Application and Challenges of Photogrammetry in Underwater Excavations: Case Studies from the Jeju Sinchang-ri and Gunsan Seonyudo Sites, Korea

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Abstract

Photogrammetry has become a widely adopted method in underwater archaeology worldwide and is increasingly used in Korean land-based archaeological investigations. However, its application in Korean underwater sites has been challenging due to strong currents and low visibility. This study examines photogrammetric applications in two Korean underwater sites: Jeju Sinchang-ri, where relatively clear visibility allowed for the creation of detailed site maps, and Gunsan Seonyudo, where sedimentation and low visibility required experimental approaches.

At Sinchang-ri, a photogrammetric survey was conducted with a Double Grid method and 10-meter grid units, enabling the production of plan before and after dredging and an artifact distribution map. High-resolution data was acquired using Metashape, resulting in 3D models and orthophotos that effectively visualized site distribution. In contrast, at Seonyudo, the presence of 1-meter-thick sediment made high-resolution artifact mapping difficult. To address this, experimental approaches were tested, including adjusting survey timing based on tidal changes and using underwater lighting for stratigraphic recording. This resulted in the creation of plan of trenches and stratigraphic cross-sections, distinguishing artifact-bearing layers from non-artifact-bearing ones. These case studies highlight the need to refine photogrammetric techniques to suit different underwater environments. As more shipwrecks are discovered, the advancement of photogrammetric methodologies will contribute to more effective underwater surveys and documentation.

1. Introduction

Photogrammetry was first introduced to underwater archaeological fieldwork in the 1960s (Bass, 1970) and has since become widely used in underwater archaeology worldwide. It is also now commonly applied to terrestrial archaeological sites in Korea. However, the application of photogrammetry to domestic underwater sites has often been limited due to strong currents and poor visibility. Recently, with the discovery of a site with relatively favorable conditions in terms of currents and visibility, photogrammetry was attempted in a Korean underwater archaeological context. Following this initial application, the technique has been adopted at other excavation sites as well.

In the waters off Sinchang-ri, Jeju, visibility is relatively good; however, the site is shallow, with depths ranging from 2 to 4 meters, and is heavily affected by ocean surges. Therefore, divers conducted photography while walking rather than swimming. To prevent the loss of artifacts after dredging, artifacts were retrieved every ten days. Additionally, orthophotos generated from photogrammetric outputs were used to create artifact distribution maps at ten-day intervals. This approach not only allowed for effective documentation of artifact distribution but also ensured that no artifacts were missed during underwater recovery, enabling simultaneous packaging on site.

At the Seonyudo site in Gunsan, located in Korea’s western sea, photogrammetry was used to attempt the generation of 3D plans of the excavation area. Due to the region's strong currents and very poor visibility, extensive photography was required to overcome these limitations. Seonyudo site’s depth was from 7 to 11m. As a result, the most suitable conditions for photography were found during the One or two days after the spring tide, the ebb tide period (from high to low tide) proved most suitable for photogrammetric recording.

2. Waters off the Jeju, Sinchang-ri

Figure 1. Location of the underwater excavation area off Sinchang-ri, Jeju Island (Red rectangle: Excavation area; Blue circle: anchor stone).

One of the first significant applications of photogrammetry in underwater archaeological investigations in Korea was conducted at the Sinchang-ri site off the coast of Jeju Island. The site first drew attention in 1983, when a local haenyeo (female diver) discovered a gold hairpin. In 1997, celadon ceramics produced at the Longquan kiln during China's Southern Song Dynasty were also recovered. The National Research Institute of Maritime Heritage conducted an underwater reconnaissance survey in 2018, followed by three underwater excavations in 2019, 2020, and 2021.

Figure 2. Dredging operation in progress at the excavation site(Left), General view of the excavation area after dredging, with artifact positions marked(Right).

