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Geological Institute of the USSR Acad. Scis., Pyshevsky per. 7, 109017 Moscow, USSR

Andrey E. DODONOV

Stratigraphy and Paleogeography of Loess in Middle Asia

Stratygrafia i paleogeografia lessów Azji Środkowej

Стратиграфия и палеогеография лёссов Средней Азии

ABSTRACT

In Middle Asia the loess and soil horizons are associated with glacials and interglacials respectively. The oldest loess was formed about 2—2.4 Ma BP. 25 buried soils have been distinguished between the base of Olduvai paleomagnetic episode and Matuyama-Brunhes reversal. Ten pedocomplexes and ten loess horizons have been determined in the last 0.75 Ma. The trend of climatic changes observed in the warm and cold intervals testifies to the intensification of cooling and aridization from the upper Pliocene to the end of the Pleistocene. The correlation of Middle Asia loess-soil scale with the regional stratigraphic schemes of Eurasia as well as with the oxygen-isotope stages is considered.

Middle Asia belongs to the desert-loess belt extending from the Loess Plateau in northern China to the deserts of eastern Caspian Basin. During the Quarternary period this belt was characterized by mainly arid and continental paleoclimate with alternation of pluvial phases.

Generally, the loesses of Middle Asia are attributed to the so-called "warm loesses" since there are no traces of cryogenic structures in loess horizons. However, this circumstance does not allow us to assign the loess as formation synchronous with interglacials, though such correspondence — of loess formation and paleoclimatic events — is claimed by some researchers (M. M. Pakhomov 1983). According to another conception shared by the author the loess horizons in Middle Asia were formed in glacial intervals and paleosols — during interglacials.

The loess mantles are widespread in southern Tajikistan, the Tashkent region, eastern Fergana and in southern Kazakhstan. The key sections

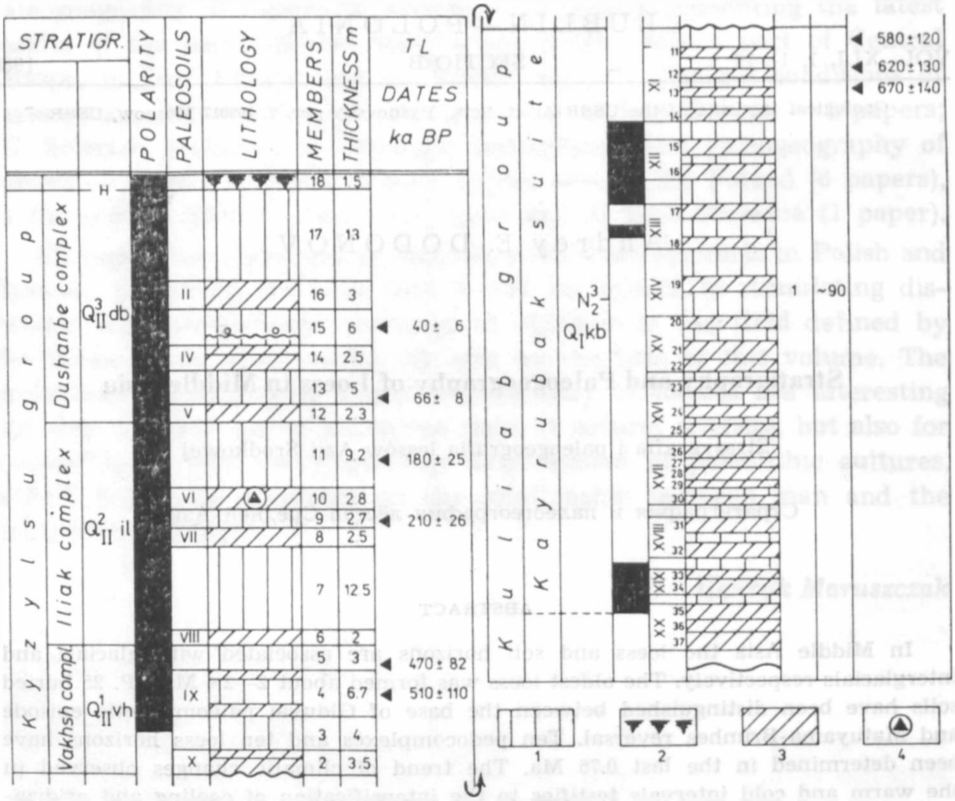

Fig. 1. Chashmanigar stratigraphic section. Indexes 11, 12, 13... denote the Eopleistocene paleosols, grouped into pedocomplexes from XI to XX
1 — loess; 2 — recent soil; 3 — fossil soils; 4 — Paleolithic finds

are located in southern Tajikistan where the thickness of loess strata reaches 180 m and stratigraphically they embrace the upper Pliocene, Eopleistocene and Pleistocene *. Among the most complete loess sections in southern Tajikistan should be noticed Chashmanigar, Khonako, Kayrubak, Karamaydan; in the Tashkent region — Orkutsai (Photo 1, 2). Subaerial deposits attributed to the upper Pliocene are represented by well-developed red paleosols and thin loess horizons, reworked considerably by soil processes. Below the Olduvai paleomagnetic episode some seven to ten paleosols are estimated in loess sections of southern Tajikistan (Karamaydan, Khonako). This subaerial sequence corresponds to subaqueous deposits containing the remains of mammalian fauna of the Khaprov faunistic assemblage (middle Villafranchian).

