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MAGNETOSTRATIGRAPHY OF OLIGOCENE–LOWER MIOCENE SEDIMENTS IN THE PERIMBEL TRANSCRIPT (TALISH MEGAZONE)

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Abstract

The article discusses paleomagnetic research conducted at the Perimbel intersection of the Talysh structure, located near the village of Yardimli district. The intersection is mainly composed of the Rupel, Hatt and Sakaraul regiolevels of the Maykop stratum. The stratigraphy and paleomagnetism of the Talysh structure have not been studied to the full extent. Paleomagnetic research was conducted to clarify the detailed stratigraphic age distribution of the collected rock samples. We know that during the Maykop period (6-33 million years ago), the magnetic field was subject to frequent changes in location, that is, the Earth's magnetic field changed its location frequently - an inversion event occurred. The results of scientific research conducted on samples taken from the Perimbel intersection of the Talysh structure prove this fact. Based on the results of the analyses, we can say that in the Oligocene and Lower Miocene, 2 hyperzones were identified separately: in the Rupel regiolevel - normal and reverse polarity alternated (samples 13-16); Hatt regiolevel - has a direct magnetization (samples 5-13); Sakaraul regiolevel - is characterized by a reverse magnetization (samples 1-5).

Analysis of both the paleomagnetic and mineralogical composition of the samples taken from the studied area was carried out in the laboratory of the ARETN Institute of Geology and Geophysics, Department of "Dynamic Geology". The boundaries of the Rupel, Hatt, and Sakaraul regiolevels were precisely defined and the paleomagnetic scale was compared with scales established for rocks of the same age taken from other areas, with the scale established for the Absheron Peninsula, and with the Bergrener et al. (1995) scale.

Keywords: *paleomagnetism, Perimbel, Talysh, Geomagnetic Polarity Time Scale (GPTS), natural remanent magnetization (NRM),*

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INTRODUCTION

According to the methodology of paleomagnetic studies, the selection of samples is carried out taking into account the genesis, lithological characteristics and structural position of the rock. In particular, in studies conducted on sedimentary and volcanogenic-sedimentary rocks, each individual lava flow is evaluated as an independent magnetic unit. This approach allows us to assess the possible internal variation within the flow and the effect of subsequent tectonic deformations.

When selecting samples, it is recommended to take them both along the direction of the lava flow (extension) and along a line perpendicular to this direction. Such a distribution allows us to check the spatial homogeneity of magnetization, identify possible local anomalies and assess the effect of structural trends on paleomagnetic results. This method is especially important in terms of more accurate determination of the initial direction of temperature magnetization arising during the cooling process.
Samples taken from sedimentary and volcanogenic sedimentary rocks are cut in the laboratory into at least 4 cylindrical or cubic oriented samples of standard size (2-22mm). Regardless of the reason for cutting cubic or cylindrical samples of the same size due to different types of magnetic cleaning, measurements are made on a single measuring device, the JR-6-spin magnetometer.
Such systematic and multiple sampling of samples allows for a more complete and accurate result and subsequent calculation of the mean direction, concentration parameter (k) and 95% confidence interval (alpha95) based on Fisher statistics, which determines the level of reliability of paleomagnetic results.
Thus, the more oriented samples are taken from both sedimentary and volcaniclastic rocks, the more accurately the statistical reliability of paleomagnetic data can be calculated.
After the rocks acquire their initial magnetization, they continue to be influenced by the Earth's magnetic field throughout geological time. As a result of tectonic processes, metamorphic effects and geomagnetic inversions occurring over millions of years, secondary remanent magnetization components of various origins are formed in the rocks. As a result, the natural remanent magnetization (NRM) in the memory of the rock takes on a multi-component character and can retain almost 10-15% of the initial magnetization in its memory. As a result of the study, the lithological composition, thickness, layering characteristics and lateral continuity of sedimentary complexes were determined.
Tectonics of the area: The Talysh tectonic zone is located in the southeastern part of the Republic of Azerbaijan, forming the eastern edge of the Caucasian segment of the Mediterranean fold belt and acting as an important structural element in the geodynamic evolution of the Alpine-Himalayan mobile belt. This orogenic system was formed under the influence of the gradual closure of the Neo-Tethys ocean basin, the convergence of continental blocks and collision processes. The geotectonic structure of the region as a whole, as in other parts of the Caucasus, is heterogeneous in nature, and this heterogeneity is associated with the combined influence of lithological-stratigraphic complexes of different ages, magmatic and volcanogenic-sedimentary associations, as well as multiphase deformation stages.
In the Talysh zone, volcanogenic-sedimentary rocks of Mesozoic and especially Paleogene age are widely developed, and intensive island-arc type magmatism and basin subsidence were observed in the Eocene stage, which is associated with the subduction regime of the Neo-Tethys[4] (Figure 1).

