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Conodont Fauna and Its Biostratigraphy of the Bamchi Formation (Lower Permian) in Yobong-Bamchi Area, Yeongweolgun, Korea

강원도 영월군 요봉-밤치 지역의 밤치층 (하부 페름기)의 코노돈트와 그 생층서에 관한 연구

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Abstract : The Early Permian Bamchi Formation is distributed in Yobong-Bamchi area in Bookmyeon, Yeongweolgun, Kangweondo with N-S trending. In this formation many limestone beds are intercalated. These limestone beds contain abundant fossils such as conodonts, fusulinids, small foraminifers, ostracods, corals, and brachiopods. This paper carries out a systematic and paleontological study on conodonts of the Bamchi Formation. The conodonts of the formation are four genera, distributed into eight species: *Streptognathodus elegantulus, S. elongatus, S. barskovi, S. wabaunsensis, Idiognathodus ellisoni, Diplognathodus expansus, D. triangularis,* and *Hindeodus minutus*. Based on this conodont fauna, the *Streptognathodus elongatus* Zone was established. This conodont biozone indicates that the geologic age of the Bamchi Formation is the Asselian to Sakmarian stage of the Early Permian Period. The limestone beds of the Bamchi Formation contains some conodonts which indicate the depositional condition was shallow and high energy environment. Therefore, it can be said that the sediments of the Bamchi Formation deposited in shallow marine environment.

Key words : Bamchi Formation, Conodonts, *Streptognathodus elongatus* Zone, Asselian to Sakmarian Stage, Early Permian Period, Pyeongan Supergroup, Yeongweol Coal Field.

요 약

강원도 영월군 북면 요봉-밤치 지역에는 전기 페름기의 밤치층이 남북 방향으로 대상 분포한다. 이 지층 내에는 여러 매의 암회색 내지 흑색의 석회암이 협재된다. 이 석회암은 코노돈트, 방추충, 소형 유공충, 개형류, 산호, 완족류 등의 화석을 풍부히 포함한다. 이 연구는 밤치층에서 산출되는 코노돈트에 관한 체계적이고 자세한 고생물학적인 연구를 수행하였다. 밤치층에서 산출되는 코노돈트는 4속 8종이며, 중요 코노돈트는 *Streptognathodus elegantulus, S. elongatus, S. barskovi, S. wabaunsensis, Idiognathodus ellisoni, Diplognathodus expansus, D. triangularis, Hindeodus minutus* 등이다. 이 코노돈트 화석에 근거하여 *Streptognathodus elongatus* Zone이 설정되었다. 이 코노돈트 생층서는 밤치층의 지질시대가 하부 페름기의 Asselian에서 Sakmarian임을 지시한다. 밤치층의 석회암에서 높은 에너지의 천해환경을 지시하는 코노돈트가 많이 산출되는 점을 고려할 때, 밤치층은 천해환경에서 퇴적된 것으로 판단된다.

주요어 : 밤치층, 코노돈트, *Streptognathodus elongatus*대, 아셀리안 내지 삭크마리안조, 전기 페름기, 평안누층군, 영월 탄전

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INTRODUCTION

The Late Paleozoic sedimentary rocks with north-south trending are distributed in the Yobong-Bamchi area of Yeongweolgun, Kangweondo (Fig. 1). These sediments are known as the Pyeongan Supergroup. This supergroup is overlying unconformably on the Ordovician Yeongheung Formation but its upper part is in tectonic, thrust fault, contact with the Cambro-Ordovician sedimentary rocks. The supergroup is classified into four units; the Yobong, Pangyo, Bamchi and Mitan Formations, in ascending order (Table 1).

Of these formations, the lower three formations consist of marine limestones, sandstones, and shales and the Mitan Formation is composed of terrestrial clastic sediments intercalating three coal seams. The limestones of the supergroup contain abundant fossils such as fusulinids, foraminifers, brachiopods, corals, crinoids, bivalves, gastropods, and conodonts. So far, many geologists studied the geology and paleontology of the supergroup. The paleontology and biostratigraphy of fusulinids of the supergroup were studied by many authors (Cheong and Park, 1977; Lee, 1984; Cheong *et al.*, 1983; Lee *et al.*, 1988). Through a detailed and systematic study of fusulinids, Cheong *et al.* (1983) recognized that the Upper Carboniferous strata are not developed and insisted that the Bamchi Formation is underlain paraconformably by the Pangyo Formation. Lee (1985) studied conodonts of the Hongjeom Formation of the Yeongweol coal field and established four conodont biozones. According to him, the geologic age of the formation ranges from the Morrowan to Missourian series of the Carboniferous Period. Park (1990) studied conodonts of the Bamchi Formation and ascertained the geologic age of the formation as the Asselian to Sakmarian stage of the Lower Permian Period.

The purpose of this paper is to carry out a systematic and detailed study on conodont fauna of the Bamchi Formation and to establish its biostratigraphy.

The illustrated conodont specimens are deposited at the Department of Geology, Kangwon National University under the catalogue numbers of DGKU 93001-93027.

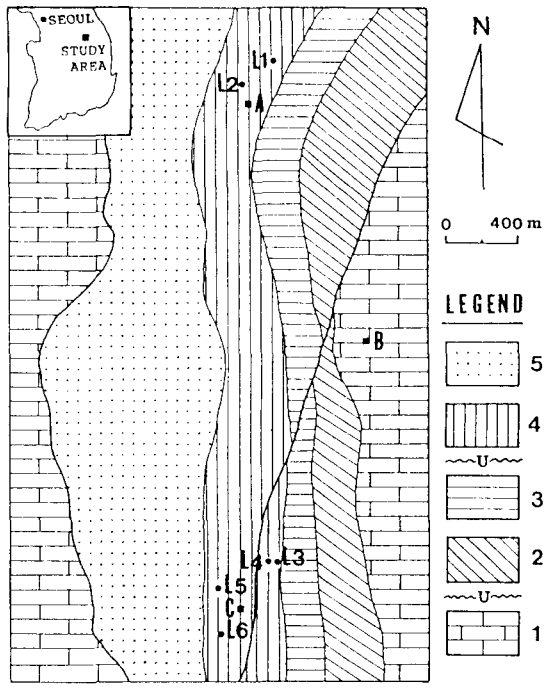

Fig. 1. The geologic map of the study area and collecting localities. 1. Cambro-Ordovician Choseon Supergroup; 2. Yobong Formation; 3. Pangyo Formation; 4, Bamchi Formation; 5. Mitan Formation. L1, Bamchi section I; L2, Bamchi section II; L3, Seonghwangdang section I; L4, Seonghwangdang section II; L5, Yobong section; L6, A small limestone outcrop at the entrance to the Yobong valley. A, Bamchi; B, Hakjeon; C; Yobong.