* The boundary between the Pliocene and the Eopleistocene is drawn at 1.8 Ma, between the Eopleistocene and the Pleistocene — at 0.75 Ma.

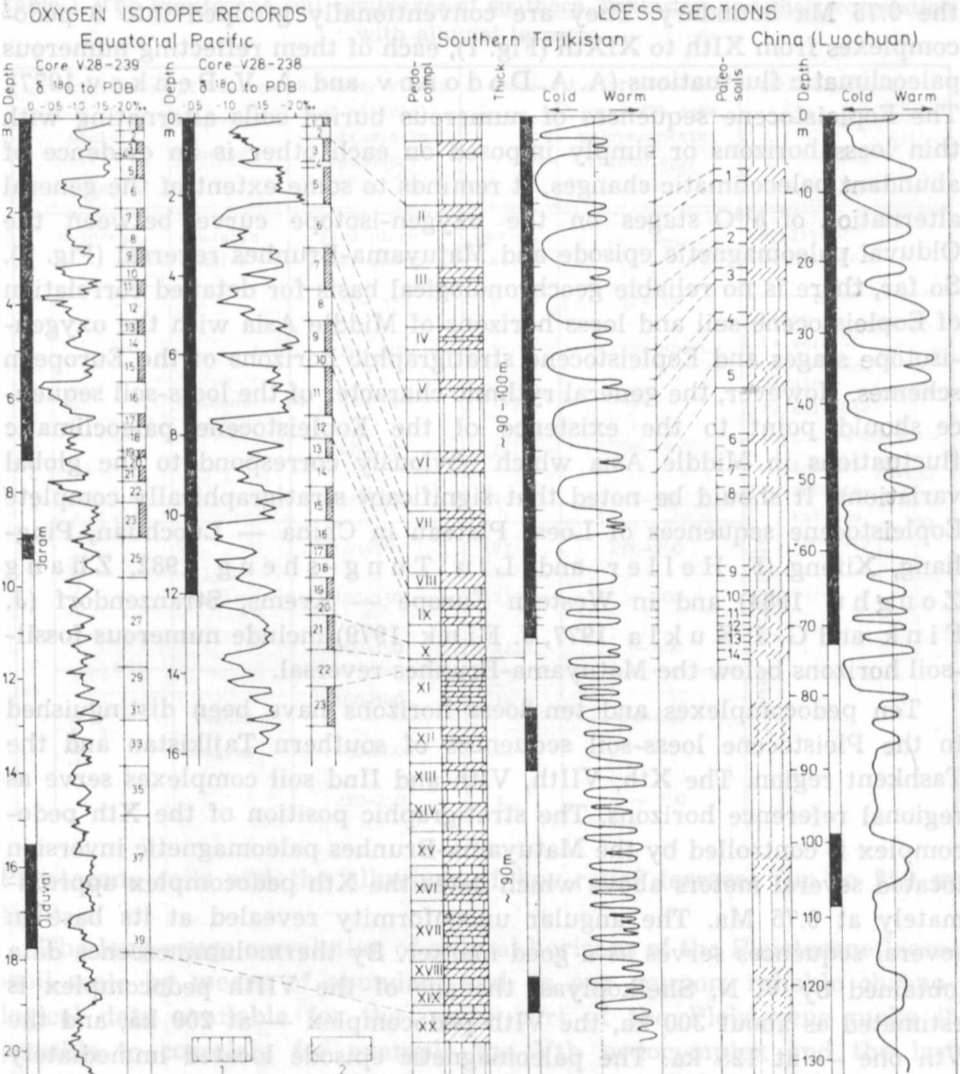

Fig. 2. Correlation of loess sequence of southern Tajikistan with oxygen-isotope data and loesses of China. The stages 1—23 after N. Shackleton and N. Opdyke (1976), the stages below 24th after Van Donk (1976). The loess section Luochuan after Wen Qizhong et al. (1985), the loess section of southern Tajikistan after A. E. Dodonov and A. V. Pen'kov (1977)

1 — loess; 2 — fossil soils

The Eopleistocene loess-soil sequence of Middle Asia comprise a considerable number of red-brown and brown paleosols. The most complete subaerial sequence of southern Tajikistan — Chashmanigar — includes 25 fossil soils from the base of the Olduvai paleomagnetic episode to the 0.75 Ma boundary. They are conventionally grouped into 9 pedocomplexes from XIth to XIXth (Fig. 1), each of them reflecting numerous paleoclimatic fluctuations (A. A. Dodonov and A. V. Penkov 1977). The Eopleistocene sequences of numerous buried soils alternating with thin loess horizons or simply imposed on each other is an evidence of abundant paleoclimatic changes. It reminds to some extent of the general alternation of $\delta^{18}O$ stages on the oxygen-isotope curve between the Olduvai paleomagnetic episode and Matuyama-Brunhes reversal (Fig. 2). So far, there is no reliable geochronological basis for detailed correlation of Eopleistocene soil and loess horizons of Middle Asia with the oxygen--isotope stages and Eopleistocene stratigraphic horizons of the European schemes. However, the general rythmic character of the loess-soil sequence should point to the existence of the Eopleistocene paleoclimatic fluctuations in Middle Asia which obviously correspond to the global variations. It should be noted that significant stratigraphically complete Eopleistocene sequences of Loess Plateau in China — Luochuan, Pingliang, Xifeng (F. Heller and Liu Tung-sheng 1982, Zhang Zonghu 1984) and in Western Europe — Krems, Stranzendorf (J. Fink and G. J. Kukla 1977, J. Fink 1979) include numerous fossil--soil horizons below the Matuyama-Brunhes reversal.