Figure 1. Photo of the eponymous section located near the village of Perimbel.

Structurally, the zone is characterized by a complex combination of fold-structural elements, depth faults and tectonic blocks.

Thus, the Talysh tectonic zone can be assessed as a complex geological system that has undergone multi-stage geodynamic development in the Caucasian segment of the Alpine-Himalayan belt, formed under the sequential influence of subduction, collision and post-collision stages. Its lithological diversity and structural heterogeneity are explained as a reflection of the long-term tectonic activity of the region and the Neo-Tethys evolution on a regional scale.

Geology of the area: The Talysh structure geologically consists mainly of Paleogene rocks. Although the area has been studied since the beginning of the 20th century [2]. However, to date, there is no generally compiled chronological scale of the Talysh structure.

The total thickness of Oligocene sediments in the Perimbel section is approximately 150 m. The CPS of the section is located at 38.54° N. latitude and 48.07° E. longitude. Lithologically, the sediments consist mainly of brown clay, argillite, and variously grained sandstones. The Lower Maykop half-bed unit contains well-rounded gravelly conglomerates, parallel-bedded sandstones, and alternating clay layers. Burnt plant remains and bitumen deposits indicate a reducing depositional environment rich in organic matter. These lithofacies are consistent with the shelf and semi-deep marine sediments developed during the Oligocene–early Miocene of the Paratethys Basin [2].

Thus, the lithofacies diversity observed in the Perimbel section indicates that the Talysh zone formed in complex paleogeographic and tectonic conditions during the Oligocene (Figure 2). The presence of volcanogenic material confirms the connection of the region to an active geodynamic regime, while terrigenous-complex sediments reflect intensive material transport from continental sources into the basin.

Figure 2. Coordinates of the study area (Perimbel intersection)

Methodology

In modern paleomagnetic studies, magnetic (AF) and thermal demagnetization methods are widely used not only to verify the stability of natural remanent magnetization (NRM), but also to separate and interpret its multicomponent structure. Since rocks acquire magnetization components with different genesis at different stages during geological time, NRM is usually formed as a superposition of several vector components. Therefore, the demagnetization procedure is considered the main analytical step for the separation of the primary component and the removal of secondary magnetizations (Figure 3).

In this context, the concept of magnetic and temperature cleaning denotes any laboratory process that results in the gradual weakening or quenching of the vector components that make up the NRM. At each temperature or alternating field step, the modulus of the total magnetization vector decreases and the direction of the vector changes; this change is accompanied, in particular, by the dissipation of secondary components. As a result, the multi-component structure of NRM is gradually simplified and the more stable component comes to the fore.

Figure 3. JR-6 two-speed Spinner Magnetometer used to determine the components of the remanent magnetization vector of rock samples and samples ready for measurement

The main graphical method widely used to visually demonstrate the high informativeness of the results of the demagnetization process with a changing magnetic field or temperature and the quality of component separation is the Zijderveld diagram proposed by Zijderveld. In this diagram, the stepwise change in the magnetization vector is depicted in two mutually perpendicular projections - horizontal and vertical planes. Both projections have a common north-south axis, and thus the three-dimensional trajectory of the vector is traced in parallel in two rectangular planes (Figure 4)

If the points in the diagram in a certain temperature or field interval are directed along a straight line towards the center, this indicates a systematic dispersion of one component in this interval. Thus, the multicomponent NRM vector is sequentially decomposed into separate linear segments, each segment representing the characteristic direction of the corresponding magnetization phase.