GEOLOGIC SETTING

The geology of the study area consists of the Early Paleozoic Choseon Supergroup and the Late Paleozoic Pyeongan Supergroup. The Choseon Supergroup is composed mainly of carbonate rocks. The carbonate rocks of the supergroup are characterized by the prevalence of dolomites and dolomitic limestones. This supergroup is divided into, in ascending order, the Sambangsan, Machari, Wagok, Mungok, and Yeongheung Formations.

The Late Paleozoic Pyeongan Supergroup covers unconformably the Early Paleozoic carbonate rocks. The supergroup consists of the Yobong, Pangyo,

Bamchi, and Mitan Formations, from bottom to top.

Yobong Formation

The Yobong Formation lies unconformably on the Ordovician Yeongheung Formation and is covered conformably by the Pangyo Formation. This formation consists of brown sandstone, reddish and greenish shale, reddish mudstone, light gray and brownish and gray limestone. Some chert nodules are included in the limestones. The bed of the basal conglomerates crops out well in some places. The gravels of the conglomerates are composed mainly of quartzite with minor amount of chert gravels. The components of the sandstone of the formation consist of quartz and rock fragments and their roundness is subangular to angular. The grain size of the sandstone is medium and its sorting is poor. The limestone of the formation consists of micrite, biomicrite, and biosparite. This limestone contains very abundant conodonts such as *Idiognathoides opimus, I. sinuatus, Declinognathodus lateralis, D. noduliferus, Diplognathodus elesmerensis, D. coloradoensis, Hindeodus minutus, Neognathodus bothrops, Neogondolella clarki, Idiognathodus delicatus,* and *Adetognathus* sp. These conodonts indicates that the geologic age of formation ranges from the Morrowan to Atokan Series of the Middle Carboniferous Period. Based on the fusulinid study, Lee (1984) suggested that the geologic age of the formation is Bashkirian Stage of the Middle Carboniferous time. The thickness of the formation is about 105 meters.

Pangyo Formation

This formation consists of the gray shale, limestone and fine sandstone. Some cherts are included in the limestones. The sandstone of the formation is composed of quartz and rock fragments. Some tourmaline grains are observed. The limestone consists mainly of the biosparite. This limestone contains abundant conodonts such as *Neognathodus roundyi, N. medexultimus, Idiognathodus delicatus, Diplognathodus edentulus, D. orphanus, D.* n. sp. A, *Gondolella bella, Streptognathodus excelsus*. Among these conodonts, it is well known that neognathodids occur only up to the Desmoinesian Series of the Middle Carboniferous Period. But in Seonghwangdang area, some conodonts of *Streptognathodus excelsus, Idiognathodus tersus, Diplognathodus edentulus, Gondolella bella* are found except for neognathodid conodonts from the upper limestone beds of the formation. This fact is not clearly understood yet whether it is caused by the ecofacial dependence of neognathodids or the age of the upper part of the Pangyo Formation is younger than the Middle Carboniferous rocks. The thickness of the formation is about 85 meters at Seongwhangdang area.

Table 1. The classification of the Pyeongan Supergroup of the study area

Period	Formation
Permian	Mitan Formation
	Bamchi Formation
	~~(Unconformity)~~~~
Carboniferous	Pangyo Formation
	Yobong Formation
	~~(Unconformity)~~~~
Ordovician	Yeongheung Formation

Bamchi Formation

This formation is underlain unconformably by the Pangyo Formation and is overlain conformably by the Mitan Formation. The formation consists of gray shale, sandstone and limestone. Some chert nodules are contained in the limestones. The sandstone is composed mainly of quartz grains and contains some rock fragments. The grain size of sands is mostly medium and their roundness is angular to subangular. The limestone is almost biosparites. This limestone contains abundant fossils such as fusulinids, small foraminifers, brachiopods, corals, and conodonts. The important conodonts are *Streptognathodus elegantulus, S. elongatus, S. wabaunsensis, S. barskovi, Idiognathodus ellisoni, Hindeodus minutus, Diplognathodus expansus, D. moori,* and *D. triangularis* (Tables 2-6). Based on these conodonts, it can be said that the geologic age of the formation is Asselian to Sakmarian Stage of the Lower Permian (more detail see the following CONODONT BIOSTRATIGRAPHY section).

Table 2. Conodonts of the Bamchi Formation at Bamchi section I

Sample Number	Ba1	Ba2	Ba3	Ba4	Ba5	Ba6	Ba7	Ba8	Ba9	Ba10
Sample Weight (kg)	2.7	2.3	1.3	3.0	1.0	2.1	1.5	2.5	3.2	2.8
D. expansus	2		6			8	9	3	1	
D. moori	6			7				4		1
Idiognathodus ellisoni		3								
Hindeodus minutus	3			1			1	4		
Streptognathodus elegantulus				*1*				*2*		
S. elongatus		25	3	3	11		2	15	4	18
S. wabaunsensis	1	6	2		4	2		1	2	3
Total	12	34	11	12	15	10	12	29	7	22

It is characteristic that the conodont fauna of the Bamchi Formation is abundant in Diplognathodids indicating shallow and high energy environmental condition and lacks Neogondolellids which show deep and low energy environment. Therefore, it can be said that the limestones of the Bamchi Formation deposited in shallow and high energy environment. The thickness of the formation is about 85 meters (Lee, 1984).

