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Underwater Magnetometer MG-01/2003 for Geomagnetic Offshore Soundings

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Abstract

A magnetometer constructed to carry out geomagnetic variation measurements on the sea bottom is described. The main difference between onshore and offshore variation measurements is – beside requirements concerning protection against the underwater environment – the fact that an offshore instrument cannot be placed according to the geomagnetic (or geographic, respectively) coordinate system. It has to be aligned "virtually" instead, by means of additional clinometer records after the real measurement. The software performing this is described here as well. The instrument has been applied successfully in the Baltic Sea several times. The data achieved thereby fits very nicely in the well-investigated onshore surrounding and efficiently helps to understand the structure of electric conductivity in the subsurface of this region.

1. Design of the Magnetometer

The bottom magnetometer MG-01/2003 was designed and built at Belsk Observatory in 2003 (Marianiuk 2005).

The set of instruments is installed within a tight capsule, resistant to high pressure and marine water, made of non-magnetic materials (see Fig. 1). The bottom magnetometer employs a suitably adjusted transduction magnetometer LEMI8G produced by the Lviv Centre of the Institute of Space Research, National Academy of Sciences of the Ukraine (Korepanov *et al.* 1998). The magnetometer consists of a three-component sensor for the measurement of three mutually perpendicular magnetic field components (see Fig. 2), and an electronic console with a microprocessor. The housing with the console contains also a 20-bit, 5-channel digital recorder with an 8 MB data storage memory. In the upper part of the capsule, there is installed a double electronic clinometer purchased from the American company Applied Geomechanics. The

N and *E* axes of the clinometer exactly coincide with the *X* and *Y* axes of the magnetometer. In the lower part of the capsule, two 12V/25Ah batteries are fixed. They ensure a continuous operation of the instrument for about 12 days. See Fig. 3 for a schematic overview of the magnetometer's design and Table 1 for its basic parameters.

Fig. 1. The bottom magnetometer MG-01/2003 in its capsule.

Fig. 2. The LEMI magnetometer in the interior of the capsule.

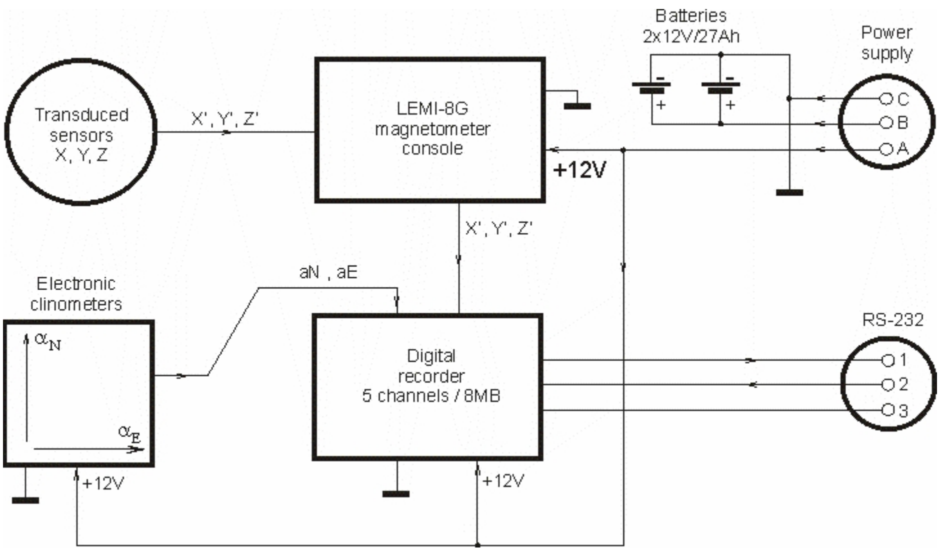

Fig. 3. Simplified block scheme of the bottom magnetometer MG-01/2003.

Table 1

Basic parameters of the bottom magnetometer MG-01/2003

Measurement range:	±65 000 nT
Accuracy of measurement:	±1 nT
Resolution of measurement:	±10 pT
Transmission band:	1 Hz … DC
Internal memory (Compact Flash):	8 MB
Capacity of memory:	416 * 10^3 samples
Sampling interval:	1 … 255 s
Measurement range of tiltmeters:	±50 °
Resolution of tiltmeters:	±0.01 °
Power supply:	120 mA/12 V
Mass of entire magnetometer:	106 kg
Maximum depth of immersion:	~1000 m

2. Algorithm of Operation

Once the magnetometer sinks in the water reservoir, the orientation and inclination of the instrument are random, and instead of the real components we record components in an arbitrary system of coordinates X', Y' and Z'. Along with the magnetic components, indications of the electronic clinometers, α_X and α_Y, are recorded.

