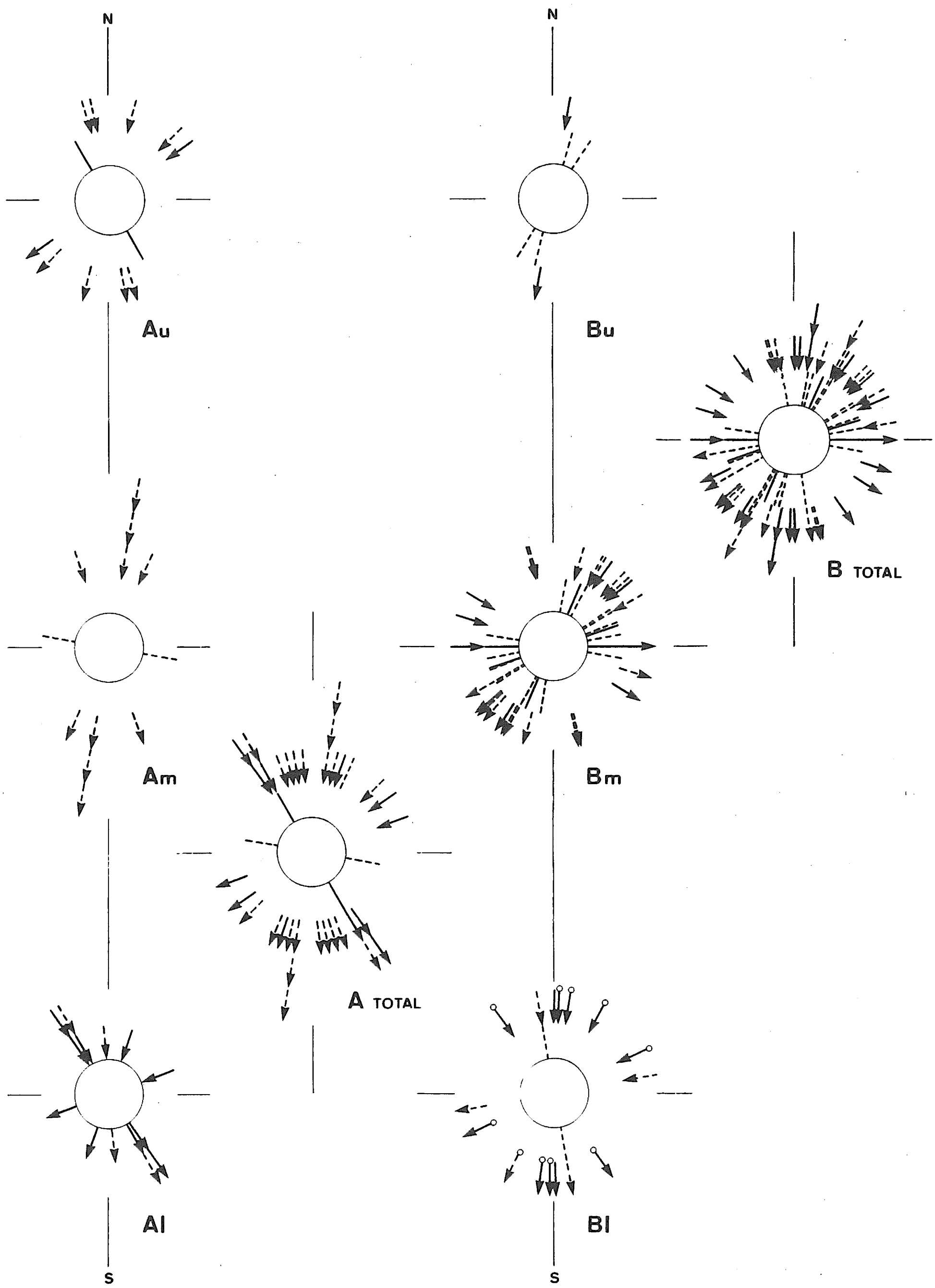

Fig. 12–a Current-rose diagrams of the Churia Group (Legend, see Fig. 12–b)

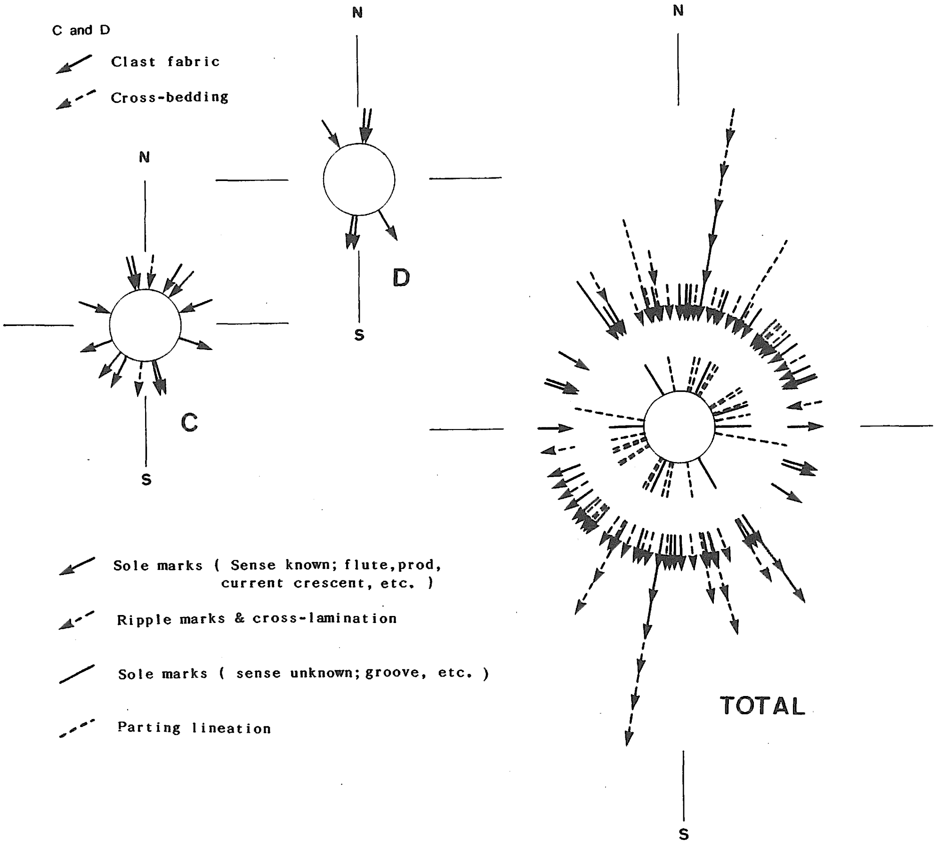

Fig. 12–b Current-rose diagrams of the Churia Group. Al, Am, Au: Arung Khola Formation (lower, middle, upper); Bl, Bm, Bu: Binai Khola Formation (lower, middle, upper); C: Chitwan Formation; D: Deorali Formation

6. Occurrence of Molluscan Fossils

Paleontological interest in the Siwalik Group has been mainly focussed on fossil mammals in connection with the evolution of hominoids. Therefore knowledge about other vertebrate and invertebrate faunas remains inadequate. This is especially true in Nepal Siwalik (Churia) Group, where only a few fragmental records of non-mammalian fauna, such as freshwater molluscs have been previously reported by WEST *et al.* (1975), TOKUOKA and YOSHIDA (1984) and so on. During the present survey, we discovered many molluscan fossils as well as plant fossils. Their localities are shown on the geologic map (App. I, Fig. 1). Their precise stratigraphic horizons are plotted in the columnar sections (App. I, Fig. 2). At several localities, small remains of vertebrates such as crocodile teeth (Plate VIII–5a and 5b), fish scales, pharyngeal teeth and bone fragments are associated with molluscan fossils.

Plant fossil-leaves occur occasionally in black or blueish-green mudstone of the Arung Khola Formation. In other formations they rarely occur and are poorly preserved. Exceptionally, many gyrogonites of charophytes are obtained from the molluscan fossil-site of F12 (in Fig. 8, ⑥) of the Binai Khola Formation.

Molluscan fossils occur at 13 sites (Nos. 1 to 13), and they are grouped into five stratigraphic horizons of F(Au), F(Bl-1), F(Bl-2), F(Bm-1) and F(Bm-2) in ascending order. F(Au) horizon is situated in the Au Member and comprises F23 site only. F(Bl-1) and F(Bl-2) horizons are in the Bl Member, the former inculudes F11, F12, F15 and F22 sites and the latter includes F14 and F17 sites. F(Bm-1) and F(Bm-2) horizons are comprehensive of the Bm Member. F(Bm-1) horizon consists of F16 site, and F(Bm-2) horizon is composed of F13, F18, F19, F20 and F21. The lowest molluscan fossil horizon of F(Au) coincides magnetostratigraphically with *Sivapithecus* horizon at the Tinau Khola section, north of Butwal (MUNTHE *et al.*, 1983). The fossil site in the present area, however, yields only ill-preserved unioids and unidentified small bone fragments. The shells from the Binai Khola Formation, usually found in blueish grey or dark grey shales, are well preserved in most cases, but deformed to various degrees. These are rich in bivalves and include some gastropods. Most bivalves are found in a conjoined state, indicating their *in situ* origin. Their occurrence at the western side of the Narayani River is of interest (Plate VIII–1). As already mentioned in TOKUOKA and YOSHIDA (1984), fossil-bearing blocks of several tens cm in size are contained in sandstone and are arranged parallel to the bedding plane. It is inferred that these blocks have been derived from the underlying fossil beds. A fossil-bearing bed of 15 cm thick, is situated 30 cm below the sandstone bed. Thus it is reasonably inferred that a broad backswamp suitable for molluscan life coexisted at one time during the fluvial sedimentation of the Binai Khola Formation, and that fossil bearing bed excavated from its original site of deposition was transported downstream to be redeposited *en block* in sandstone.

The systematic descriptions of molluscan fossils of the Churia Group are now being undertaken by K. TAKAYASU and his colleague, K. MATSUOKA of Nagoya University. Only tentative identification to generic level is shown in the present paper (Plates VIII and IX, and Table 2)

Table 2 shows the fauna found in the present area and their stratigraphical distribution. A distinct change respecting variety of species can be noticed between F(Bm-1) and F(Bm-2) fossil horizons. From F(Au) to F(Bm-1) horizons, the association of the fauna shows no abrupt change but occasional adding of species. On the other hand, the number of species is suddenly enriched at F(Bm-2) horizon. It is worthy of attention that several pelaearctic groups, such as *Bithynia, Gyraulus, Pisidium,* appear in this uppermost (molluscan fossil) horizon. This fact may be connected with the forming the Himalayan ranges.

Table 2. Freshwater molluscs and their stratigraphic distribution in the Arung Khola area

FOSSIL HORIZON [Molluscan Fossil Site]	GASTROPODA									BIVALVIA							
	Pila sp. (Pl.VIII-6,7)	Bellamya sp. (Pl.VIII-8)	"Filopaludina" sp. (Pl.VIII-9)	Melanoides sp.1 (Pl.VIII-12)	Melanoides sp.2 (Pl.VIII-13)	Brotia sp.1 (Pl.VIII-10)	Brotia sp.2 (Pl.VIII-11)	"Bithynia" sp. (small opercula only)	Gyraulus sp.	Indonaia sp. (Pl.IX-1,3)	Parreysia sp.1 (Pl.IX-5,8a,8b)	Parreysia sp.2 (Pl.IX-9)	Parreysia? sp. (Pl.IX-4)	Lamellidens sp. (Pl.IX-10)	"Rectidens" sp. (Pl.IX-6)	Physunio sp. (Pl.IX-2,7)	Pisidium sp.
F(Bm-2) [F13,F18, F19,F20,F21]	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●
F(Bm-1) [F16]		●	●			●					●	●		●	●		
F(Bl-2) [F14,F17]				●	●	●					●			●	●		
F(Bl-1) [F11,F12,F15,F22]		●		●		●					●		●	●	●		
F(Au) [F23]											●			●	●		

7. Paleomagnetic Measurements and Their Results

A. *PALEOMAGNETIC SAMPLING*

The oriented samples were taken from more than 600 sites in the surveyed area using a compass. Sites were taken preferentially from mudstones, sandy siltstones and muddy limestones. Sandstones were generally not sampled. Only one sample was obtained from one site. Detailed locations of sampling sites are shown in each route-map (App. I, Figs. 3 to 7) and Fig. 13. These are mainly involved in two sections in the North Belt (Arung Khola and Dang Khola sections) and in ten sections in the South Belt (Mahendra Highway, Satbudn Nala, No. 53 Nala, Khedi Khola, Khor Khola, Madari Khola, Darsing Khola, Jimuri Khola, Puchhare Khola and Kusaundi Khola sections).

B. *LABORATORY PROCEDURES AND PALEOMAGNETIC MEASUREMENTS*

Paleomagnetic study was carried out by M. YOSHIDA. After the samples were returned from the field, each one was fashioned into cube or cylinder; semiconsolidated samples from the Chitwan and Deorali Formations were cut into cubes measuring 2.5 cm on each side and then covered by polycarbonate nonmagnetic material. The others were cut into cylindrical cores measuring 2.6 cm in diameter and 2.6 cm in length.

The samples were measured on a fluxgate spinner magnetometer (Schonstedt SSM-1A) in the Department of Geology and Mineralogy, Hokkaido University.

Almost all samples were measurable with NRM intensities ranging between 1.0 E-5 emu/cc and 5.0 E-8 emu/cc. A few samples were difficult to measure due to the low intensity of 5.0 E-8 emu/cc of noise level, and were not accepted for paleomagnetic measurements.

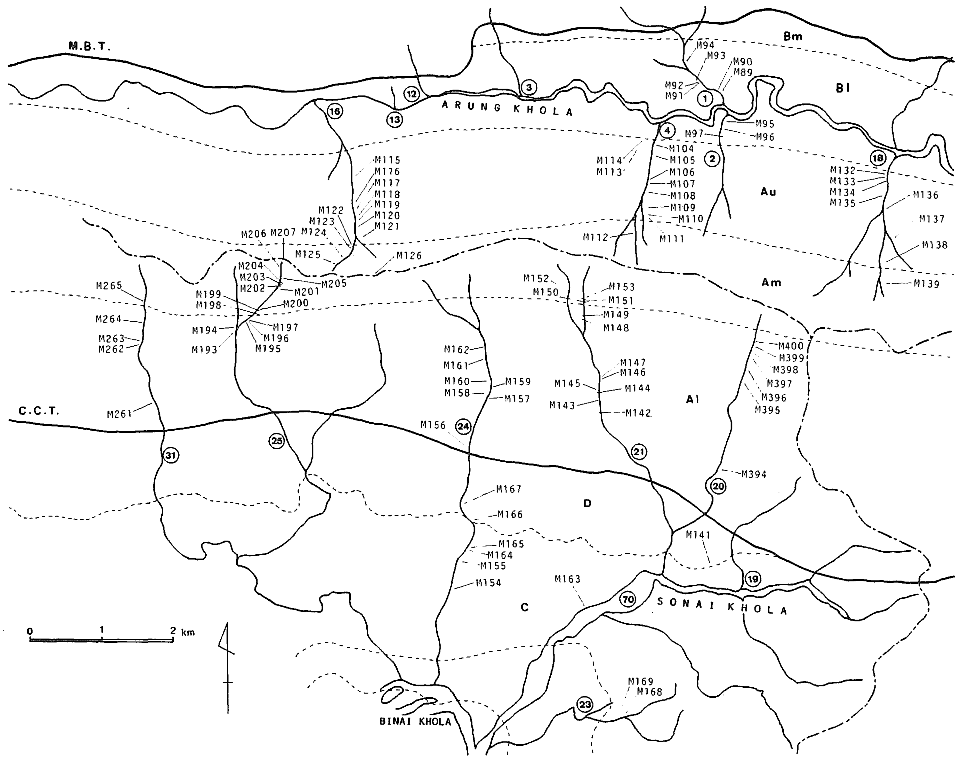

Fig. 13. Additional sampling sites for paleomagnetic measurements in the North Belt and northeastern part of the South Belt. M. B. T.: *Main Boundary Thrust*; C. C. T.: *Central Churia Thrust*; Al, Am, Au: *Arung Khola Formation* (lower, middle upper); Bl, Bm: *Binai Khola Formation* (lower, middle); C: *Chitwan Formation*; D: *Deolari Formation*

Selected samples were chosen for stepwise 400 Hz alternating field (a.f.) demagnetization in order to choose a peak field for blanket demagnetization. The results of a.f. demagnetization are shown by ZIJDERVELD diagram (ZIJDERVELD, 1967) in Figs. 14 and 15. The former illustrates the behaviour of seven samples from the North Belt, and the latter shows the results of five samples from the South Belt.

In general, two components of magnetization are present. The soft component which can be removed under a peak field of 150 oe to 300 oe mainly originates from the Earth's present magnetic field. The characteristic direction of magnetization decays linearly to the origin by increasing a peak field of a.f. demagnetization. This indicates that the samples possess minerals with good magnetic stability even though a secondary overprint is often observed.

According to the results of pilot demagnetization, a peak field of more than 150 oe to 300 oe was applied in an attempt to remove the unstable component which is not parallel to the characteristic direction of magnetization. About 20% samples were rejected from the data base because those intensities reached almost noise level and represented unstable behaviour in progressive demagnetization treatments.

The resulting direction of magnetization are given in App. III, Tables 1 and 2 with the data of virtual geomagnetic pole positions (VGPs). The data involved in

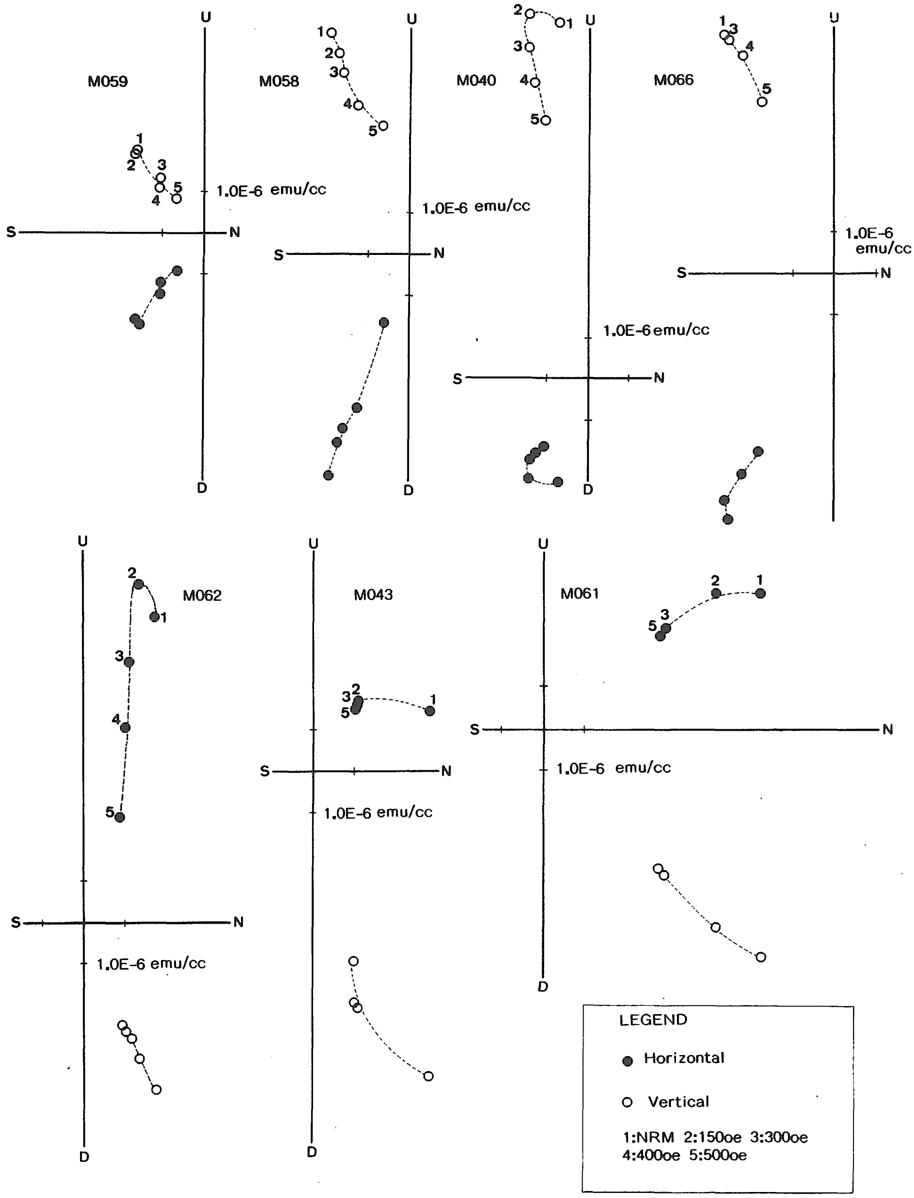

Fig. 14. ZIJDERVELD diagram of seven specimens from the North Belt. *Closed circle* horizontal component, *open circle* vertical component

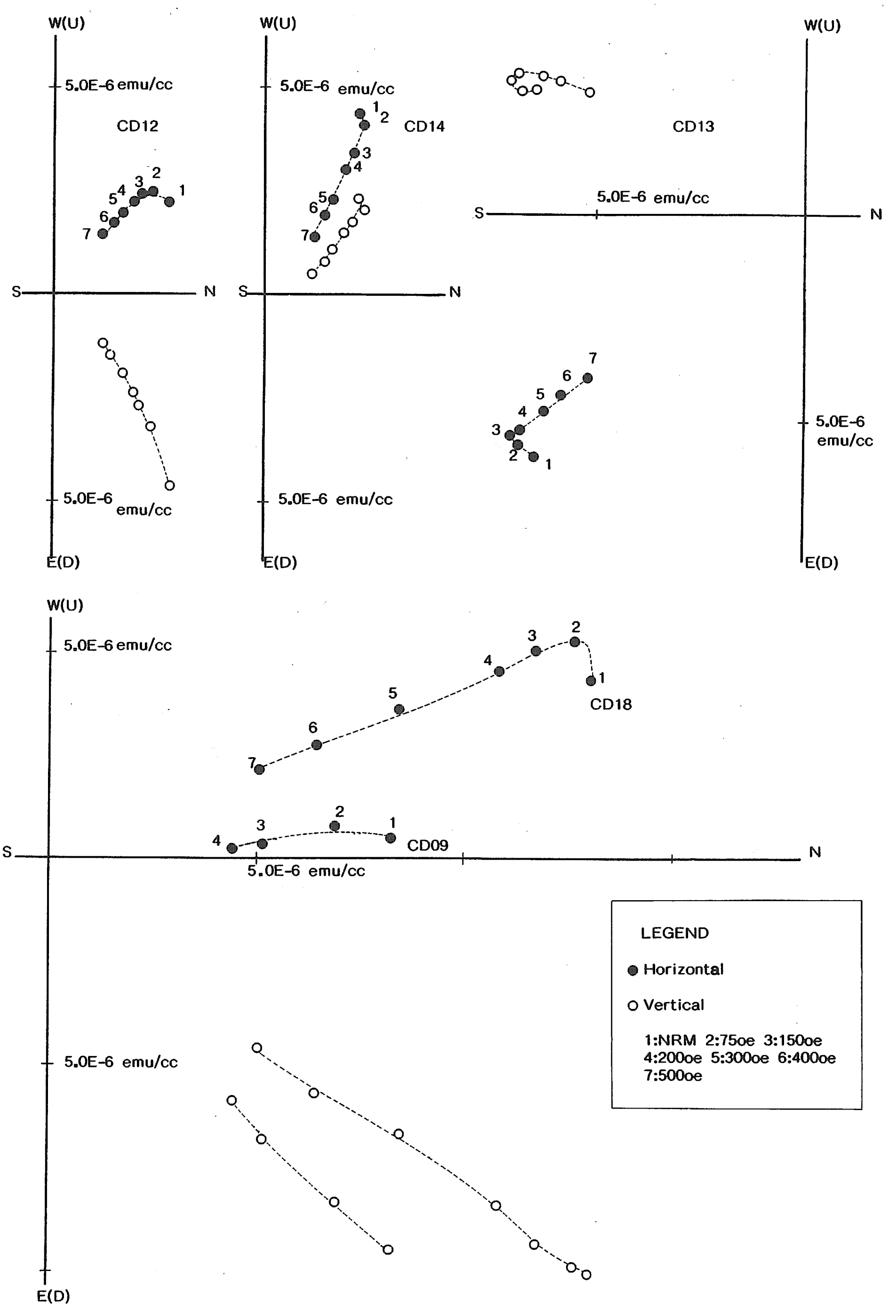

Fig. 15. ZIJDERVELD diagram of five specimens from the South Belt. The symbols are given in Fig. 14.

