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Magnetostratigraphy of the Pleistocene loess-palaeosol sequences in Ukraine and Moldova: a historical overview and recent developments

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The loess-palaeosol sequences of Ukraine and Moldova contain one of the longest and most complete terrestrial records of Pleistocene climate change in Europe. Magnetostratigraphic studies provide a first-order chronological framework for loess sequences. The literature on loess magnetostratigraphy by Ukrainian authors from the 1960s to present is vast; however, it is rather inaccessible to international readers. In this review, we summarize historical stages of the magnetostratigraphic studies in Ukraine and Moldova, and present recent developments in loess magnetic stratigraphy, including pedostratigraphy based on magnetic susceptibility variations. We highlight recent progress in the determination of the Matuyama–Brunhes boundary in the Ukrainian loess and discuss future prospects for studies of loess magnetism. In particular, mismatches between the positions of palaeomagnetic reversal boundaries (e.g., the Matuyama–Brunhes boundary, the Gauss–Matuyama boundary) and the corresponding pedostratigraphy are discussed in detail.

Key words: Quaternary, eastern Europe, loess, palaeomagnetism.

INTRODUCTION

The vast expanses of loess-palaeosol sequences in Ukraine and Moldova make these deposits a unique continental archive of palaeoclimate variations over different time scales since at least the late Pliocene (Veklich, 1968, 1982). However, in the Lower–Middle Pleistocene loess sequences, magnetostratigraphy is almost the only technique that enables development of a first-order chronological framework (Liu et al., 2015; Song et al., 2018). Once a robust magnetostratigraphy has been obtained, correlation of magnetic susceptibility records of loess and marine oxygen isotope (marine isotope stage, MIS) records (Heller and Liu, 1984; Kukla et al., 1988; Jordanova and Petersen, 1999; Marković et al., 2015; Necula et al., 2015) can be established.

The Matuyama–Brunhes boundary (MBB), the last palaeomagnetic reversal, which occurred at 780 ka (Shackleton et al., 1990; Tauxe et al., 1996) or at 773 ka according to more recent data (Channell et al., 2020; Head and Gibbard, 2015), is correlated with MIS 19. The Gauss–Matuyama boundary (GMB) at 2.58 Ma is another important calibration point, indicating the Neogene/Quaternary boundary on the geological timescale (Suc et al., 1997).

Magnetostratigraphic study of the Ukrainian and Moldovan loess-palaeosol deposits had started by Ukrainian researchers – O. Tretyak and team – in 1962 (in Tretyak, 1967), twenty years before the well-known magnetostratigraphic study of the Chinese loess by Heller and Liu (1982). Although the Ukrainian–Moldovan loess succession is one of the longest and most continuously deposited terrestrial sedimentary archives in the world, comprehensively studied by different methods, much of the literature generally, and on the magnetostratigraphy in particular, is inaccessible to international readers. In this paper, we aim to gather and synchronise all existing data on previous geomagnetic and palaeomagnetic research on Ukrainian and the adjacent Moldovan loesses, including developments using new approaches achieved in recent years. Especially, we highlight progress in magnetic susceptibility correlations and determination of the MBB position in Ukrainian loess.

OVERVIEW OF THE HISTORICAL DEVELOPMENT OF LOESS LITHOSTRATIGRAPHY

Ukraine and Moldova are located in the temperate climatic belt, only the southern Crimean coast being located in the subtropical belt. The loess-palaeosol succession of Ukraine occu-

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Fig. 1. Pleistocene formations and reference loess-palaesol sites in Ukraine and Moldova according to Veklich (1982) and Veklich and Veklich (1993)

The extent of the penultimate glaciation according to Ehlers et al. (2011); red circles/blue arrows mark the location of sites of stratotype stratigraphic palaeosol/loess units (Fig. 2)

pies more than 70% of its territory, and the loess-palaeosol succession of Moldova occupies up to 95% of its area (Veklich, 1968, 1982; Haase et al., 2007; Lehmkuhl et al., 2021; Fig. 1). The loess deposits include stratigraphically complete sequences of the Lower, Middle and Upper Pleistocene up to 60 m thick, which form one of the most comprehensive terrestrial palaeoenvironmental archives in Europe.

The alternation of loess and palaeosol units provided the basis for elaboration of the first Pleistocene stratigraphic scheme of the loess succession in Ukraine (Krokos, 1926), which included 5 loess units and 4 soil units. A more complete stratigraphic framework of the Quaternary deposits of Ukraine, in which 11 loess units and 10 soil units are described (Fig. 2), was created by Veklich (1968, 1982, 1995), Veklich et al. (1967, 1984, 1993) and Sirenko and Turlo (1986) on the basis of multidisciplinary study of more than 100 Quaternary sites. This framework was then further developed (Gozhik et al., 1995; Gerasimenko, 2004, 2006, 2010; Lindner et al., 2004, 2006; Matviishyna et al., 2010; Gozhik and Gerasimenko, 2011; Gozhyk, 2012). This scheme was also applied to Moldovan loess sequences (Veklich, 1968; Veklich and Veklich, 1993; Adamenko et al., 1996).

A multidisciplinary palaeogeographical approach was used to build the framework. It includes the following methods of palaeoenvironmental study: lithology, palaeopedology (including micromorphology), clay mineralogy, sedimentology, palaeogeomorphology, mammal faunas, mollusc faunas, pollen, cryolithology, luminescence and radiocarbon dating, palaeomagnetism, rock magnetism, and, finally, palaeoclimatology and palaeolandscape analysis (Gozhik et al., 1995, 2000, 2007; Matviishina et al., 2001; Rousseau et al., 2001; Gerasimenko, 2004, 2006, 2010; Lindner et al., 2004, 2006; Łanczont and Boguckyj, 2007; Buggle et al., 2008, 2009; Smalley et al., 2008; Boguckyj et al., 2009; Bokhorst et al., 2009; Matviishyna et al., 2010; Gozhik and Gerasimenko, 2011; Bogucki et al., 2013; Łanczont et al., 2014, 2015, 2019, 2022; Haesaerts et al., 2016, 2020; Komar et al., 2018; Bonchkovskyi, 2019, 2020; Gerasimenko and Kovalchuk, 2019; Karmazinenko, 2019; Matviishyna and Doroshkevych, 2019; Sirenko, 2019; Veklych, 2019; Manyuk, 2021; Matoshko, 2021; Popiuk et al., 2021 and many others). However, unlike synchronised geochronological data across neighbouring European loess sites (Moska et al., 2022; Sümegi et al., 2022 and references therein), many luminescence and radiocarbon dating results obtained at Ukrainian sections remain contradictory (Gozhik et al., 2000; Fedorowicz et al., 2012, 2013; Wulf et al., 2016; Constantin et al., 2019; Tecsa et al., 2020; discussed in Hlavatskyi and Bakhmutov, 2020).

