Geomorphological development at Paleolithic sites of Imjin River Region, Korea, inferred from luminescence dating

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1. Introduction

Paleolithic sites along the Imjin and Hantan rivers in Korea were investigated following the discovery of a hand axe at Chongokri village by a U.S. soldier in 1978 (Cultural relics in Seoul National University Museum, 1997). Artifacts found at Paleolithic sites of Wongdangri, Kawoli, Juwoli, Kumpari, and other locations are regarded as resembling those found at the Chongokri site, which include Acheulean-like bifaces. However, none has been dated scientifically because the artifact horizons lack suitable materials for dating. Most sites are distributed on a depositional surface of basalt lavas that moved rapidly along the Hantan River from Pyounggang as a source vent, burying the valleys of the Imjin and Hantan rivers. Therefore, to date, the estimated ages of the Paleolithic sites reported in this study area have been based on dating of the basalt lava flows.

The age of the Chongokri basalt, 0.108±0.158 Ma, was obtained first by application of the potassium-argon (K-Ar) method (Takayanagi, 1983). Thereafter, other dating methods including fission track (FT), paleomagnetism (PM), electron spin resonance (ESR), thermoluminescence (TL), and optically stimulated luminescence (OSL), in addition to further K-Ar dating, have been applied to the basalt and the deposits. However, K-Ar ages for the basalts range widely: 0.108 - 0.85 Ma. The FT ages for the deposits are 0.11 - 0.51 Ma (see Table 1). Recently, four FT ages around 0.40 Ma were obtained from baked gravel lying below the lava at Chongokri and Baekuiri (Yi *et al*., 2005).

In relation to the timing of the basalt flow, previous studies have tended to regard basalt flow as occurring during a single geological event. However, a review of data available from earlier studies (Table 1) reveals three clusters of dates for the basalt lavas (younger than 200 ka, ca. 280 ka, and older than 400 ka), implying the possibility of intermittent inflows of the basalt lavas that filled the valleys during the middle Pleistocene. Nevertheless, no stratigraphic or geomorphological evidence indicates that there indeed did occur three or more episodes of volcanic eruptions and subsequent lava flows (Yi *et al*., 2005; Yi *et al*., 2006).

An upper age limit for the Paleolithic sites in the study area is inferred as ca. 30 ka, based on the volcanic glasses of Aira-Tn tephra (AT), which overlie the occupation levels at Chongokri and Kawoli sites (Yi, 1998). Soil wedges in surface deposits of the basalt lava provide another potential indicator of age based on association with the climatic stage (Bae *et al*., 2001), but the formation of a soil wedge is not necessarily evidence of a cold stage because it has been observed in Holocene contexts (Yi, 1998).

In the absence of dating of the artifact horizons at these sites, OSL dating (first proposed by Huntley *et al*., 1985) was applied to samples that had been exposed sufficiently to sunlight before deposition. Aeolian depos-

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Table 1 K-Ar and FT ages obtained for the basalt lava along the Imjin River and Hantan River, Korea. These ages are clustered into three groups: < 200 ka, ca. 280 ka, and > 400 ka.

	Locality, sample	Method	Age (Ma)	Reference	Notes
< 200 ka	Chongokri, basalt	K-Ar	0.108±0.158	Takayanagi, 1983	
	Eundaeri (Pung cheon farm), basalt	K-Ar	0.16±0.05	Danhara *et al*., 2002	plagioclase
			0.18±0.02		Whole-rock
	basalt	FT	0.13±0.02	Nagaoka *et al*., 2008	Below Chatan Basalt
			0.11±0.03		
	basalt	K-Ar	0.14–0.18	Nagaoka *et al*., 2008	Chatan Basalt
～280 ka	Cholwon, basalt (top1)	K-Ar	0.28±0.07	Lee *et al*., 1983	
	Cholwon, basalt (top2)	K-Ar	0.28±0.07		
	Sangsari, basalt	K-Ar	0.28±0.07	Lee, 1992*	
> 400 ka	Cholwon, basalt 2nd (L. from Bottom)	K-Ar	0.69±0.06	Lee *et al*., 1983	
	Chongokni, Lower, bottom	K-Ar	0.6±0.2	Yi, 1983*	
	Chongokni, basalt	K-Ar	0.6231±0.018	Deino, 1988*	
	Chongokni, basalt	K-Ar	0.49±0.05	Danhara *et al*., 2002	plagioclase
			0.85±0.03		Whole-rock
	Eundaeri (Changjin-chon), basalt	K-Ar	0.50±0.03		plagioclase
			0.57±0.03		Whole-rock
	Chongokri, Baekuiri, silt	FT	0.51±0.07	Danhara *et al*., 2002	0-2 cm below basalt / basement boundary
			0.51±0.07		10-15 m below basalt / basement boundary
	basalt	K-Ar	0.49–0.55	Nagaoka *et al*., 2008	Chongok basalt

