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Quaternary Geology and Paleoecology of Hominid Occupation of Imjin Basin

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임진강유역 구석기 工作의 고생태학적 배경

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ABSTRACT

The survival of rich evidence of palaeolithic occupation found in the Imjin-Hant'an River basin was possible due to many fortuitous geological conditions provided there. Formation of the basalt plain in a narrow valley system which developed during the late Mesozoic insured the appearance of a basin of sedimentation in which archaeological sites would be preserved with relatively minor post-depositional disturbance. Geomagnetic and K-Ar dating indicates that lava flows occurred during the Brunes Normal Epoch. During and after the process of basin sedimentation, erosion of the plain was confined to the major channel of the present river system which developed along the structural joints formed by the lava flow. Due to characteristic columnar structure and platy cleavage of the basalt bedrock, erosion of the basalt becdrock occurred mainly in vertical direction, developing deep but narrow entrenched valleys cut into the bedrock. Consequently, the large portion of the site area remained intact. Cultural deposits formed on top of the basalt plain were left unmodified by later fluvial disturbances due to changes in the Hant'an River base-level, since they were formed about 20 to 40m above the modern floodplain. Sedimentological evidence of cultural deposits and palynological analysis of lacustrine bed formed in the tributary basin of the Hant'an River indicate that hominid occupation occurred in this basin under rapidly deteriorating climatic conditions. From three thermoluminescence dates, the timing of hominid occupation as represented by 'Acheulian-like' bifaces apparently occur sometime during 45,000 BP. Thus, deposition of cultural layers in this basin approximately coincides with the beginning of the second stadial of the final glacial, during which the Korean Peninsula must have had provided a sanctuary for prolonged human occupation.

This paper is based on information obtained through three seasons of field research. 1983 fieldwork was supported by the L.S.B. Leakey Foundation and the Foundation for Research into the Origin of Man (FROM). The nine-month long 1984 fieldwork was sponsored by the Social Science Research Council (SSRC). The 1988 fieldwork was made possible by supports from the Daewoo Foundation.

요 약

전곡리로 대표되는 임진−한탄강 일원의 구석기공작은 매우 다양하고 풍부한 양상을 보여 준다. 유물과 유적의 분포상에서 이 지역은 동북아에서 그리 흔치 않은 정도의 대규모적이며 집중적인 고인류점거의 흔적을 지닌 지역이라고 할 수 있다. 임진−한탄강 일원에 이러한 집중적인 구석기유적의 보존이 가능하였던 지질학적 이유로는, (1) 약 9천만년전 중생대말기에 단층운동 혹은 열곡운동으로 형성된 좁은 계곡 내에서 있었던 신생대 제4기말의 화산작용으로 이 일대에는 용암대지를 기반암으로 하는 퇴적분지가 형성되었고, (2) 이 퇴적분지의 기반암을 이루는 현무암의 특징적인 주상절리로, 이후 한탄강의 하곡은 침식에 상대적으로 취약한 지질구조선을 따라 오늘에 이르기까지 평면적으로 제한된 범위로 발달, 용암대지 위에 형성된 퇴적층의 대부분은 유수침식으로 인한 파괴에서 벗어날 수 있었으며, (3) 후빙기의 해수면상승으로 인한 임진강 base-level의 상승에도 불구하고, 용암대지의 두께로 인하여 그 위에 형성된 퇴적층은 이에 영향을 받지 않는 고도에 놓여 있게 되어 후빙기의 fluvial regimen의 변화에도 큰 영향을 받지 않을 수 있었기 때문이라는 점을 들 수 있다. 용암대지를 이루는 전곡현무암에 대한 고지자기 측정 및 K-Ar dating의 결과는 제4기의 용암분출이 Bruhnes Normal Epoch에 있었음을 가리킨다. 전곡현무암을 덮고 있는 퇴적층은 크게 3개의 단위로 나뉘어지나, 전곡현무암의 표면지형과 퇴적메카니즘의 지역적 차이에 따라 약간씩의 차이를 보여 준다. 고고학 유물은 매우 두텁게 발달한 강한 점토성의 적색 fluvio-coluvium 내에서 발견된다. 이 층에서 하나 이상의 cryoturbation horizon이 발견되어, 퇴적당시의 기후조건을 시사하여 준다. 이러한 증거는 한탄강의 지류역에서 확인되는 lacustrine bed에 대한 화분분석결과에서 보이는 고인류점거개시 직전의 기후의 급속한 한랭화의 증거와 잘 일치하고 있다. 구석기문화층의 퇴적은 TL dating의 결과 대략 45,000 BP를 전후한 시기에 있었다고 추정되는 바, 즉 문화층의 퇴적은 최후빙하기의 제2차 stadial의 개시와 대략 일치하는 사건이라고 할 수 있다.

INTRODUCTION

Despite the undisputed archeological and geological importance of the Imjin River Basin, field research in this area has been attempted only very recently. As far as archeology is concerned, the area had been virtually unexplored until the discovery of Chon-gok-ri in 1978. Field reconnaissances made in this area, including my own, succeeded in identifying a number of archaeological localities in this basin (Figure 1). With such abundance of archaeological remains, it may be said the whole basin is literally littered with remains of early hominid occupation.

This paper attempts to examine some ecological settings of the basin which brought about the above-mentioned archaeological phenomena in this area. Emphasis will be giarto deliminate geological factors related with larchaeological site formation in the Imjin basin.

THE IMJIN BASIN

The basin comprises most of the area between the NE-SW trending Mashikryong and Kuangju Ranges of central Korea. The Imjin River itself as well as its major tributaries all originate from watersheds in the Mashikryong Range. The drainage network today is a partly trellised one, developed along structural joints. Individual channels are very sinuous as drainages were formed within a complex network of narrow valleys created by complicated orogenic movement. Especially headward from the confluence of Imjin and Hant'an, a major

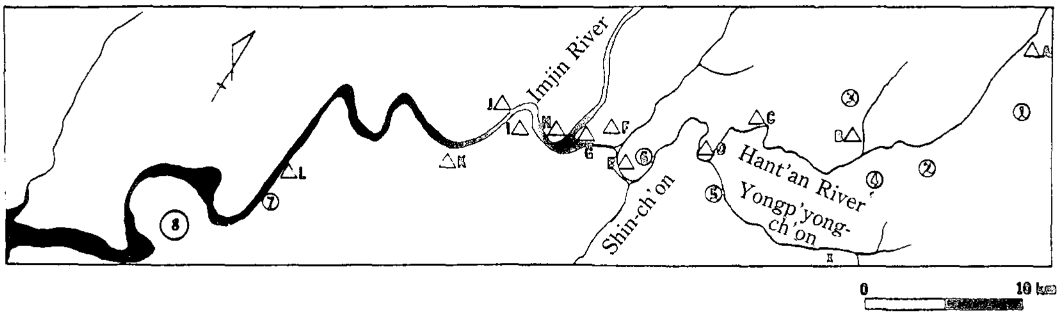

Figure 1. Drainage system of Imjin River. Triangles with alphbets indicate major archeological localities identified in this basin. Circles with numbers are major town. (1) Chip'o-ri; (2) Unch'on; (3) Chung-ri; (4) Taehoesan-ri; (5) Paekui-ri; (6) Chon-gok-ri; (7) Changp'a-ri; (8) Munsan. 'X' indicates the locality where the pollen profiled given in Figure 10 is obtained.

tributary of the former, the river follows a pronounced NE-SW trend with marked ingrowing meandering, indicating its structural origin. In the estuary, the Imjin River is joined by the Han River, both of which debouch into the Yellow Sea in Kyunggi Bay. Like the rest of Korea, the climate of the basin today is characterized by marked seasonality. On the average, annual precipitation in the basin ranges between ca. 1,100 and 1,400 mm, and its mean annual temperature lies between 10 and 11°C. (Lee 1980; cf. Figure 13).

Being accustomed to the normally rugged landscape of Korea, a person who visits the Imjin River for the first time would probably have a strong impression of the unique geomorphology of the surroundings. Along the drainages, stream erosion has exposed, over the years, steep and dark valley walls of basalt, sometimes standing vertically more than 40m above the river. On top of the basalt, the land is unusually flat, and the 'invisibleness' of the river from the valley edge gives one an illusion of an endless expanse of rolling plain situated between ranges of low hills and mountains. The bright reddish color of the surface of the plain makes a strong contrast with the dark bedrock and blue sky. The sediments of the plain are known locally as 'red-brick earth', and the tall smokestacks of brick factories are the landmark of this northernmost, rather desolate part of South Korea (Figures 2, 5 and 6).

The origin and formation of the unique geomorphology of the basin are closely related to the geological history of Ch'ugaryong Valley which intersects the basin along its eastern edge. Survival of Pleistocene hominid remains in the region was facilitated by late Cenozoic volcanic activity (cf. below). A geological and paleoecological discussion of the paleolithic archeology of the Imjin Basin should, therefore, begin with the geology of the Ch'ugaryong Valley.

GEOLOGY OF CH'UGARYONG VALLEY

The Ch'ugaryong Valley first appeared in modern literatures in 1903 when a Japanese geographer gave the name to a narrow opening between Kuangju, about 13 kilometers SE of Seoul, and Wonsan, obliquely crossing a geological strike (Koto 1903). Koto described it as a rift valley or a *graben*, but others consider it a fault valley. It has rarely been considered an erosional feature and there is presently agreement among researchers that it is geomorphologically unique in Korea (S. Kim 1964).

For a long time, suggestions about the origin of the valley have not been followed up by

Figure 2. The Imjin River basin. Photo taken from a Precambrain gneiss knob located in the north of Chon-gok-ri.

systematic field research so that they were left largely in the realm of speculation. The only systematic geological studies of the valley to date are the recent assessments of Lee and others (1983) and Lee (1983). Of course, their conclusions are still tentative and cannot resolve the conflicts surrounding the issue. However, they provide the first realistic basis for understanding the geotectonic processes under which the valley had developed.

First Stage

In brief, Lee and others (1983) recognized four major stages punctuated by volcanism in the gological history of the valley (Figures 3 and 4). The earliest is the formation of the basal rocks (mainly gneiss) of the pre-Cambrian Kyunggi Metamorphic Complex of the Yonch'on System as part of the process of Kyunggi Massif build-up, probably during the late Archeozoic. Palaeozoic geological activities are not yet known and Precambrian rocks are intruded by Jurassic biotitic granodiorite or Taebo Granite. Non-volcanic breccia deposits also formed at this time (ca. 150 MY). Deposition of these new rocks was a consequence of the Taebo Orogney. Boundaries of the basin were delimited by the Taebo Orogeny as the Mashikryong and Kuangju Ranges were built in their present positions. Other smaller chains of low-lying hills and valleys were formed, with which the basic structure of the basin was established. As newly built valleys and fault lines rearranged the drainages, the patterns of stream flow in the basin seen today appeared.

