

Chapter 8

Palaeohydrological and Palaeoenvironmental Fluctuations of the Historic Eurimji Lake

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Abstract Lake Eurimji is located in the northern part of Jaecheon, Chungbuk Province, in South Korea. It is well known for its scenic beauty as a nationally registered landscape site (Yang GS, Jungwon Munhwa 14:1–38, 2010). Since the late Bronze Age, its water has been used for agricultural irrigation. The lake was initially formed at the mouth of a flanglomerate where Jurassic granites blocked

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K. Kashiwaya et al. (eds.), *Earth Surface Processes and Environmental Changes in East Asia*, DOI 10.1007/978-4-431-55540-7_8

the main course of a stream channel at about 305 m above sea level (m.a.s.l.). Natural levees grew laterally near the main outlets of the fan-valley mouth up to about 307 m.a.s.l. The lake accumulated organic sandy mud on the sand-and-gravel streambeds extending toward the southern valley mouth near Yongdu Mt., the ages of which were dated as early as ca. 3,000 calibration years Before Present (cal-yr BP). The early evidence of lake deposits is supported by radiocarbon ages for organic muds below the lowermost artificial layers in Lake Eurimji, which vertically constitute the bottom of Eurimji bank or dyke at about 306.5 m.a.s.l. The height is about 15 m. The present study reconstructs the paleo-precipitation of Lake Eurimji by applying an age mode to core sediments in the ER3-1 borehole using the mean grain size of sediments trapped at the bottom of the lake. The results show that lake sediments accumulated at an extremely high rate, ca. 3.49 mm/year during the Early Three Kingdoms Period, around 2,120–1,340 cal-yr BP. The average grain size of the trapped sediments is proportional to the total amount of precipitation during the elapsed time of each monitoring session. Both the paleoclimatic cyclicality and historical documents indicate that droughts in the lake catchment areas prevailed at 80 AD, 120 AD, 160 AD, 310 AD, 350 AD, 460–500 AD, and 620 AD, while relatively wet conditions occurred at approximately 90 AD, 150 AD, 200 AD, 240 AD, 320 AD, 360 AD, 435 AD, and 530 AD. These drought records suggest a multi-decadal cyclicality, particularly during the Early Three Kingdoms Period. This may imply that multi-decadal to century scale fluctuations of winter and summer monsoons controlled the sedimentary regime of Lake Eurimji catchment areas during this period in South Korea.

Keywords Lake catchment • Sediment trap • Paleo-precipitation • Lake monitoring • Historical document • Drought frequency

8.1 Introduction

Lake Eurimji is the oldest historical human-made reservoir lake on the Korean peninsula; however, its exact age remains controversial. Lee (1959) suggested that the lake might have been constructed in the Iron Age, around 2,000 BP, whereas several other studies have argued that the lake was not built until the reign of King Jinheung of the Silla Dynasty (ca. 540–576 AD). The latter opinion is supported by legends related to several places named after Ureuk, a famous master of the Gayageum, a musical instrument, in the Jecheon area during this king's reign. Lake Eurimji, located at the valley mouth of the Mt. Yongdu catchment area, is now famous for its scenic beauty. Its origin may be studied by dating the construction of its banks or based on the earliest accumulation of the bottom sediment (Kim et al. 2000a, b). It remains debatable as to whether or not the lake existed at approximately ca. 2,000 yr BP (Kim et al. 2009a, b, 2010). To better understand the establishment of Lake Eurimji, it is important to obtain as many radiocarbon ages as possible from the bottommost part of its banks (Kim et al. 2012). The aims of the present study were to reveal the ages of the oldest sediments in the lake, below the Eurimji bank; obtain undisturbed bottom sediment cores and trace changes in the lake environment;

and compare paleoclimatic signals of sediment cores to extreme drought periods recorded in historical documents. To date the initial construction of Lake Eurimji, and document the paleoenvironmental and paleohydrological changes in the lake, we obtained radiocarbon dates of lake bottom sediments, gathered multi-proxy data on sediment cores, and collected trap sediments from the bottom of the lake.

8.2 Background of Study Area

The Lake Eurimji reservoir (37°10′6.9″N, 128°12′38.0″E), located at approximately 300 m above sea level (m.a.s.l.; Fig. 8.1), has been used as a water reservoir for irrigation. The reservoir has a maximum depth of 7 m, a 2-km-long shoreline, a water surface area of 158,677 m², and a water storage capacity of 6,661,891 m³ (Fig. 8.1). The height of the levee is about 11 m, and the total length is about 320 m (Jecheon City Office 2010). The Haso stream, which originates from Mt. Yongdu (871 m), brings freshwater into the lake. At the higher elevations around Mt. Yongdu (400–900 m), the main bedrock type is Precambrian granitic gneiss, and the slopes are generally steep and stepwise. Jurassic biotite granite is prevalent at lower elevations (270–400 m), where a valley plain with a relatively gentle slope once existed at the mouth of the reservoir (Kim et al. 2012). Due to differences in geological features and weathering rates, the slope of Haso stream changes at a knickpoint approximately 2.4 km upstream of the lake. The lake includes several alluvial cones (fans) consisting of sand and gravel, which were formed during the Last Glacial Period (Kim et al. 2012). The fan system exhibits three steps of incision, which are recognized as a low terrace system (Kim et al. 2012; Lee 2010). The terraces exhibit signs of frequent landslides, which are seen along the fore-edges and escarpments. Near the lake, the valley deepens as a result of strong differential erosion derived from faults after emplacement of Jurassic granite. The valley is topographically protected from severe winter monsoons, and therefore the downstream area of the Eurimji valley has favorable conditions for agriculture. It has been assumed that the construction of agricultural paddies started in the beginning of the late Bronze Age (close to 2,800 yr BP), based on the general occurrence of paddy remains in the middle part of South Korea (Lee 2006, 2010; Jang 2010; Seong 2010). The primary land use in this area has not changed in the last two millennia. At higher elevations in the Mt. Yongdu catchment, the land cover is mainly pine and broadleaf forest. The lower elevation areas are occupied mostly by agricultural lands where rice has been cultivated. The irrigation season extends from March to June, with the highest demand in April and May. The Eurimji reservoir is located in the mid-latitude temperate zone, which is characterized by seasonal winds and a continental climate. In recent decades, the seasonal mean temperatures have varied from −5.3 °C in January to 23.7 °C in August, with a yearly mean temperature of 10.2 °C. The annual mean rainfall in the area is 1,295 mm. This region receives 55 % of its precipitation during the summer monsoon season (Jecheon City Office 2010).

