Optical Investigation of Archaeological Remains on Bottom of Lake Biwa by a hovering-type AUV "Hobalin"

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***Abstract*—This paper describes the investigation results of archaeological remains on the bottom of Lake Biwa, Japan. The positions of ancient potteries were observed optically by the hovering-type AUV "Hobalin", and the positions of them were estimated by the combination of optical and acoustical methods with an accuracy of a few meters.**

Keywords*—*lake bottom, archaeological remains, AUV, Optical observation

I. INTRODUCTION

In association with the development of underwater observation technology, the underwater archaeology is becoming all the more remarkable field. Most underwater remains are formed by the local crustal deformation of coastal artifacts. Therefore, typical water depths of underwater remains are less than 30 m, and they can be investigated optically by divers. However, wrecks are distributed deeper than the usual limit of investigation depth by divers (~30 m). In this case, observation by an underwater vehicle is needed. The Lake Biwa is the largest lake in Japan, and also the ancient lake. The Tsuzuraozaki Lake bottom site is known as one of the underwater archaeological remains in the Lake Biwa (Fig.1). So far, more than 140 items of ancient pottery have been raised from the Lake bottom of the depth range of 10 to 70 m [1][2]. It is still an open question as to why many potteries are found and others are not found so much. The large scale and precise investigation is required, though it is difficult for divers to reach to the deepest area of the remains. Additionally, ancient potteries on the mud bottom are not reacted strongly by sonar or electric exploration. Therefore, optical observations by the underwater vehicle are necessary for the investigation of the underwater remains. In this study, we used a hovering type AUV, "Hobalin" for the investigation of the deepest part (depth 60 - 72 m) of the Tsuzuraozaki Lake bottom Site. Hobalin has originally been built for the deep seafloor survey (max. depth 2,000 m), and some modifications were needed for the operation of Hobalin in the lake bottom investigations.

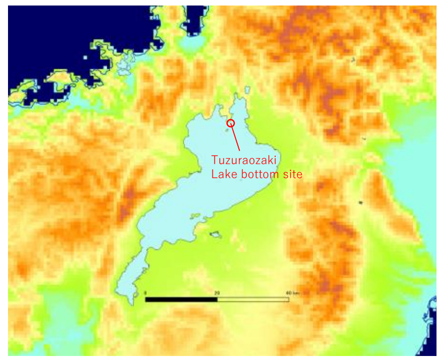

Fig. 1. The map of Lake Biwa and the location of the Tuzuraozaki Lake bottom site.

II. HOVERING-TYPE AUV "HOBALIN"

A hovering type AUV, "Hobalin" has been developed in 2015 as one of the multiple AUV system in "Next-generation technology for ocean resources exploration (Zipangu-in-the-Ocean)" project in "Cross-ministerial Strategic Innovation Promotion Program (SIP)" [3]. Hobalin has been designed as a compact AUV for deep seafloor exploration up to 2,000 m. The weight is 270 kg in air, and the bottom size is 1.2 m by 0.7 m. The schematics are shown in Fig.2, and the specifications are shown in Table 1. It does not take much deck space of the vessel, and the launch and recover are easier due to the light weight. These specifications make it possible to be operated in Lake Biwa with the research vessel "R/V Hakken" (18.9 m, 36 t) [4][5].

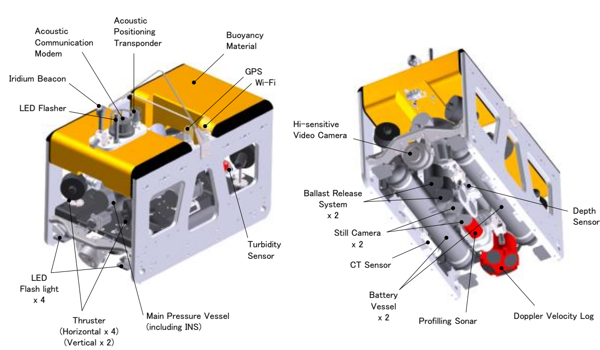

Fig. 2. Schematics of the hovering-type AUV "Hobalin".

TABLE I. SPECIFICATIONS OF THE AUV "HOBALIN"

Dimensions	1.2m(L) x 0.7m(W) x 0.77m(H)
Mass	270 kg
Depth Rating	2,000 m
Speed	0.2 m/s (at bottom cruising)
Duration	~8 hours
Navigating Sensors	Inertial Navigation System (FOG) Doppler Velocity Log (600 kHz) Depth Sensor
Actuators	Thrusters x 6 (horizontal x 4, vertical x 2) Ballast Releasers x 2 (diving and surfacing)
Communication	Acoustic Modem (9 ~ 14 kHz, cone angle 35 deg)
Positioning	USBL (21.5 ~30.5 kHz downward) (19.5~21.0 kHz upward)
Light Sources	LED Flasher x 4 Continuous LED Light x 2 Line Continuous Wave Laser x 2
Observation Devices	Digital Still Camera x 2 Video Camera x 1 USB Camera x 2 Profiling Sonar (675 kHz)
Payload Sensors	Conductivity Temperature Sensor Turbidity Sensor pH Sensor Hydrophone