Approximately 1,800 artifacts have been recovered from the site, including Longquan celadon wares, Chinese-style anchor stones, and a wooden seal. These finds strongly suggest that the Sinchang-ri area was once a navigational route for Chinese merchant vessels. Notably, a Chinese-style anchor stone located on the eastern side of the excavation area is presumed to be from the same period and serves as important evidence for identifying the shipwreck site more precisely(Figure 1).

The underwater environment of the Sinchang-ri site off Jeju Island is relatively shallow, with depths ranging from 0.7 to 2 meters. However, it offers favorable conditions compared to most underwater sites in Korea, with underwater visibility exceeding 10 meters. Owing to these conditions, the Sinchang-ri site became the first underwater excavation site in Korea where site plans were successfully produced using photogrammetry.

An Sony A7RⅢ(A7R3) camera was used for image capture, without any additional lighting equipment. Diving operations employed both SCUBA and surface-supplied air systems. Unlike most underwater sites in Korea, which are located in coastal waters, the Jeju site lies in open seas and is subject to strong ocean surges caused by waves from offshore. Therefore, within the dredging grid areas, photography was conducted by walking rather than swimming. The seabed consists of sand and basaltic bedrock.

The investigation was conducted as follows. Due to weather conditions, fieldwork was carried out for approximately three months per year between 2019 and 2021. Each excavation season was divided into 10-day sessions, during which artifacts were recovered after dredging(Figure 2).

The typical 10-day investigation sequence was as follows: installation of 10m × 10m grids and markers → pre-dredging 3D photogrammetric recording of the grid area(Figure 3) → dredging of the grid → marking artifact locations after dredging (using stainless steel with yellow stickers) → post-dredging 3D photogrammetric recording(Figure 4). → production of 3D site plans and artifact distribution maps; printing the distribution maps on tracing film(Figure 4, 5) → underwater packaging of artifacts(Figure 4)

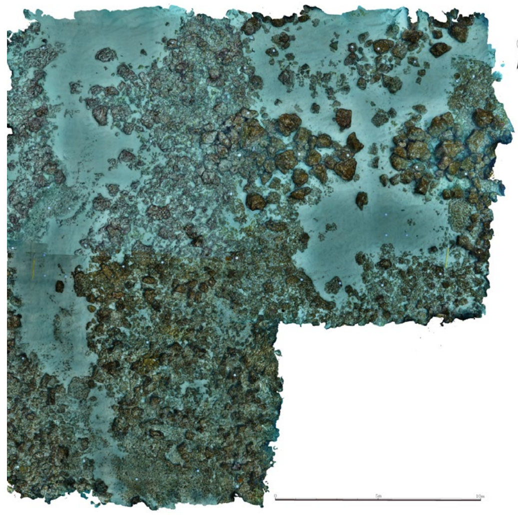

Figure 3. Example of a 3D site plan of the grid area before dredging (Grid 7, 8, 9).

The dredging depth ranged from approximately 10 to 20 cm, with basaltic bedrock exposed just beneath, at a depth of around 20 cm. For image acquisition, a Double Grid method was applied along the 10-meter grid units, which enhanced data consistency and ensured the reliability of the analysis results.

Image overlap was maintained at 80% front and 60% side, and close-range photography was conducted at a distance of 0.5 to 1 meter to obtain high-resolution data(Agisoft LLC, 2023). On average, approximately 2,000 photographs were taken per grid, requiring 60 to 100 minutes to complete.

