# Magnetostratigraphy of the Pliocene deposits in Black Sea, Caspian regions and adjacent areas

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**ABSTRACT**
The results are summarized of paleomagnetic studies of the Pliocene deposits from Kerch Peninsula, western Georgia, Azerbaijan, Turkmenia, North Cis-Caspian and Lower Volga regions. Information from a number of researchers was used alongside with the author's data obtained earlier and in the course of research within the framework of the Peri-Tethys Programme. Composite paleomagnetic sections from the areas listed were correlated and related to A. Cox (Harland *et al.* 1982) magnetochronologic scale and to the paleomagnetic scheme of the Neogene deposits from the Mediterranean region. On the basis of the paleomagnetic data, the views on chronologic relationships among some local stratigraphic units were corrected; main development stages of mollusk and ostracode faunas from the Black Sea and Caspian regions were analyzed.

**KEY WORDS**
magnetostratigraphy,
magnetozone,
polarity,
paleomagnetism,
remanent magnetisation,
Para-Tethys,
Pliocene.

**RÉSUMÉ**
Les résultats proviennent d'études paléomagnétiques dans les dépôts pliocènes de la Péninsule de Kerch, de Géorgie occidentale, d'Azerbaidjan, de Turkménie, du nord de la Cis-Caspienne et de la région du cours inférieur de la Volga. Les informations provenant d'autres chercheurs sont utilisées, ainsi que des données de l'auteur au sein et antérieures au Programme Péri-Téthys. Les coupes paléomagnétiques composites provenant des régions citées sont corrélées avec l'échelle magnétochronologique (Harland *et al.* 1982) du Néogène de Méditerranée. Sur la base des données paléomagnétiques, des corrélations chronologiques entre différentes unités locales sont revues. Les principaux stades de développement des faunes d'ostracodes et de mollusques de la mer Noire et des régions de la Caspienne sont analysés.

**MOTS CLÉS**
magnétostratigraphie,
magnétozone,
polarité,
paléomagnétisme,
magnétisation rémanente,
Para-Téthys,
Pliocène.

## INTRODUCTION

The long process disintegration of the Tethys was finished at the end of the Early Pliocene with the isolation of the Pontic and Caspian basins, after which their interconnections were but short and incidental. The independent development of the post-Tethyan water bodies has affected the composition of their faunal communities. Faunal endemism makes it difficult to divide and correlate the Plio-Pleistocene Formations in the Black Sea and Caspian regions. Some local units still lack any commonly accepted schemes of detailed division, many boundaries remain rather unclear, correlations among the local units and with the Neogene beds of the Mediterranean are ambiguous.

The paleomagnetic studies that have been performed in the last forty years, have played an important part in solving the problems of the Pliocene stratigraphy of the eastern Para-Tethys. During this period some dozens of natural sections and wells in Turkmenia, Georgia, Azerbaijan and the north-western Cis-Pontic region were investigated, which has resulted in a vast paleomagnetic data array systematized on the basis of A. Cox magnetochronologic scale (Harland *et al.* 1982). The most significant results of magnetostratigraphic research are analyzed in the present paper.

The paleomagnetic research in Azerbaijan and western Turkmenia was carried out by Khramov (1963), Trubikhin (1977), Ismail-Zade (1967) and Pevzner (1973). Their data was used as the basis for the corresponding parts of the present paper. The materials from other regions were collected and analyzed under direct supervision of the author. The sections from Kerch Peninsula and the North Cis-Caspian were studied within the framework of the Peri-Tethys Programme. While summarizing the results on Kerch and West Georgia, the author's information was supplemented by the data from Molostovsky *et al.* (1982, 1983).

Of principal importance for the Pliocene magnetostratigraphy in the eastern Para-Tethys, was A. Cox magnetochronologic scale, used as the basis for elaboration of stratigraphic relations among local units and their position in the general magnetic polarity scale. The magnetostratigraphy of the Pliocene beds from the Black Sea and Caspian regions, was essentially formed on the basis of A. Cox scale, and this is reflected in the present paper.

The information on laboratory methods and for the nature of natural remanent magnetism (NRM) can be found elsewhere and are not considered here give references, the only exception being the author's materials on Georgia, Kerch Peninsula, North Cis-Caspian and Volga regions, where the works were conducted under his direct guidance (Fig. 1).

## RESEARCH METHODS

The principal attention was focused on reference sections paleontologically well characterized. They were investigated in cooperation with geologists and paleontologists. Paleomagnetic sampling was made in parallel with fossil collection which provided reliable stratigraphic reference for magnetozones. The "top-bottom" oriented cores were selected from wells at the time of their extraction from the corers.

The sample remanent magnetization was measured with ION-1 and JR spinner magnetometers. Temperature magnetic cleaning was performed in the furnaces with m-metal screens by means of successive heating up to 400-500 °C. Heating regimes were selected experimentally with leading collections of 20-25 samples. No less than two cubes were selected for thermal cleaning from every level; their position in furnace was anti the parallel. Some samples were subjected to control cleaning with alternating field within a Helmholtz coil system in the range of $16\text{-}40 \times 10^{-3}$ A/m.

To diagnose the compositions of magnetic phases, optical and X-ray structural analyses alongside with differential thermomagnetic analyses (DTMA) were used, normal magnetization curves, Jr and Jrs, were measured, destroying fields of saturation magnetizations (H'cs) were determined.

The characteristics listed above allow to judge upon Curie points (Cp), the spectra of blocking temperatures, sizes and oxidation degrees of magnetic particles and, as the result, upon chemical compositions of the principal magnetic phases. To determine the natural remanent magnetization components and their directions, the samples were heated successively (in fifty increments) up to 400-600 °C. The process of demagnetization was analyzed by means of Zijderveld diagrams.

It is practically impossible to perform the labour-consuming experiments on each sample, if large collections are being studied, with hundreds of sampling levels from many sections represented. Therefore, to study the NRM component contents and to make mineralogic analyses, 15-25 samples with various lithologic compositions were selected from normal and reverse magnetization zones in each section, which made about 20-25% of the overall amounts of the collections. The results thus obtained were extrapolated, each magnetozone being provided with magnetic-mineralogic determinations from at least 5-10 stratigraphic levels, and narrow events from at least 2-3 ones.

Three types of NRM-carriers have been revealed: **1.** Detrital magnetite constitutes the principal magnetic phase in the Pliocene deposits of western Georgia and partially of the Kerch Peninsula and the Low Volga region. It forms angular and subrounded grains of 0.01-0.1 mm size. On

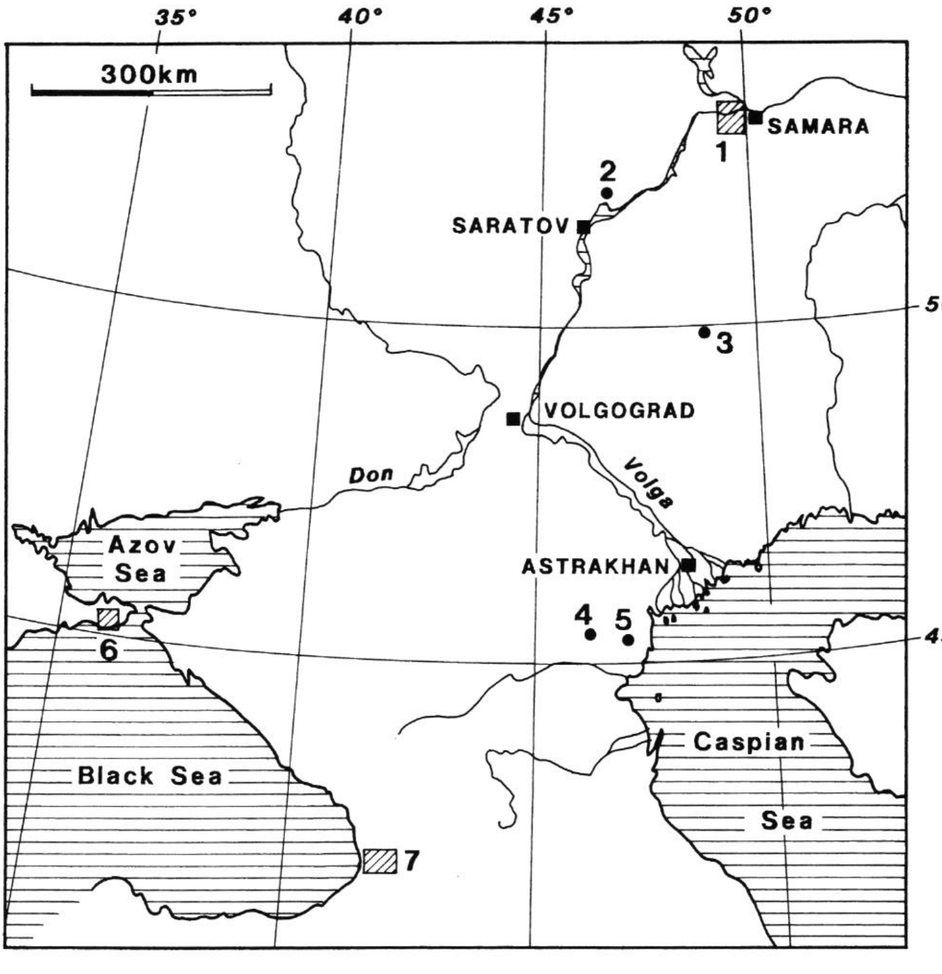



FIG. 1. — Location map showing studied sections. Sections: **1**, well 1, 5, 13, 14, 15, 18, 19 (Samara Region). **2**, well 3 (Saratov-Volga region). **3**, well 20 (Saratov-Volga region). **4**, well 13 (Kalmykia). **5**, well 48 (Kalmykia). **6**, Kerch Peninsula. **7**, West Georgia.

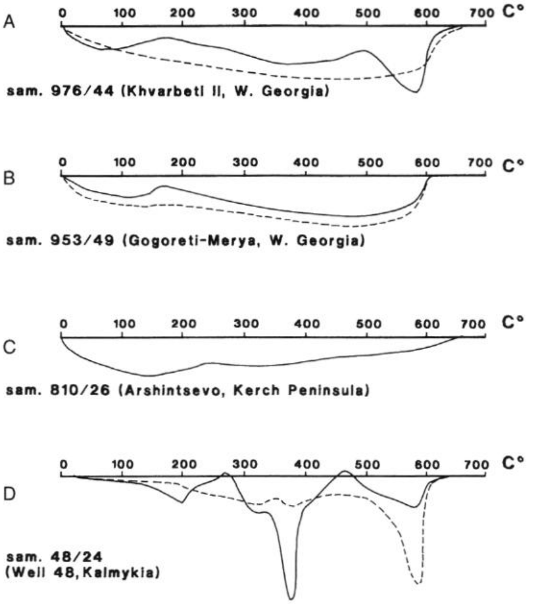



FIG. 2. — Differential curves of thermal demagnetization of Pliocene samples: **A**, **B**, magnetite samples; **C**, hydroxyde samples; **D**, authigenic greigite and pyrrhotite samples. Continuous line, first heating; pecked line, second heating.

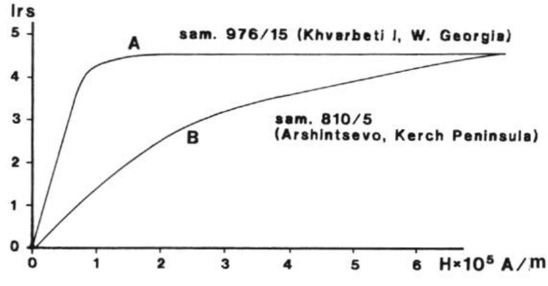



FIG. 3. — Curves of normal magnetization. **A**, magnetite samples; **B**, hematite samples.

DMTA curves it is marked with sharp Js dip at 570-580 °C. It does not display anyclear effect in Cp in finely dispersed fractions and is characterized by a wide range of blocking temperatures with the loss of Js et around 570 °C (Fig. 2A, B).

