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ROCK MAGNETISM OF THE PLİOCENE AND LOWER PLEİSTOCENE DEPOSİTS OF THE AJİNOHUR DEPRESSİON

Tahmina J. Garayeva[1], Adilakhanum R. Babayeva[2]

[1]Ministry of Science and Education of the Republic of Azerbaijan, Institute of Geology and Geophysics, AZ1143, H.Javid av., 119 Baku, Azerbaijan
[2]Baku State University, 33, Z. Khalilov str. AZ 1148 Baku, Azerbaijan

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Abstract

The article presents the results of paleomagnetic studies of Pliocene-Pleistocene deposits of the Ajinokhur structural zone. To obtain the paleomagnetic characteristics of these deposits, comprehensive experimental investigations were conducted, which made it possible to construct a magnetostratigraphic scale of the Pliocene–Pleistocene strata of the studied sections. To study the paleomagnetic properties of Pliocene-Pleistocene rocks, about 300 oriented samples were studied. he magnetic susceptibility and the natural remnant magnetization of the deposits vary between 3.1 x 10^{-3} - 7.6 x 10^{-3} BS and 5.9 x 10^{-3} - 36.1 x 10^{-3} A/m, respectively. The average value of the permanent component indicates that the magnetization is close to its initial value and can therefore be used to compile a paleomagnetic scale. Within the investigated area, the identification of regional magnetostratigraphic reference points in the Upper Pliocene–Pleistocene deposits has been substantiated, including the boundaries between the Productive thickness and the Akchagyl, the Akchagyl and the Absheron, and the Absheron and the Baku. The studied deposits have been subjected to age subdivision.

Keywords: paleomagnetism, Aghcagil, Absheron, natural remanent magnetization (NRM), magnetic susceptibility.

*Corresponding author.
E-mail address: *sadiqovataxmina@mail.ru* (*T. Garayeva*)
adila.babayeva@bsu.edu.az (A. Babayeva)

Introduction:

The development of paleomagnetic correlation methods for sedimentary sequences makes it possible to link characteristic flora and fauna assemblages to specific boundaries of the absolute geochronological scale. Such boundaries are represented by the transitions between intervals of normal and reversed geomagnetic polarity. This provides a reliable basis not only for interregional correlations but also for broader stratigraphic comparisons.

Comprehensive laboratory investigations of the Pliocene–Pleistocene deposits in the Ajinohur zone have made it possible to determine the direction of natural remanent magnetization — J_n, to establish the nature of the primary remanent magnetization, and to demonstrate its synchronicity with the time of formation of these rocks. The identified intervals of normal and reversed polarity can be regarded as reliable, since each is represented by more than three samples taken from different stratigraphic levels and can be traced in coeval and geographically distant sections (Khramov & Sholpo, 1967;

Belokon et al., 1973).

Geology:

The Ajinohur tectonic zone forms part of the Kura Depression, encompassing the marginal portion of the Kura trough and the frontal belt of foreland folds along the southern slope of the Greater Caucasus. The region exhibits surface occurrences of oil, gas, and mineralized waters. Within the Pliocene strata, substantial sand–siltstone units have been documented, which, under favorable geological conditions, may accommodate significant commercial hydrocarbon accumulations. More than three dozen closed anticlinal structures have been identified in the Upper Pliocene deposits of the Ajinohur zone, potentially serving as effective reservoirs for economically important oil and gas deposits.

The article presents the results of paleomagnetic studies conducted on sediment samples taken from three sections within the Ajinohur Depression — the Western Kocashen Ridge, the Kudbarekdag Ridge, and the vicinity of the village of Boyuk Dahna. All three sections consist of Upper Pliocene–Pleistocene.

The Western Kocashen Ridge section is composed of Upper Akchagyl, Absheron (upper, middle, and lower), Baku, and Mingachevir tier. The Kudbarekdag Ridge section includes the Productive thickness, as well as Lower, Middle, and Upper Akchagyl, Lower, Middle, and Upper Absheron, and Baku tiers. The Boyuk Dahna section is represented by the upper part of the Productive thickness, and by Upper, Middle, and Upper Akchagyl, as well as Lower Absheron tiers.