For the sake of the AUV operation in the lake, additional buoyancy materials were necessary for Hobalin to keep neutral buoyancy in fresh water. Onboard sonar for seabed navigation and observation (DVL, Profiling sonar, etc.) were not re-calibrated for fresh water, and it may have been caused approximately 1 % error of distance estimation due to change of sound velocity in water. Meanwhile, the vertical profile data of sound velocity in fresh water were observed daily before AUV dive (Fig.3) and were used for the USBL acoustic positioning system to keep position estimation accuracy.

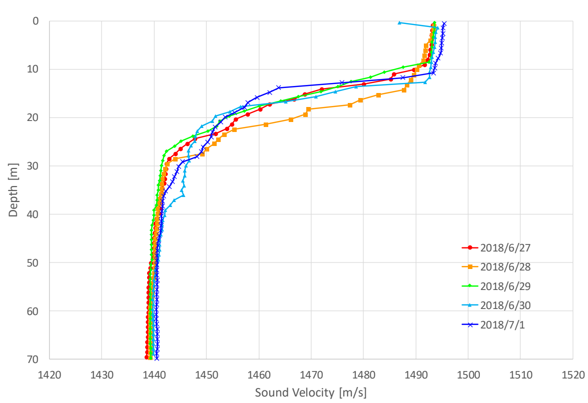

Fig. 3. Vertical profiles of sound velocity in the investigated water area.

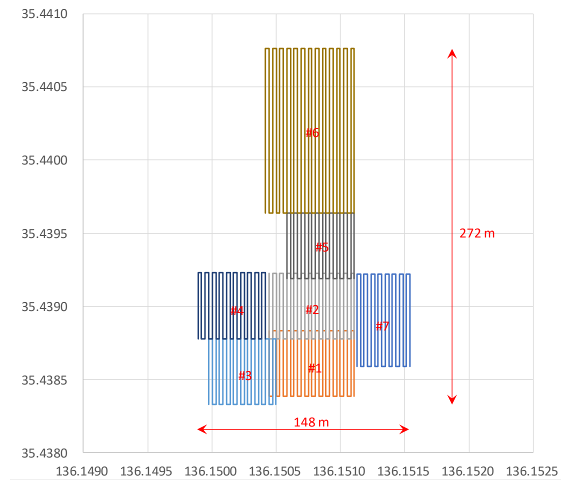

Fig. 4. The total investigation area by Hobalin from Jun.27 to Jul.1.

III. OBSERVATIONS

The optical observations of archaeological remains in Lake Biwa were conducted during Jun.27 to Jul.1 of 2018. Seven dives were operated in this investigation period, and the total time of bottom observation was 15 hours 21 minutes. The cruising speed of Hobalin was 0.2 m/s, altitude from the lake bottom was 2.5 m, two still cameras (Ricoh GR) were installed on the bottom of Hobalin with faced straight down, Field of View of 52 degrees, and were operated at the same time. The interval of survey-lines was 2.5 m. By these observations, 29,413 photographs of the lake bottom were obtained, and the investigation area was 23,110 m2 in total as shown in Fig.4.

The position estimation of Hobalin on the lake bottom was carried out every 4 seconds by the USBL acoustic positioning system (iXBlue GAPS). The main device of USBL was set beside the R/V Hakken, and the transponder was set on top of Hobalin. The position of the main device of USBL was measured every second by DGPS (Hemisphere A101). Photo shooting time was recorded synchronized with the INS (iXBlue Phins) of Hobalin. The schematics of the position estimation are shown in Fig.5.

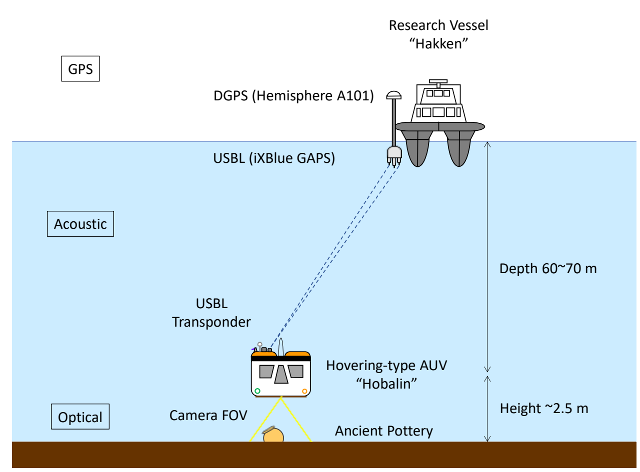

Fig. 5. Schematics of position estimation for archaeological remains.

