AGE AND PALAEOECOLOGY OF THE SIWALIK GROUP

12.1 GENERAL STATEMENT

The age of the various formations of the Siwalik Group has been well established on the basis of mammalian and other vertebrate remains. The various views on the age of these formations, summarised from the work of Pilgrim (1913, 1926, 1928, 1932, 1934), Matthew (1929), Colbert (1933, 1935), Lewis (1937) and others, are given in Pascoe (1962). The author has followed Pascoe (1962) and the more recent works of Sahni and Khan (1964), Prasad (1968), Badam (1971), Badam and Sharma (1973) in giving below the generally accepted views regarding the age of different formations. The Kamlial Formation is regarded as Helvetian in age, since it contains among other vertebrate genera, Hyaenaelurus, Anthracotherium and Listriodon. In the richly fossiliferous Chinji Formation, some of the species of the genera Macrtherium, Amphicyon, Listriodon, Conchohyus and Palaenchoerus are considered as diagnostic of Tortonian age.

Notwithstanding the rare and mostly doubtful occurrences of Hipparion in the Chinji Formation, this equid genus is well documented from the Nagri Formation which has been regarded by some workers as Lower Pliocene in age (Matthew, 1929,
Colbert, 1935f, Lewis, 1937). However, the recent work of Couvering and Miller (1971) on the *Hipparion* datum in Samos lends support to the view that the Nagris containing the earliest representatives of *Hipparion* are Upper Miocene (Sarmatian) in age (Pilgrim, 1933, 1934, et al.). The prolific Dhok Pathan fauna which includes among others, the oldest Hippopotamids, and is characterised by the maximum development of the equid genus *Hipparion*, is regarded as Pontian in age. In the Tatrot fauna, the presence of *Hipparion* and *Proamphibos* is considered to be indicative of Astian age. The appearance of *Equus*, *Bubalus* and *Rhinoceros* in the Pinjor Formation and the widespread occurrence of *Archidiskodon planifrons* in these beds, is generally regarded as indicating a Villafranchian age. The scanty fossil record from the Boulder Conglomerate Formation is not of much help in deciphering the precise age of these beds. A Cromerian age for these beds is, however, generally accepted.

The vertebrate fossils have been helpful in deciphering the palaeoecologic conditions during the deposition of the Siwaliks. There is general consensus that the entire succession from the Chinji Formation to the Boulder Conglomerate Formation represents freshwater molasse. However, controversy persists regarding the ecologic conditions during which the lowermost division, 1.2., the Kamlial Formation was deposited. Sikka
et al. (1961) who regarded the occurrence of graywacke in the Nahan Formation (equivalent of the Kamlial Formation in Simla Hills) as ecologically significant, postulated a possible marine origin for these beds. This contention was, however, contradicted by Cummins (1962) who doubted the ecologic significance of graywacke. Ganiu and Srivastava (1962) doubted the very identification of graywacke by Sikka et al. (1961). Sahni (1963) and Sahni and Khan (1964) supported the views of Cummins (1962) and Ganiu and Srivastava (1962). They suggested a freshwater origin of Kamlial beds on the basis of fragmentary vertebrate remains, leaf impressions, and fossil tree trunk. Saxena et al. (1968) reviewed the entire gamut of the problem of graywacke and the Lower Siwaliks. They supported the views of Sikka et al. (1961) on the ecologic significance of graywacke and consequently the marine origin of Kamlial Formation. In support of their contention, they further referred to the reported occurrence of marine fish genera from a Pliocene horizon of the Siwaliks of Punjab in the catalogue of Fossil Fishes of India by Menon (1964). It may be mentioned here that marine, brackish water and freshwater fossil fish-scales have been recorded from the Kamlial Formation near Kandana (Pakistan) by Nair (1945). Considering the overall evidence, the contention of Saxena
et al. (1968, p. 258) that the Kamlial-Chinji contact represented a change-over from the marine Flysch to a deltaic and alluvial Molasse sedimentation, might be true. However, since no fossils were found by the author in his samples from the Kamlial studied at two places around Murpur and Bhakra, it is not possible to say anything precisely about palaeoecologic conditions during the deposition of these beds. The overlying Chinji-Boulder Conglomerate succession was, according to Sahni and Mathur (1964), deposited mainly in four environments viz., piedmont, channel and flood plains, outwash plains and lacustrine.

