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GEOLOGY

Regional Stratigraphic Scheme and Paleogeographic Events of the Late Miocene, Pliocene and Quaternary in Armenia

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Regional Upper Cenozoic stratigraphic schemes are available from several summarizing works [2–5, 7–10]. In the present communication, these materials are discussed with consideration of new data on upper Miocene, Pliocene, and Quaternary stratigraphy and paleogeography of Armenia, which make it possible to significantly refine the scheme for Armenia.

The scheme is largely based on reference sections of the large Sevan, Ararat, and Shirak intermontane depressions, with the thickest (up to 2000 m) recent sediments in the Vorotan–Akera interfluve, and correlated with the standard stratigraphic–geochronological scale [1, 6] (table). The defined local stratigraphic units (formations, subformations, and beds) are substantiated by lithostratigraphic, biostratigraphic, and climatostratigraphic data. The units comprise sediments with features determined by rhythmic climate changes and tectonic processes that are recorded in peculiarities of lithology and faunal (largely, floral) assemblages.

The analysis of materials presented in the proposed stratigraphic scheme (table) makes it possible to reconstruct main paleogeographic events that took place throughout Armenia since the terminal Miocene to the present day.

The continental (terminal Sarmatian–initial Meotian) stage of development of Armenia can be divided into ten large erosion–sedimentation cycles: initial Sarmatian–Meotian, Pontian, Kimmerian, Akchagylian, Apsheronian (two cycles), Neopleistocene (three cycles), and Holocene. These cycles were primarily determined by tectonic vertical movements, with their subsequent relative stabilization, as well as by climate changes. Each of these cycles commenced with a well-manifested tectonic regional uplift phase followed by erosion and alluvial sedimentation that give way to a next tectonic phase and erosion. One can see a distinct trend: lacustrine sediments accumulated during epochs of relative tectonic stabilization, cooling, humidification, and forest development, whereas alluvial sediments were deposited in epochs of activation of vertical tectonic movements, deep erosion, warming (aridization), and xerophilous steppe expansion. The Quaternary erosion–sedimentation cycles were likely governed by changes in the Caspian Sea level that represented a main erosion base: transgressions in Armenia corresponded to cooling and humidification epochs, whereas regressions corresponded to warming and aridization epochs.

Since the late Sarmatian, the natural development of the Armenian territory was controlled by a general irreversible cooling that became more intense in the Quaternary. The cooling intensified from the Pliocene to Eopleistocene (in the second half of the Kimmerian and terminal phases including the Akchagylian and Apsheronian stages) and further to early, middle, and late Neopleistocene. The Eopleistocene cooling was related to cooling epoch in the Russian Plain. The early Neopleistocene cooling could be related to the Okaian Glaciation in the Russian Plain. The middle and late Neopleistocene history of Armenia comprise two cooling and humidification stages with intervenient warming episodes and two stages of the development of mountainous glaciers divided by interstades. Phases of river drainage activation and coarse-grained alluvium accumulation are controlled by dynamics of the snow line during two glaciation stages that could be related to the

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Regional stratigraphic scheme and paleogeographic events of the late Miocene, Pliocene, and Quaternary in Armenia

General scale					Formation	Subformation, Beds	Lithology. Fauna	Phases of tectonic activity (uplift) and erosion. Sedimentation basins	Principal rhythms of climate and vegetation development
System	Series	Regional stage (subseries)	Regional substage (link)	Age, Ma					
1	2	3	4	5	6	7	8	9	10
Quaternary	Holocene			0.01			Lacustrine and boggy sediments (up to 35 m). *Lymnaea, Planorbis*, *Valvata*. II–I terraces and floodplains of the Araks River system	Sevan lacustrine basin	Present-day climate and vegetation
								Major erosion phase	Semiarid. Steppes
	Pleistocene	Neopleistocene	Upper				Lacustrine, lacustrine–alluvial, and alluvial sediments (up to 50 m). V–III terraces of the Araks River system. Coarse-grained alluvium corresponding to the elevated river drainage of the Araks River: I and II phases	Sevan lacustrine basin	Humid, moderately continental. Coniferous broad-leaved forests
									Semihumid. Broad-leaved forests
								Major erosion phase	Humid, moderately continental. Coniferous broad-leaved forests
									Semiarid. Steppes (cold)
			Middle	0.1	Ararat, Arapi, Angekhakot	Upper Ararat	Tuffs of the Yerevan–Leninakan type (up to 10 m). Lacustrine, lacustrine–alluvial, and alluvial sediments (up to 100 m). *Mammuthus trogontheri chosaricus*, *Paleoloxodon antiquus*, *Dicerorhinus kirchbergensis* (=*mercki*) Jaeg., *Camelus knoblochi* Nehr., *Dreissena diluvii* Abich. VIII–VI terraces of the Araks River system	Shirak, Ararat, Sevan, and Angekhakot lacustrine basins	Humid, moderately continental. Coniferous small-leaved forests
									Semiarid. Steppes
									Humid, moderately continental. Coniferous broad- and small-leaved forests
								Major erosion phase. Uplift	Semiarid. Forest-steppes
			Lower	0.42	Ararat, Ani; Aknadash	Lower Ararat, Arzni Beds	Lacustrine and lacustrine–alluvial sediments (up to 200 m). *Dreissena, Micromelania*, *Megaloceros*. Sheet basalts (K–Ar = 0.7 Ma). X–IX terraces of the Araks River system	Shirak, Ararat, Sevan, and Angekhakot lacustrine basins	Humid, moderately continental. Dark coniferous, coniferous broad- and small-leaved forests
									Semiarid. Steppes
									Semihumid. Forest-steppes
				0.8				Major erosion phase. Uplift	Semiarid. Steppes

Table. (Contd.)