Currently, the Zijderveld diagram is accepted as the primary and main interpretation tool of demagnetization results in leading paleomagnetic laboratories. This method is considered a fundamental method both in terms of separation of components and assessment of their stability and statistical reliability.

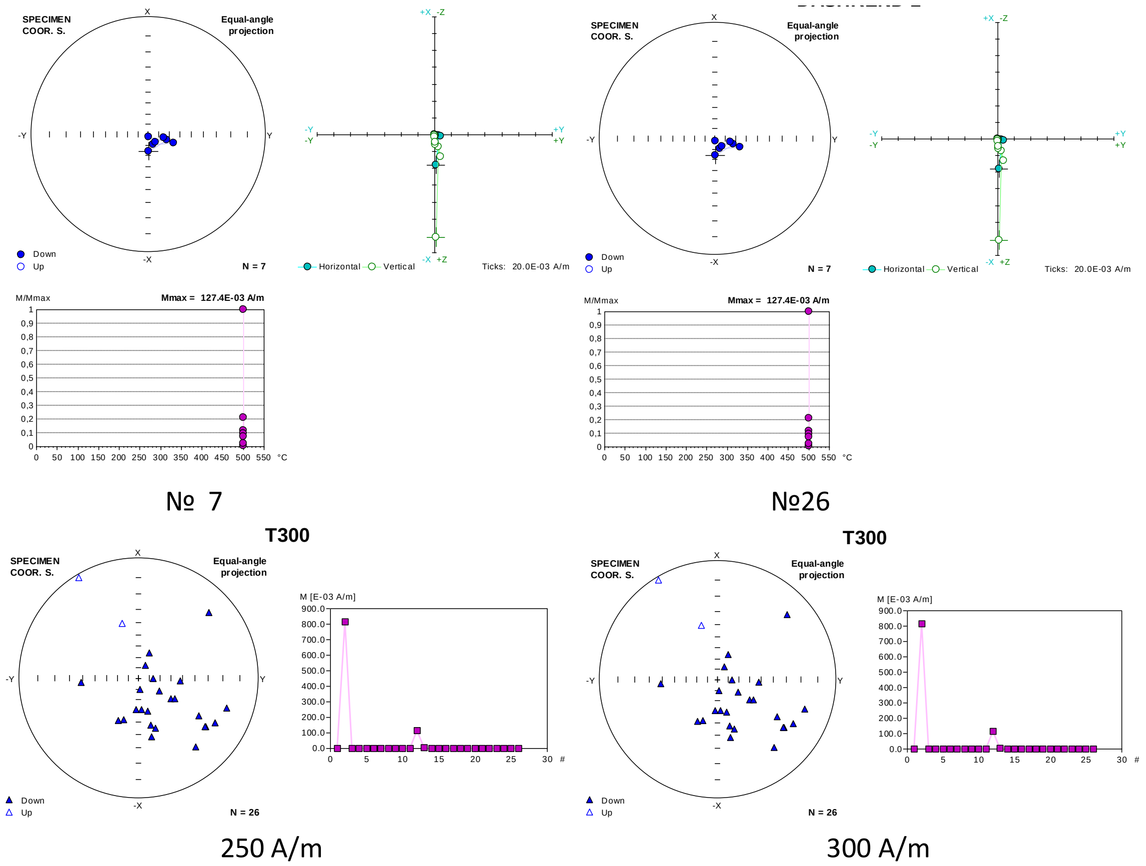

Figure 4. Zijderveld diagrams obtained as a result of magnetic cleaning of samples 7 and 26 taken from the Perimbel section with an alternating magnetic field (AF), stereograms of the samples constructed for 250 -300 A/m.

