Results of Archaeomagnetic Research in Czechoslovakia for the Epoch from 4400 B.C. to the Present.

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The research into the secular variation of the geomagnetic field, which enables the gradual explanation of the origin and maintainance of the field, has been carried out by methods of direct observations over the past 500 years, and by palaeomagnetic investigation of rocks giving approximate information on the character of the geomagnetic field at the time of the inception of the various geological formations. Research into the geomagnetic field in the so-called historical era, which is in fact an intermediate between palaeomagnetic research into the field in geological epochs and present day observations, comes under the heading of archaeomagnetism. It enables a certain elucidation of the dynamics of the field in a period covering several thousand or tens of thousand years.

Numerous archaeological discoveries on Czechoslovakian territory support the evidence that prehistoric people inhabited these regions continuously for a considerable period. This provides fertile ground for archaeomagnetic research. Several archaeologically dated sites were chosen for the first investigations of this kind, some of which were dated also with the help of the C 14 radioactive method. These sites cover the period from 4400 B.C. to the present. Samples were mostly gathered from furnaces and fireplaces in the vicinity of inhabited areas. The investigation concentrated on determining the total geomagnetic field intensity F. The successive double-heating method of E. Thellier (1959) has been used.

Results of laboratory measurements of samples from Býlany divided according to their age and covering the period between 4400 and 3000 B.C. with steps of 200 to 300 years between the various samples, are shown in Fig.1. to 3. The curves of the first two samples (dating back to 4400 B.C.) show that the demagnetization and magnetization processes are of a similar character. The demagnetization curve at first shows a gradual decrease as far as 400°C, but for higher temperatures the magnetization decreases much faster. Similarly the magnetization curve shows a considerable enhancement above 400°C. The mean coefficient $k$, defining the ratio between the original field and the laboratory field is equal to 0.8, and after correction with respect to a laboratory field equal to the present geomagnetic field 0.94. The sample (4100 B.C.) (Fig. 1.) shows $k=0.86$ after correction a being the demagnetization curve, b the magnetization and c the "mirrored" curve. The third group of samples (3600 B.C.) has $k=0.46$ for three samples. The curves for one of these samples are shown in Fig. 2. For another sample (3300 B.C.) $k=0.58$. The last group of samples from Býlany (dating back to 3000 B.C.) is represented by the samples with $k=0.85$ (Fig. 3.).

Further the demagnetization and magnetization curves of some samples from the site near Mohelnice were investigated. The site dates to 3600 to 3000 B.C. The values $I$, for vari-
ous temperatures yield a mean $k=0.61$ for the first sample, $k=0.78$ for the second and $k=0.58$ for the third sample.

For the Stehelčeveš-Homolka site (approximately 1800 B.C.) five samples taken from furnaces and the walls of a burnt down house were investigated. Three of these proved
unsuitable, because they were insufficiently baked. The remaining two samples showed remarkable stability and regular magnetization curves. The average coefficient for both the samples was 1.15 after correction with respect to the present day geomagnetic field intensity.

The Mečlov-Březí habitation near Domažlice was represented by two samples dating back to approximately 1500 B.C. Mean k=1.23.

Two samples were chosen of those collected from under the burial pyre on the Moravičany burial ground (800 to 1200 B.C.) Mean k=1.20.

The mean koefficient k for samples from the Jinonice site near Prague (400 B.C. to 0) yielded k=1.48.

The samples from the wall in Pohansko (8–9th century A.D.) gave k=1.68 (Fig. 4.).

The last group from the archaeological site at Hradiště near Mikulčice (10th century A.D.) was represented by three samples. Fig. 5. shows the appropriate curves for one of the samples. The demagnetization was regular and the decrease of the curves was larger than that of the magnetization curve; k=1.12. The second sample had k=1.1 and the third k=1.3.

A graph showing the changes of the geomagnetic field intensity in the period from 4400 B.C. to the present day from our results is shown in Fig. 6. The ordinate axis shows the ratio of $F_o$, the original field, and $F_s$, the present day field, which is defined by the coefficient $k$. For samples of the same age all the values of $k$ are shown (small circles) as well as their means (double circles). The resulting curve shows a decrease in values from 4400 B.C. (from the Bylany group of samples) to 3600 B.C., where the curve has a minimum. The curve then gradually recovers up to a maximum approximately at the beginning of the present era then decreases again to the present value. It is possible to conclude that a geomagnetic intensity cycle has its minimum value in 3600 B.C., this being about 1/2 of the present day value, and a maximum approximately in the year 0. The latter value is about 1.5 times that present day geomagnetic field intensity. The measurements are as yet too few and far between and the oldest values from 4400 B.C. were derived from one site only, there-
fore the results can be classified as preliminary. Fig. 7 shows the course of curves investigated on the territories of France, (Thellier, 1959) the Soviet Union (Burlackaja, 1962) and Czechoslovakia. As it appears the curves display a rough agreement; certain differences in the values of intensity are probably due to continental anomalies.