In the Kudbarekdag Ridge section, the rocks of the Productive thickness are represented by reddish-brown and brown loams containing subordinate interbeds of microconglomerates. In the Boyuk Dahna section, the Productive Series consists of yellowish-brown, poorly washed sandy clays with layers of coarse-grained sands and fine-pebble conglomerates. The clays are intersected by gypsum veinlets. Both the clays and the sandstones are gypsum-cemented (Shirinov & Bazhenov, 1962)(7,14).

The Akchagil Stage is traced in all three sections. The Lower Akchagil is observed in the Kudbarekdag and Böyük Dəhnə sections. The lower part of the Akchagil is represented by grey clays with rare sandstone interlayers, grey-brown banded, highly calcareous clays, sandstones, and conglomerates. It is characterized by the following fauna: *Mastra karabugasica* Andrus., *M. subcaspia* (Andrus.), *Potamides* sp., *Mastra karabugasica* Andrus., *M. subcaspia* (Andrus.), *Cardium dombra* Andrus., and others.

The Middle Akchagil is represented by grey and brown clays, grey dense laminated clays, thick grey laminated loose sandstones, dense coarse-pebble conglomerates, and limestone interbeds containing fragmented *Mactra* shells. It is characterized by the following fauna: *Cardium dombra* Andr., *C. nikitini* Andr., *Avimactra subcaspia* (Andrus.), *Mactra subcaspia* And., *M. venjukovi* And., *Classiniola utvensis* Andr., *Helix*, *Unio*, and others.

The Upper Akchagil is traced in all three studied sections. In the Western Khojashen Fold, it is represented by grey to brownish sandy clays with interbeds of loose sandstones and shell-bearing sandstones. At the top of the sequence, pebble conglomerates with interlayers of coarse-grained sandstones appear. The following characteristic fauna has been identified in this section: *Cardium dombra* (Andrus.), *C. nikitini* Andrus., *Avimactra subcaspia* (Andrus.), *Helix*, *Unio*.

In the Böyük Dəhnə section, the Upper Akchagil is composed of alternating tightly cemented fine-pebble conglomerates with ochre-yellow coarse- and medium-grained sandstones, as well as clayey sands. These deposits contain the characteristic fauna: *Cardium dombra* Andr., *Avimactra subcaspia* (Andr.), *Potamides caspius* Andrus.

In the Kudbarekdag section, the Upper Akchagil differs lithologically by a comparatively greater number and thickness of interbeds and by the appearance of sandstones. It is characterized by the following fauna: *Cardium dombra* Andr., *Potamides caspius* Andrus., *Mactra nazarlebi* K. alz., *M. ossoskovi* Andrus., *C. nikitini* Andr., *C. trimactra* Andrus., and others (Kovalevskiy, 1935).

The contact between the Akchagil and Absheron deposits is expressed differently across the region: in some places, evidence of erosion with the deposition of pebble beds can be observed, whereas in other areas the transition is entirely gradual. The lithological characteristics indicate that the floor of the Akchagil Sea was not stable. An analysis of the sections from the southern and northern zones shows that, from south to north, both the thickness of individual conglomerate layers and the size of the pebbles increase; the coastal–continental nature of the sediments suggests proximity to the shoreline.

Along the northern limb of the Khojashen Fold, the lower Absheron deposits are represented by a grey clayey unit with interbeds of thick sandstones and sands, containing a dispersed fauna throughout the sequence—*Mikromelania*, *Clessinia*, *Dreissensia*, and terrestrial forms such as *Helix*. In the Küdbarekdağ section, the deposits consist of alternating clays, sandstones, and, more rarely, conglomerates. Occasional interbeds of clayey shell-bearing rocks occur, and the sequence is characterized by the following fauna: *Anadonta strabona* Bog., *Neritina pallasi* Lindh., *Clessinia triton* Eichw., *Limnaea* sp., and others. In the Böyük Dəhnə section, the Lower Absheron is represented by a sand–pebble unit containing characteristic Absheron fauna: *Apscheronica propinqua* (Eichw.), *Dreissensia*, and *Monodacna*.(1,8,10)

The Middle and Upper Absheron have been studied in the Küdabarekdağ and Western Kocaşen sections. In these sections, this substage is represented by dense grey clays with interbeds of yellow fine-grained sands, as well as a grey-brown sandy–clayey unit. In the upper part, the fauna *Apscheronia propinqua* Eichw. occurs, while leaf impressions are found in the lower part. Throughout the unit, other previously mentioned forms such as *Mikromelania*, *Dreissinsia*, and *Corbicula* are also encountered.