Ten pedocomplexes and ten loess horizons have been distinguished in the Pleistocene loess-soil sequences of southern Tajikistan and the Tashkent region. The Xth, VIIth, VIth and IInd soil complexes serve as regional reference horizons. The stratigraphic position of the Xth pedocomplex is controlled by the Matuyama-Brunhes paleomagnetic inversion located several meters above which dates the Xth pedocomplex approximately at 0.75 Ma. The angular unconformity revealed at its base in several sequences serves as a good marker. By thermoluminescence data (obtained by V. N. Shelkoplyas) the age of the VIIth pedocomplex is estimated as about 300 ka, the VIth pedocomplex — at 200 ka, and the Vth one — at 125 ka. The paleomagnetic episode located immediately above the Vth pedocomplex is considered to be a possible analogue of the Blake episode which fixes the upper age limit of the Vth pedocomplex. The paleomagnetic episode correlated with the Lashamp event (20 ka) is located above the IInd soil complex. Besides, the relatively well studied Paleolithic sites in the VIth (Karatau) and the Vth (Lakhuti) pedocomplexes correspond to the epoch of the ancient pre-Mousterian pebble culture and thus contribute to the paleosols dating (A. A. Lazarenko and V. A. Ranov 1977, A. A. Dodonov and V. A. Ranov 1976, A. A. Dodonov et al. 1978, V. A. Ranov 1980). Geochronology of the Pleistocene pedocomplexes can be therefore represented as shown in Table 1. The same Table illustrates the correlation of the

Table 1. The Pleistocene soil complexes of southern Tajikistan and their correlation with alluvial terraces

Stratigraphic scale ka		Lithostratigraphic units	Relative hights of alluvial terraces in piedmont m	Pedocomplexes	Age of pedocomplexes /TL data, paleomagnetic chronology/ ka	Archaeological cultures /by V.A.Ranov/	age in ka
Holocene		Amudarya complex	Flod plane /low, upper/	Recent soil	10	Neolithic Mezolithic	
— 10 —							
Pleistocene	Upper	Dushanbe complex	10–15	I	12–14	Upper Paleolithic	12–35
			20–30	II	22–40		
			35–50	III	40–50	Middle Paleolithic	35–75
			60–70	IV	70–90	Lower Paleolithic: Lakhuti industry	75–150
			80–90	V	110–130	Karatau industry	~200
— 130 —							
	Middle	Ilyak complex	100–110	VI	200–250		
			120–130	VII	~300		
			140–150	VIII	~400		
— 450 —							
	Lower	Vakhsh complex	160–180	IX a	~500–650		
			190–200	IX b			
			220–250	X	~750		

Pleistocene soils and the alluvium of low-relief terraces (up to 250 m high).

The long-range correlation of several horizons of the Pleistocene loess-soil scale by means of abundant and, in our opinion, reliable chronological data available for the upper part of the Pleistocene make it possible to correlate for example the Vth pedocomplex and the last climatic optimum (about 120 ka) or the 5e substage (125 ka) of the oxygen-isotope scale (Table 2). If we assume the age of the last interglacial (Riss-Würm, Mikulinian, Eemian) to be within 130—75 ka that is corresponding to the 5 stage of oxygen-isotope curve, the IVth pedocomplex and the loess horizon separating the Vth and IVth pedocomplexes should be included in this time interval. Table 2 shows the general correlation of the horizons of the Pleistocene loess-soil scale of Middle Asia with the similar subdivisions of the Eurasian regional scales and with the oxygen-isotope stages as well.

The beginning of the loess-forming processes in Middle Asia can be regarded as the geological event which marks the onset of continental

Table 2. Stratigraphic correlation of the Pleistocene loess-soil scale of southern Tajikistan with regional scales of Eurasia

