

Properties of the chemical remanent magnetization formed at a single-phase oxidation and a subsequent decomposition of titanomagnetites

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Abstract. Regularities of influence of a single-phase (SP) oxidation and a subsequent decomposition of synthetic titanomagnetites (TM) of a different original composition ($\text{Fe}_{3-x}\text{Ti}_x\text{O}_4$ (where $x = 0.2, 0.4$ and 0.6)) upon the change of their hysteresis parameters and on properties of the resultant chemical remanent magnetization (CRM) were determined as a result of the laboratory researches. Calculations were made of the changes of magnetization of the igneous rocks similar to the investigated TM of a composition with $x = 0.4$ taking into account SP changes of the primary titanomagnetite at a high partial pressure of oxygen. The influence of CRM on safety of the primary (thermoremanent) magnetization at different stages of the SP oxidation of TM and decomposition of the cation-deficient TM was assessed. The results which were obtained may be used for interpretation of changes in the magnetic properties of the submicron grains of TM in the course of their thermal transformation on the earth surface.

Introduction

The titanomagnetites (TM) being the main carriers of the rock magnetism are not stable on the earth surface from the point of view of thermodynamics. Influenced by different physical-chemical processes, oxidation and decomposition being the main, they suffer the mineralogical transformations, which lead not only to a failure of the primary magnetization (for the volcanogenic rocks this is of a thermoremanent origin, as a rule), that carries information about an ancient geomagnetic field, but also to generation of a chemical remanent magnetization (CRM or J_{CRM}), which distorts, in its turn, the primary magnetization and, consequently, affects the paleomagnetic safety. Therefore, a great interest to generation of the CRM and to the study of its properties is quite natural [Bailey and Hale, 1981; Beske-Diehl, 1990; Borisova and Sholpo, 1991; Gapeev et al., 1991; Gromme and Mankinen, 1976; Haigh, 1958; Hall, 1976, 1977;

Heider and Dunlop, 1987; Hunt et al., 1986; Johnson and Hall, 1976, 1978; Johnson and Merrill, 1972, 1973, 1974; Kobayashi, 1959; Markov and Shcherbakov, 1987; Marshall and Cox, 1971, 1972; Merrill, 1975; Nguyen and Pechersky, 1987; Nishitani and Kono, 1989; Özdemir and Dunlop, 1985, 1988, 1989; Prevot et al., 1981; Raymond and La Brecque, 1987; Smith and Banerjee, 1985; Soppa, 1989; Soroka and Beske-Diehl, 1984].

Experiments on creation of the CRM were conducted both on the synthetic objects [Johnson and Merrill, 1972; Nishitani and Kono, 1989; Özdemir and Dunlop, 1985] and on the natural objects [Bailey and Hale, 1981; Johnson and Merrill, 1972, 1973; Marshall and Cox, 1971]. The generalized results which were obtained may be presented in the following way.

1. At a single-phase oxidation of TM the CRM inherits the direction of the primary remanent magnetization, when the ferrimagnetic grains are in a single-domain (SD) or in a pseudosingle-domain (PSD) state. However, some authors [for example, Johnson and Merrill, 1973; Nishitani and Kono, 1989] show the possibility of the CRM to generate in the direction of the applied external magnetic field. Moreover, the given CRM in the highly oxidized TM proved to be comparable, by its intensity and stability to the alternating magnetic field (\tilde{H}), with the corresponding characteristics of the primary thermoremanent magnetization (TRM)

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residue retained in the course of maghemitization [Nishitani and Kono, 1989].

2. At a single-phase oxidation of a multi-domain (MD) TM, as well as at the heterophase changes of the TM grains in the SD, PSD and MD states, the CRM being generated, reflects according to all the data available, the direction of the external magnetizing field.

Investigations of the vector of the natural remanent magnetization (\mathbf{J}_n) of the oceanic basalts have shown that generation of the field controlled J_{CRM} component is also possible at a single-phase oxidation of the titanomagnetite small and coarse fractions [Gromme and Mankinen, 1976; Hall, 1977; Johnson and Hall, 1976; Prevot et al., 1981].

The ambiguity which exists in the concepts of direction of the J_{CRM} vector has induced us to study thoroughly the rules of generation and properties of the chemical remanent magnetization at a single-phase oxidation and a subsequent decomposition of the TM grains. Along with this the following tasks have been posed: 1) study the change of the J_{CRM} value depending on the time and temperature of its formation; 2) find out the relation of the mineralogical transformations and magnetic characteristics of the TM with changes of the J_{CRM} value and stability; 3) compare the J_{CRM} value and stability with the corresponding characteristics of other types of the remanent magnetization; 4) estimate the influence of the single-phase oxidation and the subsequent decomposition of the TM on safety of the primary (thermoremanent) magnetization.

Experimental Results

The experiments on creation of the chemical remanent magnetization were carried out on the cube samples $1 \times 1 \times 1$ cm in size which were a mixture of kaolin and 1% by weight of the synthetic TM powder whose composition was $\text{Fe}_{3-x}\text{Ti}_x\text{O}_4$ (where $x = 0.2, 0.4$ and 0.6) with the $0.5\text{--}0.8 \mu\text{m}$ ferrimagnetic particles. The samples which had been demagnetized first ($H = 2000 \text{ V m}^{-1}$) along three orthogonal directions were subjected to oxidation in a thermomagnetometer with a temperature range $\Delta T = 153\text{--}518^\circ\text{C}$ in a constant magnetic field $H = H_0 = 1 \text{ V m}^{-1}$ and with the isothermal time period t from 2 minutes up to 700 hours. The CRM which was generated at this time was measured directly at the temperature of its formation in the thermomagnetometer shields. Cooling of samples down to a room temperature ($T_0 \approx 20^\circ\text{C}$) was also there with the field being switched off.