In order to eliminate secondary magnetization components, two methods are mainly used in paleomagnetic practice: stepwise thermal demagnetization and demagnetization with an alternating magnetic field (AF).

During thermal cleaning, the samples are usually heated stepwise with increasing temperature intervals starting from 100°C and up to 600–700°C. At each temperature step, the sample is kept at a constant temperature for about 1 hour, which ensures demagnetization of magnetic phases with a blocking temperature corresponding to that interval. In the lower temperature steps, mainly weakly stable components are removed, while in the higher temperature intervals, components carried by more stable minerals such as magnetite or hematite are quenched.

To carry out the thermal demagnetization process, special furnaces are used in the laboratory. For example, LDA-5/PAM1 devices manufactured by AGICO allow heating in conditions protected from a magnetic field (Fig. 3). In such devices, samples are heated in an environment with a weak residual magnetic field, which prevents the formation of new, artificial magnetization and allows only the selective quenching of existing components. Thus, stepwise thermal or alternating magnetic field demagnetization methods used to eliminate secondary magnetization components carried by rocks are the main methodological stage that allows for the separation of the primary component of paleomagnetic magnetization. The correct application of these procedures ensures a reliable reconstruction of the magnetization history of the rock, taking into account the characteristics of magnetic mineralogy.

The section surfaces in the Perimbel village area and is traced in a northeasterly direction along the forested area. The total thickness of the studied section is approximately 150 m (Fig. 2).

For the purpose of the study, paleomagnetic studies were conducted on 16 samples taken from the Perelbel section located in the Talysh structure. For the paleomagnetic study, 64 cubes were cut from these samples and analyzed (Fig. 3).

First, several types of magnetic cleaning methods were used to determine whether the rocks have natural remanent magnetization. These included temperature cleaning (by heating), cleaning with a variable magnetic field, and time cleaning (30 days in the azimuth and angle of the sample, and 60 days in the opposite direction).

Analysis of the results of stepwise demagnetization with temperature and variable magnetic fields shows that the decrease in magnetization occurs mainly due to the decomposition of secondary components.

The results of paleomagnetic studies conducted on samples taken from the Perimbel section are based on a comparison of the initial natural remanent magnetization parameters with those after the 350°C temperature stage. The table presents the declination (D), inclination (J) and normalized intensity (Jn) for each sample both in the initial state and after thermal and time (viscous component reduction) cleaning [7] (Table 1).

In the initial measurements, the D values vary over a wide range (approximately 13°–176°), indicating multicomponent magnetization. The Jn values vary in the range of 25–65 A/m, and in some samples, the presence of negatively oriented components is observed.

This type of spread is usually associated with the formation of a later acquired component under the influence of the magnetic field of the modern Earth or as a result of diagenesis or oxidation processes. Such a multicomponent structure is considered a suitable case for paleomagnetic studies.

The wide variation of the declination values and the relatively dispersed nature of the intensities in the initial measurements indicate that the rocks have multicomponent magnetization. This condition is typical for sedimentary or volcanogenic-terrigenous rocks and is usually explained by the overlap of the following components:

This type of behavior is characteristic of sedimentary rocks and has been widely described in the paleomagnetic literature [5, 6, 8].

After heating to 350°C (Table 1), a significant decrease in Jn intensity is observed in a number of samples. The tendency to cluster in D directions increases. Some of the negative or unstable directions disappear.

If the directions stabilize after 350°C, this indicates that the secondary component stabilized at low temperatures has been successfully cleaned

Table 1.

Comparison of measured values of Jn, I and D parameters before and after magnetic cleaning.