Mitan Formation

This formation lies on the Bamchi Formation conformably and its upper part contacts with the Early Paleozoic Great Limestone Group by the Machari Thrust Fault. The formation consists of dark gray medium sandstones and shale. In the upper part of the formation, three coral seams are intercalated. The sandstone of the formation is composed mainly of quartz and subordinately feldspar and rock fragments. The roundness of the sand grains is subangular to subrounded. The sandstone of the formation is poorly sorted. The thickness of the formation is about 300 meters (Lee, 1984).

CONODONT BIOSTRATIGRAPHY OF BAMCHI FORMATION

To carry out a paleontological and biostratigraphical study of conodonts of the Bamchi Formation, five sections were measured (Fig. 1) and limestone samples were collected systematically (Fig. 2). Some supplemental samples were also collected.These samples were dissolved in 15% acetic acid to obtain conodonts. The dissolved residues were dried and then concentrated in the heavy liquid (Bromoform, D=2.84). I found abundant conodonts from the limestones of the Bamchi Formation. The conodonts are *Diplognathodus expansus, D. moori, D. triangularis, Hindeodus minutus, Idiognathodus ellisoni, Streptognathodus elongatus, S. barskovi, S. elegantulus,* and *S. wabaunsensis* (Tables 2-6). Based on these conodonts, the *Streptognathodus elongatus* Zone is established. Of these conodonts, the occurrence of *Diplognathodus triangularis* should be notified. This form is found from a small outcrop of the reddish gray limestone at the entrance to the Yobong valley (collection locality L6 in Fig. 1). This species is found together with many forms of *Streptognathodus elongatus* and *Diplognathodus expansus*. According to Ding and Wan (1990), *D. triangularis* appears first from the base of the *Sweetognathus whitei* Zone of the Taiyuan Formation in the south of the North China Platform. In the stratotype of the Lower Permian System in the Ural Mountains, the *S. whitei* Zone is recognized in the Artinskian Stage (Movshovich *et al.*, 1979). Moreover, it is known that most of the Streptognathodids disappeared before the appearance of *S. whitei*. The co-occurrence of *D. triangularis* together with *S. elongatus* and *D. expansus* in the Bamchi Formation of the study area needs more detailed study to clarify wheather *D. triangularis* appears earlier than *A. whitei* or the range of *S. elongatus* exceeds the base of the *S. whitei* Zone. Or it is a mixing fauna.

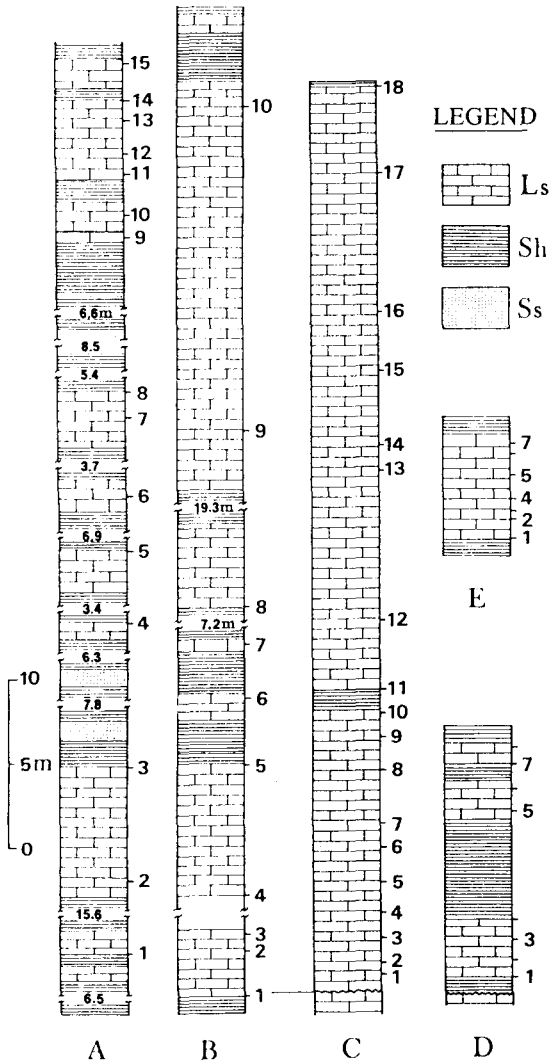

Fig. 2. Sampling horizons of the measured sections. A, Bamchi section II; B, Bamchi section I; C, Seonghwangdang section II; D, Seonghwangdang section I; E, Yobong section. Ls, Limestone; Sh, shale; Ss, sandstone.

Taxa	*Streptognathodus elongatus* Zone
D. expansus	
D. moori	
D. triangularis	
Hindeodus minutus	
Idiognathodus ellisoni	
Streptognathodus elegantulus	
S. elongatus	
S. wabaunsensis	

Fig. 3. The zonal range of the conodonts of the Bamchi Formation.

Streptognathodus elongatus Zone

The base of the *Streptognathodus elongatus* Zone is defined by the first appearance of the name-giving species and the upper boundary of the zone is by the first occurrence of the *Sweetognathus whitei* or *Diplognathodus triangularis* (Fig. 3). But the upper boundary of the zone is not defined clearly in the study area. The characteristic species of the zone are *Streptognathodus elongatus, S. elegantulus, S. barskovi, S. wabaunsensis, Hindeodus minutus, Diplognathodus expansus, D. moori,* and *Idiognathodus ellisoni* (Tables 2-6). This zone was recognized at the Seonghwangdang and Bamchi sections. Park (1989) studied the conodonts of the Unamsa Formation of the Lower Permian in Nongam area of the southern part of the Mungyeong coal field and he established the *Streptognathodus elongatus* Zone and the *Sweetognathus whitei* Zone. The *S. elongatus* Zone of the study area can be correlated well with the *S. elongatus* Zone of the Unamsa Formation in Nongam area. Ding and Wan (1990) studied conodonts of the Taiyuan Formation in the south of the North China Platform and established two conodont assemblage zones: the *Streptognathodus elongatus - S. wabaunsensis - S. fuchengensis* Assemblage Zone and the *Sweetognathus whitei - Diplognathodus triangularis* Assemblage Zone. Their former assemblage zone can be correlated with the present *Streptognathodus elongatus* Zone. The correlation of the conodont zone of the Bamchi Formation with that of Nongam area, N. America, Japan, China, and Ural Mountains is shown in Table 7.