App. III, Table 2 were reported briefly in the preliminary report (TOKUOKA and YOSHIDA, 1984).

On the basis of the value of VGP latitude, three categories of polarity are classified; a normal polarity is defined as the VGP latitude is higher than 30°N (lat. > +30°), a reversed polarity is defined as the VGP latitide is higher than 30°S (lat. < −30°) and the interval between the normal and reversed polarities is designated as an intermediate polarity.

Polarities of all paleomagnetic sample sites are plotted on the isopolarity zone map (App. I, Fig. 8). Normal and reversed polarities are useful for the purpose of establishing a magnetic-polarity stratigraphy. Intermediate polarities are tentatively shown in the map and figures, however, it is of little value from the view point of magnetic polarity stratigraphy. The data in the intermediate polarity category was rejected from the following stastical analysis.

App. II, Figs. 1 to 7 illustrate the distributions of the directions of remnant

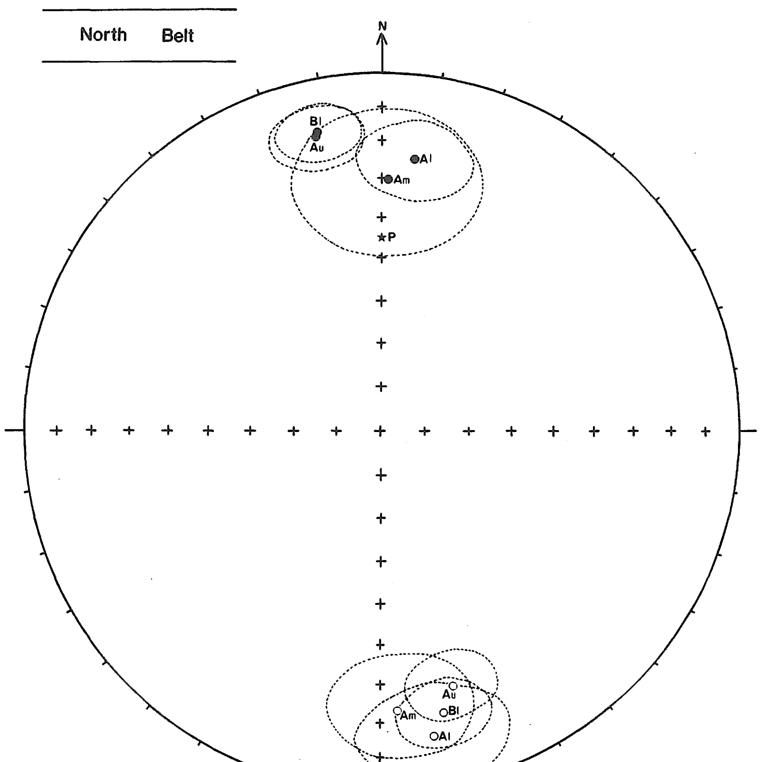

Fig. 16. Mean directions of each stratigraphic unit in the North Belt. The points are plotted on an equal area stereographic projecton with circles of 95% confidence. Filled asterisk P indicates the direction of the present geomagnetic dipole field.

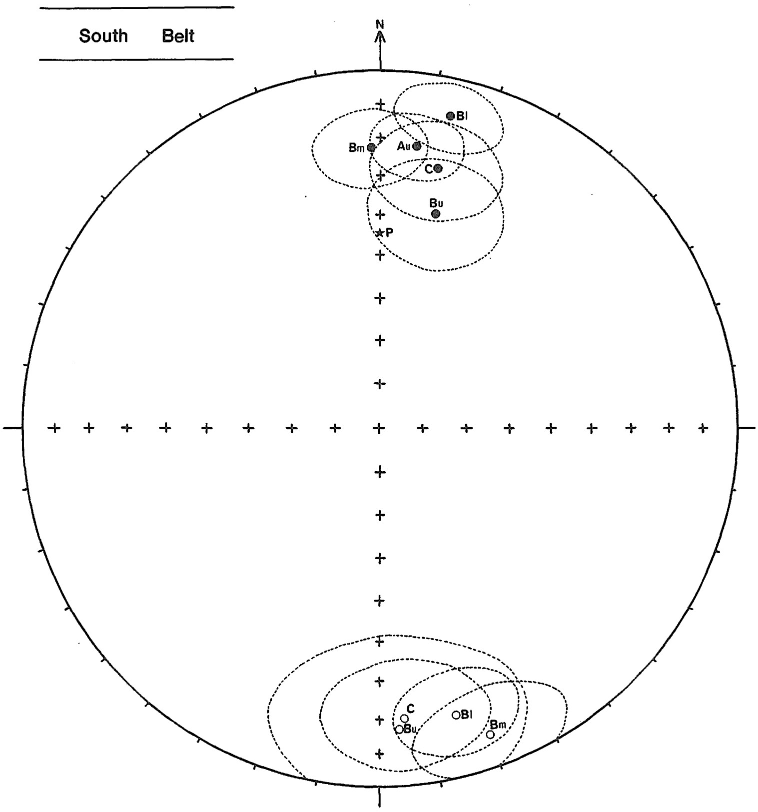

Fig. 17. Mean directions of each stratigraphic unit in the South Belt. The symbols are given in Fig. 16.

magnetization for each stratigraphic unit before and after the bedding correction. Mean directions shown in Figs. 16 and 17, and Table 3 were calculated for each in the North and South Belts using the statistics of FISHER (1953).

The bedding orientation from locality to locality is diverse and covering a variety of strike directions. In each case, an improvement in the grouping of the directions occurs after correcting for bedding tilt. This tendency is clear in the samples of the Arung Khola Formation and Bl and Bm Members (App. II, Figs. 2, 3, 5, 6, and 7). For the samples of the Bu Member, Chitwan and Deorali Formations, it is slightly scattered before and after the bedding correction (App. II, Figs. 1 and 4). The precision parameters indicate this improvement of grouping. Each value of alpha 95 shows reliability of the direction (Table 3). Directions of normal polarity sites generally show better concentrations than those of reversed polarity sites.

The results indicate that a characteristic direction of magnetization which was obtained from these beds by a.f. demagnetization and that the direction of character-

Table 3. Mean direction for each stratigraphic unit in the South and North Belts. (unit; degree)
a: after bedding correction
b: before bedding correction
n: NRM

MEAN DIRECTIONS (SOUTH BELT)

Unit		Normal sites					Reversal site				
		N	D	I	a95	K	N	D	I	a95	K
C-D	a	14	27	14	5	5	21	175	-20	16	4
	b	14	11	38	16	4	21	168	-28	16	4
	n	14	343	26	19	3	21	130	- 5	25	2
Bu	a	19	15	38	14	5	3	176	-17	24	11
	b	19	6	55	12	7	3	174	- 7	25	11
	n	19	353	49	23	3	3	189	30	39	4
Bm	a	30	358	23	11	5	19	160	- 9	15	5
	b	30	325	55	11	5	19	119	-32	17	3
	n	30	320	53	14	3	19	122	-44	22	2
Bl	a	36	13	12	10	5	22	165	-18	12	6
	b	36	338	53	10	5	22	132	-34	12	7
	n	36	327	52	11	5	22	123	-44	15	5
Au	a	27	8	22	9	8	2	-	-	-	-
	b	27	1	45	11	6	2	-	-	-	-
	n	27	1	45	12	11	2	-	-	-	-

MEAN DIRECTIONS (NORTH BELT)

Unit		Normal sites					Reversal site				
		N	D	I	a95	K	N	D	I	a95	K
Bm-l	a	28	348	17	8	10	27	167	-20	9	8
	b	28	315	64	9	9	27	128	-63	10	7
	n	28	326	64	14	3	27	121	-59	13	4
Au	a	28	348	18	9	8	27	165	-28	9	8
	b	28	316	72	10	7	27	110	-67	10	8
	c	28	318	65	11	5	27	76	-68	14	4
Am	a	12	1	31	19	5	15	176	-24	14	7
	b	12	330	67	23	3	15	145	-60	17	4
	n	12	358	66	22	3	15	131	-54	23	2
Al	a	17	7	25	11	9	15	171	-14	15	6
	b	17	358	58	12	8	15	166	-38	16	5
	n	17	-30	61	17	4	15	158	-22	23	4

istic magnetization was acquired before the tilting of the strata. Mean directions of the normal polarity sites have opposite vectors of the reversed polarity sites. These features indicate that each mean direction of the characteristic remanent magnetization is a reflection of geocentric dipole field in the duration.

C. *MAGNETIC-POLARITY STRATIGRAPHY*

SOUTH BELT

Well exposed sections with total thickness more than 4,000 m of the Churia sediments were paleomagnetically examined. The typical sections can be observed along the Mahendra Highway section. These sediments are defined as the Arung Khola and Binai Khola Formations. These are capped by a thick conglomeratic unit of the Chitwan Formation at nearby Dumkibas, which is named No. 53 Nala.

App. II, Fig. 14 shows a plot of the latitudes of VGP as a function of the lithostratigraphic position of the sampling site above the base of the section along the Mahendra Highway route. App. II, Fig. 15 shows a detailed plot of VGP latitudes of No.53 Nala section, which is situated just above the top of the Mahendra Highway section. It is noteworthy that the Au Member is predominated by a single, extensive normal polarity zone. The same conspicuous normal polarity interval can be detected in the Satbudn Nala section (App. II, Fig. 13). This is the longest monotonous polarity interval in the surveyed area.

Above this long normal polarity zone, we detected 16 normal polarity bands and 17 reversed polarity bands in the South Belt as shown in Fig. 18. These bands are encircled in eight magnetozones based on the pattern of reversal frequency. These are labeled the magnetozones N1, R2, N3, R4, N5, R6, N7 and R8 in descending order.

The magnetozone N1 is detected in the upper part of No. 53 Nala section (App. II, Fig. 15), which is lithostratigraphically of the Chitwan Formation. The magnetozone N1 is also detected in the Deorali Formation distributed along the Sonai Khola. This magnetozone is mainly magnetized in normal polarity and contains two intercalated reversed polarity bands. The magnetozone R2 is also detected from the Chitwan Formation exposed in No.53 Nala section. Except for two short normal polarity bands, reversed magnetized beds are generally detected.

The magnetozone N3 is mainly observed in the Bu Member exposed in the upper part of the Mahendra Highway, the Khedi Khola and the Puchhare Khola sections. This magnetozone is characterized by normal polarity but a short intercalation of reversed polarity band.

The magnetozone R4 is typical in the Khor Khola and Khedi Khola sections. It is common to detect an intercalation of normal polarity subzone. In the Puchhare Khola section and its eastern area, two normal polarity bands are detected. The magnetozone N5 is short and normal, but is well observed in many sections. Both magnetozones R4 and N5 belong to the Bm Member.

The magnetozone R6 is clearly observed along the upper stream of the Kusaundi Khola, and is predominated by reversed polarities. In the Madari Khola and Khor Khola sections, a distinct reversed polarity zone is observed, which is included in the magnetozone R6. The magnetozone N7 is detected in the Khor Khola and Mahendra

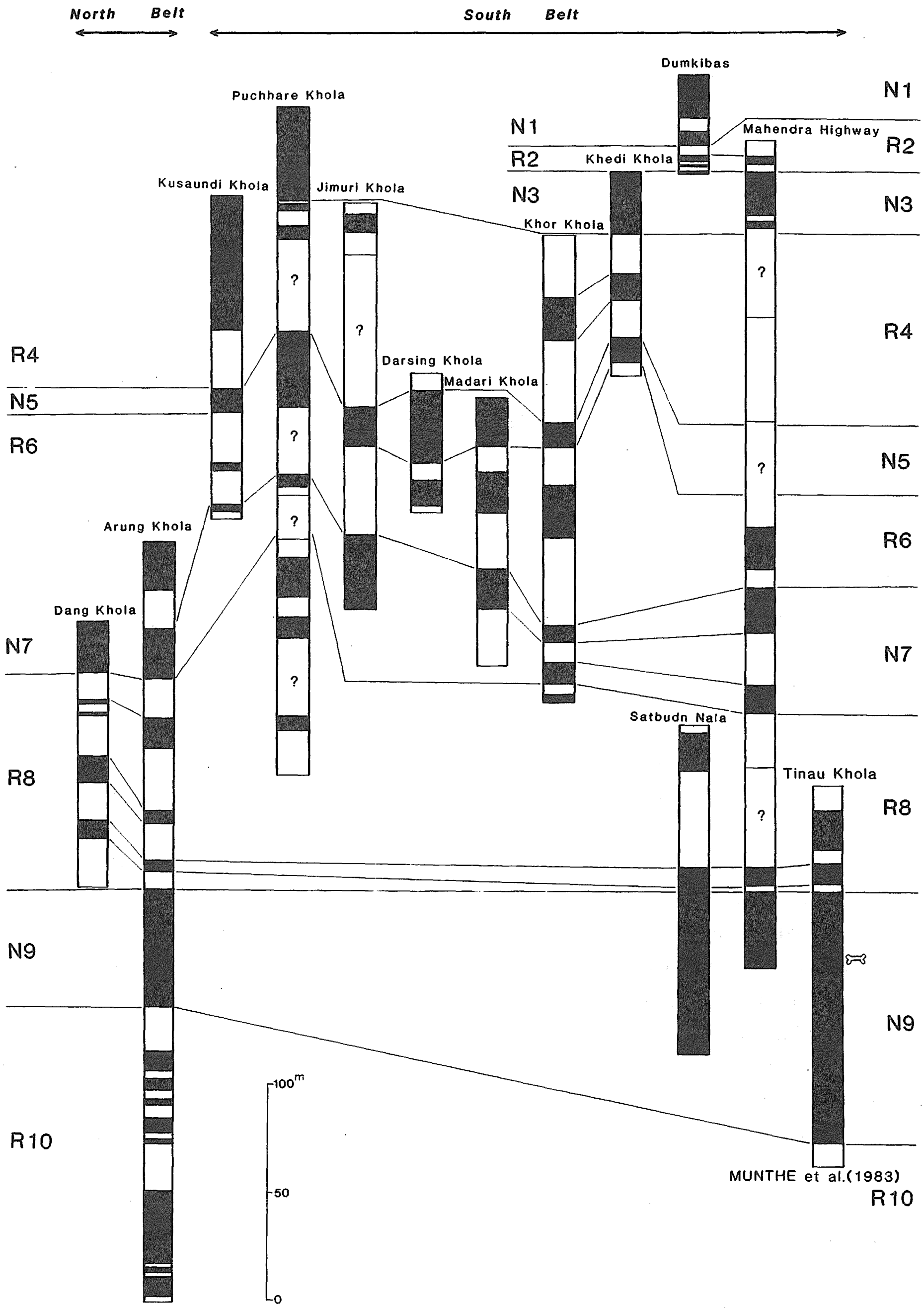

Fig. 18. Paleomagnetic correlation of the Churia Group of the present area and Butwal area on the basis of paleomagnetic polarity stratigraphy. The columnar section of the Tinau Khola is modified from MUNTHE *et al.* (1983). The bone symbol represent fossil site of "*Lower Siwalik*" mammalian fauna. (Dumkibas means No. 53 Nala)

Highway sections. The magnetozone R8 is a mixed polarity zone, which is observed along the Mahendra Highway and Satbudn Nala sections. The magnetozones R6, N7 and R8 belong to the Bl Member.

NORTH BELT

We obtained paleomagnetic samples from two long sections (Arung Khola-Murali Khola and Dang Khola sections). The results are shown in App. II, Figs. 8 and 9. Around the area south of the Arung Khola, are located some paleomagnetic sample sites. In any case, it is noted that the Au Member is again characterized by a long normal polarity zone, which is the magnetozone N9 in the South Belt.

The interval above the N9 magnetozone can be encircled into three magnetozones. They correspond with the magnetozones in the South Belt. It is concluded that the sequence of magnetozones in the North Belt is correlated with the interval below R6. The correlation among each mangetozone is shown in Fig. 18.

D. CLOCKWISE ROTATION OF THE SOUTH BELT AND PALEOLATITUDE

The results of the paleomagnetic measurements have made possible to the interpretation of the paleogeographic settings of the Churia Group, although a more detailed examination is needed.

The Au and Bl Members distributed in both belts have remarkably different mean directions of normal polarity site to each other. Those in the North Belt are shown in Fig. 16, and the Au Member indicates westerly shifted declination of 348 degrees. On the other hand those of the same horizon in the South Belt indicate easterly shifted declination of 8 degress. A gap of about 20 degrees occurs between them. In the same way, we can recognize a gap of about 25 degrees in declination between the Bl Member of the both belts. It is reasonably suggested that a clockwise 20°–25° rotation of the South Belt against the North Belt occurred after formation of the characteristic magnetization of the Bl Member. A similar rotation was know in the Potwar Plateau by OPDYKE *et al.* (1982).

It is very characteristic that inclinations of magnetization of the Arung Khola and Binai Khola Formations are clearly of a shallower angle than recent inclinations in this area. This tendency is also observed in the "*Lower Siwalik*" in the Tinau Khola section by MUNTHE *et al.* (1983). It suggests theoretically two possibilities on paleomagnetic interpretation. One is the possibility that the Churia sediments obtained their magnetization in a lower latitude region than the latitude during recent time. The mean paleolatitude is calculated as 5°N to 21°N. The other is the possibility that paleogeocentric dipole axis obliqued to the geographic pole ranging around 20°. JOHNSON *et al.* (1985) also insisted that the Siwalik sediments in the Potwar Plateau were deposited several hundreds kilometers south to the present position.

8. Discussion on the paleomagnetic correlation between the Churia and Siwalik Groups

The Arung Khola Formation exposed in the southern margin of the South Belt can be traced westward (TATER *et al.*, 1983). This type of lithofacies was called "*Lower Siwalik*" in Nepal. One of the most typical sections of the "*Lower Siwalik*" was described in the Tinau Khola section, 30 km west from the Arung Khola area, by MUNTHE *et al.* (1983). Their "*Lower Siwalik*" is lilthologically equivalent to the Arung Khola Formation.

According to the magnetic-polarity stratigraphy of MUNTHE *et al.* (1983), the "*Lower Siwalik*" has a long normal polarity zone. They correlated this polarity zone with Chron 9 based on the occurrences of characteristic taxa such as *Conohyus sindensis* and *Sivapithecus punjabicus*.

Our magnetic-polarity stratigraphy can correlate well with that in the Tinau Khola section. The magnetozone N9 corresponds to the long normal polarity zone of Chron 9 in the "*Lower Siwalik*" of the Tinau Khola.

The chronostratigraphic position of the Binai Khola, Chitwan and Deorali Formations correlate with the intervals above Chron 9. The simple correlation of the reversal sequence in the local magnetic-polarity stratigraphy to the standard magnetic-polarity time scale (LOWRIE and ALVAREZ, 1981; MANKINEN and DARLYMPLE, 1979) is attempted. The magnetozone R8, which overlies the magnetozone N9 correlatable to Chron 9, is safely correlated with Chron 8 and the lower part of Chron 7. Then the successively overlying magnetozones from R8 to N1 are possibly correlated with Chrons from 7 to 1 as shown in Fig. 20 and App. I, Fig. 8. We have no direct chronologic evidence above the magnetozone N9, however, there is some information to check the chronological flame from R8 to N1. In general, sediments of these horizons have been lithologically called the "*Middle and Upper Siwaliks*" in Nepal. WEST *et al.* (1975) and WEST (1981) briefly reported the lithology of "*Lower, Middle and Upper Siwaliks*" in western Nepal and occurrences of vertebrate fossils from "*Upper Siwalik*". They described many characteristic taxa, which belong to the *Elephas planifrons* Interval Zone by BARREY *et al.* (1982). This suggests that their "*Upper Siwalik*" can be correlated with the Gauss to Matuyama Polarity Chron. The lithologic change from "*Middle to Upper Siwaliks*" in west Nepal is likely to correspond with that from the Binai Khola Formation to the Chitwan and Deorali Formations in the present area. Thus, it is inferred that the Chitwan and Deorali Formations are lithologically regarded as the equivalent of "*Upper Siwalik*", which does not conflict to the above-mentioned paleomagnetic ages of these formations.

The interval below N9, the magnetozone R10, is long and quite complex. The correlation of this sequence with the polarity time scale is tentatively shown in App. II, Fig. 8. The basal parts exposed in the Arung Khola Formation, around R 10–3, may correspond to around Chron 14. However some of the details are left pending.