**2.** Iron ores from the Kerch region and some red clays from the Volga region possess remanent magnetization due to finely dispersed iron oxides. DMTA curves of these rocks show Js dips in the T range of 150-250 °C and at hematite Cp (Fig. 2C). Normal magnetization curves for the rocks of the first and second groups are presented in figure 3A.

**3.** Within a substantial portion of the Pliocene clays from the North Cis-Caspian and Volga regions, the chief Jn carriers are represented by authigenic iron sulfides of the FeSx type with $1.1 \leq x \leq 1.6$.

Authigenic magnetic sulfides are morphologically diverse and occur as rounded, tubular or irregular aggregates that concentrate in accumulations close to vegetable detritus, frequently in association with pyrite. Optical and X-ray analyses have proved them to be melnikovite (greigite) from the Cp of 380 and 420 °C (Fig. 2D). Magnetothermal analyses occasionally reveal hexagonal pyrrhotine among the sulfides, producing characteristic peaks in the 260-300 °C range (transition to monoclinal modification).

A series of paleomagnetic-sample thermal cleanings within the temperature range up to 500 °C was performed for the analyses of remanent magnetization component vectors. The results were used to construct Zijderveld diagrams.

Two components are characteristic of detrital NRM-carriers in the sections from western Georgia: the primary component, synchronous with sediment generation, and the secondary one, viscous, formed during subsequent geologic epochs. The metachronous secondary magnetization is completely cleared away when rock samples are heated up to 100-200 °C (Fig. 4A-D), leaving behind the true direction of the primary remanent magnetization.

Three NRM-components are characteristic of the Pliocene clays from the northern Cis-Caspian and Volga regions (Fig. 4E-H). The viscous secondary magnetization is, as a rule, cleared away when a rock sample is heated up to 100 °C. The primary magnetization, synchronous with sediment deposition is associated with authigenic sulfides and does not change its direction markedly when heated up to 200-300 °C. When a sample is heated above 300-400 °C, metachronous stable magnetization is displayed, associated with the secondary minerals magnetite and hematite which are formed within rocks as the result of primary sulfide oxidation. These components are most clearly seen in the samples from R-zones (Fig. 4E-H).

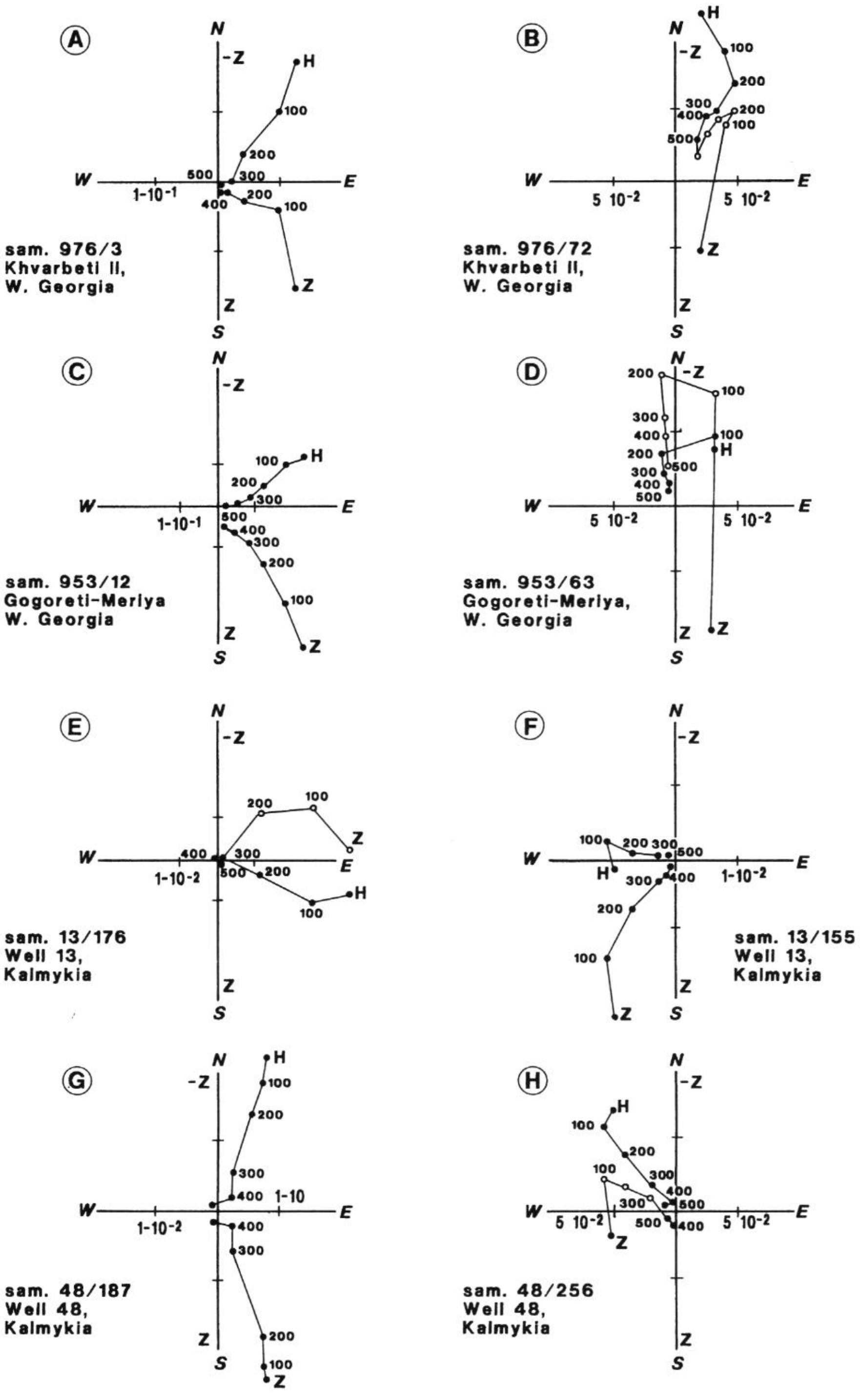



FIG. 4. — Zijderveld diagrams of thermal demagnetization of the Pliocene samples. West Georgia (**A-B**) and North Cis-Caspian region (**E-H**).

A similar process is observed in laboratories when collections are stored for long periods. Reversely magnetized samples in such cases frequently acquire stable normal magnetization. The change of magnetization polarity resulting from the influence of the secondary magnetic phases after the destruction of primary sulfides is clearly demonstrated in figure 4E, H.

The basic problem of any paleomagnetic study (providing evidence for NMR priority and geophysical nature of magnetozones) can't be ultimately solved through laboratory experiments. Some indirect tests prove to be helpful, which to a certain degree help to demonstrate the validity of conclusions on NRM primary nature.

To achieve this, beside the conventional tests (Khramov & Sholpo 1967; Khramov 1982), a number of additional features were used, applicable to the sequences with various compositions and dislocation degrees:

**1.** The closeness of Jn vector distributions was compared between rocks from various lithologic groups. In case of detrital magnetization, closeness of Jn vectors in psammite-class rocks should generally be less then in aleuro-pelites.

**2.** Jn polarity independence of lithology, facies and magnetic phase compositions was estimated. Association of various-type rocks to the zones of the same magnetization, and on the contrary, alternation of diverse-polarity zones within the monofacies sections, were regarded as indicative of the primary nature of NRM.

**3.** Geophysical nature of magnetozones is indicated by their lateral stability, consistency within certain stratogenetic series: marine, deltaic, alluvial and other facies. Testing of outer convergence with corresponding paleontologic and radiometric controls, is probably the strongest argument for confirming the primary character of NRM.

Some results of magnetostratigraphic research of the Pliocene deposite from individual regions are presented below.

## REGIONAL MAGNETOSTRATIGRAPHIC SCHEMES

### WESTERN GEORGIA (GURIA)

The author in cooperation with paleontologists Kitovani and Imnadze has examined forteen sections. The whole of the western Georgia's Pliocene is presented in clear sequence with multiple overlappings: from the base of the Pontian through the top of the Gurian Chauda. This thick complex of terrigenous sediments is rather monotonous lithologically. Blue and dark-grey massive clays and aleurites prevail over subordinate interlayers of polymictic sandstones. Stratigraphic division of the sequence is performed according to ostracode and mollusk faunas.

In the present paper it is subdivided from the bottom to the top of the section according to the schemes by Kitovani and Imnadze (Kitovany 1976).

*The Pontian stage* (180-210 m)

Characterised by a specific mollusk fauna: *Congeria digitifera* Andrussow, *Paradacna abichi* R. Hoernes, *Monodacna pseudocafilus* Barbot de Marny, etc.

*The Kimmerian regional stage*

According to the mollusk fauna, it is subdivided into a lower (Azov) horizon (8-12 m) with *Limnocardium* Andrussow *et al.* The middle and the upper horizons are not divided (30-70 m) but established from the appearance of *Dreissena polymorpha* Pallas, *D. angusta* (Roussean), *Didacna crassatellata* Deshayes, etc.

*The Kuyalnikian regional stage*

Represented by layers with mixed Kimmerian-Kuyalnikian malacofauna and typically Kuyalnikian bedding with *Didacna medea* Daviaschvili, *Submodacna pleonexia* Daviaschvili, *Monodacna postdonacoides* Daviaschvili, etc. The overall thickness of the Kuyalnikian thus defined constitutes 15-20 m.

*The Gurian horizon* (80-90 m)

Begins with beds containing *Dreissena* ex gr. *rostriformis* Deshayes. The main part of the section is characterized by *Digressodacna minor* Kitovani, *D. digressa* (Livental), *D. longipes* Kitovani, etc.

*The Nagobilevsky (Chauda) horizon* (50-90 m)

Is at the top of the Pliocene section in western Georgia and may be lowermost Pleistocene in part. The Gurian Chauda is characterized by rich and diverse malacofauna: *Digressodacna gracilior* Daviaschvili, *Tshaudanissa* Kitovani, *T. guriana* Livental, *Didacna pseudocrassa tipica* Livental, etc.

*The Pleistocene*

A 90 m thick sequence of sands with subordinate clay interlayers exposed in two sections studied containing ostracodes that are characteristic of ancient euxinic beds: *Caspiola gracilis bacuana* (Lubimova), *C. acronasuta* (Livental), *Leptocythere bicornis* Aslanova, etc.

*Comparison*

The Pliocene deposits from western Georgia are characterized by high magnetism with regular distribution of Jn and æ values over the stratigraphic section. The lower part of the Pontian is relatively low magnetic (Jn = 3-17 × $10^{-3}$ A/m, æ = 10-50 × $10^{-5}$ SI units). In the Upper Pontian and Kimmerian beds, these parameters are 20-40 × $10^{-3}$ A/m, æ = 100-280 × $10^{-5}$ SI units. The Upper Pliocene part of the section, rock magnetism reaches the maximum values: Jn = 40-150 × $10^{-3}$ A/m, æ = 300-1400 × $10^{-5}$ SI units.

Optical methods and DTMA have revealed detrital magnetite grains of 0.1-0.005 mm size in all lithologic rock varieties. It may be present as even smaller, dust-like particles. No other probable NRM-carriers were detected in rocks.

Detrital origin of the optically diagnosed magnetite is established from angular grain outlines, water-transportation marks in the form of scratches and scores, aggregations with silicate minerals. There is the dependence of magnetic fraction distribution on the rock textural features: accumulation within oblique sandstone interlayers, due to natural rewashing of sediments, increased concentrations in basal layers, accumulations of dust magnetite particles on lamination planes.

The share of metachronous viscous magnetization reaches 60-70% of the sum Jn, but in most samples it is reduced upon heating up to 200 °C. No peculiarities were observed in the behaviour of NRM vectors relative to rock lithologic or facies compositions. Just a wider dispersion in Jn directions is observed in sandstones compared to aleurolites and clays. At the same time, regular distribution of normal and reverse magnetization intervals is observed along the time scale, as well as their recurrence in the sections, reliably referenced according to fauna.