SYSTEMATIC PALEONTOLOGY

Genus *Diplognathodus* Kozur and Merril, 1975.

***Diplognathodus expansus* (Perlmutter, 1981)**

Pl. II, figs. 6-12

1975 *Ozarkodina expansus* n. sp. Perlmutter, p. 98, pl. 3, figs. 1-16. [p element]

Table 3. Conodonts of the Bamchi Formation at Bamchi section II

Sample Number	Bi1	Bi2	Bi3	Bi4	Bi5	Bi6	Bi7	Bi8	Bi9	Bi10	Bi11	Bi12	Bi13	Bi14	Bi15
Sample Weight (kg)	1.5	2.0	3.1	1.2	2.7	1.5	1.2	2.3	3.2	1.9	2.5	3.5	2.8	1.3	5.0
D. expansus	1			5	55				2			1			27
Hindeodus minutus	2				30	1			1			3			3
Streptognathodus elegantulus			1		5		1								2
S. elongatus		18	7		400	2	7	5	15		16	27	5	10	1
S. wabaunsensis					40			2	3	2	8	14		3	
Total	3	18	8	5	530	3	8	7	21	2	24	45	5	13	33

1990 *Diplognathodus augustus* Igo, Park, p. 99-100, pl. 1, figs. 4-7.

Description: This species is characterized by the smooth surface of the platform. The platform (cup) occupies about two-thirds to three quarters of the posterior part of the conodont. The outline of the platform is oval to round. The short blade meets the median of the platform and continues posteriorly as a high carina. The posterior portion of the cup extends beyond the posterior end of the carina. In upper view, the conodont is straight or curved slightly inwards. The inner platform is slightly narrower than the outer one. The carina consists of a knife-edge-like ridge. In lateral view, the height of the upper edge is almost straight or decreases slowly posteriorly. The anterior most denticle is wider and higher than the other denticles on the blade. The number of the denticles on the blade is four or so. The carina stands high above the cup. In lower view, the basal cavity is widely expanded and oval to round in outline.

Remarks: *Diplognathodus expansus* is similar to Middle Carboniferous *Diplognathodus coloradoensis* and *D. orphanus* in the smoothness of the surface of the cup. But *D. expansus* differs from *D. coloradoensis* in lacking a depression betwen the carina and blade. *D. orphanus* is different from *D. expansus* in having a nodose carina. *D. expansus* is similar to *D. triangularis* in the smoothness and wideness of the platform. But the latter differs from the former in having a more wider triangular platform. *D. expansus* is very similar to *D. edentulus*. The former differs from the latter in having a more expanded basal cavity and a smaller ratio of the blade and platform length.

Material studied: More than 481 specimens.

Occurrence: *D. expansus* occurs in the *Streptognathodus elongatus* Zone of the Bamchi Formation at Bamchi, Yobong, and Seonghwangdang sections.

***Diplognathodus moori* (von Bitter, 1972)**

Pl. II, figs. 4, 5

1972 *Anchignathodus moori* n. sp. von Bitter, p. 67-68, pl. 7, figs. 3a-f.

1990 *Diplognathodus moori* (von Bitter), Park, 100-101, pl. 1, figs. 1, 2.

Description: A small species of *Diplognathodus* is characterized by the denticulated carina and the smoothness of the cup. In upper view, the conodont is straight. The blade meets the median of the cup and continues as a carina posteriorly. The carina consists of isolated high denticles. The outline of the cup is oval to subelliptical. The cup occupies posterior about three quarters of the conodont. Viewed laterally, the carina is high and the upper edge of the conodont is straight. The anterior and posterior margins are vertical. A microstructure of fine striations on the denticles can be observed under high magnification. In lower view, a large, thin walled, subelliptical basal cavity is developed.

Remarks: *Diplognathodus moori* is very similar to other Diplognathodids in the smoothness of the platform surface. But its unique feature is denticulated carina.

Material studied: 35 specimens.

Occurrence: *Diplognathodus moori* occurs in the lower part of the *Streptognathodus elongatus* Zone of the Bamchi Formation at Seonghwangdang and Bamchi sections.

***Diplognathodus triangularis* Ding and Wan, 1990**
Pl. II, figs. 13-17

1990 *Diplognathodus triangularis* n. sp. Ding and Wan, p. 143, pl., figs. 4, 5, 7, 9, 11.

Description: A smaller species of *Diplognathodus* is characterized by the wide triangular shape of the platform (cup). The long and straight anterior margin of the platform meets the blade with right angle. The platform is pointed posteriorly. The surface of the platform is smooth. The platform occupies about three-fourths to two-thirds of the conodont. The short blade meets the median of the platform and continues as a carina posteriorly. The conodont is nearly straight in upper view. The carina consists of a knife-edge-like ridge. In some specimens, small nodes are developed at the posterior end of the carina. The length of the conodont is shorter than its width. The ratio of the length to width of the conodont is about 0.9. In lateral view, the height of the upper edge of the conodont is straight. The posterior margin of the carina is vertical. In lower view, the basal cavity is widely expanded triangular shape in outline.

Explanation of Piate I

(All shown in upper view, unless otherwise stated)

Figs. 1, 2. *Idiognathodus ellisoni* Clark and Behnken, 1971
1. DGKU 91003; X 44. Se-2, Seonghwangdang section I.
2. DGKU 93001; X 46. Ba-2, Bamchi section I.

Figs. 3, 4. *Streptognathodus barskovi* Kozur, 1975
3. DGKU 91008; X 31. Se-1, Seonghwangdang section I.
4. DGKU 91010; X 43. Ba-6, Bamchi section I.