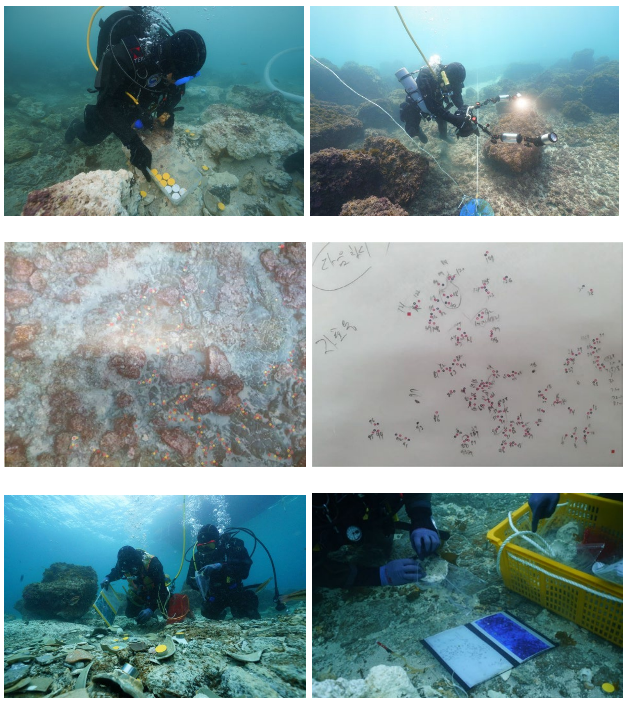

Figure 4. Top row: artifact location marking and 3D photography; middle row: artifact location map printed on tracing film; bottom row: artifact recovery and packaging.

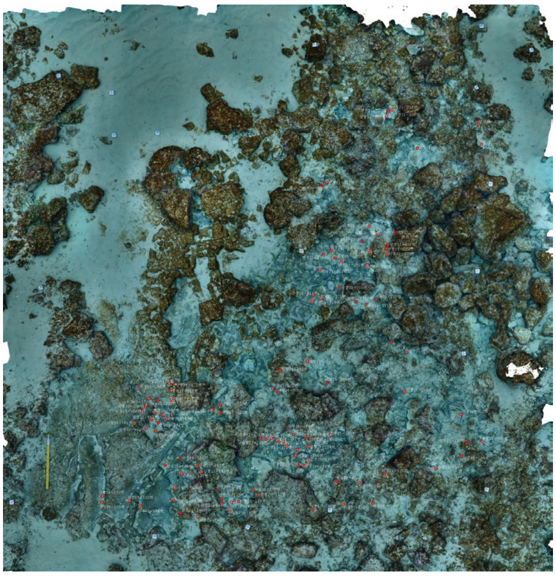

Figure 5. Example of artifact’s Distribution and numbering using a 3D Orthophoto (After Dredging and before printing).

Markers were created using the marker function provided by Agisoft Metashape, sized approximately 10 × 10 cm. These markers were attached to diving weights for use underwater. Attaching heavy weights to the markers was well-suited to the Jeju site, where strong swells and wave action were common.

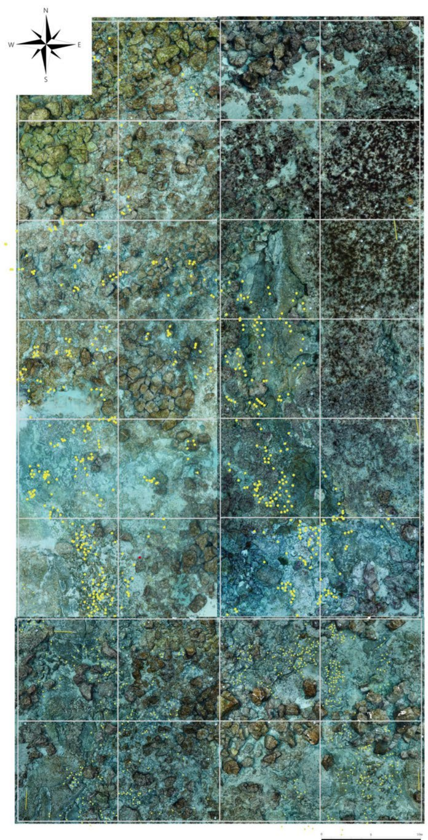

Figure 6. Plan and Artifact Distribution Map of Jeju Shinchang-ri(Grid 1–8, 40m × 80m, 2019–2021, Photographed and Using Chunk Aligned Registration).