A partial thermoremanent magnetization $J_{pTRM}(T_{CRM} - T_0)$ was created when the sample was cooled in the H_0 field. The anhysteretic remanent magnetization $J_{ARM}(H = 1 \text{ V m}^{-1}, \tilde{H} = 2000 \text{ V m}^{-1})$ was created at a room temperature. The remanent magnetization of different types was alternating field (AF) demagnetized also at a room temperature T_0 . All the remaining magnetic characteristics, which were used in this work, were measured according to standard procedures of the rock magnetism.

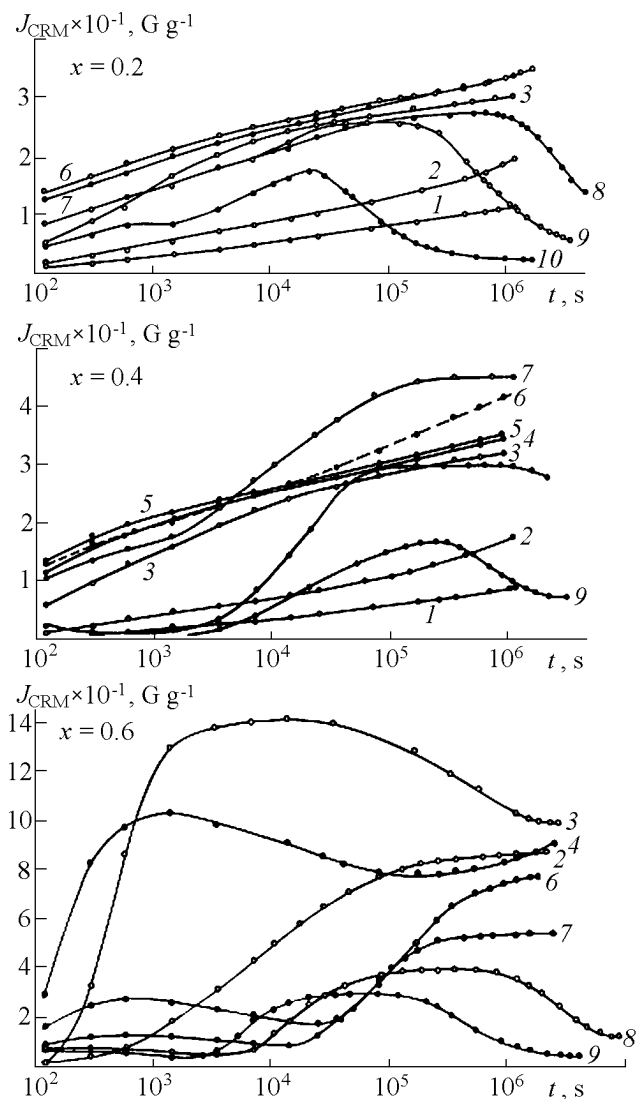


Figure 1. Behavior in time of the chemical remanent magnetization, which is formed at single-phase oxidation and subsequent decomposition of titanomagnetite $\text{Fe}_{3-x}\text{Ti}_x\text{O}_4$ of different initial composition at different temperatures: 1– 153°C , 2– 195°C , 3– 288°C , 4– 348°C , 5– 372°C , 6– 408°C , 7– 448°C , 8– 488°C , 9– 518°C and 10– 550°C .

Oxidation time and temperature effect. Figure 1a, 1b and 1c show results of study of the J_{CRM} time dependence at different annealing temperatures for the TM samples whose composition was $x = 0.2, 0.4$ and 0.6 respectively. The following regularity in behavior of the $J_{CRM}(t)$ may be clearly seen from these diagrams: originally the chemical remanent magnetization rises, then it reaches the peak value, then the value decreases and at a further temperature holdup a new, more considerable rise of the CRM occurs, which gives way to a decline at a sufficiently high annealing temperatures. Completeness of this sequence (t.i. the number of sections which could be distinguished on the $J_{CRM}(t)$ curve and which reflect one or another tendency in its change)