* in the fourth column is quoted from a reference by Bae (2002).

its are the optimum sample for OSL methods, but generally speaking, sediments that have been deposited slowly with episodes of daylight exposure are potentially suitable. Measurements using TL method were attempted with soil samples in the study area in 1984, 1993, and 1994 (Yi, 1998), but it is noteworthy that they were studied preliminarily because the dose rates used to calculate the luminescence age were based on estimated data.

In this study, measurements using both OSL and TL methods were taken of samples of sediments from the archeological sites and of pebbles and soil heated by basalt lavas filling the valley of the Imjin and Hantan rivers. The geomorphological development of this region was assessed based on the obtained luminescence ages.

2. Sample locations

Chongokri lies along the Hantan River, located 50 km northeast of Seoul. The Imjin River flows from North Korea and joins the Hantan River at Tongiri, 3 km west of Chongokri. Then it flows westward into the Yellow Sea (Fig. 1). Topographic variation exists along the Imjin-Hantan valley. The area's Quaternary geology and geomorphology were clarified by Yi (1988). The valley is filled with thick basalt lava overlying the Baekuiri Formation, with buried terrace deposits that are identifiable along the present river course of the Hantan River in the vicinity of Chongokri. The depositional surface of the basalt lava resembles that of a river terrace. With slight erosion it has formed a lava strath terrace. A lower fluvial terrace has also developed along the foot of the basalt terrace (Fig. 2). Both the basalt lava and the subsequent lava strath terraces are traceable from Chongokri to Kawoli, Juwoli and Kumpari. The Paleolithic artifacts found at Chongokri were excavated from the horizons of the flood or aeolian sediments overlying the basalt lava. The basalt lava did not reach Jangsanri, and a higher fluvial terrace occurs sporadi-