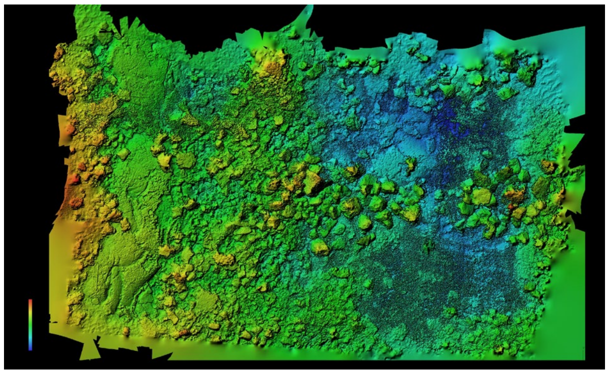

Figure 7. Digital Elevation Model (DEM) of Grid 7, 8.

The workflow using the Metashape program followed a standard sequence: photo alignment (High), point cloud generation (Medium), mesh generation (Medium), and texture mapping (Medium), resulting in the construction of a 3D model. The image acquisition was carried out both before and after dredging, with the primary goal of producing site plans and artifact distribution maps.

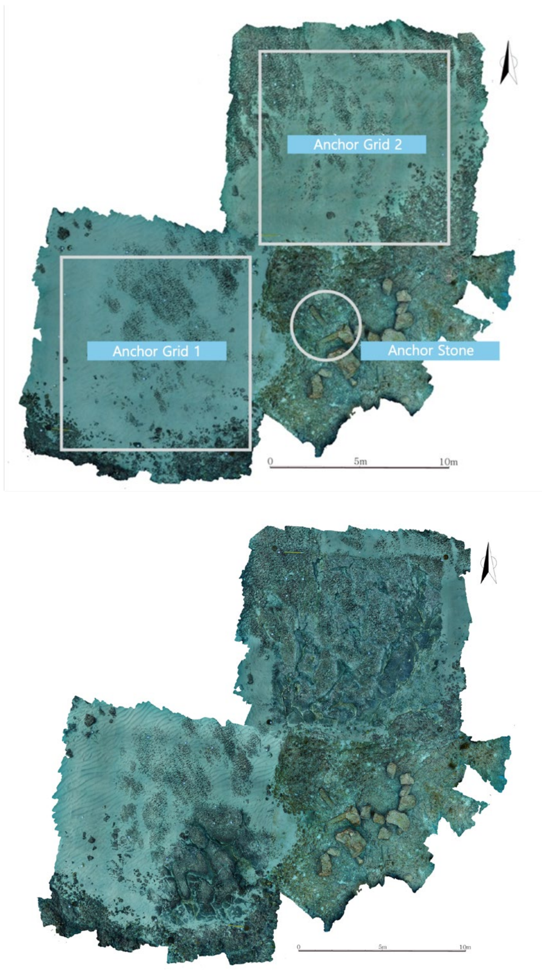

Figure 8. Plan views of Anchor Grids 1 and 2. Top: before dredging; bottom: after dredging (white rectangles: grids; circle: anchor stone).

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The completed 3D models were used to generate orthophotos, which were instrumental in creating artifact distribution maps. These maps proved highly effective for artifact recovery. Artifact positions, indicated in yellow on the orthophotos, were adjusted using Adobe Illustrator for accuracy. On the day before surfacing, the finalized distribution maps were printed on waterproof tracing film to ensure precise documentation of artifact recovery locations.

At both the western grid (Anchor Grid 1) and the northern grid (Anchor Grid 2), dredging depths ranged from 10 to 20 cm, revealing basaltic bedrock beneath. During dredging at the western grid, a small number of ceramic sherds—matching the style of those found in the first through third excavation phases—were recovered. In the northern grid, fragments of celadon vessel bases were also retrieved.

