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Release Note for Long-term Seafloor Geomagnetic Data Observed in the Northwest Pacific Basin

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Since August of 2001, long-term geomagnetic observation has been conducted at a site hereafter referred to as 'NWP' in the northwest Pacific. The seafloor observation is based on the collaboration among Dept Earth Science, University of Toyama, Earthquake Research Institute, University of Tokyo, and Institute for Frontier Reseach on Earth Evolution, Japan Agency for Marine-Earth Science and Technology. Almost continuous record of approximately 3.5 years from August, 2001 through January, 2005 has been obtained so far. The first two years of the raw record up to July, 2003 have been further processed/corrected to be ready for public release on and after January 1st, 2006. The intent of this note is to briefly outline the contents of the seafloor geomagnetic data.

Table 1 summarizes information of the seafloor site and the observed geomagnetic data.

Table 1 Outline of the seafloor site and data

Site Location: 41.102N, 159.963E, Depth=5580m (WGS84)
IAGA CODE (proposed): NWP (North West Pacific)
Observation Period: August 1st, 2001 - July 13th, 2003 (UTC)
Sampling Interval: 1 minute
Reported Geomagnetic Components: XYZF
Resolution: 0.01nT
Absolute Precision for the Geomagnetic Total Force: 0.2 nT (Toh and Hamano, 1997)
Absolute Precision for the Geomagnetic Three Components: 1 nT for Z and 5 nT for X and Y
Data Format: IAGA2002
Magnetic Sensors Used: Fluxgate for vector measurements, Overhauser for scalar measurements

Figure 1 shows the site location of NWP. The precise position of NWP at the seafloor with respect to the world-standard geodetic system, WGS84, was determined by connecting the research vessel's GPS position with results of acoustic ranging conducted from the vessel at the time of installation/recovery of the seafloor instrument. Precision of the acoustic site determination is within a few tens of meters. As for the seafloor site's IAGA three-letter code, 'NWP' will be proposed to IAGA WG V-OBS for an abbreviation of 'North West Pacific'.

The seafloor site, NWP, is geoscientifically unique in the sense that:

(1) It locates the western margin of the stationary regional geomagnetic anomaly, i.e., the Pacific non-dipole low.

(2) It locates on a very old seafloor aged 124 Ma.

The former will be useful for research on the Earth's core dynamics and structure of the D"-layer, while the latter may be of use for study of evolution of the oceanic lithosphere.

The original time-series of the seafloor geomagnetic data consists of two segments. The first segment ranges from August 1st, 2001 through July 4th, 2002 while the second one from June 30th, 2002 through July 13th, 2003. Although the segments were observed at two slightly different seafloor sites, difference of each geomagnetic component was corrected using the 5-day overlapped data. Time precision of the seafloor instrument is approximately 10^{-7} ppm, which has been further corrected using clock calibration data to yield one-minute values in UTC. The clock calibration was conducted before installation as well as after recovery by comparing the instrument's master clock with the research vessel's GPS clock.

The least count of the geomagnetic components is as small as 10 pT. However, the absolute precision of the geomagnetic total force is 0.2 nT (see Toh and Hamano, 1997) while that of the vertical component is 1 nT. As for the horizontal geomagnetic components, their absolute precision is as large as 5 nT. The difference in precision of vector field measurements stems from that of tilt and orientation measurements as described below.

The geomagnetic vector field was corrected for temporal variations of both temperature and tilt. The instrument, 'SeaFloor ElectroMagnetic Station (SFEMS; Toh et al., 1998; Toh et al., accepted)', installed at NWP is capable of measuring temperature and two horizontal components of tilt and the geoelectric field, in addition to the 3-component geomagnetic field. Precision of temperature, tilt and the geoelectric field is 0.01 degrees, 3 arc seconds and approximately 60 nV/m, respectively. Temperature correction was conducted for each geomagnetic component using temperature coefficients determined prior to the sea experiments and the observed temperature variations at the seafloor. On the other hand, temperature correction for the observed tilt data was not conducted, since both the temperature coefficient of the tilt meter used and the actual temperature variations (±0.03 deg within a year) were so small. It is well-known that correction for attitude variation of vector magnetometers is essential not only to improve the absolute precision of the observed geomagnetic field but also to detect the geomagnetic secular variation. Because the tilt meter equipped with SFEMS is as precise as 3 arc seconds (Toh et al., accepted), the absolute precision of the corrected vertical geomagnetic component is as good as 1 nT or better in mid-latitudes where NWP is located. However, that of the horizontal geomagnetic components is still as large as 5 nT due to larger errors in the instrument's orientation at the seafloor. A small fibre optical gyro (FOG), originally developed for automated tunnel drillers, was equipped with SFEMS, whose standard error of mean was as large as 10 arc seconds. Furthermore, it turns out that the FOG generates magnetic noise and is power-consuming when activated, which prevents us from monitoring orientation variation continuously. We, therefore, ended up with intermittent orientation measurements at the seafloor once in three months. The final orientation error comes from discrepancy between the FOG's reference frame and the vector magnetometer's frame. The discrepancy, however, can be estimated by generating additional magnetic dipole field from the FOG's reference frame. A triaxial coil was attached/aligned to the FOG for this purpose to generate known dipole field after each orientation measurement. The artificially added dipole field was received by the fluxgate magnetometer of SFEMS. The analysis of the in-situ orientation calibration data has yielded an orientation discrepancy of 1.529 degrees with an estimation error of 29.4 arc seconds. This sums up to a total orientation precision of slightly better than 40 arc seconds. The large orientation error and lack in continuous orientation monitoring are the major factors that weaken the meaning of the observed horizontal components.