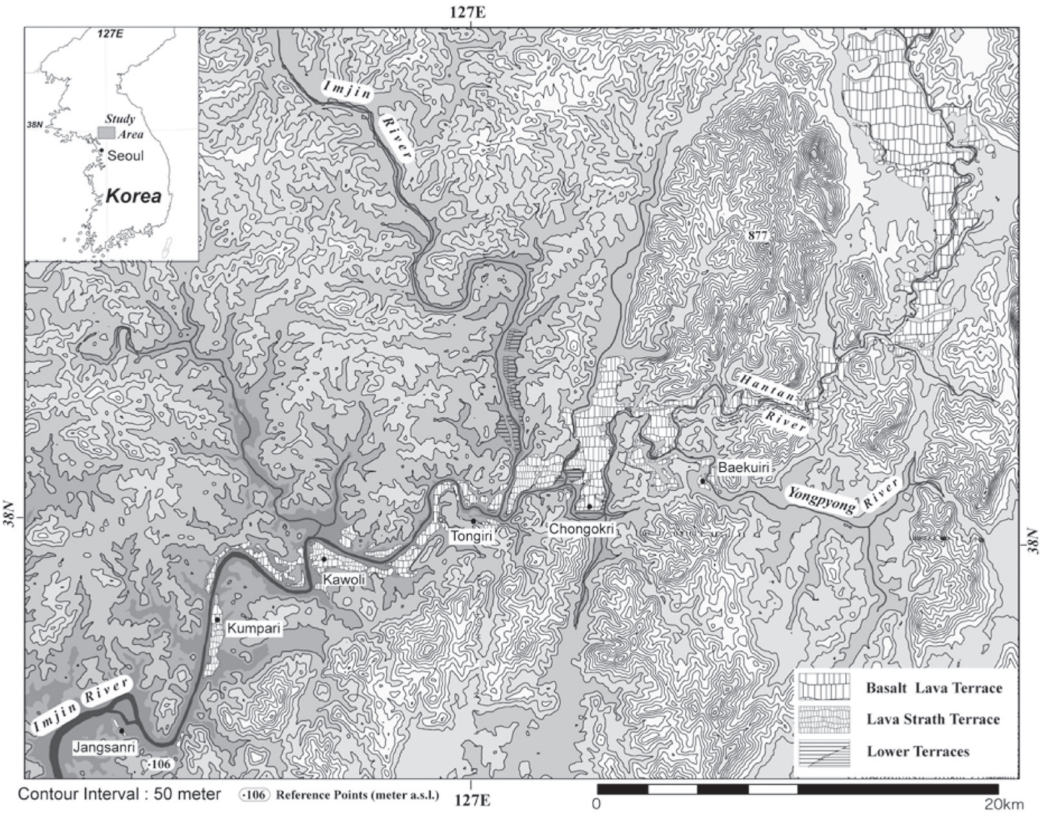

Fig. 1　Topographical map and the Paleolithic sites and outcrops along the Imjin River and Hantan River, where samples were collected for this study.

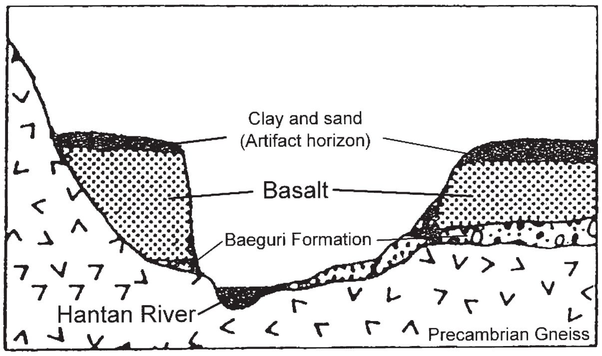

Fig. 2　Geological cross section of the Hantan Valley near Chongokri. (Bae, 2002)

Table 2　Locations and descriptions of the samples used for this study.

Site	Sample locations and context descriptions
Jangsanri	Three horizons below the artifact horizon where hand axes, choppers and cores were found (Yi, 1998). The upper layers of the terrace are composed of clay containing some pebbles. The lower layers contain many large pebbles.
Chongokri	Loamy materials (N8E16 grid) surveyed by Yi (2004) sampled from, within and above the artifact forizon, respectively.
	Three depositional samples collected above the artifact horizon at the E55S20-IV grid surveyed by Bae (2001).
Kawoli	Loamy materials above and below the artifact horizon at Loc 2 (TP19 grid) and Loc 3, respectively.
Kumpari	Loamy materials within the artifact horizon and underlying clay in W80S390 grid.
Outcrop	**Sample locations and context descriptions**
Baekuiri	Reddish granite gravels beneath the basalt lava. 38º 1' 7.7"N, 127º 8' 26.9"E
Tongiri	Buried soil beneath basalt lava. 38º 0' 8.9"N, 127º 0' 28.3"E

cally in the lower course of Jangsanri along the Imjin River. The terrace formed before the inflow of the basalt lava into the valley and developed at a higher level than that of the basalt lava. Paleolithic artifacts were also excavated from the higher terrace at Jangsanri.

The locations of samples tested using luminescence methods are presented in Table 2.