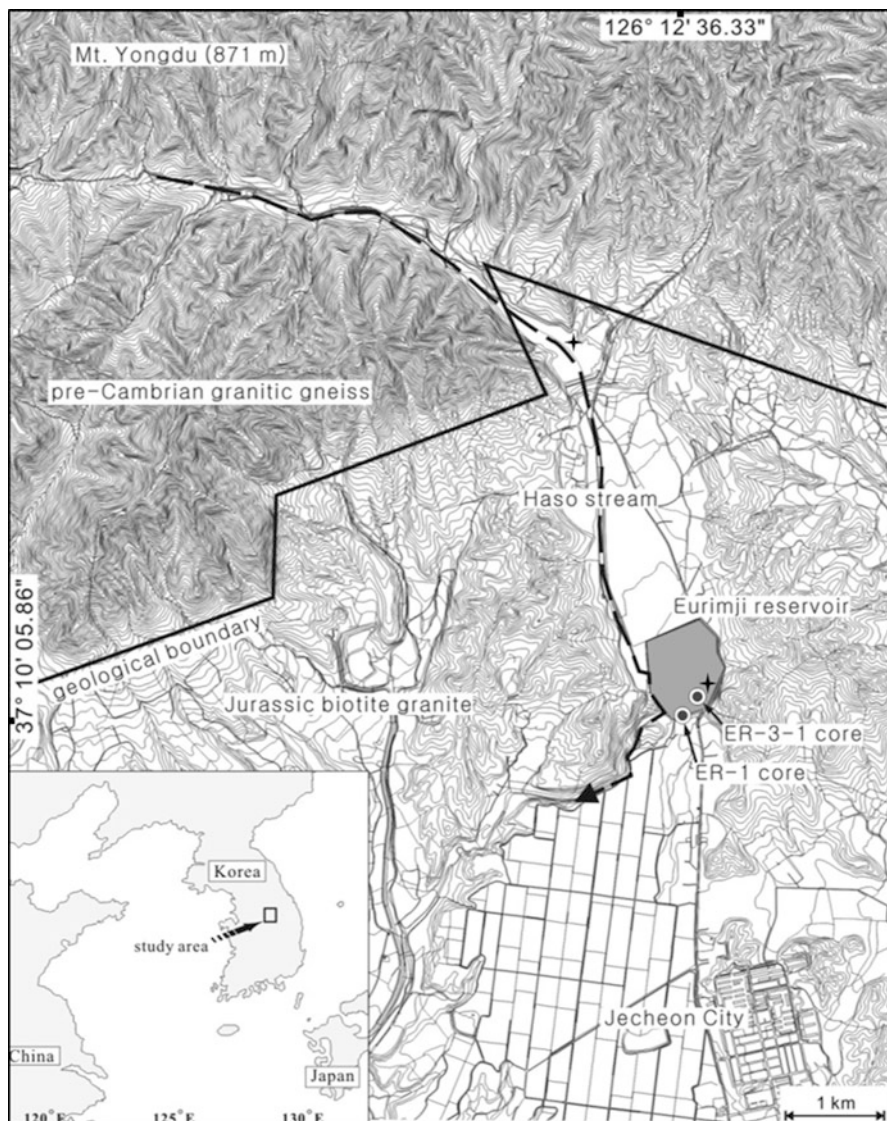


Fig. 8.1 Map of Lake Eurimji (Figure slightly modified from Nahm et al. 2012)

8.3 Materials and Methods

Echo-sounding and ground penetration radar surveys of Eurim Lake (Fig. 8.2a–d; Kim et al. 2000a, b) covered the general background of Lake Eurimji. We observed the boundaries between natural sandy gravels with organic-rich lake sediments and constructed anthropological layers in the outer Eurimji bank, where five trenches

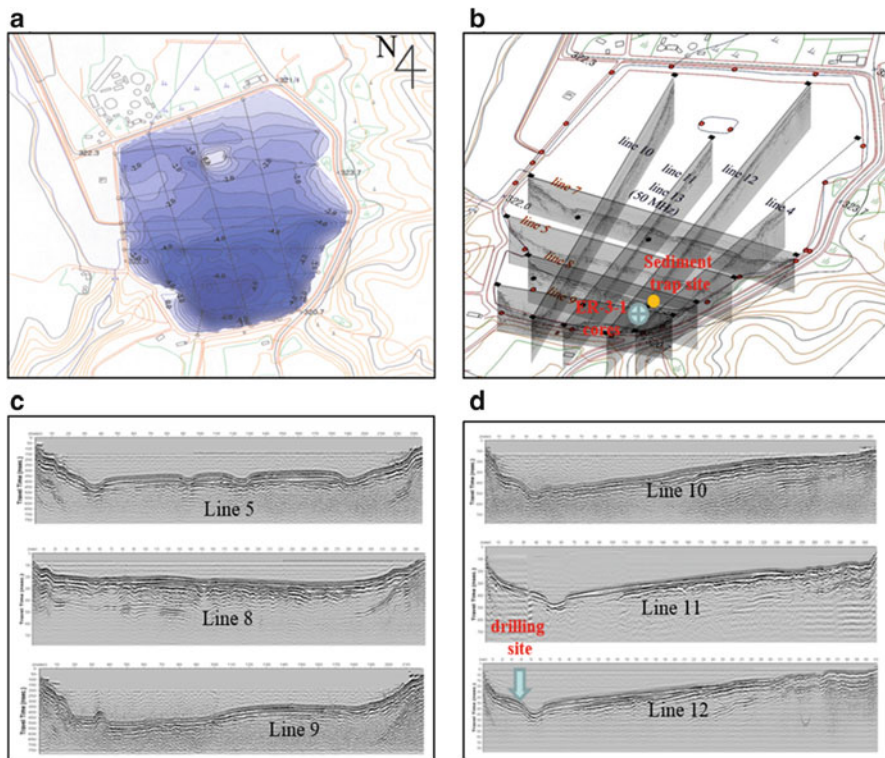


Fig. 8.2 Background information on Lake Eurimji: (a) bathymetric map, (b) GPR survey lines, (c) east–west bottom sediment profiles, and (d) north–south bottom sediment profiles

