LOWLAND TECHNOLOGY INTERNATIONAL Vol.15, No. 1, 2-9, June 2013
International Association of Lowland Technology (IALT), ISSN 1344-9656

GEOSLICER AND ITS APPLICATION FOR SOIL STRATA ANALYSIS

T. Hino [1], R. Jia [1], T. Harianto [2], K. Ohgushi [3] and T. Ichihara [4]

ABSTRACT: Many "nogoshi", i.e., lower sections of the river bank that allow upstream floodwater overflow, have been built on the Jobaru River in Kyushu Island, Japan. The soil strata in the floodplain adjacent to the Yago Nogoshi of the Jobaru River were studied using a Geoslicer. The sedimentary facies and the sedimentary ages of the soil strata were determined using Geoslicer samples. The sedimentary environment of the test site was defined, and soil strata formed by sediments during large floods were identified. The layers below ground level (G.L.) -1.50 to -1.70 m are river channel deposits, and the layers above G.L. -1.50 to -1.70 m are back marsh deposits. The results of radiocarbon dating show that the river channel deposits were formed before AD 1500. The lower layers of the back marsh deposits, which contain a considerable quantify of plant roots, were formed at approximately AD 1600. The upper layers of the back marsh deposits, which contain a small quantity of plant roots, were formed after AD 1600. The time of artificial land alterations was deduced based on the results of the sample analyses.

Keywords: Geoslicer, radiocarbon dating, sedimentation phase analysis, nogoshi.

INTRODUCTION

Active flood control measures, including land utilization, have existed in Japan since ancient times. The Planning Committee of the River Council in Japan published the report "Effective Flood Control that Includes Measures for Individual River Basins" in 2000 (MLIT, 2000). Planned flood control and water utilization was implemented 400 years ago in Japan (Kishihara et al., 2011). However, there are very few places using these measures at present. Flood control structures, such as "nogoshi" (Fig. 1), a lowering of the embankment to allow upstream floodwater overflow, still remain in the Saga lowlands of Kyushu, Japan, but they are hard to find in other places. These structures can be used to study flood control measures in river basins.

To quantitatively evaluate the effectiveness of past flood control measures in the Saga Lowlands, the sedimentary facies and sedimentary ages in the floodplains must be analyzed. The Geoslicer is a suitable device for obtaining samples for sedimentary facies analyses and sedimentary age tests (Hino et al., 2010). In comparison with the conventional boring core sampling method, the Geoslicer sampling method has several advantages: for example, the Geoslicer sample is wider and is suitable for soil strata analysis, the soil strata can be directly observed in the field immediately after sampling, and it is cheap and easy to extract undisturbed soil sample. In this study, the sedimentary facies of the soil strata in the floodplain adjacent to the Yago Nogoshi of the Jobaru River (Fig. 1), located in Kanzaki City, Saga Prefecture, Kyushu, Japan, will be analyzed using Geoslicer samples.

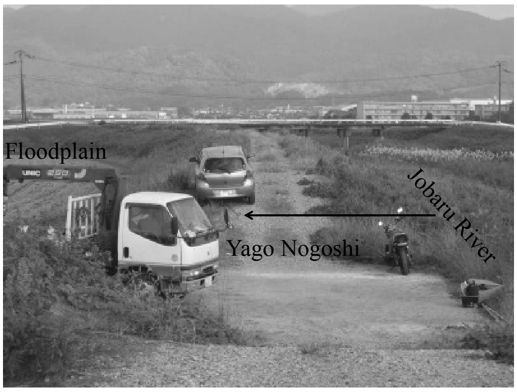

Fig. 1 The Yago Nogoshi of the Jobaru River

INVESTIGATION AND TEST METHOD

Geoslicer Investigation Method

[1] IALT member, Institute of Lowland and Marine Research, Saga University, Honjo 1, Saga 840-8502, JAPAN
[2] IALT member, J1. Perintis kemerdekaan Km. 10 makassar, 90245 Sulawesi Selatan, INDONESIA
[3] IALT member, Department of Civil Engineering and Architecture, Saga University, Honjo 1, Saga 840-8502, JAPAN
[4] Fukken Co., Ltd., 2-10-11, Hikari-machi, Higashi-ku, Hiroshima 732-0052, JAPAN
Note: Discussion on this paper is open until December 2013