Figs. 5-7. *Streptognathodus elegantulus* Stauffer and Plummer, 1932
5. DGKU 93002; X 91. SH-9, Seonghwangdang section II.
6. DGKU 93003; X 84. SH-9, Seonghwangdang section II.
7. DGKU 91004; X 88. Bi-3, Bamchi section II.

Figs. 8-17. *Streptognathodus elongatus* Gunnell, 1933
8. DGKU 91005; X 70. SH-8, Seonghwangdang section II.
9. DGKU 91006; X 76. Bi-11. Bamchi section II.
10. DGKU 93004; X 34. SH-15, Seonghwangdang section II.
11. DGKU 93005; X 36. SH-4, Seonghwangdang section II.
12. DGKU 91007; X 71. Bi-12, Bamchi section II.
13. DGKU 93006; X 35. SH-17, Seonghwangdang section II.
14. DGKU 93007; X 55. SH-9, Seonghwangdang section II.
15. DGKU 93008; X 42. SH-14, Seonghwangdang section II.
16. DGKU 93009; X 43. Bi-5, Bamchi section II.
17. DGKU 93010; X 32. Bi-5, Bamchi section II.

Figs. 18-24. *Streptognathodus wabaunsensis* Gunnell, 1933
18. DGKU 91009; X 41. Bi-14, Bamchi section II.
19. DGKU 93011; X 36. SH-14, Seonghwangdang section II.
20. DGKU 91011; X 88. Bi-11, Bamchi section II.
21. DGKU 91012; X 39. Bi-11, Bamchi section II.
22. DGKU 93012; X 34. Bi-5, Bamchi section II.
23. DGKU 93013; X 34. Bi-5, Bamchi section II.
24. DGKU 93014; X 45. SH-9, Seonghwangdang section II.

Plate I

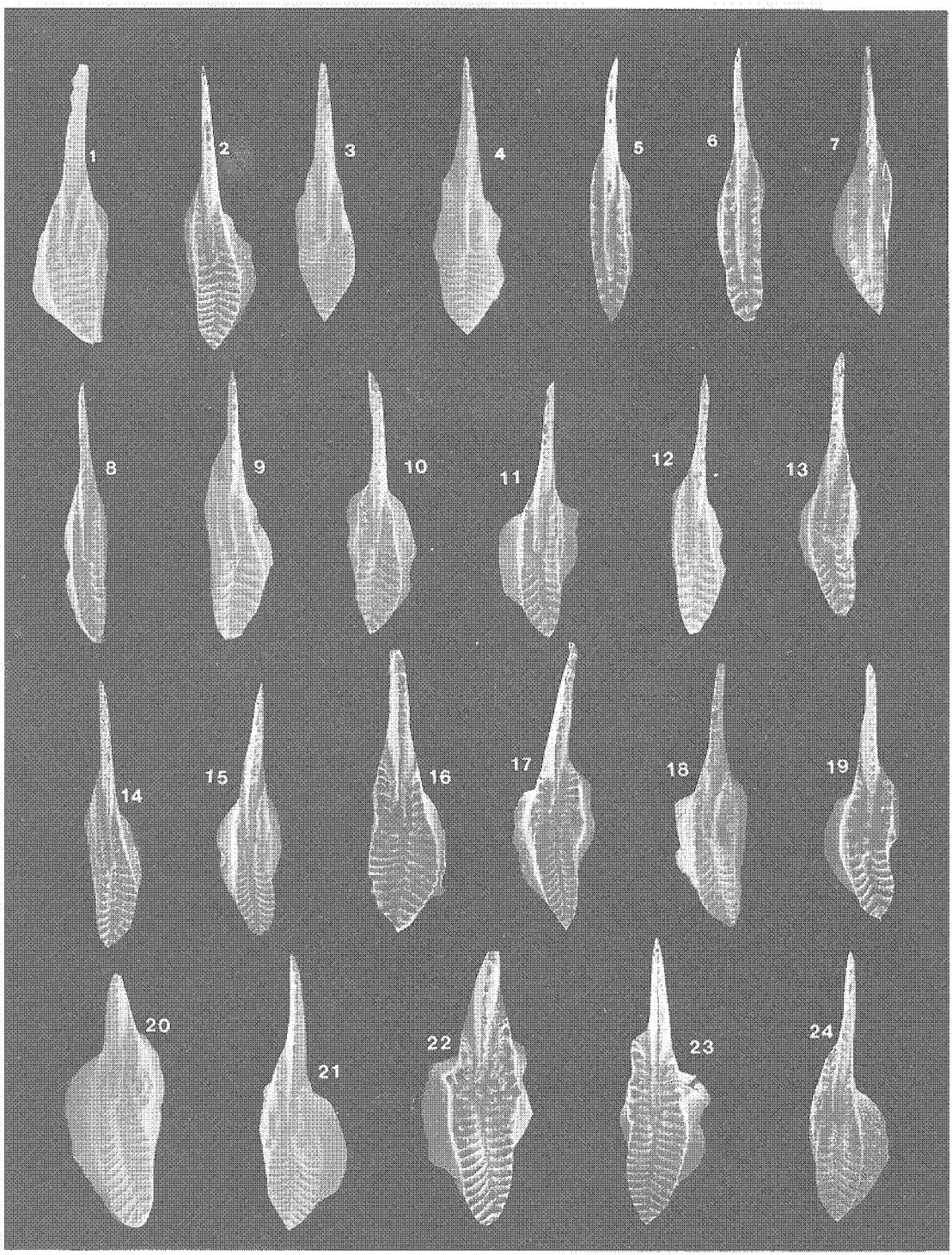

Table 4. Conodonts of the Bamchi Formation at Seonghwangdang section I and at collecting locality L6

Sample Number	Se1	Se2	Se3	Se4	Se5	Se6	Se7	Se8	L6
Sample Weight (kg)	3.0	2.9	2.0	2.0	2.0	3.9	1.6	2.1	2.5
D. expansus			5						40
D. moori	2					2			
D. triangularis									16
Hindeodus minutus	2						1		13
Idiognathodus ellisoni		1							
Streptognathodus elegantulus	5			1		3			
S. elongatus	7	11	7		22	13		2	23
S. wabaunsensis	3	5	3		9	1		3	5
Total	19	17	15	1	31	19	1	5	97