3. Measurements

3.1 Equipment

For this study, OSL measurements were made with a TL/OSL reader, NRL-99-OSTL, designed and constructed by Nagatomo *et al.* (2005). Infrared stimulated luminescence (IRSL) and blue-light stimulated luminescence (BLSL) were stimulated respectively using LED assemblies with 32 LEDs, 890 ± 50 nm for IRSL and 470 ± 40 nm for BLSL. Luminescence from samples was detected with a photomultiplier (R1140P; Hamamatsu Photonics K.K.) through two condensing quartz lenses and optical filters. Optical filters of BG-39 and HA-50, and U-340 were used routinely for IRSL and BLSL measurements, respectively, although they were exchanged readily for the other filters. Though the sample disk can be cooled to as low as -150°C with liquid nitrogen to suppress the effects attributable to thermal assistant processing of OSL (Hütt *et al.*, 1988), the measurements reported herein were taken without using this cooling system to avoid rather complicated operating procedures.

Using a Daybreak TL/OSL 1150 reader, TL measurements were taken. In routine TL measurements, samples are heated from room temperature to 500°C with a heating rate of 10°C/s in an atmosphere of nitrogen. Optical filters of BG-39 and Corning 7-59 or Corning 4-96 were used for TL measurements.

3.2 Paleodose estimation using OSL procedures

3.2.1 Sample preparation

The samples were crushed under water. The fine and semi-fine grains were separated roughly from coarse grains by settling in water. The separated fractions were treated with 10% hydrogen peroxide (H_2O_2) for ca. 16 hr. Samples were separated into two portions by suspension in acetone: 4-10 μm (polymineral fine grains) and 10-50 μm (polymineral semi-fine grains) (Zimmerman, 1977). The fine and semi-fine grain fractions were treated with 20% hydrochloric acid (HCl) for 2 hr to remove carbonate minerals such as calcite and aragonite. The distribution of grain size of semi-fine grains was measured using a digital microscope (VHX-100; Keyence Co.). The estimated size range of the semi-fine grains was 15-30 μm. Grains larger than 50 μm were not observed.

For BLSL measurements with quartz fine grains, minerals treated with HCl were treated for 9 days more with hydrosilicofluoric acid ($H_2[SiF_6]$). The obtained sample was examined using X-ray diffraction analysis, but no peak other than that of quartz was observed. Furthermore, the purity of quartz extracts was verified using IRSL. If feldspar remained, then $H_2[SiF_6]$ treatment was repeated.

3.2.2 Measurements

The treated samples were measured using a traditional multiple aliquot additive dose technique (MAAD) (Aitken, 1985) with the NRL-99-OSTL reader. Five aliquots each were used for the measurements of natural and additive-dose samples. When the dose dependence of the luminescence intensity is linear, measurements for the correction in low-dose region were made with the samples annealed at 350°C for 60 min. IRSL measurements were taken at a sample temperature of 60°C following preheating treatment (160°C for 60 s). BLSL measurements were made at 120°C following preheating treatment (220°C for 60 s) (Shitaoka and Nagatomo, 2001).

3.3 Paleodose estimation using TL procedure

3.3.1 Sample preparation

Quartz coarse-grained samples were extracted from soil and a granite pebble heated by lava flow. A granite pebble was first cut with a diamond cutter, revealing that the color of the outer part of the stone had changed to red, which was indicative of heating, and that inner part color was unchanged. The outer heated portions were cut from the body of the pebble and were immersed in Hydrofluoric acid (HF) for 2 hr to remove the outer surface layer of the pebble exposed to sunlight. The sample was then gently crushed mechanically to obtain grains smaller than 500 μm, with subsequent immersion in 20% HCl for 2 hr. The non-magnetic fraction of the treated sample was etched in 20% HF for 90 min and was finally washed in 10% acetic acid (CH_3COOH) for 2 hr to smooth the grain surface. The extracted grains had diameters of 75-250 μm.

The soil sample was pre-treated with 10% H_2O_2 for about 16 hr and was then sieved to obtain the 50-250 μm fraction. The latter was immersed in 20% HCl for 2 hr and passed through a Frantz-type magnetic separator. The non-magnetic fraction was etched in 20% HF for 90 min. Subsequently, the treated material was washed in concentrated HF (46%) for 1 min to remove the minerals other than quartz. The quartz mineral grains which were finally obtained were of 75-250 μm diameter.

