

## Discovery of submerged karst topography in Nagura Bay, Ishigaki Island by broadband multibeam bathymetric survey

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The existence of submerged exo-karst is pointed out by aerial photographs or topographic map of shallow seas (e.g., Hori 1996). However, most of these submerged karst identified by aerial exposure of high portion. There is no report on submarine topography of submerged karst area. The broadband multibeam survey was conducted in the central area of Nagura Bay, Ishigaki Island in the southern Ryukyu Islands. The sounding results are visualized at a lateral grid resolution of 1m. The observed submarine topography shows the development of various types of karst in extensive area.

The survey was carried out in August 2011 using a broadband multibeam sounding system R2Sonic 2022. This system is a shallow-water multibeam echo-sounder with selectable operating frequencies within the 200 to 400 kHz band and variable swath width from 10 to 160 degree. Within the acoustic sector, 256 receiver beams were formed using 1 degree across beamwidth x 1 degree along beamwidth. It may also rotate the swath sector either port or starboard side of the vessel. The main part of the sonar has a vertical resolution of 1.25cm. The system is operated with Hemisphere VS111 GPS Compass and Teledyne TSS Dynamic Motion Sensor DMS-10. The accuracy of VS111 GPS Compass is 0.6m in distance and 0.15 degree in direction when placing A30 and A20 antennas at 1m interval. The accuracy of DMS-10 Motion Sensor is 0.07 degree in roll and pitch, and 5cm in heave. The vertical accuracy of the system is around 5 to 10cm. The survey and data processing are carried out by the hydrographic survey software Hypack 2010. The visualization of the 3D bathymetry model is conducted by IVS 3D Fledermaus. In this research, we confirmed the observed submarine topography and the sedimentary features by SCUBA diving surveys.

Convex and concave topography consisted by closed contours is visualized in the surveyed area. The similar topography is not formed by accretion or sedimentation under the submarine environment such as coral reef formation. Because of the closed drainage, it is recognized as karst, the topography formed by groundwater flow. The following five karst types are recognized in the surveyed area. These types may reflect the difference of karstification process and stage. 1) doline karst, 2) compound doline (uvala) or mega-doline, 3) cockpit karst, 4) polygonal karst, 5) fluviokarst. SCUBA diving observations suggest the Holocene reef and reef sediments are accumulated on the submerged karst to form "cover karst" in Nagura Bay. The small-scale karst landform such as karren may buried in this covering process.

According to the aerial photographs, the shallow marginal area of Nagura Bay also consists of the submerged karst. We suggest that the Nagura Bay extent of 6 x 5 km is the largest submerged karst in Japan. The size is equivalent to Minami Daito Island in the Phillipine Sea and Hiraodai Plateau in northern Kyushu Island.

Keywords: submerged karst, coral reef, broadband multibeam echosounder, Ishigaki Island, Ryukyu Islands