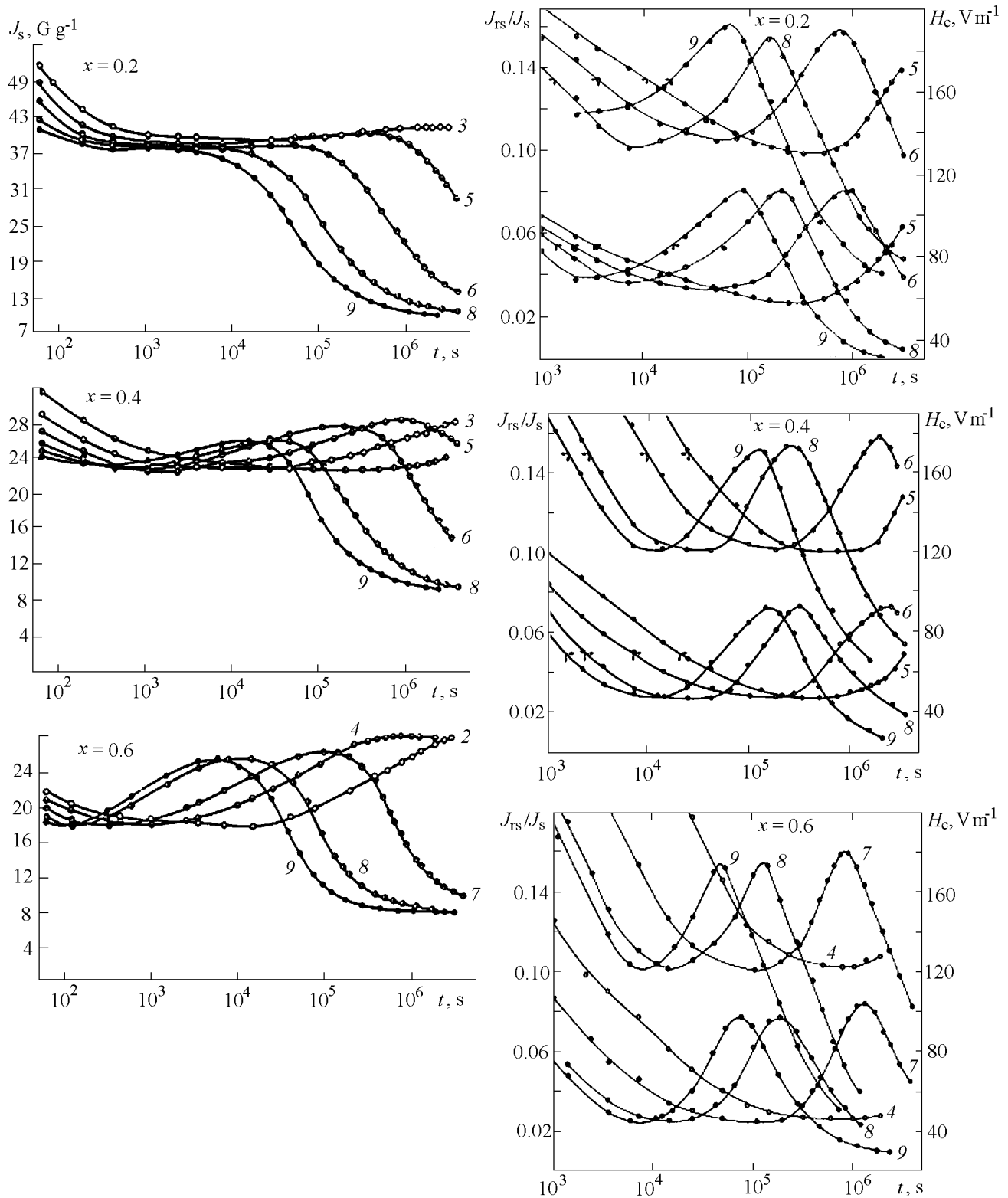


Figure 2. Time dependence of J_S (a), J_{rs}/J_S (b) and H_C (b) relation for the TM samples of different initial composition, which were subjected to an isothermal annealing in air at different temperatures: 1–408°C, 2–440°C, 3–448°C, 4–480°C, 5–488°C, 6–518°C, 7–520°C, 8–550°C and 9–565°C.

depends on temperature at which the CRM is originated.

A thorough investigation of the TM fraction of the oxidized samples with the help of an X-ray phase and thermomagnetic analyses was carried out specially to interpret unambiguously this type of behavior of the chemical remanent magnetization. The results obtained on the saturation magnetization J_S time dependencies, J_{rS}/J_S ratios and the coercive force H_c (all parameters were measured at T_0) of the TM samples annealed at different temperatures are shown in Figure 2. Three stages of transformation are clearly seen for all compositions of TM investigated: a single-phase oxidation of the initial TM, decomposition of the single-phase oxidized TM and a "secondary" oxidation of the generated magnetite. The single-phase oxidation resulted in an insignificant growth of $J_S(t)$ (recorded only at low annealing temperatures of the TM samples with the initial values $x = 0.4$ and $x = 0.6$), and afterwards to a decreasing of $J_S(t)$ (Figure 2a), and to a drop of $H_c(t)$ due to a partial relaxation of stresses in the course of annealing. At a decomposition of the cation-deficient TM the next growth of $J_S(t)$ occurred (more clearly expressed for compositions with $x = 0.4$ and $x = 0.6$), which reflected formation of a spinel phase, closer to magnetite, and an increase of $J_{rS}/J_S(t)$ and $H_c(t)$ (Figure 2b) at the beginning of the process, caused by changes of volumes of the forming phases and by the rise of stresses at their coherent coupling. The subsequent drop of $J_S(t)$ reflects oxidation of the magnetite phase which was generated in the course of decomposition and the decline of $J_{rS}/J_S(t)$ and $H_c(t)$ indicates that the stage of loss of coherence of the coexisting magnetite and haemilmenite phases has been reached. X-raygraphically the single-phase oxidation was characterized by a reduction of the TM crystalline lattice parameter with the type of the crystalline structure being retained; the diffraction reflections typical for the haemilmenite phase occurred during decomposition and the "secondary" oxidation of magnetite was accompanied occurrence of pseudobrookite.

Examination of the results allowed to connect the original growth of $J_{CRM}(t)$ with the single-phase oxidation of the initial TM, to connect the subsequent relative drop of $J_{CRM}(t)$ with the beginning of decomposition of the cation-deficient TM when the neogenic magnetite phase does not contribute to the overall CRM because of a small size of nuclei at the initial stage of decomposition. The new and a more considerable growth of $J_{CRM}(t)$ with its subsequent gradual drop (which is clearly fixed at sufficiently high annealing temperatures) may be connected with the increase of the magnetite phase volume and its subsequent oxidation. Naturally, only original growth of the chemical remanent magnetization is observed at relatively low temperatures as the TM transformation process in this case stops at the stage of generation of the cation-deficient spinel and becomes much extended in time at the given temperatures. Finally, let us also note, that when the Curie temperature (T_c) of the single-phase oxidized TM was below the heat treatment temperature, no CRM formation occurred.