Figure 2 shows the Geoslicer investigation procedures. The Geoslicer device, manufactured by Fukken Co., Ltd. in Hiroshima, Japan, includes a sample tray and a shutter plate (Patent No. 2934641, 1999). The sample tray and the shutter plate are pushed into the soil layers using a vibrating hammer or similar machine and then are pulled up together to obtain intact soil strata sandwiched between the sample tray and the shutter plate (Fig. 3).

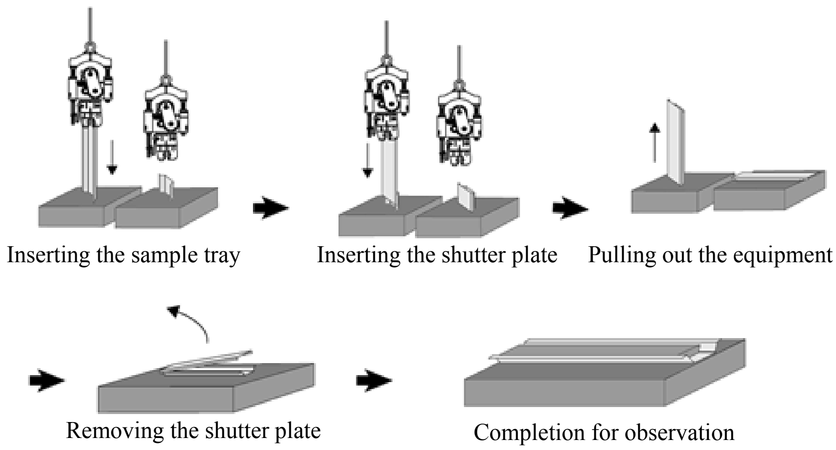

Fig. 2 Geoslicer investigation procedures

Fig. 3 Geoslicer investigation device

The Geoslicer investigation method provides several advantages compared with other investigation methods (Hino et al., 2010):

(1) It is easy to obtain sediments below groundwater level, which is difficult for trench investigations.

(2) The Geoslicer sample is wider than a boring core sample and is suitable for observation of soil strata.

(3) It is possible to conduct the investigation in a tidal zone during low tide because of the short sampling time.

(4) It is suitable for investigations of sedimentary structures and sedimentological examinations because soil strata with a constant orientation can be continually obtained in vertical and horizontal directions.

The test site is the floodplain adjacent to the Yago Nogoshi of the Jobaru River, which flows from north to south in Kanzaki City in the Saga Lowlands of Northern Kyushu, Japan (Fig. 4).

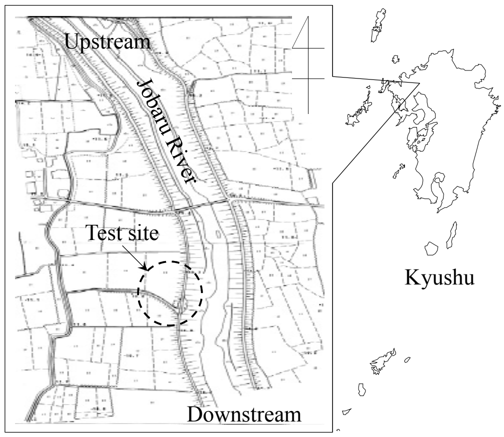

Fig. 4 Test Site

Eight vertical Geoslicer samples, with a width of 0.45 m, a length of 1.55 to 3 m and a thickness of 0.07 m, were obtained. The interval and relative location of each sample are shown in Fig. 5.

The surfaces of the samples were flattened and smoothed using a torsion sickle for better observation (Fig. 6).

Sedimentary Facies Analysis Method

Sedimentary facies analysis consists of classifying the sedimentary facies based on the observation of soil strata according to the thickness of each layer, the particle composition, the grain size composition, the sedimentary structure, the color tone and any plant or animal fossils and then estimating the sedimentary environment from the characteristics of layer boundaries and the superposition of soil strata (Walker and James, 1992; Reineck and Singh, 1980). Further details of the sedimentary environment can be estimated by comparing the sample with the characteristics of known soil strata from various experiments.