Furthermore, unlike Korea’s typical coastal waters, the site’s clear visibility and shallow depth provided an ideal environment for 3D imaging and underwater adaptation, significantly contributing to the capacity building of new excavation team members.

3. Gunsan Seonyudo Waters off

Most ships in Korea historically navigated along coastal routes, and the majority of known shipwrecks are located in the coastal waters of the West Sea (Yellow Sea). However, this region presents challenging environmental conditions—such as poor visibility, strong currents, and suspended sediments—which have prompted considerable efforts to develop archaeological recording methods capable of overcoming such difficulties. Against this backdrop, following the investigation at the Sinchang-ri site in Jeju, photogrammetry was attempted at the Seonyudo site in Gunsan, located in the West Sea.

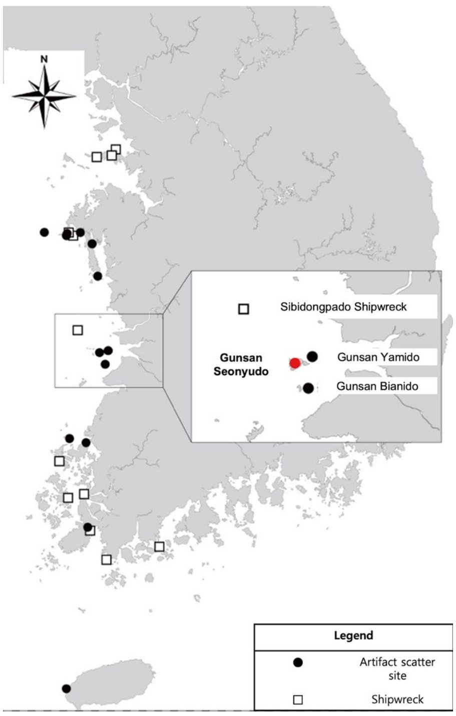


Figure 9. Distribution map of underwater sites in korea (red: location of Seonyudo).

At the Gunsan Seonyudo site, following a report of an underwater heritage discovery in 2021, three underwater excavations were conducted in 2022, 2023, and 2024. These investigations led to the recovery of over 800 artifacts, including a Bronze Age polished stone dagger (maje seokgeom). Most of the artifacts consist of Goryeo-period celadon and Joseon-period white porcelain, and are believed to originate from shipwrecks that occurred en route from Jeolla Province to Gaegyeong (present-day Kaesong) or Seoul.

The Seonyudo area is presumed to have functioned as a strategic node for both domestic coastal and international maritime routes.

The Gunsan Seonyudo site has an average depth of 3 to 7 meters. Due to suspended sediments and strong currents, visibility at the excavation site was generally poor. Nevertheless, in an effort to ensure accurate documentation, experimental photogrammetry was carried out. Through a series of empirical trials, conditions suitable for effective data acquisition were identified. As with the Jeju site, markers were used for all mapping work; however, artifact location markers were not utilized due to the high turbidity and the soft, silty seabed.