The Baku Stage has been studied in the Küdabarekdağ and Western Kocaşen sections. This stage is represented by grey, structureless, dense clays with sandstones. In the upper part, individual interbeds of yellow and brownish sandy clays and pebble beds are observed. The following fauna has been found within this layer: *Didacna eulachia* Bog., *Unio*, *Corbicula*, and *Dreissinsia*.

Metods: Paleomagnetic studies are conducted on rocks of various compositions and origins, including sedimentary, effusive, and intrusive complexes, and in some cases, metamorphic complexes and ores. The choice of an object for paleomagnetic investigation is entirely determined by the specific research goal—whether it is to identify normal or reversed polarity. In addition, there are general requirements that limit the class of suitable study objects. These limitations are mainly due to the following reasons: (1) weak magnetization of rocks, which is difficult to measure accurately with modern magnetometers; (2) poor preservation of the primary magnetization, making it impossible to isolate using existing methods, or complete loss of magnetization by the rocks; (3) incompleteness of the paleomagnetic record in the studied object (Khramov & Sholpo, 1967; Khramov & Goncharov, 1982)(6,11,1212).

For reliable paleomagnetic interpretations, it is first necessary to establish the nature of the natural remanent magnetization (NRM) of the studied rocks, to demonstrate the primary origin of the isolated component I_n^0, and to identify the minerals responsible for I_n^0.

All laboratory methods aim to determine the primary magnetization I_n^0, which a rock acquires at the time of its formation. The fact that I_n^0 is stable under various laboratory treatments (e.g., over time, temperature changes, alternating magnetic fields, etc.) does not necessarily imply that I_n^0 is the original magnetization. This is the first stage of research, during which the stability of I_n^0 relative to different laboratory treatments is assessed. This stage is carried out on leading samples from the collection, typically comprising 7–10% of the total collection.

For paleomagnetic studies, the samples were taken in those places where the occurrence elements of the layers were confidently measured. Field and laboratory studies were carried out according to the method generally accepted in paleomagnetism [2,3]. The relative error in determining NRM and χ averaged 5-10%. Natural remanence (NRM) and magnetic susceptibility (χ) of the studied rocks vary within (6-15) $\times 10^{-3}$ A/m and (0.25-2.50) $\times 10^{-3}$ SI units, respectively

To isolate the magnitude and direction of NRM, all rock samples were subjected to magnetic cleaning in an alternating magnetic field, thermal cleaning, and cleaning of viscos remanent magnetization. From geological sections had taken 200 samples and then in laboratory there were subjected of cleaning by alternating magnetic field and by temperature. As a result of temperature demagnetization according to received curves the studied samples can be divided into two groups. The first group of samples loses 50% of the initial magnetization at 120-175ºC. The stable part of In is observed at 300-350^{0}C.

The second group of samples loses 60 70% of its initial magnetization before heating to 150º C. The stable part of In is observed in the range of 250º-300ºC(fig.1).