In northern Ukraine, the Dnipro unit is the main stratigraphic marker in the Ukrainian Pleistocene stratigraphy: it contains till of the Saalian glaciation; whereas in the south, the Dnipro unit is typically represented by the thickest loess unit (Gozhik and Gerasimenko, 2011). For a detailed description of stratigraphic units of the loess-palaeosol succession of Ukraine with litho-

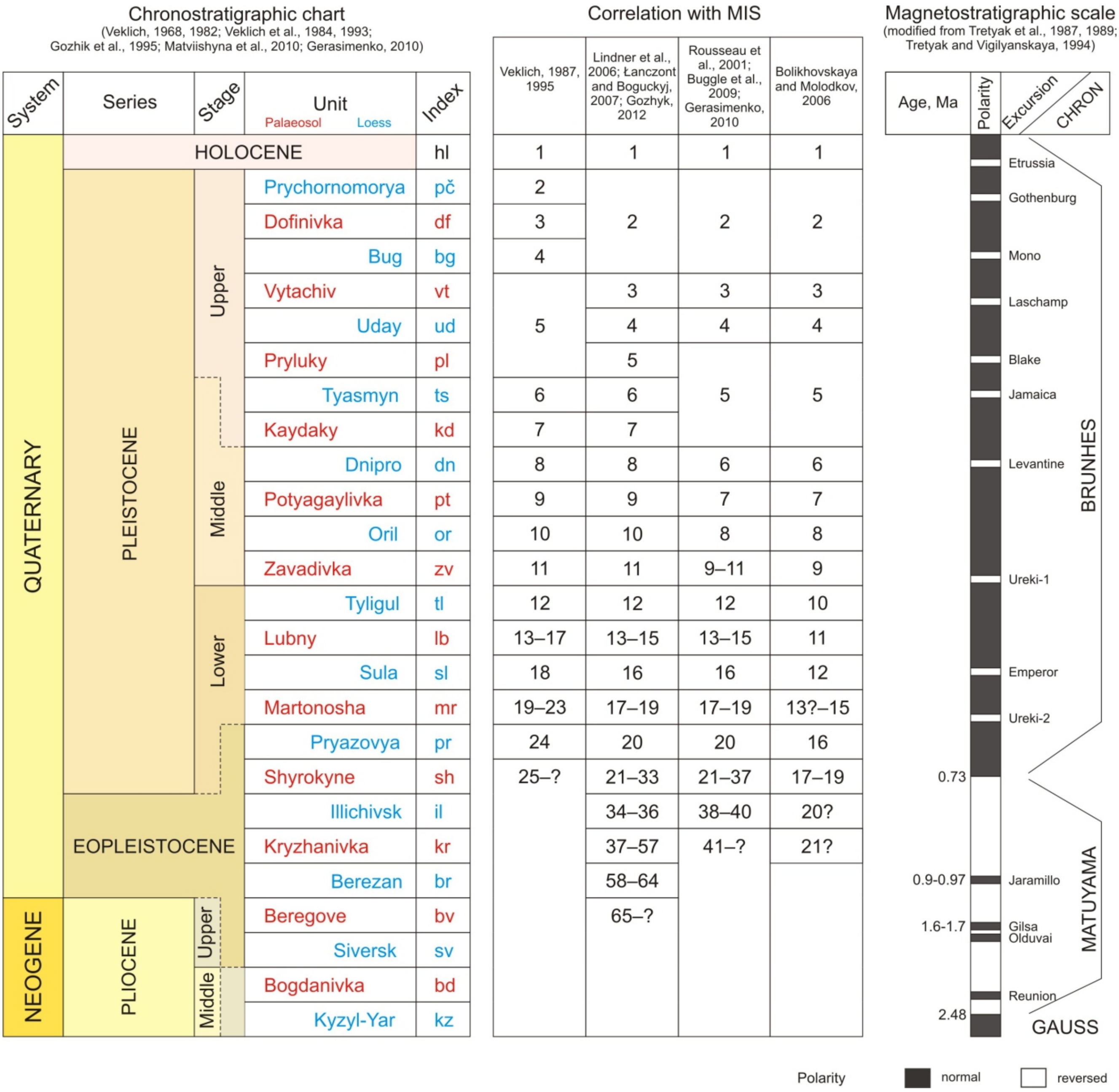

Fig. 2. Stratigraphic framework of the Quaternary deposits of Ukraine and Moldova, their relation to marine isotope stratigraphy according to different authors, and the former geomagnetic polarity scale, representing palaeomagnetic boundaries and ages according to the data of Tretyak et al. (1989)

pedological and magnetic properties, see Gozhik and Gerasimenko (2011) and Hlavatskyi and Bakhmutov (2020).

Several tens of reference Quaternary sections in Ukraine had been selected as stratotypes and parastratotypes for the stratigraphic framework (Veklich, 1982; Fig. 1).

The stratotype of the Quaternary deposits in Ukraine (and stratotype of the Kaydaky unit) was described from the Stari Kaydaky section (48°22' N, 35°07' E; Veklich and Sirenko, 1972; Veklich, 1982), 10 km south of the city of Dnipro (Fig. 1). It contains all stratigraphic units of the stratigraphic framework of the Quaternary deposits of Ukraine (Veklich et al., 1984, 1993), studied in several sub-sections (the integrated thickness of the succession is 59 m).