		Before magnetic cleaning			After magnetic cleaning		
		Jn	D	I	Jn	D	I
1	2	3	4	5	6	7	8
	1	13,84253	84,17035	40,44556	2,186435	223	-30
	2	17,8156	28,10135	62,69126	1,820385	250	-27,8355
	3	10,44319	139,8247	61,64229	12,37658	146,7926	-34,4429
P	5	3,178003	62,73053	46,62477	23,32151	25,8914	48,03212
E	6	10,70089	176,8415	45,94162	22,11833	92,79713	44,48932
R	7	3,920893	161,657	59,83695	7,823644	26,81773	58,77082
İ	8	5,280133	69,9077	31,89713	12,4035	294	49,70172
M	9	18,90446	142,6301	47,24121	6,653074	50,15476	56,22166
B	10	2,390899	79,65132	-12,1	10,27002	22,87251	45,85853
E	11	21,07149	153,9195	25,37501	7,411147	49,15964	83,95961
L	12	4,68839	15,16973	51,12516	15,63375	42,23213	69,15021
	13	22,89777	93,59854	45,35082	20,12718	90,86309	-16,9565
	14	5,402638	91,22147	-29,74	5,736802	269	-41,7496
	15	2,689349	160,421	40,03671	15,65445	145,618	-14,4639
	16	16,67382	13,037	64,82486	6,0748	44,17447	36,10875

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The cleaning carried out at 350°C in the Perimbel section shows that the initial magnetization is multicomponent. After 350°C, a more stable direction begins to form. It is evident that the rocks partially retain the magnetization of the initial sedimentary origin.

These results indicate that paleomagnetic data in the Oligocene–Lower Miocene sediments of the Perimbel section can be reliable. Thus, despite the detailed analysis of the cleaning that continues up to the 350–700°C interval, the best cleaning is the 350°C temperature cleaning [10].

As a result of the stepwise temperature cleaning carried out up to 350°C, we observe a decrease in the intensity of residual magnetization and a relative stabilization of the declination indicators in a number of samples.

Comparison of the results of the initial and stepwise temperature cleaning carried out up to 350°C shows that in some samples a change in direction is observed, which confirms the influence of the modern geomagnetic field. The fact that the temperature and final magnetic cleaning give corresponding results indicates that the separation of magnetic components was carried out correctly from a methodological point of view.

After the 350°C stage, we applied the spherical distribution model – Fisher statistics for the statistical processing of directions (Table 1).

The results of the Perimbel section show that the rocks did not completely lose their initial magnetization and that the samples that had lost their magnetization in the low-temperature stage were mainly eliminated. However, for the complete separation of the characteristic component and more accurate construction of magnetostratigraphic results, a thermal purification stage lasting up to 450–580°C is considered appropriate, and we have considered this temperature interval.

After the purification procedure, a concentration of Jn vectors around one direction is observed, which indicates the separation of the initial magnetic component. In terms of Fisher statistics, this is characterized by an increase in the concentration parameter (K) and a decrease in the reliability cone (a95) [3, 9,17].

The analysis of magnetostratigraphic results shows that the magnetization zone identified in the Perimbel and adjacent sections covers several magnetization intervals in the Oligocene–Lower Miocene interval. Comparison of these changes with GPTS allows for a more precise determination of the chronostratigraphic position of the sediments and acts as an important age indicator in cases where biostratigraphic data are limited.

The presence of stable inversion components recorded in the Lower Maykop levels can be correlated with magnetic chronologies corresponding to the middle–upper Oligocene. The increase in normal magnetization zones in the upper levels may reflect the transition to the Lower Miocene stage. Such a magnetostratigraphic sequence provides a reliable basis for assessing the regional tectonic development and subsidence rate of the Talysh zone.

The obtained paleomagnetic directions were analyzed after structural correction, and the results can be used to assess regional tectonic movements.

Thus, the analysis of lithofacies, mineralogical and paleomagnetic data allows for a comprehensive reconstruction of the age, sedimentation rate and tectonic development stages of the Oligocene-Lower Miocene sediments of the Perimbel and surrounding section. Magnetostratigraphy acts as an independent and high-resolution chronological tool that complements biostratigraphic and lithostratigraphic data in the region.