STRATIGRAPHIC SCALE AGE Ma BP	PALEOMAGNETISM	EUROPE: ALPS	EUROPE: NORTH-WEST EUROPE	EUROPE: HUNGARY Paks, Mende (Pécsi 1984)	EUROPE: EUROPEAN PART OF THE USSR	OCEAN: $\delta^{18}O$ STAGES AGE ka BP (Shackleton, Opdyke 1976)	MID. ASIA: TAJIKISTAN Loesses and Pedocomplexes (Dodonov, Penkov 1977)	CHINA: LUOCHUAN Loesses and soils (Wen Quizhong et al. 1985)	
HOLOCENE		HOLOCENE	HOLOCENE	RECENT SOIL	HOLOCENE		RECENT SOIL	RECENT SOIL	
0,01; PLEISTOCENE; UPPER	BRUNHES	WÜRM III	WEICHSEL; ALLERÖD BÖLLING	LOESS; H_1 HUMUS, H_2 HUMUS	VALDAJAN OVER HORIZON; UPPER	1	LOESS; I PK	MALAN	
				LOESS		13; 2	LOESS	LOESS	
		WÜRM II	DENEKAMP (STILLFRIED B)	MENDE UPPER MF_1-MF_2	MIDDLE; BRYANSK SOIL	3	II PK	1-SOIL	UPPER LISHI
				LOESS			LOESS	LOESS	
			HENGELO MOERSHOOFD	BASAHARC DOUBLE BD_1-BD_2			III PK	2-SOIL	
		WÜRM I		LOESS	LOWER	4	LOESS	LOESS	
			BRÖRUP AMERSFOORT; STILLFRIED A	BASAHARC BASE BA	MEZIN SOIL COMPLEX	5 a b c	IV PK	3-SOIL	
				LOESS		5 d	LOESS	LOESS	
		RISS-WÜRM	E E M	MENDE BASE MB_1-MB_2	MIKULINIAN HORIZON	5 e	V PK	4-SOIL	
0,13; MIDDLE		RISS II	SAALE; WARTHE	LOESS	MOSCOVIAN HORIZON	128; 6	LOESS	LOESS	
		RISS I-II	TREENE	PAKS Phe	ODINTSOVIAN HORIZON	195; 7	VI PK	5-SOIL	
		RISS I	DRENTHE	LOESS, SAND	DNIEPRIAN HORIZON	251; 8	LOESS	LOESS	LOWER LISHI
		MINDEL-RISS	HOLSTEIN	ALLUVIAL FOREST SOIL Mtp	LIKHVINIAN HORIZON	297; 9	VII PK		
				SANDY LAYERS		10	LOESS		
						11	VIII PK		
		MINDEL	ELSTER		OKANIAN HORIZON	440; 12	LOESS		
				PAKS LOWER DOUBLE PD: PD_1		13	IX PK: IXa		
						14			
					KOLKOTOVIAN HOR.	15			
		GÜNZ-MINDEL	CROMER	LOESS	PLATOVIAN HORIZON	16	IX PK: LOESS		
				PD_2		17			
						18	IXb		
						19			
0,70; LOWER				LOESS		20	LOESS		
				PAKS-DUNAKÖMLOD PDK	MIKHAILOVKAN HORIZON	729; 21	X PK		
0,80; EOPLEISTOCENE	MATUYAMA	GÜNZ	MENAP	LOESS	MOROZOVKAN HORIZON	22	LOESS		

and arid climate. This event has occurred diachronously in different regions of Eurasia. However, we must bear in mind that the geochronological data concerning the age of the oldest loess generations are incomplete and that the oldest, so called stone loesses and the Pleistocene loesses are conventionally assumed to be adequate formations. The oldest stone loesses in southern Tajikistan formed at about 2.4—2 Ma ago (Fig. 3). In northern China the beginning of the loess-forming processes is dated at about 2.4 Ma (Zhang Zonghu 1984). In the south-east of the West Siberian Plain the age of the oldest loess (at the boundary of Kachkovian and Krasnodubrovian suites) is about 0.7—0.6 Ma (S. A. Arkhipov et al. 1982, I. A. Volkov and V. S. Zykina 1982). In Kashmir valey the loess mantle that contains no more than ten paleosols (D. P. Agrawal and A. B. Vora 1982) seems to be dated only within the Brunhes epoch. In the Potwar plateau in northern Pakistan the loess reach 60 m after H. De Terra and T. T. Pater-