The parastratotype of the Quaternary deposits in Ukraine (and stratotype of the Lubny and Sula units) was described from the Vyazivok section (49°57' N; 32°57' E; Veklich et al., 1967; Veklich, 1968), 8 km south of the city Lubny (Fig. 1). It is the most stratigraphically complete section in the Dnipro Lowland (Veklich et al., 1967; Veklich, 1968, 1982; Matviishina et al., 2001; Rousseau et al., 2001; Haesaerts et al., 2016). This section is 59 m thick and includes eight well-developed palaeosol units (including the Kryzhanivka unit) which alternate with loess units.

Since the 1970s, the loess outcrop at Roksolany (46°11'N; 30°26'E) has been recognised as one of the most complete Quaternary records in the Black Sea area (Tretyak and Volok, 1975; Gozhik, 1976). The 55 m thick section includes extraordinarily thick loess units and nine palaeosol units. The section is one of the most studied loess sites in the region, attracting the attention of many research groups, including palaeomagnetologists (described below).

The older loess succession of the stratotype of the Kryzhanivka unit and the Kuyalnyk deposits was studied from the section at Kryzhanivka village (46°33' N; 30°47' E), east of

Table 1

Criteria for dividing the magnetostratigraphic research in Ukraine and Moldova into three main stages in view of the development of palaeomagnetic methods and equipment (see text for explanation)

Stages of magnetostratigraphic studies		Early (1962–1994)	Middle (1995–2012)	Modern (2013–present)
Palaeomagnetic equipment used (on the samples from Ukraine and Moldova)	MA-21 astatic magnetometer	+		
	LAM-22 astatic magnetometer	+	+	
	JR-4 spin-magnetometer		+	+
	JR-6 spin-magnetometer			+
	JR-6A spin-magnetometer		+	+
	DC SQUID magnetometer			
	Furnace in Helmholtz coil (20–300°C)	+		
	AF demagnetiser in Helmholtz coil (up to 60 mT)	+	+	+
	MMTD80 furnace		+	+
	LDA-3A AF demagnetiser		+	+
	Shielded room			
Applied types of demagnetisation	Thermal	+	+	+
	Alternating field	+	+	+
	Chemical	+		
Application of rock magnetic and auxiliary techniques	Magnetic mineralogy		+	+
	Coercivity		+	+
	Mössbauer spectroscopy	+	+	
	Magnetic susceptibility correlations		+	+
	AMS		+	+
	U-Pb provenance of detrital zircons			+
Regions studied	Western Ukraine	+	+	+
	Central Ukraine	+	+	+
	Southern Ukraine	+	+	+
	Eastern Ukraine	+	+	
	Moldova	+	+	
International research teams involved from…	Western Europe		+	+
	Russia	+	+	
Number of loess sections with the detected…	MBB (Ukraine/Moldova)	5/2	11/1	4/0
	GMB (Ukraine)	2	1	0

Odesa (Veklich, 1968). It includes 34 m of well-stratified Kuyalnyk (subaqueous equivalent of the Beregove unit) to Zavadivka deposits.

The Pliocene and Lower Pleistocene deposits are best distinguished at the Beregove section (44°54' N; 33°36' E), 30 km north of Sevastopol, on the western Crimean shore. This section is the stratotype of the Beregove unit and it includes a 36 m thick succession from the Yarkiv to the Berezan deposits (Veklich, 1982).

The loess sequences in Moldova, Hagimus (46°47' N; 29°30' E), Etulia Nouă (45°31' N; 28°26' E) and many others were also studied by Ukrainian loess researchers (Veklich, 1968; Veklich and Veklich, 1993; Adamenko et al., 1996). In terms of stratigraphic completeness and thickness (up to 50 m), these sections are equal to most Ukrainian reference sections.

In the last few years comprehensive sedimentological (Matoshko et al., 2019) and palaeomagnetic studies (Hlavatskyi and Bakhmutov, 2021; Bakhmutov et al., 2021) were conducted on the Dolynske section (45°30' N; 28°18' E) at the Lower Danube River, southern part of Ukraine. The palaeomagnetic studies focused on the alternation of palaeosols, loesses and pedosediments in the Bogdanivka to Dnipro units, exposed in three sub-sections, in total up to 30 m thick. The stratigraphic completeness of the Dolynske section, its geomorphological location within the Pliocene Danube terraces, and convenient geographical setting, qualify it to be one of the reference sections for the loess-soil succession in Europe. In addition, the lowermost Dolynske 3 sub-section may be regarded as a continental analogue of the Calabrian and Gelasian, potentially including both palaeomagnetic boundaries (Hlavatskyi et al., 2022a, c).

HISTORY OF MAGNETOSTRATIGRAPHIC STUDIES

The 60 years of the magnetostratigraphic study of the Ukrainian–Moldovan loess, as the palaeomagnetic techniques developed (see Table 1), can be divided into three main stages:

(1) The first stage is the early times of palaeomagnetic research of loess, from 1962 until the publication of the composite Pleistocene magnetostratigraphic scale of Ukraine (Tretyak and Vigilyanskaya, 1994). The first stage is separated into two phases. The first phase (1962–1975) was a time of field reconnaissance of loess exposures, extensive study of loess magnetism, recognition of mineral-carriers of natural remanent magnetisation (NRM), and the development of the main principles of palaeomagnetic stratigraphy. A detailed investigation of the fine structure of the geomagnetic field, the construction of the first regional Cenozoic magnetostratigraphic scales and the resolution of issues in the palaeomagnetic stratification of the loess-palaeosol sequences were the focus of the second phase (1976–1994).

(2) The second stage (1995–2012), the most extensive period of loess magnetic research, was the continuation of

in-depth research aimed at determination of the MBB and GMB by the Ukrainian research teams, and the rise of international involvement which brought new methods including magnetic susceptibility stratigraphy, usage of SQIUD magnetometers and novel software tools. The first stratigraphic correlation of the Ukrainian–Moldovan loess using magnetic susceptibility with other loess records in the world and with marine oxygen isotope stages was the focus of the second stage.