The present studies were in part, intended at tying up the age and palaeoecology of different formations of the Siwaliks on the basis of mollusc, ostracode, charophyte and angiosperm fossil suite with that established on the vertebrate fauna of these beds. However, the present collection includes only a few taxa which are helpful in deciphering age. Most of the other taxa are long ranging, new or indeterminate (see Text Figures 22, 23 and 24). Some of these, however, have thrown light on the palaeoecologic conditions during the deposition of different beds. The age and palaeoecologic conditions during the deposition of the Siwaliks, as deciphered from the present fossil suite is dealt with in the sequel.
As already mentioned, the two sections of the Kamlial Formation studied by the author were devoid of fossils. The palaeoecologic conditions during the deposition of these beds have already been commented upon in the earlier part of this chapter. It is, therefore, not necessary to add any further comment on the age and palaeoecology of Kamlials.

Of the eight sections of Chinji Formation studied, only five (Localities BI, EIII, HII-HIV) contain fossils. The assemblage comprises three taxa of ostracodes (Text Figure 23), six of charophytes (Text Figure 24) and four of leaves. The ostracodes, all of which are apparently confined to the Chinji Formation include a new species *Rupipris pandai* and the remaining two are indeterminate. The charophytes dominated by the genus *Tectochara* include two well known taxa viz., *T. mariani* and *T. mariani huangi*, a new species *T. sahnii* and three indeterminate. Of the known taxa, *T. mariani* described originally from the Oligocene/Miocene of Switzerland (Heer, 1855, *non vidi*) is widely distributed in rocks ranging in age from Oligocene ( Chattian) to Pliocene (Pannonian) in the Holarctic region (Papp, 1961, Straub 1952, Grambast and Grumbast 1954, Maedler, 1955, Horn af Rantzien 1959a, Wang 1961, 1965, Grumbast and Paul 1965, Maslov 1963, Castel 1967).
T. meriani huangi was originally described from the Kuchar Group of China (Lu, 1945 *non vidi*, *fide* Horn af Rantzien, 1959a). It occurs widely in rocks ranging in age from *?* Cretaceous, Oligocene (Chattian) to Miocene (Tortonian) in the Holarctic region (Papp, 1951, Maedler, 1955, Wang, 1961, 1965, Castel, 1967). Both, T. meriani and T. meriani huangi are being recorded in this work for the first time from the Indian subcontinent. While the former ranges from Chinji to Dhok Pathan, the latter is apparently confined to the Chinji Formation and does not occur in younger beds. This supports the general contention (based on the vertebrate fossil assemblage) that the Chinji Formation is of Tortonian age.