Second Stage

The second stage is marked by Cretaceous tectonic activities, which played the most critical role for the formation of the valley. Volcanic activity accompanying tectonism deposited a variety of new rocks. A series of large-scale,

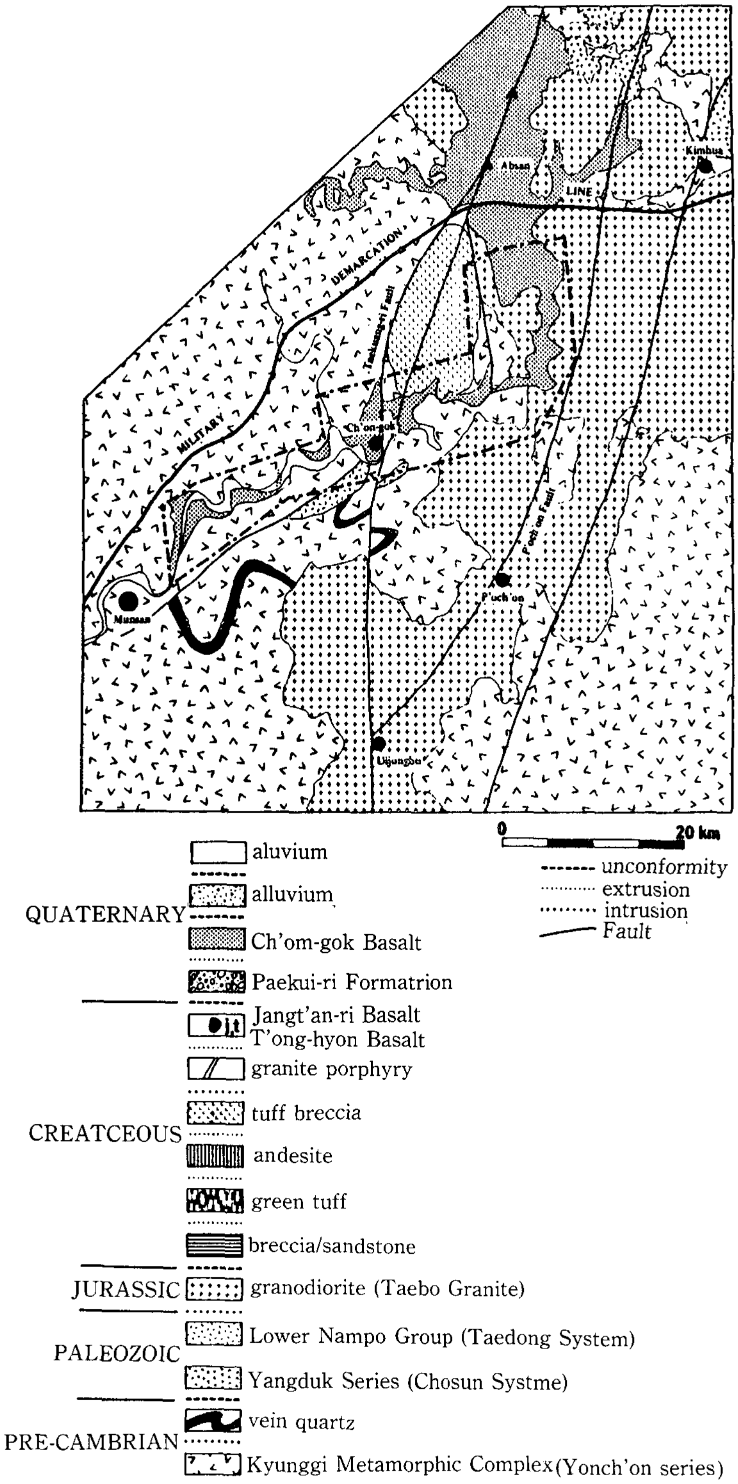

Figure 3. Geological map of the Imjin Basin (modified after the Geological Society of Korea 1955; 1956; 1973 a, b). Details of the area bounded by the broken line is shown in Figure 4.

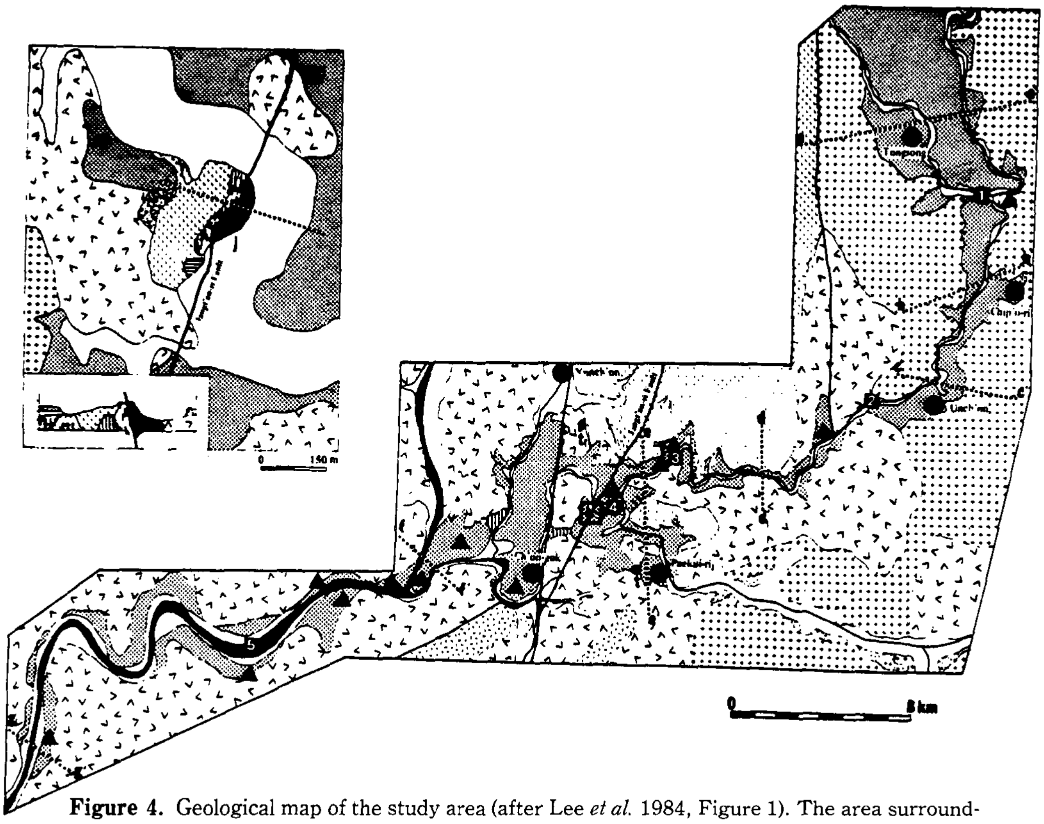

Figure 4. Geological map of the study area (after Lee *et al.* 1984, Figure 1). The area surrounded by solid square is enlaged on the upper left inset. For the names of towns (solid circles), see Figure 1. For the gradient of the basalt plain and river, compare the number on this map and Figures 7 and 8. a—a' to g—g' indicate profile lines where cross-sectional profiles of the basin were taken (see Figure 5.

central eruptions occurred along the Changt'an-ri Fault, resulting in massive deposition of green tuff and/or tuff breccia in the central part of the valley. There were also lava flows as evidenced by outcrops of tholeiite and basalt, which were named the T'onghyon and Changt'an-ri Basalts, respectively (Lee *et al.* 1983). These are sometimes referred to collectively as the Old Basalt (Lee 1983). K-Ar determinations suggest that these activities occurred ca. 90 MY ago. Although stratigraphically 'older', the T'onghyong Basalt is dated to 89.5±4.5 MY, and is thus chronometrically 'younger' than or contemporaneous with the Changt'an-ri Basalt (94.2±4.7 MY) (Yi 1984a, 1984b). A single fission-track date of 52±2 MY indicates a mid-Tertiary age for the tuff breccia deposits that Lee (1983) named the Chijang-pong Acidic Volcanic Rocks. However, as these are intruded by the Changt'an-ri Basalt (Lee *et al.* 1983), there true age should be older than ca. 90 MY.

Third Stage

The third stage is characterized by long-term erosion of preexisting rocks beginning in the late Cretaceous and continuing into the Quaternary, and by the deposition of the unconsolidated gravel-sand beds of Paekui-ri Formation. During this episode, there appears to have been some small-scale volcanic activity of late Tertiary age, as indicated by a K-Ar date of 2.9±0.3 MY obtained from a weathered basalt boulder hauled from the valley floor onto the top of the plain for construction purposes (Yi 1984a, 1984b). Outcrops of Paekui-ri Formation are exposed beneath the younger lava beds of the next

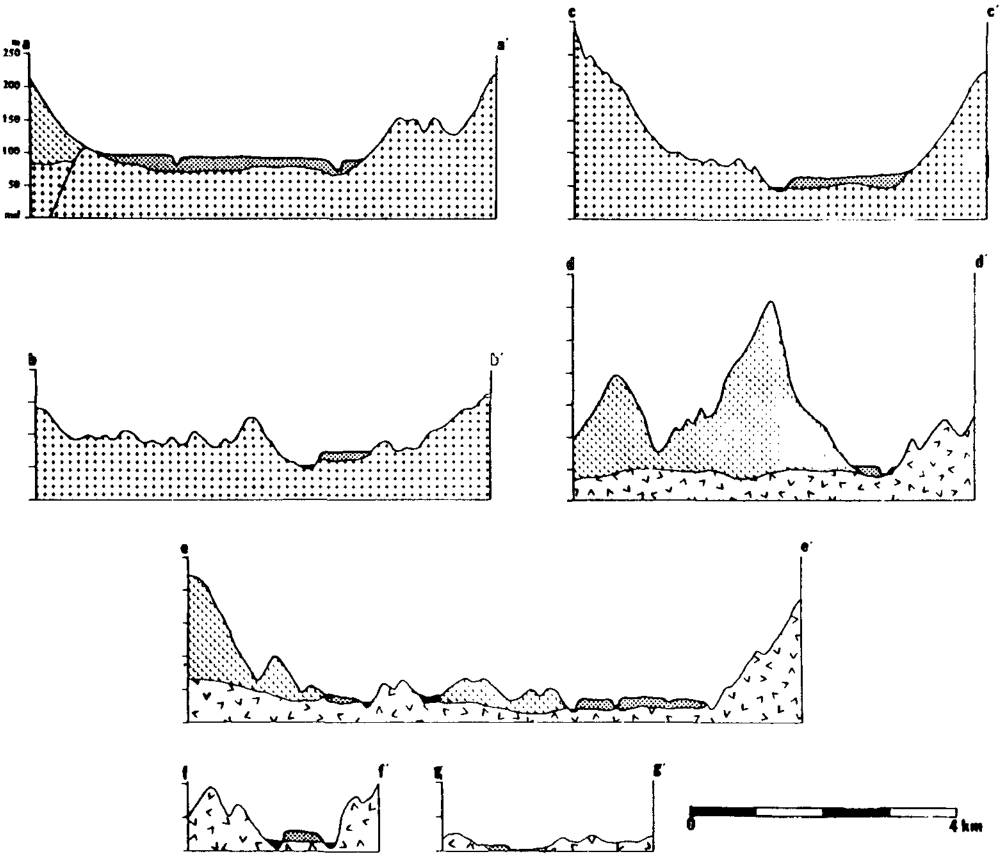

Figure 5. Cross section profiels of the Imjin River valley. For the locations of profiles, refer to Figure 4.

stage. They are most extensively exposed aroung Chong-gok-ri and Paekui-ri along the drainages. The Paekui-ri Formation is well-stratified, and has a thickness of from 2 to 7m. Occasionally, the top portion of the formation appears reddish black in color as a result of oxidization due to contact with hot, molten rocks. The lithological composition of the gravels of the Paekui-ri Formation reflect the local geology (cf. Table 1), and raw materials for lithic manufacture were obtained from its outcrops by early hominids (Yi 1984b).