(3) The third stage (2013–present), which was preceded by a hiatus in research by international teams, is characterised by recent resumption of palaeomagnetic and rock magnetic research, published in high-profile journals and at international conferences. The main aim of the studies was the resolution of the problem of correlation of some key sections in the glacial and non-glacial zones and credible determination of the MBB in the loess cover of Ukraine. Different western European research groups carried out study on loess magnetism as a palaeoclimate proxy. Recently published studies by the authors of this paper are part of this third stage.

EARLY PERIOD (1962–1994): FOUNDATION

The first palaeomagnetic study of the upper Neogene (formerly named as late Tertiary) and Quaternary deposits of Ukraine and Moldova was started by the Ukrainian research team headed by O. Tretyak in 1962 (in Tretyak, 1967) at the Institute of Geophysics of the NAS of Ukraine (Kyiv). O. Tretyak was thus a pioneer of the palaeomagnetic investigation of loess.

The first palaeomagnetic measurements on loess as well as its magnetostratigraphic interpretation were applied by Tretyak (1967) on samples collected from the loess sites in southern Moldova (Slobozia Mare, Cîşliţa-Prut sections and Beleu lake), the Odesa suburbs (Khadzhybey Estuary, Kryzhanivka), Crimea (Cape Tarkhankut, Beregove), and the Dnipro River (Stari Kaydaky; Fig. 3). In successive studies, O. Tretyak and team studied more than 60 key loess-palaeosol sequences in Ukraine and Moldova (Tretyak, 1972, 1980, 1983; Tretyak and Volok, 1974, 1975, 1976, 1982; Dudkin, 1983; Tretyak et al., 1987, 1989; Fig. 3).

A distinct feature of these studies was large-scale fieldwork including continuous sampling and many laboratory measurements of duplicate specimens, using thermal and alternating field demagnetisation procedures. Continuous sampling was carried out with a resolution of 5 cm and cubes with an edge of 5 cm were made directly at study sites. The samples were measured using astatic magnetometers (LAM-22 and MA-21) at the Kyiv palaeomagnetic laboratory (located in the village of Demydiv, 35 km north of Kyiv). For the standard procedure of thermal and alternating field demagnetisation in non-magnetic space (Helmholtz rings) equipment produced in the Institute was used. However, during the measurements by astatic magnetometers, it was impossible to isolate the specimens from the influence of the geomagnetic field, which contributes to the formation of viscous magnetisation (caused by superparamagnetic grains). If the superparamagnetic component made a significant contribution to the magnetisation of the samples (especially in palaeosol layers from the southern regions), the results of determining the direction of primary magnetisation after magnetic cleaning were not considered as reliable and were excluded from further interpretation (Tretyak, 1983).

Iron minerals were considered as carriers of rock NRM and their magnetic characteristics were studied (Tretyak, 1983). Theoretical and methodological developments were used to justify the technique of systematic temperature cleaning of the magnetisation of sedimentary rocks (Tretyak, 1967, 1983). In addition, mechanisms of chemical remanent magnetisation and its diagnostic signs were thoroughly studied (Tretyak, 1983).

Special attention was paid to the development of magnetostratigraphic scales in sedimentary rocks. As the Brunhes chron geomagnetic excursions (including those recorded in subaerial deposits) were actively studied at the time (see Petrova et al., 1990, 1992 and references therein), the “fine structure” of the geomagnetic field in the Pliocene–Pleistocene was analysed (Tretyak, 1983; Dudkin, 1983; Tretyak et al., 1987), and on this basis, a regional palaeomagnetic stratigraphic scale of the Pliocene-Quaternary deposits of Ukraine and Moldova was developed (Tretyak et al., 1989; Tretyak and Vigilyanskaya, 1994).

In the early magnetostratigraphic studies (Tretyak and Volok, 1975, 1976, 1982; Tretyak, 1980, 1983), following the geomagnetic polarity scale of Cox (1969), the position of the MBB in the Ukrainian–Moldovan loess sequences was not clear: it was initially inferred to be in the Berezan loess, the upper or lower part of the Sula loess, or the Lubny palaeosol. For instance, at Hagimus (eastern Moldova) as well as at Urzuf (Azov Lowland), the Matuyama/Brunhes reversal was initially identified in the upper part of the Sula loess unit (Tretyak, 1983). However, based on the thorough study of other southern Ukrainian and Moldovan key sections (e.g., Kryzhanivka, Etulia Nouă) the MBB was detected in the Shyrokyne palaeosol (e.g., Tretyak et al., 1987, 1989; Fig. 4). Consequently, it was suggested (Tretyak and Vigilyanskaya, 1994) that the Shyrokyne soil unit represents the first interglacial within the Brunhes chron.

Initial palaeomagnetic studies at the Roksolany site, coupled with radiocarbon and thermoluminescence dating (Tretyak and Volok, 1975; Gozhik, 1976; Tretyak, 1980), did not detect the MBB; however, frequent changes of magnetic polarity were reported (Fig. 4). Tretyak et al. (1987, 1989) interpreted the palaeomagnetic data obtained at Roksolany as representing geomagnetic events (excursions) of an unstable geomagnetic field within the Brunhes chron.

In the Kryzhanivka section, Tretyak et al. (1987) found the MBB lay in the Shyrokyne unit (Fig. 4). In the mid-part of the 10 m thick Berezan unit a thin (1.0 m) normal polarity zone (overlying the 0.4 m thick red-brown clay layer br_2) was interpreted as the Jaramillo event (former age 900–960 ka).

In the Beregove section, the Gauss–Matuyama reversal was detected in the Kyzyl-Yar unit (Tretyak et al., 1987; Fig. 4). Also, a few zones of normal polarity within the Matuyama chron were identified and named by Tretyak et al. (1989) as the Reunion, Olduvai and Gilsa excursions (Fig. 2, right). The 1.5 m thick Berezan unit at Beregove is characterised by reversed polarity. However, the position of the GMB at Velyka Lanna (borehole 11, northern Donbas) was identified by O. Tretyak in the upper part of the Bogdanivka soil unit (Sirenko et al., 1993).