Of the five fossiliferous sections, the Chinji Formation is best developed at Locality IIII exposed along old Kotla-Triloknath road. Here, in a succession of 169 m, two fossiliferous shale horizons were encountered. Of these, the lower one (samples BR/5,6) is about 40 m from the base of the section, while the upper one (sample BR/20) is about 18 m below the uppermost sandstone bed. In the fossil assemblage of the lower horizon, only one ecologically significant taxon Eucypris nandei is encountered. Since most of the species of the genus Eucypris prefer pond or shallow lacustrine environs
and are found in association with rich vegetable matter (Baird, 1838, Brady, 1868, Brady and Norman, 1889, Gurney, 1920, Klie, 1938, Singh, 1971b, unpublished, Singh, 1973d), its occurrence in the present suite perhaps indicates a shallow lake basin during the deposition of this bed. This lower shale horizon apparently does not extend laterally in the two adjacent sections (HII and HIV) of Chinji Formation. The upper fossiliferous bed contains only Tectochara marianii whose precise palaeoecology is not known. This upper fossiliferous horizon apparently extends in both the adjacent sections and occurs at about 256 m from the base at Locality HII (samples Th/15-19) and 70 m from base at Locality HIV (sample KL/9). In the former only charophytes are found while in the latter Hucypris panderi also occurs beside the charophytes. It is, therefore, likely that the charophyte bearing horizons at Localities HII and HIV also form part of the lake basin which probably existed during the deposition of this upper fossiliferous bed at Locality HIV. The remaining succession in all the three sections comprises mostly lateral accretion deposits with a few interbedded vertical accretion sediments. Johnson and Vondra (1972) who worked on the sedimentation of Siwaliks in Hari Talyangar area, east of Hamirpur (Locality D) also observed the preponderance of lateral accretion deposits
in the Nahan Sandstone, equivalent of the Chinji Formation. They further mention that only a few flood basin palaeosols are associated with these deposits.

12.3 MIDDLE SIALIKIS

The Nagri Formation was studied in four sections, of which, only one (Locality FII) was found to contain fragmentary ostracodes and the remaining were unfossiliferous. Since the ostracodes are indeterminate these cannot be used either for deciphering age or palaeoecology. However, on the basis of general lithology, which comprises sandstones, frequently interbedded with siltstones, and shales, the Nagris apparently constitute interbedded lateral and vertical accretion fluvial deposits with which are associated flood basin palaeosols (Johnson and Vondra, 1972). The flood basins are more frequent in the Nagri Formation than in the older beds.

Of the seven sections of Dhok Pathan Formation encountered, only four (Localities III, GI-GIII) contain fossils, while the remaining were found to be unfossiliferous. The fossil assemblage comprises eight taxa of molluscs (Text Figure 22), seven of ostracodes (Text Figure 23), and four of charophytes (Text Figure 24). Of the molluscs, five are known viz., Malanocides tuberculata,
Lamellidens jammuensis, Lamellidens sp. cf. L. subparallelus, Parreysia (Parreysia) tatrotensis and P. (Parreysia) sp. cf. P. (P.) edwini, while the remaining three are indeterminate.

Of the known molluscan taxa, Melanoides tuberculata is at present widely distributed in the Recent (Prashad, 1918, fide Benthem Jutting, 1956, Brown 1965 et auctorum) and has already been recorded from the Pinjor Formation (Bhatia and Mathur, 1973). It is apparently a long-ranging species.

Among the unionids which dominate the molluscan assemblage, Lamellidens jammuensis, earlier recorded from Upper Siwaliks (Prashad, 1927, Bhatia and Mathur, 1973) apparently extends downwards into the Dhok Pathan Formation. Lamellidens sp. cf. L. subparallelus so far known only from the Chinji Formation (Vokes, 1936) perhaps also occurs in the Dhok Pathan Formation. Parreysia (Parreysia) tatrotensis, earlier described from the Tatrot Formation is now known to occur in the Dhok Pathan beds as well. Parreysia (Parreysia) sp. cf. P. (P.) edwini which is known from Pegus of Burma (Gupta, 1930) also occurs in the Dhok Pathan Formation. While it is difficult to surmise anything regarding the age of Dhok Pathan Formation on the basis of molluscs, future work might prove some of the species to be of importance in age determination.