3.3.2 Measurements

The treated samples were measured using MAAD technique with a Daybreak TL/OSL 1150 reader. The samples were heated from room temperature to 500°C in a nitrogen atmosphere. For the pebble sample, the dose response of TL using BG-39 and Corning 7-59 filters was not clear. TL measured using a Corning 4-96 filter showed linear dose response. The TL of soil samples was measured using optical filters of BG-39 and Corning 7-59. Five aliquots each were used for measurements of natural and additive-dose samples in the same manner as those used for OSL measurements. The dose dependences of the TL intensities for both pebble and soil samples were linear. The samples annealed at 350°C for 60 min were used for measurements for nonlinearity correction in the low-dose region.

3.4 Dose-rate estimation

Alpha, beta, and gamma dose rates were calculated using published conversion factors and measured concentrations of U, Th, and K obtained using a low-background gamma-ray spectrometer with a high-purity Ge (HPGe) detector (EGSP 8785; Eurisys Mesures). The HPGe detector is shielded with oxygen-free copper (10 mm thick) and low-background lead (10 mm thick) enclosed in a lead box (150 mm thick). The calibration curves used to obtain the U, Th, and K contents were produced using five standard rock samples provided by the Geological Survey of Japan (Ando *et al*., 1987). Contents of U and Th were obtained as an average of the estimated contents by application of calibration curves for the peaks from both pre-Rn and post-Rn nuclides, presuming a radioactive equilibrium between them. The dose rates were obtained by converting the U, Th, and K contents applying the data given by Adamiec and Aitken (1998). The water contents of the samples (weight of water/dry weight) were used for the conversion (Zimmerman, 1977).

The beta dose rates were measured separately using the sample itself and a TL dosimeter (TLD) (Ichikawa *et al*., 1982). The sample was crushed into grains of about 50 μm and then pressed into two disks of 50 mm diameter and 5 mm thickness. The TLD powders (Matsushita, $CaSO_4$:Tm) of ca. 100 μm were spread in a monolayer between two disks, shielding alpha particles from the sample with a 3.5 mg/cm^2 thick polyethylene sheet. Then the disks were put in a 200 mm thick lead box for about three weeks. The beta dose rate was estimated from the TL intensity of the TLD powder, which was given a known dose by a Third National Standard ^{60}Co source at Hiroshima University.

The beta dose rates estimated from the contents of radioactive elements were compared with those obtained by TLD. The difference of dose rates estimated using the two methods was found to be less than 10%. This fact implies that the alpha and gamma dose rates estimated from the contents of radioactive elements were also estimated reasonably, although the possibility of Rn emanation should be examined. The dose rate of cosmic rays was assumed as 0.10 mGy/a.

For IRSL measurements using semi-fine grained samples, reduction of the alpha dose rate because of attenuation of alpha particles should be corrected because the surfaces of the semi-fine grains were not removed by HF treatment. The overall correction factor for alpha, beta, and gamma dose rates is extremely small, e.g. 2% for a 50 μm grain size (Nagatomo *et al.*, 2004).

4. Results of luminescence dating

The examples of IRSL, BLSL, and TL measurements are presented in Fig. 3: the luminescence intensities are given as a function of added doses. Although the data are scattered, the response of luminescence intensities to added doses can be regarded as linear, and measurements for the nonlinearity correction, e.g. supralinearity, were conducted. The results of measurements, paleodoses, dose rates and luminescence ages are presented in Table 3. For IRSL measurements with polymineral fine grains, which comprise feldspars, the fading of IRSL intensities after irradiation was observed for five months. Although the observation period was rather short, notable fading was not found for the samples.

Luminescence dating results for respective sites are listed below.

Jangsanri site: Samples Jangsanri-a, Jangsanri-b, and Jangsanri-c, respectively correspond to samples 3, 4, and 5 in the reference by Yi (2004). The altitudes above mean sea level (a.m.s.l.) of the samples were ca. 39.4 m, 39.0 m, and 38.8 m, respectively, for Jangsanri-a, -b, and -c. All samples were measured by IRSL with fine grains and show almost identical age. No fading of IRSL intensities was observed within five months for these samples.