Detailed discussion on the seafloor instrument, the correction method, the error estimation briefly outlined above is given in Toh et al. (1997), Toh et al. (1998), and Toh et al. (accepted). Next, an example of the seafloor geomagnetic data will be demonstrated in the following.

Figure 2 shows two-year long temporal variation of the vertical geomagnetic component observed at NWP. If we adopt the frozen-flux approximation in the Earth's core (Roberts and Scott, 1965), the variation can be understood indicative of the 'core surface flow'. It is evident from the figure that the vertical geomagnetic component at NWP is presently increasing, which is in good agreement with prediction by the secular coefficients determined by Ørsted Satellite (Olsen, 2002; Toh et al., 2004). Further analysis has revealed that the observed geomagnetic secular variation for the vertical component can be explained by the westward drift of the equatorial dipole terms (g_1^1 and h_1^1) alone. Surprisingly, even though the axial dipole term (g_1^0) does decrease, it seems to be exactly canceled out by increase of non-dipole secular terms to leave the equatorial dipole term alone in the observed geomagnetic secular variation at NWP. Although it is beyond the scope of this short note to reveal why they cancel out with each other, it is certain that apparent contribution of the non-dipole geomagnetic field is absent in the observed geomagnetic secular variation of the vertical component at NWP.

Variations of the seafloor geoelectric field were also measured simultaneously with the geomagnetic field using two orthogonal electric dipoles of 5 m long each. Silver-silver chloride electrodes were attached four tips of the dipoles. Figure 3 (left) shows the one-dimensional (1D) electrical conductivity structure beneath NWP estimated using both magnetotelluric (MT) and geomagnetic depth sounding (GDS) methods. At long periods (~7days), C-response functions (Schultz and Larsen, 1987) were used to convert the GDS responses into equivalent MT impedances. The 1D model reveals three electrically conductive zones beneath the very old seafloor at depths of around 40 km, 125 km and 250 km, respectively. The right diagram of Fig. 3 shows the result of resolution analysis of the 1D inversion. When the required χ^2 misfit is relaxed in the inversions, structures required by the data persist most. It is readily seen in Fig. 3 that the conductor centred at 125 km is most persistent, while the conductors at 40 km and 250 km become less significant in this order. This implies that the electrical thickness of the resistive Pacific plate is ~100 km where an abrupt increase of electrical conductivity is resolved in the final 1D model.

The contents of the seafloor geomagnetic data and the results of its preliminary analysis have been outlined above. It is finally noted that the geoelectric data will also be open to public shortly via Japan Agency for Marine-Earth Science and Technology.