From the recorded "inclined" magnetic components and the indications of the electronic levels, it is possible to calculate the real, "upright", magnetic components *H*, *D*, and *Z* (or *X*, *Y* and *Z*, if we know the approximate value of magnetic declination in the study area), which are needed to calculate the results of geomagnetic sounding.

To explain the procedure, let us use an analogy to the investigations on land. While making the land geomagnetic survey, we first install a magnetometer sensor on a stable stand, and then perform the following two operations:

1. In accordance to the indications of bubble levels, we level the magnetometer sensor with an accuracy to a few angular minutes.
2. Having made the leveling, we turn the sensor about the vertical axis so as to obtain the maximum indications on the *X* channel and minimum (i.e., nearly zero) on the *Y* channel. Then, the *X* axis of the magnetometer coincides with the magnetic north direction and the horizontal component *H*, and the *Z* axis is directed vertically.

A similar procedure is made on the data read from the bottom magnetometer by the LEMI3TRD software developed by Dr. Krzysztof Nowożyński (Nowożyński 2005). In the first stage, the program makes a virtual leveling of the instrument on the basis of electronic levels' data; in the second stage it virtually rotates the magnetometer's sensor (cf. Fig. 4).

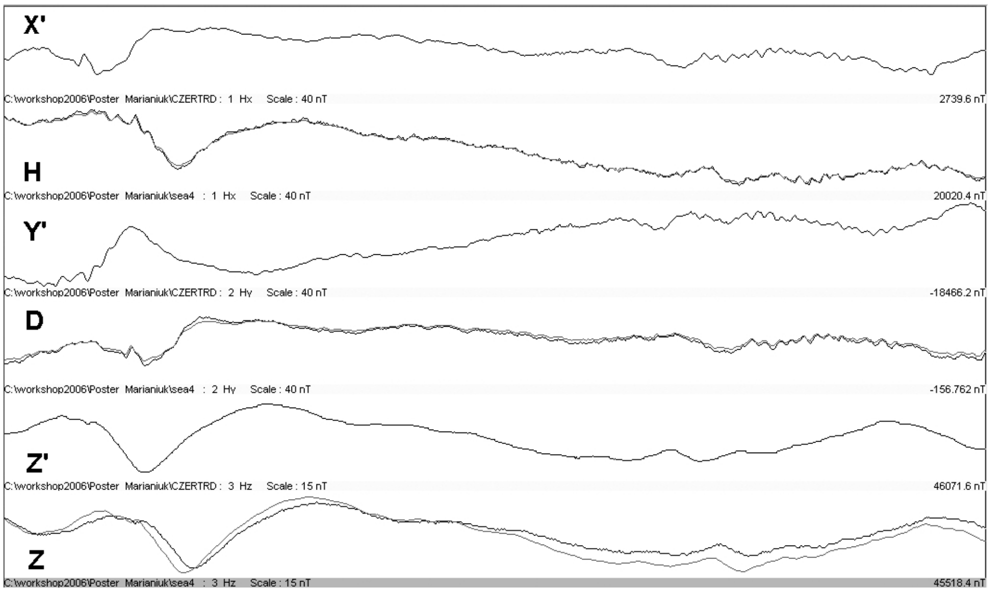

Fig. 4. The 85 min time series measured by the bottom magnetometer MG-01/2003 between Rügen and Bornholm Islands (cf. Fig. 5). X′, Y′, Z′ are raw data in the coordinate system according to the magnetometer's orientation. H, D, Z indicate components after rotation in the geomagnetic system. For comparison there are displayed data of Rügen site as gray lines. The scale of the y axis is 40 nT for the horizontal and 15 nT for the vertical components.

The magnetometer possesses two tight interfaces at the capsule. One interface is used for adjusting the magnetometer's measurement parameters and for reading out of the recorded data. The other one enables a charging of the batteries in the interior of the magnetometer. When the magnetometer is taken back from the water, the data recorded is read out and virtually corrected for its orientation by means of the program LEMI3TRD. As a result, one gets data files in TRD format which is the default for further processing of geomagnetic and magnetotelluric field data at the Institute of Geophysics PAS.

3. Soundings in the Baltic Sea

After construction of the magnetometer, a number of tests have been carried out to check whether the new device and the associated software work properly. First experiments were carried out in the measurement houses and in the fire-rescue pool of the observatory. Subsequent field measurements took place in the large, deep Lake Rajgrodzkie in North-East Poland.

In 2005, there were made two geomagnetic soundings in the Baltic Sea (Jóźwiak *et al*. 2005). These offshore soundings were accompanied by a number of onshore sites close to the Polish coast and on the islands Bornholm, Usedom, and Rügen. Their locations are displayed in Fig. 5.

