Long-term stability of benchmarks for seafloor geodesy

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1. Introduction

We need stable seafloor benchmarks as well as measurement systems to observe seafloor crustal movement. There are two problems in seafloor geodesy in subduction zones. One is thick sediment that covers the seafloor, and the other is the way we let instruments fall down by thousands of meters in the water to the bottom. Some people suspect that the measurement can be as unreasonable as geodetic measurements with an instrument dropped from an airplane with a parachute on rice fields. Because flat seafloor is generally covered with thick sediment and locally steep topography is rare, we have little problem if we drop instruments from the sea surface. The problem is how the thick sediment has influence on geodetic measurements.

2. Observation of horizontal crustal movement

GPS/Acoustic precise seafloor positioning is proposed and pursued for observation of horizontal seafloor crustal movements. Fujimoto et al. (1990) was the first to deploy seafloor benchmarks for seafloor geodesy and confirm their stability on the seafloor; 1.1m-square concrete blocks were deployed in the central part of Sagami Bay, Central Japan. Some ten years later, we deployed three precision acoustic transponders for GPS/A measurements on the seafloor at about 5,500m depth seaward of the Japan Trench. Because the above-mentioned concrete block is too large for the base of the instrument, we adopted a 0.9m-square FRP frame with some 5cm thickness. The seafloor was formed about 100 Ma and is covered with sediment thicker than 1km.

We had a chance in the next year to visually inspect one of the instruments with the JAMSTEC ROV Kaiko. We found that the sediment was muddy, and that the frame of the instrument sank only a few centimeters; it stood stably on the seafloor as if it were on a flat sand beach (Fujimoto et al., 2002). Relative subsidence among the edges of the frame is less than 1cm. The acoustic transducer of the instrument was held about 80cm high from the frame. Therefore, horizontal motion of the transducer relative to the seafloor due to the inclination of the instrument during 1 year must be less than 1cm. In this way, an acoustic transponder with an appropriate base deployed on flat bottom can be a benchmark for monitoring horizontal seafloor crustal movement.

3. Observation of vertical crustal movement

The most probable way to detect vertical crustal movement can be ocean bottom pressure monitoring. For example, Fujimoto et al. (2003) detected pressure variations across the spreading axis of the southern East Pacific Rise, which suggest depression of the seafloor associated with it cooling after an episodic volcanic event. Ocean bottom pressure recorders, which have been deployed with bases made of iron rods, may be less stable than the acoustic transducers mentioned above. However, rods inserted into the mud become firmly stuck within 1 hour or so. Floatation in the water decreases the effect of gravity. Therefore, there may be little possibility of long-lasting depression of the instrument in the mud. It will be better if the pressure recorder is equipped with a FRP frame mentioned above and is deployed on the flat bottom.

4. Seafloor gravimetry

An ocean bottom gravimeter is generally expensive, and has a problem of long-term drift of the gravity sensor. Therefore, gravity measurements for studies of seafloor crustal movements are often carried out repeatedly with seafloor benchmarks. Gravity measurements can be carried out directly on benchmarks if they are as large as those installed in Sagami Bay. However, operations on the bottom with an ROV or manned submersible can move the position or attitude of a benchmark. We had better carry out gravimetry beside the benchmark and measure the difference of water depth between the gravimeter and the benchmark with a pressure sensor.