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The method of magnetic research in the Hornsund Fiord area in Spitsbergen

ABSTRACT: This paper describes the method of prospective magnetic research under natural conditions of strong interference by the external variable magnetic field. This method of synchronized measurements, when some given assumptions are satisfied, permits magnetic survey of the accuracy 1–2 nT to be carried out. It was used in detailed investigations of weak anomalous fields.

Key words: Arctic, magnetic research, Spitsbergen

1. Introduction

The specific measurement conditions in Spitsbergen account for the fact that in many fields of prospective geophysical research a modification to the conventional technique of field investigations is necessary. While with respect to the seismic method or to some kinds of geoelectrical research this is related to the relief of the terrain and to the presence of the zone of permafrost, in the case of the magnetic method the nature of phenomena which complicate its application is totaly different.

At the geomagnetic latitude of Spitsbergen there are intensive 24-hour variations in the external magnetic field. The amplitude of the variations is often several times as large as the magnitude of the anomalies observed, while an additional factor to complicate their reduction is the strong dependence of the variations on the longitude of the observation point. These conditions are therefore inconvenient, particularly for the performance of detailed survey and mapping of weak anomalies with an amplitude of several to dozen-odd nT, since at a similary high interference level the survey accuracy is limited not so much by the sensivity of the measuring device as by the accuracy of reduction and depends directly on the field research method.

In the course of magnetic investigations in Spitsbergen in the summer of 1979 several versions of the field research method were tested. The method of synchronized measurements proved to be the most efficient. It was implemented using a set of two proton magnetometers PMP-4 (manufactured by the Experimental Laboratory "GEOPAN" of the Institute of Geophysics, Polish Academy of Sciences, Warszawa, ul. Pasteura 3) whose quartz clocks can be synchronized. The measurement accuracy was 1 nT. This method was adapted to detailed research over small areas within which a stationary interference distribution is usually assumed.

In the area of the Hornsund Fiord investigations by this method were performed on the Hans Glacier and for magnetic mapping within the complex of metamorphic rocks and magma intrusions.

2. Measurement conditions

The technical possibilities of magnetic investigations in Spitsbergen are determined by the above-mentioned properties of the variable external magnetic field. The variation amplitude of the total intensity T or its components H and Z can reach here a value of several hundred nT, whereas the character of these variations is nonlinear even at such short time intervals as one minute. This can be seen in the case of a continuous registration of the vertical component Z at the magnetic observatory of the Polish Polar Station in the Hornsund area and in the case of short-series measurements of discrete T with a proton magnetometer in the very same area (Fig. 1).

This is not an extreme example. Similar violent variations quite often occur here and are characteristic of a large number of days over the short summer season. In a slightly other way, it can be said that the occurrence frequency of these storm interferences or depression changes are in this region more or less at level corresponding to the occurrence frequency of the S_q type behaviour in lower geographical altitudes.

Another specific property of the measurement conditions in Spitsbergen is the high dependence of the variation on the longitude of the observation point. This involves greater demands as to the magnitude and accuracy of corrections introduced for the solar time. In view of the nature of the variation, an essential influence on the reduction accuracy can be exerted by small time changes e.g. of the order of 30 s. It follows from the analyses