Fourth Stage

The final stage is marked by renewed volcanism and lava flows of late Quaternary age, which led to the formation of a basalt plain within the valley system. Erosional cycles of late Pleistocene and Holocene age complete the geological sequence. Basalts overlying the Paekui-ri Formation are themselves capped by alluvial sediments in many cases; these have been designated the Chon-gok Basalt by Lee and others (1983). A maximum of six lava flows are recognizable from the matrix of Chon-gok Baslt within the area shown in Figure 4. Lee (1983) recognized that a single sheet lava formed the basalt plain from around the town of Chongok-ri to near Changp'a-ri (Figures 1, 4 and 5). This major flow is the third one from the bottom at localities where all six flows are arranged in stratigraphic sequence. Petrological and chemical analyses indicate there are no significant differences in lithological composition among the six lava beds, all of which are of alkali-olivine baslt (Lee *et al.* 1983).

Figure 6. The Hant'an River. The river flows along the structural joint of Precambrain gneiss (left side of the valley) and Quaternary basalt (right). Photo taken at Kosok-chong.

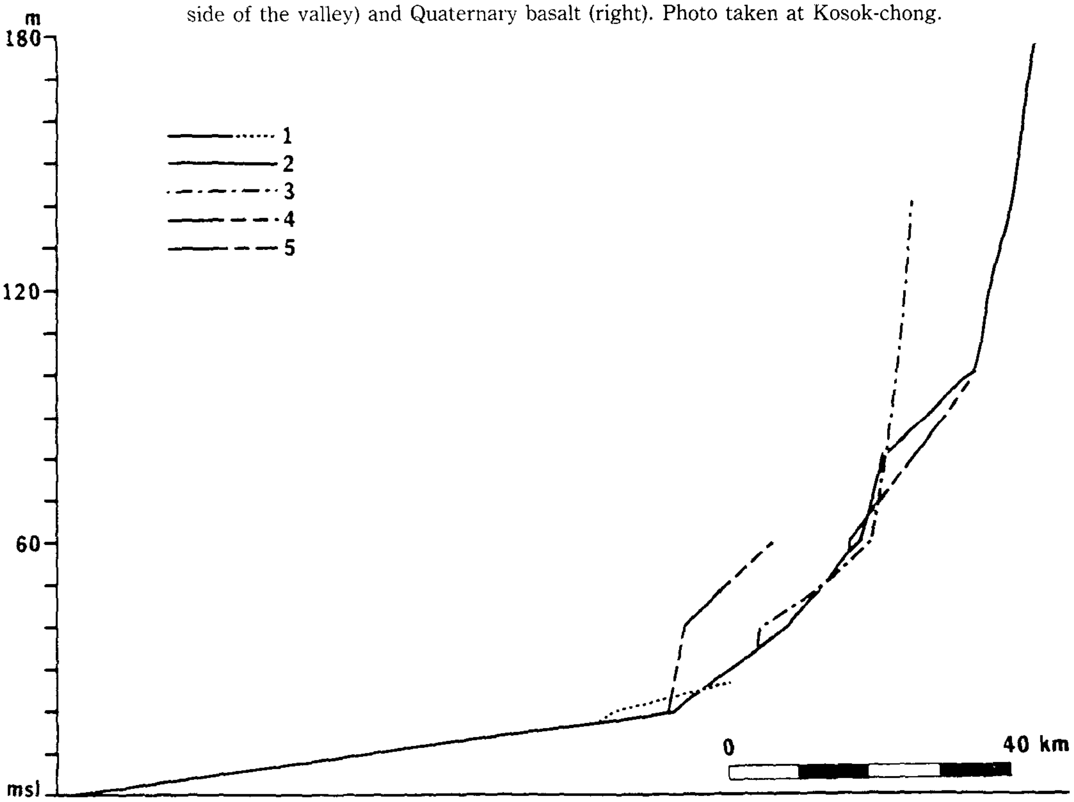

Figure 7. Longitudinal gradient profile of the Imjin River and its major tributaries. (1) Imjin River; (2) Hant'an Rier; (3) Yongp'yong-ch'on; (4) Shin-ch'on; (5) P'och'on-ch'on.

Table 1. Physical and lithological characteristics of diverse fluvial gravel deposits. Lithological composition was measured for 30 sets of 100 random samples of rock-size particles from each deposit, while size composition is based on measurements obtained from 7 samples from each. Size distribution, roundness and flatness of cobbles are based on measurements of 7 sets of 100 random sample for each deposit.

Deposit	Lithology (%)				Size Composition (by weight)				Physical Properties of Cobbles		
	Basalt	Quartz/ Quartzite	Granite	Others	>256(mm)	>64	>4	<4	Size	Roundness	Flatness
Paekui-ri	2.8*	8.5	42.6	43.7	15.5	72.6	8.7	3.2	134.6	436	2.26
Formation	0.5-6.6**	7.0-15.0	5.0-56.5	6.0-47.0	10.0-24.2	70.0-83.5	5.1-16.7	1.5-6.8	129.4-149.3	146-930	1.24-3.30
	0.11***	2.3	10.3	4.7	3.5	9.6	2.7	1.0	36.6	58.7	0.46
Fluvial Bed	92.2	0.3	2.8	4.7	6.2	42.5	38.2	13.1	109.7	414	1.89
on the Basalt	74.0-100.0	0.0-1.0	0.0-14.5	2.0-16.0	2.4-13.0	33.6-57.0	28.7-45.6	6.4-19.8	93.6-120.5	100-963	1.30-2.94
	4.26	0.01	1.08	13.6	3.5	9.4	3.9	2.7	49.6	74.5	0.37
Pleistocene	0.6	2.3	87.7	9.8	13.7	66.4	14.3	5.6	106.7	320	3.16
Terrace Deposit	0.0-1.5	1.0-6.0	66.5-98.5	2.0-13.0	11.3-22.8	46.8-26.7	12.0-23.4	1.2-10.7	87.4-113.5	240-670	1.35-4.20
	0.13	0.74	9.23	3.43	2.5	12.7	2.9	1.4	39.6	41:5	0.44
Holocene	85.4	3.6	6.0	5.0	18.9	68.3	8.8	4.0	104.3	496	2.15
Terrace Deposit	80.0-97.0	0.5-9.5	0.0-19.0	1.5-13.0	14.0-26.8	57.7-75.4	6.3-18.9	1.8-8.6	88.6-127.1	186-890	1.05-3.87
	7.4	1.52	3.26	2.99	2.0	6.6	2.5	1.7	38.3	88.6	0.58
Modern	86.0	3.8	7.5	2.7	16.7	58.0	16.6	8.7	109.0	403	1.76
Floodplian	79.0-98.0	0.0-11.0	1.5-1.30	1.0-6.5	9.6-23.6	39.7-645.	10.8-23.6	4.3-16.7	69.8-132.0	120-940	1.26-3.35
	10.02	1.98	2.05	1.63	4.2	12.4	2.4	1.2	53.1	75.3	0.54

* mean ** range *** Standard deviation

Individual flows of the Chon-gok Basalt are separated from each other by a thin (<50 cm) layer of "clinker", best represented between the third and fourth flows. Each flow consists of a porous and a compact part as a result of differential cooling of the upper and lower portions of the flow. Occasionally small-scale ropy structures and pillow lava beds are seen in the basalt matrix. On average, the thickness of the Chon-gok Basalt ranges bewteen 10 and 20m. However, near the town of Tongson, there are localities where it is more than 40m thick and the basal rocks underneath the basalt have not yet been exposed (Figure 6). In general, thickness decreases toward the estuary and increases in upstream areas.

K-Ar determinations obtained from the Chon-gok Basalt (Yi 1984a, 1984b; cf. Figure 11) and geomagnetic measurements (Lee 1983; Lee *et al.* 1983) both indicate that the lava flows took place during the Bruhnes Normal Epoch (<0.7 MY). The position of the Virtual Geomagnetic Pole during the lava flows is calculated to be 82.4° N and 80.6° E from 100 samples analyzed by Y. S. Lee (1983), 84° N and 163° W from 17 samples studied by Lee nd others (1983) and 73° N and 135° W by P. Kim (1964). Thermoluminescence dates obtained from the sediment matrix overlying the Chon-gok Basalt indicate that the major lava flows in the basin occurred prior to ca. 45,000 BP (cf. below).

Changes in thickness and in the number of lava beds indicate that the flows originated in the upstream areas of the Hant'an River. An examination of the direction of pipe structurs within the lava beds also supports this conclusion (Lee 1983). However, the exact source area of the Chon-gok Basalt can be only inferred indirectly because of the current political obstacles to conducting field research in this area.

Above the Military Demarcation Line, two volcanic craters within small cinder cones exist. Since they are arranged along an extension of the Jangt'an-ri Fault which runs along the center of the valley (Figures 4 and 5), it is speculated that lava flows occurred in the form of central eruption as the old Mesozoic fault was reactivated due to renewed tectonism (Lee *et al.* 1983). The crater of Absan is suspected to be the principle source for the Chon-gok Basalt, since lava flows from the other yet-unnamed crater travelled northeast toward Wonsan. From large-scale topographic maps, lava flows traversed a distance of ca. 155 km from the suspected source of Absan when measured along the current drainage, covering an area of approximately 125km^2.