Along with investigation of the CRM generated in the direction of an external magnetizing field, the magnetic measurements of all samples were made in projections orthogonal to \mathbf{H}_0 . The results show that the J_{CRM} is firmly single-

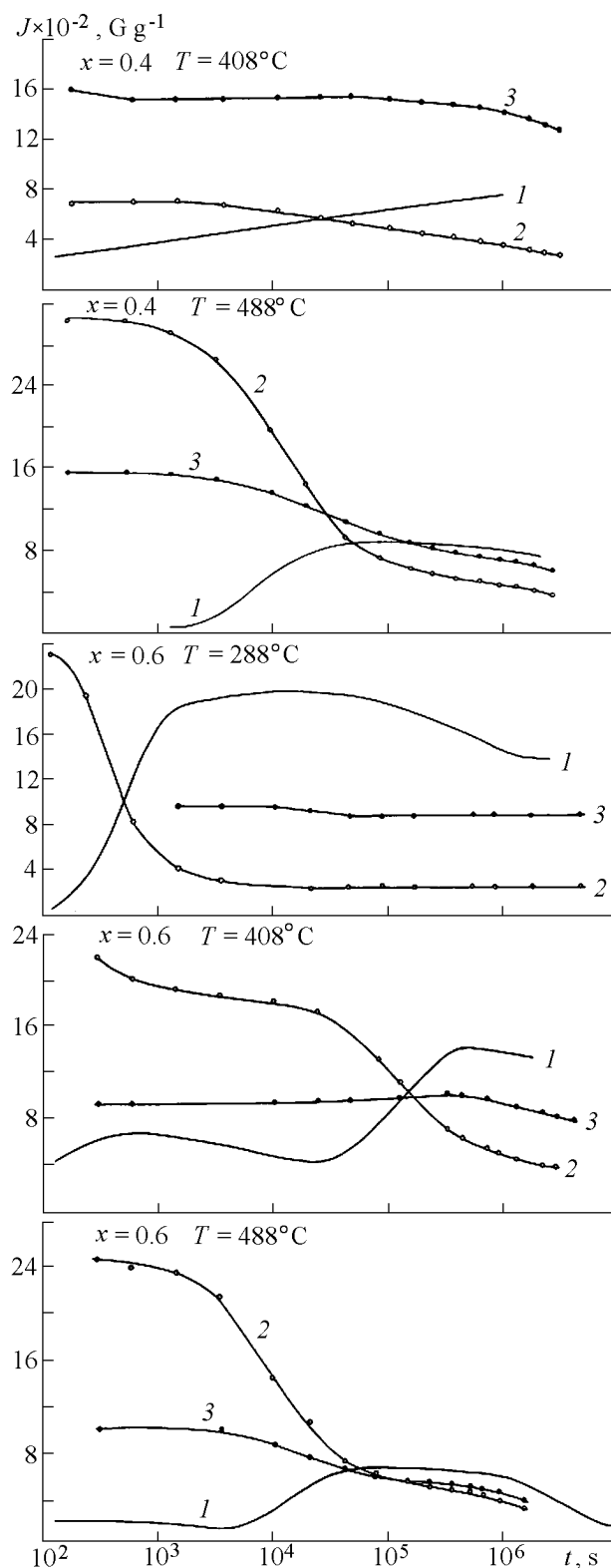


Figure 3. Relation between CRM (curve 1), pTRM (curve 2) and ARM (curve 3) at 20°C and a holdup time at different temperatures of annealing (T) the TM samples of different initial composition.

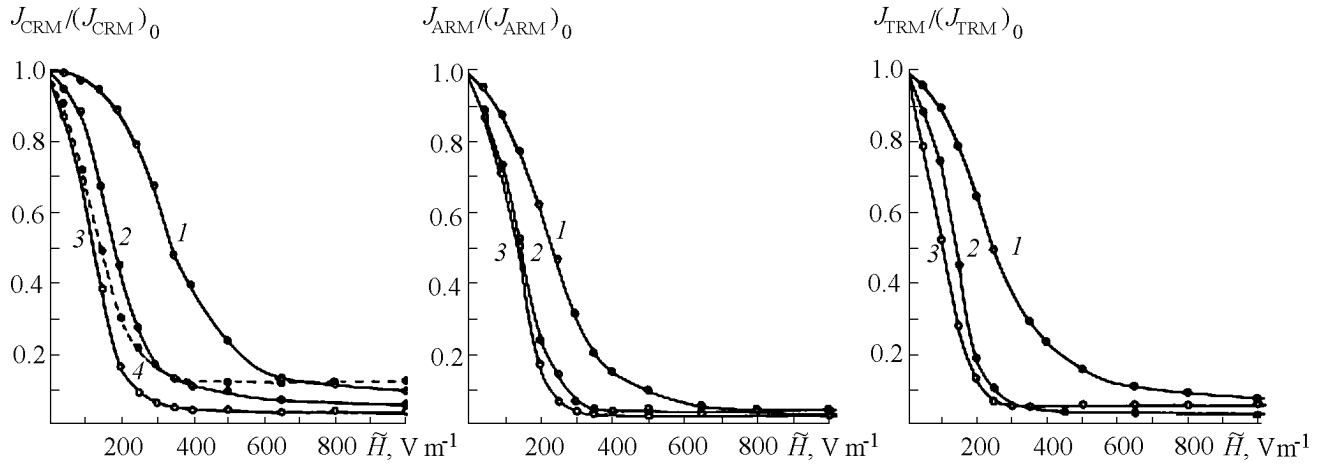


Figure 4. Demagnetization of CRM, ARM and pTRM by alternating magnetic field \tilde{H} for the TM samples (initial $x = 0.6$) with different time hold in the air at 408°C : 1–10 minutes; 2–7 hours; 3–201 hour, 4–505 hours.

component throughout the studied time interval of the TM transformations and is generated towards the external magnetic field ($\mathbf{J}_{\text{CRMf}} \parallel \mathbf{H}_0$).

Influence of the original titanomagnetite composition. The experiment has shown that the value of CRM formed on a titanium-rich TM ($x = 0.6$) appeared to be greater than for the titanium-poor TM ($x = 0.2$ and $x = 0.4$) both at the single-phase oxidation and at the stage of a subsequent decomposition of TM. This difference is expressed distinctly at the single-phase oxidation stage (Figure 1).