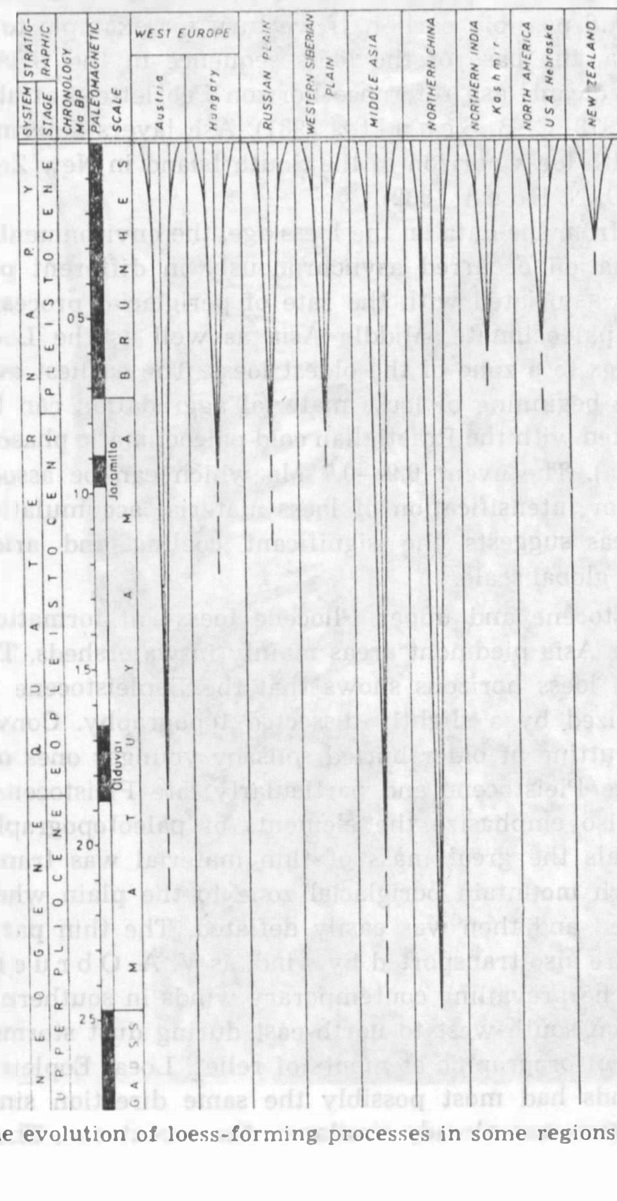

Fig. 3. The evolution of loess-forming processes in some regions of the Earth

s o n (1939). The geological setting of these loesses suggests their age to be confined to the Brunhes epoch time interval. The age of the oldest loess in the European part of the USSR is ascribed to the Eopleistocene/Pleistocene boundary (about 0.9—0.7 Ma) (I. P. G e r a s i m o v et al. 1980, V. N. S h e l k o p l y a s 1974). The thickest loess section Krems in Austria shows the loess and paleosol horizons as far deep as the Olduvai paleomagnetic event (J. F i n k and G. J. K u k l a 1977). In Hungary the loess began to be formed at 0.8—0.9 Ma ago (M. P é c s i 1984) though there occurred older loess-like deposits in the Great Hungarian Plain since 1.8 Ma and possibly earlier. If we turn for example to loess areas outside Eurasia, the base of the loess sequence in the USA, Nebraska is dated by a volcanic ash reference horizon Peorlette-0 at about 0.6 Ma (G. K u k l a 1978, C. B. S c h u l t z 1981). Ash layers determine the age of the oldest, 7th loess horizon of the South Island in New Zealand to be about 270 ka (D. N. E d e n 1982).

As follows from the data on the loess age, the environment favourable for their formation occurred asynchronously in different parts of the Earth and was associated with the rate of periglacial processes and the aridization of paleoclimate. Middle Asia as well as the Loess Plateau in China belongs to a zone of the oldest loess. The earliest event corresponding to the beginning of loess material aggradation can be approximately correlated with the Praetiglian cold paleoclimatic phase in Western Europe (2.4 Ma). The event 0.9—0.7 Ma which can be associated with the beginning or intensification of loess material accumulation in some continental areas suggests the significant cooling and aridization of paleoclimate in global scale.

The Eopleistocene and upper Pliocene loess-soil formation is developed in Middle Asia piedmont areas mainly in watersheds. The attitude of paleosol and loess horizons shows that the Eopleistocene watersheds were characterized by a slightly dissected topography. Convergence of paleosols and cutting of older buried soils by younger ones occurred on paleoslopes. The Pleistocene and particularly late Pleistocene loess and soil horizons also emphasize the elements of paleotopography. During mountain glacials the great mass of thin material was transported by rivers from high mountain periglacial zone to the plain where the silt was accumulated and then was easily deflated. The thin particles from desert areas were also transported by wind, as V. A. O b r u c h e v (1911) had observed. The prevailing contemporary winds in southern Tajikistan are blowing from south-west to north-east during dust storms to follow the main trend of orographic elements of relief. Local Eopleistocene and Pleistocene winds had most possibly the same direction since orographically the region was already similar to the recent one. The paleogeo-