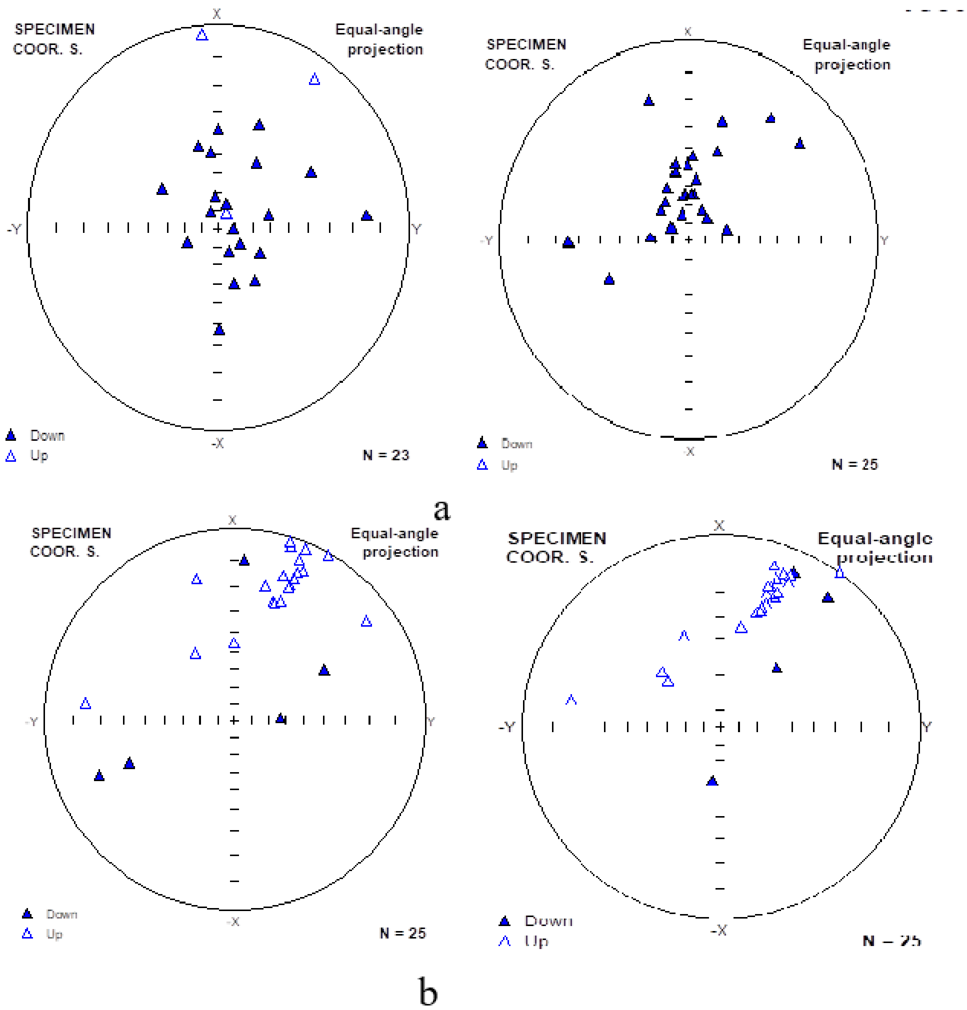


Fig.1 Characteristic curves of rock demagnetization by thermal cleaning (a - group I; b - group II) The rocks of the second group, when heated to 150^0C, lose 60-70% of the initial magnetization.

The results of the demagnetization indicate that in a significant part of the rocks, primary magnetization has been preserved. To determine natural remanent magnetization, the rock samples underwent both thermal and alternating magnetic field cleaning. All of samples are demagnetized by alternating field demagnetizer KLY5. The investigated rocks can roughly be classified into two groups. At the first group of rocks at alternating magnetic fields 400-450 mT 15% of natural remanent magnetization (NRM) are saved. The second group of curves removes half of the natural remanent magnetization under 100 mT alternating magnetic fields, whereas some amount which is less than half remains In =400 A/m fields (fig.2).