Comparison of CRM with other types of the remanent magnetization. Changes of CRM, pTRM and ARM, formed on the duplicate samples ($x = 0.4$ and $x = 0.6$) with different time temperature holdup are shown in Figure 3. The remanent magnetization values presented here correspond to values measured at a room temperature. From the analysis of these dependencies one might arrive at a conclusion that at the single-phase stage of the TM oxidation the CRM value, measured at T_0 is more than half the corresponding ARM value; the CRM and ARM values are comparable at the stage of decomposition of the cation-deficient TM. Depending on temperature at which the single-phase oxidation takes place the share of pTRM (or TRM) in the overall magnetization of $J_{\text{CRM+pTRM}}$ might be both dominating and inconsiderable. Inferences can be made that the contribution of pTRM and of CRM to $J_{\text{CRM+pTRM}}$ might be equal at the intermediate temperatures of the single-phase oxidation of TM. But at the stage of decomposition of the cation-deficient TM the share of pTRM in the overall magnetization was always less than the corresponding CRM component.

All three types of the remanent magnetization under investigation were compared for their resistance to the effect of the alternating magnetic field. Figure 4 shows the results of this AF demagnetization for the TM samples of $x = 0.6$ composition at different stages of their time T -holdup. It

is seen from these diagrams that resistance of the pTRM to AF cleaning is less than that of the CRM and AF stability of the CRM is less than that of the ARM for all states of the TM. A similar tendency was obtained also for the TM samples with the initial $x = 0.2$ and $x = 0.4$ composition.

The samples with the titanomagnetite fraction of the $x = 0.4$ composition which was subjected to the single-phase oxidation were also assessed for the change of the chemical remanent magnetization depending on the oxidation parameter (Z) of the given ferrimagnetic. Figure 5 shows the

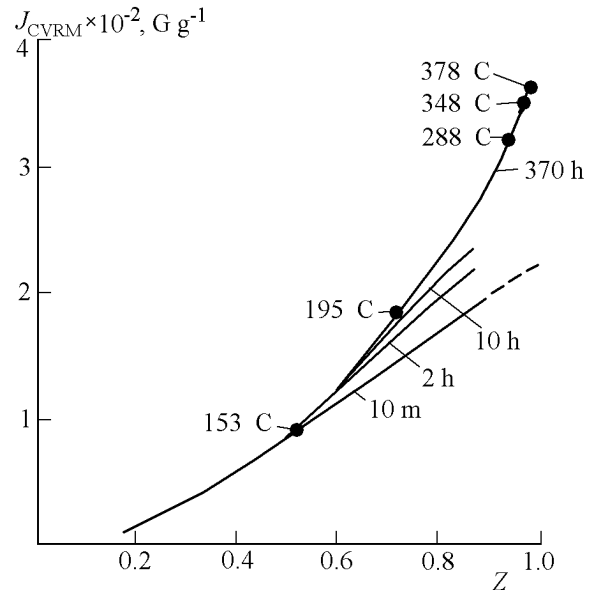


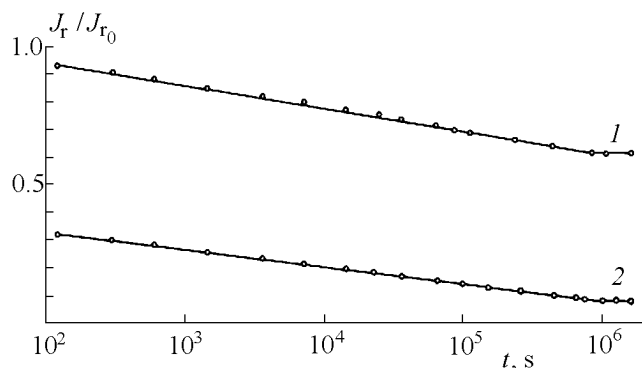
Figure 5. Variation of CRM depending on time of its formation and the single-phase oxidation parameter (Z) at different temperatures of the TM samples of $x = 0.4$ composition.

Table 1. Values of the viscous magnetic properties (in the field $H = 1 \text{ V m}^{-1}$) of the TM samples ($x = 0.4$) at different temperatures and different parameter (Z) of their single-phase oxidation

Z	$S_v, \text{ G/g}$				$J_{\text{VRM}}, \text{ G/g}$		
	20°C	153°C	195°C	288°C	10 ⁶ years	10 ⁸ years	10 ⁶ years
					20°C	20°C	150°C
1	2	3	4	5	6	7	8
0.53	0.09×10^{-3}	0.76×10^{-3}			0.00277	0.00295	0.0109
0.73	0.29×10^{-3}	0.99×10^{-3}	1.30×10^{-3}		0.00469	0.00527	0.0145
0.95	0.54×10^{-3}	1.20×10^{-3}	1.61×10^{-3}	2.49×10^{-3}	0.00723	0.00831	0.0183

$J_{\text{CRM}}(Z)$ curves for samples with (0.16–370)-hours of the (153–378°C) temperature holdup in the field H_0 , demonstrating a considerable change with the increase of the CRM annealing time which is expressed particularly for the highly oxidized TM. The following reasoning might explain this effect. The single-phase oxidation of the TM up to high values of Z causes equalizing of the vacancy concentration throughout their volume. Grains become more homogeneous and due to this stresses are partially removed and the coercive force drops down. Along with the fall of H_C the energy barrier that precludes reorientation of magnetization will also reduce. Therefore, the particle magnetic reversal will become easier and, thus, the viscous magnetization must become more intensive and this is observed in reality.