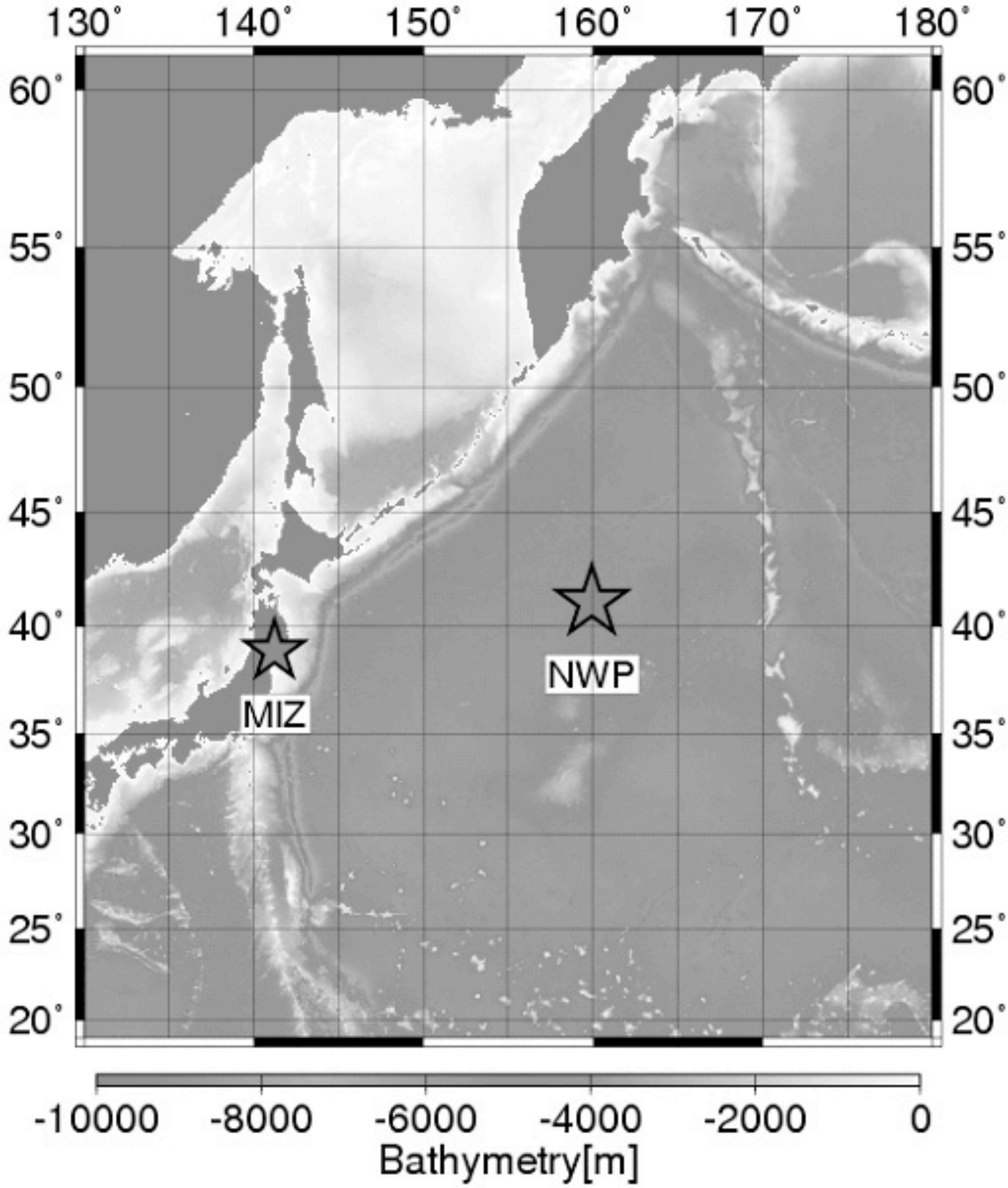

Fig. 1 Location of the seafloor site, NWP. It is situated on the northwest Pacific basin as deep as 5,600 m and as old as 124 Ma. It locates approximately 1,500 km east of Mizusawa Geodetic Observatory (MIZ), one of the closest geomagnetic observatories to NWP.

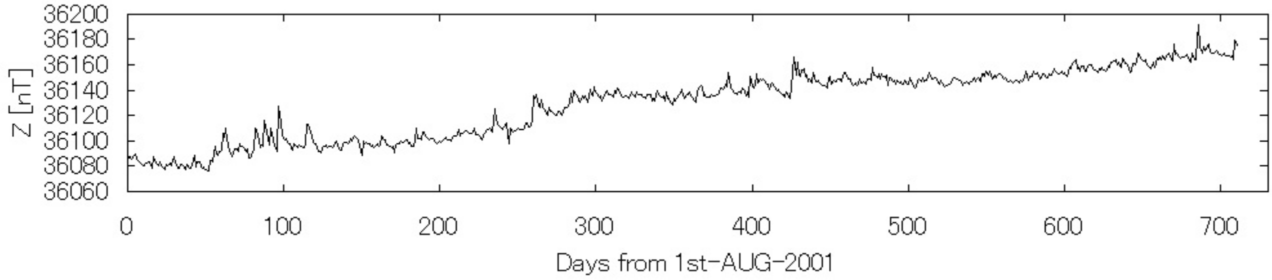

Fig. 2 Observed secular variation revealed in the vertical component of the geomagnetic field. The time-series shown is as long as almost two years. It is evident that the geomagnetic vertical component is presently increasing in the northwest Pacific, and most of the increase can be explained by the westward drift of the equatorial dipole, viz., the P_1^1 terms.