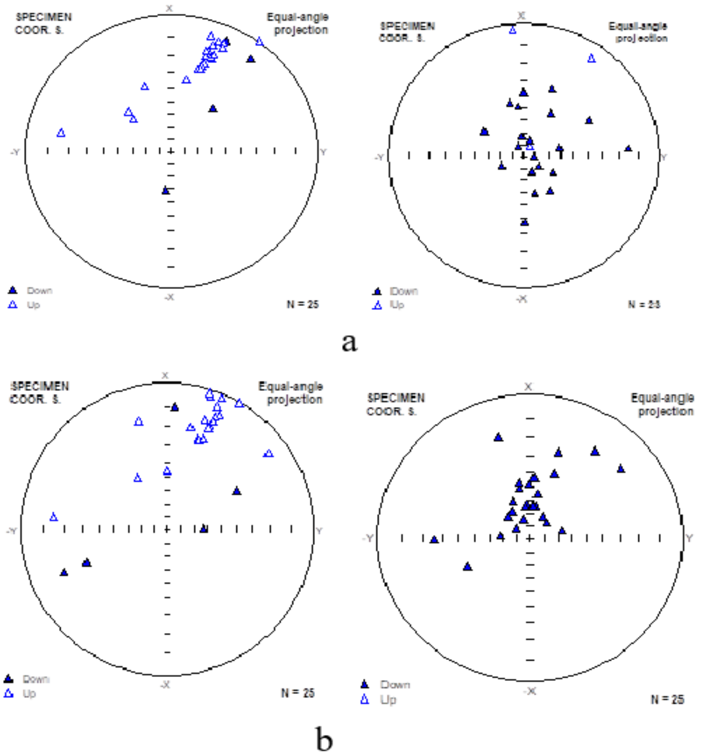


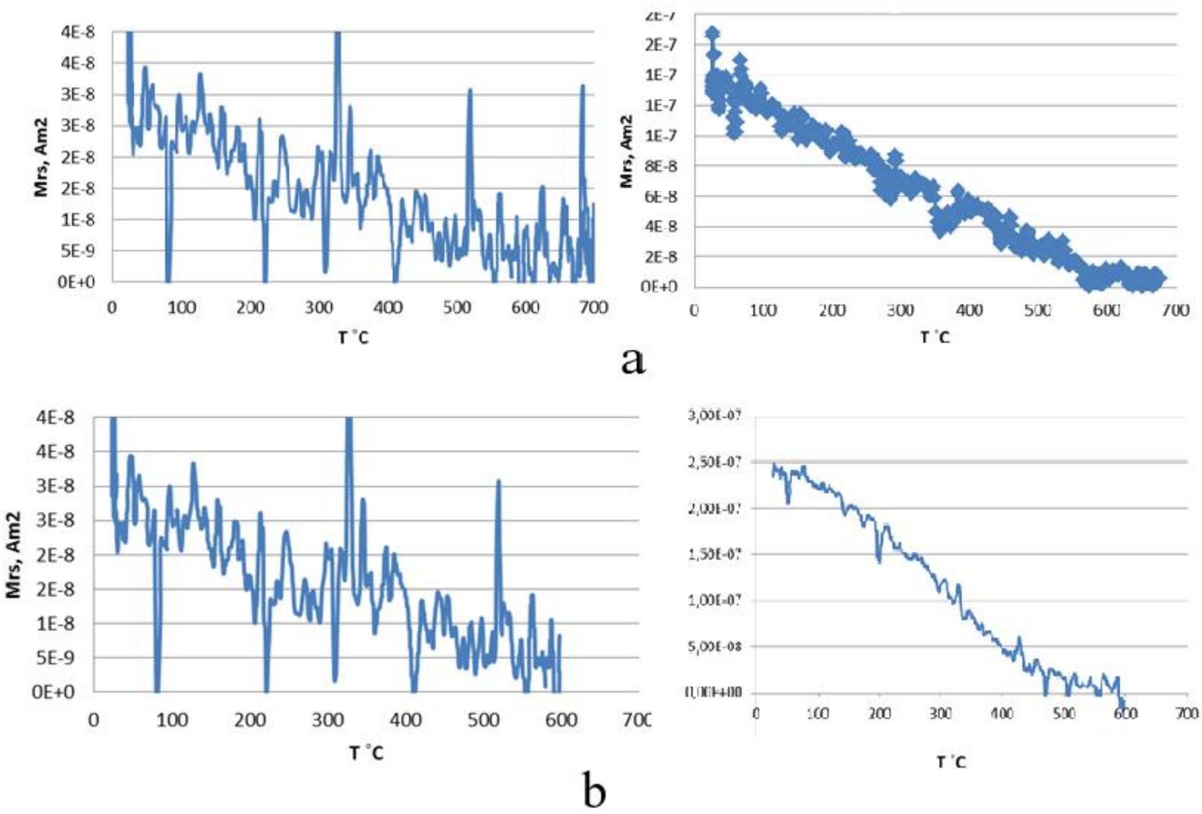
Fig2. Characteristic curves of rock demagnetization by an alternating magnetic field (a-I group, b-II group)

One of the most important characteristics of the chemical composition of ferromagnetic minerals is their Curie temperature, that is, the temperature at which the orderly arrangement of magnetic moments (spins) is destroyed and a ferromagnet becomes a paramagnet. Such a transition is not accompanied by any chemical changes or changes in the crystal structure of the substance and refers to phase transitions of the second kind. These transitions are completely reversible and are observed both when the sample is heated and when it is cooled. Thus, the Curie temperature is a stable constant for a given substance. (Khramov A.N., Goncharov G.I. et al., 1982).