Chongokri site: The luminescence ages of two samples, Chongokri-a and Chongokri-b from the N8E16 grid, are consistent with the stratigraphy. Results obtained for these samples from IRSL measurements with polymineral fine grains are about 25% younger than those by BLSL with quartz fine grains. The possibility of long-term fading of feldspars in polymineral fine grains is considered.

The luminescence age of Chongokri-2 shows it to be the youngest among the samples of Chongokri-1, -2, and -3 collected at the same E55S20-IV grid, although the Chongokri-2 horizon is lower than the Chongokri-1 horizon (see Notes in Table 3). Furthermore, these samples, which were collected from the layers above the artifact horizon (see Table 2), are younger than those of Chongokri-b collected from the artifact horizon. Vasilchuk *et al.* (2002) reported that their results of radiocarbon (^{14}C) dating are reversed to the stratigraphical order at this location, i.e., 31,500 ± 600 aBP, 31,000 ± 600 aBP, and 25,700 ± 3,000 aBP for

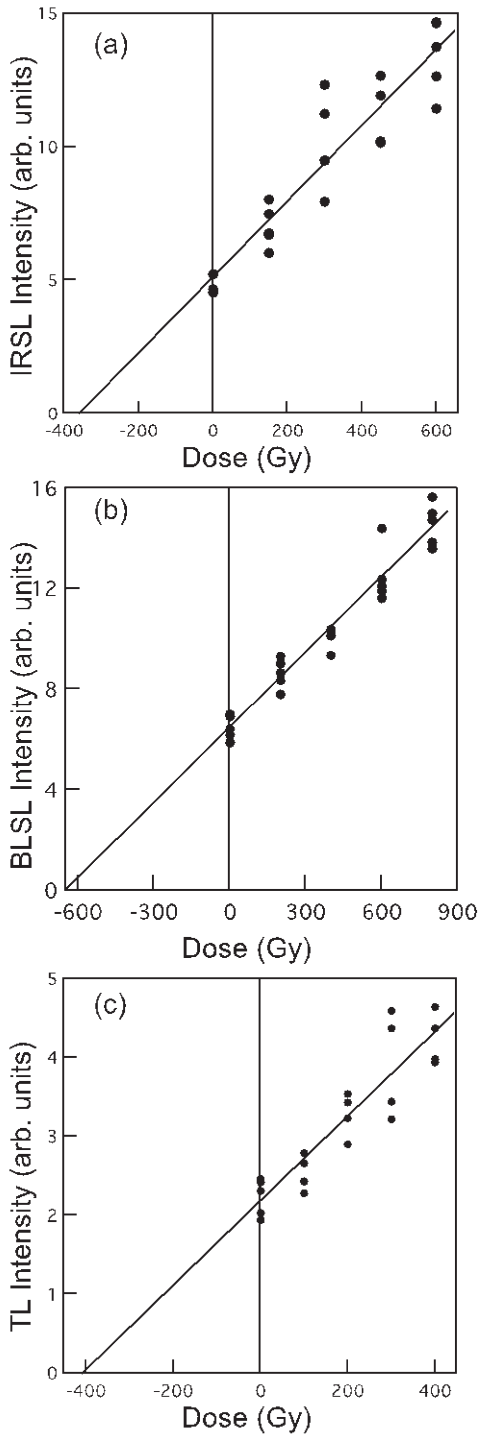

Fig. 3 OSL and TL growth curves as a function of added doses: (a) Kawoli-3, IRSL; (b) Chongokri-b, BLSL; and (c) Tongiri, TL.

Table 3　Results of OSL and TL dating for the sediments and a pebble and soil heated by basalt lavas.