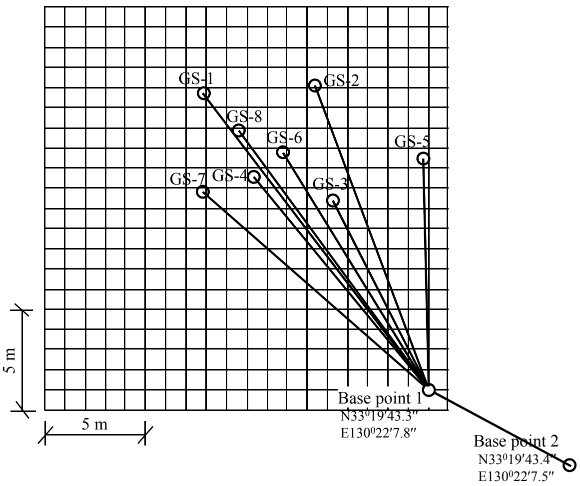

Fig. 5 Relative location of Geoslicer samples

Fig. 6 Smoothing of the soil strata samples

Radiocarbon Dating Technique

Radiocarbon dating is a technique that uses the decay of the carbon isotope in plant and animal remains (carbide of plants, animal bones, shells, etc.) to estimate the sedimentary age of the soil strata. The dating method is based on the fact that carbon is found in various forms, including the main stable isotope (^{12}C) and an unstable isotope (^{14}C). The half-life of the carbon isotope, ^{14}C, is approximately 5730 years. Through photosynthesis, plants absorb ^{14}C in the atmosphere (primarily in the form of carbon dioxide). Because the ^{14}C cannot be replenished except through photosynthesis, the amount of ^{14}C in the plant will be reduced by half approximately 5730 years after the death of the plant. It is possible to determine when the plant died by determining the proportion of ^{14}C in the sample. In the case of animal remains, the principle of age determination is the same, because the animal ingested the ^{14}C in a fixed form in the plant. The plant debris in the soil strata were used for radiocarbon dating in this study.

The radiocarbon dating measures the age of the plant debris and is not always the same as the sedimentary age of the soil strata. During sampling, samples in upper layers may be dropped down to lower layers and samples in lower layers may be carried to upper layers, which can result in conflicting age measurements.

The above-mentioned sampling errors can be minimized using the Geoslicer to obtain soil strata because wider samples better preserve the sedimentary structure. However, the plant debris will inevitably be moved to other soil strata because of the vertical disturbances of the soil strata. The only way to eliminate abnormal values is to increase the measurement frequency.

TEST RESULTS AND DISCUSSIONS

Sedimentation Phase Analysis Results

The samples were photographed using a digital camera, with a ribbon rod placed beside each of the samples. The images were processed to show 0.5 m of soil strata each, and then they were combined to form a sequence photo, showing the entire sample. Figure 7 shows the combined sequence photos of the samples at locations GS-1, GS-3 and GS-6.

Figure 8 shows six typical sedimentary facies of the obtained samples:

(a) Back-marsh deposits (GS-1, 1.25-1.50 m): Primarily composed of taupe and brown silt; many traces of plant roots are observed in this layer.

(b) Cutoff channel deposits (GS-1, 1.95-2.20 m): Primarily composed of dark gray massive silt.

(c) Natural levee area deposits (GS-6, 1.65-1.90 m): Primarily composed of yellowish-brown sand.

(d) River channel deposits (GS-3, 1.70-1.90 m): Primarily composed of sand with parallel lamination, mixed with fine gravel.

(e) River channel deposits (GS-3, 2.00-2.30 m): Primarily composed of sand and gravel. The diameters of the gravels are primarily 2 to 40 mm, and the gravels are primarily granite and andesite.

(f) Cultivated soil (GS-1, 0.00-0.17 m): A blackish-brown, sandy silt layer distributed at the surface (10-20 cm), containing a large quantity of organic matter.