Thermomagnetic studies in Pliocene-Pleistocene rock samples have established various minerals- carriers of magnetization. (33) As a result of the studies, two groups of samples were identified. As a result of the studies, two groups of samples were identified. On the thermomagnetic curves $Irs(T^0)$ for samples of the first group, the hematite phase is clearly visible ($Tc=675^0$-700^0C). An inflection was fixed on the curves of the first and second heatings in the region of 180-220^0C and 340-400^0C. The inflection of the curves in the region of 2000C shows that there are iron hydroxides, and the inflection in the region of 340-400^0C is apparently due to the presence of maghemite. During the heating process, maghemite is destroyed, releasing superparamagnetic magnetite, which causes the presence of hematite(2,3,4).

On the curves of the second group of samples, an inflection is fixed at a temperature of 160-200^0C (first heating), corresponding to the Curie point of iron hydroxides. When reheated, the samples of the second group are characterized by a smooth curve, which indicates the presence of one ferromagnet with the Curie point of magnetite Tc = 580-600^0C (Khramov A.N., Goncharov G.I., Sholpo). (Fig. 3).

Thus, taking into account the result of complex geological and mineralogical studies, we can say that they complement each other well, and the conclusions we made about the presence of certain In carrier minerals are correct.



a) *b)*

Fig.3 Characteristic curves of thermomagnetic analysis: a- first group; b - the second group (1 - the first heating, 2 - the second heating).

Paleomagnetic directions and paleomagnetic poles of the southeastern part of the **Ajinohur Depression**

Table 1

Region	*Section*	*Age*	*Region coordinates*		*NRM directions*				*Polarity*	*Paleomagnetic poles*				*Paleo latitude ϕ^o_m*
			φ	*Λ*	*D^0or*	*J^0or*	*K*	*α95*		*Φ*	*Λ*	*Θ_1*	*Θ_2*	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
AJİNOHUR DEPRESSİON	*Western Khojas- hen*	*Apshe-ron*	*41,5*	*47*	*225 50*	*-52 53*	*17 14*	*7 5*	*R N*	*43 45*	*154 142*	*9 7*	*5 4*	*39*
		Akcha-gil	*41,5*	*47*	*226 50*	*-42 49*	*17 21*	*12 15*	*R N*	*47 36*	*146 153*	*16 17*	*10 9*	*38,7*
	Kudbaregdag	*Apshe-ron*	*41,5*	*47*	*224 50*	*-51 40*	*14 22*	*8 8*	*R N*	*48 43*	*149 144*	*10 10*	*6 6*	*39*
		Akcha-gil	*41,5*	*47*	*222 54*	*-53 43*	*16 24*	*9 6*	*R N*	*45 37*	*157 144*	*10 8*	*6 4*	*39,5*
	Boyuk dajna	*Akcha-gil*	*41*	*47*	*223 49*	*-58 39*	*19 17*	*7 9*	*R N*	*47 44*	*151 146*	*9 11*	*5 6*	*38,3*

Sections of Western Khojashen Ridge and Kudbarekdag are located in the Ajinour steppe (Table 2). Values of the coordinates of the mean vector In:for the section of the West Khojashen ridge $D=50^0$; $J=53^0$; $K=14$; $\alpha95=5^0$; $\Phi= 45^0$; $\Lambda=142^0$; for the section, the Kudbarekdag ridge $D=50^0$; $J=40^0$; $K=22$; $\alpha95=8^0$; $\Phi= 43^0$; $\Lambda=144^0$ anh of the Boyuk Dahna $D=49^0$; $J=39^0$; $K=17$; $\alpha95=9^0$; $\Phi= 44^0$; $\Lambda=146^0$ (tab.1) [5]

As a result, the comprehensive magneto-mineralogical studies conducted have made it possible to identify the carriers of remanent magnetization within the rocks, determine the Curie point, evaluate demagnetization in both constant and alternating magnetic fields, and so on. The magnetic properties of the Pliocene and Pleistocene sediments were thoroughly examined, and it was revealed that the values of natural remanent magnetization and magnetic susceptibility vary over a wide range. The reason for such variation in magnetic properties is attributed to the composition and abundance of ferromagnetic minerals within these sediments [3,4] (Fig.4).