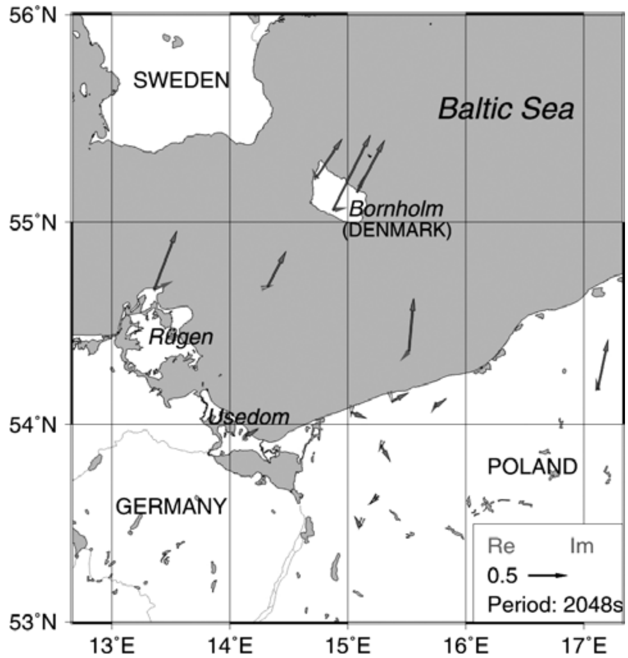

Fig. 5. 2005 measurement area with induction arrows.

The measurements were a complete success. Figure 4 shows time series before and after rotation in the proper coordinate system. A comparison of the corrected time series with data from a land site underlines the similarity, i.e. reasonability, of the offshore measurements (same figure). The geomagnetic transfer function obtained from the time series data are of the same quality as the onshore ones. Figure 6 shows induction arrows over period for the offshore sounding between Bornholm and Rügen.

The induction arrows and perturbation vectors of both offshore sites fit very well into the picture drawn by the surrounding onshore sites, as Figs. 5 (induction arrows) and 7 (perturbation vectors excited by magnetic component X at Niemegk Observatory) show. Moreover, they make that picture more detailed and exact. It can be concluded from it that an anomaly of electric conductivity, which is even better conducting than the sediments of the North German-Polish Basin to the South, strikes there in the east-west direction along the Baltic coast.

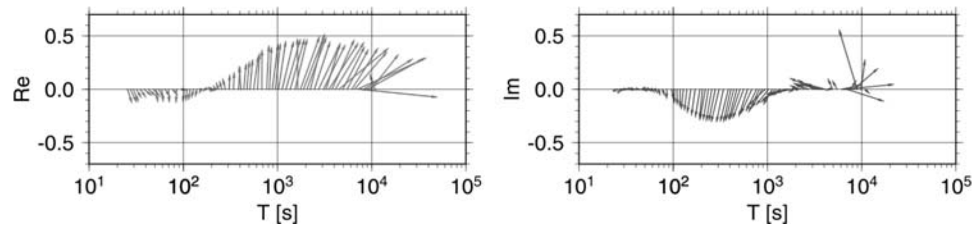

Fig. 6. Induction arrows (real and imaginary) of offshore site between Rügen and Bornholm Islands. The smoothness of the transfer function up to several 1000 seconds indicates a good data quality.

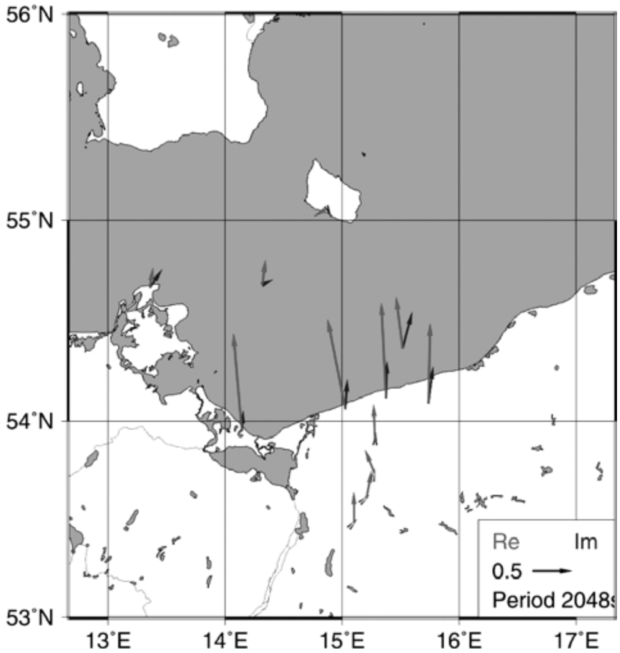

Fig. 7. Perturbation vectors describing the anomalous horizontal field with respect to X component measured simultaneously at Niemegk Observatory. The huge north components along the Baltic coast indicate an anomalous, EW striking current system in this region, possibly due to graphite in the old suture between Baltica and Avalonia.

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