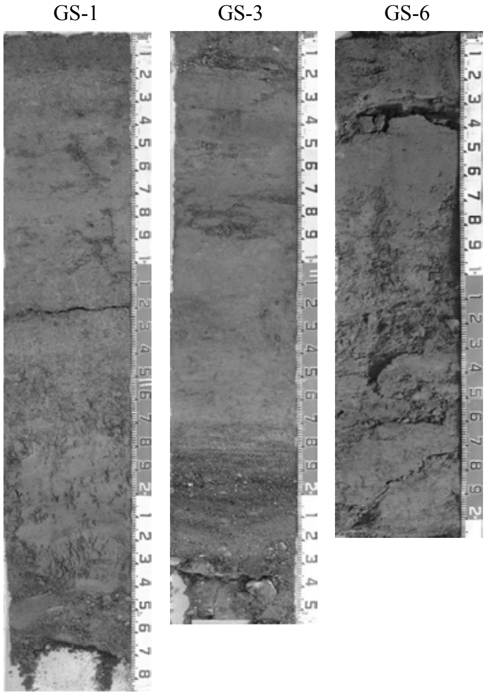

Fig. 7 Photos of the Geoslicer samples (GS-1, GS-3 and GS-6)

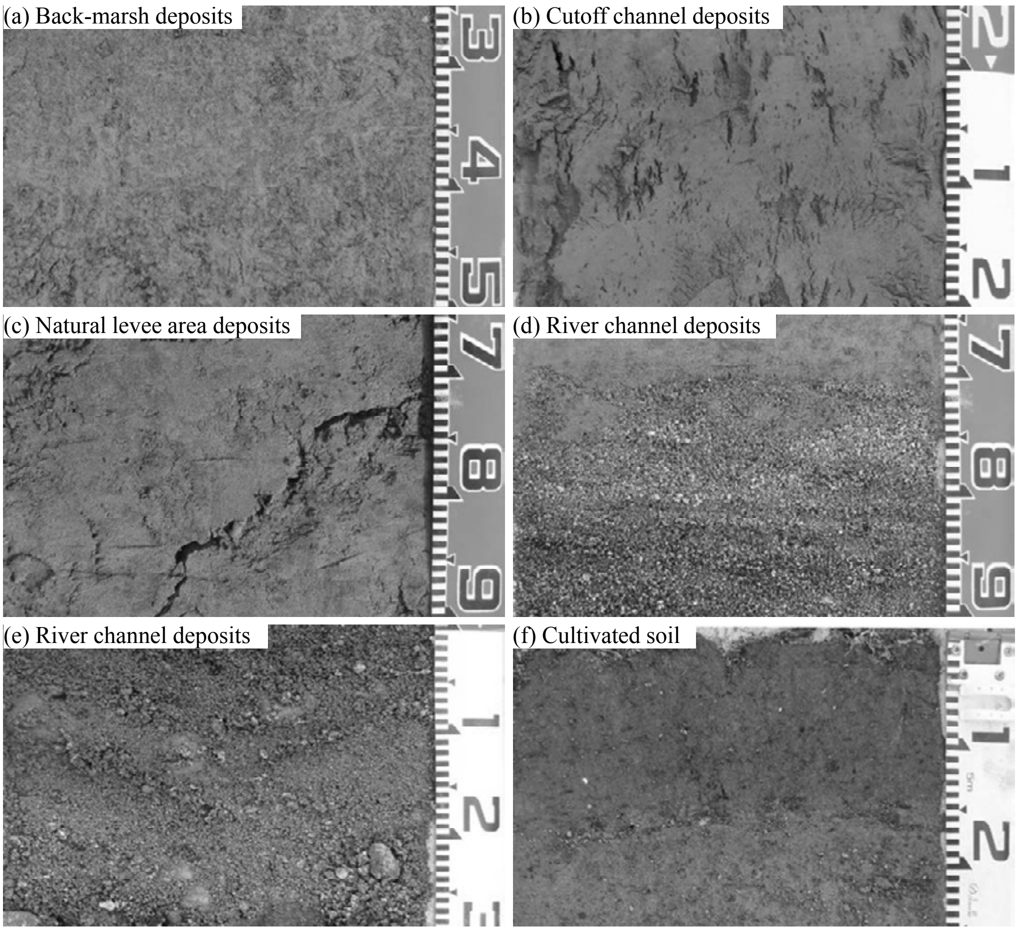

Fig. 8 Typical sedimentary facies of the samples: (a) GS-1 (1.25-1.50 m), (b) GS-1 (1.95-2.20 m), (c) GS-6 (1.65-1.90 m), (d) GS-3 (1.70-1.90 m), (e) GS-3 (2.00-2.30 m), and (f) GS-1 (0.00-0.17 m)

Figure 9 shows the sedimentary facies analysis for a typical Geoslicer sample (GS-1). In the figure, a dark brown and unconsolidated sand and gravel layer is identified at ground level (G.L.) -2.70 to -2.55 m. The diameters of the gravels are 2 to 40 mm, and they are primarily sub-rounded granite and andesite gravels. At G.L. -2.55 to -2.45 m, the sample shows a dark gray, fine sand layer with parallel lamination, covered with a 2 to 5 mm-thick mud drape. At G.L. -2.45 to -1.75 m, the sample contains a dark gray, massive silt layer carrying a few thin layers of very fine sand. At G.L. -1.75 to -1.00 m, the sample shows a sandy silt layer, colored from taupe to brown, with many traces