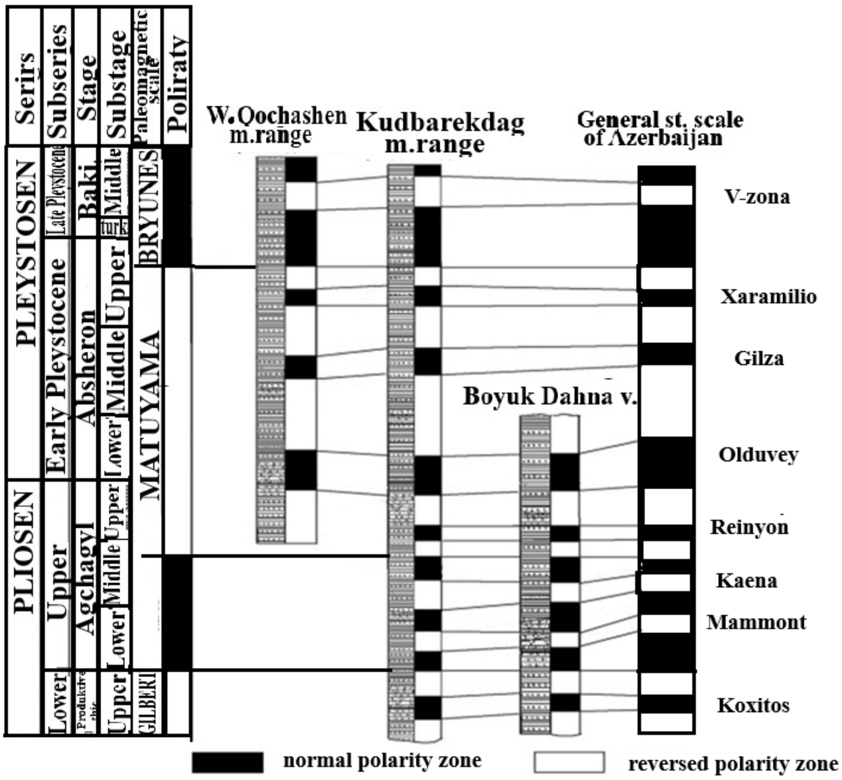


Figure 4. The magnetostratigraphic scale of the Upper Pliocene–Pleistocene deposits and its correlation with the General Stratigraphic Scale of Azerbaijan

Based on paleomagnetic data, a zone of reversed magnetization (R-zone) was identified in the Lower Baku deposits of the Gocashen and Kudaberdak (Kudbatrekdaq) ridges. The reversed-polarity zones identified within the normal Brunhes Chron can be considered essential markers for establishing a detailed stratigraphic scale of Quaternary deposits. The Absheron and the upper part of the Upper Aghcagil correspond to the reversed-polarity Matuyama magnetozone. Four normal-polarity zones were identified here. In the Upper and Middle Absheron, two zones of normal polarity were detected, while at the base of the Lower Absheron, at the boundary with the Aghcagil Formation, a normal-polarity zone corresponding to the Olduvai subchron was distinguished The Lower Absheron can be traced in all three sections. In the Upper Aghcagil, a normal-polarity zone was identified. The Aghcagil interval as a whole contains a normal-polarity zone. In the Middle and Lower Aghcagil, a normal-polarity interval corresponding to the Gauss magnetozone is present, within which two reversed-polarity zones—Kaena and Mammoth—were identified. In the Productive Series sediments, a single normal-polarity zone was detected, corresponding to the Cochiti subchron(Beggner, 1995)(5,9).

Thus, detailed paleomagnetic investigations have made it possible to subdivide the Upper Pliocene–Pleistocene sediments into intervals of normal and reversed magnetic polarity and to perform interregional correlations.

