

A NEW SIWALIK CORRELATION.

G. EDWARD LEWIS.

ABSTRACT.

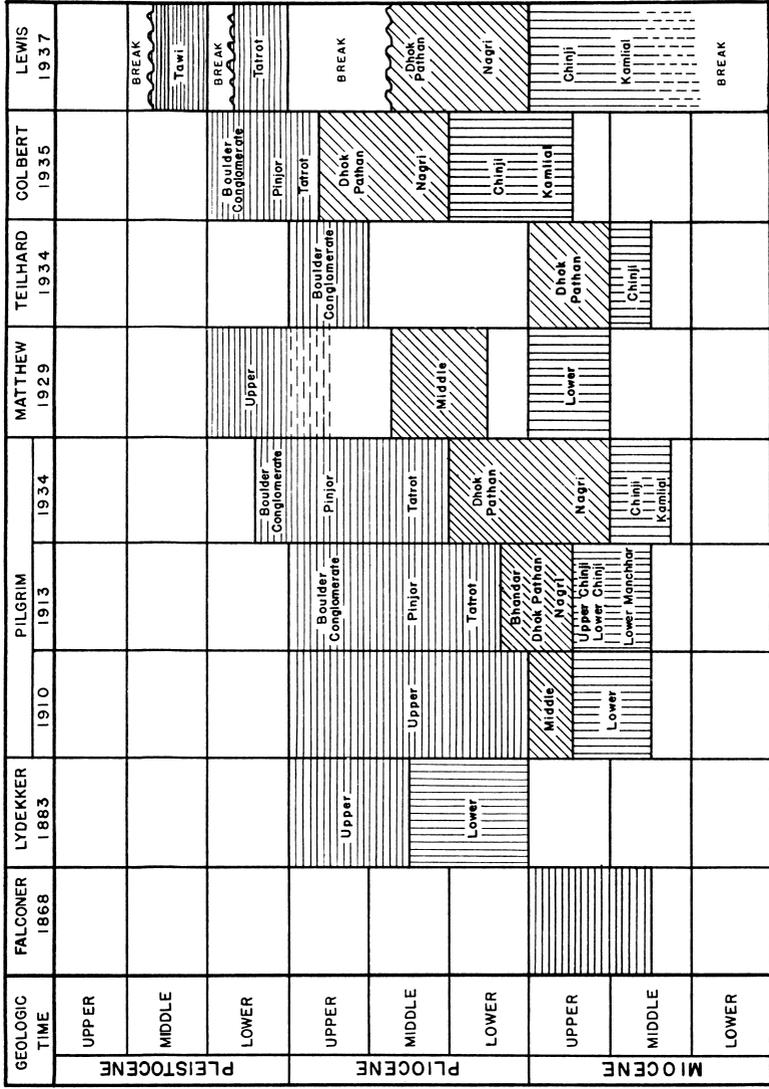
A new Siwalik correlation is presented. *Hipparion* is recognized as having appeared in the Upper Miocene of North America, and the Chinji and Sarmatian *Hipparion* faunas are correlated on the basis of showing the earliest Old World migrants of this genus. *Equus* is recognized as having appeared at the beginning of the Pleistocene in North America, and the Old World horizons where this genus first appears as a migrant are referred to the Lower Pleistocene. A comprehensive correlation with the Geologic Time Scale and the classic Old and New World faunal assemblages is presented, as is a conspectus of Siwalik stratigraphy, indicating the Siwalik Series to range between Middle Miocene and Middle Pleistocene in age, and (from oldest to youngest) including the Kamlial, Chinji, Nagri, Dhok Pathan, Tatrot (= † Tatrot + † Pinjor), and Tawi (new name = † Boulder Conglomerate) formations.

INTRODUCTION.

Dr. Paul Dimitri Krynine is now engaged in a petrographic study of Siwalik sedimentation based on samples collected by the author. His results will appear in a future publication, as will the author's observations on Siwalik gross lithology and its geomorphic expression, in an effort to outline non-faunal criteria effective in the determination of the various formations.

The author gratefully acknowledges much first-hand information on the faunal assemblages of the North American Tertiary graciously proffered by Dr. Robert W. Wilson.