Paleomagnetic zonality peculiarities in the Pliocene and Quaternary deposits from some reference sections are presented in figures 5, 6, paleomagnetic correlation of the sections in figure 7.

Comparisons of the individual columns make it possible to distinguish four magnetozones, complicated with narrow opposite-polarity subzones, within the recent deposits from western Georgia. The first from below Rn zone includes the whole of the Pontian plus the Lower and the Middle Kimmerian. In the uppermost part of the Pontian and in the Lower Kimmerian from Khvarbeti II, Makharadze and Gogoreti-Meriya sections, four n-subzones are traced, each one from 3-6 m thick. The middle Kimmerian deposits are reversely magnetized everywhere. On the whole, the structure of the lower Rn interval, as well as the stratigraphic range occupied, make it possible to refer the interval to the Gilbert Zone in the general magnetochronologic scale.

The lower Kuyalnikian and upper Kimmerian parts of the section, reduced due to ancient erosion, are relatively less well known. The upper Kimmerian in the Khvarbeti II outcrop is composed of normally magnetized beds with the apparent thickness of about 5 m. The lower Kuyalnikian horizon also reveals normal polarity Jn within outcrops along the Skurdubi and Tsina-Gele rivers and in some other localities where the apparent thicknesses at outcrop constitute 6-8 m (Fig. 7).

Zubakov (1990) established the stratigraphic range of this N-zone within parallel sections with the upper Kimmerian and the lower Kuyalnikian and identified it with Gauss Zone.

Stratigraphically higher, there is a large reverse polarity interval embracing the Nagobilevsky (Chauda), Gurian and the upper half of the Kuyalnikian and unambiguousaly identified with the Matuyama Zone. Four successive N-subzones were recognized and traced along the strike within this zone: from the middle of the Chauda

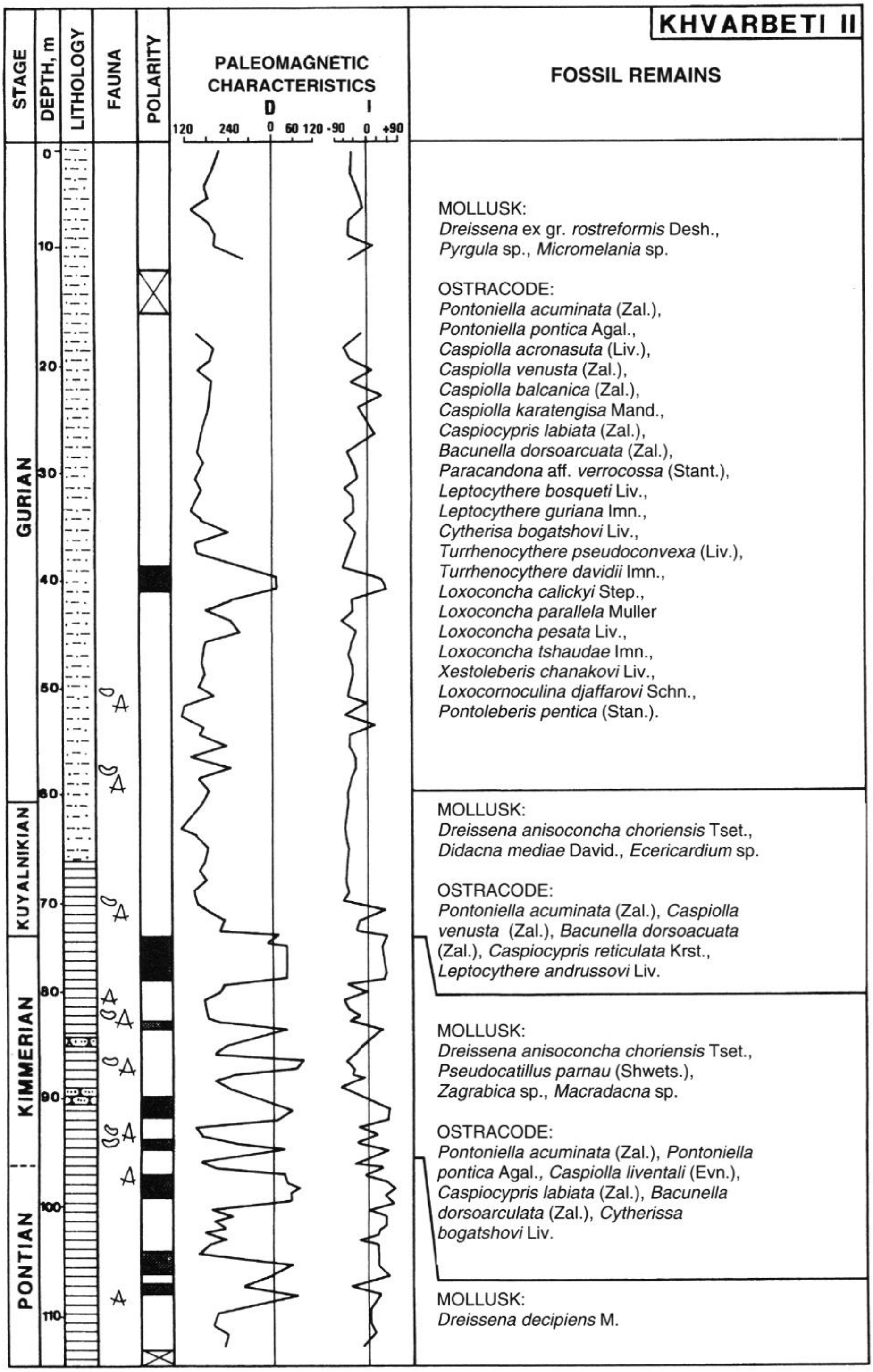
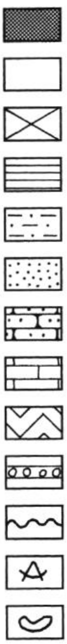



FIG. 5. — Paleomagnetic section of the Pliocene deposits of western Georgia.

in the top of the Gurian, at the Gurian-Kuyalnikian boundary, in the upper part of the Kuyalnikian (Fig. 7).
The first, third and fourth subzones are most logically interpreted as being analogous to the Jaramillo, Olduway and Reunion episodes. The second subzone, from the uppermost Gurian with the Kwemo-Natanebi episode, has also been recognized by Zubakov & Kochegura (1976) at the same stratigraphic level in western Georgia. The age of the later according to thermoluminescent analysis is 1.1-1.2 Ma; chronologically similar N-subzones have been found within basaltic covers of Madeira Island and in California (Mancinen *et al.* 1978).
The upper zone of normal magnetization corresponds to the ancient euxinic beds and from its stratigraphic position may be identified with the middle part of the Brunhes Zone. It is complicated with a reverse-sign subzone, most possibly analogous to the Lower Khazarian (Dnieper) episode with the absolute thermoluminescent dating of 0.35 Ma (Zubakov 1990).

LEGEND FOR FIGS 5-8, 11

| | |
|---|---|
| Jn | Natural remanent magnetization |
| æ | Magnetic susceptibility |
| N, n | Normal polarity Jn |
| R, r | Reverse polarity Jn |




THE NORTH-WESTERN CIS-PONTIC REGION

The recent deposits from Taman, Kerch Peninsula and northern Cis-Azov region were paleomagnetically studied by Tretyak & Volok (1976), Semenenko & Pevzner (1979), Molostovsky *et al.* (1984) and Zubakov (1990). Individual portions of the section are presented here from natural outcrops. A continuous succession was studied by Semenenko & Pevzner (1979) from the well cores. Up to now, practically the whole of the Pliocene sequence from the base of the Pontian stage through the overlaying Pleistocene loams has been characterized paleomagnetically (Eberzin 1940).

*The Pontian stage*

With the characteristic malacofauna of *Paradacna*, *Valenciennius* and *Congeria*, it is represented by 20-120 m thick monotonous grey clays.

*The Kimmerian stage*

The Kimmerian stage, as distinct from the Pontian, is lithologically well differentiated. Its lower (Azov) horizon, when present, is distinguished by its variable composition. This consists of clays, iron sands and poor iron ores in Taman; in the Chegercha syncline in Kerch Peninsula, it is recognised within a clayey monofacial section by the substitution of the Pontian *Paradacna abichi* R. Hoernes by the Kimmerian *Paradacna deformis*, *Dreissena rostriformis* Deshayes, etc.
The middle (Kamyshburun) horizon is built of massive iron ores containing abundant *Dreissena*, *Paradacna*, *Monodacna*, etc.
The top (Pantikapei) horizon is composed of grey and olive clays with thin interlayers of poor iron ores.
The thickness of the Kimmerian does not exceed 20 m within the zones of shallow-water sedimentation and increases up to 220 m in the axial parts of the synclinal basins.

*The Kuyalnikian stage*

The Kuyalnikian stage in the eastern part of the Kerch Peninsula lies unconformably upon

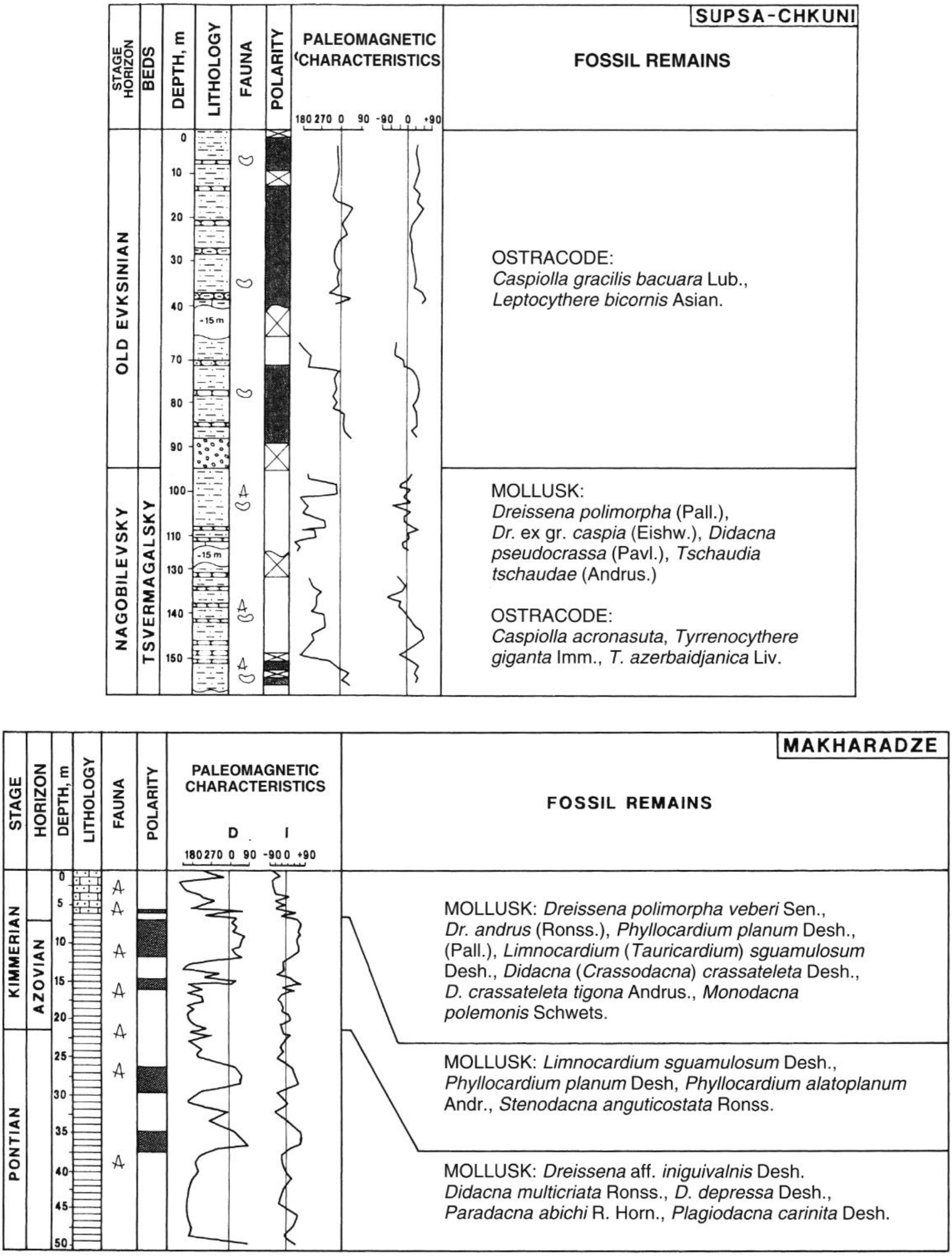



FIG. 6. — Paleomagnetic section of the Pliocene and lower Pleistocene deposits of western Georgia. Legend: see figure 5.