of plant roots. At G.L. -1.00 to -0.15 m, the sample contains a sandy silt layer colored from taupe to brown. Very fine, patchy, lens-shaped sand (approximately 0.01 m × 0.02 m^2) are found at the depth of G.L. -0.30 m, -0.40 m, and -0.45 m. At G.L. -0.15 to 0.00 m, the sample shows a layer of blackish brown sandy silt, which is the surface soil of the paddy field at the present time.

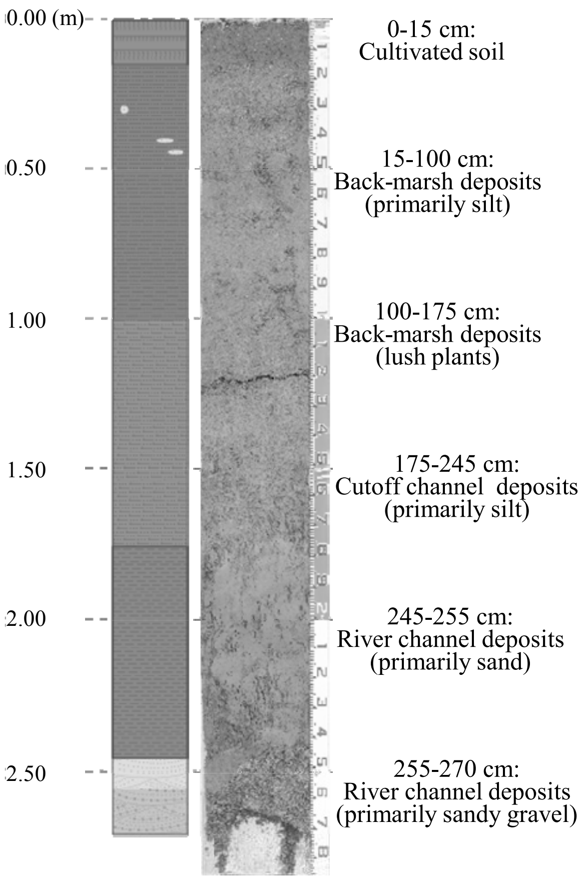

Fig. 9 Typical sedimentary facies analysis result (GS-1)

Figure 10 shows the results of the sedimentation facies analyses for all Geoslicer samples. The test site is in the paddy field. Based on the broad sedimentary environment definition (Shimoyama et al., 2010), it was created by the back marsh deposits of a floodplain. The sediments in back marsh deposits generally consist of suspended fine sands carried by the water of the river, and contain lush plants during the period without sedimentation (Allen, 1978). Based on this characteristic, Fig. 10 shows the cross-section of each soil stratum.