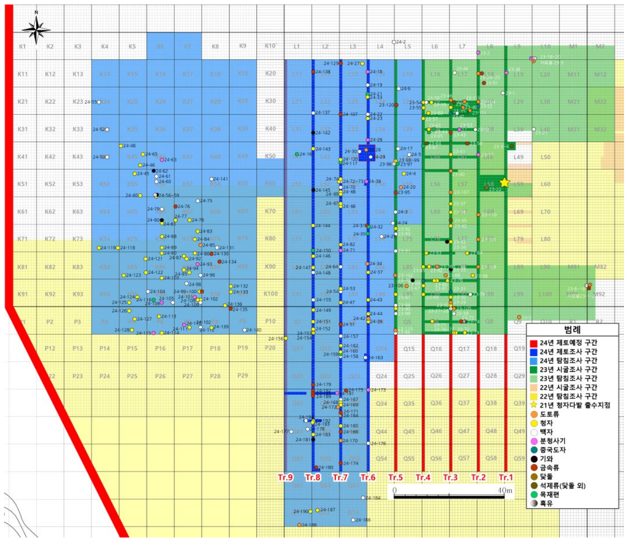
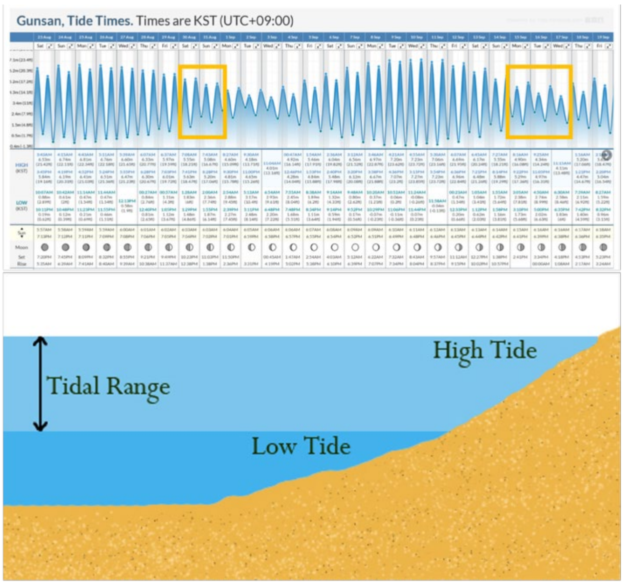


Figure 10. Detailed map of the Gunsan Seonyudo underwater site (dark areas: dredging survey; light areas: surface survey).

The first objective was to produce a plan view of a 10-meter trench after dredging was completed. The imaging method involved two steps: first, the outer edges of the trench were photographed while swimming at a height of approximately 0.5 meters above the seabed; second, the interior of the trench was documented by walking through it, capturing close-range images from a distance of 0.3 to 0.5 meters. Image acquisition was conducted on a day within the 1st to 3rd tidal cycle after the spring tide—when tidal variation is minimal—and timed during the transition from high tide to low tide to ensure optimal conditions.

The detailed conditions for image acquisition were as follows. Plan-view photography was conducted on August 14, 2024. At that time, the Seonyudo site in Gunsan was in the Second tidal cycle a period characterized by relatively stable currents. On the day of the survey, high tide occurred at 08:40, and image acquisition took place between 08:40 and 10:00, during the ebb tide (from high to low tide). The tidal range on that day was approximately 172 cm, which is relatively small. As a result, favorable visibility was achieved despite the silty conditions typical of the West Sea. These conditions were effective in improving the stability of underwater photography and the accuracy of image alignment(Figure 11).



선유도 물때표 (Seonyudo, 평균해면하: 343 Cm) (동경:126:25 북위:35:48)