Lee and his colleagues (1983) suggested that the Ch'ugaryong Valley is a failed arm of the Y-shaped triple rift system (i.e., an aulacogen) which developed in the central northern part of Korea. Based on their findings, a scenario of the geotectonic history of the valley can be summarized as follows:

1) During the Cretaceous, three spreading sites developed by tectonism in the central northern part of Korea. The Ch'ugaryong Valley is one of these three, which coalesced at Wonsan. In this valley, the axis of rift corresponded to the Changt'an-ri Fault, which is one of many structural lines of the Ch'orwon-Yonch'on Fault System established during the Taebo Orogeny;
2) By the end of the Cretaceous, minor faults paralleling the axis of the rift resulted in the enlargement of the valley floor. As a consequence, the linear belt of Ch'ungaryong Valley system was established. Tectonic activity in the valley was relatively limited, so that it remained an aulacogen. Full-blown rift valleys were formed in the remaining two arms of the rift system;
3) Following Cretaceous tectonic activities, the basement of the valley was gradually uplifted and eroded. Differential erosion of the Jurassic granite brough about the formation of small basin-like feature in the middle portion of the valley system; and
4) After a long period of erosion, volcanic activities resumed during the Pleistocene, which resulted in the formation of the basalt plain.

It should be mentioned that the spreading of the valley floor suggested in this scenario is based on the rather flimsy evidence of the linear arrangement of the two late Cenozoic craters and the symmetrical distribution of Cretaceous volcanic rocks at sharp angles to the axis of the Jangt'an-ri Fault (Figures 4 and 5).

Y.S. Lee (1983) refutes the preceeding 'rift valley hypotesis' on the basis of his contention that 59 geomagnetic samples of the Old Basalt show the same demagnetization level, implying that they were formed during the same, short geological episode. He thinks that the formation of the valley system was a result of the development of complex fault systems in the area. He agrees with others that the most critical stage in valley formationis related to late Cretaceous volcanic activities which led to the deposition of tuff breccias, or the Chichang-pong Acidic Volcanic Rocks. But he sees volcanic eruption as due to rejuvenation of a right-lateral strike slip fault which connects Seoul and Wonsan, followed by the formation of two block faults (the Taekuang-ri and Tongson Faults) which defined the graben in which Cretaceous volcanic rocks were deposited (Figures 4 and 5).

In sum, there is an on-going debate about the formation processes of the valley, and its complex geological history is not yet fully understood. Limitations imposed on Korean researchers to study this area due to military reasons and the inaccessibility of the northern portion of the valley are critical problems which hamper advances in our understanding of the geological history of the area. For the moment, a solid judgement cannot be made regarding which hypothesis is more likely to be correct.

DESCRIPTIVE MORPHOLOGY OF THE BASALT PLAIN

The Basalt Plain

Since the current drainages of the basin cut into the lava beds, well-defined terrace morphology is developed along the channels (Figures 5 and 6). In this case, the terrace system is structural in origin; its primary morphology was determined by the lava flows. Fluvial erosion has shaped the current linear basalt plain in a process which is still continuing today. Figure 7 shows the longitudinal gradient profiles of the major channels which have shaped the morphology of the basin.

The surface of the linear basalt plain appears quite flat, but there is of course a slow and steady change in elevation. While the Absan crater is located at an elevation of 453 m above mean sea level, at the northernmost point accessible by civilians below the DMZ (which is about 10 km distant from Absan), the suface of the plain lies at about 180 m. Around Chon-gok-ri, which is about 50 km downstream from this point along the Hant'an, the elevation is about 50 to 60 m. The basalt plain terminates another 50 km downstream from Chon-gok-ri at an elevation of ca. 15 m (Figure 8).

The overall pattern of change in elevation of the surface of the plain is gradual, but at some

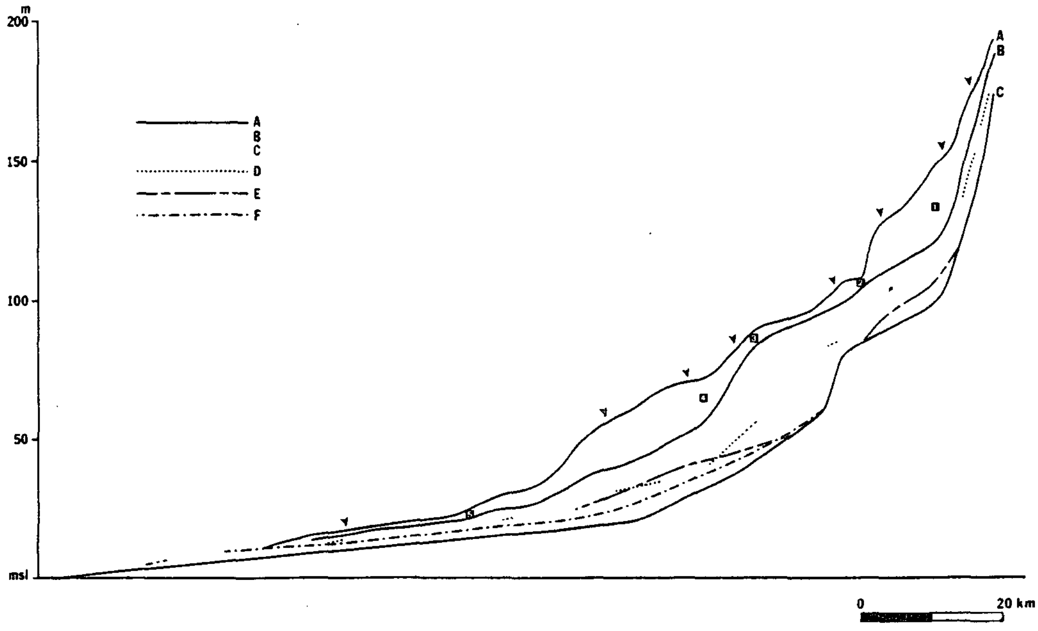

Figure 8. Longitudinal gradient profile of Hant'an-Imjin River channels and other related features. (A) surface of the basalt plain; (B) surface of the lava beds; (C) current channel level; (D) Pleistocene terrace; (E) pre-lava flow water level (Paekui-ri Formation/pre-Cambrian basal rocks); (F) Holocene terrace. For the location of numbers, see Figure 4. Arrowheads indicate locations where cross-sectional profile of the river valley were made (see Figures 4 and 5).

points it drops off more or less rapidly. Such 'break points' are recognizable on the longitudinal profile of the surface gradient of the plain, indicated by line A in Figure 8. On this diagram, up to point 2, the elevation decreases rapidly at an average rate of ca. -4.3 m per kilometer. Between points 2 and 3, however, the gradient value changes at about -1 m per kilometer. The gradient increases between points 3 and 4, where the elevation drops 20 m in a distance of ca. 8 km. There is a local increase in elevation between points 4 and 5, but on average it declines at ca. -1.4 m per kilometer. From point 5 to the terminus of the basalt, elevation declines steadily at a rate of ca. -0.6 m per kilometer.

This pattern of change in elevation of the basalt plain can be explained by considering two components which together define its morphology. One is, of course, the topography of the basalt bedrock itself which determines the basal morphology of the plain. The other is the morphology of the sediment coverings over the basalt bedrock, from which the elevation of the surface of the plain is measured.

Elevational change of the basalt bedrock is shown by line B of Figure 8. The thickness of the basalt can be determined by the distance between lines B and F, the latter indicating the ancient valley floor prior to the lava flows. In downstream areas, line F indicates the contact between the Paekui-ri Formation and the Chongok Basalt, or the level of the paleochannel bed immediately prior to the lava flows. In upstream areas, the basalt directly overlines the basal rocks. Although outcrops of the Paekui-ri Formation occur on occasion, erosion of the Chongok Basalt has not yet progressed sufficiently, so that it is hard to trace the valley floor along the middle portion of the Hant'an River.

There are several major points where the surface topography of the basalt changes rather abruptly. Overall, the pattern of change consists of an alternation of rapid and slow decreases in elevation. As far as thickness is concerned, rapid decrease at point 1 is followed by gradual increase up to point 3. Thickness decreases again between points 3 and 4, but there is virtually no change in thickness beyond point 4 to the end of the flow. The morphologhy of the lava beds must have a direct relationship with the shape of the ancient valley, of course, since, other things being equal, factors of width, depth and valley gradient determine the pattern of movement of the fluid-like lava.

As seen in Figures 3 and 4, point 1 should have been the first major choke point for the lava flows. Up to this point, the gradient of lava more or less parallels that of the basal rocks, and channel width is relatively stable. However, the sudden decrease in the width of the valley opening at this point should have allowed only small amounts of lava to pass through, resulting in decreased thickness in the lava beds downstream. But as the gradient of the valley floor becomes steeper between points 2 to 3, the lava beds get slightly thicker. The rapid drop in both gradient and thickness after point 3 is related with the increase in channel width since at this point the lavas had to cover a larger area. However, since only one flow advanced this far, and since there is not much downstream change in channel morphology, there are only gradual declines in gradient and thickness from point 4 onward.

It should be remembered that the drainage system was in place and functioning all the time that the lava flows were being deposited, and that it was merely shoved from one side to the other. The river probably soon began to cut down through the basalt to form the current, relatively entrenched drainage pattern. Nevertheless, the formation of relatively hard, impermeable basalt plain within a narrow valley system insured the appearance of a basin of sedimentation. The sediments which cap the

Chon-gok Basalt and in which artifacts occur appear chiefly fluvio-colluvial in origin but include some *in situ* weathering material of basalt bedrock (cf. below). As was the case with the basalt bedrock, the thickness of sediment varies throughout the plain as indicated by changes in the vertical distance between lines A and B in Figure 8.

Variation in the thickness of sediment over the basalt can be easily recognized from the gradient profiles (Figures 8 and 9). According to thickness, they can be grossly divided into three or four zones. The thickness, they be grossly divided into three or four zones. The thickest sedimentary deposits occur above point 2, where in general deposits are 10 to 15 m thick. Between points 2 and 3, however, sediment coverings rarely exceed 2 m and the eroded surface of basalt bedrock is exposed in many places. Thick deposits appear again beyond point 3, but from point 5 to the terminal point of the lava flows, deposits are only 2 to 3 m thick. Sediment coverings occur continuously for another 5 or 6 km beyond this terminal point over Precambrian rocks at approximately the same elevation as the basalt. Ultimately, they merge with Holocene terrace deposits near the town of Munsan.