The accompanying chart of comparative correlations by divers authors shows the wide differences of opinion (Fig. 1) on this much-mooted subject. Pilgrim (33, 34, 35, 36), Matthew (27), and Colbert (9, 10) have presented ample compilations of fact, obviating the need of going into all the details in this short paper. Doctor Pilgrim's pioneer work in identifying the presence of the several faunas (34) and the late Doctor Matthew's "Critical Observations" (27) served to direct the lines of later investigations. Doctor Colbert's thoroughgoing study is a major contribution, and his faunal syllabus forms a most useful part of his memoir (10, pp. 29-36). It is the purpose of the present publication to state as tersely as possible a new interpretation of the correlation of the various Siwalik faunas with those of the Cenozoic of North America and Western Eurasia, and their position in the Geologic Time Scale (Fig. 2).



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Fig. 1. Comparative correlations of the Siwalik formations by various authors.

DISCUSSION.

Colbert (10, p. 21) has stated briefly the two lines of approach to this correlation problem:

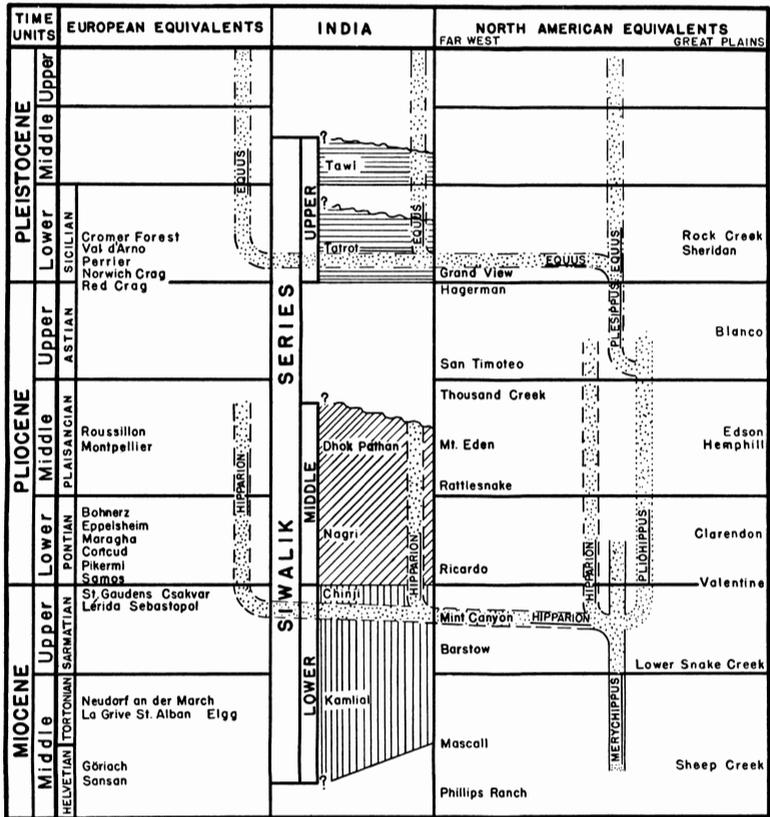
"Two methods of attack have been followed in the attempted solution of the perplexing question regarding the age of the Siwalik beds.

"1. The several Siwalik faunas have been considered on the merits of their general aspects, and have accordingly been compared directly with the similar faunas of eastern Europe and of Asia. This method is the one that has been followed by Dr. Pilgrim.

"2. The Siwalik faunas have been compared not only to the faunas of Europe and of Asia, but also to those of North America, and particular attention has been paid to the appearances of the various kinds of fossil horses and of the other definitely invading types into the region under consideration. This was the method followed by Dr. Matthew."