Table 5. Conodonts of the Bamchi Formation at Seonghwangdang section II

Sample Number	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	SH11	SH12	SH13	SH14	SH15	SH16	SH17	SH18
Sample Weight (kg)	3.3	3.1	2.5	2.0	2.5	1.7	2.2	1.9	4.6	3.7	2.5	2.0	2.1	3.3	2.3	3.5	2.2	2.5
D. expansus	50	33	1	1	2	4	7		5		11	4		1	2	30	1	1
D. moori	10	2												1				
Hindeodus minutus	8	4				1		1			1					2		
Streptognathodus elegantulus						2			3				1	2	1		2	
S. elongatus	15	18	5	9	11	11	21	2	23	8		1	7	22	2		27	9
S. wabaunsensis		2		3	4	5	1		7	1		1	1	9	2		2	2
Total	83	59	6	13	17	23	29	3	38	9	12	6	9	35	7	32	32	12

Remarks: *Diplognathodus triangularis* is similar to other Diplognathodid forms in smoothness of the platform surface. Its unique feature is widely expanded triangular outline of the platform.

Material studied: 19 specimens.

Occurrence: The specimens of *D. triangularis* are found only from a small limestone outcrop near the entrance to Yobong valley (L6). The biostratigraphic significance of its occurrence is still debatable in the study area (detailed discussion see the BIOSTRATIGRAPHY section).

Genus *Hindeodus* Rexroad and Furnish, 1964
Hindeodus minutus (Ellison, 1941)

Pl. II, figs. 1-3

1941 *Spathodus minutus* n. sp. Ellison, p. 120, pl. 20, figs. 50-52.

1975 *Ozarkodina minuta* (Ellison), Perlmutter, p. 102-103, pl. 2, figs. 26-30. [p element]

1981 *Anchignathodus minutus minutus* (Ellison), Igo, p. 26, pl. 10, figs. 5, 8, 11.

1981 *Anchignathodus minutus permicus* n. subsp. Igo, p. 26-27, pl. 10, figs. 1-4.

1990 *Hindeodus typicalis* (Sweet), Park, p. 101, pl. 1, fig. 18.

Synonym lists by 1975 see Perlmutter.

Description: This conodont is slightly arched and blade-like in outline. The surface of the cup is smooth. The erect cusp is triangular in lateral view and is more wider than the other denticles. On the anterior edge, two or three small denticles are developed. The posterior process consists of round nodes. Under the high magnification, microstructure of fine striations are observed on the surface of denticles. In lower view, a narrow, subelliptical basal cavity is present. The basal cavity occupies the posterior three-fourths of the unit. The basal cavity continues as a groove under the anterior part of the conodont.

Remarks: *Hindeodus minutus* is very similar to

Table 6. Conodonts of the Bamchi Formation at Yobong section

Sample Number	Yo1	Yo2	Yo3	Yo4	Yo5	Yo6	Yo7
Sample Weight (kg)	3.9	4.7	4.6	2.0	2.8	2.0	2.5
D. expansus	20	44	20	7	20	32	16
Hindeodus minutus			4	3	2	1	2
Streptognathodus elegantulus		1	1	2	7	3	
S. elongatus	16	55	28	30	90	19	33
S. wabaunsensis	1	2	1	1	3	1	2
Total	37	102	54	43	122	56	53

H. typicalis. The height of the upper edge of *H. typicalis* diminishes gradually from the cusp to its rear end. But in *H. minutus*, the upper edge tends to be an abrupt offset immediately behind the cusp.

Material studied: More than 94 specimens.

Occurrence: *Hindeodus minutus* occurs in the *Streptognathodus elongatus* Zone of the Bamchi Formation at Bamchi, Yobong, and Seonghwangdang sections.

Genus *Idiognathodus* Gunnell, 1931

Idiognathodus ellisoni Clark and Behnken, 1971

Pl. I, figs. 1, 2

1971 *Idiognathodus ellisoni* n. sp. Clark and Behnken, p. 435-436, pl. 1, figs. 15-21.

Description: *Idiognathodus ellisoni* is characterized by the concave platform surface covered with parallel fine transverse ridges. The inner accessory lobe may be present or absent. The long blade meets the median of the platform and continues posteriorly as a carina very short distance. The carina meets the transverse ridge with right angle. A slit like median trough may be developed on the posterior part of the platform surface. The basal cavity is deep and long and continues as a groove on the underside of the blade.

Material studied: Four specimens.

Remarks: The present specimen is different from the holotype of *I. ellisoni* in weakness or lacking of accessory lobe. *I. ellisoni* differs from *I. delicatus* in the more concave surface of the platform. Perlmutter (1975) considered this species as a synonym of *Streptognathodus wabaunsensis*, but I think *I. ellisoni* is valid species because it lacks a typical median trough of Streptognathodids.

Occurrence: This form occurs in the lower part of the *S. elongatus* Zone of the Bamchi Formation at Seonghwangdang and Bamchi sections.

Genus *Streptognathodus* Stauffer and Plummer, 1932

Streptognathodus elegantulus Stauffer and Plummer, 1932

Pl. I, figs. 5-7

1932 *Streptognathodus elegantulus* n. sp. Stauffer and Plummer, p. 47-48, pl. 4, figs. 6, 7, 22, 27.

1972 *Streptognathodus elegantulus* Stauffer and Plummer, Von Bitter, p. 52-53, pl., 1, figs. 1a-e. [sp element]

1975 *Idiognathodus elegantulus* (Stauffer and Plummer), Perlmutter, p. 99-100, pl. 1, figs. 3-12. [p element]

Lists of the synonym by 1968 see Von Bitter, 1972.

Description: *Streptognathodus elegantulus* is characterized by the narrow and long platform and a long carina. The long blade meets the median of the platform and continues posteriorly as a carina. The anterior part of the carina consists of a ridge and changes gradually into a low and narrow nodose ridge. It reaches nearly the end of the platform. The median trough is deep and long. The inner and outer margins of the platform are composed of round nodes. No accessory lobe is present.