Among the ostracodes, five are well known species, viz., Ilyocypris
I. gibba, Candona lactea and C. neglecta, while the remaining two are new - Limnocythere inaj and Zonocythere mckenziei. All the known taxa occur widely in the Recent. Ilyocythere bradyi, I. gibba, Candona lactea and C. neglecta are well known cosmopolitan species, while Cypris sp. cf. C. decaryi is known from Ethiopian and Neotropical regions. All these ostracodes, except Cypris sp. cf. C. decaryi, have already been recorded from the Tatrot and/or Pinjor Formations of the Upper Siwaliks (Bhatia and Khosla, 1967, Mathur, 1972) and are apparently long ranging. Cypris sp. cf. C. decaryi is so far known only from the Recent (Gauthier, 1933 non vidi, Triebel, 1961, Hartmann, 1964a). The new taxa have not been encountered in either the younger or the older horizons. Though nothing can be surmised regarding the age of the Dhok Pathan Formation on the basis of the fauna known at present, it is likely that future workers might find some of these as reliable age indicators. The charophytes include the well known species Tectochara mariani and three new taxa. The age and distribution of T. mariani (and T. mariani huangi) has been discussed elsewhere. In view of its reported range up to Pliocene (Pannonian) in other parts of the world, a Pontian age for the Dhok Pathan (also suggested by the vertebrate fauna) may be true.
Of the four sections studied around Daulatpur (Locality G), the Dhok Pathan Formation is best developed at Locality GII, exposed in a stream near village Bagh. In a succession of 265 m, two fossiliferous horizons were encountered. Of these, the lower one (samples BA/8-12) is about 76 m from the base and contains only fragmentary molluscs. This lower fossiliferous horizon also extends in the adjacent locality (GIII) where again it contains only molluscan shell fragments, but apparently does not extend in the remaining two Localities (GI and GIV). The upper fossiliferous horizon (samples BA/18-25) at Locality GII is about 45 m above the lower one. This contains a rich assemblage of molluscs, ostracodes and charophytes. The ecologically significant species in this fossil suite are Melanoides tuberculata among the molluscs, and Candona lactea, Ilyocypris gibba and Cypris sp. cf. C. decaryi among the ostracodes. Though some of these species are known to inhabit varying environments, yet the assemblage on the whole apparently indicates a lacustrine environ for this bed (Prashad, 1918, Holmes, 1937, Klie, 1938, Hoff, 1942, Stephanides, 1948, 1960, Straub, 1952, Petkovski, 1958, 1961, Coope et al., 1962, Staplin, 1963, McKenzie, 1964, Hartmann, 1964, Fox, 1965). The continuation of this fossiliferous bed in the adjacent locality (GIII) contains fragmentary molluscs.
The red and gray beds are distributed throughout the Dhok Pathan Formation exposed around Daulatpur (Locality G). The beds comprise chocolate shales and siltstones, gray sandstones and conglomerates. Clark (1962) proposed a field classification of red beds with different palaeoecologic conditions. The present succession of red beds belongs to 'Variegated Red Beds' type of field classification. Such beds according to Clark (1962) are indicative of fluvial deposition under warm, humid environment on flood plains. Similar palaeoecologic conditions for the Dhok Pathan Formation are postulated on the basis of lithology and fossil content.

12.4 UPPER SIWALIKS

A total of thirteen sections of the Tatrot Formation of the Upper Siwaliks were studied. These include eleven fossiliferous sections (AI - AVII, DI, DIII, GI - GIV), most of which contain unidentifiable fossil leaves and fragmentary molluscs. In all, twelve taxa of ostracodes (Text Figure 23), five of charophytes (Text Figure 24), and three of angiosperms have been recorded from the Tatrot Formation in the present work. The ostracodes include ten already known taxa viz., Ilyocypris bradyi, I. gibba, Ilyocypris sp. cf. I. australiensis, Candona lactea, C. marangoensis, Candonopsis
Kingsleyi, Cypris subglobosa, Zonocypris costata, Potamocypris minuta patriciae and Limnocythere bhatiai and a new taxon Limnocythere bhatiai indica. Limnocythere bhatiai recorded earlier from the Tatrot Formation has recently been recorded from a lake in the Jaisalmer area, Rajasthan (S. B. Bhatia and M. S. Mannikeri, personal communication). The other known taxa are widely distributed in the Recent. The charophytes include two known species, Chara surainurica and C. rantzieni and two new Hornichara maslovi and Chara grambasti. Of these, Chara surainurica is apparently confined to the Tatrot Formation. Hornichara maslovi extends up to Pinjor Formation while Chara rantzieni and C. grambasti further extend to Late Pleistocene terrace deposits. The angiosperms include a known seed Boraginocarous lakhanpalii, beside a new leaf Litsea daulatpurenis and another indeterminate leaf. All these three angiosperm taxa are apparently confined to Tatrot Formation. Though at present it is difficult to decipher the precise age of the Tatrot Formation on the basis of these ostracodes, charophytes and angiosperms, yet it is likely that future workers may find some of these taxa to be of stratigraphic value.