In 1968–1969 a few sections in southern Ukraine (e.g., Melekyne) and Moldova (Hagimus, Etulia Nouă and others) were studied by Russian palaeomagnetics workers (published in 1970–1973: Pevzner, 1970; Virina et al., 1971; Pospelova and Gnibidenko, 1972; Velichko et al., 1973a, b). Additionally, in 1978–1979 samples from loess sections located within the Dnipro Upland (Stayky, Muzychi, Vyshhorod etc.; S. Faustov and team in Veklich, 1982; Faustov et al., 1989), Middle Dnister basin (Kulikova, 1980), Kerch peninsula (Zubakov et al., 1982) were palaeomagnetically studied. Due to large sampling intervals, these studies were of a reconnaissance nature, in which general patterns of changes in the geomagnetic field were distinguished. A number of essential details were omitted, which affected the stratigraphic and magnetostratigraphic conclusions of the authors, in particular, on the division of the terrace successions of the river Dnister (Veklich, 1982).

In the first stratigraphic schemes of Ukraine (Veklich, 1982, 1987, 1995; Veklich et al., 1984, 1993) the MBB was linked to the upper part of the Martonosha soil unit (correlative

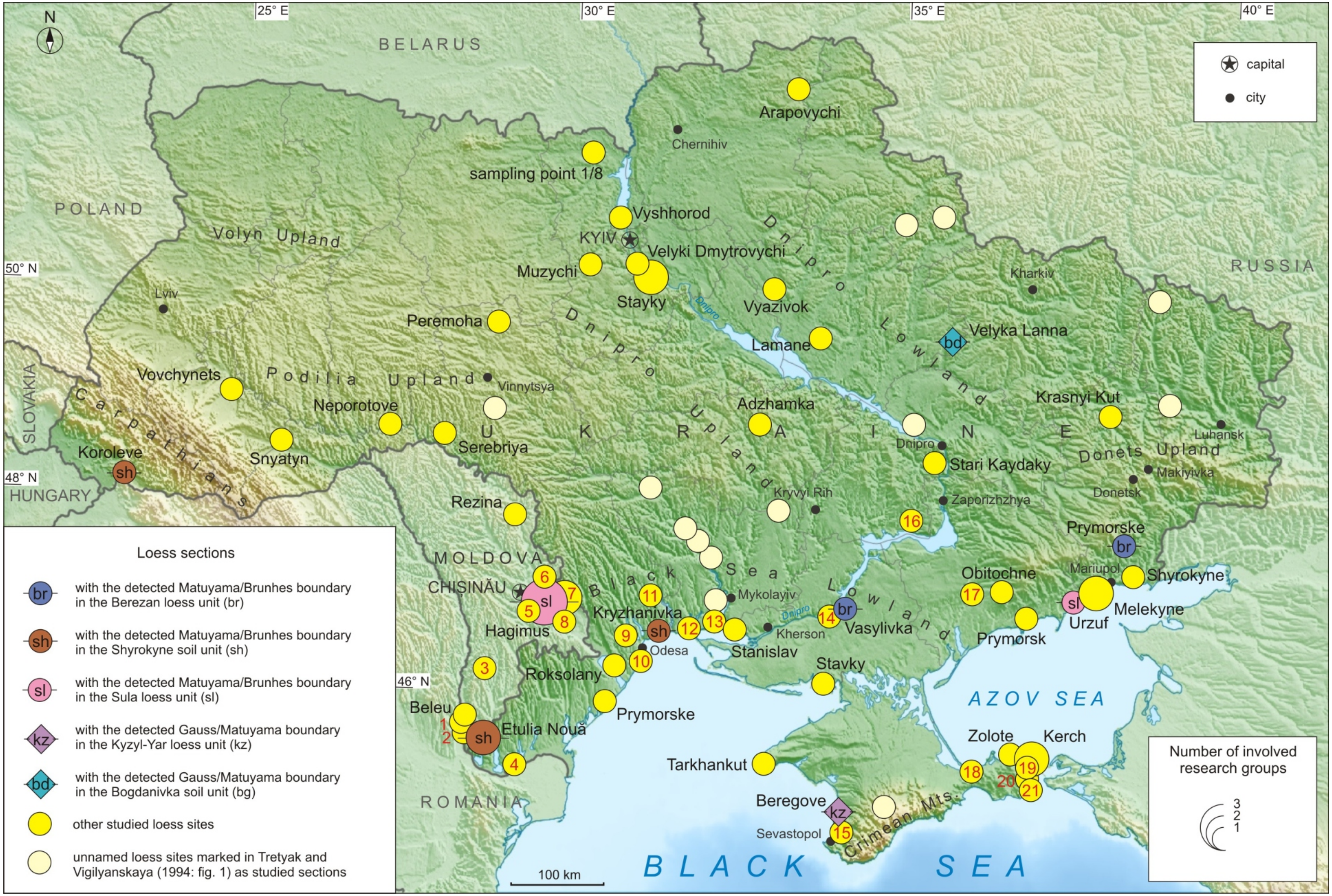

Fig. 3. Loess sites studied palaeomagnetically in 1962–1994 on the physical map of Ukraine and Moldova (adapted from Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Ukraine_relief_location_map.jpg)

Numbers on the map show sampling sites: 1 – Slobozia Mare; 2 – Cîşliţa-Prut; 3 – Baimaclia; 4 – sampling point 4/62 (hereafter designation of Tretyak, 1967); 5 – Fîrlădeni; 6 – Varniţa; 7 – Tiraspol (Kolkotova Balka section); 8 – Chiţcani; 9 – Khadzhybey Estuary; 10 – Chornomorsk; 11 – Tyligul Estuary; 12 – Rybakivka; 13 – Parutyne; 14 – Lyubymivka (Crimea); 15 – Lyubymivka (Kherson Oblast); 16 – sampling point 18/B; 17 – sampling point 2/63; 18 – Kamyanske; 19 – sampling point 7/63; 20 – sampling point 12/63; 21 – sampling point 6/63