Remarks: This form is different from the other Streptognathodids in lacking accessory lobe and having narrow platform. *S. elegantulus* was found firstly from the Graford Formation in Texas, N. America (Stauffer and Plummer, 1932) and its occurrence was reported continuously from many strata

of the Upper Carboniferous of the world. The occurrence of Permian *S. elegantulus* is not so much known. Its Permian specimens were known from the Admire and Council Grove Groups in Kansas, U.S.A. (Perlmutter, 1975).

Material studied: More than 46 specimens.

Occurrence: This form occurs in the *Streptognathodus elongatus* Zone of the Bamchi Formation at Seonghwangdang, Yobong, and Bamchi sections.

***Streptognathodus elongatus* Gunnell, 1933**
Pl. I, figs. 8-17

1933 *Streptognathodus elongatus* Gunnell n. sp., p. 283-284, pl. 33, fig. 30.
1933 *Streptognathodus simplex* Gunnell n. sp., p. 285, pl. 33, fig. 40.
1941 *Streptognathodus elongatus* Gunnell, Ellison, p. 130, pl. 22, fig. 3.
1975 *Idiognathodus elongatus* (Gunnell), Perlmutter, p. 99-100, pl. 1, figs. 3-12.
1981 *Streptognathodus elongatus* Gunnell, Igo, p. 43-44, pl. 7, figs. 10, 12-15.
1990 *Streptognathodus elongatus* Gunnell, Park, p. 101-102, pl. 1, figs. 8-11.

Description: *Streptognathodus elongatus* is characterized by the deep median trough, short carina and lack of the accessory lobe. The long blade meets the median parts of the platform and continues as a carina posteriorly. The carina reaches about one-third of the platform and ends abruptly. The platform is long and its surface is ornamented with parallel transverse ridges which are interrupted by the shallow median trough. The platform curves inward where the carina ends. In lateral view, the platform begins to decline posteriorly where the carina ends. The basal cavity is long and deeply excavated and continues as a groove on the underside of the blade.

Remarks: *Streptognathodus elongatus* differs from *S. elegantulus* in possessing longer transverse

Explanation of Plate II

(All shown in upper view, unless otherwise stated)

Figs. 1-3. *Hindeodus minutus* (Ellison, 1941)
1. DGKU 91001; X 82. Bi-12, Bamchi section II. Lateral view.
2. DGKU 93015; X 68. Bi-5, Bamchi section II. Lateral view.
3. DGKU 93016; X 64. SH-2, Seonghwangdang section II. Lateral view.

Figs. 4, 5. *Diplognathodus moori* (von Bitter, 1972)
4. DGKU 93017; X 131. Se-7, Seonghwangdang section I. Lateral view.
5. DGKU 93018; X 94. SH-1, Seonghwangdang section II. Lateral view.

Figs. 6-12. *Diplognathodus expansus* (Perlmutter, 1981)
6. DGKU 93019; X 110. SH-1, Seonghwangdang section II.
7. DGKU 93020; X 76. SH-2, Seonghwangdang section II.
8. DGKU 93021; X 104. SH-9, Seonghwangdang section II.
9. DGKU 93022; X 77. Collecting locality L6.
10. DGKU 93023; X 86. Collecting locality L6.
11. DGKU 91015; X 78. Ba-7, Bamchi section I. a, upper view; b, lateral view.
12. DGKU 93024; X 90. SH-1, Seonghwangdang section II.

Figs. 13-17. *Diplognathodus triangularis* Ding and Wan, 1990
13. DGKU 91018; X 90. Collecting locality L6.
14. DGKU 93025; X 74. Collecting locality L6.
15. DGKU 91016; X 74. Collecting locality L6. a, upper view; b, lateral view.
16. DGKU 93026; X 97. Collecting locality L6.
17. DGKU 93027; X 77. Collecting locality L6.