Stream Flow

The variable thickness of the sediment cover at different parts of the plain of course is dependent upon variation in the smount of sediment input and output. Since in this case fluvial activity is the only major agent of basin sedimentation involved, the variation is a direct reflection of the different magnitudes of fluvial erosion and deposition at different parts of the plain subsequent to the lava flows.

Assuming an equal amount of stream discharge at any point in the drainage, the type of stream flow can be said to be largely determined by channel morphology. Since the rate and amount of basin sedimentation are determined by the flow type, given the same degree of susceptibility of the bedrock to erosion and transportability of materials derived from erosion throughout the course of the flow, varia-

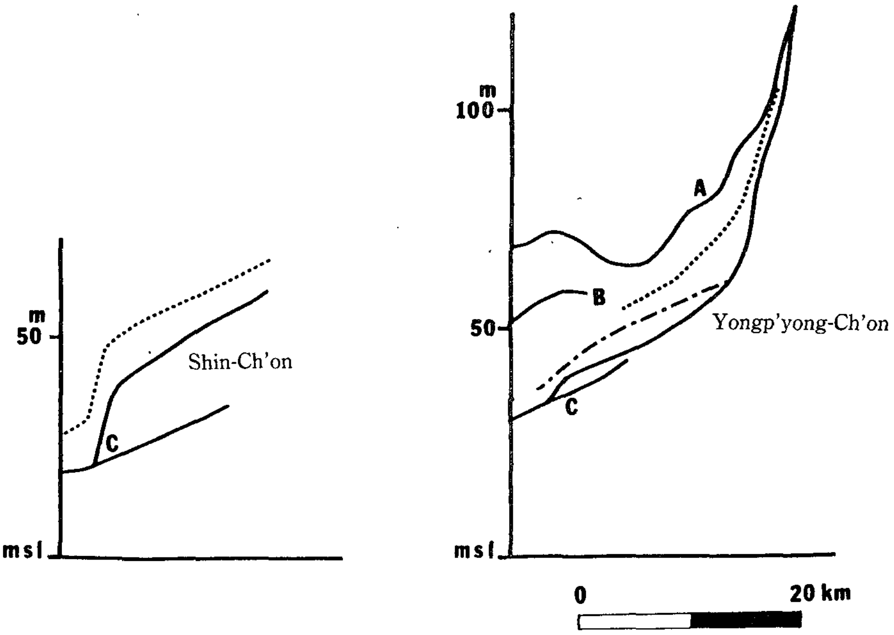

Figure 9. Longitudinal gradient profile of Yongp'yong-ch'on and Shinch'on river channels and other related features. For the legend, see Figure 8.

tion in sediment deposition is directly related to variation in channel morphology. This means that in general there is a higher probability of thicker deposits accumulating where valley floors are relatively wide and bedrock gradient is less steep and where, in consequence, stream flows with reduced velocity.

It is not, therefore, an accident that thicker deposits occur up to point 2 and below point 3, where the valley floor is relatively wide. At the same time, shallow sediment coverings between points 2 and 3 can be explained by the high susceptibility of these deposits to erosion. Here, the valley floor is extremely narrow, seldom exceeding 100-200 m. Since lateral movement of the channel is defined by the width of the valley floor, such a narrow opening implies that any material which might have been deposited there would have had a high probability of being rapidly eroded and carried away. Although a decrease in the bedrock gradient would have reduced the velocity of the flow, it would not have been able to compensate for the increase in erosion due to narrowed channel width. From around point 5, valley walls are less steep and low-lying hills surrounding the drainage provide pockets of lowlands. They could have functioned as overbank reservoirs where sediments would have tended to accumulate during floods, thus contributing to the overall thinning-out of the alluvial deposits over the basalt plain in downstream areas.

Although variation in channel morphology as determined by the morphology of the ancient valley system and lava flows is an important factor in causing variation in sedimentation, it is not the only factor. For one thing, the amount of erosion which took place after the establishment of the current drainage pattern should be taken into account. Today, there are more second and third order streams in the basin below the confluence of Imjin and Hant'an than above it, so that the rate of erosion is accelarated there. Also, the extreme thickness of deposits up to point 2 may be related in part to the fact that in this area of the basin, the valley walls are of Jurassic granodiorite, which is much more susceptible to mechanical weathering than rocks of more compact textures in other parts. Or it may be that lava flows did not bring about significant changes in the hydrological regimen of the upstream areas (cf. below). All these variables are difficult to quantify or illustrate, but their potential roles might have been important, either singly or in combination, in determining currently observesd geomorphology and topography.

PALEOECOLOGY OF THE HOMINID OCCUPATION

Paekui-ri Formation

The pattern of basin sedimentation discussed above is of course a phenomenon which occurred during one stage of the life cycle of the Imjin drainage system. For the area indicated in Figure 4, channel courses have remained virtually unchanged from before the lava flows till today. Lava flows might have temporarily blocked the streams, but they failed to cause permanent changes in the drainage system of the basin (cf. below). Thus, the current drainage network can be called a superimposed system—one which is rejuvenating an older system covered by lava flows (cf. Figure 11).

Although the basic drainage system could be as old as the basin itself, only fragments of the geological record exist that pertain to the 'pre-lava flow' drainage system. The earliest evidence of the paleohydrological system of the basin is know from outcrops of the Paekui-ri Formation, which is unconformably overlaid by the Chon-gok Basalt. The limited occurrence of the outcrops of this formation makes it difficult to determine its extent and spatial distribution with accuracy.

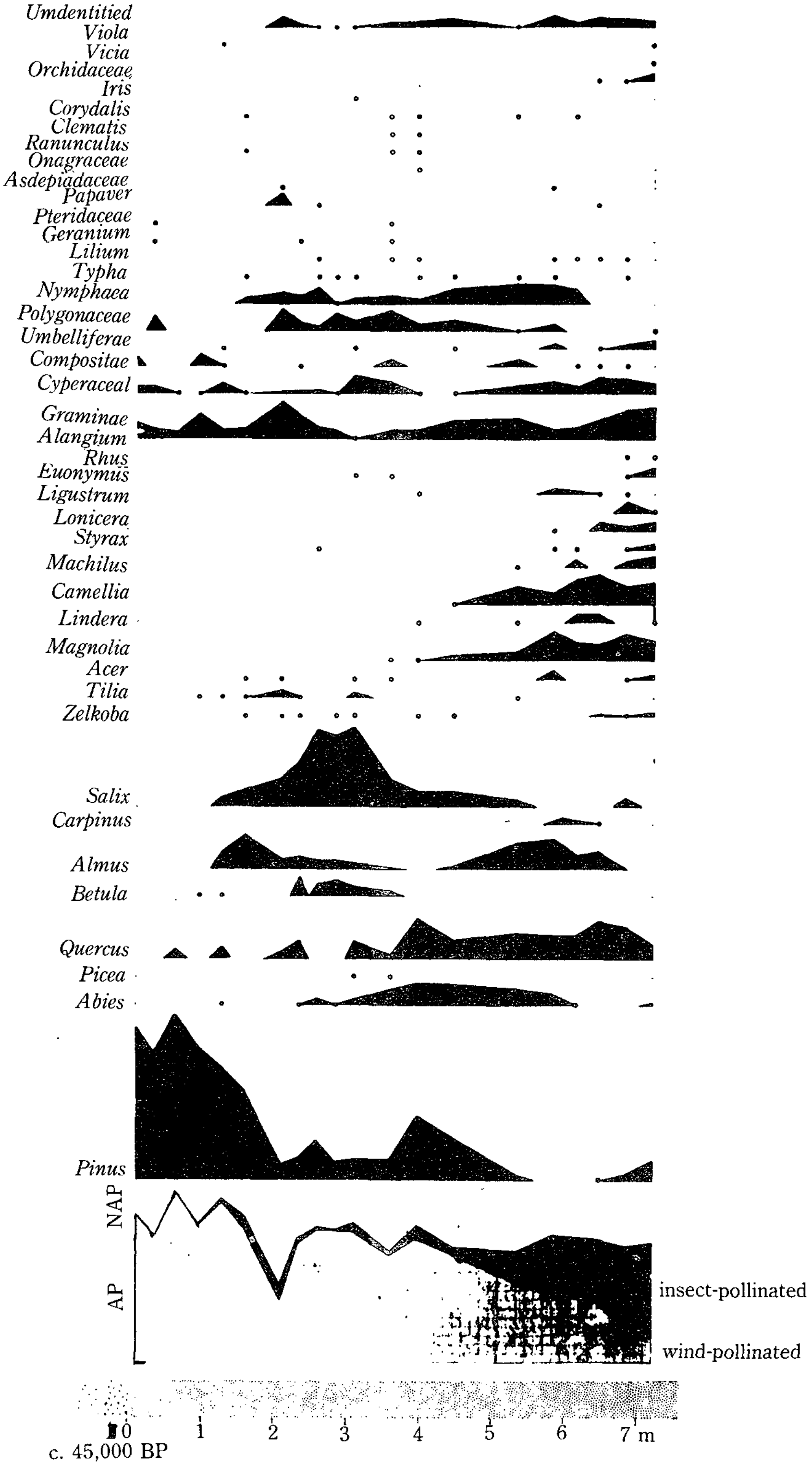

Figure 10. Pollen profile indicationg palaeoclimtic changes between the lava flows and large-scale basin sedimentation. The location of the section sampled is indicated in Figure 1.