The results obtained show that there are alternating zones of direct and reverse magnetization in the studied horizon. These zones are represented by paleomagnetically stable rocks, and their sequence reflects the exposure of the Earth's magnetic field to pole reversals during the Paleogene period.

Thus, petromagnetic studies conducted in the Talysh zone show that it is possible to isolate a stable component in Paleogene rocks and a regional magnetostratigraphic scale can be constructed based on the zonal distribution of these components.

Table 2

General paleomagnetic and paleotectonic results

	N	φ	λ	x	y	z	D	I	R	k	a_{95}	Φ	Λ	$Θ_1$	$Θ_2$
Perimbel	11	38,54	48,07	-2,45	-1,8	9,7	72	54,7	10,18	13	14	34	297	19	14
Perimbel	11	38,54	48,07	3,88	-5,8	-3,8	188	-27,6	7,93	4	30	-65	247	32	18
Perimbel	16	38,54	48,07	0,11	-3,18	4,20	112	25,11	5,27	1	54	-8	294	58	31

The statistical results of the paleomagnetic studies conducted on the Perimbel section are summarized in the table. The parameter N shown in the table indicates the number of samples involved in the study. The table also shows the modern geographical coordinates – ϕ (latitude) and λ (longitude), which characterize the location of the section (38.54° N latitude and 48.07° E longitude). Based on the results of the measurements conducted on the section, two different polarization groups and their general statistical indicators were identified.

As a result of the paleomagnetic analyses conducted on 11 samples taken from the section, the average values of the inclination and tilt angles obtained for each sample are D = 72° and I = 54.7°. Here, the Fisher concentration parameter K = 13, and the confidence angle α_{95} = 14°, which indicates that the results have relatively satisfactory statistical reliability. The coordinates of the geomagnetic pole are calculated as Φ = 34° and Λ = 297°, respectively.

The results of the other samples 12-16 show a different magnetization direction. Here, the average declination is characterized by the values of D = 188° and inclination I = –27.6°, which indicates the presence of a reverse polarization component. For this direction, the Fisher concentration parameter K = 4, and the confidence angle is α_{95} = 30°. The coordinates of the geomagnetic pole are determined as Φ = –65° and Λ = 247°.

All samples are characterized by the average values of D = 112° and I = 25.11° obtained as a result of the laboratory processing. For these results, the concentration parameter K = 1, and the confidence cone angle is α_{95} = 54°, which indicates that the directions are sufficiently dispersed. The coordinates of the geomagnetic pole are calculated as Φ = –8° and Λ = 294° [12].

The figure we present is a complex paleomagnetic scale reflecting the changes in the parameters of magnetic susceptibility (χ), remanence intensity (Jn), declination (D) and inclination (I) along the magnetostratigraphic section. The stratigraphic age distribution is given in the left part of the scale, and it is shown that the section consists of Oligocene (Rupel and Hat beds) and Lower Miocene (Sakaraul) sediments [11, 15].

Figure 4 shows that the value of magnetic susceptibility χ changes along the section. The increase in magnetic susceptibility is usually associated with an increase in the amount of ferrimagnetic minerals (especially magnetite and hematite). Sharp increases in k along the section can be explained by the presence of volcanogenic components in the depositional environment. Although the lower part of the Oligocene has a relatively stable value, towards the Miocene the magnetic minerals in the samples have a higher index, which indicates that the dynamics in sedimentary conditions have increased [4, 5]

The declination value is usually observed to vary in the range of 30–360°. However, in samples taken from the Oligocene strata, this value varies between 170–210°, which is explained by the presence of rocks with reverse magnetization.

Both positive and negative alternating inclination values are observed along the section, which confirms the presence of normal and reverse magnetization.