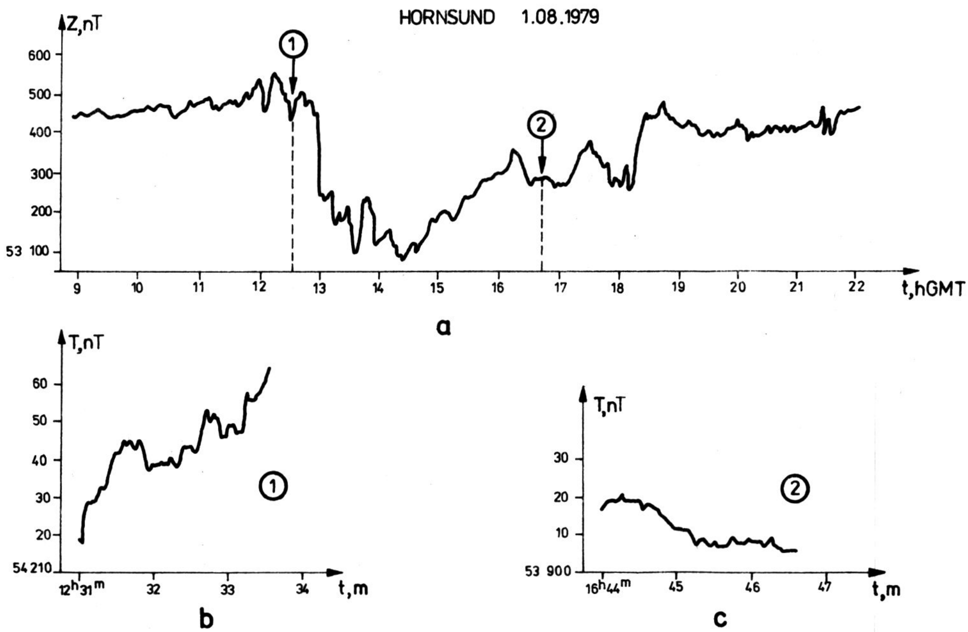

Fig. 1. 24-hour variations in the magnetic field in the area of the Hornsund Fiord in Spitsbergen a. continuous registration of the vertical component Z at the magnetic observatoy of the Polish Polar Station. b,c. series of discrete measurements of the total intensity T

performed that in some cases this correction changes the value reduced by about 5 nT.

The measurement conditions considered here in short account for the fact that the application of no matter what research method in which the reduction would be interpolation-based is ineffective, since this involves excessive error in the determination of anomaly. Such methods include, for example, the method of observation with one device, according to the repetition drill $P_0 \ldots P_i$, scheme P_o, $P_{i+1} \ldots$ or the method of observation with two devices but with synchronization that is not complete with the base registration.

3. Method of synchronized measurements

The method of synchronized, measurements is such a method which permits the measurement of the same element of the field simultaneously at two points. In the version of this method used here it is assumed that during synchronization the variable part of the field, within given limits, is the same at the two measurements points, p_o and p_i.

When therefore the structure of measured element T is written in the simplest general form as a superposition of the constant part T_c, which describes the geomagnetic field, and the variable part δT, which characterizes 24-hour behaviour; i.e. $T = T_c + \delta T$, then, according to the assumption about δT, the sequence of the differences $\Delta T = T(p_i,t) - T(P_0,t)$ is a function independent of time and expresses anomalous changes in the geomagnetic field.

This is an idealized model of magnetic measurements, in which it is assumed that $\delta T_p = \delta T(p_i,t) - \delta T(p_o,t) = 0$ with a given accuracy. This corresponds to the conditions when in the vicienity of the reference (base) point p_0 the process $\delta T(p, t)$ is stationary, i.e. such that its distribution does not change for the transition from p_0 to p_i. In practice, however, the difference δT_p for arbitrary choice of p_0 and p_i is usually different from zero and depends on a number of factors, including the longitude change $\Delta\lambda$ between these two points.

In the area of Spitsbergen this dependence is particularly strong. The present method of detailed investigations for this area neglected, hovewer, the necessary correction of observation times resulting from the change $\Delta\lambda$. The distances between the measurement points and the reference point were chosen so that their influence on δT_p was minimum. A double error of the magnetometer, ± 2nT, was taken as the criterion of reduction accuracy. All measurements, irrespective of the magnitude of the amplitude of anomalies observed, were taken under the above principle.

With relatively smooth 24-hour changes this criterion could be achieved over a rather small area $2\,\Delta\lambda = 0°8'$ wide. For a central position of the base this gave a time shift of about ± 15 s. Under these conditions, with the mean latitude of Hornsund, 77°N, the maximum permissible distance in the West--East direction between measurement points and the base is about 2 km. Similar dimensions were also taken for this area in the South-North direction.

The effect of the equipment—related synchronization error on the reduction accuracy over such an area will be discussed for the case of investigations performed on the Hans Glacier. This example can also illustrate reduction errors resulting from the lack of corrections for solar time.