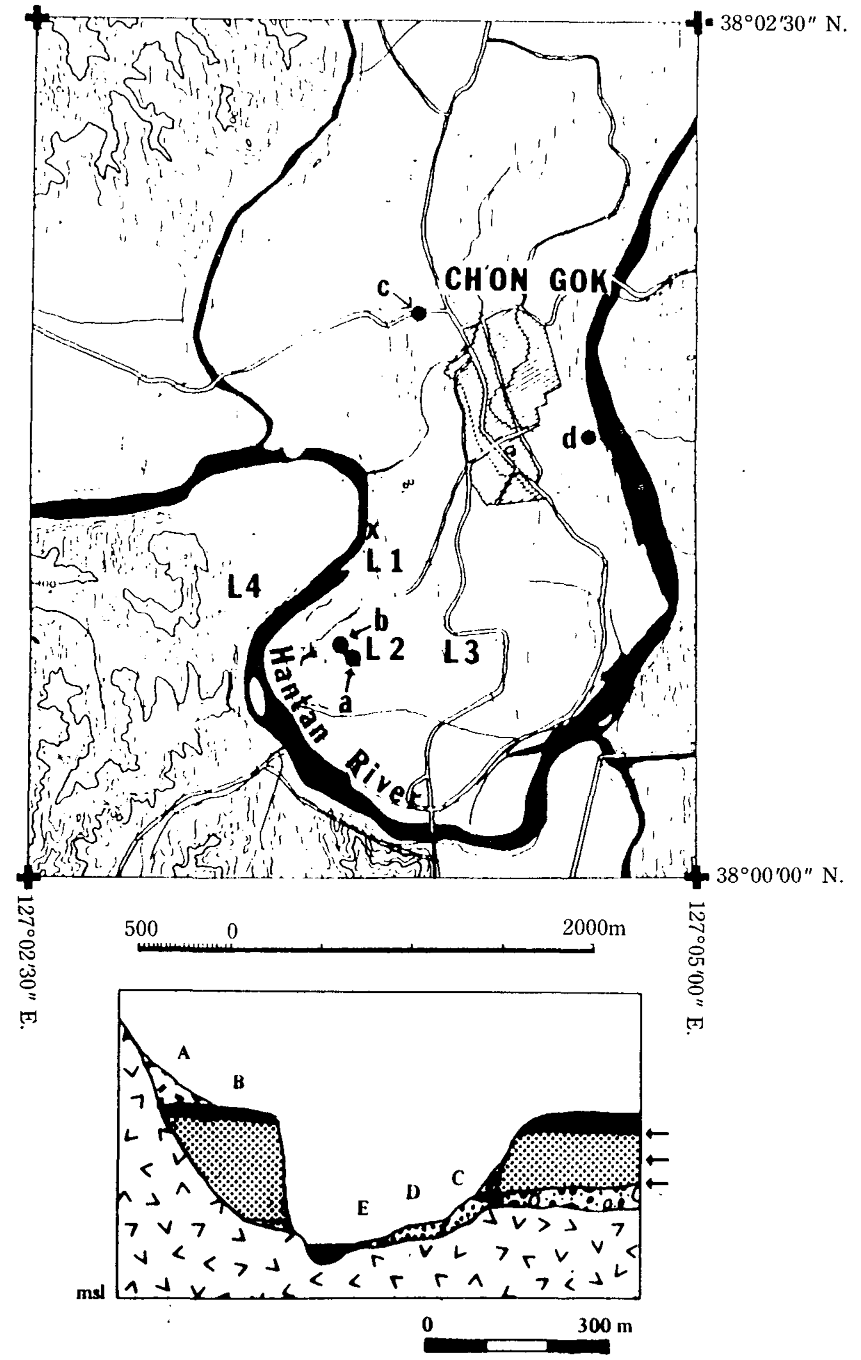

Figure 11. Topographic map of Chong-gok-ri area (upper) and idealized cross section of the Hant'an River valley (lower). Upper: L1-L4: archaeological localities; a-d: localities where sediment profile was observed (see Figure 12); x: location of K-Ar samples. Lower: arrows: relative stratigraphic position of K-Ar samples which produced dates of 0.6±0.2 MY, 0.4±0.1 MY, and 0.12±0.15 MY from bottom to top (Yi 1984a). For the legend of the lower diagram, see Figure 4, except A (colluvium and/or talus) and B ("Red Clay"). Terrace C covers outcrops of the Paekui-ri Formation. Terrace D possibly consists of two components of different ages, but differentiation is difficult at this locality. Its age is estimated to be c. 700 AD from archaeological evidence. E indicates the modern floodplain of the Hant'an River.

A typical example of a Paekui-ri Formation outcrop consists of well-stratified overbank silt layers and interbedded sands and gravels. Its thickness usually does not exceed 2 to 4 m, but can sometimes reaches 7 or 8 m. The top silt layers of the formation sometimes reveals buried palaeosol horizon in dark grey colour whose best examples are seen in the vicinity of the Chon-gok-ri localities. The morphological and lithological characteristics of the Paekui-ri gravels are shown in comparison to other fluvial deposits of the basin in Table 1.

The well-stratified nature of the formation suggests that the overall hydrological environment in which deposition occurred was a relatively quiet, low-energy one. Similarity in the morphological characteristics of Paekui-ri gravels with those of younger channel beds (Table 1) also implies that the hydrological environment of the basin had not been changed significantly for a considerable period of time. Sporadic occurrences of erratic boulder-size rocks within generally well-sorted gravel beds underscores this point. This pattern of gravel composition is commonly seen in modern fluvial deposits of Korea where extreme seasonality in discharge gives otherwise quiet streams the enormous kinetic energies to carry such large materials by traction.

Channel-Blocking and Lacustrine Formation

When lava flows originating in the upstream area of Hant'an River reached a confluence of channels, depending on the elevation and gradient of the tributary, lava flows would have tended to travel against the tributary, as seen along the Yongp'yong-ch'on (Figures 4 and 9). As tributaries are blocked by lava flows, normal channel flow stopped temporarily and tributary basins are transformed into lakes. The cooling down of subsequent lava flows as they plunged into these lakes would have occurred much more rapidly than under the normal circumstances. In such cases, distinctive 'pillow' lava beds developed. A good example of pillow lava is seen at the confluence of the Hant'an and Yongp'yong-chon Rivers, but smaller ones occur at serveral other localities.

By blocking the normal flow pattern of drainages, the formation of lava dams at confluences brought about a change in the hydrological regimen of the drainage system as previous channels are transformed into lakes. A return to the 'normal'state of the drainage system would have occurred when channels were reopened, a condition which could have occurred under many possible circumstances. Probably the most common scenario would have been when sedimentation of the lava-dammed lake raised the elevation of the lake bed to a point that it began to exceed that of the dam itself. There are indicatins that this happened in at least two tributaries of the Hant'an, the Yongp'yong-ch'on and Shin-ch'on Rivers, but the evidence is much better in the former case, so that discussion will concentrate on data gatherd along the Yongp'yong-ch'on.

From the confluence of the Hant'an and the Yongp'yong-ch'on, the lava flow traveled about 5 km against the flow of Yongp'yong-ch'on (Figures 4 and 9).From this point to the headwaters, well-preserved remnants of depositional terraces are seen for a distance of about 15 km. There are at least two cycles of terrace formation along these streams. As will be discussed later, the lower terrace is developed as a strath terrace which cut into the older terrace deposits. It is difficult to estimate what the total thickness of the terrace deposit might be. However, at present the upper terrace lies 20 to 25 m above the valley floor.

The upper terrace deposit consists of two parts. The top 5 to 10 m is comprised of well-stratified, interbedded fluvial sand-gravel beds later covered by angular, coarse-grained fragments resulting from the granular disintegration of crystalline rocks of the surrounding granite hills (i.e., grus). As seen in Table 1, the overall morphological characteristics of the gravels do not deviate greatly from those of other fluvial deposits of different ages, but they are dominated by granite cobbles with little basalt and equally scarce quartz/quartzite. Below the alluvium is a massive (> 20 m) lacustrine silt bed, dark grey green in color but with some oxidized portions. The results of physical analyses of sediment samples from the lacustrine matrix are indicated in Table 2. In addition to the large clay-silt component of the sediments, a large amount of mica and organic materials and the existence of only two mineral grains of mica and quartz, all point to its lacustrine origin. Pollen samples from these deposits were also obtained and analyzed (Figure 10). Since these deposits formed immediately after the lava flows and prior to the formation of the artifact-bearing "Red Clay" beds over the basalt plain (cf. below), palynological data should provide information pertinent to the paleoclimatic conditions prevalent during the hominid occupation of the basin (cf. below).

That these terrace deposits consist of two components with different sedimentological characteristics indicates that its formation took place under two different sets of environmental conditions. It is evident that the lower, lacustrine portion resulted from the formation of the lava-dammed lake in this tributary basin. The top of the lacustrine beds coincides with an elevation of ca. 55 m, which is the maximum height of the lava dam (Figure 9, line B). Thus, the sand-gravel beds overlying the lacustrine portion must have formed when normal channel flow resumed again after breaching of the lava dam. A thermoluminescence date of 45,400 ± 5,500 BP was obtained from a thin (20-50 cm) silt layer which separates the lacustrine and sand-gravel matrices (Figure 10), and which indicates the date of the reopening of the channel.

Basin Sedimentation

While massive fluvio-lacustrine depsotis were forming in the tributary basins, the sur-

Table 2. Mechanical analysis of sediment samples

Name	Number of Samples	Median (mm)	Mean (mm)	Sorting (%)	Skewness	Kurtosis	Size	Color	Roundness	Inclusions (%)		
										Organics	Mica	Quartz
Lacustrine Bed on the Basalt	3	0.046-0.084	0.064-0.082	4.6-10.8	0.420-0.910	0.324-0.380	clayey silt	olive gray (5 Y)	subangular	<1-3	absent	absent
Lacustrine Terrace Deposit	5	0.033-0.070	0.039-0.080	4.8-8.0	0.385-0.780	0.234-0.300	clayey silt	olive gray (5 Y)	subangular to subround	2-10	35-65	33-60
Yelow Clay	3	0.002-0.004	0.002-0.004	2.6-4.3	0.265-0.964	0.101-0.110	clay	yellow (10Y to 10YR)	massive	absent	absent	absent
Red Clay	6	0.002-0.008	0.004-0.019	4.1-18.6	1.125-1.950	0.143-0.165	silty clay	red (5 YR)	subangular	present	present	present
Fluvial Bed between Red and Yellow Clay	4	0.061-0.510	0.295-0.623	4.4-26.1	0.211-0.197	0.265-0.431	silty sandy to sandy gravel	yellow (10YR to 5Y)	massive	present	present	present

face of the basalt plain should also have undergone transformation as weathering of the bedrock and fluvial erosion and deposition took place. Profiles of sediments covering the basalt revealed in road-cuts and archeological excavations indicate that this sediment cap consists of three major components: (1) the "Red Clay", (2) the fluvial channel bed and (3) the "Yellow Clay" (from top to bottom—cf. Figure 12). This stratigraphic generalization is based largely on observations made in downstream areas southwest of the town of Unch'on (Figures 1 and 4). In the upstream reaches of the Hant'an River, the extreme thickness of the sediement covering and problems with conducting field observation there made it difficult to derive a generalized stratigraphy.

The terms of "Yellow Clay" and "Red Clay" as used here are not with formal pedological definitions. These terms are mere direct translations of common Korean terms used to indicate clay-rich sediments of bright red and yellow colors occurring in the basin.