To date the result has been that American students of the problem have consistently allocated each Siwalik fauna to a later time than have the European workers (Fig. 1). I do not believe that the two above "methods of attack" are incompatible and mutually exclusive, but rather that they are complementary. As a result, the oldest Siwalik Kamlial is allocated to an early date, while the youngest Tawi is placed even later in geologic time than indicated by Colbert. This is not a compromise decision, but represents a decision independently reached. Prior to my field work in India, a study of the Old and New World Tertiary mammalian faunas suggested that the truth might lie between the extreme viewpoints, as is so frequently the case. After several months of field study, and later to an ever-increasing degree, this interpretation seemed well-warranted. This view was communicated briefly to Doctor Colbert in a letter sent to him from India in 1932 (later published, 10, pp. 12-13) indicating that the age of the Siwalik Series extended from Middle Miocene to Middle Pleistocene time. This upper limit subsequently has been confirmed by de Terra and Teilhard de Chardin, who correlate the †Boulder Conglomerate with the second glacial period of the Kashmir Valley (44, pp. 805, 819). It is to Doctor Matthew's credit that, without any field investigations and with much of the laboratory material having no adequate field information attached to it by the early collectors, he produced what seems to be the most accurate of the several correlations (Fig. 1). In this connection, it must be remembered that he was discussing only the Chinji, Dhok Pathan, and Tatrot (= † Pinjor). My own research leads me to agree with Doctor Matthew's placing of these three formations in the geologic time scale.

North America is indicated as the theatre of evolution of the Equidae, the Old World forms representing migrants from the New World, and the best stratigraphic correlation practice



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Fig. 2. Correlation of the Siwalik formations with Old and New World equivalents, based on the appearance and migration of equid genera.

advocates the dating of any given horizon by invading types if they are present. The writer therefore believes that the appearance of *Equus* and indications of the onset of glaciation in Cenozoic mammaliferous deposits both mark the beginning of Pleistocene time, and the presence of an *Equus* fauna militates against any pre-Pleistocene age. Hence the Upper Siwalik is regarded as being confined to the Pleistocene.

The great divergence of opinion as to the age of the Chinji is due principally to the tacit assumption, on the part of those who have heretofore dealt with this problem, that *Hipparion* first appears in North America in the Lower Pliocene (9, 10, 27, 43, etc.). As a matter of fact, the earliest *Hipparion* described to date is reported from the Upper Miocene, prior to the latest Miocene. This occurrence is most important and should be stressed. In 1928, Stock (41) reported the "discovery in marine deposits, presumably the Puente formation of southern California, of a tooth identified as belonging to the species *Hipparion mohavense* Merriam. . . . The San José Hills in which the locality occurs are shown on the geological map recently published by English to be largely constituted by the upper division of the Puente formation of upper Miocene age." In 1930, Maxson (28) reported three species of *Hipparion* from the Mint Canyon formation, one of them identified as *Hipparion* ? near *mohavense* Merriam. Kew (21, p. 52) states that the "Mint Canyon formation (Upper Miocene) . . . beds rest beneath the Modelo (?) sandstone and shale with a marked unconformity, which is shown by a considerable difference in dip and strike" and refers the Modelo formation to the Upper Miocene (*ibid.*, Pl. 3). Hudson and Craig (19, p. 509) conclude that the Modelo formation ranges in age from Middle Miocene to uppermost Miocene.

It is most significant that *Hipparion mohavense* is closer to Eurasian species of *Hipparion* than any other North American species. In fact, Merriam (30, pp. 557-558) remarks that "few if any clearly diagnostic characters in form or pattern" of the teeth of *H. mohavense* "may be considered as certainly separating them from the Chinese *H. richtofeni*" and if it were not for the wide geographic separation he would be inclined to include *H. mohavense* in the *H. richtofeni* group. He adds: "Some of the characters which have been used to separate *H. richtofeni* from *H. gracile* seem to disappear with the study of large collections. . . . In many respects *Hipparion mohavense callodonte* of the Ricardo *Hipparion* group resembles a type from the island of Samos, which has been referred to *H. gracile*." The Mint Canyon *Hipparion* is very close to the Siwalik species of *Hipparion*, and there seems to be no adequate reason for presuming the latter to have had an independent origin, as suggested by Stirton (43, p. 282). Stirton's alternative suggestion (*loc. cit.*) that the Old World *Hipparion*

may be derived from "a *Merychippus* in this country [*i. e.*, North America] older than the Niobrara River [Valentine] fauna" seems to be the more reasonable interpretation. Nearly a quarter of a century before Maxson's description of the Mint Canyon *Hipparion* fauna, Merriam (30, p. 558), speaking of the *Hipparion*-like species of *Merychippus* of the Barstow and *Hipparion mohavense* of the type locality, pointed out that "the proximity of the two in morphologic characters, geographic situation, and in time, strongly suggest close relationship." The Barstow (30, Figs. 41, 42) and Mint Canyon (28, Fig. 6) *Merychippus sumani* is as near to *Hipparion mohavense* and the Old World *Hipparion* as a distinct genus can be, and actually much closer to them than is the *H. gratum* cited and figured by Colbert (10, Fig. 70, 1) as the earliest North American *Hipparion*. The figured specimen actually appears to be closer to *Merychippus* than to *Hipparion*, and its enamel pattern is more primitive than that of *M. sumani* as figured by Maxson (28, Fig. 6).