Fig. 2 shows two pairs of graphs, a_0 and b_0, achieved for points about 1.5 km ($\Delta\lambda = 2'$) and 2 km ($\Delta\lambda = 3'$) distant from the reference point. In both cases measurement series consisted of 20 observations, and were taken, as were all the other measurements, with an automatic release of the magnetometer measurement signal. When retaining the concurrence, shown in the graphs, of the field registration (upper graph) with that of the base (lower graph), the measured results arrange along the "parallel" curves and the sequence of the differences ΔT converges in the mean

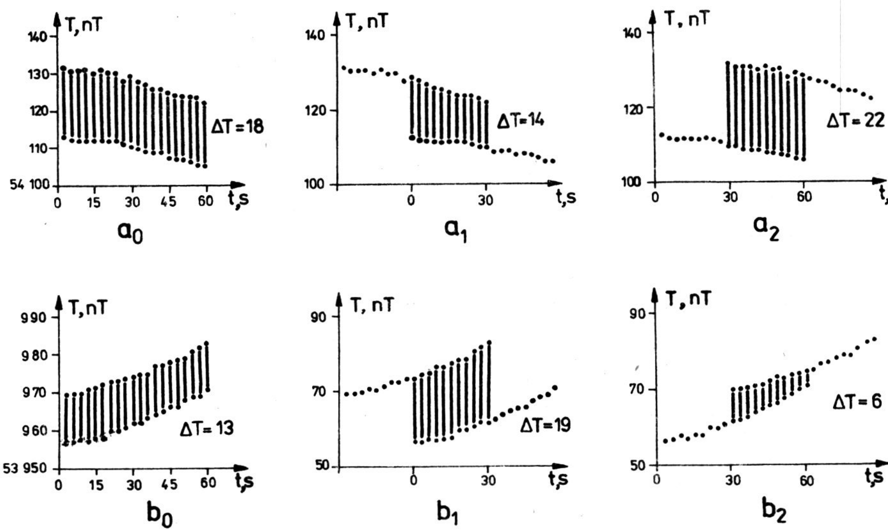

Fig. 2. Synchronic observations of T. Example of the investigations from the Hans Glacier a_0, b_0—full synchronization a_1, b_1, a_2, b_2—time shift of ± 30 s.

to the constant. The maximum deviation of a single measurement from the mean does not exceed the equipment—related error, i.e. 1 nT.

In curves a_1 and a_2 and b_1 and b_2 the former behaviour was desynchronized and the shift on the time axis is ± 30 s. The effect of desynchronization is a change in the absolute value of ΔT and also partial loss of "parallelness", which is particularly distinct in curve b_2. The mean values of anomaly in these examples, calculated from the coinciding measurements in the series, differ from the output data by ± 4 and ± 6 nT. These results are the measure of reduction errors which can occur, particularly with single measurements when the concurrence principle is not maintained.

In addition to the possibility of synchronization, another advantage of the automatic release of the magnetometer measurement signal is the constant working frequency. It is very convenient in the presence of strong interference, when minimization of reduction errors requires longer measurement series. PMP-4 magnetometers can work at freguencies of 40, 20 and 10 observations a minute and the corresponding accuracies of 2.1 and 0.25 nT. In all kinds of investigation in Spitsbergen the second working range was used, whereas the number of observations in a series was each time dependent on the character of interference and on the magnitude of the amplitude of expected anomalies. The initial moment for the implementation of a series was established with conventional signal transmitted by a walkietalkie.

4. Examples of application

The present method was used in investigations of the base of the Hans Glacier and in magnetic mapping within a complex of metamorphic and magma rocks. Only some results of these investigations are given here to illustrate the efficiency of the method over a wide of the magnetic properties of rocks.

Fig. 3 shows an example of investigations performed in the area of the northern shore of the Hornsund Fiord. The measurements were taken at the foot of the Fugleberget, in a section built of rocks with very weak differentiation of magnetic properties. The object of mapping was the contact zones within a series of slates and marbles of the Precambrian metamorphic complex. The profile section shown is an example of micromagnetic investigation with a sampling step of 5 m. In this case the anomalies ΔT were calculated from a synchronic series of 8 observations and the variation registered in their distribution represents real petrological changes confirmed by geological observations.