General scale					Formation	Subformation, Beds	Lithology. Fauna	Phases of tectonic activity (uplift) and erosion. Sedimentation basins	Principal rhythms of climate and vegetation development
System	Series	Regional stage (subseries)	Regional substage (link)	Age, Ma					
1	2	3	4	5	6	7	8	9	10
Quaternary	Pleistocene	Eopleistocene (Apsheronian)	Upper	0.8	Gorisi. Ishkhansar	Upper Gorisi. Tatevi Beds	Lacustrine sediments (up to 150 m). Formation of 170- to 180-m-high pebble terraces (Nubarashen and others). Volcanics of the Iskhansar Formation (up to 600 m)	Shirak (?), Ararat, Sevan, and Tatev lacustrine basins	Humid, moderately continental. Coniferous small- and broad-leaved forests
									Semiarid. Forest-steppes
									Semihumid (temperate). Forest-steppes
								Major erosion phase. Uplift	Semiarid. Steppes
			Lower			Lower Gorisi. Norvan Beds	Lacustrine sediments (up to 30 m). Tuff and lava breccia, andesites (K–Ar = 1.2 Ma)	Shirak (?), Ararat, Sevan, and Norvan lacustrine basins	Semihumid (temperate-warm). Mixed forests
									Semiarid. Steppes
								Major erosion phase. Uplift	
Neogene	Pliocene	Akchagylian	Upper	1.8	Sisian. Nurnus	Shaki	Doleritic basalts (up to 70 m) (K–Ar = 2.21–2.47 Ma). Lacustrine and lacustrine–alluvial sediments (up to 140 m). *Cardium nikitini*, *Avimactra subcaspia*, *Dicerorhinus etrusicus*, *Equus stenonis*, *Hipparion*, *Ochotona*	Shirak, Ararat, Sevan, and Sisian lacustrine basins	Humid, moderately continental. Coniferous small- and broad-leaved forests
									Semihumid. Forest-steppes
									Semihumid (temperate-warm, temperate). Broad-leaved forests and forest-steppes
			Lower	12.42	Sisian. Khoti	Upper Akera. Vardashen Beds	Lacustrine and lacustrine–alluvial sediments (up to 360 m). *Cardium dombra*, *C. radiferum*, *Mactra subcaspia*, *Micromelania eldarica*, *Avicardium nikitini*, *Potamides caspius*. Volcaniclastic rocks (K–Ar = 3 Ma)		Semiarid. Steppes
									Semiarid (seasonal humid). Subtropical savanna
								Major erosion phase. Uplift	Semiarid. Steppes
		Kimmerian	Upper	3.4	Subbotan	Lower Akera	Lacustrine and lacustrine–alluvial–volcanogenic sediments with interbeds of volcanic tuff (up to 300 m). (K–Ar = 4.8 Ma) *Dreissena*, *Lymnaea*.	Shirak, Ararat, Sevan, and Akera lacustrine basins	Semihumid (cold). Forests similar to present-day Baikalian ones
			Lower	5.3			Coarse-grained alluvium of the Araks–Vorotan–Akera river system (“Unconformity Formation”) (up to 60 m)	Major erosion phase (pre-Akchagylian). Uplift	Semiarid. Steppes

Table. (Contd.)

General scale					Formation	Subformation, Beds	Lithology. Fauna	Phases of tectonic activity (uplift) and erosion. Sedimentation basins	Principal rhythms of climate and vegetation development
System	Series	Regional stage (subseries)	Regional substage (link)	Age, Ma					
1	2	3	4	5	6	7	8	9	10
Neogene	Miocene	Meotian–Pontian		5.3	Vokhchaberda	Upper	Volcanosedimentary and volcaniclastic rocks (up to 850 m) (Ka–Ar = 5.15 Ma)	Large lacustrine basin separated from the Eastern Paratethys. Uplift.	Mediterranean. Subtropical forests similar to present-day forests of the western Caucasus piedmonts (Novorossiisk region)
				7.0		Lower	Volcanosedimentary and lacustrine rocks (up to 25 m). Membranipora, *Unio*, *Dreissena*, *Planorbis*		Mediterranean. Subtropical forests similar to present-day forests of the Crimean southern coast
		Sarmatian	Upper	9.3	Razdan		Marine sediments (up to 800 m). *Mactra* (*Sarmatimactra*) *caspia*, *M*. (*S*.) *timida*	Marine basin of the Eastern Paratethys	Mediterranean. Subtropical forests similar to present-day forests of southern Europe and northern Africa
				11.2					

Middle Russian and Valdaian glaciations in the Russian Plain.

Thus, the geological development of the Armenian territory during the past 11 Ma was characterized by rhythmic changes of the environment and its individual components against the background of a long-term gradual irreversible cooling trend. All these changes took place synchronously on both regional and interregional scales.

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