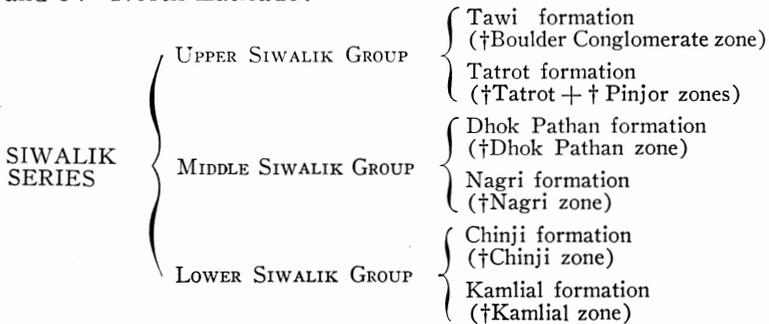
In Europe and India, *Hipparion* first appears in the Sarmatian and Chinji respectively. It has been argued that these early Eurasian occurrences cannot be older than Lower Pliocene (27, 9, 10), assuming that the genus has its origin in the early Pliocene of North America. The Mint Canyon occurrence nullifies this argument. It has also been argued that the Chinji is of Middle Miocene age—Tortonian, or upper Vindobonian (35, 36, 43). This argument is negated also, if we accept the inevitable postulate that *Hipparion* had its origin in North America and migrated to the Old World. Borissiak has made it abundantly clear that the Sebastopol ossiferous deposits are intercalated in upper middle Sarmatian measures (5, p. 105). Pilgrim has repeatedly pointed out that the Chinji faunal assemblage as a whole has a Miocene aspect, and can account for the seemingly anomalous presence of *Hipparion* only by the unlikely suggestion that its origin is in no way connected with that of the same genus in North America. He remarks (*in litteris*, 10, p. 157) that "somewhere or other the ancestral form of the *Hipparion* of Sebastopol and Pikermi must have existed, and since the American deposits are so well known that its presence could hardly escape notice there, it seems more likely that it will one day be found in the Old World." The answer would seem to be that the reported presence (28, 41) of this ancestral form generally has escaped notice.

The following interpretation is advanced:

1. *Hipparion* is of North American origin.
2. *Hipparion* migrated to Eurasia from North America.
3. *Hipparion* arrived in Eurasia in Sarmatian—late Miocene—time, subsequent to its appearance in the Mint Canyon of North America.

SYSTEMATIC STRATIGRAPHY.

Colbert (10, pp. 13-19) has given a good summary of the perplexing dilemma of the nomenclature of Siwalik rock units. The present study proposes a scheme of nomenclature which admittedly has its faults, but on the whole, it seems to the author that it is the most workable plan which can be arrived at without temporizing. Unfortunately, there has been a tendency to confuse faunal zones with geographically named formations, both in North America and abroad. The classification here proposed follows as closely as possible the principles set forth in 1933 by a committee on stratigraphic nomenclature representing the United States Geological Survey, the American Association of State Geologists, the American Association of Petroleum Geologists, and the Geological Society of America (3). It is applied to that part of India lying between Longitude 72° and 75° 30' East of Greenwich, and 32° 30' and 34° North Latitude:



TAWI FORMATION (MIDDLE PLEISTOCENE).

This geographic formation name is proposed here as a substitute for the term "Boulder Conglomerate," and is based on the section in the Tawi River valley (75° 10' E, 33° N) near Udhampur, where de Terra and Teilhard de Chardin (44, p.

805, Figs. 8, 14) correlated the Boulder Conglomerate with the second glaciation of the Pir Panjal region. The Tawi is overlain unconformably by younger deposits, and is separated from the older rocks by an unconformity (11, 31, 33, 35, 44, 45, 46). The author made no collections from the Tawi, but the literature indicates no great difference of fauna as compared with the Tatrot.

TATROT FORMATION (LOWER PLEISTOCENE).