Sample	Paleodose (Gy)	Dose rate (mGy/a)	Luminescence age (ka)	Method	Notes
Jangsanri-a	1,260±140	6.11±0.22	210±20	FG/IRSL	Lower layer of artifact horizon
Jangsanri-b	1,230±140	5.57±0.18	220±30	FG/IRSL	Lower layer of artifact horizon
Jangsanri-c	1,190±230	5.49±0.19	220±40	FG/IRSL	Lower layer of artifact horizon
Chongokri-a (N8E16 grid)	370±60	4.81±0.09	76±13	FG/IRSL	Upper layer of artifact horizon
	480±80		99±16	Quartz-FG/BLSL	
Chongokri-b (N8E16 grid)	410±50	4.15±0.08	99±12	FG/IRSL	Artifact horizon
	550±100		130±20	Quartz-FG/BLSL	
Chongokri-1 (E55S20-IV grid)	450±140	4.79±0.17	93±29	FG/IRSL	58 m (a.m.s.l)
	490±70		100±10	Quartz-FG/BLSL	
Chongokri-2 (E55S20-IV grid)	450±110	5.12±0.17	88±21	FG/IRSL	56.5 m (a.m.s.l)
	370±90		73±18	Quartz-FG/BLSL	
Chongokri-3 (E55S20-IV grid)	490±410	5.17±0.17	94±80	FG/IRSL	56 m (a.m.s.l)
	460±230		88±45	Quartz-FG/BLSL	
Kawoli-1 (Loc. 2, TP19 grid)	260±60	5.53±0.15	47±11	Semi-FG/IRSL	Upper layer of artifact horizon
Kawoli-2 (Loc. 2, TP19 grid)	440±130	5.57±0.14	79±24	Semi-FG/IRSL	Lower layer of artifact horizon
Kawoli-3 (Loc. 3)	230±100	4.36±0.09	52±23	Semi-FG/IRSL	Upper layer of artifact horizon
Kawoli-4 (Loc. 3)	n. d.	5.29±0.18	n. d.	Semi-FG/IRSL	Llower layer of artifact horizon
Kumpari-1 (S60W380 grid)	130±100	6.12±0.31	22±17	FG/IRSL	Artifact horizon
Kumpari-2 (S60W380 grid)	280±40	6.20±0.22	45±7	FG/IRSL	Llower layer of artifact horizon
Baekuiri, pebble	960±300	5.21±0.16	180±60	CG/TL	
Tongiri, soil	610±80	3.92±0.18	160±20	CG/TL	

FG, fine grains; Semi-FG, semi-fine grains; Quartz-FG, quartz fine grains; and CG, coarse grains. IRSL, infra-red stimulated luminescence; BLSL, blue-light stimulated luminescence; and TL, thermoluminescence. n.d., not determined.

the horizon of a.m.s.l. 61.6 m, 21,950 ± 200 aBP for that of a.m.s.l. 60.2 m, and 16,100 ± 300 aBP for that of a.m.s.l. 58.05 m. This reversal might be attributable to the disturbance of soil caused by cracks observed in the strata of this grid.

Kawoli site: The luminescence ages of two samples, Kawoli-1 and Kawoli-2, from locality 2 (TP19 grid) are consistent with the stratigraphical order. Data for the sample, Kawoli-4 from the locality 3 were dispersed and luminescence age could not be determined. This result might be attributable to incomplete or insufficient zeroing caused by the depositional condition.

Kumpari site: Results for the artifact horizon and the clay below it are consistent with the stratigraphical order.

Baekuiri and Tongiri outcrops: TL ages of the pebble and soil sample heated by basalt lavas are regarded as obtained successfully because only the apparently well-baked samples were used for the present measurements.

5. Discussion

5.1 Geomorphological development of the Imjin-Hantan Valley

The baked pebble and soil below the basalt lava were dated back to 160 - 180 ka using TL measurements. The sediments that intercalate Paleolithic artifacts, overlying the basalt lava, were also dated back to ca. 30 - 100 ka. We reconstructed the geomorphological evolution of Imjin-Hantan valley where Paleolithic sites were located on the basalt-lava terrace and higher terrace, based on the dating results.