IV. Data Analysis

The obtained photographs were adjusted their image quality by “automatic smart correction” function of Adobe Photoshop Elements 8, and then the existence of ancient remains was determined by shape, size, surface color of the objects. The bottom sediments of the investigated area were mainly mud, and partially gravel. Some modern wastes were also found. Because Hobalin altitudes were kept in 2.5 m, the lake bottom images were affected by the turbidity of the lake water and clear images were not obtained. However, they have sufficient resolution and contrast for the shape determination of artificial objects. Nine ancient potteries are found, as shown in Fig. 7. The scales of nine segmented photos are the same. The time and position data of photo shooting are shown in Table 2. The position of Hobalin at the shooting time was estimated by the median of immediately before and after of USBL data. The position of R/V Hakken at the shooting time was estimated by the median of immediately before and after of DGPS data. The distribution of nine ancient potteries are shown in Fig.6.

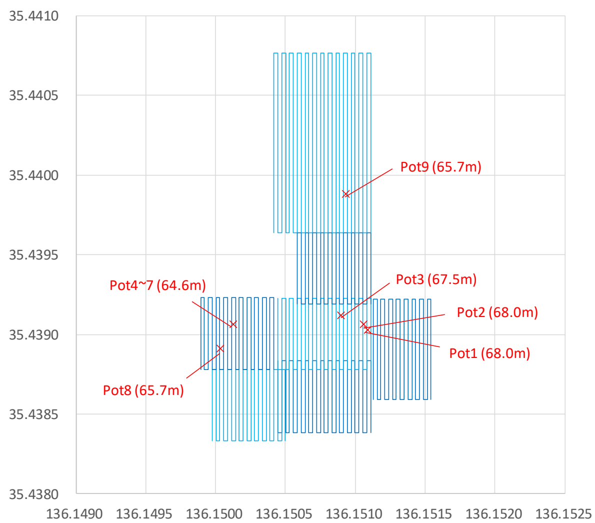

Fig. 6. The distribution of detected ancient potteries with depth estimation.

The error of position estimation of Hobalin located 2.5 m above the ancient pottery can be described by the resultant error of DGPS and USBL.

$$\sigma_{total}{}^2 = \sigma_{DGPS}{}^2 + \sigma_{USBL}{}^2$$

According to the DGPS manual, the positioning error is 1.2 m when the GPS radio signal is weak. According to the USBL manual, the positioning error is 0.53% of the slant length when the acoustic signal is weak. The resultant errors are shown in Table 2. All of the position errors for detected ancient potteries are within 1.5 m.

V. Conclusions

Investigation of the deepest part of the Kazuraozaki underwater archaeological remains in Northern end of Lake Biwa was carried out using an AUV, Hobalin. The depth of the site was 60 - 72 m, where it is difficult to investigate by divers. Though Hobalin had been designed and built for deep-seafloor exploration, it worked in the lake water without any serious trouble. 23,110 m^2 area of the lake bottom were observed by two still cameras mounted on Hobalin, and nine ancient potteries were determined from photographs. Additionally, because slant length between the research vessel and the AUV was relatively shorter than ocean exploration, the position of the AUV was estimated with higher accuracy.

A survey of archaeological remains will not be completed at once, and repeated investigations are necessary. In that sense, it is an important task to preserve the current situation and lead to the next survey. In this survey, photographs of nine ancient potteries were taken and the latitude, longitude, and depth of the place are shown within an error of a few meters. It is thought that the efficiency of the survey from the next time can be improved significantly.

Probably, this is the first report of wide position distributions of underwater remains (deeper than 30 m) on the lake bottom by optical observations.

Acknowledgments

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References

[1] http://www.pref.shiga.lg.jp/edu/sogo/kakuka/ma07/treasure_of_water/files/wot_16.pdf *(in Japanese)*

[2] https://www.city.nagahama.lg.jp/section/kyouken/junior/category_01/01_kodai/remains/tsuzura.html *(in Japanese)*

[3] A.Okamoto, et. al., “Development of Hovering-type AUV "HOBALIN" for Exploring Seafloor Hydrothermal Deposits”, Proc. Oceans’16 Monterey (2016) 160511-038.

[4] http://www.biwako-trust.com/?p=1681 *(in Japanese)*

[5] M.Kumagai et. al., “A new autonomous underwater vehicle designed for lake environmental monitoring”, Advanced Robotics, Vol.16 No.1 (2002) 17-26.