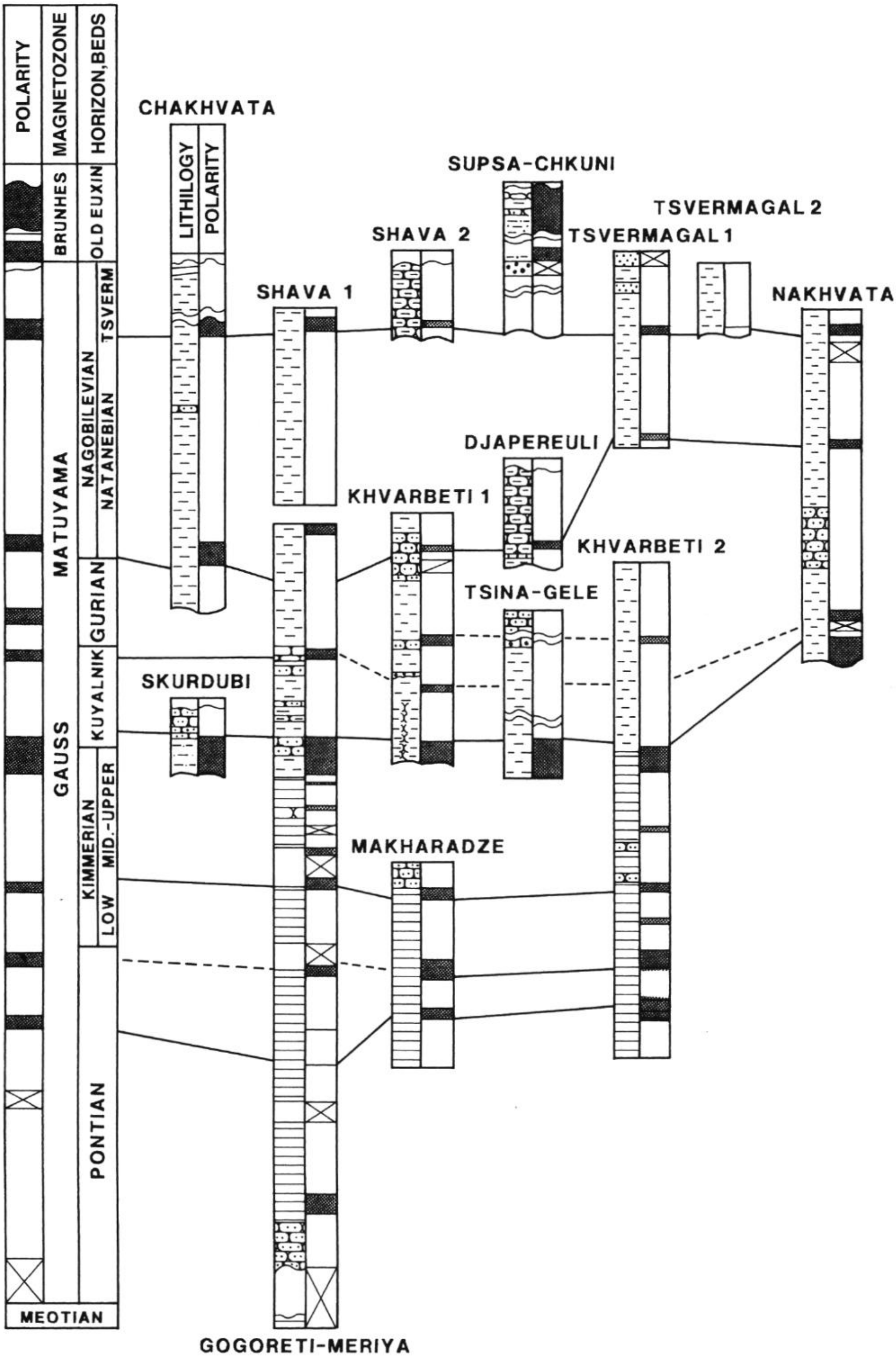



FIG. 7. — Paleomagnetic section and correlation of the Pliocene deposits of western Georgia. Legend: see Fig. 5.

various Kimmerian horizons. It is represented by a 12-16 m thick unit of bluish-grey clays and sands. The thickness of the Kuyalnikian beds is as high as 80 m in the Chegercha synclinal fold. The *Dreissena* (and *Lymnocardium*) containing bearing layers belong to the lower Kuyalnikian here, and the overlying Taman layers with *Avimactra subcaspia* Andrussow and *Cardium dombra* Andrussow to the upper Kuyalnikian (Nevesskaya *et al.* 1986).
Continental analogues of the marine Kuyalnikian are common in the Cis-Azov region, with the well-studied sequences of small mammal from the lower (Kuyalnikian) and the upper (Odessian) parts.

The Kuyalnikian sequence is succeeded by the Tyup-Djankoi beds; the Pliocene section is crowned with a clay member attributed to the "Gurian" layers. The Tamanian beds may serve as a good correlation reference; they overlie older deposits and are recognized by the Actchagylian-type mollusks.

*Comparison*
The Pliocene deposits from Kerch Peninsula and the adjacent areas are generally low magnetic: Jn = 0.3-0.8 × $10^{-3}$ A/m, æ = 10-15 × $10^{-5}$ SI units. In the iron ores Jn reaches 1-2 × 10 × $10^{-3}$ A/m, æ = 20-55 × $10^{-5}$ SI units.
The magnetic properties of the bulk of the rocks are determined by fine clastic magnetite. In iron ore layers, NRM is mainly carried by authigenic FeO.OH and $Fe_2O_3$ developed over siderite and chlorite.
Substantial metachronous magnetization, coinci-

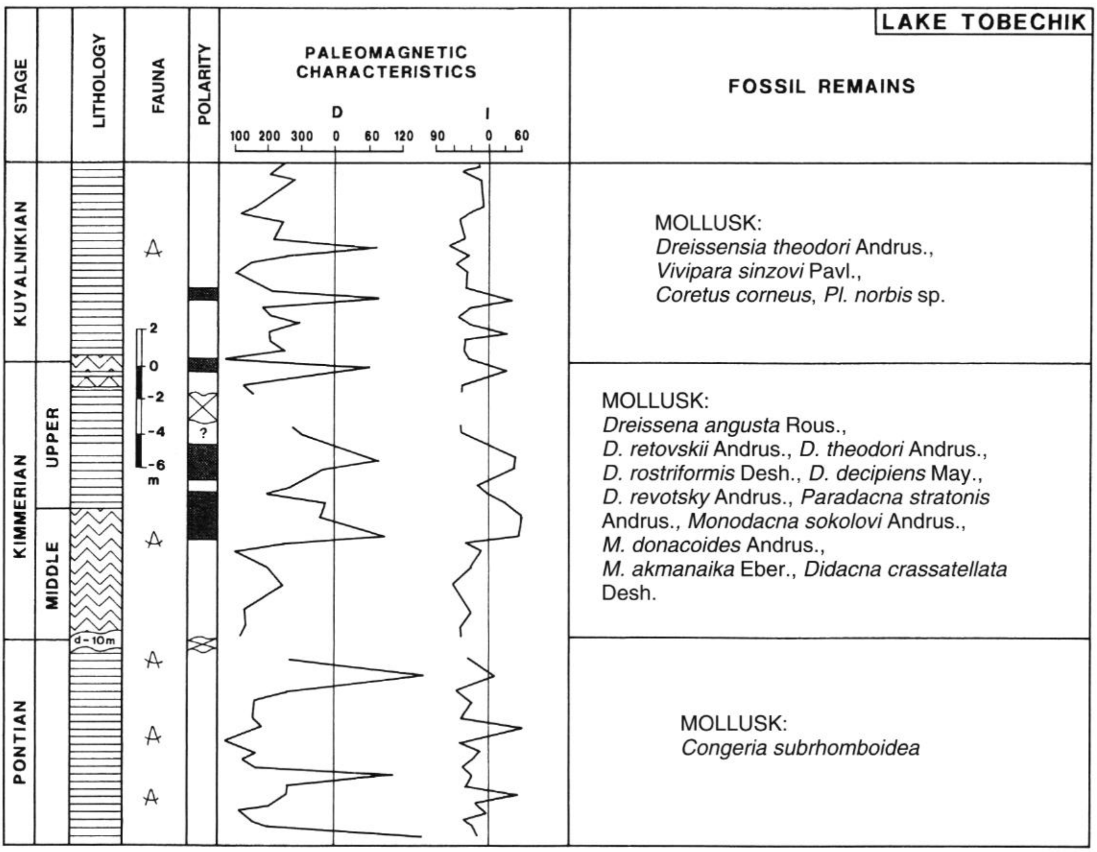



FIG. 8. — Paleomagnetic section of the Pliocene deposits in Kerch Peninsula. Legend: see figure. 5.

ding with the recent field, is present practically in all the rocks. Its main part is destroyed in the 200-300 °C temperature. Jn components allow to judge on the section magnetic zonalities quite confidently. It is necessary to note that the distribution of the normal and reverse magnetisation intervals doesn't depend on lithology, facies or composition of magnetic minerals. It is seen from figure 8, that the layers with detrital magnetite from various parts of the section are characterized by NRM of various polarities. At the same time, within the middle Kimmerian, the ore horizons with chemical remanent magnetization reveal the same Jn polarity as the hosting clays with allothigenic magnetite.