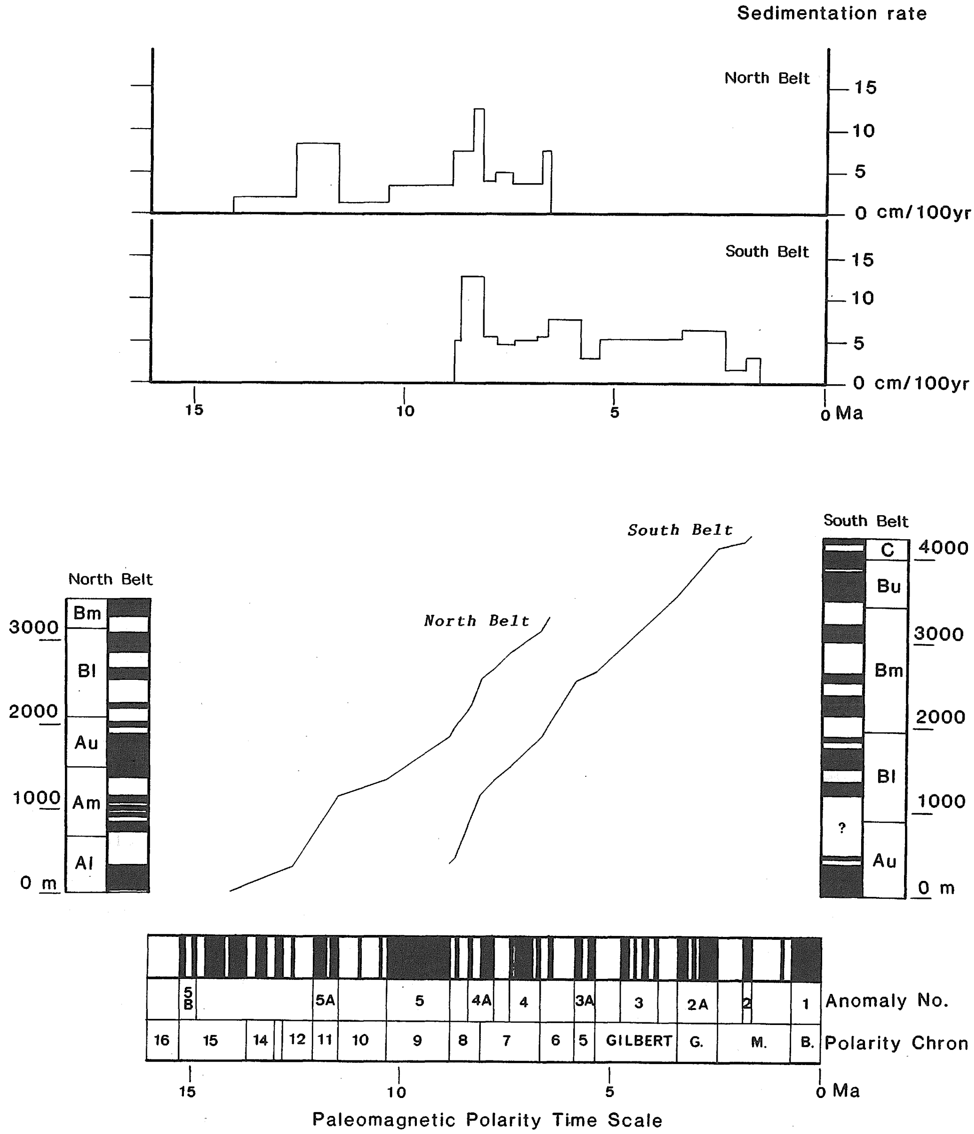

Fig. 19. Comparison of the North and South Belts composite magnetic polarity stratigraphy with the LABRECQUE *et al.* (1981) time scale. The slope is directly proportional to sedimentation rate. The upper two diagrams illustrate the fluctuation of sedimentation rate.

Owing to a lack of radiometric dating and/or paleontological evidence, a definite conclusion about the chronology must be reserved.

Depending on the correlation between the local magnetic-polarity stratigraphy and the time scale, we discuss the sedimentation rate of the Churia Group (Fig. 19).

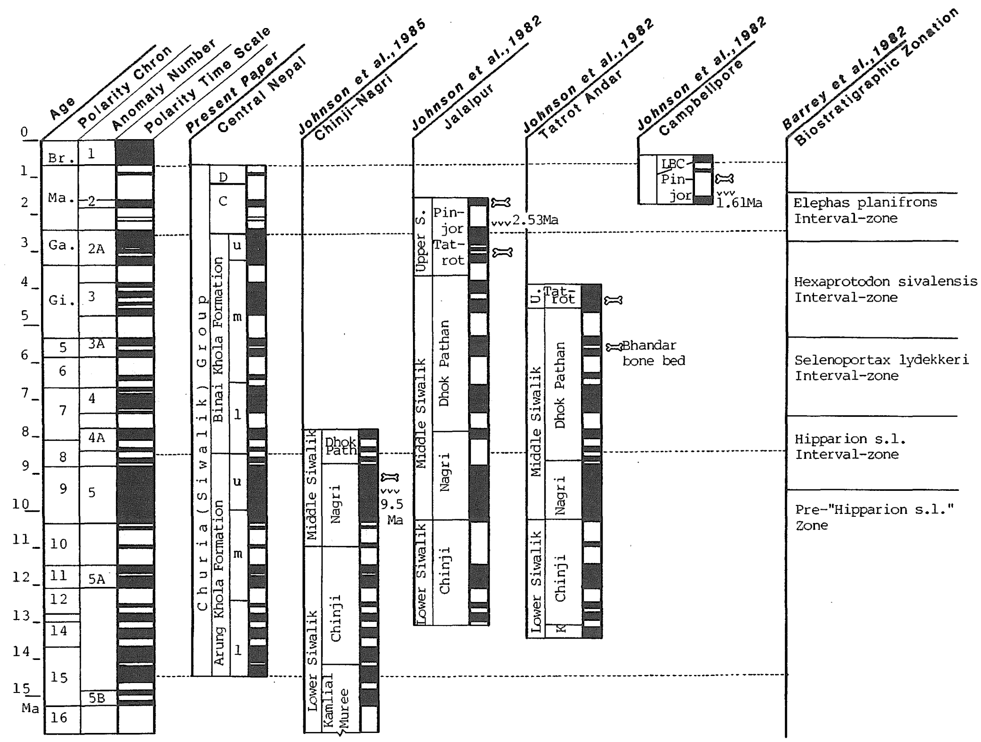

Fig. 20. Tentative magnetostratigraphy and chronology of the Late Cenozoic clastic sedimentary succession observed in the Sub-Himalayan Ranges of Nepal and Pakistan. Bone symbols indicate fossil sites of typical vertebrate fauna. The right column shows the range of biostratigraphic zone by BARREY *et al.* (1982)

The sedimentation rate was usually 0.2 to 0.5 mm/yr, but in the Al to Am Members and in the Bl Member it became quite rapid. In particular, where the phase of deposition in the Bl Member is simultaneous in both belts, the rate is generally faster in the South Belt than in the North Belt. It also means the rates of deposition of younger sediments is more rapid than those of older sediments.

The relationship with the classic biostratigraphic divisions of type Siwaliks in Pakistan and the Churia Group is shown in Fig. 20. The Al and Am Members are correlated with the *Chinji* zone (*Lower Siwalik*). These are dated paleomagetically in Chron 10 to Chron 15. The Au Member corresponds to the *Nagri* zone. The Binai Khola Formation is almost same to the *Dhok Pathan* and *Tatrot* zones, which ranges from Chron 8 to the Gilbert Reversed Polarity Chron. The Chitwan Formation corresponds to the *Pinjor* zone dated from Gauss Normal Polarity Chron to Matuyama Reversed Polarity Chron. It may be possible to correlate the Deorali Formation with the *Boulder Conglomerate* of Lower Pleistocene.

It should be remarked that the nomenclature of "*Lower, Middle and Upper Siwaliks*" is chronologically different between the type area and Nepal.

9. Summary and Conclusions

1. The detailed geologic mapping of the Arung Khola area has clarified the stratigraphy and geologic structure of the Churia Group, of which results are represented in the colored geologic map of App. I, Fig. 1. The Churia Group, which is thrust southward by the Midland metasediments by the Main Boundary Thrust, is separated by the E-W trending Central Churia Thrust into the North and South Belts. The group is divided into the Arung Khola Formation (Al, Am and Au Members; 2,100 m), Binai Khola Formation (Bl, Bm and Bu Members; 2,800 m), Chitwan Formation (700 m) and Deorali Formation (450 m) in ascending order. The strata up to the Bm Member occur in the North Belt, whereas in the South Belt strata down to the Au Member occur.

2. The paleomagnetic measurements have lead fruitful results for the correlation of the Churia Group to the Magnetic-polarity time scale. The correlation of the Churia Group to the Siwaliks in the Tinau Khola, 30 km west of the present area and those in the Potwar Plateau in Pakistan has been satisfactorily established, especially by means of the long-continued normal magnetopolarity zone of N9 (Chron 9). Chron 9 is recognized not only in the South Belt but also in the North Belt. The iso-polarity zone map attempted for the first time in a land area is illustrated in App. I, Fig. 8. Magnetostratigraphically, the Al and Am Members are correlated with the *Chinji* zone (*Lower Siwalik*)-Chron 10 to 15, and the Au Member to the *Nagri* zone (lower half of *Middle Siwalik* including Chron 9). The Binai Khola Formation correspond mostly to the *Dhok Pathan* zone (upper half of *Middle Siwalik*) and *Tatrot* zone (lower half of *Upper Siwalik*), which ranges from Chron 8 to the Gilbert Reversed Polarity Chron. The Chitwan Formation is correlatable to the *Pinjor* zone (upper half of *Upper Siwalik*), and the Deorali Formation to the *Boulder Conglomerates*. Lithostratigraphic nomenclature of "*Lower, Middle and Upper Siwaliks*" is different chronologically between the type area and Nepal.

3. The sedimentary sequence of the Churia Group forms a coarsening-upward sequence as a whole, which attains a thickness of 6,000 m, reflecting the rising Himalayas. Fining-upward sequences are observed to be several to several tens meters in thickness throughout the Arung Khola and Binal Khola Formations. These are surely formed by lateral migration of each channel-bar system. Paleocurrent analysis strongly indicates that clastic materials have been supplied from the northern hinterlands. Successive changes of the hinterland is also specified from the petrographic analysis. Sandstones of the Al and Am Members are predominated by quartz and poor in rock-fragments, and belong to quartz arenite, whereas those of the Au, Bl and Bm Members are comparatively poor in quartz and rich in rock-fragments and

micas. The latter is also characterized by their *Pepper-and-Salt* appearance, which indicates a high biotite content. Dominant influxes of biotite started in the Au Member have obviously resulted from the upheaval of schistose, granitic and gneissose rocks in the Great Himalayas. Referring to the magnetic time scale, the sedimentation rate can be estimated to be in 0.2 to 0.5 mm/yr in the Churia Group. In the Al to Am Members and in the Bl Member it became quite rapid, and it was faster in the South Belt than in the North Belt. This is roughly consistent with the ratio in the Potwar Plateau (JOHNSON *et al.*, 1985).

4. Many freshwater molluscs have been obtained in the serveyed area. These are rich in bivalves and include some gastropods. Most bivalves are found in a conjoined state. Only tentative identification in generic level was attempted in the present paper.

5. Based on paleomagnetic results it is inferred in the Arung Khola and Binai Khola Formations in the South Belt were rotated about 20 degrees against the North Belt and that their paleolatitude is calculated to be 5 to 21 degree North. These paleolatitudes suggest that the terrane situated more than 500 km southward from the present position, although these data should be examined carefully in further studies. A clock-wise rotation was inferred in the Potwar Plateau by JOHNSON *et al*; (1982 and 1985), and shallow inclination for the "*Lower Siwalik*" in Nepal was also suggested by MUNTHE *et al.* (1983).

6. Faults and folds systems of the present area have been clarified in detail. These are reflected well geomorphologically, and are inferred to be active structures. Notwithstanding the recognition of comformable relations throughout the Churia Group, clasts surely originating from the Churia Group itself are abundant in the Deorali Formation. Syn-sedimentary tectonic movements (or syn-tectonic sedimentation) characterize the Sub-Himalayan foothills, which is interpreted by underthrusting of the Sub-Himalayan terrane against the Lesser Himalayan terrane.

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Explanation of Plates

(Localities are shown in Text-Figure 2.)

Plate I. *(Arung Khola Formation)*

Fig. 1. Alternating beds of less sandstone and more mudstone. Mudstones are often variegated. Al Member of the North Belt along the tributary of the Arung Khola. (Loc. P1)

Fig. 2. Alternating beds of sandstone and mudstone in equal amount. Mudstones are sometimes variegated. Am Member along the Arung Khola (Loc. P3)

Fig. 3. Same as Fig. 2. (Loc. P2)

Fig. 4. Alternating beds of more sandstone and less mudstone. Au Member along the Arung Khola. (Loc. P4)

Fig. 5. Alternating beds of more sandstone and less mudstone. Mudstones are sometimes variegated. Au Member in the South Belt along the Mahendra Highway. (Loc. P27)

Plate II. *(Lower Member of the Binai Khola Formation in the North Belt)*

Fig. 1. Thick-bedded sandstones sometimes gravel-bearing along the Arung Khola. Thin-bedded siltstones are intercalated. (Loc. P5)

Fig. 2. Thick-bedded sandstones sometimes gravel-bearing at the entrance of the Murali Khola. A sandy limestone is at lower right. (Loc. P6)

Fig. 3. Close-up of sandy limestone of Fig. 2. Sedimentary structures of parallel and current-ripple laminations are observed well on a weathered surface.

Fig. 4. alternating bed of sandstone and mudstone along middle stream of the Arung Khola. (Loc. 8)

Fig. 5. Alternating bed of sandstone and mudstone along upper stream of the Arung Khola. The bottom surface of the sandstone bed is mud-cracked (*arrow*). See Plate VII, Fig. 1. (Loc. P9)

Fig. 6. Thick-bedded sandstones frequently intercalating conglomeratic zones along the Murali Khola. (Loc. P7)

Plate III. *(Binai Khola and Chitwan Formations in the South Belt)*

Fig. 1. A panoramic view of cuesta geomorphology of north-dipping beds of Bl and Bm Members, south of Deorali. Alternations are comprised of thick-bedded sandstones with thin intercalations of siltstone. (Loc. P12)

Fig. 2. Alternating beds of sandstone and siltstone of Bl Member. All beds are overturned. (Loc. P14)

Fig. 3. A distant view of alternating beds of less sandstone and more siltstone of the lowest part of Bl Member. (Loc. P13)

Fig. 4. Thick-bedded conglomeratic sandstones of Bu Member at Puchhare Khola. (Loc. P16)

Fig. 5. Calcareous hard beds, marker horizon in the Chitwan Formation at the entrance of the Gangti Khola along the Binai Khola. The bed is steeply dipping and folded. The axial part of the Gangti Khola Syncline. (Loc. P19)

Plate IV. *(Binai Khola Formation at the Mahendra Highway)*

Fig. 1. Thin-bedded alternation of sandstone and mudstone of Bl Member. (Loc. P26)

Fig. 2. Alternating beds of more sandstone and less mudstone of lower part of Bm Member. (Loc. P23)

Fig. 3. Alternating bed of more sandstone and less siltstone of middle part of Bm Member. (Loc. P23)

Fig. 4. Alternating beds of sandstone and pebble-bearing sandstone with intercalations of siltstone of Bu Member along the Binai Khola, south of Dumkibas. Lower terrace gravels overlie them unconformably. (Loc. P21)

Fig. 5. Conglomeratic sandstone of Bu Member. (Loc. P22)

Plate V.

Fig. 1. A panoramic view of the Great Himalayas in back-ground (AP *Annapurna*, MS *Manaslu*), Mahabharat Range (M), and Churia Hills (C) in fore-ground from the Mahendra Highway. The Binai Khola is in center of the photo. Terrigenous materials constituting Churia Hills were supplied from these northern mountain ranges. (viewed from Loc. P25)

Fig. 2. Bad-land hill, southeast of Dumkibas constituted from conglomerates of the Chitwan Formation. The fluvial plain of the Binai Khola is in fore-ground. (viewed from Loc. P24)

Fig. 3. Bad-land geomorphology of a part of Fig. 2. (viewed from Loc. P25)

Fig. 4. Thick-bedded conglomerates of the Chitwan Formation. Beds are inclined and are overlain by higher terrace. Gravels are almost all of quartzites. Close-up of Fig. 5. (Loc. P20)

Fig. 5. A distant view of the cliff constituted from conglomerates of the Chitwan Formation. It is overlain by red gravel beds of higher terrace unconformably. (Loc. P20)

Plate VI.

Fig. 1. A lower hilly range constituted from Deorali conglomerates along the Binai Khola. The mountain range in back-ground is made of the Arung Khola Formation. The Central Churia Thrust is running between both ranges. (viewed from Loc. P18)

Fig. 2. The Central Churia Thrust (*arrow*) forming kern col geomorphology. *left* Deorali Formation (D), *right* Arung Khola Formation (A). (viewed from Loc. P17)

Fig. 3. A cliff consisting of gently dipping Deorali Formation at Deorali. The Deorali Formation is mostly composed of thick-bedded and poorly sorted conglomerates. Details are shown in Text-Fig. 7. (Loc. P11)

Fig. 4. Debris-flow deposit of Deorali conglomerates consisting mostly of angular to subangular boulders of sandstones of the Arung Khola Formation. Locality is same as Fig. 3.

Fig. 5. Close-up of angular to subangular cobble and boulder of the Deorali conglomerates of Fig. 3.

Plate VII. (*Sedimentary features of the Churia Group*)

Fig. 1. Mud-cracks on the bottom surface of a sandstone bed of Bl Member along upper stream of the Arung Khola. See also Plate II, Fig. 5. (Loc. P9)

Fig. 2. Well-preserved rain-drops on the top of a siltstone bed of Bm Member at the Narayani River. (Loc. P28)

Fig. 3. Current-crescent and flute marks on the bottom surface of a sandstsone bed of Au Member at upper stream of the Arung Khola. (Loc. P10)

Fig. 4. Crowded flute marks on the bottom of the limestone bed of Bl member at the entrance of the Murali Khola. See Plate II, Fig. 2 for the outcrop.

Fig. 5. Crowded flute marks on the bottom of a sandstone bed of Bl Member. (Loc. P15)

Plate VIII.

Fig. 1. Occurrence of molluscan fossils in Bm Member. Well-preserved molluscs are also found in the underlying siltstone bed, of which horizon is shown by arrow. Mudstone blocks (lag deposit) are observed along a truncation surface shown by hammer. (Loc. F21 site)

Fig. 2. Molluscan fossils in siltstone of Bl Member at upper stream of the Arung Khola (F12

site). Most shells are found in a conjoined state.

Fig. 3. Close-up of Fig. 1. A bivalve shell is of *Lamellidens* sp.

Fig. 4. Molluscan fossil occurrence of Bl Member at middle stream of the Arung Khola. Most *Parreysia* sp. 1 are found in a conjoined state. (Loc. F11 site)

Fig. 5a and b. A crocodile tooth (Loc. F16 site)

Fig. 6. *Pila* sp. (Loc. F13 site)

Fig. 7. *Pila* sp. (operculum). (Loc. F13 site)

Fig. 8. *Bellamya* sp. (Loc. F18 site)

Fig. 9. "*Filopaludina*" sp. (Loc. F20 site)

Fig. 10. *Brotia* sp. 1 (Loc. F17 site)

Fig. 11. *Brotia* sp. 2 (Loc. F13 site)

Fig. 12. *Melanoides* sp. 1 (Loc. F11 site)

Fig. 13. *Melanoides* sp. 2 (Loc. F17 site)

(*All figures of fossils are in natural size*)

Plate IX.

Fig. 1. *Indonaia* sp. (Loc. F20 site)

Fig. 2. *Physunio* sp. (Loc. F20 site)

Fig. 3. *Indonaia* sp. (Loc. F20 site)

Fig. 4. *Parreysia?* sp. (Loc. F19 site)

Fig. 5. *Parreysia* sp. 1 (Loc. F11 site)

Fig. 6. *Lamellidens* sp. (Loc. F11 site)

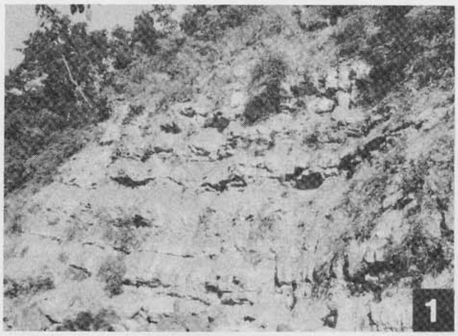
Fig. 7. *Physunio* sp. (Loc. F18 site)

Fig. 8a and b. *Parreysia* sp. 1 (Loc. F11 site)

Fig. 9. *Parreysia* sp. 2 (Loc. F19 site)

Fig. 10. "*Rectidens*" sp. (Loc. F20 site)

(*All figures are in natural size*)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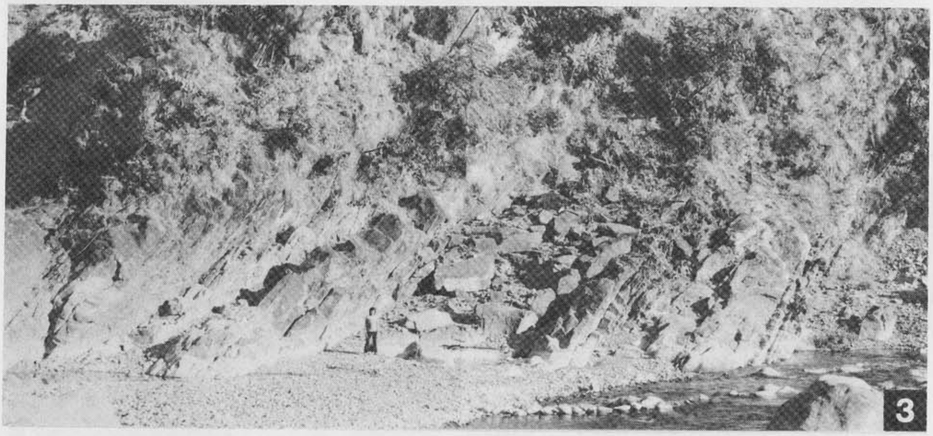
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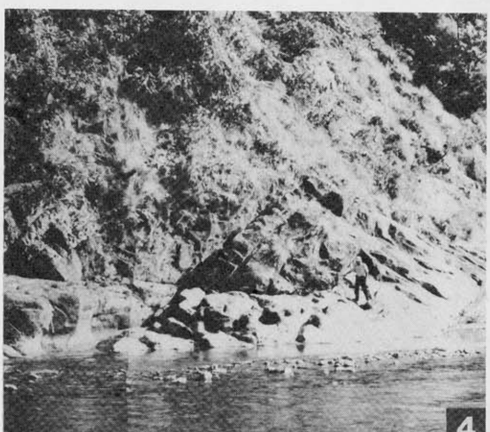
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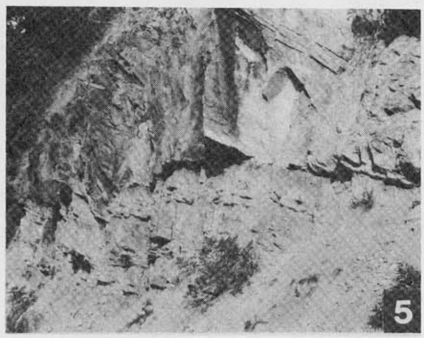
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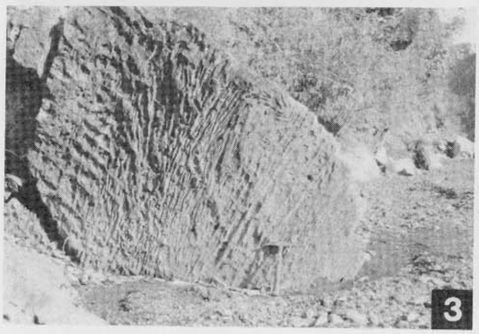
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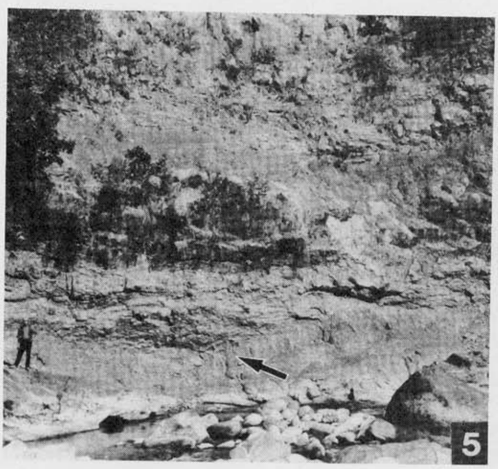
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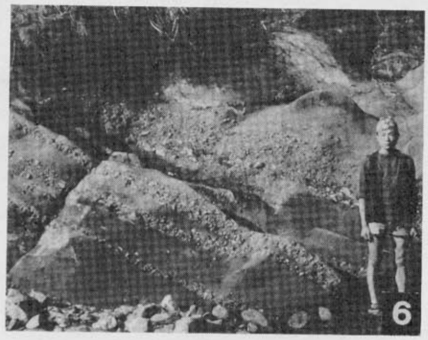
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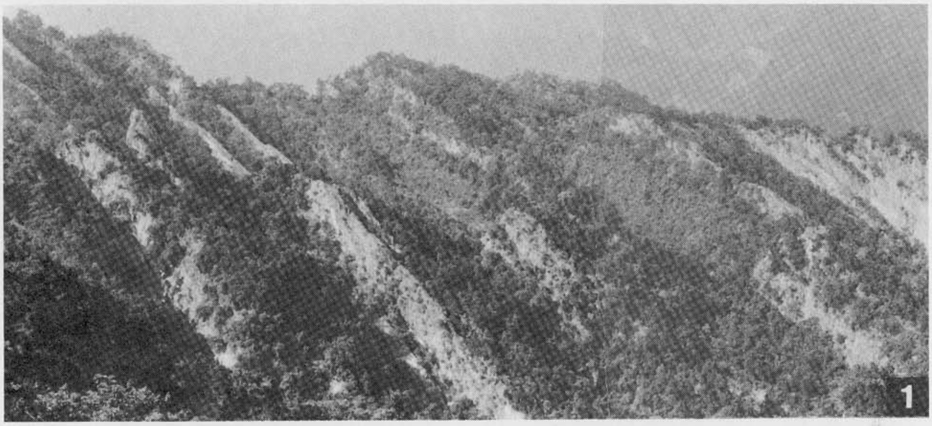