Conclusions:

A regional magnetostratigraphic scale for the Upper Pliocene–Pleistocene deposits of the southern slope of the eastern Greater Caucasus has been established. This scale includes nine reversed-polarity and nine normal-polarity zones and serves as the principal basis for the stratigraphic subdivision of the sedimentary sequences.

For the first time in the studied area of the southern slope of the eastern Greater Caucasus, the identification of regional magnetostratigraphic markers within the Upper Pliocene–Pleistocene deposits has been substantiated. These include the boundaries between the Akchagil and the Productive Series, the Akchagil and the Absheron, and the Absheron and the Baku. Age differentiation of the studied deposits, interregional correlation, and dating of the identified geological events have been carried out using paleomagnetic data

The regional magnetostratigraphic scale of the Upper Pliocene–Pleistocene deposits of Western Azerbaijan is recommended for use in large-scale geological mapping, in addressing both theoretical and applied problems of geomagnetism, and in solving practical stratigraphic tasks such as determining sedimentation rates, establishing the age of individual horizons, identifying sources of iron-bearing minerals, and others.

References:

[1] Isaeva, M.I., & Garaeva, T.D. (2008). Magnetostratigraphic studies of the Pliocene–Pleistocene deposits of the Adzhinaur section. *Catalogue of Seismopredictive Observations in Azerbaijan for 2008*, Nafta-Press, 114–119.

[2] Isaeva, M.I. (2007). Magnetometric studies of the Pleistocene and Holocene deposits of the Southern Caspian. *Proceedings of the Institute of Geology, NAS of Azerbaijan*, 104–113.

[3] Isaeva, M.I., & Garaeva, T.D. (1999). Thermomagnetic studies of Pliocene rocks of the Adzhinaur region. *Proceedings of ANAS, Earth Sciences Series*, No. 1, 96–99.

[4] Isaeva, M.I. (1990). *Paleomagnetism of Cenozoic formations in the oil- and gas-bearing regions of Azerbaijan.* Doctoral dissertation, Baku.

[5] Berggren, W.A., Kent, D.V., Swisher, C.C., & Aubry, M.-P. (1995). A revised Cenozoic geochronology and chronostratigraphy. In: *Geochronology, Time Scale and Global Stratigraphic Correlation.* SEPM Special Publication No. 54, 129–212.

[6] Belokon, V.I., Kochegura, V.V., & Sholpo, A.E. (1973). *Methods of Paleomagnetic Investigations of Rocks.* Leningrad: Nedra.

[7] Vekilov, B.G., & Fedorov, P.V. (1978). Quaternary marine deposits of Azerbaijan and their place in the Pleistocene stratigraphy of the Pont–Caspian region. *Proceedings of the Academy of Sciences of the Azerbaijan SSR*, XXVI(4), 57–60.

[8] Garaeva, T.D. (1998) Magnetic properties of rocks of the Absheron stage in the sections of the southern slope of the Greater Caucasus. *Proceedings of ANAS, Earth Sciences Series.*

[9] Zubakov, V.P., & Kochegura, V.V. (1976). Magnetochronological scale of the latest stage (5 million years). In: *Geomagnetic Studies*, No. 17, 37–44. Moscow: Nauka.

[10] Kovalevsky, S.A. (1935). *Continental Strata of Adzhinaur (Stratigraphy and Genesis).* Aznefterazvedka Trust, Baku–Moscow.

[11] Khramov, A.N., Goncharov, G.I., Komissarova, R.A., et al. (1982). *Paleomagnetology.* Leningrad: Nedra, 311 p

[12] Khalilov, A.G. (1965). *Stratigraphy of the Lower Cretaceous Deposits of the Southeastern End of the Greater Caucasus.* Baku: Nauka Publishing, 208 p.

[13] Sadygova (Garaeva), T.D. (1995). *Paleomagnetism of the Upper Pliocene–Pleistocene deposits of Western Azerbaijan.* Candidate of Sciences dissertation.

[14] Shirinov, F.A., & Bazhenov, Yu.N. (1962). *Geological Structure of the Foothills of the Southern Slope of the Greater Caucasus (Adzhinaur–Kengebiz–Gyurdzhivan Ridge).* Baku: Azerneshr.