Paleomagnetic columns for the principal sections

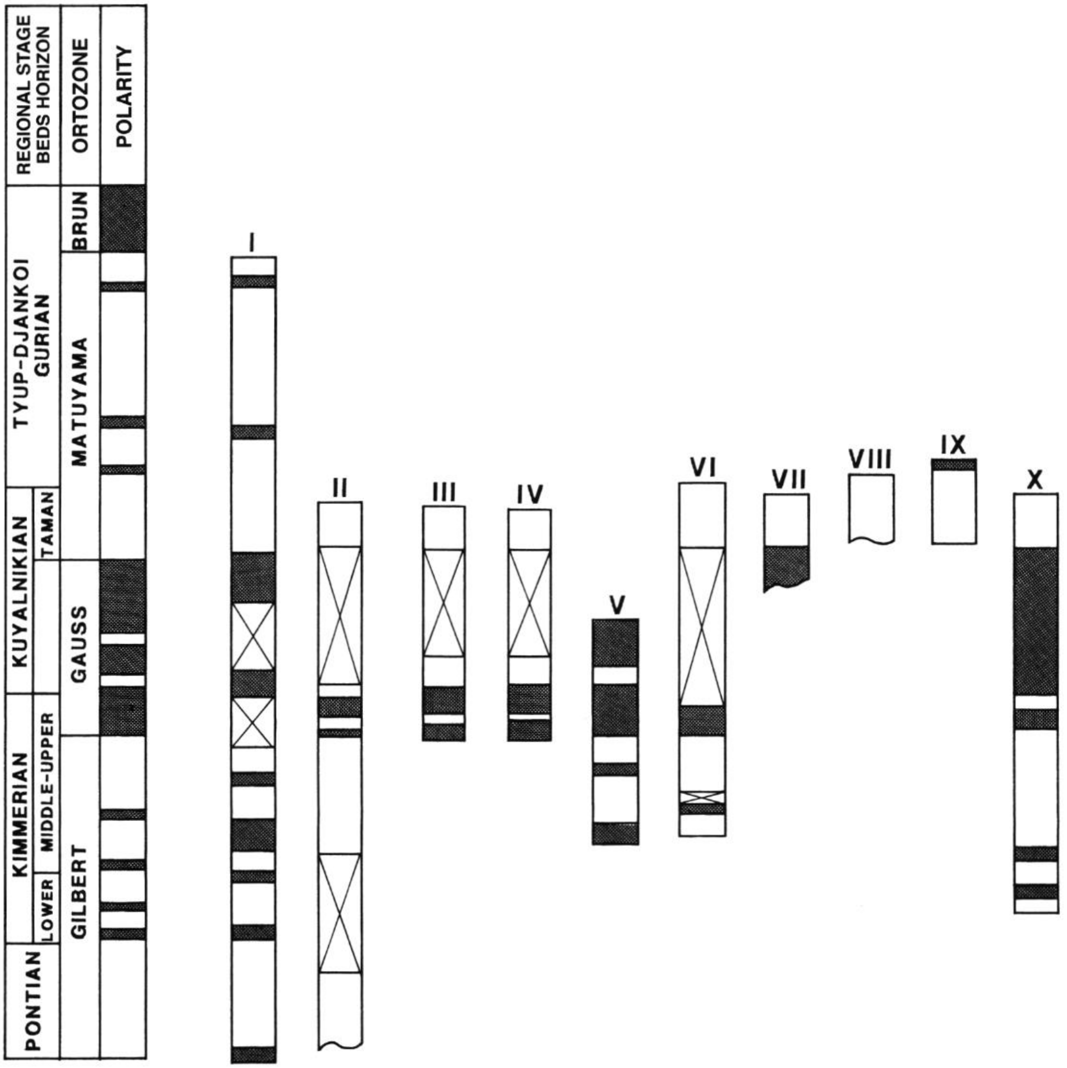



FIG. 9. — Paleomagnetic section and correlation of the Pliocene deposits of north-western Cis-Pontic region. **I**, Chegercha synclinal fold (Semenenko & Pevzner 1979); **II**, Tobechnik; **III**, Arshintsevo (II, III: Molostovsky 1986); **IV**, Arshintsevo; **V**, Lubimovka (Sevastopol); **VI**, Krasny Kut; **VII**, Babach-Tarama; **VIII**, Kryjanovka; **IX**, Liventsovka (IV-IX: Treyak & Volok 1976); **X**, Taman Peninsula (Zubakov & Kochegura 1976).

from the Crimea and Taman are shown in figure 9. Their comparison demonstrates a similar sequence in magnetic polarity changes along the stratigraphic scale.

The Pontian stage is everywhere characterized by reverse magnetization. The main part of the Kimmerian section is composed of the rocks with dominating reverse polarity Jn; four normal polarity subzones are distinguished there (Semenenko & Pevzner 1979). Higher in the section, a normal magnetization interval is recorded, embracing the most of the upper Kimmerian and the lower Kuyalnikian. In the upper Kimmerian part of the section, two reverse polarity subzones are documented in the Lake Tobechik section. The upper Kuyalnikian (Taman layers) is everywhere composed of reverse polarity Jn rocks.

The similar paleomagnetic column structure is characteristic of the continental analogues of the Kuyalnikian regional stage. The lower horizon with the Kuyalnikian microtheriofauna there is characterized by normal magnetization, the upper one, characterized by the Odessa small mammal complex, is reversely magnetized (Tretyak & Volok 1976).

The reverse-polarity interval passes on from the Tamanian layers to the Tyup-Djankoian and Gurian beds and terminates in the lowermost of the covering loam sequence, the major portion of which forms a part of Brunhes magnetozone.

The order revealed in the Pliocene magnetozone stratigraphy (R, N, R), combined with reasonable reliable paleontologic control, allows correlation of the magnetozones with Gilbert, Gauss and Matuyama zones. Their stratigraphic equivalents are:

**1.** For Matuyama Zone the upper Kuyalnikian, Tyup-Djankoian and Gurian beds.

**2.** For Gauss Zone the upper horizon of the Kimmerian and the lower Kuyalnikian; r-subzones of the Pantikapei horizon probably correlate with the Kaena and Mammoth episodes.

**3.** Gilbert Zone may involve the bulk of the Kimmerian and the Pontian stage as it is seen in the north-western Cis-Pontic region. N-subzones of the Kimmerian part of the section may be as a group identified with Gilbert-zone episodes.

### The northern Cis-Caspian and Low Volga region

The Pliocene deposits from this vast region are poorly studied paleomagnetically, and at present the data on just eight reference wells are available. The principal Upper Pliocene units from the Caspian region have been recognized there according to ostracode and mollusk faunas. The sections were paleomagnetically studied by Eryomin under the guidance of Molostovsky; mollusks were defined by Fedkovich and ostracodes by Karmishina. The principal stratigraphic and paleomagnetic data on the sequence are given below (Kolesnikov 1940; Nevesskaya *et al.* 1986; Muratov & Nevesskaya 1986).

#### *The Actchagylian regional stage*

Is subdivided into three substages according to the existing stratigraphic scheme, but the lower Actchagylian deposits in the Volga region are sporadic. In the sections studied, they have been registered only in well N3, where a 17 m thick clay member containing *Dreissena polymorpha* Pallas, *Pisidium amnicum* Muller, *Planorbis planorbis* Linne, was assigned to the lower substage.

The middle substage, built of clays and aleurolites is common; it overlies various formation unconformably right down to the Upper Cretaceous and is characterized by rich and diverse mollusk complex: *Cerastoderma vodgti* (Andrussow), *C. konschini* (Andrussow), *C. pseudoedule* (Andrussow), *Avicardium nikitini* (Andrussow), *Avimactra venjukovi* (Andrussow), *Av. subcaspia* (Andrussow) and by ostracodes: *Loxoconcha varia* Suzina, *Candona convexa* Livental, *C. combio* Livental, *Leptocythere gubkini* (Livental), etc. The middle Actchagylian is 14-125 m thick.

The upper Actchagylian substage conformably overlies the middle one and is represented by 20-70 m thick interbedded aleurites and sands. Small Dreissena, *Avimactra subcaspia* (Andrussow), *Cerastoderma dombra* (Andrussow) are known as well as ostracodes: *Paracyprideis naphatatscholana* (Livental), *Cyprideistorosa* (Jones), etc.

#### *The Apsheronian regional stage*

Division of this into three parts is commonly accepted. The lower substage is restricted to the south of the territory (wells N1, 123), where it conformably overlies the Actchagylian deposits and is separated from the later ones by a monotonous, poorly fossiliferous series containing mainly representatives of *Dreissena* genus: *D. distincta* Andrussow, *D. polymorpha* (Pallas), *D. eichwaldi* Andrussow, etc.

The lower Apsheronian are lithologically represented by grey aleuritic clays 14-18 m thick in the wells investigated.

The middle Apsheronian over most of the region transgressively overlies the eroded surface of the Actchagylian structures. It is composed of grey calcareous-clays, aleurites and sands containing rich mollusk assemblages: *Parapscheronia raricostata* (Sjogeren), *P. eurodesma* (Andrussow), *Monodacna minor* Andrussow, etc; its thickness ranges from 60 to 330 m.

The upper Apsheronian is lithologically similar to the middle Apsheronian and there is a gradual transition between them. This interval of the section is characterized by sharp depletion of malacofauna dominated by small *Dreissena*. Rare remains of *Monodacna*, smooth *Apscheronia*, *Pseudocatillus* occur. The upper Apsheronian deposits are 20-40 m thick.

*Comparison*

In many sections, the rhythmic character of sedimentation is well pronounced. Each rhythm includes a sandy (regressive) and a clayey (transgressive) member, with a sum thickness of 30-50 m. Among the authigenic minerals, siderite and iron hydroxides are characteristic of regressive facies, while magnetic iron sulfides and pyrite are characteristic of transgressive ones. Fine clastic (0.05-0.001 mm) magnetite in various amounts is present in all the facies.

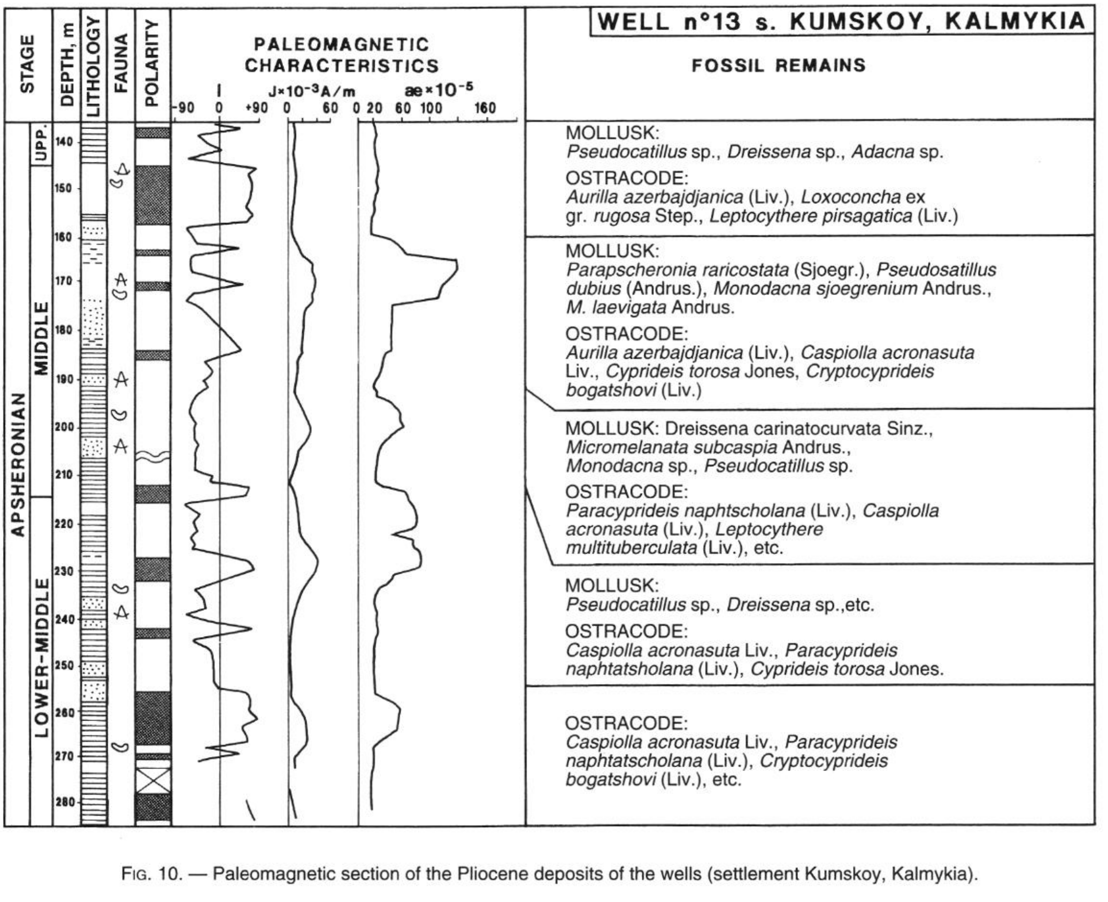



FIG. 10. — Paleomagnetic section of the Pliocene deposits of the wells (settlement Kumskoy, Kalmykia).