were dug by the Jungwon National Research Institute of Cultural Heritage in 2012–2013 (JNRICH 2014) (Fig. 8.3). Sediment traps were installed at the lake bottom to obtain bottom sediments, which was performed in late spring/summer/early autumn (April–September) and late autumn/winter/early spring (October–March) in two different years. Meteorological data were recorded at Jecheon Meteorological Post about 2 km from Lake Eurimji, and total precipitation was checked during each interval of lake sediment monitoring. In addition, extreme events documented in the *Samguk-Sagi* (Chronicles of the Three Kingdoms) were analyzed to determine every 10-year drought frequency during the Three Kingdom Period (50–650 AD). Sedimentological borehole logging was performed for the cores of the lake bottom (ER3-1, 37°10′06.97″N, 126°12′38.69″E) (Fig. 8.1 and Table 8.1). ER-1 cores (Fig. 8.1) obtained from Eurimji bank in 2009 were used to reference artificial layers (Nahm et al. 2012; Kim et al. 2012). Cores (6.98 m long; ER3-1) were obtained from the reservoir bottom using a standard stationary piston sampler with an inner diameter of 74 mm. The core was cut and sliced at an interval of 0.5 m. The cores were sub-sampled in the laboratory at 1-cm intervals. After removing carbonates and organic matter using 10 % HCl and 30 % H₂O₂, respectively, a

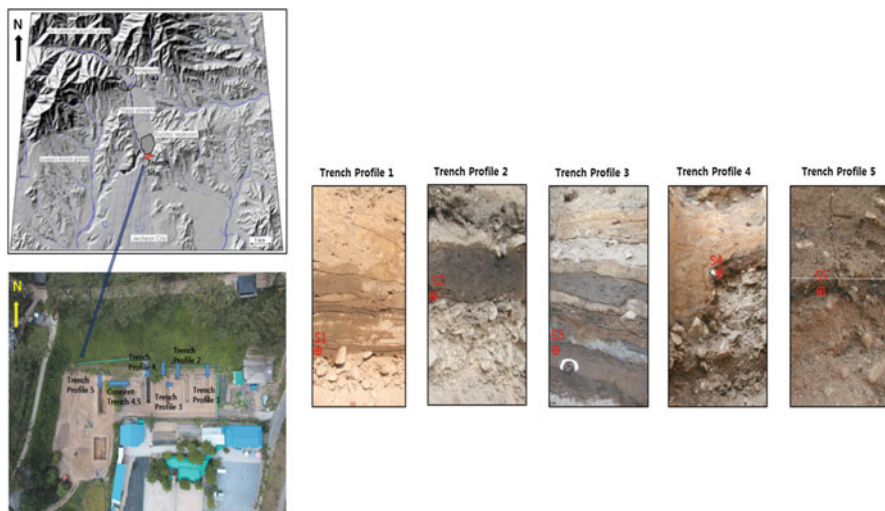


Fig. 8.3 Excavated trench sites in the outer bank of Lake Eurimji. Note: Radiocarbon ages of the bottom sediments are $1,740 \pm 50$ (S1) at trench profile 1, $1,740 \pm 50$ (S2) at trench profile 2, $1,740 \pm 50$ (S3) at trench profile 3, $1,740 \pm 50$ (S4) at trench profile 4, and $1,740 \pm 50$ (S5) at trench profile 5. The radiocarbon ages at the connected trenches 4 and 5 are listed in Table 8.1

Table 8.1 Geographical characteristics of the borehole drilled at the Lake Eurimji

Boreholes	Coordinates	Core length (m)	Altitude (m.a.s.l.)	Remarks
	Lat./Long.			
ER-3-1	N 37° 10' 06.97''	6.98	314.23-307.25	Lake Eurimji bottom
	E 126° 12' 38.69''			

grain-size analysis of the bulk sediment was performed using a Mastersizer 2000 laser particle analyzer (Malvern Instruments, Ltd., Worcestershire, UK) capable of detection in the 0.02–2,000- μm range, with sodium hexametaphosphate used as the dispersing agent. Eight samples for radiocarbon dating were obtained from the ER-3-1 sediment cores and organic muds with plant remains in bank bottoms. Radiocarbon ages were measured at the KIGAM AMS laboratory using an HVEE AMS/multipurpose beam line-MPS 4130-Tandetron device. The CalPal07 program (www.calpal-online.de) was used to convert radiocarbon ages (^{14}C yr BP) to calendar years (BC or AD) (Danzeglocke et al. 2008).

Low-frequency magnetic susceptibility was measured using an MS2 susceptibility meter (Bartington Instruments, Ltd., UK) with dual-frequency sensors. The averaged results were used to calculate the percent frequency-dependent susceptibility as defined by Thompson and Oldfield (1986). An aliquot of each of the sediment subsamples was dried to a constant weight at 60 °C, ground to a particle size of 0.063 mm, decalcified using 1N HCl, and then homogenized using an agate mortar and pestle. Aluminum capsules containing 2–3 mg of the processed

sediment samples were analyzed for total organic carbon (TOC) and total nitrogen (TN) concentrations were determined by combustion at 900 °C in a FlashEA-1112 (Thermo Finnigan S.p.A., Milan, Italy).

8.4 Results

8.4.1 Core Description

The core was subdivided into four sedimentary units (Fig. 8.4). From the bottom to the top, these were: unit 1 (307.25–308.02 m, 0.77-m thickness), unit 2 (308.02–310.55 m, 2.53-m thickness), unit 3 (310.55–311.90 m, 1.35-m thickness), and unit 4 (311.90–314.23 m, 2.33-m thickness). Figure 8.4 shows the profiles of several sedimentological and geochemical properties that were analyzed from core ER3-1. Table 8.2 summarizes the nine ¹⁴C ages that were obtained from core ER3-1 and the profiles of excavated trenches (Nahm et al. 2012; JNRICH 2014).

– Unit 1 (307.25–308.02 m)

The sediments in unit 1 were classified as S (sand) and zS (silty sand). The interval from 307.25 to 307.44 m included several sub-angular pebbles. One thin clay layer was intercalated from 307.48 to 307.53 m (5-cm thickness). An upward-fining trend was obvious from 307.56 to 307.98 m (Fig. 8.6).