TABLE II. POSITIONS OF DETECTED ANCIENT POTTERRIES

	Photo Shooting Time UTC	R/V Hakken DGPS		Hobalin USBL			Slant Length	Total Error
		Latitude	Longitude	Latitude	Longitude	Depth		
Pottery1	2018/6/28 1:18:07	35.439101	136.151008	35.439029	136.151087	67.16	65.44	1.25
Pottery2	2018/6/28 1:21:28	35.439240	136.150845	35.439065	136.151061	66.87	70.02	1.26
Pottery3	2018/6/28 1:48:17	35.438628	136.150135	35.439122	136.150895	66.33	108.64	1.33
Pottery4-7	2018/6/29 2:15:45	35.438971	136.150806	35.439061	136.150126	63.50	87.18	1.29
Pottery8	2018/6/29 2:29:46	35.438435	136.150144	35.438911	136.150037	64.25	81.80	1.28
Pottery9	2018/6/30 2:31:00	35.440894	136.151409	35.439880	136.150934	62.79	134.79	1.40

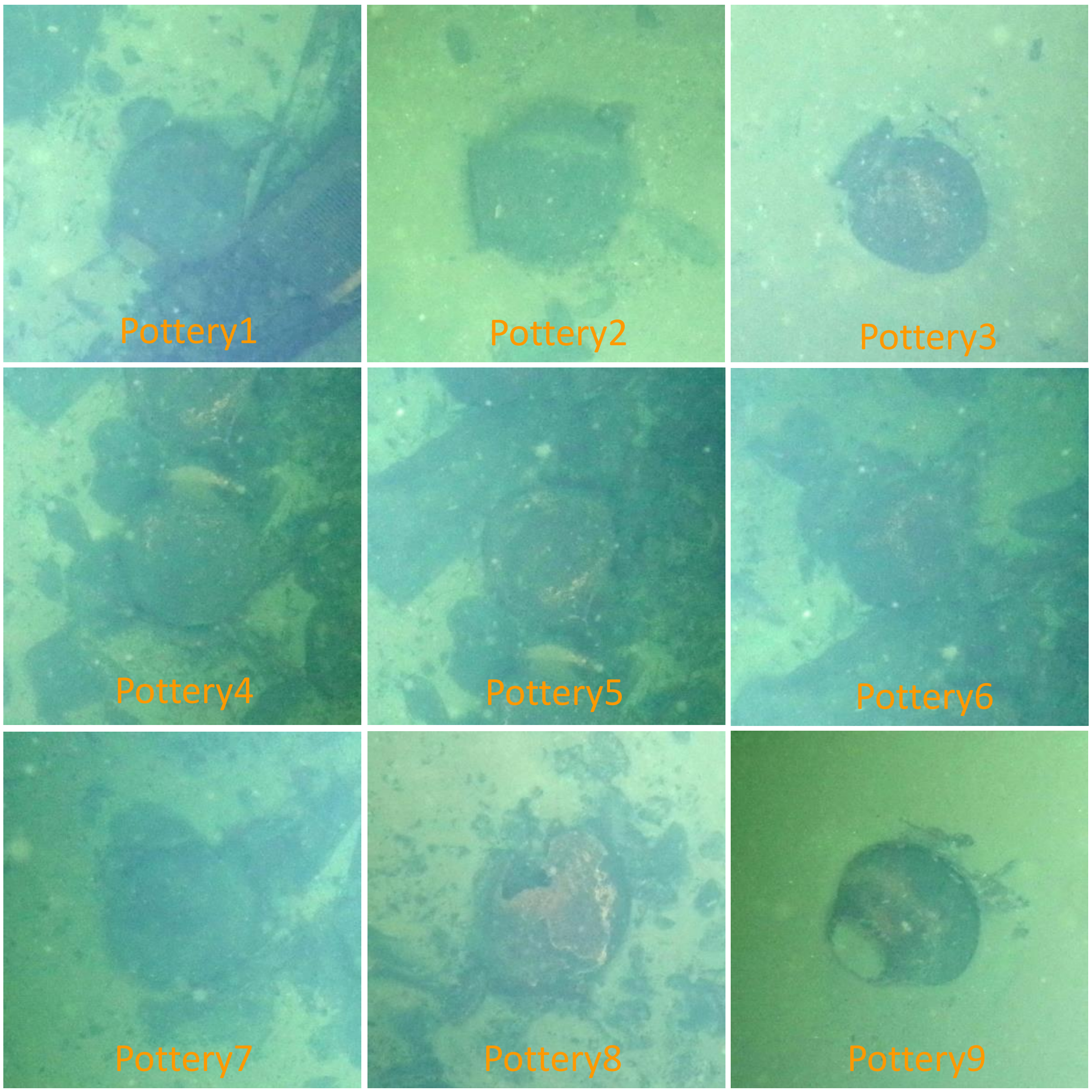

Fig. 7. Image quality adjusted and trimmed photographs of ancient potteries in depth of 60 – 70 meters in Lake Biwa.