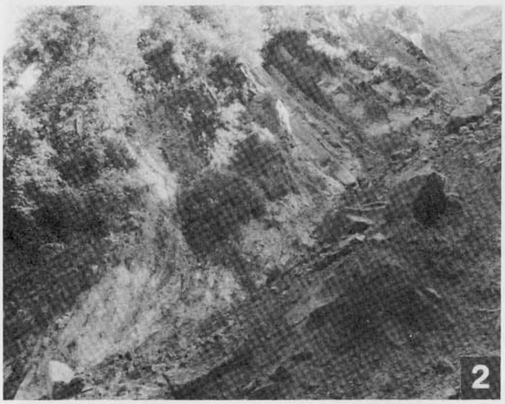

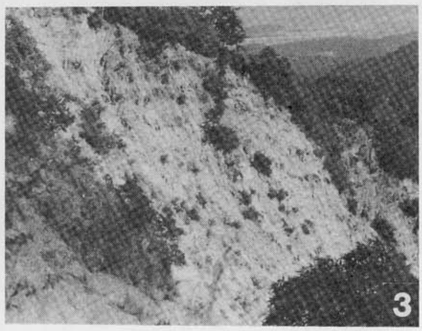

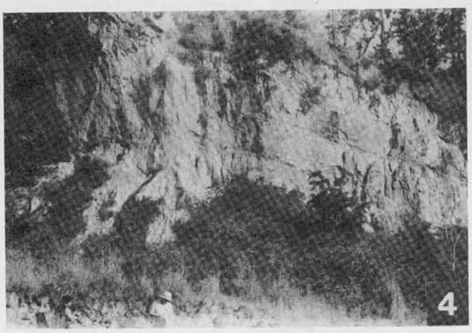

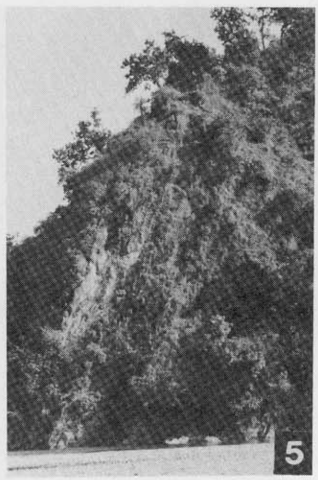

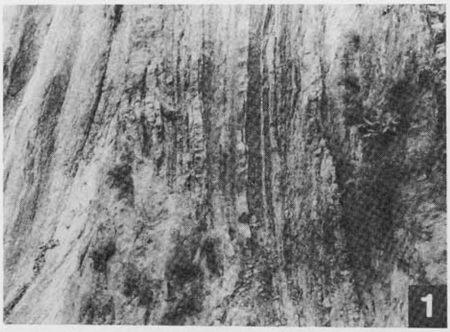
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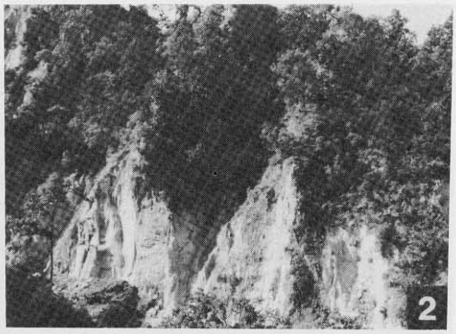
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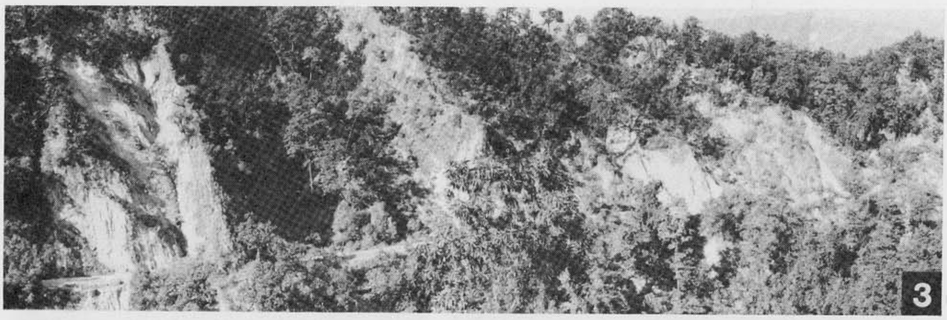
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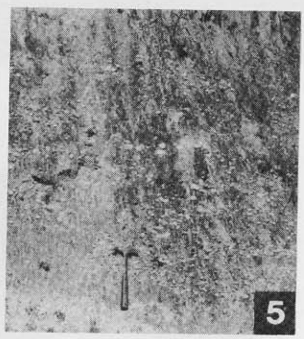
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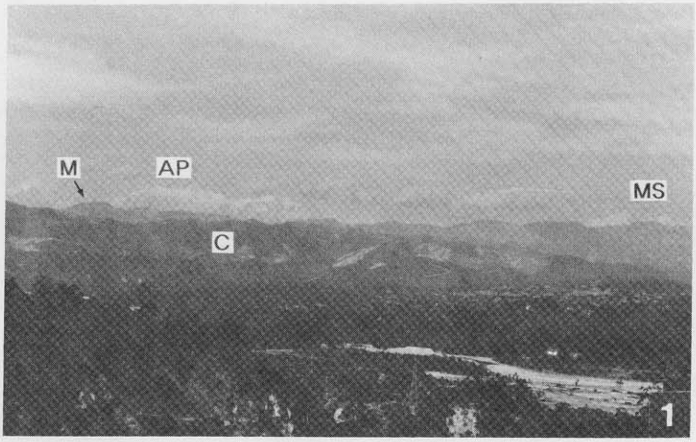
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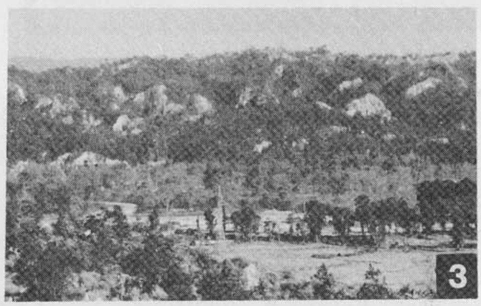
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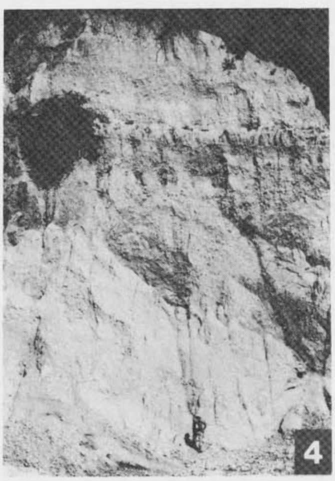
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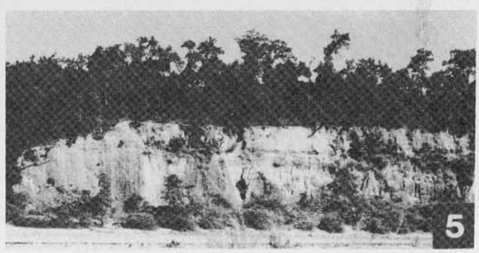
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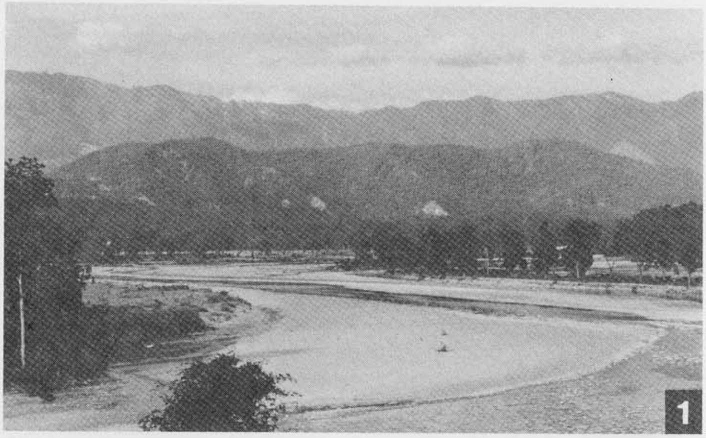
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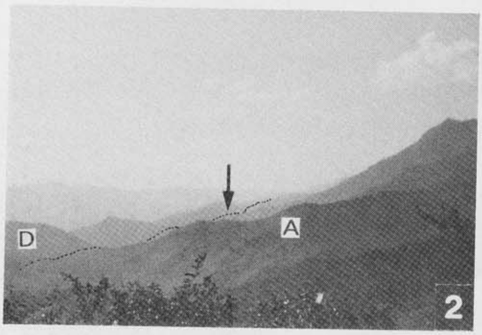

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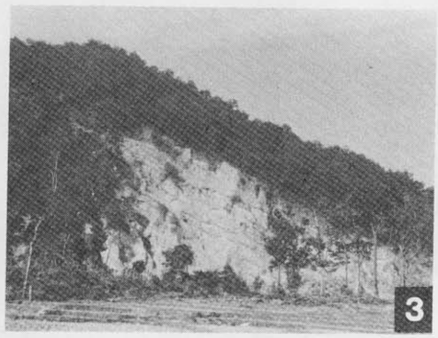
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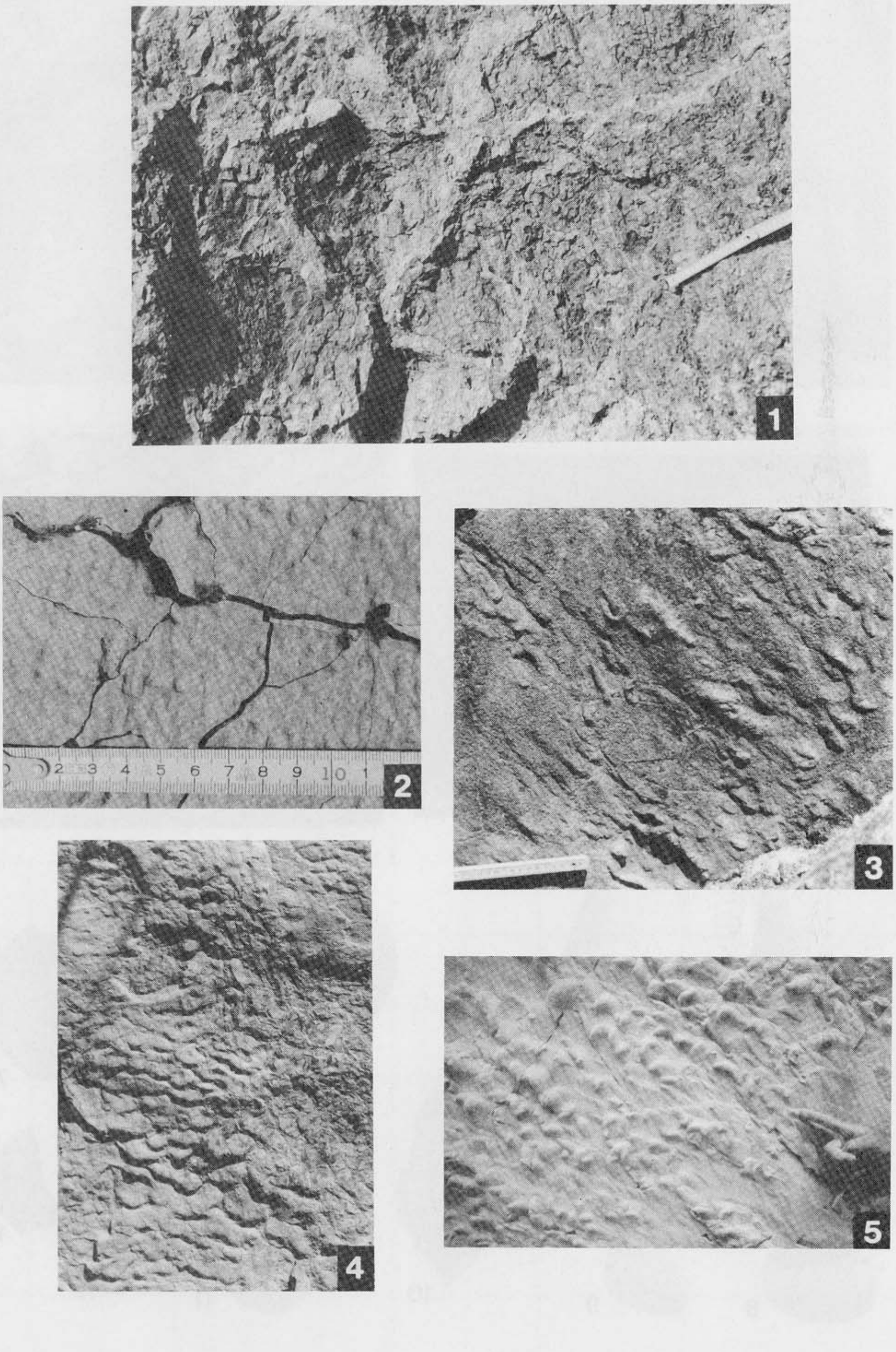

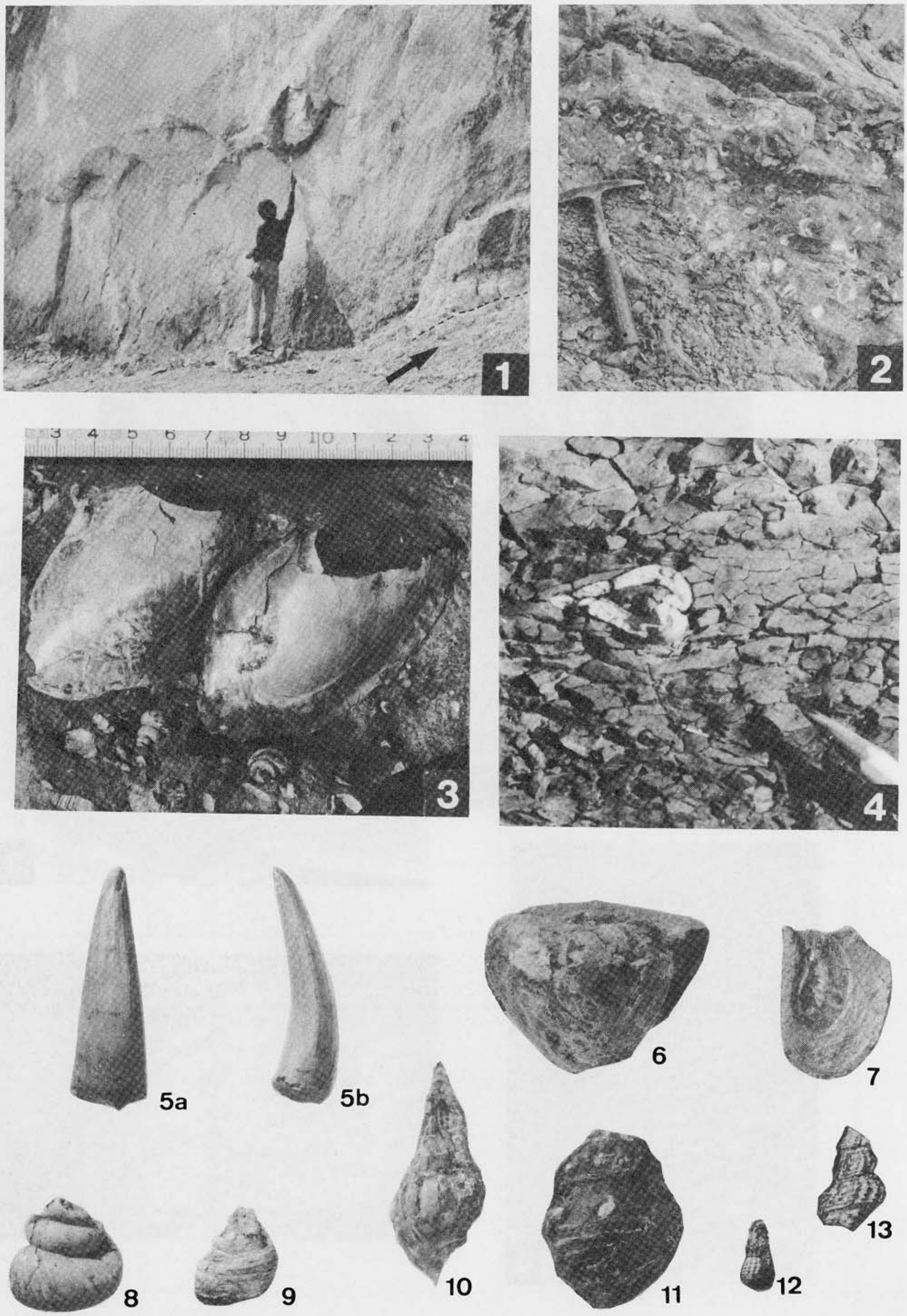
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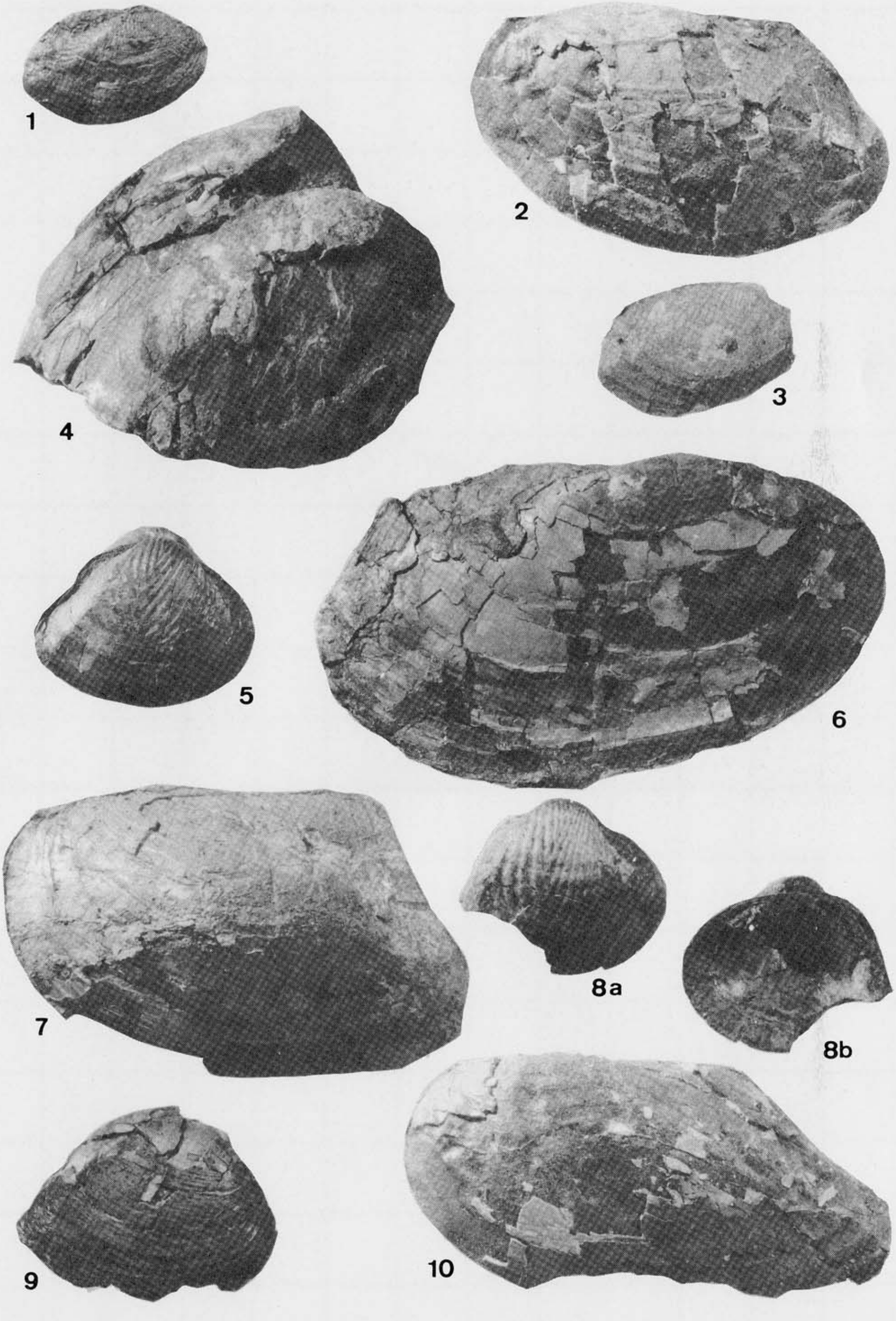
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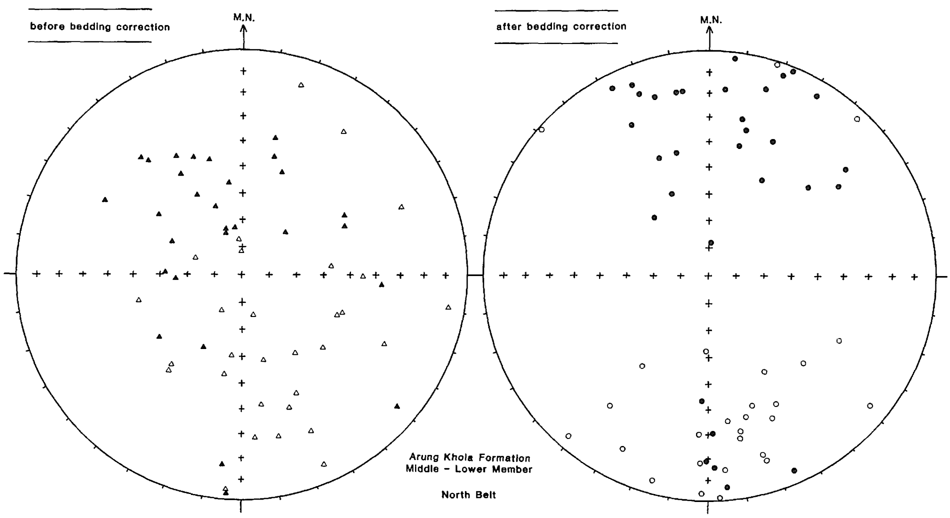
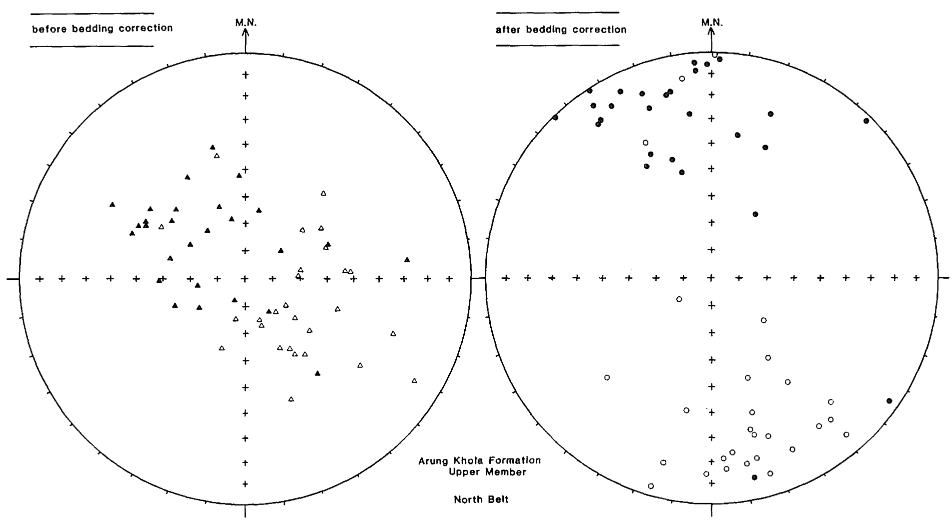
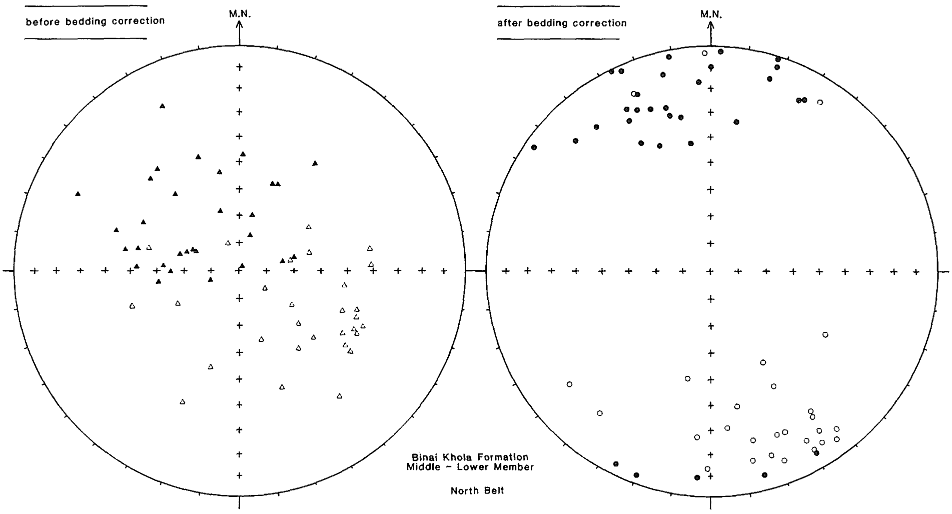
Appendix II