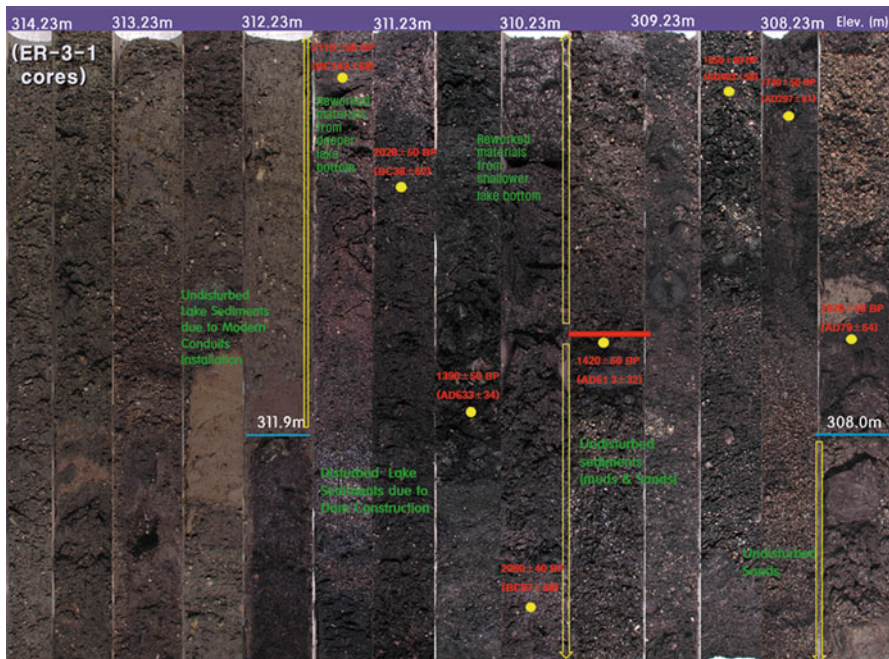


Fig. 8.4 Photographs of bottom sediment cores in Lake Eurimji

Table 8.2 Radiocarbon ages of core sediment ER3-1 taken from Lake Eurimji

Core	Sample ID	Material	Altitude (unit)	^{14}C yr BP	$\delta^{13}\text{C}$	Calendar year
ER-3-1	ISa090033	Bulk carbon	309.52 m (2)	$1,420 \pm 50$	-26.0	AD 613 ± 32
ER-3-1	IWd090006	Plant fragment	309.45 m (2)	$1,250 \pm 50$	-27.5	AD 768 ± 69
ER-3-1	ISa090102	Bulk carbon	308.81 m (2)	$1,650 \pm 40$	-24.8	AD 403 ± 58
ER-3-1	ISa090034	Bulk carbon	308.05 m (2)	$1,740 \pm 50$	-23.6	AD 297 ± 61
ER-3-1	ISa090035	Bulk carbon	307.51 m (1)	$1,920 \pm 50$	-24.0	AD 79 ± 54
ER-B-1	KGM-Isa120028	Bulk carbon	306.40 m (0)	$2,020 \pm 30$	-24.7	BC 24 ± 84
ER-B-3	KGM-Isa120029	Bulk carbon	304.90 m (0)	$2,420 \pm 40$	-27.6	BC 497 ± 98
ER-B-3	KGM-Isa120030	Bulk carbon	305.10 m (0)	$2,550 \pm 30$	-28.7	BC 772 ± 29
ER-B-3	KGM-Isa120031	Bulk carbon	306.20 m (0)	$2,500 \pm 30$	-22.8	BC 650.5 ± 32.5

– Unit 2 (308.02–310.55 m)

Silt and sand were dominant. The sediments in unit 2 were classified as zS and sZ (sandy silt). Unit 2 was characterized by four layers of plant matter (308.5, 309.0, 309.4, and 310.4 m) between sediments, and the spacing between layers varied from 50 to 90 cm. AMS ^{14}C dating of the bulk carbon in the sediments that were sandwiched between the plant layers indicated an age of about 2,000–1,600 ^{14}C yr BP, but the results from the plant materials indicated a range 1,300–1,200 ^{14}C yr BP. The upper part of unit 2 (–309.52 m.a.s.l.) was disturbed artificially after ca 1,200 yr BP.

– Unit 3 (310.55–311.90 m)

Unit 3 was composed of dark gray to black zS and sZ. Some pebbles were observed around 311.56-m elevation. Unit 3 was also disturbed artificially after ca 1,200 yr BP.

– Unit 4 (311.90–314.23 m)

This unit consisted primarily of yellowish-brown sZ, with some clay layers. This unit showed increased magnetic susceptibilities. Present-day garbage (styrofoam) was found at around 312.80 m. It was also disturbed by ancient agricultural activity.

To construct a meaningful age model based on radiocarbon ages, it may be important to confirm whether this core conforms to a linear age model. Only sediment cores below 309.5 m.a.s.l. were undisturbed, and thus we used sediment cores from between 309.5 and 307.25 m.a.s.l. to consider climate changes; we selected unit 1 (307.25–308.02 m) and the lower part of unit 2 (308.02–309.5 m) for further study of multi-proxy data.

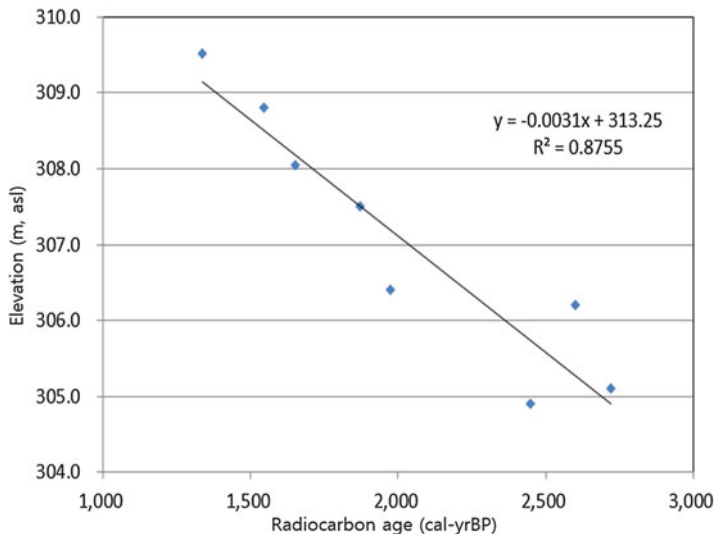


Fig. 8.5 Age model of bottom sediments in Lake Eurimji based on radiocarbon dating of an undisturbed core sediment (ER3-1)