The interpretation of the curves obtained by the successive double-heating method is unique for the cases, when the demagnetization and the “mirrored” magnetization curves, reduced with respect to \( k \), are approximately identical. But some samples display a considerable disagreement between both curves, especially in the beginning and end sections. For example, the values of the demagnetization and “mirrored” magnetization curves of some samples for 600° and 670°C differ widely. If these values had been included for computing \( k \), it would have been impossible to achieve an agreement between the “mirrored” curve and the demagnetization curve along their whole length. Owing to the fact that a number of similar cases were encountered during the laboratory investigation, it was necessary to undertake the explanation of this feature and its causes, and decide to what extent results obtained from archaeological samples baked at temperatures less than Curie point, could be used.

Dust of similar composition to that of material found in archaeological furnaces was
used to make samples, which were then baked in a known laboratory field at various temperatures: sample “a” at 300, “b” at 400, “c” at 450, “d” at 500 and “e” at 670°C. This group of samples was then subject to laboratory investigation by the successive double-heating method in the same field as was used for the artificial baking of the samples. The results given in Fig. 8. (a to e) show great differences in magnetization of the samples treated at different temperatures.

The sample baked at 300°C (Fig. 8 a) shows relatively low magnetization. When applying the successive double-heating process, the demagnetization curve at first displays a decrease, but from 400°C onwards it increases and then decreases again. This is caused by intense magnetization of the sample in the temperature interval between 400 and 670°C under the influence of heating in positions differing by 180° of arc. This also leads to the appearance of certain discrepancies, which are caused by a sharp enhancement of magnetization. The magnetization curve of sample “a” shows that the magnetization, created at Curie point temperature, is about ten times higher that the original magnetization created at 300°C. If the “mirrored” curve is then constructed with $k=1$ (both fields were identical), it can be seen that both curves are practically identical up to 300°C, but have widely differing values for higher temperatures. The second sample heated to 400°C (Fig. 8 b), showed similar features. Although the original magnetization obtained at 400°C is considerably higher, being approximately half of the maximum magnetization corresponding to the Curie point temperature, differences can be seen between the demagnetization curve and the “mirrored” magnetization curve for temperatures higher than 400°C, while for lower temperatures these curves are completely identical. Similar features are encountered with samples “c” and “d,” (Fig. 8. cd) the original magnetization of which differs less and less from the maximum magnetization. Sample “e”, originally heated to Curie point temperature, displays an overall approximate agreement between both curves except for some deviations, which rest with the measurements or mineralogical changes.

The results thus obtained, enabled an important conclusion to be made in establishing the intensity of the geomagnetic field with those of archaeological samples baked at temperatures lower than the Curie point. As can be seen from the demagnetization and “mirrored” magnetization curves, good agreement is achieved between both up to temperatures, to which the samples were originally heated, whereas for higher temperatures the curves display remarkable deviations. It then follows that even samples, which have not been completely baked, and whose curves differ at higher temperatures, can be used for archaeomagnetic investigations of the total geomagnetic field intensity. Magnetization values characterizing a strong enhancement of the magnetization curve and corresponding to a section of the demagnetization curves, where the decrease is not proportional to the enhancement mentioned, cannot be used to compute the coefficient $k$, which describes the geomagnetic field intensity during a certain period. This could be seen very well in Fig. 8a for the section, where $T=300^\circ$C and in Fig. 8b for $T=400^\circ$C. In evaluating the results of the successive double-heating method, it has proved convenient to use values corresponding to temperatures from 0°C to that, at which the intersection of the demagnetization and magnetization.
curves occurs, especially if it is evident from the curves that the “mirrored” magnetization curve cannot comply with the demagnetization curve throughout. Having constructed the “mirrored” curve, it is then comparatively easy to decide, which values can be included for computing $k$ and which not.

Some samples show that the demagnetization and magnetization curves intersect each other at very low temperatures (below 300°C), and have a considerably differing course after intersection (the magnetization curve rises considerably to a high magnetization value, so that this is many times higher than the original magnetization; the demagnetization curve has a smaller upward slope and an unsystematic course.) In these cases it is evident that the original magnetization of the sample was created at temperatures lower than 300°C and that it cannot be used for archaeomagnetic purposes.

References.