Transgressive and regressive sedimentation stages are recorded by sharp variations of scalar magnetic characteristics. In transgressive clay facies, the values of Jn = 20-150 × $10^{-3}$ A/m, æ = 80-500 × $10^{-5}$ SI units. In regressive sand facies Jn = 0.5 × $10^{-3}$ A/m, æ = 10-30 × $10^{-5}$ SI units. The magnetic-mineralogic analyses have revealed authigenic iron sulfides of the pyrrhotine-greigite (melnikovite) group to be the main NRM-carriers in the transgressive parts of the rhythms. In

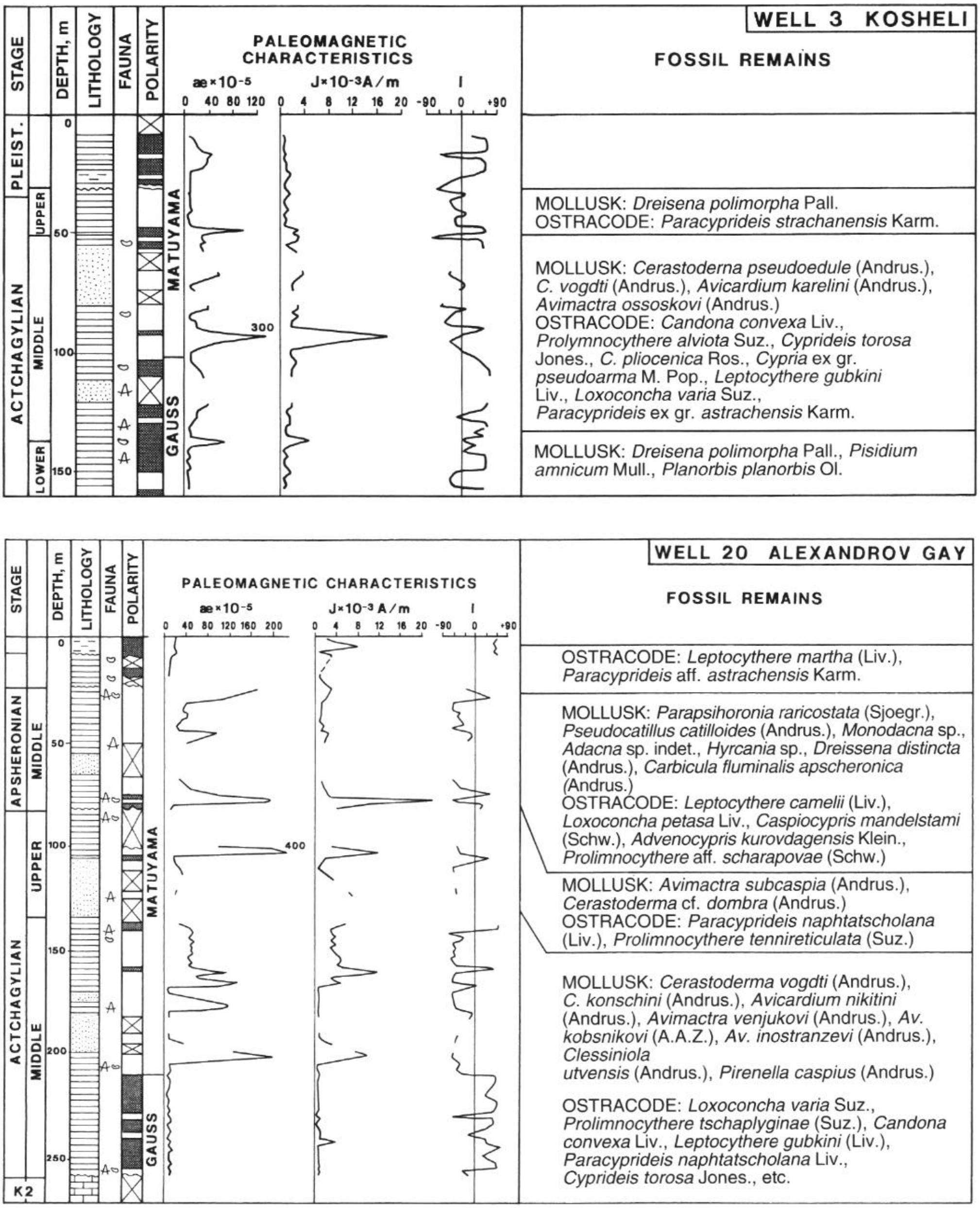



FIG. 11. — Paleomagnetic sections of the Pliocene deposits in Saratov-Volga region.

regressive sand facies, magnetization is determined by clastic magnetite. Thus, in most sections of marine Pliocene from the North Cis-Caspian, alternating intervals are observed: these of dominant detrital or chemical remanent magnetizations.

One should be especially cautious while interpreting the data on the rocks with their magnetization caused by authigenic sulfides. The latter ones are quickly oxidized under atmospheric conditions, thus, the cores should be analyzed not later than in two to three weeks after extraction from the wells. While analyzing the results, those of the first thermal cleaning step (below 350 °C) and those of the second one (550-580 °C) separately. At the first stage, chemical remanent magnetization is dominant in such rock types; at the second stage, after passing the Curie point for sulfides, magnetite remains the only NRM carrier.

To construct the paleomagnetic columns, the only samples used were those with the chemical and detrital Jn components revealing the same type of orientation in space (Fig. 4E-H).

Notwithstanding the differences in lithology, facies and compositions of magnetic phases, there is a stable temporal regularity in the behaviour of natural remanent magnetization in the recent deposits from the North Cis-Caspian and Volga regions.

Within the range from the lowermost part of the Pleistocene to the lower Actchagylian inclusive, two large paleomagnetic intervals are omnipresent: the upper, reverse polarity one, and the lower, normal polarity one. The reverse-polarity zone accounts for the whole of the Apsheronian and the upper half of the Actchagylian stages and the normal-polarity zone corresponds to the lowermost middle and lower Actchagylian (Figs 10, 11).

Matuyama and Gauss zones may be considered as their analogues in magnetochronologic scale. Within the Matuyama Zone, some narrow normal-sign zones have been revealed, which may be correlated according to their stratigraphic position with Reunion (middle-upper Actchagylian boundary), Olduwai (the base of the Apsheronian) and Jaramillo (the uppermost middle Apsheronian) events.

### Western Turkmenia

Paleomagnetic studies of the Pliocene deposits in the Trans-Caspian region were carried out separately by Khramov (1963) and Trubikhin (1977). Khramov (1963) has investigated the Middle Pliocene red-bed (Cheleken) Formation, Actchagylian and Apsheronian regional stages. Trubikhin has examined the Upper Pliocene sequence comprising the Apsheronian and Actchagylian stages.

#### *The Cheleken Formation*

The Cheleken Formation is composed of red and grey clays, aleurolites, sandstones and contains rare remains of mollusks *Turrucaspia* sp., *Hyrobia* sp. and brackish-water ostracodes of the genera *Hiocypris*, *Limnocythere*, *Cyprinotus*.

Maximum thicknesses occur in the Cheleken Peninsula (2600 m) and they reduce to 200-300 m to the east (Muratov & Nevesskaya 1986).

#### *The Actchagylian and Aspheronian regional stages*

It is commonly accepted that, within the sections studied by Khramov, the Actchagylian beds conformably overlie the Cheleken Formation delete. They are generally composed of rocks with reverse remanent magnetization; the overlying lower and middle Apsheronian beds are also reversely magnetized.

Trubikhin has performed complex studies (paleomagnetic and lithologic-mineralogic) of twenty sections of the Actchagylian and Apsheronian stages in the western Turkmenian Depression and Kopet-Dag foothills (Trubikhin 1977). Thick (200-700 m) Upper Pliocene sequences of marine and continental origin are developed in these regions. In the sections studied, grey clays and sand-interlaid aleurolites dominate; they were divided in detail according to the mollusk faunas. Nevesskaya has revealed the following from Trubikhin's collections:

**1.** In the lower Actchagylian, *Mactra subcaspia* Andrussow, *M. carabugasica* Andrussow, *M. ovala* Tschelzov and *Cardium dombra* Andrussow.

**2.** In the middle Actchagylian, multiple *Mactra subcaspia* Andrussow, *M. instranzevi* Andrussow, *M. aviculoides* Andrussow, *Cardium dombra*

Andrussow, *C. cucurtennse* Andrussow, *C. konschini* Andrussow, etc.

**3.** The upper Actchagylian substage is characterized by brackish-water *Dreissena, Clessionola, Micromelania* and *Teodoxus* along with depleted *Cardium* and *Mactra* assemblages.

Representatives of *Dreissena, Micromelania, Teodoxus, Didacnonija, Pseudocatilus* and other genera are characteristic of the Lower Apsheronian. The middle Apsheronian is characterized by diverse *Cardium Apscheronia, Paraapscheronia, Monodacna* and other genera. *Hypanis, Hircania, Micromelania, Monodacna, Dreissena* occur in the upper Apsheronian.

*Comparison*

Principal magnetostratigraphic sections for the Upper Pliocene in western Turkmenia are presented in figure 12. They clearly demonstrate the bizonal structure of the paleomagnetic column,

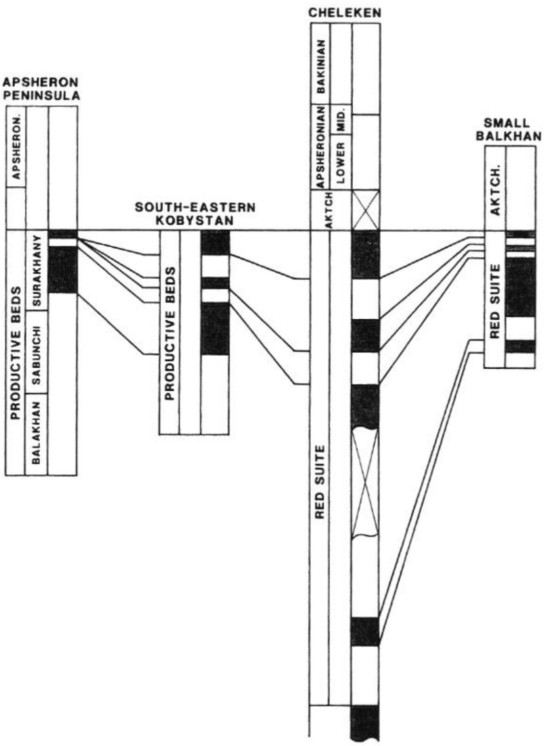



FIG. 12. — Paleomagnetic correlation of sections of the Pliocene and Pleistocene deposits of eastern Azerbaijan and western Turkmenia (Khramov 1963).

with the lower, normally-magnetized zone embracing the lower and the lowermost middle Actchagylian. The stratigraphic range of the upper, reversely polarized zone is wider and includes the upper part of the Actchagylian plus the whole of the Apsheronian. Trubikhin (1977) interprets the regional N and R zones as being analoguous to Gauss and Matuyama zones in standart magnetostratigraphic scale.

Khramov's paleomagnetic column extends Trubikhin's scheme within the Middle Pliocene. If peculiarities of paleomagnetic section structure are considered, it seems possible that the Gauss Zone is not confined to the Actchagylian, but includes the normally magnetized uppermost of the Cheleken series sequence. The predominantly reversely magnetized middle and lower parts of the Cheleken may be correlated with Gilbert Zone.

The paleomagnetic data available evidently do not conform to the traditional concept of the Actchagylian discordantly overlying the red-bed and the Torongly suites. This conclusion may be explained by the absence of the lower, normally magnetized Actchagylian beds (Actchagylian-Gauss) in the highs of the Cheleken Peninsula, where the red-bed suite is overlain by the Actchagylian beds with reversely-polarized natural remanent magnetization (Actchagylian-Matuyama). Hence, the correctness of the conclusion on the lower Actchagylian horizons is thinning on the ancient structure during the period before the second Actchagylian transgression.

