

Application of portable XRF analysis for provenance of seabed worked stone in coastal area of Kochi Prefecture

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Many stone pillars around 1m long, which look like artifacts, lie on the seafloor in off Tsumajiro, Kochi Prefecture, Japan. Tsumajiro area has been repeatedly damaged by tsunami from Nankai earthquakes, and extreme rainfalls by typhoon events. Therefore, we suggest that a tsunami or river floods might have transported the pillars offshore, or coseismic land subsidence might have caused them to become submerged. To assess the origin of the submerged stone pillars in the Tsumajiro area (Tsumajiro pillars), we analyzed mineralogy, geochemistry and physical property of Tsumajiro pillars, of rocks from natural exposures and quarries in Tsumajiro and neighboring areas, and of building stones in use in the Tsumajiro area. We analyzed concentrations of major and trace elements in samples using a portable X-ray fluorescence (pXRF) spectrometer, and estimated mineral composition of samples using powdered XRD analysis. Porosity and grain density were also measured on all samples.

In the XRF spectral data, we clearly recognized peaks for 12 elements (Mg, Si, S, K, Ca, Ti, Mn, Fe, Rb, Sr, Zr, and Pd) in all samples. Therefore, we selected these 12 elements for PCA. In the PCA results for all samples, we could clearly divide those into sandstone group and shale group from the first principle component, where components of Mg, Fe, and Ti strongly influenced. In PCA results for sandstone only, we could see the characteristics of each samples much more clearly. Submerged pillars showed similar characteristics, where a component of Zr was strongly contributed, with Tatsukushi formation in Misaki group (natural exposures and quarries) and foundation stones for main building at Tsumajiro area. Porosity, grain density, and mineral composition were also similar between Tsumajiro pillars, Tatsukushi formation, and a foundation stone.

Our results suggest that the submerged stone pillars were made from Tatsukushi sandstone and had been utilized as building stones for structures such as steps and foundations in Tsumajiro village.

Keywords: Principle Component Analysis (PCA), Provenance, pXRF, sedimentary rock, Nankai earthquake