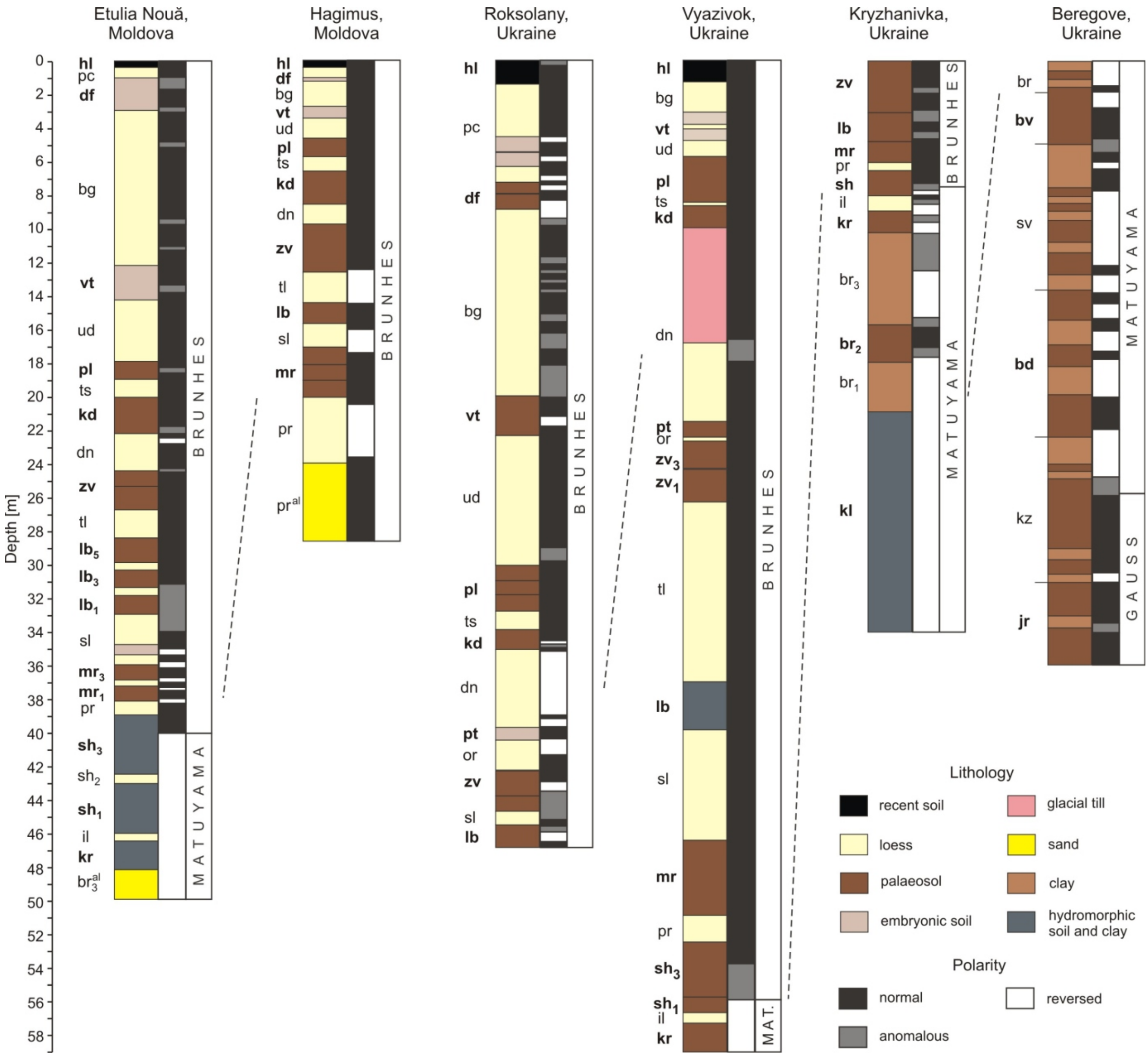

Fig. 4. Correlation chart of key loess sections of Ukraine and Moldova that have been studied palaeomagnetically (Tretyak, 1980, 1983; Tretyak et al., 1987, 1989; Vigilyanskaya, 2001)

kl – Kuyalnyk unit, jr – Yarkiv unit

of MIS 19–23; Fig. 2). The Pryazovya loess (MIS 24) and upper part of the Shyrokyne soil (MIS 25), characterised by normal polarity, were correlated by Veklich (1982, 1987) and Veklich et al. (1984, 1993) with the Jaramillo subchron, while others (Tretyak et al., 1987, 1989; Tretyak and Vigilyanskaya, 1994) considered them to be part of the Brunhes chron. There was also a significant difference in the interpretation of the position of the GMB. Veklich (1982) positioned this boundary (and the boundary between the Neogene and Quaternary) in the upper part of the Beregove unit, while Ukrainian palaeomagnetologists found the GMB in the Kyzyl-Yar loess unit in the Beregove stratotype section (Tretyak et al., 1987, 1989).

MIDDLE PERIOD (1995–2012): INTERNATIONAL COLLABORATION

The next important advance in palaeomagnetic study of these loess successions took place in the second half of the 1990s and the 2000s, when systematic magnetostratigraphic and rock magnetic studies in the western Black Sea region, Middle Dnipro region and Volyn-Podilia Upland were conducted by several international research teams.

Nawrocki et al. (1996) analysed and compared the magnetic susceptibility record in the western Ukrainian and Polish loess-palaeosol sequences. These authors concluded that the magnetic susceptibility varies mainly with the degree of decomposition of detrital magnetite grains, in turn conditioned by palaeoclimate. The susceptibility curves of the Boyanychi section in western Ukraine (Fig. 5) and some Polish loess sections were correlated with the oxygen-isotope fluctuations in deep-sea sediments established in Shackleton et al. (1990).