The sedimentation phase analyses show that the lowest layers of the observed soil strata are river channel deposits, which are sediments primarily composed of sand and gravel. This suggests that the old channel of the Jobaru River passed through the test site. The river channel is expected to meander and change in the natural environment.

The river channel was cut and Cutoff River was formed with the meandering of the river channel. Then, Cutoff River became Oxbow Lake. After the formation of Oxbow Lake, the supply of main sediments from the river was cut and only silt and clay carried by water when the water level is high was deposited. The upper boundary of the river channel deposits and the upper boundary of the cutoff channel deposits in Oxbow Lake are at approximately the same height, thus it is thought that this sedimentary facies represents the river sediments deposited under natural conditions.

The clay and andesite gravels with diameters of 0.10 m are found at G.L. -1.20 m (GS-4) and G.L. -1.30 m (GS-5). These gravels are unlikely to be naturally contained in the back marsh deposits, thus they are thought to be mixed artificially added. The frequency of the plant root traces changed significantly above and below the soil stratum containing gravels, which suggests that artificial land alterations may have been conducted around this layer. It is thought that the artificial land alterations were conducted in the Edo Period.

The thin sand layers (patchy sand layers) are found at approximately G.L. -0.30 m. It is believed that the original sand layers were disturbed by plants and scattered to form the patchy sand layers. Suspended silt and clay carried by water are normally the only sediments in the back marsh area. The sand layers are found only in the locations close to the nogoshi, suggesting that the sand was not transported because of the reduction in flow velocity of the river water overflowing nogoshi.

Radiocarbon Dating Results

Table 1 shows the wood chips collected from soil strata during visual observation. The results of radiocarbon dating using these wood chips are shown in Fig. 10.