In the more easterly regions of the Turkmenian Depression, the normally magnetized, lower part of the Actchagylian is available, but the Cheleken part of the Gilbert Zone falls out of the section and the marine Actchagylian with latent discordance overlies the reversely magnetized Torongly Formation, assigned to the Gauss Zone by Trubikhin (1977).

AZERBAIJAN

Eastern Azerbaijan is among the most paleomagnetically-studied regions. Following Khramov's pioneering works (1963), the majority of the most representative sections have been studied including the Lower Pleistocene, Apsheronian, Actchagylian beds and the Balakhan (productive) sequence of the Middle Pliocene.

*The productive sequence*

It is formed by the sediment accumulations of a brackish-water basin; they are represented by alternating aleurolites, clays, sands and sandstones with the total thickness up to 2500 m. The section is subdivided into several parts.

The upper part of the sequence, right to the base of the Balakhan suite, is characterized by a relict ostracode fauna of *Bakunella*, *Pontoniella* and *Caspiola*, genera common in the Pontian stage. The Balakhan, Sabunchi and Surakhany suites, constituting the upper part of the productive sequence, contain the Actchagylian ostracodes: *Limnocythere*, *Leptocythere*, etc. (Nevesskaya *et al.* 1986; Muratov & Nevesskaya 1986).

*The Actchagylian stage*

It is represented by grey aleurolites and clays with sand and rare limestone and conglomerate iterlayers. The thickness of the Actchagylian varies between 50-70 and 600-800 m and it is subdivided into three parts according to malacofaunal composition. The criteria used for this division are the same as for the Trans-Caspian region: a depleted assemblage in the lower Actchagylian (*Cerastoderma*, *Clessiniola*, *Pirenella*, *Mactra*), a rich assemblage of the middle Actchagylian *Cardium*, a depleted assemblage of *Mactra* and *Cardium* in the upper Actchagylian (Ali-Zade 1954; Muratov & Nevesskaya 1986).

The Actchagylian beds transgressively and unconformably overlie ancient deposits of the Middle Jurassic. The Balkhan series is the only exception and is believed to be connected with the Actchagylian through gradual intertransitions.

*The Apsheronian regional stage*

It is lithologically similar to the Actchagylian and differs in paleontologic nature. The Apsheronian deposit thicknesses do not exceed 250-300 m on the highs and are as high as 1500-2000 m in the depressions. The Apsheronian is divided into three substages according to the composition of mollusk fauna (Muratov & Nevesskaya 1986).

The lower Apsheronian is characterized by *Monodacna*, *Dreissena*, *Hyrcania*, *Corbicula* and other genera. The middle substage is distinguished by the development of *Monodacna* and *Didacnaides* genera, and for origination of new species of *Hircania* and *Apscheronia* genera.

The upper Apsheronian is characterised by the disappearance of the ribbed apsheronids (*Apscheronia*) widely common in the middle substage (Nevesskaya *et al.* 1986; Muratov & Nevesskaya 1986).

*Comparison*

In Khramov's magnetostratigraphic scheme (1963), based on the sections from the Apsheron Peninsula and Kobystan, magnetic zones of the Apsheronian and Actchagylian are recognized, as well as those in the upper part of the productive sequence within the Surakhan, Sabunchi and Balakhan Formations (Fig. 12).

According to Khramov's and Ismail-Zade's data, the Actchagylian and Apsheronian stages in eastern Azerbaijan are united by a common zone of reverse polarity. The underlying beds of the Surakhan are marked with dominant normal magnetization both in the Apsheron Peninsula and Kobystan. A large interval of stable reverse polarity is registered downwards through the section; it includes the Sabunchi and Balakhan suites (Ismail-Zade *et al.* 1967; Khramov 1963).

A relatively detailed survey of the Upper Pliocene part of the section was presented by Ali-Zade *et al.* (1973) and Asadulayev & Pevzner (1973), who has confirmed the bizonal structure of the Actchagylian paleomagnetic section. As in western Turkmenia, the lower half of the Actchagylian stage is composed of normal-polarity rocks, whereas the upper horizons of the Actchagylian and the whole of the Apsheronian are reversely magnetized.

Two normal subzones are recorded within the Apsheronian part of the section. One of them is associated with the Actchagylian-Apsheronian boundary, the other one almost coincides with the middle/upper Apsheronian contact.

Four magnetozones are documented within the composite paleomagnetic section through the Plio-Pleistocene in Azerbaijan. The top normally

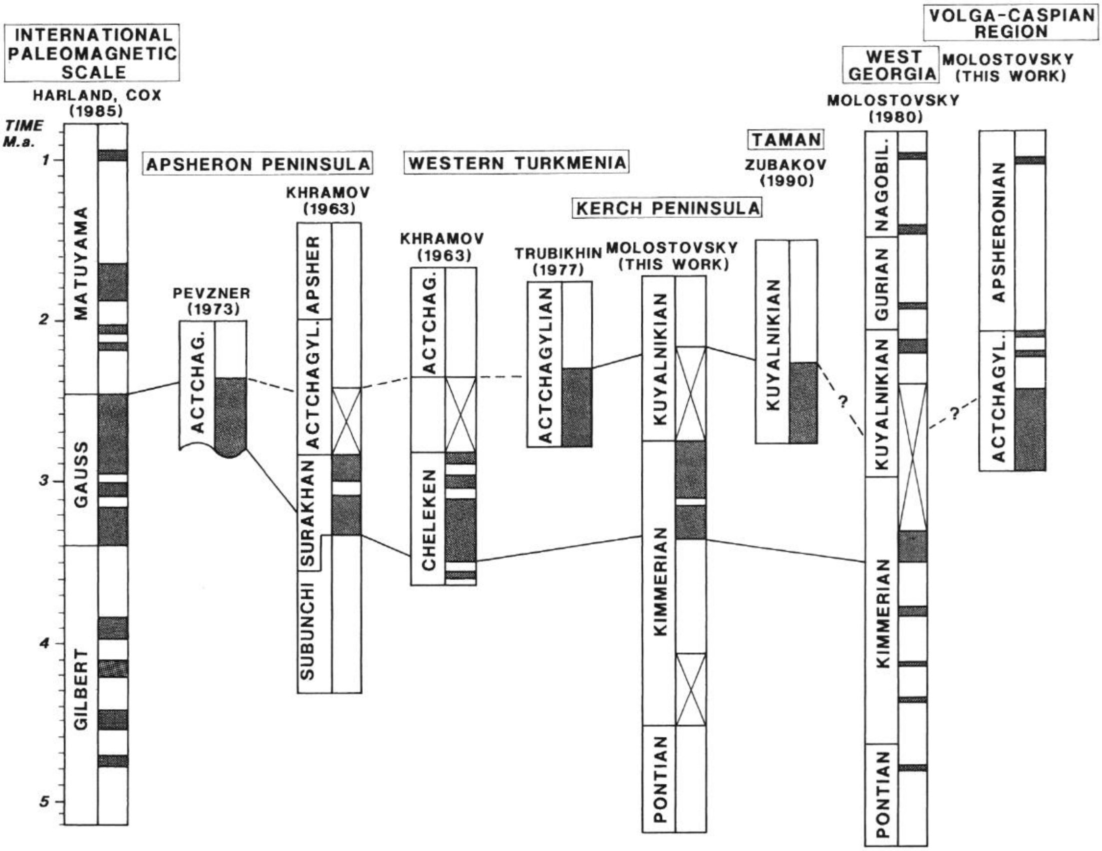



FIG. 13. — Paleomagnetic correlation of the Pliocene and Pleistocene deposits of Black Sea and Volga-Caspian regions.

magnetized zone, equivalent to the Pleistocene, is clearly identified with the Brunhes Zone. The underlying R-zone, which includes the Apsheronian and the upper half of the Actchagylian, is referred to Matuyama Zone by analogy with adjacent regions.

Based on the regional scale pattern, the Gauss Zone should unite the lower half of the Actchagylian and the Surakhan suite.

Such a combination of marine and brackish-water facies within the Gauss Zone is similar to that observed between the Actchagylian and the Chelecen suite in western Turkmenia. Similarly, a stratigraphic discordance is revealed between the Actchagylian and the productive sequence within the section lacking the lower part of the stage and with the Surakhan suite overlain by the reversely magnetized Actchagylian (Fig. 13).

## CORRELATION OF THE PLIOCENE DEPOSITS FROM THE BLACK SEA AND CASPIAN REGIONS BY PALEOMAGNETIC DATA

Correlation of the data from western Turkmenia, Azerbaijan, western Georgia, north-western Pontic and northern Cis-Caspian regions, shows practically identical successions in alternation of large normal and reverse-polarity intervals through the whole of the Pliocene section, from the base of the Pontian through the base of the Pleistocene. It should be noted that the same type of magnetic zonation has been revealed within coeval deposits of different origins, irrespective of magnetic phase mineral composition or of the character of natural remanent magnetization.

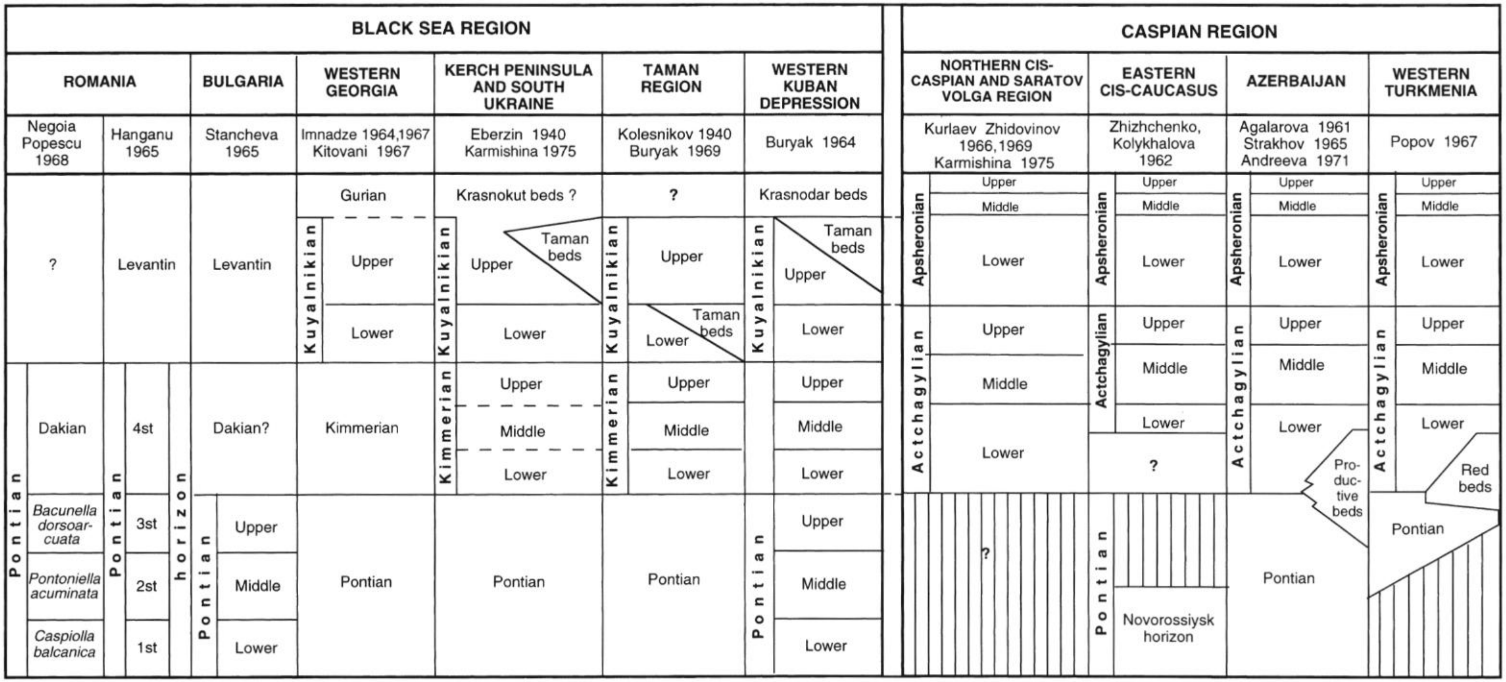



FIG. 14. — Correlative scheme of the Pliocene deposits of Caspian and Black Sea regions (Karmishina 1975).