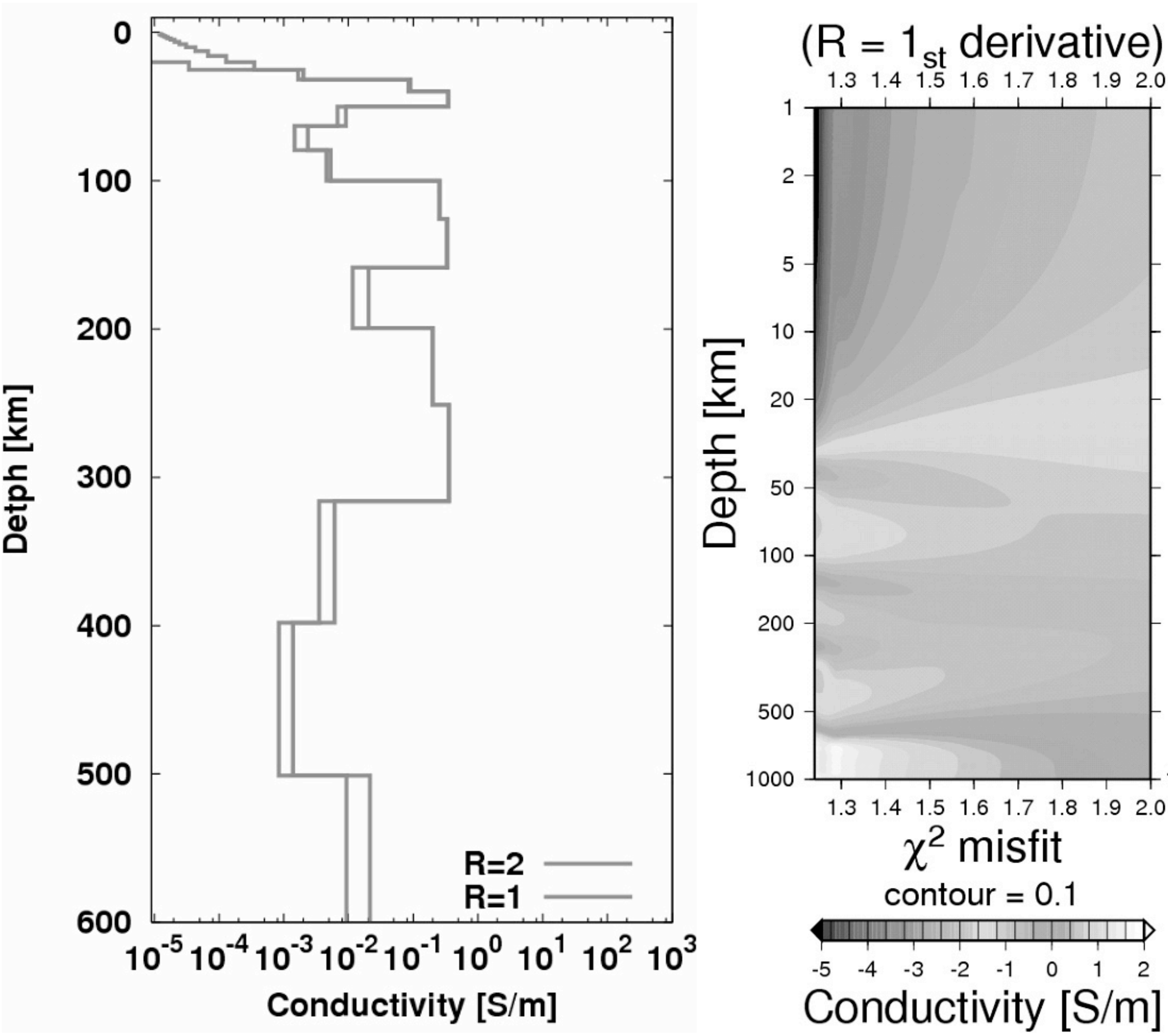

Fig. 3 The 1D electrical conductivity structure (left) and its resolution (right) estimated by inverting the seafloor geoelectromagnetic data. 'R=1' corresponds to the results with 'smoothness' constraint on the 1D structure during the inversion. 'R=2' is for those with 'roughness' constraint.

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