Pilgrim (34, p. 276) described the Tatrot and its fauna (type locality, Tatrot village, 73° 21' E, 32° 52' 30" N, near the base of the formation), and distinguished a younger †Pinjor "zone" between the Tatrot and the Tawi (*op. cit.*, p. 278). Later writers have followed this usage, supposing that *Hipparion* and other pre-Pleistocene forms occur and that advanced forms such as *Archidiskodon* do not occur in the Tatrot as contrasted with the supposedly distinct †Pinjor. The author's collections fail to warrant this distinction, and the vertebrates represent a common fauna. *Archidiskodon* is represented in a large collection from the type locality at Tatrot, and while *Hipparion* was also collected, this latter genus was found to occur only as rolled, isolated teeth in the basal Tatrot conglomerate, secondarily derived from older horizons. The name "Tatrot" is chosen in preference to "Pinjor" for two reasons:

1. "Tatrot" has page priority.
2. "Tatrot," in common with all the other geographical "zone" names proposed by Pilgrim, with the single exception of "Pinjor," is located in the Salt Range-Potwar area, where the mutual relations of the divers horizons of the Siwalik section are best displayed. *Equus* first appears in the Tatrot formation, as far as the Siwalik series is concerned. The basal Tatrot conglomerate marks the upper limit of the considerable break, faunal and physical, separating the Middle and Upper Siwalik.

DHOK PATHAN FORMATION (MIDDLE PLIOCENE).

Sections made in the type locality of the Tatrot late in 1932 revealed angular unconformity and abrupt lithologic changes between the Dhok Pathan (type locality, Dhok Pathan village on the Soan River, 72° 21' E, 33° 8' N) and the Tatrot. This break was theoretically predicted by Pilgrim in 1913 (34, p.

275) and later demonstrated by Wadia (45, Pl. 8, Fig. 3), and by de Terra and Teilhard de Chardin (44, pp. 808-810). The basal Tatrot conglomerate has been noted by Cotter (11, pp. 121, 122) and by de Terra and Teilhard de Chardin (*op. cit.*). As to the age of the Dhok Pathan, I agree with Matthew that it is post-Pontian, and equivalent to the age range between the Rattlesnake and Thousand Creek in North America (27, Fig. 1). The Edson, Mount Eden and Hemphill appear to be its nearest New World equivalents, and it is correlated with the Montpellier and Roussillon of Europe. In all these Old World cases, *Hipparion* is represented in the faunas. Matthew (27, p. 553) and Colbert (10, p. 25) have pointed out that the Dhok Pathan Giraffidae are more advanced than those of Pikermi and Samos. The author again calls attention to the occurrence of *Plesiogulo brachygnathus* in the Dhok Pathan (23, p. 80), and it is a noteworthy fact that this genus is restricted to the Edson, Mount Eden, and Hemphill in North America. *Indarctos* is confined to the Dhok Pathan in India and to the Rattlesnake in North America (40, p. 170). Pilgrim, Colbert, and Matthew have adequately discussed the remaining faunal elements. It seems improbable that the Dhok Pathan is quite as young as indicated in Colbert's chart showing comparative correlations (9, Fig. 1; 10, Fig. 13). Teilhard de Chardin's correlation of the Dhok Pathan is most difficult to understand, as he makes it equivalent to the Sebastopol (43, Table 3), which is even older than Pilgrim (36) believes it to be. Moreover, it is represented as directly following the Chinji, the Nagri having been omitted, and above the Dhok Pathan is a great gap without any indication of intervening horizons, extending from the Dhok Pathan (correlated with the Sebastopol, usually recognized as Sarmatian) to the "Upper Siwalik (Conglomerate)" (correlated with the Val d'Arno). Matthew's correlation appears to be the most accurate.

NAGRI FORMATION (LOWER PLIOCENE).

The fauna characteristic of this formation (type locality, Nagri village, 72° 30' E, 32° 46' N) is transitional between those of the Chinji and the Dhok Pathan. It seems advisable to locate the base of the Nagri at the horizon where the bright red siltstones, so typical of the Chinji, die out and the thick sandstones of the Nagri begin. Pilgrim (34, p. 274) originally included a few feet of "red nodular clay with a pisolitic fer-

ruginous band containing *Hipparion*," the "Nurpur zone," but the field evidence does not seem to warrant this distinction, which has been quoted by later authors. The fauna is best correlated with the Pontian *Hipparion* fauna. At the base of the Nagri true pebble beds are frequently observed. This fact, coupled with the predominant sandstones of the Nagri, may indicate that these clastics, coarser than those of the Chinji, possibly indicate a break between these two formations. It was not possible to demonstrate this during my field work.