Experiments on estimation of changes of the viscous magnetic properties of the TM during their single-phase oxidation were carried out in the following way. After the alternating magnetic field destroyed the CRM generated in the course of oxidation of the TM samples (originally $x = 0.4$) to different Z -states (with the isothermal period from 2 minutes up to 370 hours at a fixed temperature from 153 to 288°C) the samples were subjected to a repeated holdup under similar temperature conditions and also at 20°C; the time changes of magnetization ($J_{\text{VRM}}(t)$) after the action of the constant magnetic field H_0 on the samples were recorded. The dependencies obtained in coordinates $\Delta J_{\text{VRM}} - \Delta \log t$

**Figure 6.** Zero-field decay of CRM (curve 1) and VRM (curve 2) in TM sample ($x = 0.4$ and $Z = 1.0$) at 378°C.

were described well by a straight line that allowed the magnetic viscosity coefficient S_v (calculated according to equation $S_v = dJ_{\text{VRM}}/d \ln t$ by a change of the viscous magnetization J_{VRM} with time t under action of the constant magnetic field) to be calculated by its inclination. The results are presented in the Table 1 (columns 2, 3, 4 and 5). The analysis of the data shows that velocity of the viscous magnetization is greater on the samples with a high oxidation parameter of the titanomagnetite grains than on the weakly oxidized TM and along with this the temperature rise leads to an increase of S_v . However, with the T rise, influence of the parameter of the TM single-phase oxidation on speed of their viscous magnetization reduces.

Thus, investigation of the magnetic properties of the single-phase oxidized TM samples (initial $x = 0.4$) has shown that at the oxidation parameters $Z < 0.5$ intensity of the occurring CRM is proportional to Z ; at higher values of Z the viscous magnetization of samples becomes apparent and the magnetic viscosity coefficient becomes greater both with the oxidation temperature rise and with the rise of the TM oxidation level.

Just as in the experiment on investigation of the CRM properties of single-phase oxidized magnetite samples [Gapeev *et al.*, 1991], we succeeded in separation of a reversible (viscous) and an irreversible (chemical) CRM components on a single-phase oxidized (up to $Z \sim 1.0$) TM sample with the $x = 0.4$ composition. The results are presented in Figure 6 (curve 1). It is well seen that the value of CRM originated on the original sample in the magnetic field 1 V m^{-1} in the course of its oxidation up to $Z \sim 1.0$ ($T = 378^\circ\text{C}$, $t = 30$ hours) reduces during the subsequent thermal cleaning ($H = 0 \text{ V m}^{-1}$) with the time following strictly the logarithmic law and at about 220-hour holdup at 378°C it becomes equal to $\sim 60\%$ (or 0.0222 G/g) of its original value; a further annealing during ~ 240 hours more did not change the remainder of the CRM. The same figure shows for comparison curve 2 demonstrating the time destruction (taking place according to the logarithmic law) in the course of the 378°C cleaning ($H = 0 \text{ V m}^{-1}$) of the viscous remanent magnetization (VRM); the latter was created in the course of a 30-hour heat treatment at the given temperature in the field 1 V m^{-1} of the single-phase oxidized ($Z \sim 1$) and of the TM desired sample demagnetized by the alternating field. It is important to state that the given

VRM amounted to $\sim 40\%$ (or 0.0154 G/g) of the complete CRM acquired in the course of the titanomaghemitization of the original TM during the same time range. Thus, the experiment has proved that no matter what way of separating "pure" CRM and VRM components of the complete CRM of the TM sample ($x = 0.4$) single-phase oxidized up to $Z \sim 1$ was used by us, the relations of these components obtained turned to be identical, namely $J_{VRM}/J_{CVRM} \sim 0.4$ and $J_{CRM}/J_{CVRM} \sim 0.6$.

As to the separated components of the CRM resistance to the alternating magnetic field effect it has been found experimentally that AF stability of the complete CRM is higher than stability of its viscous component but it is less than resistance to AF cleaning of a "pure" chemical CRM component.

Influence of CRM on safety of the original (thermoremanent) magnetization. All experiments on creation of the CRM described earlier were performed on the samples which had been demagnetized first. Under the natural conditions, however, as has been mentioned before, the process of generation of the CRM is of an superimposed nature and a primary role here belongs to magnetization of the igneous rocks, which are of a thermoremanent origin, as a rule. This brings up a point about influence of the secondary transformations of the TM on safety of the TRM of the parent phase. The following experiments were carried out to estimate this influence.

A complete TRM was created on the titanomagnetite sample cubes placed in the evacuated quartz capsules in the course of their cooling in a constant magnetic field 1 V m^{-1} from 300, 400 and 510°C for formulations of TM with $x = 0.6, 0.4$ and 0.2 respectively. The values obtained were equal to 0.215 G/g, 0.236 G/g and 0.242 G/g respectively. After the TRM has been created the sample was removed from the capsule and was oxidized in air in the thermomagnetometer shields. The change of the original magnetization was recorded directly at the annealing temperatures. The results have shown that unlike the previous experiments, according to which generation of the CRM is described by its extreme dependence on time, behavior of the original TRM in the course of oxidation of TM is char-

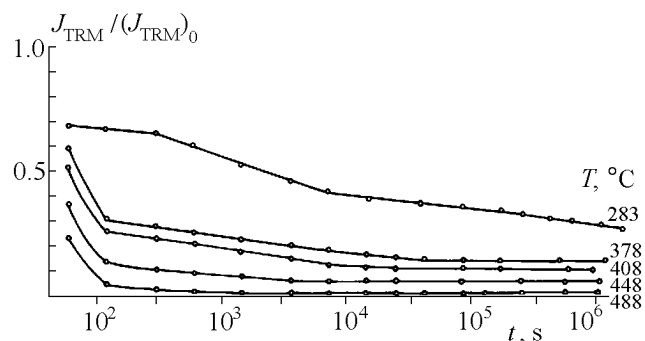


Figure 7. Relative change of the primary TRM in the course of a single-phase oxidation and decomposition of the TM samples (initial $x = 0.4$) at different annealing temperatures (T).