8.4.2 AMS Dating

The results of the AMS dating are shown in Table 8.1. The oldest age of the bottom sediments was calculated to be ca. 1,920 yr BP from core ER3-1, but 2,500 yr BP based on the third, fourth, and fifth trenches of the outer bank. Above 309.5 m.a.s.l., the gray mud layer with plant fragments yielded an age of 1,200–1,300 yr BP from core ER3-1 (Nahm et al. 2012). However, the bulk sediment samples from the gray sandy mud layers obtained from the trench profiles at the outer bank revealed an older age than that reported in previous research (Nahm et al. 2012). Our data suggest that the oldest sediments date to the late Bronze Age. The accumulation rate of bottom sediments was calculated to be 3.49 mm/year (Fig. 8.5), an unusual and relatively high rate compared to a natural lake. This may have been caused by anthropological interference in the catchment area of this lake even below 309.5 m, while the upper elevations could have been heavily disturbed by the construction of the lake's banks at ca. 1,200 yr BP (Kim et al. 2012; Yang et al. 2009; Nahm et al. 2012).

8.4.3 Sediment Trap

Sediment traps were manufactured divided into four compartments on the bottom and installed oriented in a north and south direction at the southeastern corner of

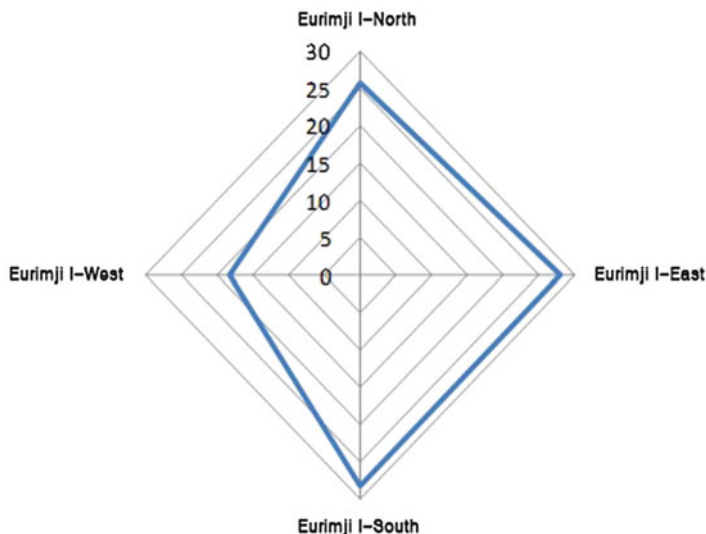


Fig. 8.6 Monitoring data obtained using an oriented sediment trap in Lake Eurimji

Lake Eurimji, where the ER-3-1 sediment cores were obtained, from October 2011 to April 2013. Bottom sediments were recovered biannually, and total weights and mean grain sizes were measured. We found that the total amounts of sediment derived from the north and east were higher than from the other two directions (Fig. 8.6).

The mean grain size was coarser in summer than in winter (Fig. 8.7). Accumulation of bottom sediment was indicative of a north- and east-direction anomaly of sediment inflow into the lake, depending on prevailing bottom currents. In the late spring and summer (April–September), both the amount of trap sediments and mean grain size increased, probably because of intense rainfall during the summer monsoon (Fig. 8.8).

8.4.4 Multi-proxy Data

Core ER3-1, taken between the elevations of 309.5 and 307.25 m.a.s.l., was used to determine environmental changes in the lake based on multi-proxy data (Fig. 8.9; Nahm et al. 2012). The bottom sediments were predominantly sands (~70 %) with some silts (~30 %) and clays (1–2 %). The mean grain size was 2.73–6.21 phi, with an average size of 3.52 phi (very fine sand) among 67 sub-samples analyzed below 309.5 m.a.s.l. The magnetic susceptibility (MS, Lf) was 704.3–3030.7 m-SI (mean, 704.3 m-SI). The mean TOC and TN values were 0.8 wt.% (0.28–1.71 wt.%) and 0.05 wt.% (0.02–0.11 wt.%), respectively. The mean TOC/TN ratios ranged