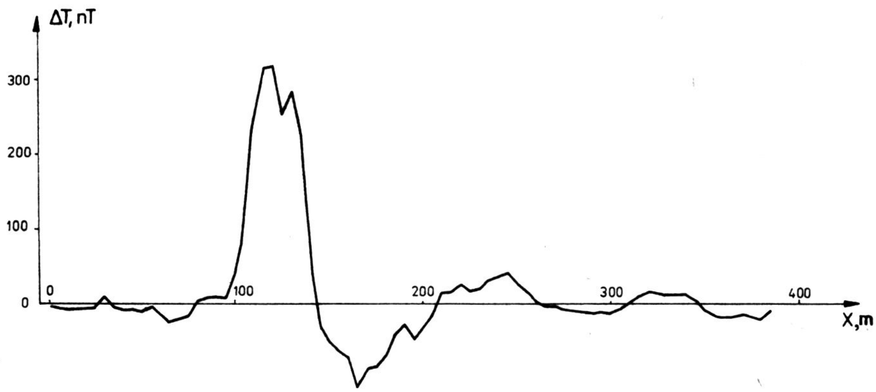

Fig. 3. A fragment of the profile ΔT in the zone of metamorphic rocks

Another example of the investigations in the Hornsund area is the profile over the dolerite in Skål Valley (Fig. 4). This profile rans across to the extension of the dyke, in the South-North direction. As in the

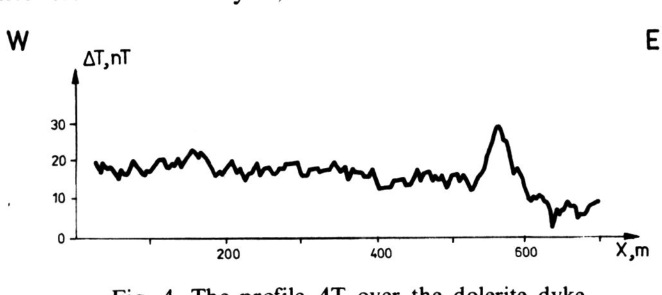

Fig. 4. The profile ΔT over the dolerite dyke

previous case, the sampling step was also 5 m. In this case, in view of the large amplitude of the anomaly (about 400 nT), the number of observations in a series limited to 3. The anomaly in question has a shape typical of finite, twodimensional bodies with diagonal magnetization.

5. Conclusion

The examples given here and also other results of investigations in Spitsbergen show than even at large geomagnetic latitudes the range of measurement difficulties can be limited with simple technical operations. The method of synchronic observationns, which assures a high accuracy in the determination of an anomaly, requires, however, magnetometers to work in the same measurement frequency regime and the initial moment of a series to be in agreement, since it can be seen in Fig. 2 that slight time shifts can cause reduction error up to several nT. which in effect can often make measurements useless for the purposes of geological interpretation.

In addition to its high precision, the method is also very economical. It excludes the necessity of time registration, interpolation etc. which are always connected with the conventional method of reduction, under the assumption of a linear character of changes between successive repetitions of measurements at base points. In the method of synchronic observations it is only necessary to calculate the differences between successive measurement pairs corresponding in time. At full synchronization the maximum deviation from the mean usually does not exceed the value of a single equipment-related error. This method can also be recommended for investigations with strong industrial interference, whenever for any reasons it is not possible to use the gradient technique.

6. Резюме

Обсуждается методика разведочных магнетических исследований при естественных сильных внешних возмущениях магнитного поля. Это методика синхронизированных измерений, которые, при определенных условиях, дают возможность получить съемку с точностью 1—2 n T. Методика была применена в детальных исследованиях слабых аномальных полей.

7. Streszczenie

W pracy omówiono metodykę prospekcyjnych badań magnetycznych w warunkach naturalnych, silnych zakłóceń zewnętrznym zmiennym polem magnetycznym. Jest to metodyka pomiarów synchronizowanych, która przy spełnieniu określonych założeń pozwala uzyskiwać zdjęcia o dokładności 1—2 nT. Zastosowano ją w badaniach szczegółowych słabych pól anomalnych.

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