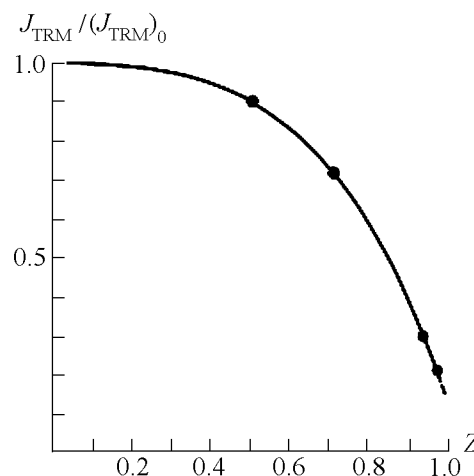


Figure 8. Relative change of the primary TRM in the course of a single-phase oxidation of the TM samples of $x = 0.4$ composition. All values correspond to values measured at a room temperature.

acterized by a monotonous diminishing of its value up to minor values of CRM acquired by the sample at the TM decomposition stage. The changes of $J_{TRM}(t)$ in the course of oxidation of the TM samples with the initial $x = 0.4$ are shown in Figure 7 as an example. The change of value of the initial TRM from the single-phase oxidation of the sample of the same TM fraction is shown in Figure 8. Both figures demonstrate an essential change of the J_{TRM} at an extreme stage of the single-phase oxidation and a subsequent decomposition of TM. It follows from these data that a considerable destruction of the initial TRM along with generation of the CRM in the course of the heterophase change of the TM must result in a considerable distortion of the primary paleomagnetic record.

Experiments on creation of the CRM in the $H_0(1 \text{ V m}^{-1})$ field perpendicular to a direction of the TRM which had been created first on the initial sample in a similar magnetic field in order to make a quantitative assessment of influence of oxidation and decomposition of TM on safety of the paleomagnetic information. The remanent magnetization in this case was measured both in the direction of the external field of the CRM generation and in the direction of the initial magnetization perpendicular to the above field. These experiments have shown that the value and direction of the J_{CRM} , obtained in the case of the demagnetized and magnetized TM initial samples of all compositions under investigation do not change. This means that the chemical remanent magnetization, generated at the stage of the single-phase oxidation of TM and at the stage of decomposition of the cation-deficient TM, reflects the direction of the external magnetizing field only. Aside of this, a special attention was paid to a study of behavior of the resultant vector of the remanent magnetization (\mathbf{J}_r) in the course of this experiment with the TM samples of the $x = 0.2$ and $x = 0.4$ composition in the oxidation process. The distinguishing feature of the dependencies obtained (Figure 9), as it was expected, was an insignificant deviation of \mathbf{J}_r from the direction of the

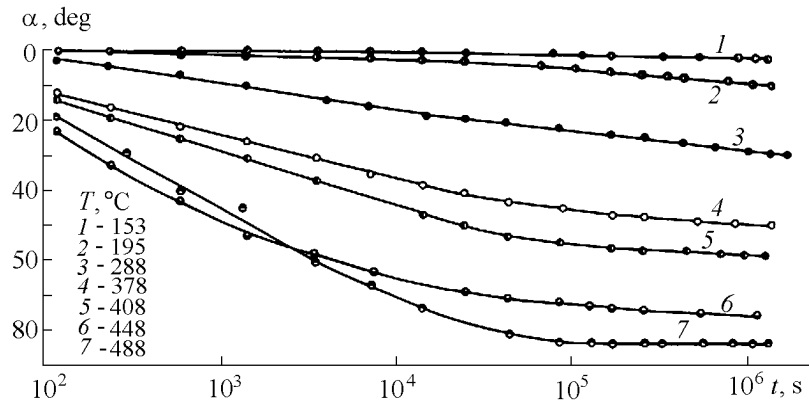


Figure 9. Inclination (in degrees) of the remanent magnetization \mathbf{J}_r resultant vector from direction of the primary \mathbf{J}_{TRM} at different temperatures (T) in the course of a single-phase oxidation and subsequent decomposition of the TM (initial $x = 0.4$).

initial \mathbf{J}_{TRM} at a single-phase oxidation (see also Figure 10) and its strong reorientation towards the external the external during creation of the CRM with the signs of the TM decomposition.

During the last experiment with the TM samples with the initial $x = 0.4$, stability of the newly generated CRM and leavings of the undecayed initial TRM was also compared. The results of a simultaneous stepwise demagnetization of mutually perpendicular types of the remanent magnetization by an alternating magnetic field are shown in Figure 11. It follows from this that at the single-phase stage ($T \leq 378^\circ\text{C}$) of the TM oxidation by small \tilde{H} -fields the chemical remanent magnetization is destroyed somewhat more strongly and the TRM is destroyed by greater - fields. This may be explained, on one hand, by influence of a viscous component of the CRM and on the other hand, by

occurrence of stresses and by an increase of the magnetic rigidity of TM at their single-phase oxidation. Attention is attracted on the same figure to a 45-degree slope of straight portions of the curves, which characterizes the \mathbf{J}_r coordinates of the heterophase modified TM after a corresponding \tilde{H} -cleaning of its TRM and CRM components thus indicating to their (components) similar resistance to this type of action. This complies with the results of the investigation of stability of the above presented pTRM and CRM. Thus, separation of the CRM-component and the retained primary TRM-component of \mathbf{J}_r (just as pTRM-component) by their magnetic field stability becomes impossible because of overlapping of the coercive spectra. This condition, of course,