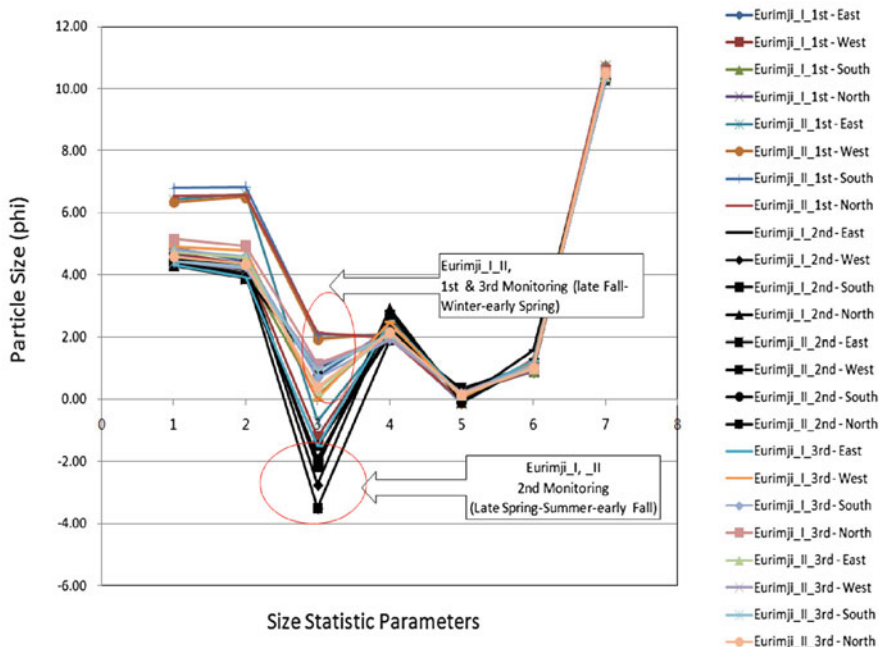


Fig. 8.7 Weight of bottom sediment obtained from Lake Eurimji

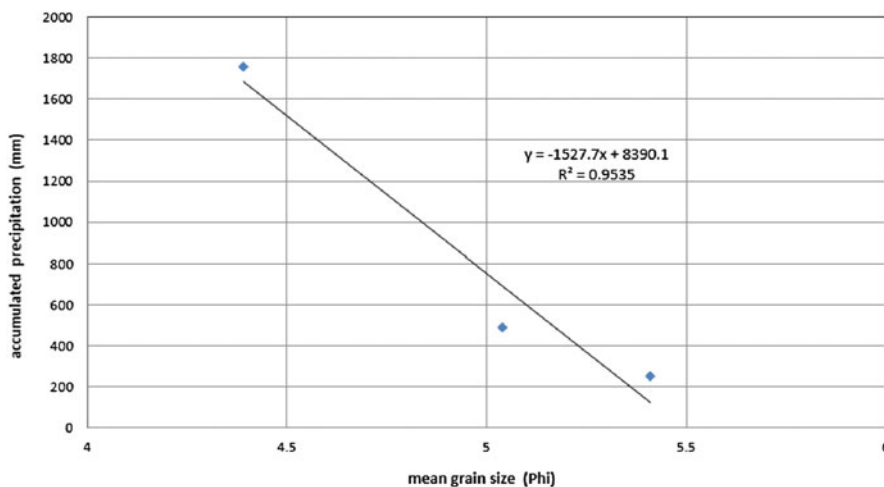


Fig. 8.8 Mean grain size versus rainfall during the monitoring period in Lake Eurimji

between 11.9 and 33.1, averaging 18.2. In unit 1 (N = 22) the mean grain size, MS, TOC, TN, and TOC/TN were 3.66 phi, 395.4 m-SI, 0.44 wt.%, 0.03 wt.%, and 14.0, respectively. In the lower part of unit 2 (N = 44) the values were 3.44 phi,

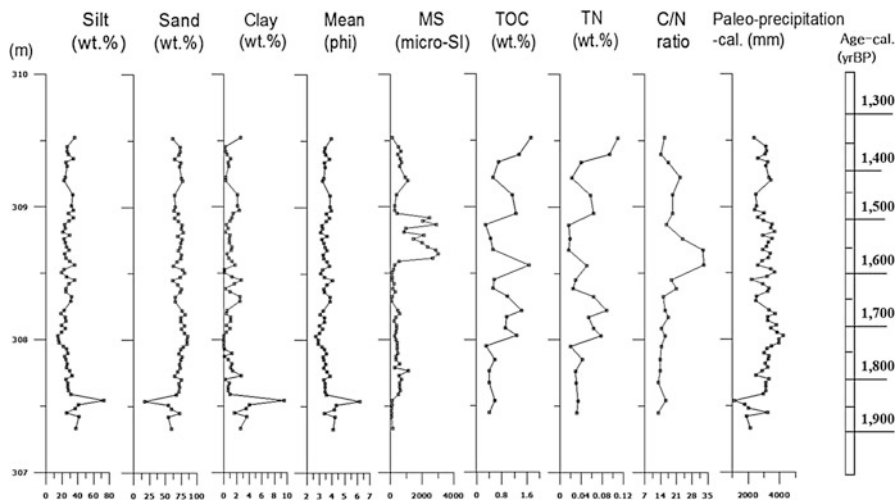


Fig. 8.9 Grain size, magnetic susceptibility, TOC, TN, T/C, and paleo-precipitation (calculated) between 1,400 and 1,900 cal-yr BP

858.8 m-SI, 0.95 wt.%, 0.05 wt.%, and 19.6, respectively. This implies that bottom sediments in unit 2 are coarser with a higher MS than those in unit 1; they also have more organic carbon and nitrogen (Nahm et al. 2012).

8.5 Documentary Records (Samguk-Sagi)

Written documents related to extreme climate events are available from Samguk-Sagi. Extreme drought signals were expressed as “no rain, dry, very or extremely dry.” In particular, during the Silla Dynasty, drought frequency was very high during the periods 286–335 AD, 786–835 AD, and 886–935 AD (Table 8.3). In this study the raw data were compiled and re-arranged in 10 year-cycles to correlate with the bottom sediments of Lake Eurimji cores (ER3-1).

8.6 General Discussion

8.6.1 Age of Lake Eurimji Reservoir

Previously, the Eurimji reservoir was thought to have been constructed using stone dams during the late Iron Age, or 540–576 AD, during the reign of King Jinheung of the Silla Dynasty (Yang et al. 2009). However, some bank materials – including wood fragments, twigs, leaves, and seeds – may indicate a much younger date of

Table 8.3 Dryness frequency data based on the “Samguk-Sagi” (historical document of the Early Three Kingdoms Period) (KMI 2011)

Historical age (yr BP)	Number of dryness	Historical age (yr BP)	Number of dryness
1,340	1	1,620	0
1,350	1	1,630	3
1,360	1	1,640	1
1,370	2	1,650	1
1,380	1	1,660	1
1,390	0	1,670	2
1,400	0	1,680	0
1,410	1	1,690	2
1,420	1	1,700	2
1,430	0	1,710	0
1,440	1	1,720	1
1,450	5	1,730	0
1,460	0	1,740	3
1,470	2	1,750	1
1,480	0	1,760	2
1,490	1	1,770	1
1,500	1	1,780	0
1,510	0	1,790	0
1,520	0	1,800	1
1,530	2	1,810	1
1,540	3	1,820	0
1,550	1	1,830	1
1,560	1	1,840	1
1,570	2	1,850	1
1,580	0	1,860	1
1,590	0	1,870	2
1,600	0	1,890	1
1,610	1	1,990	0

construction (ninth century AD). These materials also suggest that ancient engineers constructed an earthen dam by mixing tree debris with tamped clays to prevent reservoir water seepage. Since the ninth century AD, the bottom sediments of the lake at ca. 310.4 m.a.s.l. have been repeatedly disturbed either due to bank repair or modern deliberate rupturing to avoid lake flooding during excessive rainfall. The age of the oldest lake sediments in the lake below Eurimji bank, however, has been controversial. The present study clarifies the age by dating sediments from the bottommost part of the Eurimji bank.

The bottom sediments contain four sedimentary layers, which formed in the following four stages: (1) the post-dam-construction upper mud layer; (2) the middle layer of the artificial fill related to the dam construction, (3) the lower lake layers, and (4) the lowermost alluvial layer of the initial valley (Kim et al. 2009a, b, 2010).