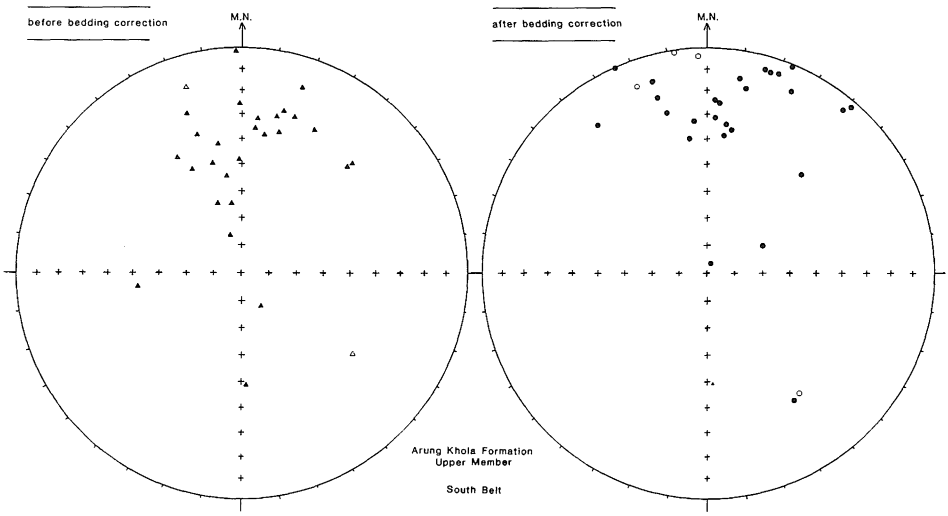
App. II, Fig. 1. The direction of characteristic magnetization of Al and Am Members in the North Belt. Symbols are given in App. II, Fig. 7.



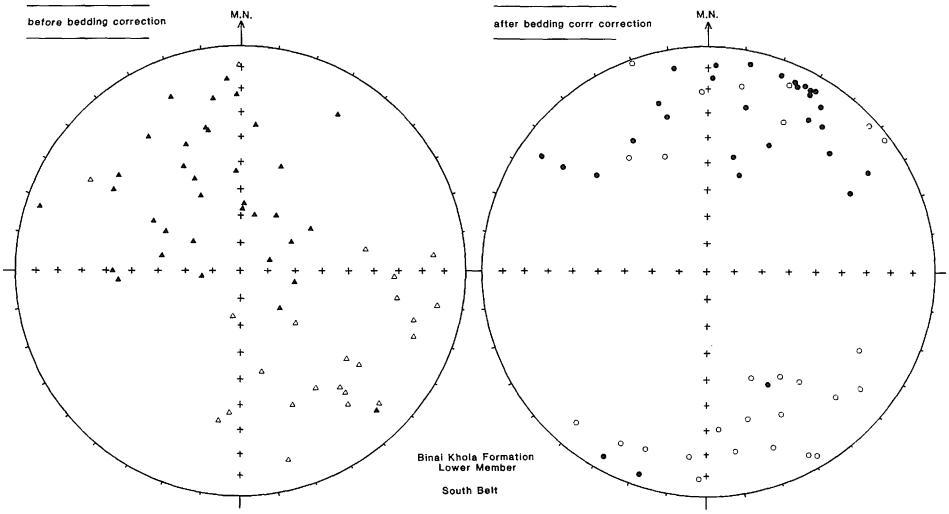
App. II, Fig. 2. The direction of characteristic magnetization of Au Member in the North Belt. Symbols are given in App. II, Fig. 7.



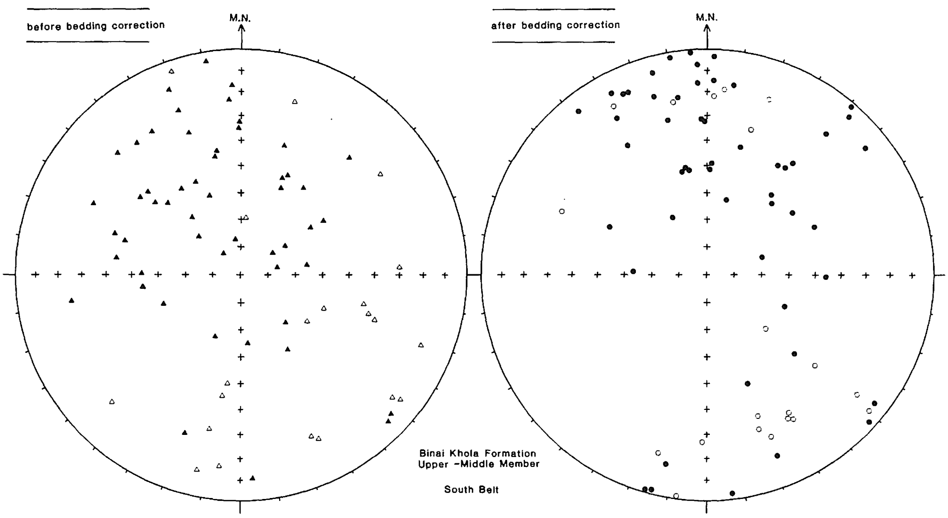
App. II, Fig. 3. The direction of characteristic magnetization of Bl and Bm Members in the North Belt. Symbols are given in App. II, Fig. 7.



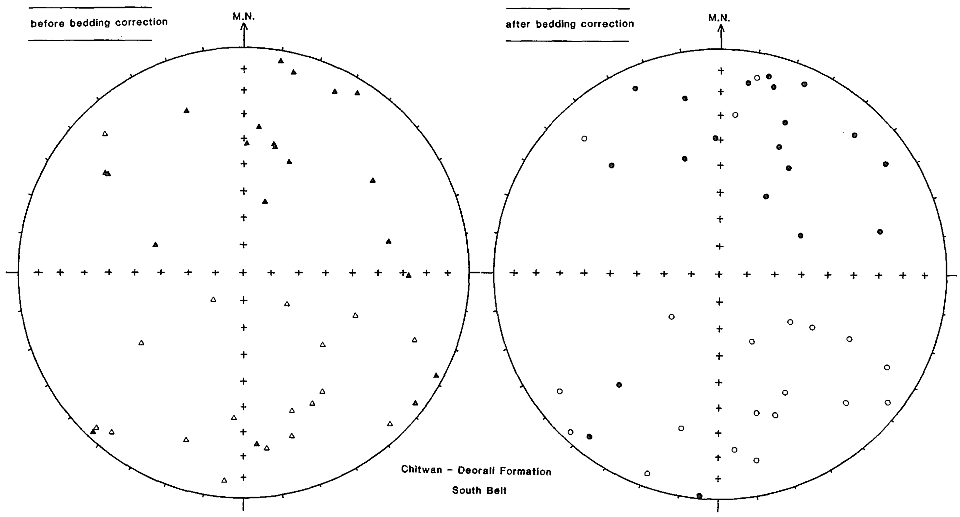
App. II, Fig. 4. The direction of characteristic magnetization of Au Member in the South Belt. Symbols are given in App. II, Fig. 7.



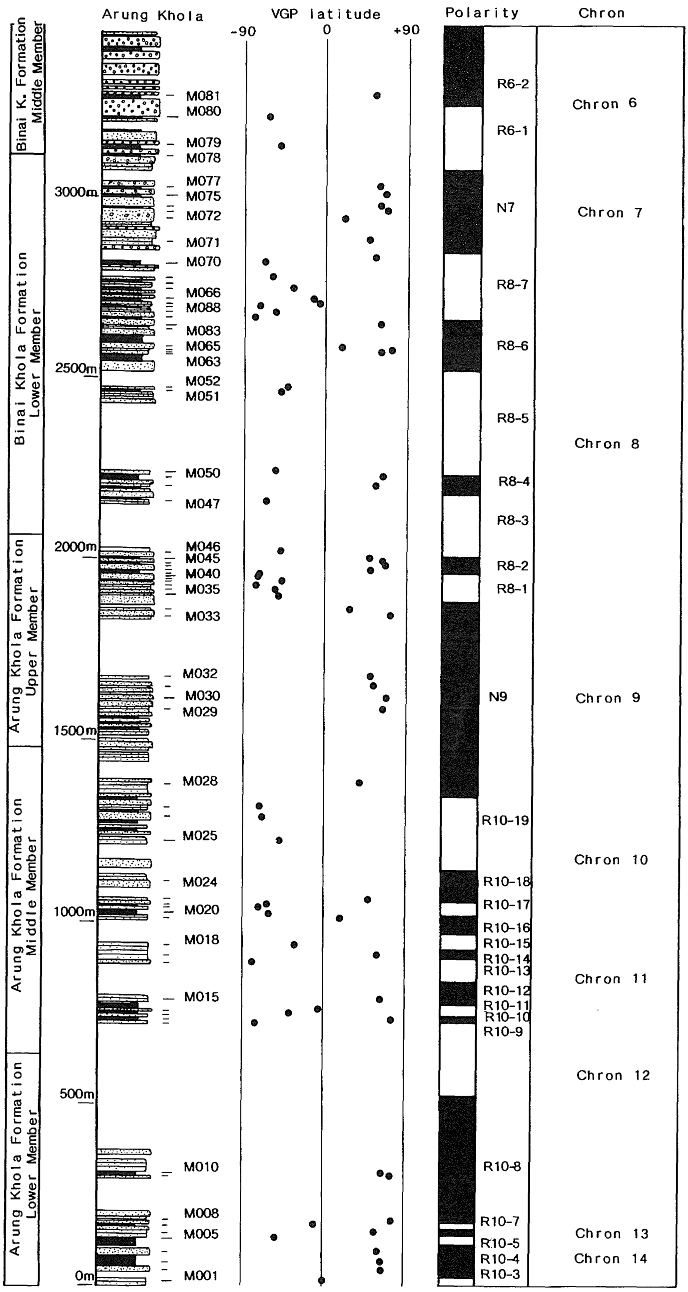
App. II, Fig. 5. The direction of characteristic magnetization of Bl Member in the South Belt. Symbols are given in App. II, Fig. 7.



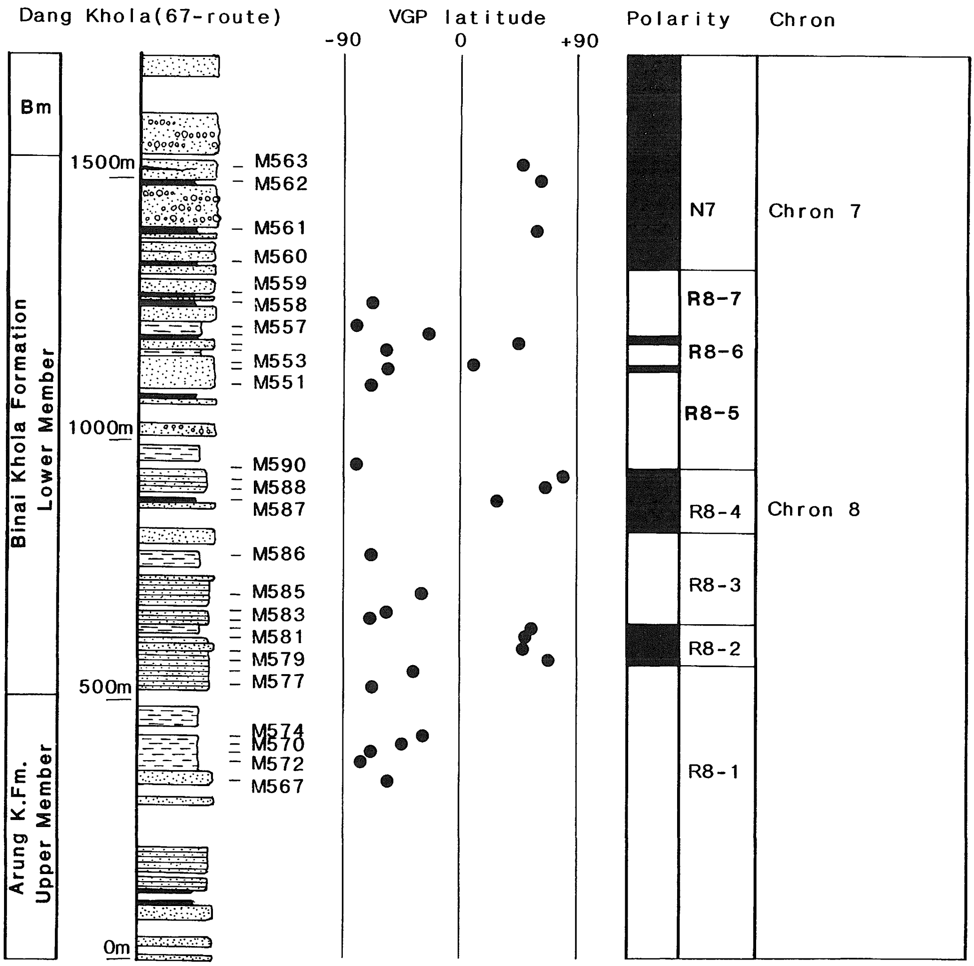
App. II, Fig. 6. The direction of characteristic magnetization of Bm and Bu Members in the South Belt. Symbols are given in App. II, Fig. 7.



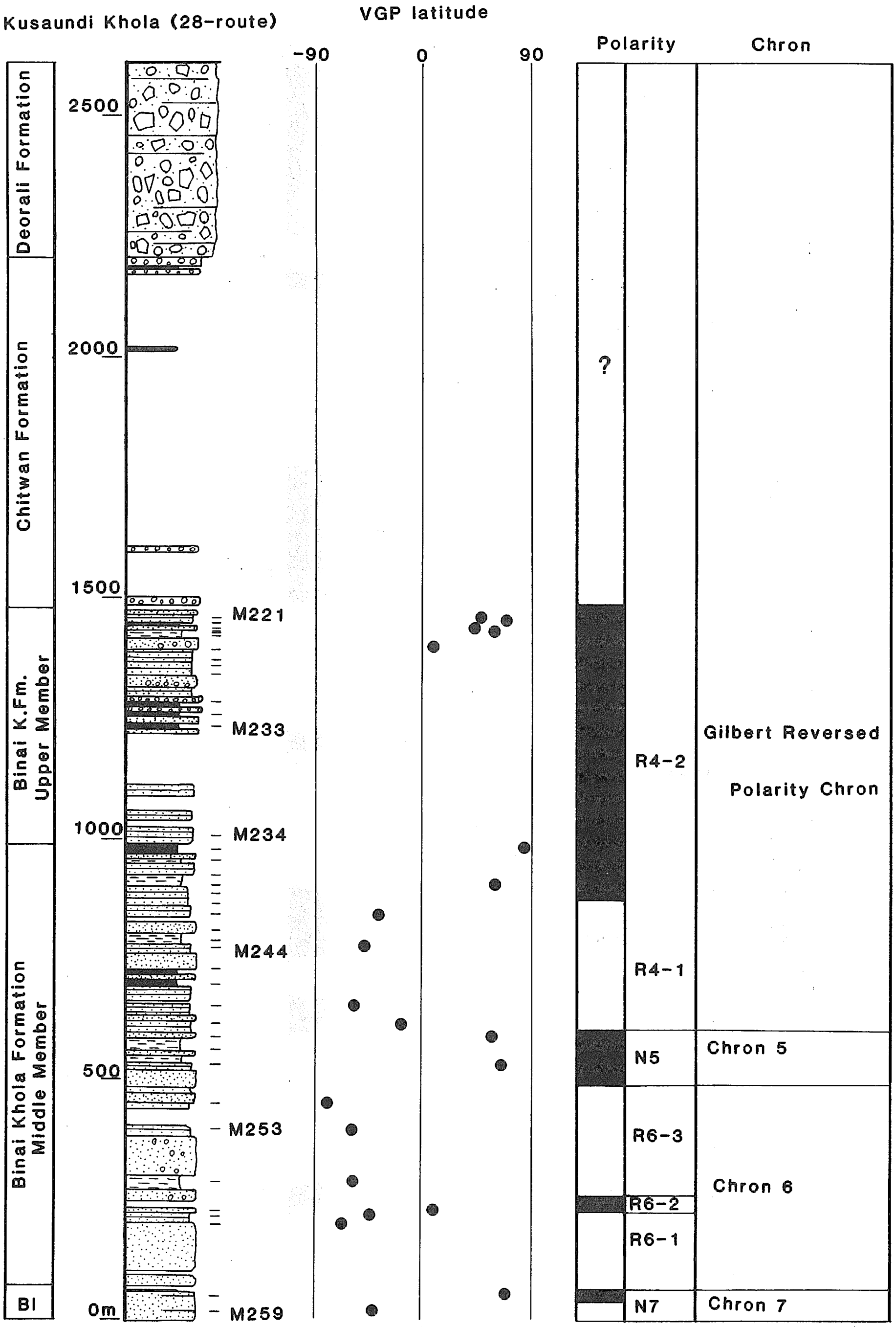
App. II, Fig. 7. The direction of characteristic magnetization of the Chitwan and Deorali Formations on equal area projections. *Triangles* indicate the direction before the bedding correction, *Circles* after the bedding correction, *Closed symbols* mean the projection on the lower hemisphere, *open symbols* on the upper hemisphere.