The "Yellow Clay" is a type of residual clay, derived from the underlying basalt and rich in montmorillonite (Lee 1984). It directly overlies the basalt, and is (usually) overlain unconformably by fluvial sand-gravels of 0.5-2 m in thickness. Sometimes the basalt is directly overlain by sands and gravels in areas where the "Yellow Clay" was removed by erosion. However, not only is the boundary between the "Red Clay" and the fluvial channel bed sometimes difficult to define, in many cases they also demonstrate a time-transgressive stratigraphic relationship. Lamina of fluvial channel deposits are at some places 'inserted' into the "Red Clay", indicating that they were formed by the same fluvial mechanisms (Figure 12; also see Tables 1 and 2 for mechanical properties of their samples). At higher elevations, the sandgravel bed is missing between two

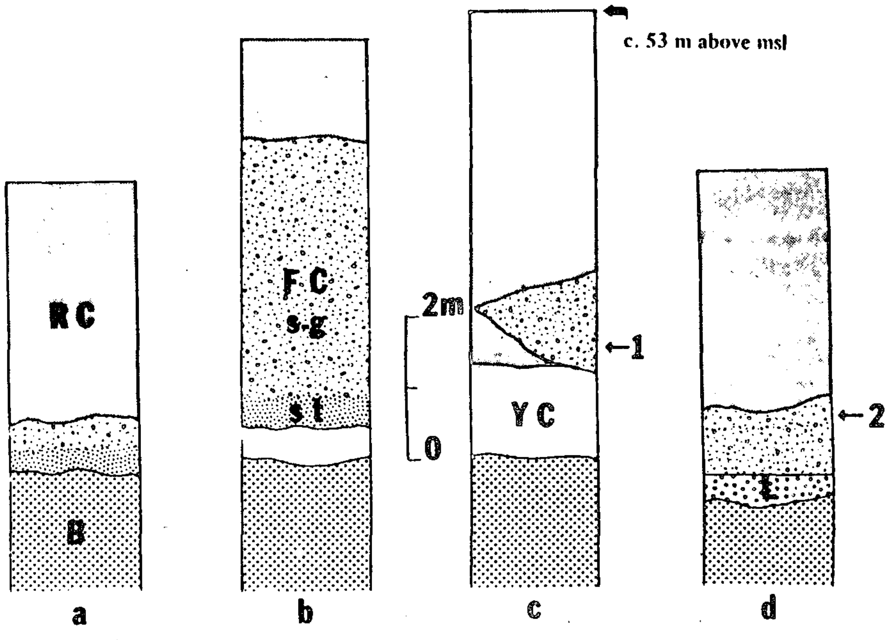

Figure 12. Schematic diagram of sedimaent profiles observed around Chon-gok-ri. For exact location, see Fiugre 11. Profiles a and b are based on information provided by boreholes done in 1982 by Chon-gok-ri research teams (Lee 1984). Numbers 1 and 2 indicate stratigraphic positions of two thermoluminescence dates of 46,050 ± 5,430 (1) and 48,200 ± 6,690 BP (2). RC: "Red Clay"; FC: fluvial channel bed; s-q: snad gravel; st: silty; YC: "Yellow Clay"; L: lacustrine deposit; B: basalt.

clayey beds. In such cases, continued leaching has obscured their boundary.

Two thermoluminescence dates of 46,500 ± 5,430 and 48,200 ± 6,690 BP obtained from the silt layer of the fluvial channel bed (Figure 12) indicate the fluvial sedimentation over the basalt occurred at approximately the same time as channel reopening in the Yongp'yong-ch'on basin (cf. above). Artifacts found over the basalt plain thus represent hominid activities there at about the time when the bottom of the lavadammed Yongp'yong-ch'on Lake reached the elevation of the baslat plain and stream discharge was returning to the pre-lava flow level. In addition to the chronometric evidence, continuation of the tread of the upper terraces of the Yongp'ong-ch'on basin into the surface of sediment coverings over the basalt plain (Figure 9) provides morphostratigraphic evidence indicating formation by the same depositional agency (i.e., fluvial processes).

The "Yellow Clay" is only poorly developed around the Chon-gok-ri archeological localities, and I have speculated that its formation was completed shortly after the lava flows (Yi 1984a 1984b). At other localities, however, it is extremely well-developed, sometimes reaching several metres in thickness. It seems that the amount of time required to produce this residual clay before the deposition of fluvial sediments should be much greater than previously supposed. The relatively weak development of the "Yellow Clay" around Chon-gok-ri may be the result of fluvial erosion. Given the thickness of both the "Yellow Clay" developed over the basalt and the lacustrine terrace deposit formed in the tributary basin, and three thermoluminescence dates, it can be concluded that the "Yellow Clay" and lacustrine terrace deposit were formed at about the same time over a period of tens of thousands of years up untill ca. 45,000 BP.

While the weathering process was transforming the basalt into the "Yellow Clay", a drainage system developing over the basalt plain appears to have shapped its surface by eroding the basalt and/or the residual clay and by depositing new kinds of sediments. However, the amount of sediment deposited by such a process appears extremely meager, and so far fluvial sediments of stratigraphically comparable age to the "Yellow Clay" have not been identified. If there were any significant fluvial activities on the plain before the large-scale fluvial depositionof the "Red Clay" matrix, they must have occurred in the form of erosion which brought about the differential survival of the "Yellow Clay".

There are some deposits of an age comparable to the "Yellow Clay" developed on top of the basalt. They are greyish yellow silty lacustrine deposits, usually found as small and isolated patches. They appear to have been deposited in the bottom of small ponds developed on the irregular surface of the cooled lava. From visual inspection, the amount of organics and mineral grains in these samples in much less than those from the terrace lacustrine deposits (see Table 2 for physical properties). Where they were later modified by fluvial activities, a stratigraphic unconformity or evidence of secondary deposition is usually found. Their best example is seen around the town of Chon-gok-ri (Figure 11).

While no quantitative data are available to reconstruct change in the amount of water and sediment discharge due to the blocking of the normal flow of the Yongp'yong-ch'on River, the chronometry of the fluvial channel bed overlying the basalt (see above) underscores the importance of the role of this particular channel in basin sedimentation, at least for the downstream areas of the Hant'an River below the confluence. In the upstream areas, however, there are no major tributaries of Hant'an which might have been locked by lava flows. Thus, the volume of stream discharge, at least theoretically, should have been the same before and after the lava flows, which implies that fluvial activities as they relate to basin sedimentation might have had different roles those played in the downstream areas.

The reader should be reminded that the upstream area was covered by at least three more lava flows. The amount of time that it took for these flow episodes to be completed cannot be determined, nor can their combined impact on fluvial activities of the Hant'an be addressed. Although it is difficult to know how watercourses behaved upstream during the period of "Yellow Clay" formation, and whether "Yellow Clay" beds survive there as they do downstream, if fluvial deposits of ages comparable to that of the "Yellow Clay" do exist, given the thickness of the deposits, they may occur in the upstream area.

Nevertheless, throughout the basin, the top portions of the sediment matrix are made up of "Red Clay" of similar physiochemical composition, except where sediments in upstream areas are covered by grus derived from the surrounding granodiorite mountains. There are no stratigraphic breaks recognized in the distribution of the "Red Clay". Such homogeneity in both composition and morphology of the covering fluvial deposit throughout the basin probably means that the major episode of basin filling occurred *after* the reopening of the channel of the Yongp'yong-ch'on River, and that the overall amount of sedimentation which occurred prior to this time probably is quite limited.

With its widespread and homogeneous distribution, the specific origin of the "Red Clay" was a matter for dispute during the early phases of the Chon-gok-ri campaigns (i.e., 1979) and there was even a suggestion that it is a type of wind-blown deposit (e.g., Park 1984). Other than to indicate its fluvial origin, it is difficult to pinpoint a source. Several samples obtained from the Chon-gok-ri localities indicate a mineralogical composdition similar to that of the bedrocks of the surrounding Kyunggi Metamorphic Complex. They have high clay mineral content, rich in chlorite and kaolinite (Lee 1984).

Although no detailed sedimentological data are available to allow us to determine the orgin of the "Red Clay", from the above-mentioned information and general geomorphological observations of the basin, the "Red Clay" seems to have been derived from the reddish residual clays developed on the slopes of the surrounding hills and mountains which, throughout the basin, tends to have a uniform color and texture regardless of the lithological variation in parent materials (i.e., the Red Clay *sensu stricto* — cf. Kang 1978). It would have been derived from source areas in mass originally by slope-wash, and later carried by the stream in suspension. Despite its thickness, its homogeneity in composition and distribution over the basalt plain, with the virtual absence of mineral grains larger than silt size and the relatively weak development of the associated channel beds, all indicate that the "Red Clay" is the result of overbank deposition by repeated short-term flooding throughtout basin. Such a process of sediment transport and deposition is still commonly observable today in Korea during the rainly season.

Terrace Morphology and Stream Downcutting

The streams that wandered over the basalt plain at some point began to converge to form a major channel. As we see today, the major channel should have developed on the plain along the structural joint formed by the basalt flows (the area most susceptible to erosion and downcutting). As streams cut through the basalt, its characteristic columnar structure and platy cleavage resulted in the formation of a deep and narrow valley. Large-scale sedimentation over the basalt plain stopped when the newly-cut channel became wide and deep enough to prevent overflows from sweeping the surface of the plain. Along the Yongp'yong-ch'on and other tributaries once filled with fluvio-lacustrine deposits, similar processes of downcutting rejuvenated the channels.

As downcutting continued, small scale terraces were developed. The narrow width of the newly-cut valley precluded the development of largescale terrace morphology. Since the probability of greater fluctuation in water level increases in a narrow valley, any terrace features which migh have formed probably would have been quickly eroded. Survival of such features would have been posible only under extremely fortuitous circumstances, since, due to its physical characteristics, erosion of the basalt occurred mainly in a downward direction, rather than laterally. At the same time older terrace materials which were cut by later fluvial activities are made up of sediments highly susceptible to rosional processes, so that there would have been even less chance of survival than for those terraces developed in the basalt. As a result, the total number of treads of these younger terraces, as well as their continuity, is very difficult to determine.

By observing fragmentary channel bed remnants that appear as alluvium clinging to the valley wall, three cycles of terrace development were tentatively recognized in the valley system above the current floodplain. However, the two Holocene units are difficult to distinguish from one another since erosion has blurred their boundaries. From archeological evidence, the age of the lower Holocene unit can be estimated to be around 700 AD (cf. Figures 8, 9 and 11).

Above the Holocene units, usually in the middle of the steep valley wall, a series of remnant channel beds cut into the basalt can be observed. Examples of this terrace tread occur mainly at upstream localities of the Hant'an (Figure 8). Along the Shin-ch'on and Yongp'yong-chon, the strath terrace is cut into the earlier terrace deposit with occasional thin alluvial coverings. Sometimes the tread of this strath terrace is found in the middle of Paekui-ri Formation and in this case it is covered by retransported materials from the "Red Clay" matrix, best seen around Chon-gok-ri.