During the construction of the artificial bank at the southern end of the lake, many parts of the oldest bottom sediments above 309.5 m.a.s.l. were disturbed, and artificial bank materials were mixed with older bottom sediments of about 2,000 yr BP. Anthropogenetic mixing of layers is likely to be higher in sediment cores obtained from above 310.6 m.a.s.l., where disturbance from major bank construction carried out in the ninth century AD is evident (Nahm et al. 2012).

However, the lower layers of sediments were dated to ca. 1,920 yr BP (Table 8.2), and showed a linear pattern of sediment heights versus sediment ages to about 1,420 yr BP. In addition, they contained more muddy sands and gravels, as found in the excavation trenches at the outer wall of the Eurimji bank. The oldest sands and gravels below the bank materials are assumed to be derived from old valley-fills and fluvial deposits. This was also identified in core ER-1 (Fig. 8.1), particularly below 308.0 m (Nahm et al. 2012; Kim et al. 2012; Yang et al. 2009). This may suggest that the bottom sediments of the lake accumulated long before the construction of the major bank at ca. 1,200 yr BP. In fact, based on the ER3-1 core, the bottom sediments existed 1,920–2,550 yr BP. Our data suggest that ancient people could have built artificial levees using the gravel and sand material deposited at the bottom of the Eurimji Valley, particularly in a notched-shaped valley overlain by concavely fractured Jurassic basement rocks at the southwestern part of Lake Eurimji (Kim et al. 2000a, b). This concave part below the Eurimji bank was identified between trenches 4 and 5 during the excavation of the outer wall of the bank (Fig. 8.3).

8.6.2 Environmental Changes During the Early Three Kingdoms Period

Sediment cores taken from above 307.25 m up to the lower part of unit 2 in the ER3-1 borehole (309.5 m.a.s.l.) were relatively stable. As shown in Table 8.2, the oldest age was determined to be ca. 2,550 yr BP (–772 BC), which is considered the late Bronze Age on the Korean Peninsula. As shown in Fig. 8.9, the multi-proxy data indicate that the small mean grain size is related to the drought signals in general; therefore, relative drought periods may be inferred from the dominance of fine-grained sediments in Lake Eurimji. The drought periods included 80 AD, 120 AD, 160 AD, 310 AD, 350 AD, 460–500 AD, and 620 AD. Relative wet signals were found at 90 AD, 150 AD, 200 AD, 240 AD, 320 AD, 360 AD, 435 AD, and 530 AD (Fig. 8.10). In addition, five MS peaks were identified at approximately 160 AD (307.75 m), 275 AD (308.20 m), 390 AD (308.65 m), 440 AD (308.90 m), and 540 AD (309.25 m) (Fig. 8.9). These peaks were neither positively proportional to the TOC, TN, and C/N values nor related to grain size or size populations. This may reflect human interference since 2,000 yr BP. Considering both the stable bottom parts of the sediment cores and bottom sediments in the excavated trenches, we obtain a sedimentation rate as high as 3.49 mm/year (Fig. 8.5). This high rate of sedimentation may also reflect human interference in areas where vegetation was rather scarce (Kang et al. 2009). At about 308.2–308.6 m.a.s.l., palynological evidence is poor because of low palynological productivity between AD 380 and

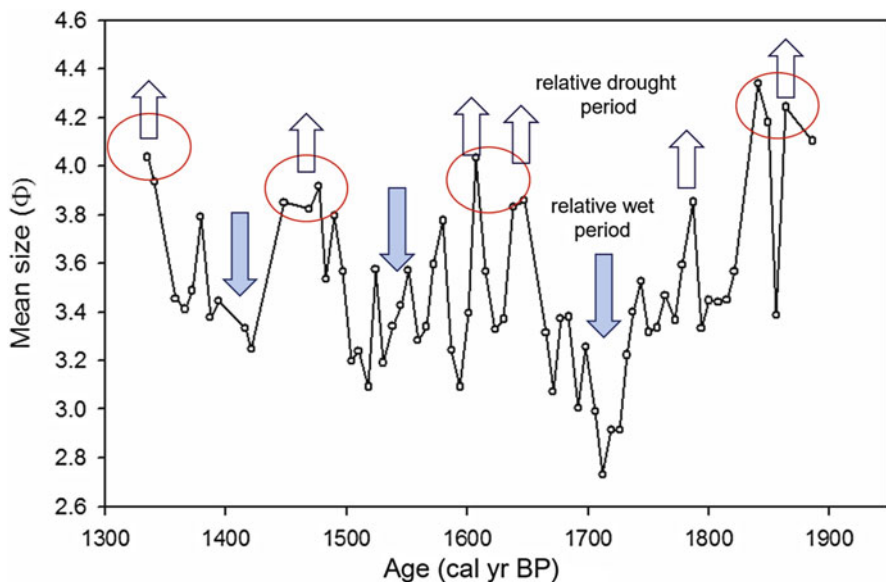


Fig. 8.10 Comparison of relative drought periods inferred from fine-grained sediments in Lake Eurimji during the Silla Dynasty (AD 50–650). Relative drought signals - 80 AD, 120 AD, 160 AD, 310 AD, 350 AD, 460–500 AD, and 620 AD; relative wet signals - 90 AD, 150 AD, 200 AD, 240 AD, 320 AD, 360 AD, 435 AD, and 530 AD

AD 285 (Kang et al. 2009). The low production might be influenced either by a dry climate in general or by human interference in or around Lake Eurimji catchment areas. Human influence may be more plausible because the sedimentation rate after 2,100–2,200 yr BP accelerated, as reported for the Paju Wetland, where since about the third century BC, the natural sedimentation rate has increased up to 0.16–0.29 mm/year (Nahm et al. 2012). However, this rate is far less than that seen in Lake Eurimji. This may be due in part to differences in prevailing agricultural activity between these sites.