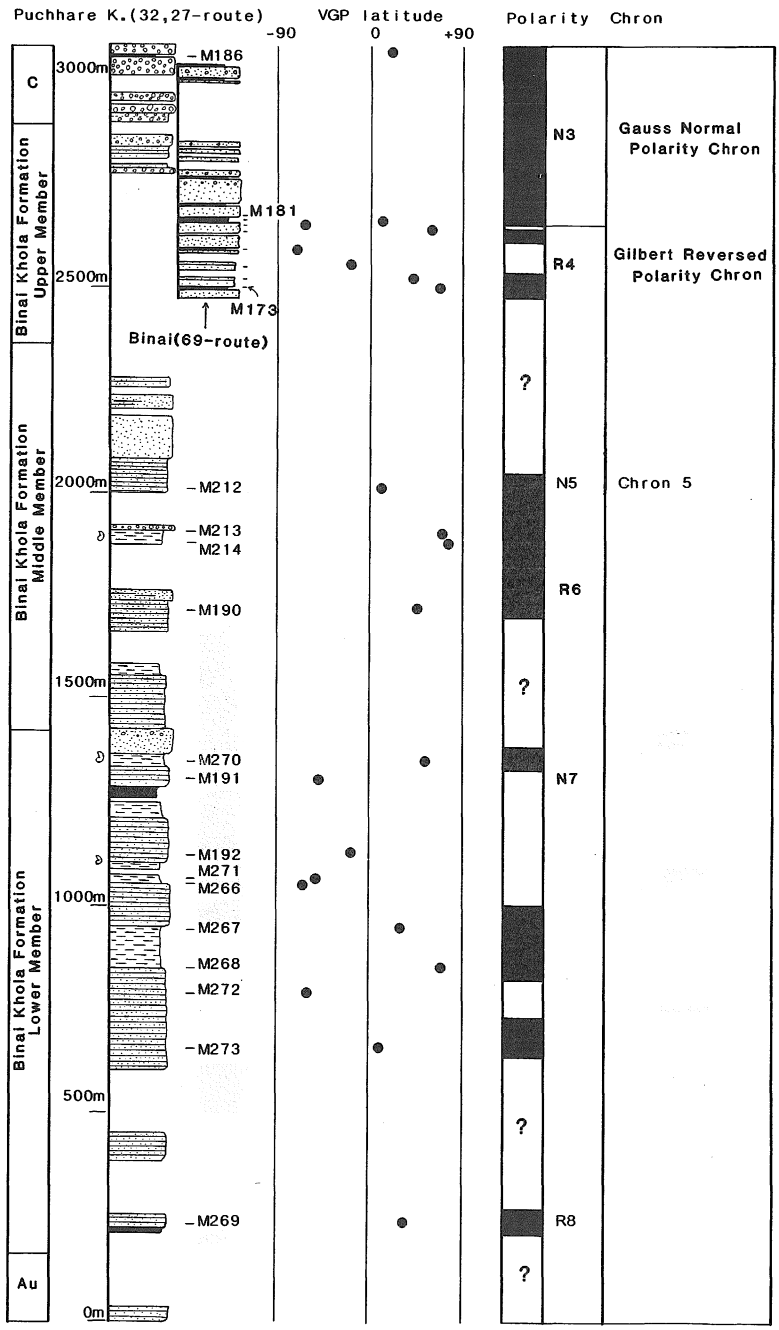
App. II, Fig. 8. Magnetic polarity stratigraphy of the Arung Khola and Binai Khola Formations along the Arung Khola and the Murali Khola. The right column shows estimated correlation with the polarity time scale.



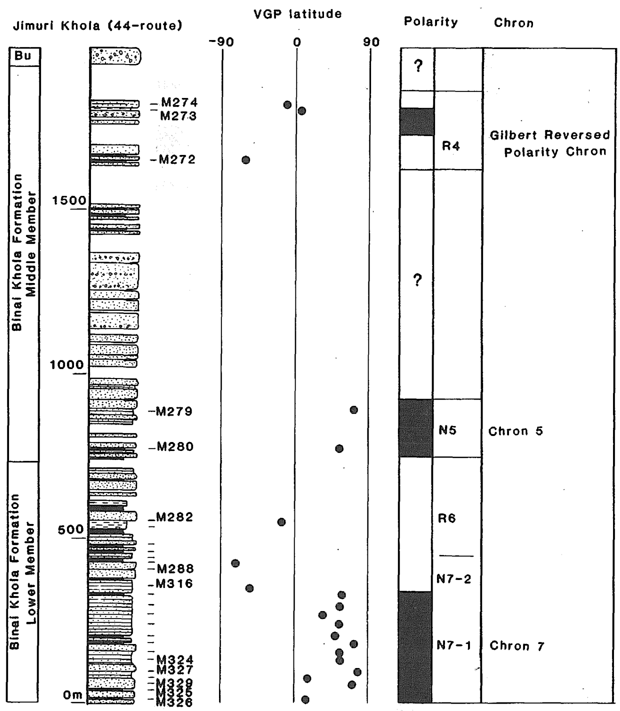
App. II, Fig. 9. Magnetic polarity stratigraphy of the Arung Khola and Binai Khola Formations along the Dang Khola. The right column shows estimated correlation with the polarity time scale.



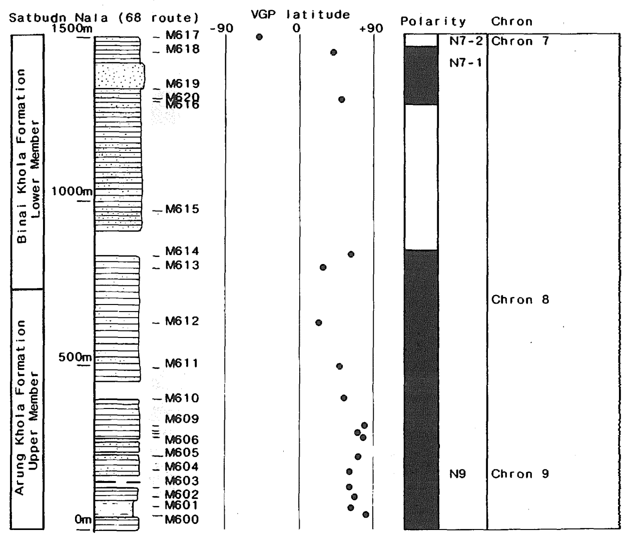
App. II, Fig. 10. Magnetic polarity stratigraphy of the Arung Khola Formation along the Kusaundi Khola. The right column shows estimated correlation with the polarity time scale.



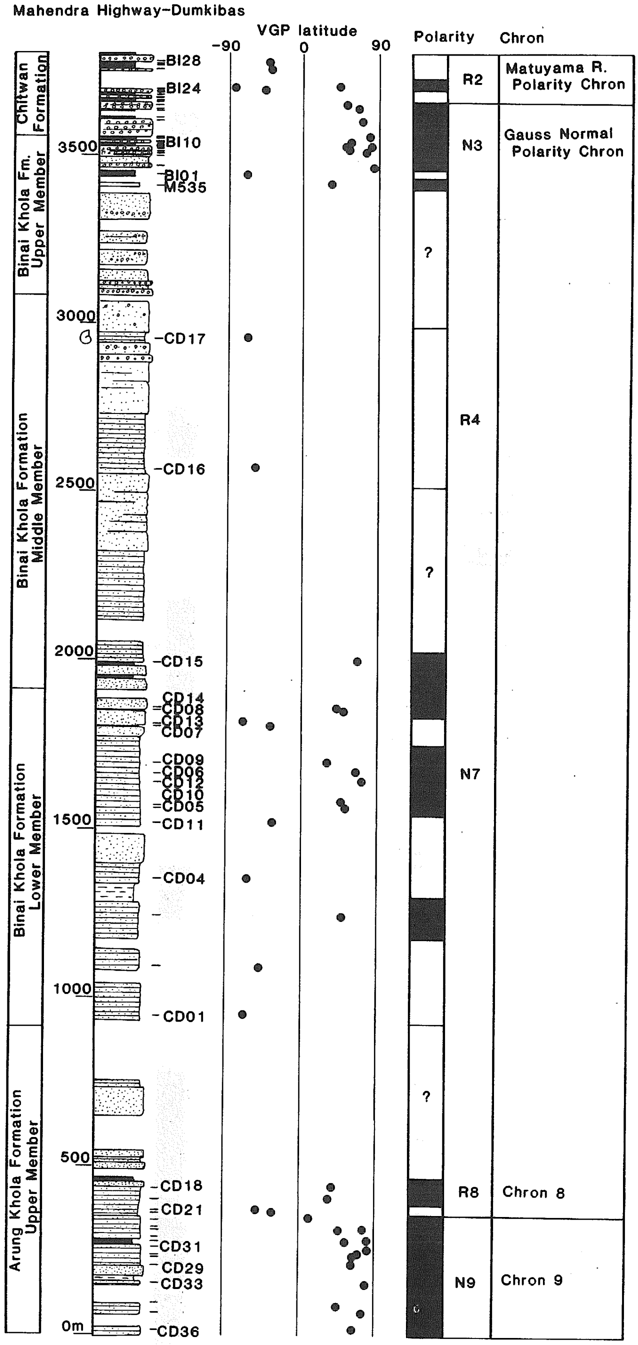
App. II, Fig. 11. Magnetic polarity stratigraphy of the Binai Khola Formation along the Puchhare Khola and its western tributary. The right column shows estimated correlation with the polarity time scale.



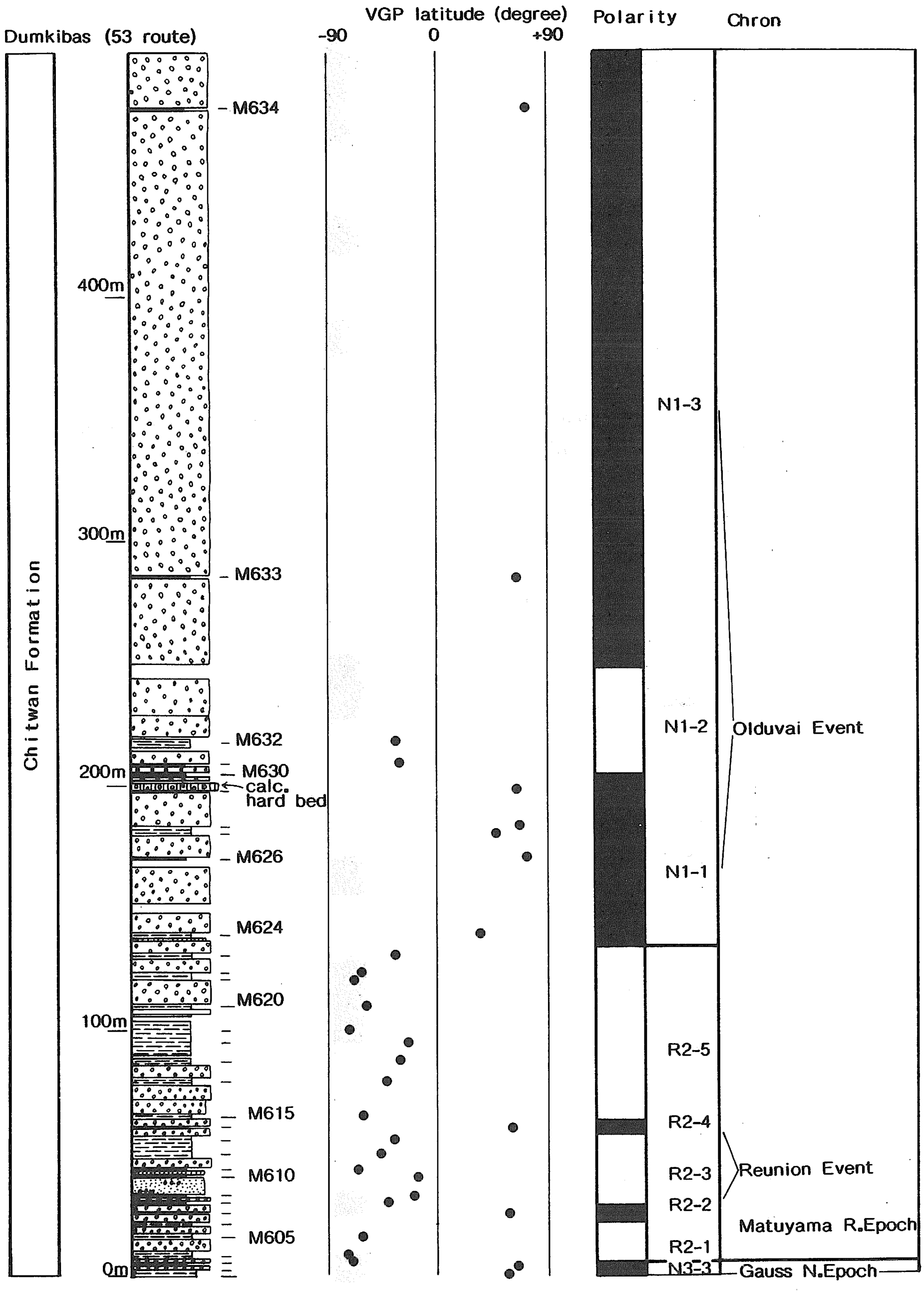
App. II, Fig. 12. Magnetic polarity stratigraphy of the Binai Khola Formation along the Jimuri Khola. The right column shows estimated correlation with the polarity time scale.



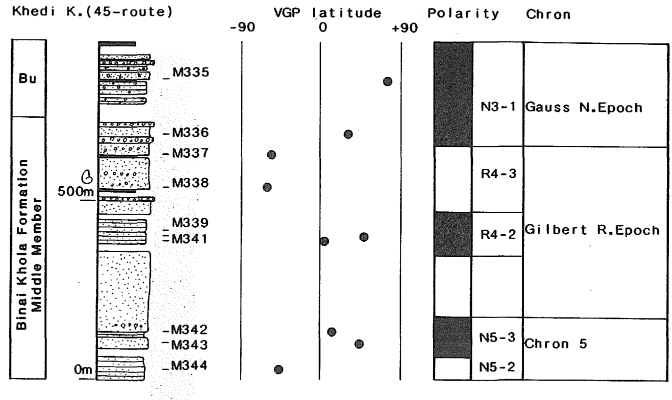
App. II, Fig. 13. Magnetic polarity stratigraphy of Au and Bl Members along the Satbudn Nala, south of the Mahendra Highway. The right column shows estimated correlation with the polarity time scale.



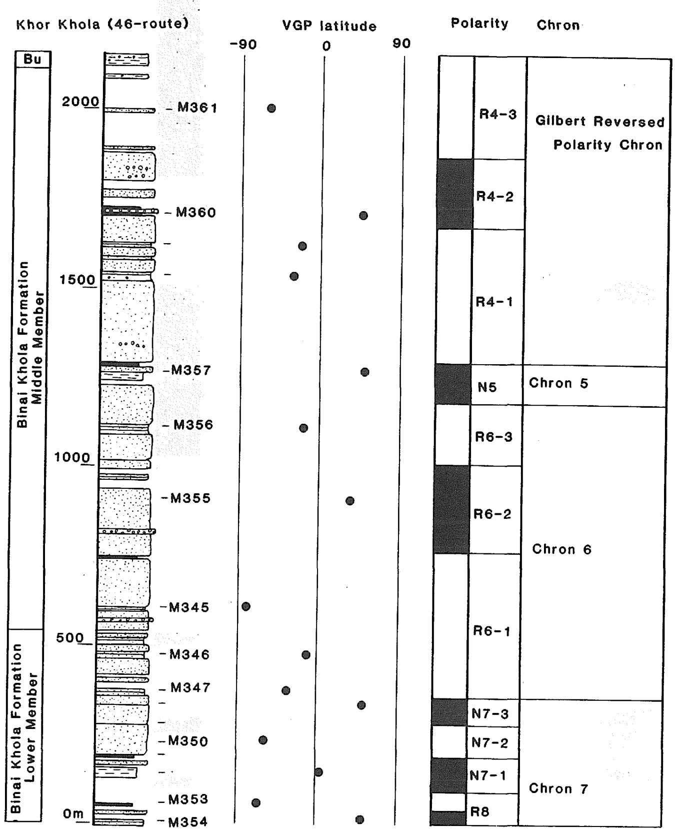
App. II, Fig. 14. Magnetic polarity stratigraphy of the Churia Group succession along the Mahendra Highway. The right column shows estimated correlation with the polarity time scale.



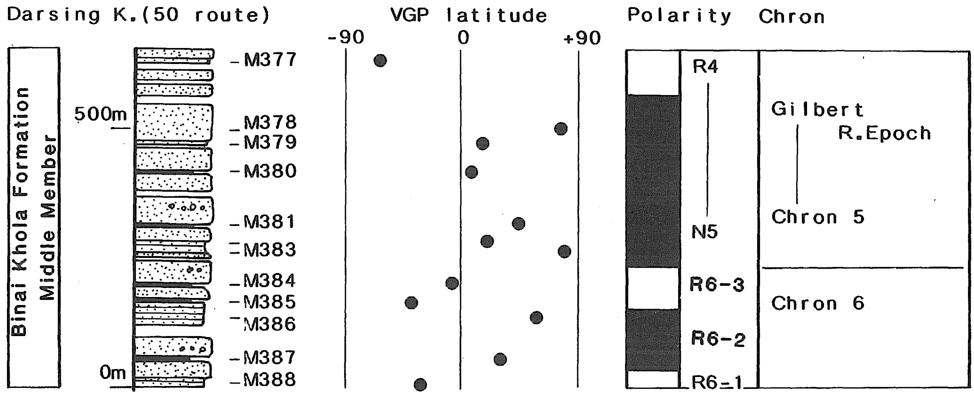
App. II, Fig. 15. Magnetic polarity stratigraphy of the Chitwan Formation along the Binai Khola and its tributary in the vicinity of Dumkibas village. The base of this section can be correlated with the top of the Mahendra Highway section of App. II, Fig. 14. The right column shows estimated correlation with the polarity time scale.



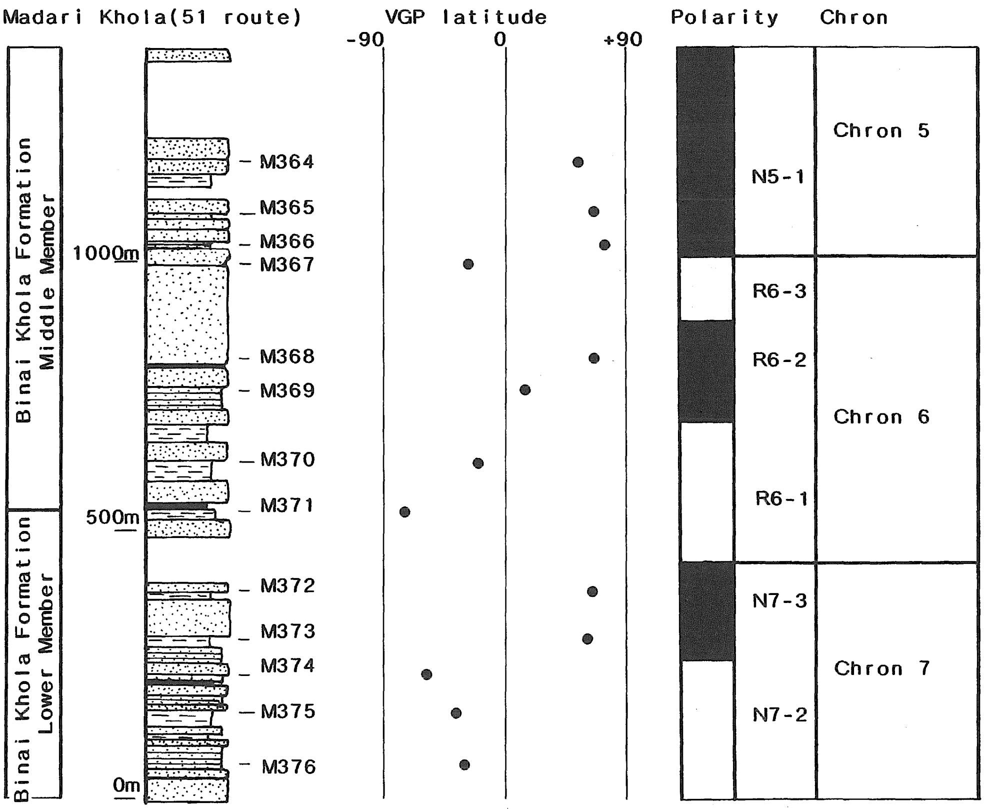
App. II, Fig. 16. Magnetic polarity stratigraphy of the Binai Khola Formation along the Khedi Khola. The right column shows estimated correlation with the polarity time scale.



App. II, Fig. 17. Magnetic polarity stratigraphy of the Binai Khola Formation along the Khor Khola. The right column shows estimated correlation with the polarity time scale.



App. II, Fig. 18. Magnetic polarity stratigraphy of the Binai Khola Formation along the Darsing Khola. The right column shows estimated correlation with the polarity time scale.



App. II, Fig. 19. Magnetic polarity stratigraphy of Binai Khola Formation along the Madari Khola. The right column shows estimated correlation with the polarity time scale.