In Nawrocki et al. (1999), magnetic susceptibility records from the Volyn Upland (at Boyanychi), the Podilia Upland (Yezupil) and the Black Sea Lowland (Prymorske/Kurortne; Fig. 5) were compared. At Prymorske, a distinct magnetic susceptibility peak in the Zavadivka soil unit, in view of the thermoluminescence data of Gozhik et al. (1995), was corre-

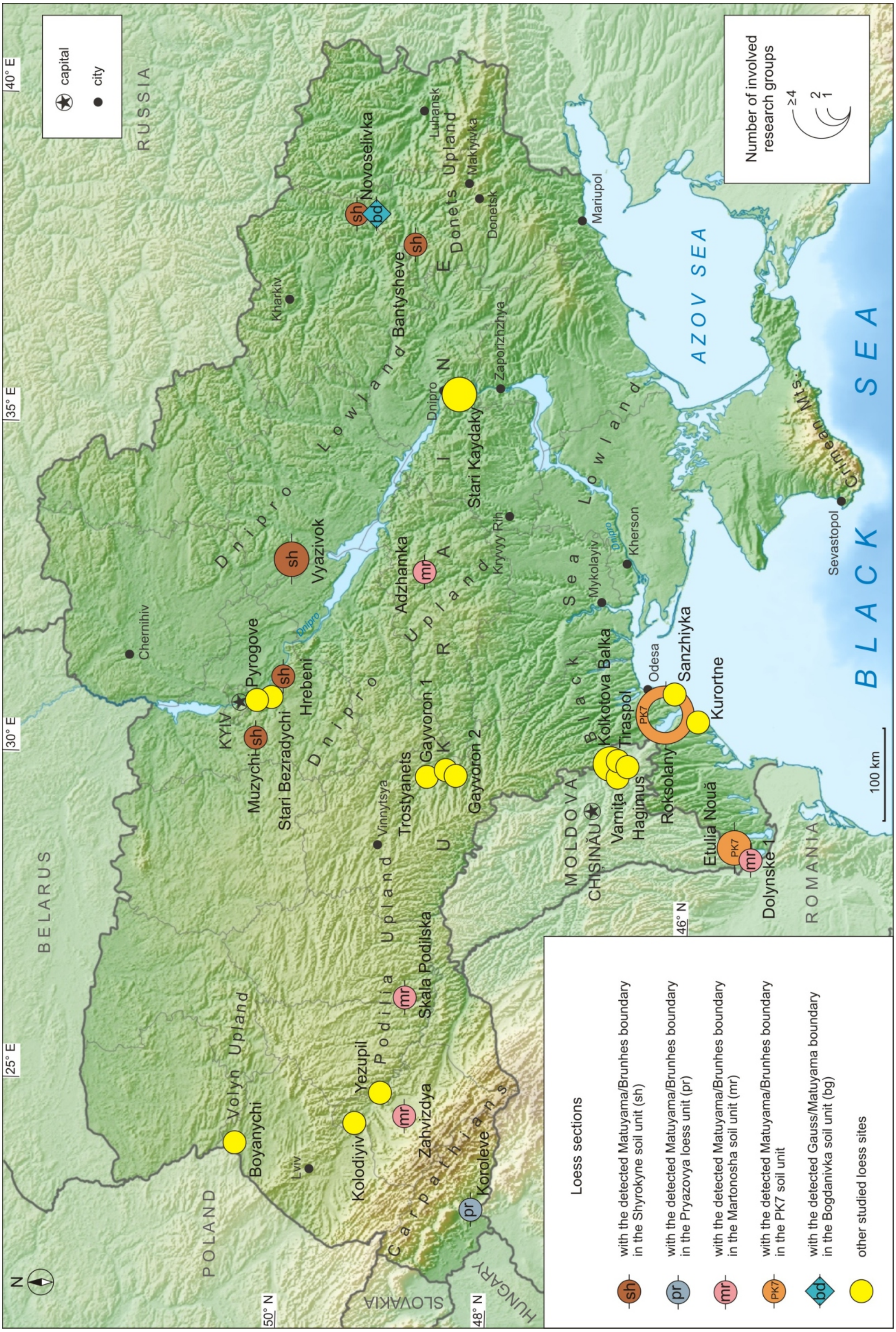

Fig. 5. Loess sites studied palaeomagnetically in 1995–2012

lated with the Holstein interglacial. A detailed palaeomagnetic investigation (above the Lubny unit) did not detect the presence of reversed polarity in the samples, indicating deposition of the succession studied after the Matuyama/Brunhes reversal.

Based on the combined results of investigations into key sections in Moldova (at Etulia Nouă, Kolkotova Balka) and southern Ukraine (at Roksolany), a chronostratigraphy, which differed from the previous ones, was proposed by Russian and other international workers (Heller et al., 1996; Tsatskin et al., 1998, 2001, 2008; Sartori, 2000; Evans and Heller, 2003; Gendler et al., 2006; Dodonov et al., 2006). Ukrainian scientists did not participate in these studies and Ukrainian stratigraphy, biostratigraphy and previous palaeomagnetic results were overlooked. According to Heller et al. (1996) and Tsatskin et al. (1998) the MBB at Roksolany was detected in the L6 loess unit which, according to previous interpretation (Gozhik et al., 1995), corresponds to the Tyasmyn unit (and MIS 6). Furthermore, Sharonova et al. (2004) and Pilipenko et al. (2005) identified three reversed-polarity episodes in the upper part of the section. At Etulia Nouă, the MBB was identified in the PK7 soil unit, which was correlated previously by Veklich and Veklich (1993) with the Lubny unit (MIS 13–17). Nonetheless, Tsatskin et al. (2001) correlated the L6 loess unit with MIS 20 and the PK7 soil unit with MIS 21. This magnetostratigraphic interpretation brought confusion to Ukrainian loess stratigraphy for many years (Gozhik, 2013).

In the Zahvizdya section in western Ukraine (Fig. 5), Nawrocki et al. (2002) identified the MBB in the Zahvizdya hydromorphic palaeosol labelled as S7 (which is comparable to the Martonosha unit). A correlation between the S7 palaeosol at Zahvizdya and the PK6 palaeosol of Tsatskin et al. (1998) at Roksolany, and, thus, MIS 19, was suggested (Nawrocki et al., 2002).