Since the middle Bronze Age (ca. 3,500 yr BP) in Korea, agricultural activities have been widespread, and cultivation of rice, millet, barley, wheat, and soybean has been recorded at many archeological sites, including in association with Mumun pottery and Doldaemun, Gongyeolmun, and Ijunggyeon since ca. 1,500 BC (Lee 2006, 2010). Many small-scale agricultural paddy fields and agricultural tools have been documented at many excavation sites in Korea. Therefore, in Lake Eurimji catchment areas, the multi-proxy data may not represent pure natural signals of environmental change. However, sediment trap data from the monitoring site indicate that mean grain size increases with the total amount of precipitation, which applies in general to the ER-3-1 sediment cores, in which the mean grain size may be related to the total amounts of paleo-precipitation since 1,920 yr BP. This will elucidate possible changes in relative dryness and wetness in the Lake Eurimji catchment areas.

8.6.3 Historical Climatic Signals

Historical reservoirs have been excavated on the Korean peninsula. The Lake Eurimji reservoir bank was initially constructed from the late Bronze Age (ninth century BC) to the Iron Age (~first century AD), while the major construction was performed during the eighth century AD in the reign of King Wonseong of the Silla Dynasty. Baekgolje dam in Kimjye County was initially constructed in 330 AD, Sijye in Gyeonju City in 429 AD, Cheonjae in Youngcheon City in 531 AD, and Gonggeumji in Sangju City after 655 AD (Jang 2010; Seong 2010; Lee 2010; Yang et al. 2009). Construction of hydrological banks or dams suggests that ancient societies needed water reservoirs, as well as hydrological facilities, to enable agricultural activity during periods of drought. It is interesting that among the drought signals documented in Samguk-Sagi, the period between 286 AD and 335 AD is particularly conspicuous (Fig. 8.11). This may coincide with the construction age of Baekgolje dam in Kimjye County. Paleoclimatic signals based on sediment cores can also be compared to the drought signals recorded at Samguk-Sagi. In the present study on Lake Eurimji, we found that historical drought signs were associated with poor palynological productivity (Kang et al. 2009), small mean grain size (Fig. 8.10), and low MS (Fig. 8.9). Proxies (TOC, TN, C/N) related to biomass (Fig. 8.9), however, may not indicate any direct response to drought. In particular, the frequency of drought between 286 AD and 335 AD near Lake Eurimji may have been extremely high (Figs. 8.10 and 8.11), in line with Park and

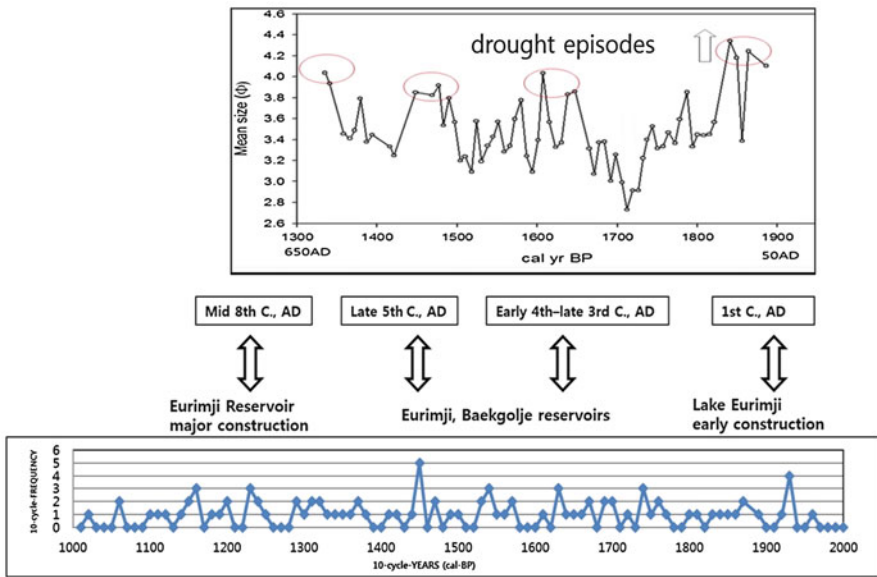


Fig. 8.11 Correlations of climatic changes between documentary records and bottom sediment cores

Rii (2007). Dry periods prevailed in the Korean Peninsula from 600 BC to about 800 AD, as is evidenced by data from the Yugu fluvial plain in the Keum River Basin and documented historical data from Samkuk-Sagi (Yoon and Hwang 2009; Lim et al. 2012).

8.7 Conclusion

The sediment layers of the Lake Eurmji reservoir consist of old alluvial (valley-fill) deposits in the lower part (<307 m.a.s.l.); pre-1,400 yr BP pre-damming natural lake deposits in the middle part (307–310.4 m.a.s.l.); and artificial material (310.4–315 m.a.s.l.) and heavily contaminated and disturbed post-damming lake deposits in the upper part (>315 m.a.s.l.). The earliest stone bank construction may have been initiated at ca. 2,000 yr BP during the late Iron Age. The major stage of construction took place during the time of the Unified Silla Dynasty, in the ninth century AD. The bottom sediments of the lowermost level of the reservoir were dated to the late Bronze Age to the early Iron Age based on the excavated trench profiles. The base of the Eurimji bank, composed of organic-rich sandy sediments and derived from natural processes, were dated to 2,550 yr BP (in excavated profiles) and 1,920 yr BP (in the reservoir).

A particularly severe drought period was found between 286 and 335 AD. This is consistent with a previous study by Park et al. (2007) that found drought signals in 311–320 AD. Historical extreme droughts may be associated with natural climatic changes that occurred in late 3rd and early fourth century AD in South Korea. The construction of an early Baekgolje dam (historically recorded in 330 AD, during the reign of King Biryu of the Baekje Dynasty) may also be associated with the prevalence of drought in the southern part of the Korean Peninsula. Radiocarbon ages of 2,550–1,920 yr BP in Lake Eurimji sediments and 2,020–1,720 yr BP in accumulated plant layers at the bottom of the Baekgolje dam both suggest that general dryness has prevailed since 2,000 yr BP in the southwestern part of Korea. In summary, it can be concluded that both Lake Eurimji reservoir sediments and Baekgolje dam sediments suggest that droughts in the Korean Peninsula induced nation-wide construction of hydrological banks or dams, particularly during the early Three Kingdoms Period (275–360 AD).

Acknowledgments This research was supported financially by the China-Japan-Korea international collaboration research project (2011–2013) funded by the National Research Foundation of Korea, and the Basic Research Project of the Korea Institute of Geoscience and Mineral Resources (KIGAM) funded by the Ministry of Knowledge Economy of Korea, and the Radioactive Waste Management of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government Ministry of Knowledge Economy (2012171020001B).

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