No direct evidence is available to provide information on the age of the formation of this particular terrace feature. However, the very fact that it is a strath terrace, combined with its vertical distance from the top of the plain, indicates a possible Pleistocene age since strath terraces develop by lateral erosion during a quiescent period between episodes of accelarated vertical downcutting, possibly corresponding to a short interstadial episode. Gradual merging of this ancient channel bed with Holocene units in the downstream area (Figure 8), which might have something to do with the gradual westward tilting of the landmass, is another indirect indicator of its antiquity.

Paleoecology of Hominid Occupation

From the previous discussion, we saw that the fluvial environment during the time of hominid occupation was characterized by relatively stable and low-energy stream acitity with occasional episodes of largescale flooding. From excavations, the "Red Clay" matrix appear to include remains from at least two (and possibly many more) different occupational episodes. The timing of the earliest occupation appears to be sometime between 50,000 and 40,000 BP, based on the three thermoluminescence dates.

Palynological analyses of samples obtained at various places over the basalt plain made during the excavations at Chon-gok-ri failed to provide adequate information about the paleoclimatic and vegetation during the hominid occupation (Chang 1984). Although 55 pollen grains was identified (a very small sample), most of them are from the topsoil. Figure 10 is the pollen diagram of samples taken from the lacustrine formation along the Yongp'yong-ch'on. As deposition of this formation continued up until large-scale fluvial sedimentation over the basalt, this pollen profile contains some useful data regarding the general trend of climatic change during the period between the lava flows and the first occupation of the basin by hominids (as indicated by artifacts found in fluvial deposits over the plain).

From Figure 10, two or three pollen zones can be recognized. It shows that rapid climatic cooling occurred either shortly before the end of lacustrine deposition or at the beginning of "Red Clay" formation. Occurrence of warm-climate species (e.g., *Camelia, Magnolia*) in the basal part of the diagram, today found in the so-called "Camelia Belt" along the southern coast

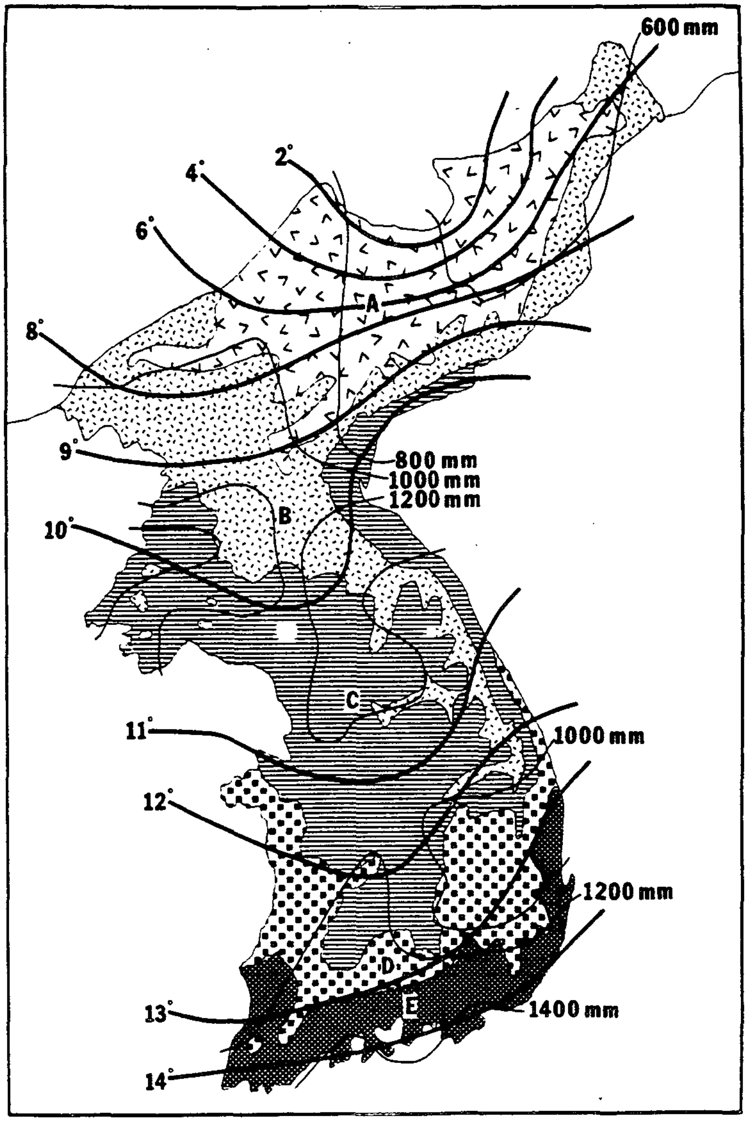

Figure 13. Mean annual temperature, preciption and vegetation zones of Korea (modified after Lee 1980, Figures 3.18 and 3.26, and Korean Oversea Information Service 1983, p.395). (A) Coniferous Belt, (B) *Abies-Betula* Belt, (C) mixed forest (northern type), (D) mixed forest (southern type), (E) *Camelia* Belt.

of Korea, indicate that mean annuall temperature was at least about 3 or 4°C. higher than today (Figure 13). However, the disappearance of these thermophilous species and an abrupt increase in *Pinus* in the upper portion of the pollen diagram indicate an episode when temperatures were, at a minimum, 1 to 2°C. lower than today, since this pollen assemblage would be typical to today, since this pollen assemblage would be typical to today's "Abies-Betula Belt" or "Coniferous Belt". Temperature change of this magnitude indicates a major climatic deterioration—a change significant enough to be taken as evidence of the onset of glaciation in the region.

With the chronometric dates, this pattern of paleoclimatic change fits well into general climatic curves during the late Pleistocene up to ca. 40,000 BP (cf. Bowen 1978: 81) and is in accord with some of the findings made in China (e.g., Cui and Xie 1982, He and Chen 1982, Liu 1982). The rapid decline in temperature was not, however, accompanied by a significant reduction in precipitation, which is evidenced by both the amount of fluvial deposition over the basalt and the continuation of massive fluvial sedimentation in the Yongp'yong-ch'on basin. The occurrence of a few grains fo *Pinus* and Gramineae within the matrix of Teh "Red Clay" (Chang 1984) might be taken to suggest that the climate of the area was stable during the period of basin sedimentation. Given that the trend of climatic change indicated in Figure 10 continuted into the period of "Red Clay" formation, it can be concluded that the hominid occupation of the basin took place under ecological conditions similar to those of northern Korea today.

From these paleoclimatic data, the hominid occupation of the basin probalbly occurred during a cold phase of the last major Pleistocene glaciation, marked by glacial advance and remarkable changes in sea level throughtout the world. In this part of the world, however, the *direct* impact of glaciation was hardly felt. Vegetation evidently changed, however, as pine forest replaced the diversified temperate broadleaf forest (the latter and ample source of food for humans) (Figure 14).

The quantity of artifacts scattered about and their continuous distribution across the surface of the ancient floodplain indicate how favorable this rather protected basin must have been for early huntergatherers. The residues they left there were soon covered by repeated alluviation, and were thus protected within the matrix of "Red Clay" from serious disturbance until they were exposed by natural and human induced erosion in the late 1970s. However, most organic compounds were oxidized under the wet and relatively warm climatic conditions of the late Pleistocene and Holocene.

Although there is no reason to rule out the possibility of the survival of other open-air paleolithic sites in Korea, it is also appearent that the basin represents a unique opportunity for the study of paleolithic archeology of Northeast Asia in general and Korea in particular. Severe Holocene erosion and alluviation cycles in other parts of the Peninsula greatly diminish the likelihood of the discovery of the remains of Pleistocene open-air sites in relatively primary contexts.

In summary, the survial evidence of paleolithic occupation in the Imjin River basin was possible due to many forturitous geological conditions provided there. First of all, formation of a basin of sedimentationin which archological sites would be preserved with relatively minor post-depositional disturbance.During and after the process of basin sedimentation, erosion of the plain was confined to the major channel of the present river system which developed along the structural joints formed by the lava flows. Furthermore, due to characteristic columnar structure and platy cleavage of the basalt bedrock, erosion of the

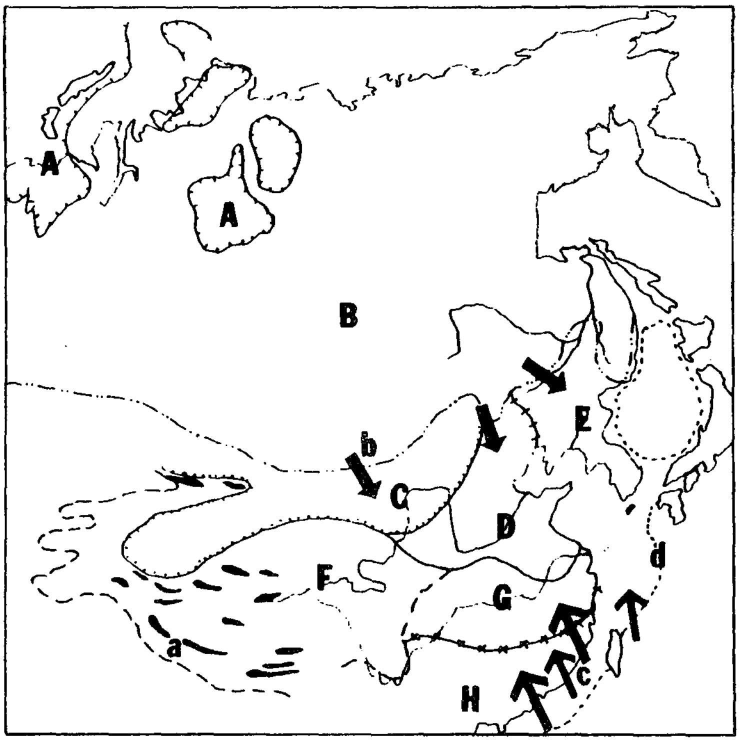

Figure 14. Natural zones of East Asia during the Dali (Würm or the last glacial episod) Maxima (after Zhou 1982). (A) continental glaciers, (B) tundra, (C) gobi-sand desert, (D) loess steppe, (E) undefined, (F) Tibet Plateau, (G) "net-motif" Red Clay, (H) "brick-motif" Red Clay. (a) mountain glaciers, (b) winter wind direction, (c) summer wind direction, (d) coastline.

basalt bedrock occurred mainly in vertical direction, developing deep but narrow entrenched valleys cut into the bedrock. Consequently, the large portion of the site area remained intact. At the same time, cultural deposits formed on *top* of the basalt plain were left unmodified by later fluvial disturbances due to changes in the Hant'an River base level (i.e., changes in sea level), since they were formed about 20 to 40 m above the former floodplain (Yi 1984a, 1984b).

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