Plate II

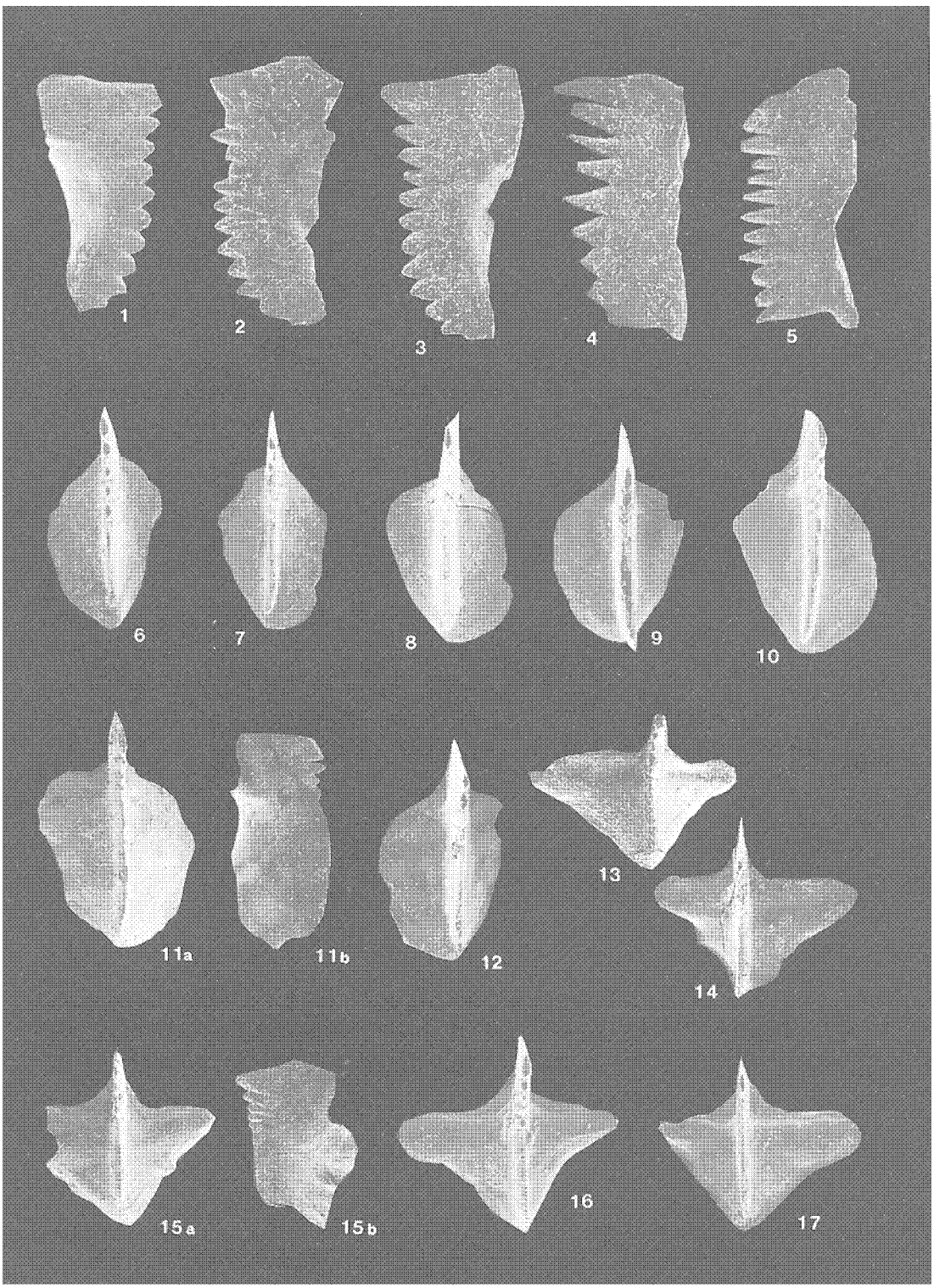

Table 7. The correlation of the conodont zone of the Bamchi Formation with that of other areas

present paper	Nongam area (Park, 1989)	N. America (Clark, *et al.*, 1979)	China (Ding & Wan, 1990)	Japan (Igo, 1981)	Ural Mts. (Movshovich *et al.*, 1979)
	S. whitei	*N. bisselli-S. whitei*	*S. whitei-D. triangularis*	*N. bisselli-S. whitei*	*N. bisselli-S. whitei*
St. elongatus	*St. elongatus*	*St. elongatus*	*St. elongatus* *St. wabau.-St. fuche.*	*St. elongatus*	*St. elongatus-St.wabaunsensis*

D., Diplognathodus; N., Neogondolella; S., Sweetognathus; St., Streptognathodus

ridges, i.e., in the wider platform. The carina of the former extends about one-third of the platform and ends abruptly, whereas the carina of the latter reaches nearly the rear end and its height decreases slowly. *S. elongatus* differs from *S. wabaunsensis* in lacking an inner accessory lobe.

Material studied: More than 1158 specimens.

Occurrence: *S. elongatus* occurs in the *S. elongatus* Zone of the Bamchi Formation at Bamchi, Yobong, and Seonghwangdang sections.

***Streptognathodus wabaunsensis* Gunnell, 1933**

Pl. I, figs. 18-24

1933 *Streptognathodus wabaunsensis* n. sp. Gunnell, p. 284, pl. 33, fig. 32.
1933 *Streptognathodus walteri* n. sp. Gunnell, p. 284, pl. 33, fig. 31.
1933 *Streptognathodus acuminatus* n. sp. Gunnell, p. 285, pl. 33, fig. 33.
1933 *Streptognathodus farmeri* n. sp. Gunnell, p. 285, pl. 33, fig. 34.
1933 *Streptognathodus flangulatus* n. sp. Gunnell, p. 285, pl. 33, fig. 35.
1941 *Streptognathodus simulator* n. sp. Ellison, p. 132, pl. 22, fig. 25, 27.
1941 *Streptognathodus wabaunsensis* Gunnell, Ellison, p. 131, pl. 22, figs. 18, 19, 21, 22.
1990 *Streptognathodus wabaunsensis* Gunnell, Park, p. 102, pl. 1, figs. 12-15, 16, 17.

Description: *Streptognathodus wabaunsensis* is characterized by the wide platform and possessing an inner accessory lobe. The concave platform surface is ornamented with long transverse ridges which are interrupted by shallow median trough. The long blade meets the median part of the platform and continues posteriorly as a carina. The carina reaches about one-third of the anterior part of the platform and ends abruptly. The platform curves inwards where its width is greatest. An inner accessory lobe is present and composed of one to five nodes. The basal cavity is deep and long and continues anteriorly as a groove on the underside of the blade.

Remarks: *S. wabaunsensis* differs from the other Streptognathodids in having an inner accessory lobe.

Material studied: More than 174 specimens.

Occurrence: *S. wabaunsensis* occurrs in the *S. elongatus* Zone of the Bamchi Formation at Bamchi, Yobong, and Seonghwangdang sections.

LOCALITIES OF SAMPLE COLLECTIONS

Bamchi section I (L1): The limestone beds of the Bamchi Formation crop out along the route 413 near the Bamchi pass (Long. 128°28′50″E; Lat. 37°18′01″N).

Bamchi section II (L2): The limestone beds of the Bamchi Formation crop out along the route 413 near the closed Bamchi Elementary School (Long. 128°28′44″E; Lat. 37°17′57″N).

Seonghwangdang section I (L3): The lower part of the Bamchi Formation crop out at small valley near the Seonghwangdang (Long. 128°28′49″E; Lat. 37°16′33″N).

Seonghwangdang section II (L4): Thick limestone beds of the lower part of the Bamchi Formation

crop out along the slope of the left side of small valley, Seonghwangdang section I (Long. 128°28′44″E; Lat. 37°16′33″N).

Yobong section (L5): The limestone beds of the Bamchi Formation at the mountain slope of the Yobong valley (Long. 128°28′37″E; Lat. 37°16′29″N).

Location L6: The dark brownish reddish, flat limestone near the entrance to the Yobong valley (Long. 128°28′37″E; Lat. 37°16′20″N). Its thickness is about one meter.

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