CHINJI FORMATION (UPPER MIOCENE).

The village of Chinji, after which this formation is named, is built on the crest of a typical cuesta of Nagri sandstone, and the type locality ($72^{\circ} 22' E$, $32^{\circ} 41' N$) is further south, between the village and Chinji Forest Rest House. An interpretation of the significance of the appearance of *Hipparion* in the Chinji has been presented above. Dr. Barnum Brown's collections and those made by the writer (10, p. 23) have already established the fact that, contrary to previous views, *Hipparion* occurs in the lower portion of the Chinji. Admittedly, the most ubiquitous occurrence is in the Middle Siwalik. On the basis of isolated teeth, there is no apparent difference between the species appearing in the older portion of the Chinji and those in the topmost Dhok Pathan. The Yale collections indicate a single faunal assemblage for the Chinji as a whole. Matthew (27, p. 553) and Colbert (10, pp. 25-26) show that the Chinji Giraffidae are at least as advanced as those of Pikermi. The mammalian fauna of Sebastopol, in which *Hipparion* appears for the first time in Europe, is definitely of Sarmatian age (5, p. 105) but the fauna is not materially different from that of the Pontian. Colbert (10, p. 159) reached this same conclusion. I therefore correlate the Chinji with the Sarmatian of Sebastopol, allocating both to the Upper Miocene, believing their age to be somewhat younger than that of the Mint Canyon, the oldest formation from which *Hipparion* is recorded in North America.

KAMLIAL FORMATION (MIDDLE TO UPPER MIOCENE).

The village of Kamlial, from which Pinfold derived this name (37, p. 154), is located on the Chinji formation, and the

type locality (72° 30' 30" E, 33° 15' 30" N) of the older Kamliāl formation is $\frac{5}{8}$ mile WSW of Kamliāl village. Pilgrim (35, p. 911, and in later publications) correlates the Kamliāl with the Helvetian of Sansan, but the fauna seems to be transitional between those of the Bugti and Chinji, and does not militate against a correlation with the Tortonian. Cotter (11, pp. 101-103) has given an excellent summary of the relations between the Murree, Kamliāl and post-Kamliāl Siwalik formations. It seems more advisable to include the Kamliāl with the Siwalik series, rather than with the Murree. True, where both the Kamliāl and upper Murree are well developed there is no obvious lithologic break between them. However, the youngest Murree is barren of fossil vertebrates as far as is known, while there is a marked influx of vertebrates beginning in Kamliāl time. Several authorities suggest that this reflects a more profound change. Wadia, for example (46, p. 79), believes that "the Kamliāl stage indicates the advent of clear (fresh and running) water conditions in the Punjab for the first time after the retreat of the sea of Eocene and Oligocene times and the filling up of the lagoons in which the greater part of the Murrees were laid down. Fluvial conditions, after a few minor oscillations, were now definitely established in North West Punjab." Anderson's suggested "Nimadric" (2, pp. 674, 684), with an older Murree and a younger Siwalik series, seems to offer the most workable solution, and he recognizes the Kamliāl as being oldest Siwalik. This classification is accepted by the present writer. In the northern Salt Range, south of Chinji, the Kamliāl was found to lie upon the Eocene (Ypresian) limestones with abrupt unconformity. One and one-half miles south of the village of Jaba, a short distance south of Musewālī Khangah, this abrupt physical break was marked by a basal Kamliāl conglomerate containing secondarily derived nummulites in addition to numerous vertebrate bones. Osborn (31, Fig. 413) indicates breaks between the Chinji and the Kamliāl, and between the "† Pinjor" and "† Boulder Conglomerate," but shows none between the Dhok Pathan and the Tatrot, where there is a considerable break. The author found no evidence of a break between the Kamliāl and the Chinji, and the presence of such a break seems unlikely in view of the gradual advent of finer clastics with the transition to the Chinji, the clastics of which are, on the average, the finest in any Siwalik formation.

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