Among the fossiliferous sections, the Tatrot Formation is best exposed near Dhamala (Locality AVII) where it measures
148 m. In all, four fossiliferous horizons are met with in this section. The lowermost fossiliferous shale (sample E11), about 50 m from the base, contains ostracodes and charophytes. The ecologically significant ostracode taxa are *Candonopsis marangoensis*, *C. lactea*, *Candonopsis kingslei*, *Cypris subzloboasa* and *Limnocythere bhatiai*. Though most of these species are capable of living in a varied habitat, the assemblage on the whole is suggestive of a shallow water lacustrine environ with slight current action. The presence of abundant ilyocyprids indicates current action (Holmes, 1937, Klie, 1938, Hoff, 1957, Coope et al., 1962, Staplin, 1963b, Fox, 1955, Bhatia and Singh, 1971, Singh 1971b, and 1973d). Sahni and Khan (1964) have also suggested on the basis of vertebrate fauna, large shallow water river and lake basins. This bed is overlain by a trace fossil bearing sandstone (sample E12) which apparently indicates filling up of the basin and somewhat drier conditions. About 18 m above this bed lies a shale horizon containing fragments of a turtle which do not throw any light on the precise palaeoecology during the deposition of this bed. The only other fossil bearing horizon (sample B20) is just below the uppermost sandstone bed in this section. Since most of the ostracodes and charophytes contained in this bed and the lowermost
fossiliferous shale (sample Bll) are common, similar palaeoecologic conditions i.e., a shallow water basin with slight current action, apparently prevailed during the deposition of this bed also. These fossiliferous horizons probably do not extend in the other sections of Tatrot Formation at Locality A, which are sparcely fossiliferous. It is likely that the palaeoecologic conditions during the deposition of Tatrot Formation were more or less similar to those prevailing during the deposition of the lower 40 m thick succession at Locality AVII. The relatively thick succession of shales in the Tatrot Formation which fall in the 'Variegated Red Bed' category of Clark's (1962) field classification of red beds apparently indicate savanna climate. Since the beds of the Tatrot Formation show an alternation of finer and coarser sediments, these have been regarded as cyclical or rhythemic deposits (Sahni and Khan, 1964).