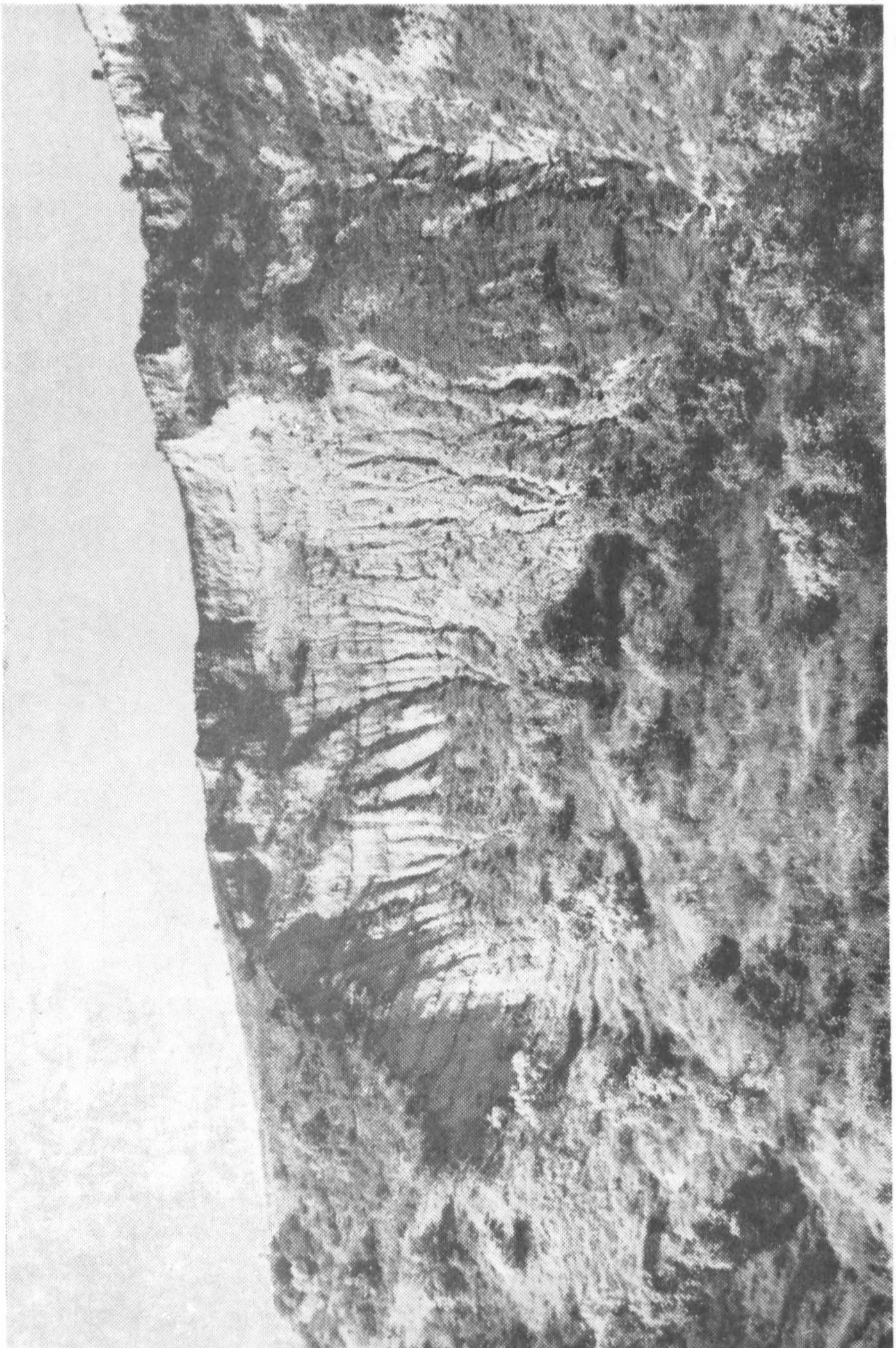

Photo 1. Loess outcrops Chashmanigar in southern Tajikistan

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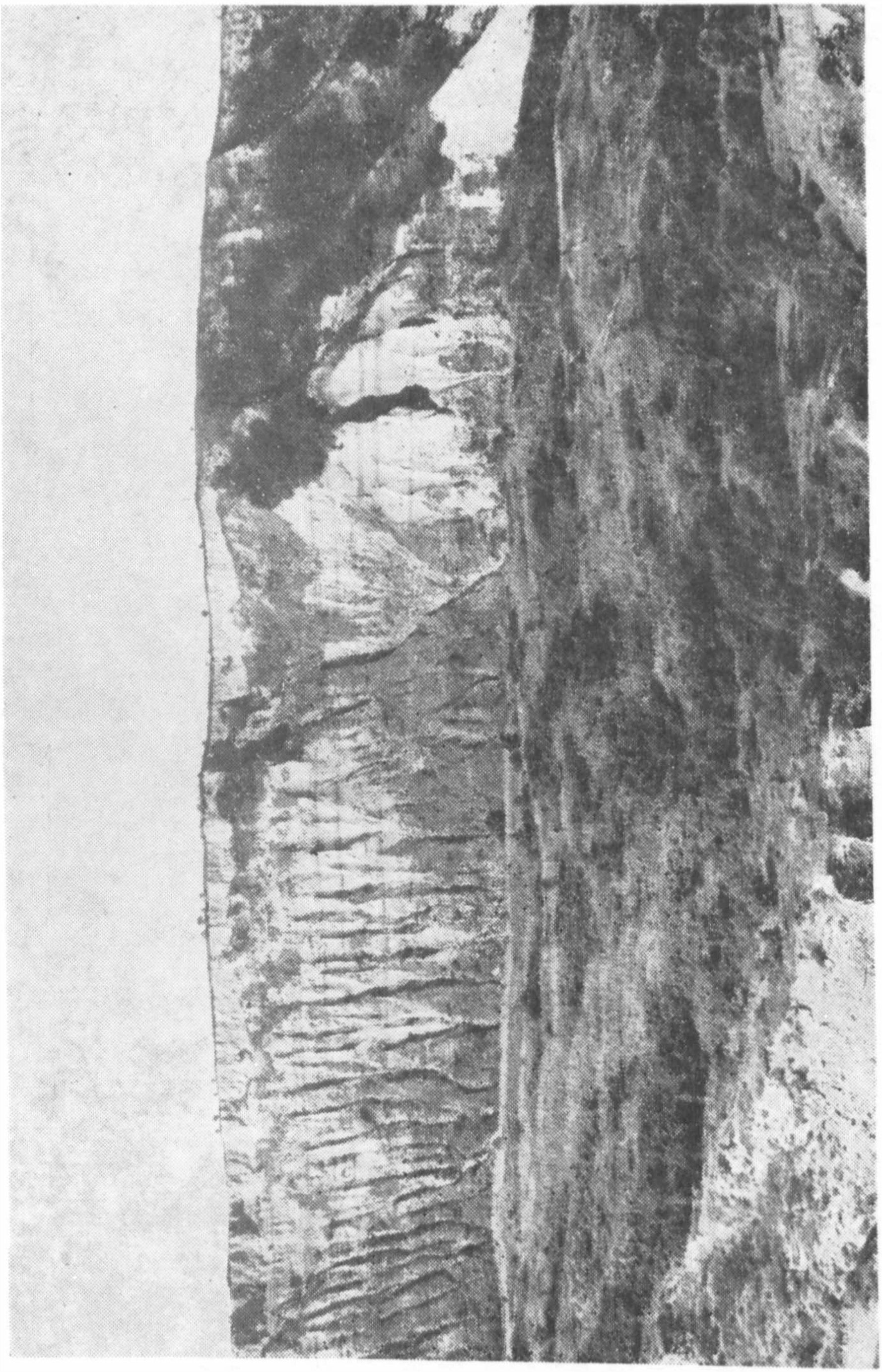