2024년 8월	음력	물때	달의 크기	만조	간조	일출/일몰	월출/월몰
[목] 1	2024.6.27	3 물		00:22 (554) ▲+371 12:26 (471) ▲+222	07:12 (249) ▼-305 19:04 (159) ▼-312	05:42/19:39	01:59/17:37
[금] 2	2024.6.28	4 물		01:32 (583) ▲+424 13:33 (496) ▲+278	08:18 (218) ▼-365 20:07 (134) ▼-362	05:43/19:38	02:57/18:29
[토] 3	2024.6.29	5 물		02:25 (612) ▲+478 14:25 (527) ▲+340	09:09 (187) ▼-425 20:59 (110) ▼-417	05:44/19:37	03:59/19:13
[일] 4	2024.7.1	7 물	그믐	03:08 (635) ▲+525 15:08 (556) ▲+392	09:50 (164) ▼-471 21:42 (93) ▼-463	05:45/19:36	05:03/19:49
[월] 5	2024.7.2	8 물		03:44 (648) ▲+555 15:45 (578) ▲+430	10:26 (148) ▼-500 22:19 (87) ▼-491	05:45/19:35	06:06/20:18
[화] 6	2024.7.3	9 물		04:17 (654) ▲+567 16:19 (591) ▲+452	10:57 (139) ▼-515 22:52 (88) ▼-503	05:46/19:34	07:08/20:44
[수] 7	2024.7.4	10 물		04:46 (653) ▲+565 16:52 (596) ▲+463	11:25 (133) ▼-520 23:22 (98) ▼-498	05:47/19:33	08:06/21:08
[목] 8	2024.7.5	11 물		05:14 (645) ▲+547 17:24 (594) ▲+462	11:51 (132) ▼-513	05:48/19:32	09:03/21:30
[금] 9	2024.7.6	12 물		05:41 (632) ▲+518 17:56 (586) ▲+452	23:50 (114) ▼-480 12:16 (134) ▼-498	05:49/19:31	09:59/21:52
[토] 10	2024.7.7	13 물		06:08 (610) ▲+471 18:29 (572) ▲+431	00:19 (139) ▼-447 12:42 (141) ▼-469	05:49/19:30	10:56/22:14
[일] 11	2024.7.8	조금		06:37 (581) ▲+411 19:04 (553) ▲+398	00:49 (170) ▼-402 13:10 (155) ▼-426	05:50/19:29	11:54/22:39
[월] 12	2024.7.9	무시		07:08 (545) ▲+338 19:47 (530) ▲+357	01:24 (207) ▼-346 13:43 (173) ▼-372	05:51/19:28	12:53/23:09
[화] 13	2024.7.10	1 물		07:46 (502) ▲+253 20:44 (506) ▲+311	02:07 (249) ▼-281 14:25 (195) ▼-307	05:52/19:27	13:56/23:44
[수] 14	2024.7.11	2 물		08:40 (460) ▲+172 22:06 (494) ▲+279	03:10 (288) ▼-218 15:27 (215) ▼-245	05:52/19:25	15:00/ ----
[목] 15	2024.7.12	3 물		10:08 (431) ▲+126 23:45 (512) ▲+296	04:51 (305) ▼-189 16:52 (216) ▼-215	05:53/19:24	16:03/00:26

Figure 11. Tidal chart on August 14, used for plan-view photography (Top : Sample of Tidal table, Bottom : high tide at 2024, August, 08:40 AM).

Despite photographing under relatively favorable visibility, the silty nature of the West Sea seabed resulted in sediment being stirred up by divers, complicating both photography and alignment processes. In particular, when photographing in the direction of the current, it was difficult to maintain a consistent speed, and suspended sediments further reduced image clarity. Therefore, swimming against the current proved more effective for obtaining high-quality results.

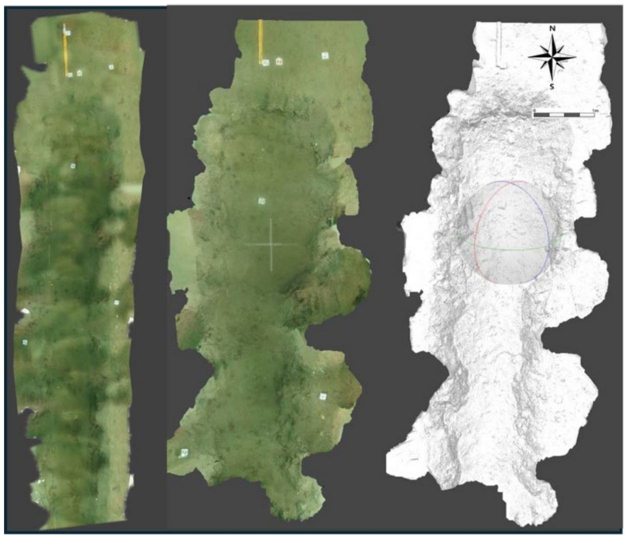


Figure 12. Plan of Trench-7 (100–95m) from the 2024 Gunsan Seonyudo Excavation (left: Tile, Mid : texture effect applied, right: texture effect removed).