All the six sections (Localities AI - AVI) of the Pinjor Formation studied by the author were found to be fossiliferous. However, the majority of fossiliferous beds encountered, contain only fragmentary molluscs. In all, eighteen taxa of molluscs (Text Figure 22), twenty-one of ostracodes (Text Figure 23) and four of charophytes (Text Figure 24) have been recorded from these beds in the present work. Among the
molluscs, the known taxa are *Viviparina bengalensis*, *V. dubiosus*, *Amnicola (Alocinma)* sp. cf. *A. (A.) sistanica*, *Tricula* sp. cf. *T. montana*, *Melanoidea tuberculata*, *Gyraulus singularis*, *Lamellidens iamuensis*, *L. lewisi*, *L. proctori*, *Parrydia* (Radiatula) *bonnandi*, *Pisidium* (Afropisidium) *clarakaum*, *P. (A.) sivalensis* and *P. (Neopisidium) navillianum* while the remaining five are indeterminate. Most of these extend to the Recent. Others which apparently do not continue above the Pinjor Formation include *Viviparina dubiosus* and *Lamellidens proctori* known from an Upper Pliocene horizon of Burma (Annandale, 1924). *Lamellidens iamuensis* is now known to range from Dhok Pathan to Pinjor Formation (present work). *L. lewisi* is known from Tatrot and Pinjor Formations (Vokes, 1935). *Pisidium* (Afropisidium) *sivalensis* is apparently confined to Pinjor Formation. The ostracode suite comprises among the known taxa, *Darwinula* sp. cf. *D. cuneata*, *Ilyocypris* sp. cf. *I. australiensis*, *I. bradyi*, *I. gibba*, *Candona candida*, *C. lactea*, *C. fabaeformis*, *C. marengoensis*, *C. neglecta*, *Hemicypris pyxidata*, *Cypris subglobosa*, *Strandesia tuberculata*, *Cypridopsis* sp. cf. *C. vidua*, *Potamocypris minuta patriciae*, *Potamocypris* (Erythra) *arguata*, *Zonocypris costata* and *Limnocythere bhatiai* and among the new, *Limnocythere bhatiai indica* and *Paracypretta batei*. 
All the known taxa extend to the Recent. As mentioned earlier, *Limnoxythere bhatiai indica* occurs in Tatrot and Pinjor Formations. *Paracyathretta batai* is apparently confined to the Pinjor Formation. Among the charophytes from the Pinjor Formation, the vatical distribution of *Hornichara maslovi*, *Chara rantzieni* and *C. gramastii* has already been discussed (p.293). In addition to these, *Chara contraria*, a well known charophyte taxon also occurs in the assemblage. It is a cosmopolitan species in the Recent (Horn af Rantzien, 1959b, Pal et al., 1962) and is also widely distributed in Quaternary of Europe and America (Daily, 1961, 1970). The Pinjor Formation is best developed at Locality AI exposed in a tributary of Patiali Rao near village Bari Parch (Locality A). In all six fossiliferous horizons were met with in this 650 m succession of the Pinjors. The lowermost (BP/5,6) occurs just above the basal sandstone bed. In this shale bed, the only ecologically significant species, *Ilyocyoris gibba*, though occurring in varied environs, is generally regarded as indicative of current action (Hoff, 1942, Staplin, 1963b). The next fossiliferous horizon (samples BP/31-35) is about 332 m above this bed. It contains a rich assemblage of molluscs, ostracodes and charophytes. The species of some ecologic significance occurring in this assemblage include *Vivinarus*
bengalensis, Melanoides tuberculata, Parreysia (Radiatula) bonneandi, Pisidium (Neopisidium) nevillianum, P. (Afropisidium) clarkeaum, Cyraulus singularis, Illyocryptis bradyi, Darwinula sp. cf. D. cuneata, Candona candida, G. lactea, Hemicypris pyxidata, Cypridopsis sp. cf. G. vidua and Zonocypria costata. Although some of these taxa occur in varied environs, the entire assemblage is typical of lacustrine environ (Sars, 1903, Baird, 1910, Annandale, 1918, Gurney, 1920). About 21 m above this succession, a siltyshale bed (sample BP/36) contains Viviparus dubiosus whose ecology is not known. The remaining two other fossiliferous horizons containing only fragmentary molluscs occur about 192 m (samples BP/39, 40) and 250 m (samples BP/43-46) above this bed. Halstead and Nanda (1973) distinguished eight cyclothems within a 40 m thick succession of Pinjor Formation exposed near Panchkula, SE of Locality A. The environment of deposition of Pinjor Formation encountered in the other five sections, was more or less similar to that prevalent at Locality AI.

The Boulder Conglomerate Formation was studied in four sections. Only one of these (Locality AII) contained an indeterminable bivalve and the remaining sections were found
to be devoid of fossils. As such, it is difficult to decipher the age and palaeoecology of the formation. Since the succession is dominated by conglomerates and sandstones with only a few interbedded siltstones, these are apparently fluvial deposits. Sahni and Khan (1964) have also deciphered similar palaeoecologic conditions during the deposition of the Boulder Conglomerate Formation.