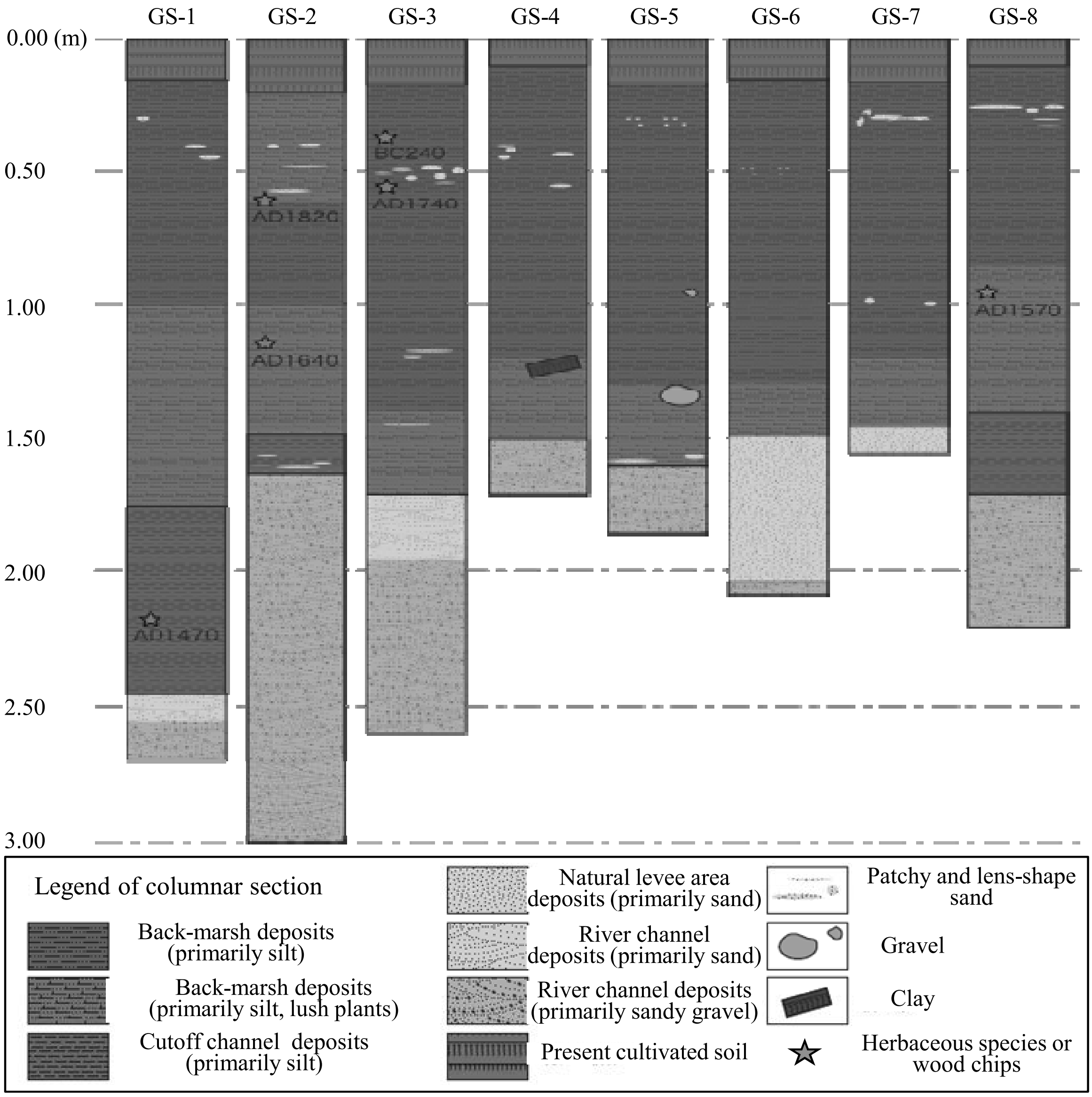

Fig. 10 Sedimentation phase analysis results (GS-1−GS-8)

Table 1 Samples for radiocarbon dating

No.	G.L. (m)	Sample	Size (mm^2)
GS-1	-2.35	Herbaceous species	3×30
GS-2	-0.70	Wood chip	3×15
GS-2	-1.30	Wood chip	4×10
GS-3	-0.45	Herbaceous species	5×15
GS-3	-0.60	Wood chip	3×4
GS-8	-0.92	Wood chip	5×5

The measured date of origin of the herbaceous species from the Cutoff channel deposits at G.L. -2.35 m (GS-1) using radiocarbon dating is AD 1470±20 (Reimer et al., 2009; Bronk Ramsey, 2009). Thus, the test site was the channel of the meandering river until approximately AD 1500.

The soil strata, primarily composed of silt, are thought to be the back marsh deposits of the floodplain. Numerous traces of plant roots are found in the lower layers of the back marsh deposits. It is thought that many lush plants existed in the past, including plants with thick and deeply developed underground stems, such as reeds. The measured date of origin of the wood chips at G.L. -1.30 m (GS-2) and G.L. -0.92 m (GS-8) are AD 1640±30 and AD 1570±20, respectively. The traces of plant roots are fewer in the upper layers of the soil strata, primarily composed of silt.

The measured date for the wood chips at G.L. -0.70 m (GS-2) is AD 1820±20, and the measured date for the wood chips at G.L. -0.60 m (GS- 3) is AD 1740±20. The measured date for herbaceous species at G.L. -0.45 m

(GS-3) is BC 240±20. This is an example of an upper layer showing an older age than the lower layer, which sometimes occurs in radiocarbon dating because of secondary sample movement.

Change of the sedimentary environment

The test site is in the area of meandering of the Jobaru River prior to AD 1500. Thus, the identified sand and gravel layers are thought to be filling sediments of the river channel. Then, the river channel was abandoned by the meandering of the river, and it is assumed that Oxbow Lake (around GS-1, GS-2 and GS-8 in Fig. 5), as part of the cutoff channel, existed in the test area. There were wide back marsh areas in the floodplain until this time. Because the plants were lush in the back marsh, traces of plant roots are found in the soil strata. At approximately AD 1600, the traces of plant roots decreased, perhaps because the area was used as a paddy field, as it is today.