Appendix III

Table 1

Results of the paleomagnetic measurements (1)

Site No.	NRM Dec.	Inc.	Intensity	Demagnetization Condition	Dec.	Inc.	Intensity	Bedding Corr. Dec.	Inc.	VGP latitude	longitude	Horizon
M001	65	14	8.36E-7	500oe	74	-14	1.05E-6	82	-26	1	190	Al
M002	3	61	6.43E-6	400oe	45	68	7.65E-7	25	35	65	186	Al
M003	19	50	2.61E-6	500oe	21	50	2.45E-6	17	15	64	220	Al
M004	10	41	2.04E-6	500oe	14	38	1.67E-6	20	6	59	220	Al
M005	209	73	1.15E-7	400oe	184	-4	1.15E-7	181	18	-55	83	Al
M006	30	27	1.52E-7	500oe	15	45	5.12E-8	22	2	56	223	Al
M007	134	-52	7.64E-7	500oe	101	22	1.43E-6	98	-15	-10	177	Al
M008	318	55	1.73E-7	400oe	330	57	5.60E-8	14	34	75	208	Al
M009	331	48	1.90E-6	150oe	328	47	1.69E-6	4	19	72	254	Al
M010	283	58	8.99E-7	300oe	271	62	6.17E-7	29	50	65	158	Al
M011	98	-28	1.10E-7	150oe	115	-30	1.00E-7	164	-38	-74	156	Am
M012	308	52	7.43E-6	300oe	306	52	7.38E-6	12	30	74	220	Am
M013	129	19	1.71E-6	400oe	130	10	2.07E-6	129	-10	-36	159	Am
M014	119	43	1.25E-5	500oe	119	43	1.28E-5	96	-1	-5	172	Am
M015	341	32	9.09E-7	500oe	344	46	7.86E-7	7	3	63	247	Am
M016	104	-49	7.76E-7	300oe	110	-50	7.20E-7	172	-35	-79	132	Am
M017	321	32	4.82E-6	500oe	319	32	4.86E-6	338	10	59	310	Am
M018	98	-7	2.04E-6	500oe	99	-8	1.95E-6	117	-36	-32	181	Am
M019	55	17	7.51E-7	500oe	55	20	8.06E-7	57	-31	19	205	Am
M020	354	-77	5.04E-6	300oe	359	-81	4.85E-6	216	-48	-60	340	Am
M021	91	-38	5.31E-6	400oe	84	-57	8.03E-6	161	-39	-73	162	Am
M022	189	-47	5.52E-5	500oe	189	-53	2.97E-5	195	-6	-62	52	Am
M023	181	54	9.63E-8	500oe	233	52	9.94E-8	317	61	51	28	Am
M025	80	-37	3.68E-7	500oe	91	-45	2.87E-7	132	-42	-47	182	Am
M026	145	-57	5.48E-7	150oe	165	-58	6.62E-7	182	-3	-62	81	Am
M027	163	-76	2.77E-6	400oe	165	-75	2.70E-6	183	-17	-71	77	Am
M028	56	38	1.84E-7	400oe	59	46	1.80E-7	43	-5	39	201	Am
M029	244	62	1.52E-5	500oe	249	62	7.19E-6	334	39	65	346	Au
M030	345	62	2.59E-6	300oe	340	62	2.10E-6	356	9	67	276	Au
M031	311	50	8.40E-5	300oe	306	46	5.96E-5	330	13	54	323	Au
M032	286	54	3.52E-7	500oe	299	32	3.11E-7	316	0	51	16	Au
M033	265	86	6.07E-7	500oe	269	58	5.46E-7	342	44	73	350	Au
M034	303	16	6.15E-7	500oe	280	8	6.07E-7	286	1	28	28	Au
M035	359	25	7.08E-7	500oe	110	-31	2.48E-7	140	-19	-49	157	Au
M036	75	-46	8.39E-7	300oe	85	-54	8.85E-7	144	-20	-53	154	Au
M037	58	-64	7.82E-7	150oe	68	-59	6.48E-7	163	-38	-74	157	Au
M038	88	-50	2.20E-6	300oe	85	-46	1.51E-6	136	-25	-47	164	Au
M040	104	-73	8.99E-6	500oe	122	-73	6.55E-6	166	-31	-73	140	Au
M041	86	-70	1.16E-6	500oe	80	-70	8.88E-7	165	-29	-72	137	Au
M042	286	46	2.27E-6	500oe	296	45	2.04E-6	326	8	49	324	Au
M043	331	66	7.77E-6	500oe	302	66	4.87E-6	346	18	67	304	Au
M044	312	59	3.56E-6	500oe	286	61	2.84E-6	340	21	64	316	Au
M045	303	43	1.55E-6	500oe	292	44	1.08E-6	324	17	51	331	Au
M046	340	36	2.45E-7	150oe	301	-53	1.77E-8	226	-36	-47	353	Au
M047	130	-54	2.78E-6	500oe	133	-53	2.49E-6	162	-14	-64	127	Bl
M048	286	39	5.72E-6	500oe	288	42	4.82E-6	332	21	58	327	Bl
M049	316	49	5.15E-6	500oe	319	54	3.55E-6	346	12	65	300	Bl
M050	119	-41	2.82E-6	500oe	118	-42	2.47E-6	150	-9	-54	141	Bl
M051	119	-41	2.45E-6	500oe	119	-40	2.49E-6	143	-7	-48	146	Bl
M052	282	-59	1.16E-6	500oe	284	-56	8.61E-7	231	-20	-40	3	Bl
M053	73	72	3.85E-6	400oe	80	74	3.16E-6	27	17	58	206	Bl
M054	65	-31	1.73E-7	400oe	88	-41	1.08E-7	152	-41	-65	172	Bl
M055	120	-52	2.71E-6	500oe	97	-51	1.25E-6	145	-22	-54	155	Bl
M056	118	-51	9.72E-7	400oe	80	-71	3.46E-7	169	-38	-78	149	Bl
M057	119	-45	6.86E-6	500oe	122	-45	5.55E-6	159	-10	-61	130	Bl

Table 1 (*continued*)

Results of the paleomagnetic measurements (2)

Site No.	NRM Dec.	Inc.	Intensity	Demagnetization Condition	Dec.	Inc.	Intensity	Bedding Corr. Dec.	Inc.	VGP latitude	longitude	Horizon
M058	110	-44	7.85E-6	400oe	109	-44	5.33E-6	145	-24	-55	157	Bl
M059	126	-37	3.36E-6	500oe	127	-38	1.45E-6	147	-10	-52	144	Bl
M060	319	47	8.84E-7	500oe	316	43	6.31E-7	333	1	52	312	Bl
M061	327	41	8.26E-6	500oe	321	42	4.95E-6	335	3	54	310	Bl
M062	336	65	4.39E-6	500oe	343	68	2.59E-6	0	10	67	196	Bl
M065	102	-42	2.12E-7	500oe	58	17	2.48E-7	59	-22	21	199	Bl
M066	113	-42	8.61E-6	500oe	112	-43	6.23E-6	141	-11	-48	151	Bl
M067	41	-37	2.44E-7	500oe	81	-41	2.07E-7	119	-41	-35	185	Bl
M069	158	-35	3.51E-6	500oe	160	-43	2.61E-6	166	6	-58	112	Bl
M070	65	-59	1.07E-5	200oe	59	-61	9.93E-6	151	-51	-65	193	Bl
M071	300	49	1.69E-5	200oe	296	51	1.41E-5	331	26	59	332	Bl
M072	281	56	2.58E-6	200oe	31	10	2.27E-6	41	-43	24	222	Bl
M073	286	61	1.16E-7	200oe	293	73	1.40E-7	345	27	70	313	Bl
M074	258	66	1.38E-6	200oe	260	60	1.38E-6	331	36	62	344	Bl
M075	277	66	2.59E-6	200oe	268	65	2.47E-6	337	40	68	345	Bl
M077	94	30	1.82E-5	200oe	282	52	1.42E-5	335	23	61	325	Bl
M079	141	-36	1.07E-5	200oe	141	-29	7.42E-6	150	8	-48	132	Bm
M080	111	-48	3.82E-6	200oe	111	-49	3.12E-6	155	-22	-62	145	Bm
M081	336	-50	3.02E-7	500oe	22	56	1.10E-6	18	1	58	227	Bm
M082	291	70	7.00E-6	400oe	288	70	6.65E-6	349	32	76	315	Bl
M084	44	-49	2.48E-7	400oe	14	70	9.79E-8	17	13	64	221	Bl
M085	102	-82	7.25E-6	400oe	128	-78	6.43E-6	185	-26	-77	62	Bl
M086	113	-42	3.18E-6	500oe	115	-39	2.96E-6	146	-15	-53	150	Bl
M087	153	-63	1.48E-5	500oe	163	-64	1.07E-5	181	-12	-71	81	Bl
M088	153	-44	1.28E-7	400oe	124	61	8.18E-8	89	-18	-4	182	Bl
M089	6	-20	2.42E-7	300oe	14	10	1.38E-7	29	-69	7	246	Bl
M091	244	-57	1.93E-6	300oe	241	-64	1.90E-6	206	4	-53	38	Bl
M092	95	-62	2.51E-7	300oe	76	-64	1.12E-7	158	-22	-65	143	Bl
M094	273	49	3.17E-6	300oe	271	52	2.75E-6	314	19	43	342	Bl
M095	101	0	5.29E-7	300oe	87	25	6.01E-7	73	1	15	181	Bl
M096	347	73	1.00E-6	300oe	34	89	5.58E-7	10	34	78	210	Bl
M097	272	42	1.10E-6	300oe	280	47	6.00E-7	321	20	49	338	Bl
M098	288	61	4.15E-6	300oe	273	62	4.70E-6	339	25	66	324	Bl
M099	315	85	1.42E-6	300oe	79	70	1.67E-6	29	16	57	201	Bl
M101	311	74	2.71E-6	300oe	293	72	2.39E-6	345	30	72	321	Bl
M102	251	-33	1.20E-6	300oe	251	-48	2.71E-7	218	-20	-51	10	Bl
M103	0	73	5.66E-6	300oe	19	77	4.10E-6	356	18	72	277	Bm
M104	181	-75	2.28E-6	400oe	161	-72	2.18E-6	173	-23	-75	110	Au
M105	47	-60	1.45E-6	400oe	48	-63	1.51E-6	145	-54	-59	198	Au
M106	162	-32	1.64E-7	400oe	127	-34	1.00E-7	129	30	-25	139	Au
M108	287	40	1.04E-6	400oe	145	76	6.99E-7	20	24	66	205	Au
M110	61	-29	6.68E-7	400oe	60	-31	7.16E-7	113	-15	-24	170	Au
M111	330	47	3.17E-6	400oe	330	47	3.05E-6	334	-34	38	296	Au
M112	10	65	4.86E-6	400oe	11	65	4.87E-6	358	6	66	269	Au
M114	200	-67	2.73E-6	400oe	199	-63	2.55E-6	196	-4	-62	48	Au
M115	117	-45	9.05E-7	400oe	127	-37	6.93E-7	139	-9	-46	156	Au
M116	0	6	7.65E-8	300oe	39	7	9.30E-8	52	-54	11	222	Au
M117	353	65	2.94E-6	400oe	346	68	2.59E-6	1	-1	63	261	Au
M118	240	66	3.29E-6	400oe	210	81	1.73E-6	23	38	68	181	Au
M119	311	67	3.71E-6	400oe	263	72	2.26E-6	330	42	62	-4	Au
M120	358	53	8.34E-5	400oe	356	52	2.92E-5	3	3	65	256	Au
M121	202	85	6.38E-7	400oe	137	74	4.87E-7	353	28	77	295	Au
M122	260	74	8.83E-6	400oe	239	70	6.49E-6	345	50	75	17	Au
M123	31	27	9.95E-7	400oe	68	58	5.17E-7	11	36	78	202	Au
M124	11	-77	7.96E-8	400oe	83	29	5.35E-8	45	4	40	195	Au

Table 1 (*continued*)

Results of the paleomagnetic measurements (3)

	NRM			Demagnetization				Bedding Corr.				
Site No.	Dec.	Inc.	Intensity	Condition	Dec.	Inc.	Intensity	Dec.	Inc.	latitude	longitude	Horizon
M125	125	16	3.81E-7	300oe	142	46	1.73E-7	35	62	56	133	Au
M127	141	62	9.55E-5	300oe	176	38	7.58E-5	121	86	21	91	Bl
M128	307	6	6.67E-7	280oe	285	68	8.15E-7	337	17	62	319	Bl
M129	351	-80	3.10E-6	300oe	196	-52	2.70E-6	184	8	-60	76	Bl
M130	117	-4	2.90E-7	300oe	80	10	5.36E-7	71	5	18	180	Bl
M131	4	55	2.26E-6	300oe	349	54	1.54E-6	358	-4	61	268	Bl
M132	241	-88	5.18E-7	300oe	163	-74	4.32E-7	182	-14	-72	77	Au
M133	87	-50	3.61E-7	300oe	81	14	4.66E-7	80	-14	5	184	Au
M135	357	-51	2.96E-7	300oe	108	-55	1.40E-7	155	-17	-61	142	Au
M136	291	65	2.73E-6	300oe	315	54	1.63E-6	334	9	57	317	Au
M137	116	-69	7.05E-7	300oe	153	-62	7.47E-7	175	-16	-72	99	Au
M138	51	69	1.18E-6	300oe	51	74	5.06E-7	356	5	66	273	Au
M139	31	50	1.17E-6	300oe	339	63	1.67E-6	352	19	72	290	Am
M141	171	10	2.37E-5	300oe	175	25	1.61E-5	175	30	-48	91	D
M142	169	-20	4.12E-8	300oe	5	-31	2.54E-8	25	-81	-10	256	Al
M143	178	15	2.67E-7	300oe	218	-47	7.44E-8	217	-28	-54	4	Al
M144	188	11	1.31E-7	300oe	67	25	9.38E-8	52	25	39	178	Al
M145	163	56	1.21E-7	300oe	65	49	4.78E-8	48	41	46	166	Al
M147	343	17	2.02E-7	300oe	351	73	3.30E-8	333	26	61	333	Al
M148	313	43	1.31E-6	300oe	320	35	1.37E-6	332	7	54	318	Al
M149	350	39	2.25E-6	300oe	330	40	1.70E-6	339	15	62	315	Al
M150	313	37	3.88E-7	300oe	217	-47	3.52E-7	206	-15	-60	25	Am
M151	239	39	2.67E-6	300oe	240	44	2.54E-6	270	51	13	23	Am
M152	293	69	8.09E-6	300oe	290	72	8.30E-6	345	43	76	353	Am
M154	60	12	1.02E-6	300oe	78	34	1.31E-6	75	27	19	167	C
M155	333	-11	3.20E-6	300oe	315	-15	2.40E-6	315	-15	34	323	C
M156	169	-37	7.51E-7	300oe	171	-41	6.86E-7	178	15	-57	87	Al
M157	153	-23	2.67E-7	300oe	113	-52	2.33E-7	150	-49	-64	189	Al
M158	54	7	2.16E-7	300oe	155	-41	1.23E-7	168	-30	-76	134	Al
M159	182	-28	2.97E-7	300oe	167	-27	1.86E-7	175	-14	-71	99	Al
M160	98	59	2.12E-7	300oe	68	71	1.51E-7	124	55	-9	127	Al
M161	157	-15	1.06E-6	300oe	160	-37	1.32E-6	169	-27	-75	127	Al
M162	187	20	2.00E-6	300oe	186	16	1.71E-6	178	30	-48	86	Al
M163	347	-10	1.80E-5	300oe	89	72	4.88E-6	65	57	34	144	C
M164	301	51	4.38E-6	300oe	252	58	1.44E-6	277	53	19	22	C
M167	14	30	3.95E-6	300oe	7	35	1.54E-6	8	15	70	240	D
M168	306	29	5.56E-7	300oe	118	2	9.05E-7	119	-15	-30	167	C
M169	34	42	2.20E-7	300oe	18	63	2.40E-7	32	57	60	142	C
M170	114	-23	1.19E-6	300oe	96	24	1.06E-6	91	3	-1	172	Bu
M171	129	-6	1.05E-6	300oe	173	65	5.16E-7	112	59	129	39	Bu
M172	29	-33	6.92E-7	300oe	63	-27	3.79E-7	64	-57	2	218	Bu
M173	268	62	5.34E-7	300oe	37	51	6.64E-7	15	62	68	115	Bu
M174	144	49	1.38E-7	300oe	56	59	2.29E-7	55	51	41	153	Bu
M175	206	64	3.91E-7	300oe	147	57	3.61E-7	132	46	-20	128	Bu
M176	191	36	1.24E-6	300oe	153	-20	1.00E-6	160	-33	-70	154	Bu
M177	10	11	5.80E-7	300oe	19	40	3.41E-7	33	42	60	170	Bu
M178	180	-12	1.55E-6	300oe	176	11	1.04E-6	173	2	-63	99	Bu
M179	326	29	6.21E-7	300oe	305	-5	3.83E-7	304	-6	28	334	C
M180	69	70	2.05E-6	300oe	81	65	1.88E-6	91	46	10	148	Bu
M184	66	52	1.48E-7	300oe	43	30	1.26E-7	42	7	43	196	Bu
M185	144	39	1.09E-5	300oe	143	40	4.36E-6	98	35	1	153	Bm
M186	67	34	3.80E-7	300oe	62	5	2.87E-7	61	-10	23	192	C
M190	300	25	2.52E-5	300oe	296	28	9.32E-6	322	9	47	329	Bm
M191	84	-35	7.22E-6	300oe	85	-16	4.85E-6	140	-36	-53	173	Bl
M192	37	-6	7.78E-7	300oe	65	-4	6.09E-7	98	-48	-19	197	Bl

Table 1 (*continued*)

Results of the paleomagnetic mesurements (4)

Site No.	NRM Dec.	Inc.	Intensity	Demagnetization Condition	Dec.	Inc.	Intensity	Bedding Corr. Dec.	Inc.	VGP latitude	longitude	Horizon
M193	346	75	1.44E-6	300oe	339	73	1.54E-6	343	19	67	311	Al
M194	206	-62	5.07E-8	300oe	315	-33	1.12E-7	268	-50	-15	326	Al
M195	306	61	6.11E-7	300oe	338	74	7.36E-7	350	19	71	296	Al
M196	273	21	7.54E-7	300oe	275	15	9.35E-7	285	4	14	349	Al
M197	94	-68	1.32E-5	300oe	96	-70	1.39E-5	156	-31	-66	156	Al
M199	315	63	3.60E-7	300oe	94	37	1.37E-7	55	31	38	172	Am
M200	184	-42	1.32E-7	300oe	209	-75	1.35E-7	183	-30	-80	67	Am
M201	288	-58	4.53E-7	300oe	256	-51	4.23E-7	221	-6	-45	17	Am
M202	170	5	3.21E-7	300oe	175	-29	1.77E-7	175	6	-61	94	Am
M203	359	67	5.16E-7	300oe	299	31	4.82E-7	311	-1	35	332	Am
M204	87	43	3.74E-7	300oe	140	20	7.13E-7	115	50	-6	135	Am
M205	31	-19	1.21E-5	300oe	35	-23	1.03E-5	31	8	53	205	Am
M206	180	-62	4.04E-6	300oe	186	-60	2.73E-6	177	-1	-65	90	Am
M207	125	31	1.00E-5	300oe	206	60	1.05E-6	3	79	47	85	Am
M212	357	-12	6.27E-7	300oe	347	-30	1.78E-7	296	-45	8	318	Bm
M213	320	43	1.28E-5	300oe	310	49	5.37E-6	2	15	71	257	Bm
M214	286	67	5.88E-7	300oe	263	54	3.16E-7	15	41	76	181	Bm
M221	350	-17	1.37E-7	300oe	348	46	7.28E-8	349	-24	49	280	Bu
M222	224	-24	5.83E-8	300oe	79	76	9.28E-8	9	17	70	236	Bu
M224	9	16	3.48E-7	300oe	18	21	1.96E-7	17	-34	42	241	Bu
M225	312	34	3.26E-7	300oe	278	44	2.09E-7	328	34	59	346	Bu
M227	88	-35	5.48E-7	300oe	103	14	2.57E-7	88	25	7	163	Bu
M235	247	59	7.13E-7	300oe	202	66	7.50E-7	2	49	85	107	Bm
M238	314	40	2.04E-6	300oe	308	43	1.41E-6	335	13	59	319	Bm
M241	166	-51	9.68E-6	300oe	128	-14	6.00E-6	132	3	-37	150	Bm
M244	148	-16	4.20E-6	300oe	156	-23	3.69E-6	158	15	-51	119	Bm
M247	133	-55	9.00E-7	300oe	106	-40	7.17E-7	150	-28	-60	158	Bm
M248	88	-1	3.01E-7	300oe	75	-9	4.41E-7	102	-42	-21	191	Bm
M249	315	56	1.95E-6	300oe	289	41	1.36E-6	330	21	57	331	Bm
M251	339	48	1.24E-6	300oe	334	52	1.31E-6	356	1	64	273	Bm
M252	116	-51	1.66E-5	300oe	124	-60	3.68E-6	182	-27	-79	74	Bm
M253	174	-57	2.35E-5	300oe	187	-50	1.06E-5	195	2	-60	53	Bm
M254	87	-42	1.53E-6	300oe	103	-43	1.42E-6	149	-30	-60	161	Bm
M255	159	46	5.87E-7	300oe	109	39	1.76E-6	81	11	10	172	Bm
M256	84	-41	1.88E-6	300oe	87	-30	1.01E-6	130	-38	-45	179	Bm
M257	100	-55	2.50E-6	300oe	111	-57	2.12E-6	161	-29	-70	147	Bm
M258	335	64	1.73E-5	300oe	332	59	1.12E-5	2	10	68	258	Bl
M259	114	-40	2.83E-5	300oe	100	-30	1.59E-5	134	-21	-45	165	Bl
M260	110	-51	2.48E-6	300oe	111	-14	1.74E-6	128	-15	-38	163	Bm
M261	108	-30	7.48E-8	300oe	184	4	6.15E-8	183	43	-39	80	Al
M262	142	-51	2.90E-6	300oe	145	-55	3.04E-6	162	-15	-65	130	Al
M263	338	-78	7.87E-7	300oe	353	-78	7.60E-7	183	-62	-73	271	Al
M264	295	56	2.60E-6	300oe	295	61	2.64E-6	337	43	69	-4	Al
M265	281	69	1.68E-6	300oe	267	66	1.48E-6	336	57	66	29	Am
M266	101	-46	1.13E-6	300oe	128	-33	9.63E-7	159	-17	-64	136	Bl
M267	319	31	7.52E-7	300oe	338	19	1.21E-6	325	-39	31	302	Bl
M268	263	49	1.29E-6	300oe	266	45	1.08E-6	343	24	69	317	Bl
M269	10	32	2.03E-7	300oe	359	-10	1.65E-7	339	-45	33	286	Bl
M270	334	55	1.09E-5	300oe	69	79	8.51E-6	34	21	54	192	Bl
M271	136	-20	1.26E-5	300oe	133	-15	6.92E-6	149	-5	-53	140	Bl
M272	108	-24	1.12E-5	300oe	106	-21	9.15E-6	152	-29	-62	157	Bl
M273	85	43	4.42E-7	300oe	112	50	7.88E-7	83	-1	6	177	Bl
M274	64	-4	2.28E-7	300oe	101	10	2.05E-7	100	-3	-10	170	Bu
M275	358	3	4.99E-7	300oe	339	14	1.91E-7	345	9	64	300	Bu
M276	11	46	1.81E-7	300oe	7	69	2.16E-7	38	38	55	173	Bu

Table 1 (*continued*)

Results of the paleomagnetic measurements (5)