The black and white intervals given in the figure characterize direct and reverse magnetization, respectively. These magnetization zones are associated with global inversion events of the Earth's magnetic field and can be correlated with the Geomagnetic Polarity Time Scale (GPTS), which is the basis of magnetostratigraphy [16, 17]. Two direct and two reverse paleomagnetic zones have been identified along the section. Based on these zones, it was possible to accurately determine the Oligocene-Miocene boundary. The constructed magnetic zones were compared with the North-Western Gobustan (Khilmili and Pirekushkul), the general scale of Azerbaijan, and the scale of Bergenner et al. (1995) [3, 13, 14].

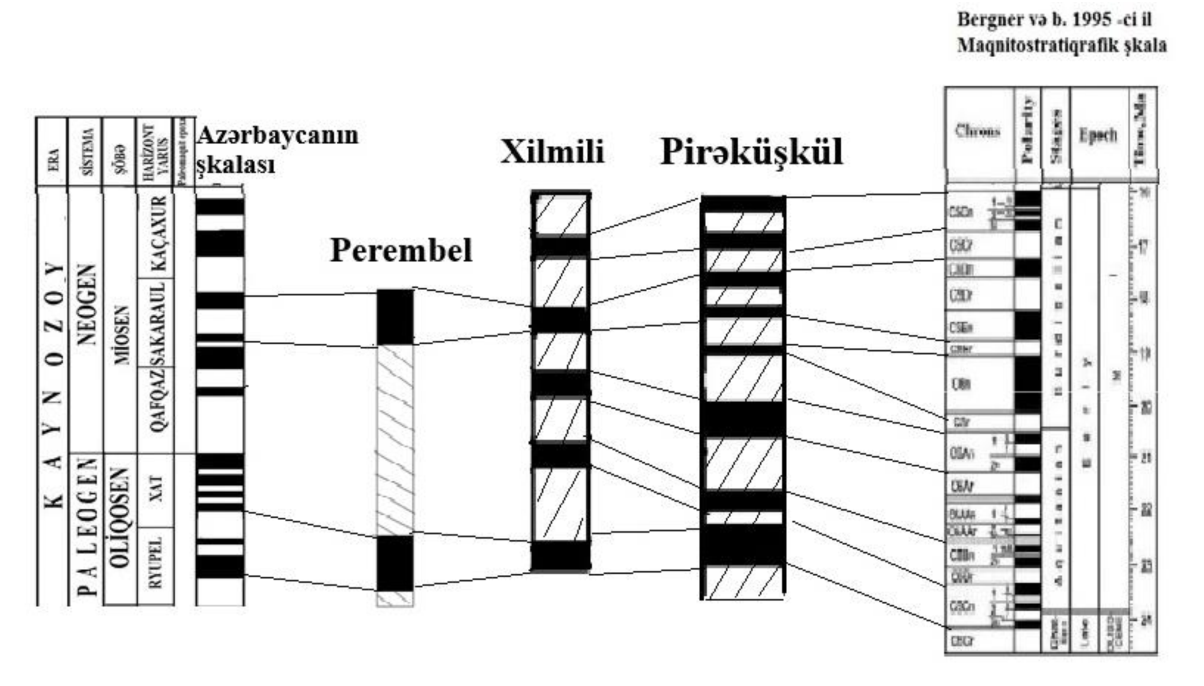

Figure 5. Correlation of samples taken from the Talysh zone, Perimbel section with scales established for rocks of the same age, with the general scale of Azerbaijan and the scale of Bergrener et al. (1995) of North-western Gobustan (Khilmili and Pirekushkul).

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CONCLUSION

The complex temperature, alternating magnetic field and time treatment confirmed the presence of both single-component and two-component magnetization structures in the Oligocene sediments of the Perimbel section.

During temperature treatment at 350°C, a significant part of the secondary magnetization components is eliminated, and a more stable magnetic component begins to separate.

Overall, the results obtained indicate that there are 2 straight and 2 reverse magnetic zones in the Perimbel section. The magnetostratigraphic interpretation of these zones and the chronostratigraphic position of the sediments were clarified.

The paleomagnetic scale established for the Perimbel section was compared with the general Azerbaijani scale and the Bergenner et al. (1995) scale.

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