The Matuyama-Brunhes inversion should be considered the most reliable reference level for inter-regional correlation. The correlation between local stratigraphic units and the paleomagnetic scale is presented in figure 13.

The summary of the biostratigraphic correlation schemes for the Pliocene of the Pontic-Caspian region is shown in figure 14.

Comparison of the schemes makes it possible to consider the revisions introduced by paleomagnetic data into the traditional concepts of Pliocene stratigraphy:

**1.** The Kimmerian stage cannot be correlated with the middle-lower Actchagylian due to magnetic polarity differences.

**2.** Paleomagnetic data eliminate the idea of referring the Taman layers to the lower Kuyalnikian (Buryak 1969) due to different polarity Jn of these stratigraphic units. For the same reason, the lower Kuyalnikian cannot be correlated with the upper Actchagylian.

**3.** Magnetozone correlation between the Pliocene sections from Azerbaijan and Turkmenia does not confirm the traditional idea of the Actchagylian confirmably overlying the productive and red-bed sequences. The Actchagylian overlies various Middle Pliocene horizons transgressively, with clear stratigraphic unconformity.

The proposed paleomagnetic modifications of biostratigraphic schemes do not usually encounter significant objections, the only exception being the Pontian stage and its position within the magnetostratigraphic scale has been debatable for two decades.

There are three published points of view on the problem of the position of the Pontian. Two of them prefer the idea of a "short" Pontian (0.6-0.8 Ma), and correlate the Pontian stage with the lowermost part of Gilbert Zone (Trubikhin 1977; Molostovsky *et al.* 1982) or with zone 6 (Semenenko & Pevzner 1979) of the general paleomagnetic scale. After numerous changes of opinion, Zubakov has assumed of a "long" (about 2 Ma) polyzonal Pontian within the lowermost Gilbert Zone plus the whole of zones 5 and 6 (Zubakov 1990).

The idea of "a long Pontian" seems somewhat speculative, because within the sections from the Crimea, Taman, Georgia and Roumania, the Pontian stage or its analogues correspond to the monopolar R-zone, which is more in accord with the idea of a "short" Pontian.

The idea of correlating the Pontian with the sixth epoch of the paleomagnetic scale originated after NN11 zone nannofossils were found within the lower (Azov) horizon of the Kimmerian and those of the NN12 zone in the Middle Kimmerian.

Based on the nature of nannoplankton and magnetozone distributions within ocean sediments and the stratotype section of the Neogene in Italy, Semenenko & Pevzner (1979) have compared the lower Kimmerian with zone 5 and the upper Messinian, and the Pontian with zone 6 and the lowermost part of the Messinian. The Miocene/Pliocene boundary in the eastern Para-Tethys was, accordingly, removed from the base of the Pontian to the bottom of the middle Kimmerian.

These ideas were questioned (Trubikhin 1986) on the basis of paleomagnetic data for the reference sections of the Mio-Pliocene from Roumania and this present author's data from western Georgia, with the magnetic zonation indicating the correspondence of the Pontian and the lower Kimmerian to the Gilbert Zone and hence to the lowermost Pliocene.

Both models are subject to correction after additional paleontologic and paleomagnetic studies have been carried out.

The study of cores from the equatorial Pacific has shown *Discoaster quinqueramus* to disappear at various stratigraphic levels. In the well PC-12-66, the boundary between zones NN11 and NN12 occurs within the upper third of the foraminifer zone N17, which corresponds to the middle of the paleomagnetic scale fifth epoch. In wells 77 and 158 this change is recorded at a higher stratigraphic level, within zone N18, which is usually correlated with the Gilbert Zone (Dunn & Moore 1981). Thus, the definition of the index-species for the NN11 zone in the Pontic Azov horizon has lost its relerame, because it cannot serve as a correlation index for the Lower Kimmerian and the fifth epoch of the paleomagnetic scale.

The position of Gilbert Zone within the stratigraphic scale for the Mediterranean has altered in recent years. It follows from Cita (1983) that the conclusions of Ryan *et al.* (1974) on the correlation of the Messinian to magnetozones 5 and 6 were only tentative, because the Messinian stage stratotype has not been studied paleomagnetically due to weak magnetization of the rocks.

Research in eastern Crete has shown that the upper Messinian (evaporites plus "*lago mare*" formations) corresponds to the lowermost part of the Gilbert Zone and the middle and the lower parts of the stage to magnetozones 5 and 6 (Langereis *et al.* 1977).

From the evidence discussed above, it seems most reasonable to refer the Pontian to the lowermost part of the Gilbert Zone and correlate it with the upper Messinian and, partially, with the lower Zanclian. In this case the Miocene-Pliocene boundary, as it is accepted in the Mediterranean, should occur within the Pontian stage.

Paleomagnetic correlation of the Pontian with the Mediterranean units reduces the level of uncertainty arising from biostratigraphic scheme comparisons. Nevesskaya *et al.* (1986) believe that the Pontian may correspond to the Messinian in the Mediterranean, in full or in part, or the lowermost part of the Zanclian, or the uppermost Messinian and lowermost Zanclian.

Magnetostratigraphic correlation of the Pliocene beds from the eastern Para-Tethys and the Mediterranean region is shown in figure 15.

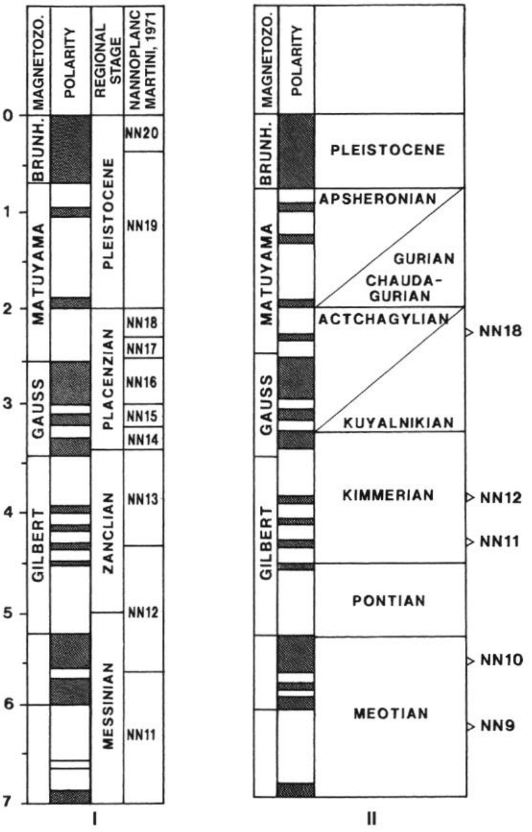



FIG. 15. — Paleomagnetic correlation of sections of the Neogene of Mediterranean (**I**) and eastern Para-Tethys (**II**).

## PALEOMAGNETIC CALIBRATION OF OSTRACODE AND MOLLUSK FAUNAS FROM THE PONTO-CASPIAN REGIONS

Unification of regional paleomagnetic schemes on the basis of A. Cox scale has provided the framework for a comparative analysis of ostracode and mollusk faunas development stages within the Pontic and Caspian regions. According to Karmishina (1975), three stages may be recognized in the development of the Pliocene basins and their ostracode biota: the Pontian, Actchagylian and Apsheronian for the Caspian; the Pontian, Kimmerian early Kuyalnikian and late Kuyalnikian Gurian for the Euxinic. The Pontian stage is accepted as common for both regions, and the Actchagylian is generally correlated with the Kimmerian early Kuyalnikian Gurian.

Projection of the biostratigraphic scheme on to the paleomagnetic scale reveals the chronologic asynchroneity of a number of evolutionary boundaries (Fig. 16).

Within the Euxinic Basin, the Pontian stage came to an end in the middle of the Gilbert epoch, probably after the Tver episode. The Actchagylian ostracode complex supplants the Pontian one at about the same level within the lowermost part of the Balakhan suite (Karmishina 1975; Muratov & Nevesskaya 1986).

The Actchagylian stage in the Caspian corresponds to the whole of the Gauss epoch and to

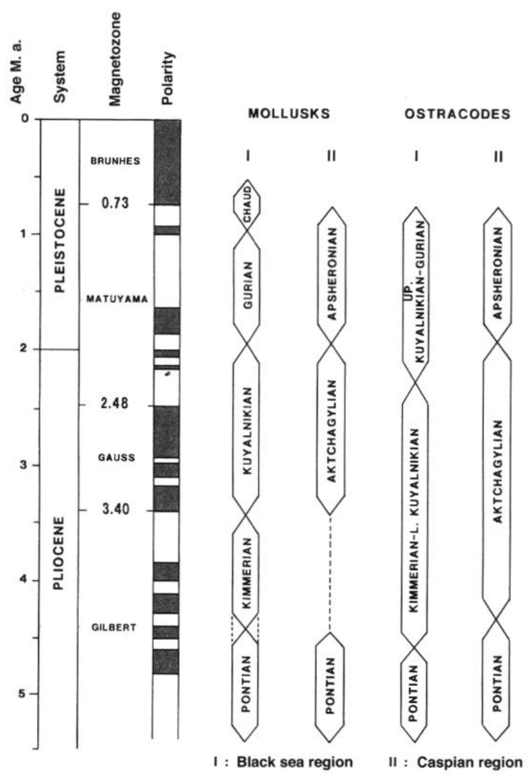



FIG. 16. — Principal studies of development of the Pliocene ostracodes and mollusks of eastern Para-Tethys correlation with paleomagnetic scale (ostracodes: Karmishyna 1975; mollusks: Nevesskaya *et al.* 1986).

the early Matuyama up to Olduwai episode; it covers the time interval of 3.4-1.9 Ma Its presumed analogue in the Pontic region, the Kimmerian early Kuyalnikian stage, occupies a different magnetochronologic interval: the major part of the Gilbert epoch and the whole of the Gauss epoch (4.57-2.47 Ma).

The Apsheronian and the late Kuyalnikian Gurian stages have different durations: their time ranges constitute 1.89-0.73 and 2.47-0.73 Ma respectively. Comparative analysis of the evolution of the Pontic-Caspian malacofauna demonstrates that the Apsheronian stage is equivalent to the Gurian and Chaudian stades collectively in duration, and the Kuyalnikian stage is shorter than the Kimmerian.

In principle, similar relationships based on the magnetic polarity scale may be determined between the Pliocene faunas from eastern and western Para-Tethys as well as between them and the fauna of the Mediterranean region.

## CONCLUSION

In the Pliocene sections from the Black Sea and Caspian regions, three major zones of the general magnetochronologic scale are recognized and traced consistently; they are complicated by a number of subordinate subzones. The Upper Pliocene R-zone is identified with the Matuyama Zone (0.73-2.47 Ma) and comprises the most of the Upper Pliocene + Eopleistocene. The middle, Gauss N Zone (2.47-3.4 Ma), comprises the Middle and the lowermost part of the Upper Pliocene. The lower, Gilbert Zone (3.4-5.3 Ma), corresponds to the most of the Kimmerian part of the Middle and Lower Pliocene.

Unification of local stratigraphic schemes, correlations among the regional geologic events and comparisons of marine sections from the eastern Para-Tethys and the Mediterranean region, these are the obvious positive results obtained from many years of paleomagnetic research.

The most urgent task for the nearest future is to perform correlations among the marine and continental Plio-Pleistocene Formations from the northern Peri-Tethys on the basis of paleomagnetic zonalities. There are most real prerequisites available for broad correlations of such type.

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