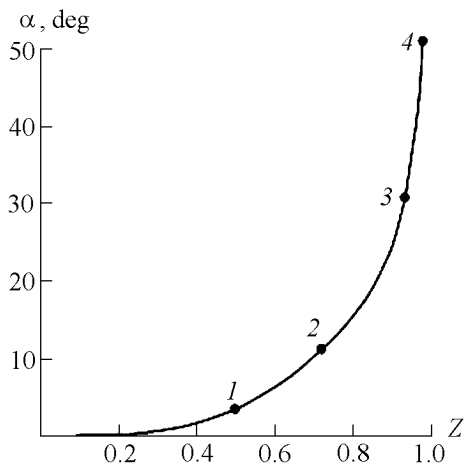


Figure 10. Inclination of the remanent magnetization \mathbf{J}_r resultant vector from direction of the primary \mathbf{J}_{TRM} at a single-phase oxidation of the TM sample of $x = 0.4$ composition for 370 hours at different temperatures: 1-153°C, 2-195°C, 3-288°C and 4-378°C.

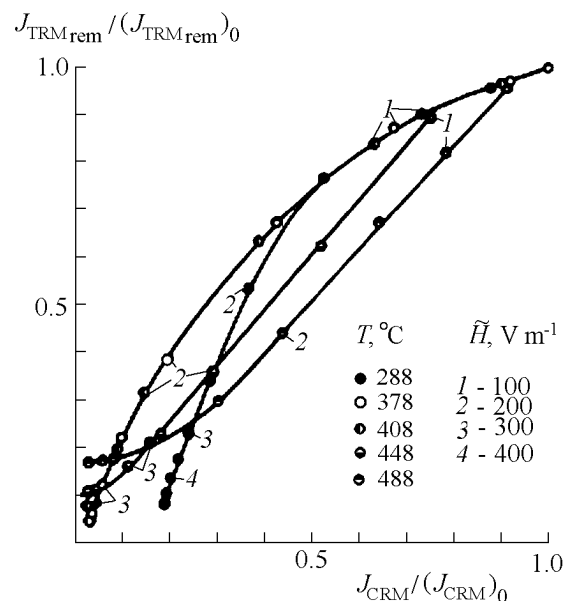


Figure 11. Zijderveld diagram of AF demagnetization (with 50 V m^{-1} steps) for the TM samples (initial $x = 0.4$) at different stages of their oxidation and decomposition.

complicates the use of the \tilde{H} -cleaning method in the practice of the paleomagnetic investigations for separation of the characteristic (thermoremanent) magnetization for the rocks with the transformed TM.

Discussion of Results

This investigation has shown that the chemical remanent magnetization, reflecting a direction of the external magnetizing field, occurs not only upon the heterophase change of TM (which accepted unconditionally by all the researchers) but also in the course of a single-phase oxidation of the stoichiometric single-domain TM; along with this destruction of the primary thermoremanent magnetization takes place. On the other hand, according to the kinetic investigations of the TM transformation processes [Gapeev and Gribov, 1990, 1997], the single-phase oxidation of TM and decomposition of the cation-deficient TM processes on the earth surface may be very much extended in the geological time scale. All this taken together means that the chemical magnetization of the TM may be formed and reflect the terrestrial magnetic field of different geological epochs and during the geomagnetic field inversions as well. Therefore, a possibility of a partial remagnetization of the rock as a result of occurrence of the secondary J_{CRM} components of different age becomes realizable not only due to decomposition of the cation-deficient TM, but also in the course of the preceding titanomaghemitization.

The investigation has shown that only high-oxidized TM may play an important role in generation of J_n at the stage of the single-phase oxidation due to a considerable contribution to their remanent magnetization of the chemical component and its viscous constituent. By assuming that regularities of growth of the viscous magnetization during the geological time are exactly the same as those estimated in the laboratory experiment (see Table 1), then the J_{VRM} taken by the surface basalts (at 20°C), similar to the TM composition ($x = 0.4$) under investigation, will make 0.00277 G/g at $Z \sim 0.53$, 0.00469 G/g at $Z \sim 0.73$ and 0.00723 G/g at $Z \sim 0.95$ for 1 million years and 0.00295 G/g, 0.00527 G/g and 0.00831 G/g for 100 million years respectively. It may be seen from comparison of these findings with the thermomagnetization that the viscous component will make no more than 1.5% at $Z < 0.5$. However, at a more deep stages of the single-phase oxidation when, according to our results, the initial TRM reduces by about 6 times, while the chemical magnetization component proper increases by 95% of the TRM remainder and velocity of the viscous magnetization becomes 6 times greater only on account of the oxidation level rise, the viscous magnetization on the earth surface may amount to approximately 20% of the nonfailed thermomagnetization after 1 million years, provided the geomagnetic field is constant. It is obvious, that the viscous component may contribute even more to the natural magnetization of the rocks due to a rise of the magnetic viscosity along with the temperature rise (see Table 1, column 8). In case of a frequent inversion of the geomagnetic field the total

magnetization will, evidently, be completely determined by a contribution of the nonfailed portion of the TRM.

The established regularities regarding influence of the single-phase oxidation and a subsequent decomposition of the single-domain TM upon safety of the primary (thermoremanent) magnetization allow us to draw a conclusion that it is not possible to use the multi-domain and also SD grains of TM for the paleomagnetism purposes both with a high single-phase oxidation level and also with the signs of decomposition due to a considerable distortion of their original magnetization. At the same time, since the CRM value at the initial stages of the single-phase oxidation of TM, according to this investigation, still does not exceed 10% of the primary TRM and deviation of the resultant vector of the remanent magnetization from the primary TRM direction is not more than 10°, one might suppose that the single-phase oxidation cannot be a serious obstacle for the use of a weakly oxidized ($Z < 0.5$) titanomagnetite SD fraction in the paleomagnetism practice.

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