The final plan covered a trench measuring approximately 10 meters in length, 1 meter in depth, and 1 meter in width. As with the Jeju site, the use of markers improved alignment accuracy and allowed for objective assessment of the trench's dimensions. While video-based photogrammetry using a GoPro was also tested, it proved unsuitable due to image noise caused by suspended particles.

For the 10-meter section of Trench 7, approximately 900 photographs were taken over the course of about one hour. The same camera used at the Jeju Sinchang-ri site, the A7R3, was employed. The 3D processing was performed using Ultra High quality for the point cloud and Medium quality for the mesh(Figure 12).

The second objective was the creation of stratigraphic profiles, which were photographed to objectively analyze the sediment layers and artifact-bearing strata. As with the plan views, photography was conducted during high tide on the day of maximum tidal height, timed with the shift from high to low tide, to maximize visibility. To clearly capture the stratigraphy, lighting equipment (Cylux 4K) was used.

Figure 13. Visibility conditions during stratigraphic recording.

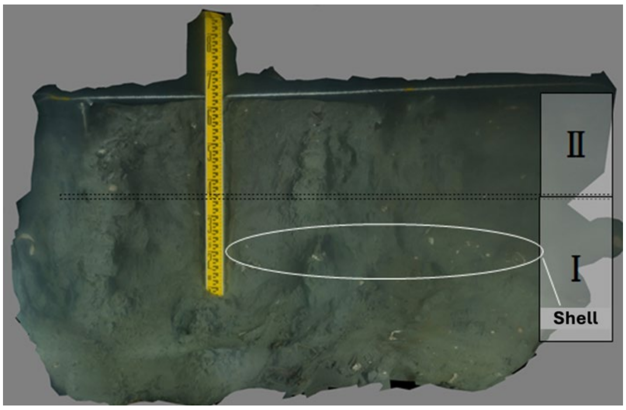


Figure 14. Section of Trench-8 (127-125m) from the 2024 Gunsan Seonyudo Excavation (I layer: hard clay layer containing artifacts and shells, II layer: soft clay layer containing shells, White circle: shell layer).

Approximately 130 photographs were taken for the stratigraphic profile, and both the point cloud and mesh were processed at medium quality settings. The resulting output was a cross-sectional profile measuring 1 meter in length, 1 meter in width, and 1 meter in depth. This section allowed for a distinguishable separation between artifact-bearing and sterile layers. However, due to time constraints, it was not feasible to photograph the entire trench, which extended up to 100 meters in length(Figure 13, 14).

4. Conclusion

This study compared and examined photogrammetric methods applied at the Sinchang-ri site in Jeju and the Seonyudo site in Gunsan. At the Sinchang-ri site, relatively clear visibility enabled the production of precise site plans. In particular, the use of orthophotos generated within the photogrammetry software to create artifact distribution maps, followed by printing these maps on waterproof paper for underwater artifact recovery and simultaneous packaging by assigned artifact numbers, proved to be highly effective. Moreover, this case served as the first application of photogrammetry in Korean underwater archaeology, leading to experimental attempts at the low-visibility Seonyudo site.

At Seonyudo, poor visibility conditions made it difficult to produce high-resolution artifact distribution maps. To address this challenge, image acquisition was attempted during tidal windows with minimal variation in water level. In particular, suspended sediment remains a persistent issue in Korea's western coastal waters, and the study focused on developing efficient imaging methods to mitigate this. As a result, the most favorable outcomes were obtained when photography was conducted during the ebb tide between high and low tide within the 1st to 3rd tidal cycles after the spring tide, when tidal fluctuation was minimal.

These case studies demonstrate the importance of identifying optimal photogrammetric approaches for different underwater environments and confirm the potential of applying such techniques to various types of underwater sites, including shipwrecks. It is expected that as more shipwrecks are discovered and photogrammetric techniques continue to advance, more effective methods for underwater investigation and documentation will emerge.

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