Photo 2. Loess outcrops Khonako in southern Tajikistan

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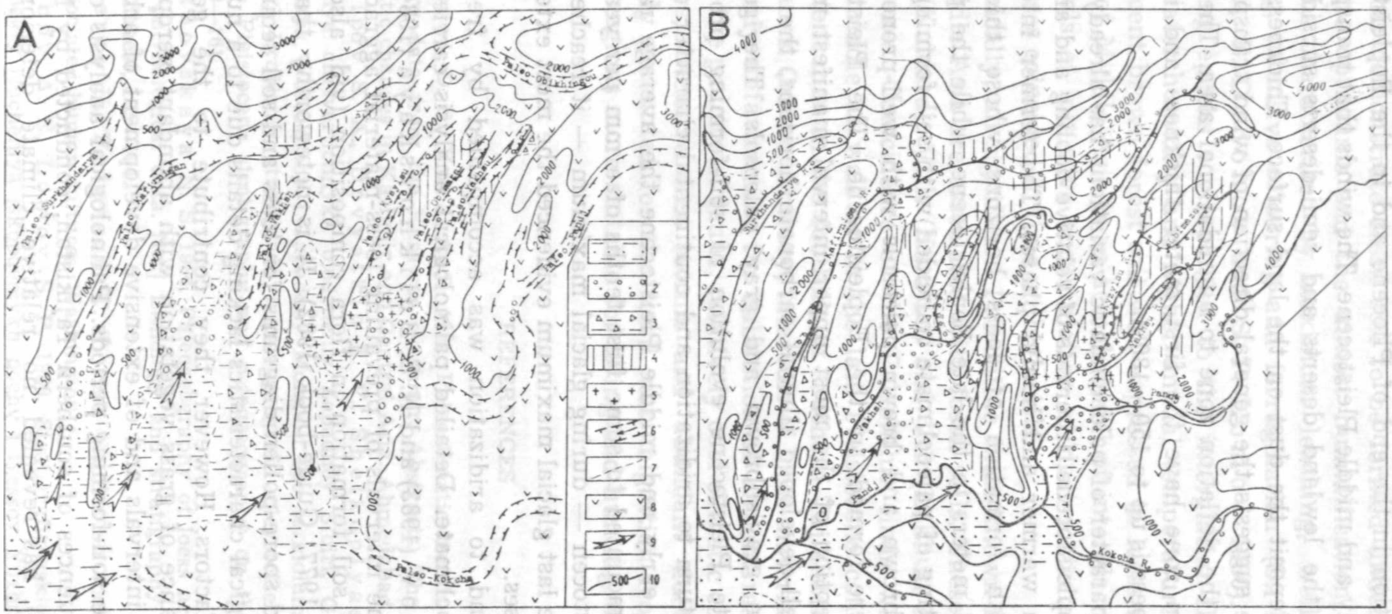

Fig. 4. Litho-paleogeographical schemes of southern Tajikistan: A — upper Pliocene-Eopleistocene, B — lower-middle Pleistocene

1 — sands with silt interbeds — alluvium of plain-valley accumulation zone; 2 — pebbles with sands — alluvium of mountain valleys; 3 — coarse material, silt — proluvium; 4 — loess-soil formations; 5 — intrusions of saliferous deposits; 6 — paleovalleys, the arrow shows the direction of river runoff; 7 — facial boundaries; 8 — pre-upper Pliocene rock complex; 9 — prevailing direction of winds transported thin material; 10 — paleoisohypses

graphic schemes of southern Tajikistan (Fig. 4) reflect the paleoenvironment of loess formation in the end of Pliocene and in the Eopleistocene as well as in the early and middle Pleistocene. The winds that transported thin material from the lowland deserts and semi-deserts subsided in piedmont areas to deposit the dust on the land surface. Thickness analysis of loess mantle suggests the general direction of wind transport of loess material from the deflation zone to aggradational area. The loess strata near deflation zone have the first meter thickness and in the aggradational area loess is up to 150—180 m.

The oscillatory character of paleoclimatic variations has already been manifested in the Eopleistocene. Intervals of relative cooling and aridization alternated with warmer and humid phases. The former intervals were associated with formation of loess horizons whose thickness amounted to several meters in the late Eopleistocene, while the phases of warming and wetting of paleoclimate coincided with soil-forming processes. Mainly red-brown and brown paleosols with well-pronounced calcrete horizons were formed in the Eopleistocene. The Pleistocene strata with the exception of the most upper interval manifest mainly brown soils with well-developed illuvial carbonate horizons, the upper Pleistocene — brown, grayishbrown and gray paleosols. The general Eopleistocene — late Pleistocene evolution of soil-forming processes reveals the gradual turn to aridization and continental character of the paleoclimate. In the early and middle Pleistocene the average rate of dust accumulation amounted to some first tenths of a mm per year; by the end of late Pleistocen — during glacial maximum — it reached 1—1.5 mm per year. The last glacial maximum evidenced the most extensive loess-forming processes.