The basalt lava of high fluidity erupted and flowed into the Imjin-Hantan valley in ca. 100 - 200 ka. The lava flow reached as far downstream as Kumpari, damming those rivers around Chongokri. A temporary lake presumably appeared along the paleo-Hantan River and the Yongpyong River upstream of the natural dam because lacustrine of silty or clayey deposits underlies in the Yongpyong River Basin. Subsequent overflow from the dam caused resumption of the incision on to the basalt lava along the present river course of the Imjin River, forming the lava strath terrace and lower fluvial terraces. During such geomophological processes, Paleolithic stones, as remnants of the humans habitation, were intercalated in the aeolian and flood deposits overlying the basalt lava and lava strath terraces. Development of the higher terrace occurred earlier than that of the basalt-lava terrace, considering the geomorpho-chronological positions between them. Such a geomorphological sequence is confirmed by the TL and OSL ages obtained from Jangsanri site and the basalt lava. Jangsanri site, located on the higher terrace that occurs in the lower stream side than Kumpari, was dated back to over 200 ka. Furthermore, the ages of the basalt are ca. 100 - 200 ka.

5.2 Implications for human occupation of the Imjin-Hantan valley

A notable finding of this study is that humans had already appeared in this valley before the inflows of the basalt lavas. They had resettled the region despite the catastrophic environmental events. Although evidence is lacking for the wide range of the ages for the basalt lavas, as presented in Table 1, it might be true that the basalt lava moved rapidly down the valley system in several episodes. Consequently, some undetected Paleolithic sites might lie underneath these flows. Humans at Chongokri, Kawoli, and Kumpari sites occupied the site after the lava inflow of ca. 100 - 200 ka, and the Jangsanri site before the lava inflow.

6. Conclusion

Sediments from four Paleolithic sites and a pebble and soil underlying the basalt lava flows at two outcrops along the Imjin River and Hantan River in Korea were tested using OSL and TL dating methods. The TL ages of the burnt pebble and baked soil, ca. 180 ka and 160 ka, suggest that the influx of lava occurred about 150 ka before present. The IRSL and BLSL ages for samples from Chongokri, Kawoli, and Kumpari sites, ca. 100 ka, 60 ka, and 30 ka, respectively, suggest that the Paleolithic occupation occurred after deposition of aeolian and fluvial soil deposits on the lava flow. The Jangsanri site located on the river terrace might date earlier than the inflow of the lava of high fluidity that reached Kumpari. Although evidence is lacking with the wide range of the ages for the basalt lavas as demonstrated in Table 1, it might be true that the basalt lava moved rapidly down the valley system in several episodes. Humans at Chongokri, Kawoli, and Kumpari sites occupied the areas after the lava inflow of ca. 100 - 200 ka, and Jangsanri site before the lava inflow.

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ルミネッセンス年代測定から検討した臨津江流域の旧石器遺跡に関する地形形成の変遷

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要　旨：

臨津江・漢灘江流域の両岸を形成する玄武岩溶岩の年代測定は、これまで K-Ar や FT 年代測定など理化学的年代測定によって行われ、0.85～0.1 Ma という幅の広い結果が得られてきた。そして、これら結果を精査すると、溶岩は複数回流れた可能性があることがわかった。しかし、いまだ確定的な年代結果は得られていないのが現状である。そのため、玄武岩溶岩の上層にある堆積層から検出される旧石器遺跡の年代を求めることができなかった。

本研究では、玄武岩溶岩の上層にある堆積層の OSL 年代測定、および玄武岩溶岩直下の溶岩によって焼けた土壌や石の TL 年代測定を行った。その結果、旧石器が検出される堆積物は約30～100 ka、焼けた土壌や石は約160～180 ka のルミネッセンス年代を求めた。また、高位段丘上に位置する長山里旧石器遺跡は、約200 ka の年代値が求められた。この遺跡は臨津江の下流に位置し、約160～180 ka の溶岩が流れてくる以前に形成された旧石器遺跡であることがわかった。

キーワード：旧石器遺跡、臨津江、地形形成、玄武溶岩、ルミネッセンス年代測定、大韓民国