CONCLUSIONS

Eight soil strata samples were obtained using a Geoslicer in the floodplain adjacent to the Yago Nogoshi of the Jabaru River on Kyushu Island, Japan. The sedimentary facies were analyzed based on sedimentological examination of the samples. The sedimentary ages of the strata were determined using radiocarbon dating. Based on the investigation and test results, the following conclusions can be made:

1) River channel deposits, or cutoff channel deposits, are distributed in the layers deeper than ground level (G.L.) -1.50 to -1.70m. These layers are thought to be filling sediments of the river channel. The layers over G.L. -1.50 to -1.70 m are thought to be back marsh deposits consisting primarily of silt.

2) Numerous traces of plant roots are found in the lower layers of the back marsh deposits, whereas such traces are fewer in the upper layers of the back marsh deposits. At the upper layer of the back marsh deposits, thin sand layers are found and the sand layers are thought to be deposited during large floods of the Jobaru River. It is likely that the clay and andesite gravels found in the back marsh deposits resulted from artificial land alterations.

3) Radiocarbon dating results show that the river channel deposits were deposited by AD 1500. The lower layer of the back marsh deposits, with many plant roots, were formed at approximately AD 1600 and upper layers of the back marsh deposits with fewer plant roots were formed after AD 1600.

ACKNOWLEDGEMENTS

The authors are grateful to the Japan Society for the Promotion of Science for funding the present research work under 2011-2013 Grant-in-Aid for Scientific Research • Scientific Research (B) (General), 23310128 (Principal Investigator: Koichiro Ohgushi at Department of Architecture and Civil Engineering, Saga University). Logistical and financial support, given to the third author while a visiting associate professor at the Institute of Lowland and Marine Research, Saga University, Japan, are gratefully acknowledged.

REFERENCES

Allen, J. R. L. (1978). Fluvial sedimentation. In: Fairbridge, R.W. and Bourgeois, J. (Editors), The Encyclopedia of sedimentology, dowden hutchinson &Ross, New York: 335-33.

Bronk Ramsey. (2009). Bayesian analysis of radiocarbon dates, Radiocarbon. 51(1): 337-360.

Hino, T., Igaya, Y., Chai, J.C., Jia, R., Shirai, Y., and Tanaka, J. (2010). Properties of soft clays in the Saga plain with respect to embankment construction. Proceedings of the International Symposium and Exhibition on Geotechnical and Geosynthetics Engineering: Challenges and Opportunities in Climate Change, Bangkok, Thailand: 167-177.

Kishihara, N, Iwayama, H., Izumi, I. and Kuroiwa, A. (2011). Study on the flood control system as part of the flood control basin Jobaru River in Saga Plain, Research on Lowland Technology, Lowland Research Association, Saga University, No.20: 5-12. (in Japanese)

Patent No. 2934641 (1999). T. Nakata, Japan Nuclear Cycle Development Institute, FUKKEN CO., LTD.

Planning Group of the River Council, Ministry of Land, Infrastructure and Transport (2000). Effective Flood Control That Includes Measures for Individual River Basins: 16 (in Japanese)

Reimer, P. J., Baillie, M. G. L., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Bronk Ramsey, C., Buck, C. E., Burr, G. S., Edwards, R. L., Friedrich, M., Grootes, P. M., Guilderson, T. P., Hajdas, I., Heaton, T. J., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., McCormac, F. G., Manning, S. W., Reimer, R. W., Richards, D. A., Southon, J. R., Talamo, S., Turney, C. S. M., van der Plicht, J. and Weyhenmeyer, C. E. (2009). IntCal09 and Marine09 radiocarbon age calibration curves, 0-50,000 years cal BP. Radiocarbon. 51(4): 1111-1150.

Reineck, H.E. and Singh, I.B. (1980). Depositional Sedimentary Environments. Springer-Verlag, New York: 549.

Shimoyama, S., Matsuura, H. and Hino, T. (2010). Geology of the Saga District, Quadrangle Series, 1:50,000, Fukuoka (14), No. 71, NI-52-11-9, 97. (in Japanese with English summary)

Walker, R.G. and James, N. P. (1992). Facies models - response to sea level change. Geological Association of Canada, St. John's: 409.