The general trend to aridization was accompanied by frequent fluctuations of paleoclimate. Detailed palinological analysis carried out by M. M. Pakhomov (1983) and N. S. Bolikhovskaya (1984) has demonstrated that the intervals of prevailing loess-material aggradation differ from those of soil formation in flora composition (vid. also Excursions guide-book 1977, Guide-book 1982). It is noteworthy that the majority of published spore-pollen diagrams for loess and soil sequences demonstrate palinological characteristics lacking details due to a number of misrepresenting factors. However, they contribute to the general picture of predominance of grass vegetation with abundant xerophytes in the loess-forming intervals and of extensive development of arboreal vegetation during the soil-forming periods. Palinological analysis of vegetation in loess sequences of southern Tajikistan, conducted by M. M. Pakhomov (1983), has revealed no relative climate deterioration (cooling and more distinct continental features) during loess-forming intervals. However, the comparative pedological analysis of loesses and paleosols demonstrate fossil soil to be formed under conditions of temperature optimums and the utmost humidification, particularly in the horizons characterized by maximum leaching, well-expressed texture, claying, intensive colouring and ferrugination (S. P. Lomov et al. 1982, A. E. Dodonov and S. P. Lomov 1980). Therefore, the soil-forming epochs corresponded to the interglacial climate characterized by greater humidity and higher annual temperatures. The formation of the recent brown forest soil well-expressed in loess mantles in piedmont areas of Middle Asia is an actual model of interglacial environment. The intervals of intensive accumulation of dust material and loess-forming processes coincided in time with glacials.

Basically, all significant Paleolithic finds known from loess sequences in Middle Asia are associated with fossil soils. These are the sites in the XIth (Kuldara), VIth (Karatau) and Vth (Lakhuti and Khonako) pedocomplexes. Coincidence of the Paleolithic finds with paleosols in the early-middle as well as in the late Pleistocene confirms widespreading of ancient man in the foothills of southern Tajikistan during interglacial optimums. On the contrary, intervals of loess material accumulation were obviously unfavourable for habitation of ancient man. Extensive steppe zones, the paucity of fauna, relatively cool climatic conditions with severe winters, intensive dust storms and abundant dust accumulation has possibly accounted for the fossil man migration from the loess zone to other regions more suitable for living and hunting wild animals.

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STRESZCZENIE

Lessy i występujące wśród nich gleby kopalne w Azji Środkowej związane były z odpowiednimi zdarzeniami okresów glacjalnych oraz interglacjalnych. Wiek najstarszych lessów wynosi około 2,4—2,0 Ma. W interwale między początkiem Olduvai event (około 1,8 Ma) oraz inwersją na granicy paleomagnetycznych epok Matuyama-Brunhes (około 0,75 Ma) wydzielono 25 gleb kopalnych, które połączono umownie w dziewięć kompleksów glebowych — od XIX do XI. W ostatnim okresie liczącym 0,75 Ma wydzielono dziesięć kompleksów glebowych (od X do I) oraz dziesięć poziomów lessowych. Przebieg zmian paleoklimatycznych, rekonstruowany na podstawie wyników badań profili lessowych, charakteryzuje tendencja do ochłodzenia i wzrostu suchości (arydyzacji) klimatu, trwająca od późnego pliocenu do końca plejstocenu. Najwcześniejsza rubież, a mianowicie na początku sedymentacji lessów około 2,4 Ma, korelowana jest z początkiem chłodnego stadium Pretiglianu. Geochronologiczna rubież 0,9—0,7 Ma, z którą związany był w licznych regionach początek, a w innych wzmożenie tempa akumulacji lessowego materiału, oznacza przejście do etapu znaczącego ochłodzenia i arydyzacji klimatu w skali globalnej. Maksimum ostatniego glacjału było okresem najpowszechniejszego rozwoju akumulacji lessów.

РЕЗЮМЕ

В Средней Азии горизонты лёссов и ископаемых почв ассоциируются соответственно с ледниковыми и межледниковыми событиями. Самые древние лёссы имеют возраст около 2—2,4 млн. лет. В интервале между основанием палеомагнитного эпизода Олдувей и инверсией Матуяма-Брюнесс выделяется 25 ископаемых почв, которые условно объединяются в девать педокомплексов с XI

по XIX. Десять педокомплексов и десять горизонтов лёссов устанавливаются за последние 0,75 млн. лет. Палеоклиматический тренд, реконструируемый по лёссово-почвенным разрезам, показывает усиление похолодания и аридизации с позднего плиоцена до конца плейстоцена. Самый ранний рубеж начала лёссообразования — 2,4 млн. лет — коррелируется с началом холодной стадии претиглия. Геохронологический рубеж 0,9—0,7 млн. лет, с которым в ряде районов суши связано начало или усиление накопления лёссового материала, отражает значительный этап увеличения похолодания и аридизации палеоклимата в глобальном масштабе. Последний ледниковый максимум был временем наиболее широкого развития процессов лёссообразования.