	NRM			Demagnetization				Bedding Corr.		VGP		
Site No.	Dec.	Inc.	Intensity	Condition	Dec.	Inc.	Intensity	Dec.	Inc.	latitude	longitude	Horizon
M277	329	38	2.83E-7	300oe	320	63	2.64E-7	2	52	83	98	Bu
M279	230	20	2.08E-6	300oe	340	33	1.83E-6	357	16	71	273	Bm
M280	346	24	3.84E-7	300oe	359	32	1.23E-7	2	-22	52	260	Bm
M282	292	-27	3.34E-6	300oe	122	28	1.32E-6	107	-1	-16	166	Bl
M287	145	-27	1.73E-5	300oe	139	-32	1.25E-5	171	-20	-73	114	Bl
M296	296	56	7.75E-6	300oe	282	61	6.23E-6	18	53	72	143	Bl
M304	293	14	8.19E-6	300oe	288	7	4.88E-6	305	11	33	342	Bl
M307	7	44	7.98E-7	300oe	37	63	3.56E-7	28	49	65	158	Bm
M313	9	62	1.24E-6	300oe	100	70	2.60E-6	58	18	32	179	Bl
M314	30	36	5.83E-7	300oe	21	49	7.16E-7	24	-11	50	224	Bl
M316	150	-66	1.74E-6	300oe	134	-29	9.63E-7	151	-7	-55	139	Bl
M317	336	50	2.99E-6	300oe	2	65	2.20E-6	21	8	60	218	Bl
M318	308	36	4.53E-6	300oe	33	66	3.13E-6	26	10	57	209	Bl
M319	339	24	1.50E-6	300oe	59	60	1.13E-6	48	-4	35	197	Bl
M320	326	48	1.03E-6	300oe	1	67	9.01E-7	25	9	57	211	Bl
M321	338	34	2.97E-6	300oe	358	23	1.82E-6	358	-23	51	267	Bl
M322	318	55	8.05E-6	300oe	302	70	4.24E-6	13	27	73	215	Bl
M323	357	60	1.43E-5	300oe	14	69	6.17E-6	28	8	55	208	Bl
M324	323	20	7.12E-6	300oe	325	29	3.05E-6	340	-2	56	302	Bl
M326	66	-7	2.27E-7	300oe	163	43	1.12E-6	91	54	13	141	Bl
M327	355	79	2.50E-6	300oe	264	76	2.59E-6	13	47	78	160	Bl
M328	291	41	6.18E-7	300oe	105	46	6.60E-7	75	18	17	172	Bl
M329	312	55	1.21E-5	300oe	300	53	7.84E-6	345	30	72	321	Bl
M330	356	19	1.51E-7	300oe	181	53	4.03E-7	74	42	23	157	Bl
M331	134	-9	8.75E-7	300oe	135	13	1.00E-6	126	1	-32	155	Bl
M332	283	57	8.78E-7	300oe	298	59	1.31E-6	26	38	65	179	Bl
M333	187	-32	5.95E-6	300oe	188	-33	4.18E-6	198	5	-57	49	Bl
M334	71	17	2.31E-7	300oe	135	52	2.60E-7	94	23	1	161	Bl
M335	344	78	1.62E-6	300oe	313	70	9.67E-7	351	22	73	295	Bu
M336	135	52	4.23E-7	300oe	135	66	4.23E-7	66	47	31	155	Bm
M337	176	-41	1.31E-6	300oe	191	-31	8.97E-7	192	15	-55	63	Bm
M338	202	-52	2.00E-5	300oe	188	-45	1.26E-5	196	1	-60	51	Bm
M340	311	74	2.79E-7	300oe	23	51	1.13E-7	20	-19	49	232	Bm
M341	339	31	8.34E-8	300oe	112	34	1.29E-7	88	9	3	170	Bm
M342	19	-16	4.55E-7	300oe	328	-26	3.87E-7	294	-30	13	328	Bm
M343	142	67	5.77E-7	300oe	56	71	3.05E-7	41	2	43	199	Bm
M344	21	13	2.31E-7	300oe	54	-25	1.91E-7	132	-61	-48	208	Bm
M345	151	-72	1.21E-6	300oe	134	-62	5.69E-7	176	-30	-80	105	Bl
M346	46	-13	4.13E-7	300oe	196	5	5.03E-7	179	69	-12	84	Bl
M347	167	-62	6.18E-7	300oe	166	-14	3.94E-7	151	42	-33	115	Bl
M348	4	65	4.65E-7	300oe	61	69	8.12E-7	30	9	54	205	Bl
M350	346	4	1.14E-6	300oe	189	-73	1.40E-6	206	-15	-60	25	Bl
M352	58	-6	1.49E-6	300oe	129	31	2.99E-6	88	7	3	171	Bl
M353	101	-20	9.17E-7	300oe	80	-44	9.59E-7	157	-47	-70	185	Bl
M354	125	-54	3.86E-7	300oe	6	35	3.20E-7	11	-18	53	245	Bl
M355	24	73	4.88E-6	300oe	55	76	3.56E-6	51	11	37	187	Bm
M356	41	19	7.20E-7	300oe	69	3	4.78E-7	94	-54	-18	204	Bm
M357	357	-2	2.20E-7	300oe	359	35	5.29E-8	5	-19	53	255	Bm
M358	118	-19	8.02E-7	300oe	134	8	4.60E-7	127	7	-31	152	Bm
M359	66	11	3.86E-7	300oe	72	-7	2.60E-7	101	-54	-23	202	Bm
M360	326	80	3.78E-6	300oe	324	80	3.32E-6	40	20	49	189	Bm
M361	135	20	1.80E-7	300oe	108	-37	2.53E-7	149	-27	-59	158	Bm
M362	335	19	7.61E-7	300oe	339	23	6.15E-7	336	13	59	317	Bm
M363	197	31	2.11E-7	300oe	235	32	9.58E-7	236	32	-21	26	Bm
M364	327	28	2.45E-7	300oe	315	24	3.65E-6	332	10	55	320	Bm

Table 1 (*continued*)

Results of the paleomagnetic measurements (6)

Site No.	NRM Dec.	Inc.	Intensity	Demagnetization Condition	Dec.	Inc.	Intensity	Bedding Corr. Dec.	Inc.	VGP latitude	longitude	Horizon
M365	350	44	1.74E-6	300oe	349	43	1.83E-6	2	3	65	259	Bm
M366	23	54	7.83E-7	300oe	56	54	7.15E-7	346	30	73	319	Bm
M367	106	-23	2.99E-6	300oe	88	-11	1.98E-6	110	-44	-28	190	Bm
M368	308	38	5.32E-6	300oe	312	44	3.80E-6	344	19	67	309	Bm
M369	124	-52	1.05E-6	300oe	45	1	7.04E-7	51	-53	13	222	Bm
M370	240	-32	5.04E-7	300oe	225	-21	3.78E-7	231	45	-19	37	Bm
M371	136	-36	6.36E-6	300oe	129	-38	2.75E-6	164	-32	-73	146	Bl
M372	349	46	1.20E-6	300oe	332	46	1.17E-6	351	10	67	287	Bl
M373	271	35	9.26E-7	300oe	270	42	6.47E-7	330	34	61	345	Bl
M374	104	-56	1.11E-6	300oe	92	-32	6.69E-7	145	-42	-59	178	Bl
M375	117	-23	1.48E-6	300oe	111	-19	1.18E-6	127	-15	-37	163	Bl
M376	105	-33	8.38E-7	300oe	100	-12	7.80E-7	117	-25	-30	174	Bl
M377	30	-6	3.10E-7	300oe	186	-16	2.81E-7	188	-1	-64	65	Bm
M378	293	-8	7.03E-7	300oe	315	52	2.90E-7	346	51	76	22	Bm
M379	287	-32	1.76E-6	300oe	291	-14	8.65E-7	288	-1	15	345	Bm
M380	335	14	4.11E-7	300oe	260	8	3.91E-7	268	36	6	12	Bm
M381	268	10	1.35E-6	300oe	341	-5	6.35E-7	331	-16	45	307	Bm
M382	57	-76	6.33E-7	300oe	261	25	4.60E-7	274	63	20	34	Bm
M383	184	2	3.24E-7	300oe	287	45	1.01E-6	350	51	79	29	Bm
M384	352	-44	5.27E-7	300oe	342	-69	5.60E-7	268	-31	-9	339	Bm
M385	126	-1	2.45E-6	300oe	132	9	2.28E-6	130	-7	-38	157	Bm
M386	271	49	2.12E-6	300oe	250	60	9.60E-7	36	41	57	170	Bm
M387	23	42	1.10E-6	300oe	50	39	1.06E-6	50	-23	28	205	Bm
M388	347	58	3.39E-7	300oe	199	27	5.73E-7	160	47	-33	104	Bm
M389	328	54	6.82E-7	300oe	338	59	7.39E-7	349	50	79	22	Bm
M390	301	25	3.75E-7	300oe	271	54	5.56E-7	297	50	35	14	Bm
M391	223	39	7.11E-8	300oe	146	-2	6.60E-8	130	24	-28	141	Bm
M393	9	10	4.76E-7	300oe	351	4	4.51E-7	351	2	63	284	Bm
M394	245	9	1.04E-7	300oe	17	15	4.87E-8	18	-2	57	228	Al
M395	156	-24	4.09E-7	300oe	156	-24	3.98E-7	163	-18	-67	130	Al
M396	202	14	1.69E-6	300oe	132	-50	9.12E-7	152	-36	-64	166	Al
M397	40	-19	9.94E-7	300oe	125	18	1.79E-6	119	14	-23	153	Al
M398	310	9	1.09E-5	300oe	262	35	1.08E-5	267	49	10	22	Al
M399	2	50	1.28E-6	300oe	352	56	1.10E-6	13	41	77	183	Al
M400	166	-11	9.40E-7	300oe	156	-7	9.59E-7	156	6	-53	126	Al
M501	312	15	4.51E-7	400oe	33	6	3.26E-7	335	11	57	315	C
M502	233	-6	1.15E-7	300oe	11	16	8.14E-8	14	11	64	232	C
M503	117	60	2.09E-7	500oe	172	-22	3.14E-7	174	-22	-73	108	C
M504	148	-21	8.61E-8	400oe	160	-35	7.19E-8	164	-36	-74	151	C
M505	100	-61	3.75E-7	500oe	146	-36	6.46E-7	150	-39	-62	170	C
M506	31	37	4.35E-7	530oe	193	74	5.72E-7	167	75	0	89	C
M507	349	48	3.27E-7	300oe	27	11	6.95E-7	24	9	57	216	C
M508	88	-24	4.31E-7	300oe	125	-70	2.76E-7	124	-58	-42	203	C
M509	342	23	2.22E-8	400oe	144	46	1.19E-7	149	57	-21	109	C
M510	94	-22	4.81E-7	400oe	106	-10	5.07E-7	104	-13	-16	173	C
M511	187	-16	8.08E-7	300oe	152	-34	5.97E-7	158	-32	-67	155	C
M512	120	5	4.00E-7	300oe	224	-76	3.09E-7	226	-67	-48	307	C
M513	94	-52	6.97E-7	400oe	111	-45	8.60E-7	120	-50	-37	194	C
M514	349	10	3.65E-7	300oe	23	46	1.54E-7	34	43	59	169	C
M515	137	-63	2.00E-7	300oe	132	-50	4.61E-7	153	-62	-62	216	C
M516	146	-14	2.77E-7	500oe	219	-5	5.04E-7	218	8	-43	27	C
M517	54	26	1.10E-7	500oe	111	-19	3.66E-8	116	-35	-32	181	C
M518	100	-23	1.51E-7	530oe	150	47	4.39E-7	135	38	-26	130	C
M519	225	14	1.90E-7	300oe	183	-35	3.61E-7	193	-30	-75	30	C
M520	192	-22	1.90E-7	300oe	198	-22	2.23E-7	199	-6	-59	222	C

Table 1 (*continued*)

Results of the paleomagnetic measurements (7)

Site No.	NRM Dec.	NRM Inc.	NRM Intensity	Demagnetization Condition	Demagnetization Dec.	Demagnetization Inc.	Intensity	Bedding Corr. Dec.	Bedding Corr. Inc.	VGP latitude	VGP longitude	Horizon
M521	133	-35	5.66E-7	300oe	163	-7	6.36E-7	168	-16	-69	118	C
M522	108	41	3.18E-7	300oe	185	-7	2.42E-7	185	1	-64	72	C
M523	85	28	3.11E-7	500oe	127	4	4.61E-7	127	-5	-35	158	C
M524	67	38	1.79E-7	400oe	55	30	8.07E-8	56	12	33	184	C
M526	345	25	1.15E-7	400oe	341	26	1.56E-8	349	22	72	302	C
M527	317	14	8.34E-7	300oe	306	26	4.89E-7	315	33	47	352	C
M529	230	72	8.69E-8	300oe	14	41	3.87E-7	23	28	65	197	C
M531	88	22	7.16E-7	500oe	223	3	9.59E-7	221	34	-31	38	C
M532	309	14	3.71E-7	400oe	235	-44	3.59E-7	233	-13	-36	5	C
M533	331	9	3.87E-7	400oe	2	41	7.09E-7	16	15	65	221	C
M534	330	0	5.95E-7	300oe	306	27	4.39E-7	343	46	74	2	C
M535	344	34	4.44E-7	300oe	355	77	2.48E-7	73	69	30	126	Bu
M536	311	59	1.59E-6	300oe	288	57	6.62E-7	358	40	86	293	C
M537	359	47	2.38E-5	500oe	305	-25	3.57E-6	286	-11	11	341	C
M551	121	-18	9.51E-7	500oe	132	-60	2.70E-7	166	-23	-70	129	Bl
M552	196	-27	1.74E-7	300oe	203	-36	3.58E-7	200	3	-57	45	Bl
M553	218	65	2.95E-7	300oe	196	43	2.26E-7	222	81	12	72	Bl
M554	129	-39	6.60E-5	300oe	126	-41	5.11E-5	151	-14	-57	144	Bl
M555	119	-4	1.32E-7	300oe	36	42	8.74E-8	33	-13	44	214	Bl
M556	298	-50	2.74E-7	300oe	151	7	2.66E-7	132	36	-25	134	Bl
M557	108	-61	3.60E-6	300oe	124	-67	3.03E-6	174	-30	-79	114	Bl
M558	139	-51	1.94E-6	300oe	143	-53	1.91E-6	168	-14	-68	117	Bl
M561	1	53	1.01E-5	300oe	25	56	7.00E-6	18	6	61	224	Bl
M562	313	35	2.31E-6	300oe	340	46	1.86E-6	349	4	63	289	Bl
M563	330	31	1.03E-6	300oe	335	22	5.25E-7	336	-16	48	301	Bl
M567	80	-33	5.36E-7	300oe	86	-52	5.33E-7	144	-42	-58	178	Au
M568	133	-53	2.43E-6	300oe	141	-55	2.62E-6	163	-10	-64	124	Au
M570	29	-55	1.08E-6	300oe	42	-48	7.29E-7	129	-66	-45	217	Au
M571	153	-65	7.92E-7	300oe	147	-60	6.92E-7	169	-17	-70	117	Au
M572	107	-66	3.63E-6	300oe	129	-67	3.33E-6	176	-21	-75	98	Au
M573	312	46	3.61E-6	300oe	300	47	2.68E-6	340	14	63	312	Au
M574	139	60	3.20E-7	300oe	159	6	2.14E-7	136	34	-29	132	Au
M575	78	-69	4.83E-6	300oe	86	-71	5.29E-6	191	-40	-80	9	Au
M576	152	-49	4.95E-6	300oe	146	-57	4.18E-6	166	-19	-70	125	Au
M577	132	-60	7.28E-6	300oe	129	-60	6.54E-6	160	-27	-68	145	Au
M578	1	-49	2.71E-6	300oe	349	-43	1.97E-6	237	-76	-38	292	Au
M579	324	64	3.49E-5	300oe	321	67	2.34E-5	348	17	69	299	Au
M580	302	55	1.58E-6	300oe	308	55	1.74E-6	327	2	49	321	Au
M581	301	47	1.77E-6	300oe	298	48	1.56E-6	325	16	52	332	Au
M582	331	42	4.79E-7	300oe	346	40	5.35E-7	352	-12	55	278	Au
M583	44	-49	3.00E-6	300oe	56	-57	3.10E-6	160	-51	-72	196	Au
M584	160	-45	6.06E-6	300oe	159	-42	6.46E-6	168	10	-57	106	Au
M585	26	12	8.90E-7	300oe	121	-14	2.96E-7	125	6	-30	153	Au
M586	188	-67	9.49E-7	300oe	194	-75	8.67E-7	194	-16	-68	44	Au
M587	24	-31	1.58E-6	300oe	295	22	8.41E-7	305	5	32	339	Bl
M588	102	41	2.44E-7	300oe	1	48	1.69E-7	3	3	65	256	Bl
M589	279	79	3.22E-6	300oe	251	79	2.92E-6	351	43	81	348	Bl
M590	354	56	3.04E-6	300oe	335	-80	2.06E-6	192	-49	-79	331	Bl
M600	4	30	2.34E-6	300oe	10	38	1.78E-6	353	40	82	328	Au
M601	341	34	2.62E-7	300oe	342	36	2.81E-7	335	0	64	35	Au
M602	26	33	3.41E-6	300oe	27	30	3.39E-6	10	14	68	235	Au
M603	6	27	2.24E-6	300oe	359	26	2.12E-6	352	-2	61	280	Au
M604	12	30	7.06E-6	300oe	13	30	7.32E-6	16	7	62	227	Au
M605	329	40	3.40E-6	300oe	331	41	3.28E-6	346	28	72	316	Au

Table 1 (*continued*)

Results of the paleomagnetic measurements (8)

Site No.	NRM Dec.	Inc.	Intensity	Demagnetization Condition	Dec.	Inc.	Intensity	Bedding Corr. Dec.	Inc.	VGP latitude	longitude	Horizon
M606	357	48	4.43E-6	300oe	351	54	4.55E-6	7	34	80	221	Au
M607	342	46	5.74E-6	300oe	345	48	4.37E-6	354	21	73	285	Au
M609	339	64	1.28E-5	300oe	342	63	1.00E-5	7	39	82	204	Au
M610	15	43	2.14E-6	300oe	15	36	1.39E-6	22	1	56	220	Au
M611	119	73	1.06E-6	300oe	151	77	8.14E-7	44	40	49	168	Au
M612	334	53	6.04E-6	300oe	229	31	5.92E-6	266	84	24	70	Au
M613	188	49	2.59E-7	300oe	133	70	4.80E-7	61	29	30	171	Bl
M614	297	30	2.08E-6	300oe	303	33	1.81E-6	336	22	63	325	Bl
M617	167	-56	1.50E-5	300oe	168	-52	1.17E-5	221	-12	-47	13	Bl
M618	13	25	3.06E-6	300oe	32	20	1.74E-6	27	-27	41	227	Bl
M620	339	50	1.48E-5	300oe	332	52	7.07E-6	31	8	53	205	Bl
	(degree)	(degree)	(emu/cc)	(peak A.F.)	(degree)	(degree)	(emu/cc)	(degree)	(degree)	(degree)	(degree)	

Table 2 (after TOKUOKA and YOSHIDA, 1984)

Results of the paleomagnetic measurements (Mahendra Highway - Dumkibas Route)

	After Demagnetization(Mean Direction)						Bedding Corr.		VGP				
Site No.	Dec.	Inc.	Intensity	N	K	alpha95	Dec.	Inc.	latitude	longitude	dp	dm	Horizon
BI01	192	-12	1.40E-6	2	329	5	195	-19	-70	43	2	5	Bu
BI02	355	32	4.21E-7	3	1	82	4	43	86	207	63	102	Bu
BI03	103	58	1.27E-7	3	1	61	121	47	-12	1	51	79	Bu
BI04	287	59	8.27E-8	4	3	35	261	69	16	45	51	60	Bu
BI05	0	44	4.47E-7	4	2	46	13	55	75	130	47	65	Bu
BI06	25	50	1.71E-7	3	20	17	39	53	55	152	16	23	Bu
BI07	357	18	2.03E-7	3	60	10	359	33	80	265	6	11	Bu
BI08	26	55	6.71E-8	3	7	29	43	55	52	148	29	41	Bu
BI10	326	52	1.55E-7	3	3	41	329	66	57	45	56	67	Bu
BI11	71	68	1.06E-6	2	20	21	91	63	18	130	26	35	Bu
BI12	356	24	2.03E-7	4	192	5	358	32	80	269	3	5	Bu
BI13	3	9	3.50E-7	3	2	47	3	18	72	252	25	48	C
BI14	263	77	1.51E-7	3	3	46	205	69	-8	67	66	78	C
BI15	77	55	2.45E-7	3	1	66	81	41	17	154	49	80	C
BI16	14	42	9.74E-8	3	9	25	25	38	66	179	17	29	C
BI17	14	-11	2.36E-7	1	-	-	11	-13	55	243	-	-	C
BI18	127	-18	8.07E-8	4	1	57	125	-30	-39	172	34	62	C
BI19	119	-85	8.12E-8	4	0	78	339	-83	-13	268	147	151	C
BI20	77	11	9.73E-8	3	1	71	78	4	11	176	35	71	C
BI21	97	30	4.91E-8	4	5	29	101	19	-6	158	15	30	C
BI22	136	-6	1.49E-7	4	6	26	135	-20	-46	159	14	27	C
BI23	187	-30	1.59E-7	4	1	50	185	-40	-84	31	36	60	C
BI24	91	27	7.13E-8	3	4	40	44	15	43	188	21	41	C
BI25	229	-5	6.72E-8	4	2	47	229	-8	-38	10	23	47	C
BI26	36	-36	5.41E-8	4	2	49	29	-38	34	229	33	57	C
BI27	223	-5	1.20E-7	4	12	19	223	-3	-41	17	9	19	C
BI28	272	28	4.73E-7	3	4	36	268	37	8	12	24	42	C
CD01	158	-36	2.04E-7	2	57	13	182	-8	-67	77	6	13	BI
CD02	186	-37	1.26E-6	3	159	6	209	6	-49	35	3	6	BI
CD03	346	35	1.90E-6	1	-	-	46	26	45	179	-	-	BI
CD04	147	-38	3.77E-6	1	-	-	199	-17	-65	34	-	-	BI
CD05	346	36	4.62E-7	2	402	4	30	11	54	203	2	4	BI
CD06	356	16	1.68E-6	3	158	6	12	7	63	233	3	6	BI
CD07	92	-52	1.74E-7	2	2	57	239	-48	-38	336	48	74	BI
CD08	336	39	7.19E-6	1	-	-	34	13	51	198	-	-	BI
CD09	357	53	7.30E-6	1	-	-	53	-3	31	192	-	-	BI
CD10	351	24	1.77E-6	2	102	9	38	20	49	190	4	9	BI
CD11	195	-16	4.40E-7	2	1	85	149	36	-35	117	58	99	BI
CD12	308	32	4.43E-6	2	103	9	1	16	71	257	4	9	BI
CD13	141	-24	8.59E-6	2	1777	2	185	-18	-72	66	1	2	BI
CD14	301	-23	3.80E-6	1	-	-	311	35	44	-6	-	-	BI
CD15	322	27	7.33E-7	1	-	-	357	7	66	269	-	-	Bm
CD16	118	0	1.26E-6	2	1	139	146	-32	-58	162	87	156	Bm
CD17	127	-10	5.36E-8	1	-	-	158	-24	-65	141	0	1	Bm
CD18	345	85	5.07E-7	3	152	6	64	68	36	126	8	10	Au
CD19	263	51	5.82E-7	1	-	-	18	87	31	84	-	-	Au
CD20	178	49	4.50E-6	1	-	-	146	32	-35	122	-	-	Au
CD21	126	-39	1.90E-6	1	-	-	143	-33	-56	165	-	-	Au
CD22	45	34	4.62E-7	1	-	-	40	8	45	196	-	-	Au
CD23	19	28	1.56E-6	3	95	8	25	13	58	207	4	8	Au
CD24	334	48	2.16E-6	1	-	-	355	33	80	290	-	-	Au
CD25	78	33	1.60E-6	2	79	11	79	6	11	175	5	11	Au
CD26	350	41	5.60E-7	1	-	-	3	25	76	248	-	-	Au
CD27	344	-15	1.01E-6	1	-	-	339	-13	51	296	-	-	Au
CD28	358	0	7.58E-7	2	20	21	357	-5	60	267	10	21	Au
CD29	18	15	2.14E-6	2	1056	2	20	7	59	218	1	2	Au
CD30	341	26	2.50E-6	3	18	18	344	13	65	300	9	18	Au
CD31	358	48	1.43E-5	2	1313	1	3	32	79	242	4	8	Au
CD32	6	36	3.67E-6	2	131	8	5	26	75	241	4	8	Au
CD33	353	64	3.77E-8	1	-	-	10	37	78	203	-	-	Au
CD34	45	33	2.68E-6	2	3472	1	41	4	43	197	1	1	Au
CD35	6	32	2.90E-6	2	276	5	12	18	69	227	2	5	Au
CD36	15	27	1.40E-7	2	93	10	17	8	61	223	5	10	Au

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APPENDIX I, FIGURES 1 to 8