The anisotropy of magnetic susceptibility (AMS) of the youngest loess in western Ukraine was analysed and the prevailing palaeowind directions during the Weichselian were interpreted (Nawrocki et al., 2006). It was concluded for the first time that the Ukrainian loess deposits, like the Chinese and Alaskan loesses, appear suitable for application of the AMS method.

Palaeomagnetic studies of the Kolodiyiv loess section in western Ukraine (Fig. 5) have identified the Blake (118 kyr) and Laschamp (40 kyr) palaeomagnetic episodes (Nawrocki et al., 2007). The former was found in the upper soil of the last interglacial (Horokhiv, correlated with MIS 5e), while the Laschamp episode was identified in the upper part of the Dubno palaeosol unit (MIS 3).

In the Skala Podilska section (Podilia Upland; Fig. 5), the MBB was detected in the upper part of the alluvial deposits overlain by the Martonosha soil unit (S6; Boguckyj et al., 2009). Boguckyj et al. (2009) explained the stratigraphic position of the MBB in terms of the local geomorphological conditions of sediment accumulation, the peculiarities of the genesis of the alluvial facies, local redeposition of material, as well as significant epigenetic weathering of the sediments. In addition, in the uppermost part of the section at a depth of 0.5 m, in the near-surface chernozem-type soil, a reversed polarity direction associated with the Blake palaeomagnetic event was observed (Boguckyj et al., 2009).

Rousseau et al. (2001) used magnetic susceptibility as a tool in the chronostratigraphic interpretation of the Ukrainian loess sequence in the northern glaciated area. The low-field magnetic susceptibility, palynology and pedostratigraphy of the Upper Pleistocene sequence at Vyazivok were found to be very similar with those of the Vestonice section (Czech Republic). As a result, the Kaydaky soil unit of Vyazivok was correlated with MIS 5e (Rousseau et al., 2001).

In addition to the grain-size distribution and pedo-chemical elemental ratios, magnetic susceptibility as a proxy for precipitation (and temperature) was analysed from the Stari Bezradychi, Pyrogove (Middle Dnipro area) and Sanzhiyka (western Black Sea shore) loess sections and correlated with those in Serbia (Bokhorst et al., 2009). By the close similarity of the magnetic susceptibility records in the different loess sections, it was shown that these ratios reflect the effects of weathering intensity as a result of precipitation changes.

Buggle et al. (2008, 2009) based on the results of detailed geochemical, palaeopedological, pollen and magnetic susceptibility studies of the Stari Kaydaky section, correlated its late Middle–Upper Pleistocene interval with that in the Serbian and Romanian loess sites and with the global marine isotope record (Lisiecki and Raymo, 2005). Referring to very similar results from Vyazivok (Rousseau et al., 2001), the Kaydaky soil unit at Stari Kaydaky was correlated with MIS 5e. Below in the section, four interglacial soil units were described, Potyagaylivka, Upper Zavadivka, Lower Zavadivka and Lubny, which were correlated with MIS 7, MIS 9, MIS 11 and MIS 13–15, respectively. The palaeomagnetic investigation of this interval by V. Bakhmutov (in Buggle et al., 2009) corroborated that the succession was deposited during the Brunhes chron.

Magnetostratigraphic studies carried out by the Ukrainian research group continued. Vigilyanskaya and Tretyak (2000) and Vigilyanskaya (2001, 2002) described magnetostratigraphic data for several loess-palaeosol sequences located in the Middle Dnipro region and Donbas. The GMB was interpreted to be in the upper part of the Bogdanivka soil unit in the Novoselivka borehole (Vigilyanskaya and Tretyak, 2000), whereas the MBB was detected in the Shyrokyne soil unit in the Novoselivka borehole as well as at the Bantysheve, Muzychi, Grebeni and Vyazivok sections (Vigilyanskaya and Tretyak, 2000; Vigilyanskaya, 2001, 2002; Fig. 5).

Bakhmutov et al. (2005) conducted alternating field demagnetisation and thermal demagnetisation of samples from the Dolynske section. According to their interpretation, the MBB fits within the Lubny soil unit (according to the stratigraphic scheme of Veklich and Veklich, 1993), which was thus renamed as the Martonosha unit (Bakhmutov et al., 2005). Similar results were obtained from the loess section at Adzhamka (Dnipro Upland), where the MBB was interpreted to be located at the top of the Martonosha soil unit (Sirenko et al., 2008). However, at several Southern Bug valley sections (Gayvoron 1, Gayvoron 2, Trostyanets; Fig. 5), studied by V. Bakhmutov in 2008 (in Matviishyna, 2011), the MBB was not detected in the lowermost stratigraphic layers (Martonosha and Pryazovya units).

In stratigraphic schemes proposed for the Ukrainian Quaternary at the time, the MBB was placed in the lower part of the Martonosha unit (MIS 17–19; Gozhik et al., 2000; Lindner et al., 2004, 2006; Matviishyna et al., 2010; Gerasimenko, 2010; Gozhik and Gerasimenko, 2011; Gozhyk, 2012; Fig. 2). Despite the updated magnetostratigraphic data of Tretyak and Vigilyanskaya (1994), Vigilyanskaya and Tretyak (2000) and Vigilyanskaya (2001, 2002), the Pryazovya loess and upper part of the Shyrokyne soil, characterised by normal polarity, were still correlated by geologists with the Jaramillo subchron. Only one stratigraphic scheme of the loess-palaeosol succession of Ukraine, in which the Shyrokyne unit was equated with MIS 17–19 (Bolikhovskaya and Molodkov, 2006; Fig. 2), was in agreement with the palaeomagnetic studies. Another significant difference in the stratigraphic models proposed for the loess-palaeosol sequences of Ukraine (Fig. 2) was the chronological placement of the Kaydaky palaeosol unit and the Dnipro loess. In view of the new data, some authors (Rousseau et al., 2001; Vozgrin, 2001; Gerasimenko, 2004, 2006, 2010;

Bolikhovskaya and Molodkov, 2006; Buggle et al., 2008, 2009; Matviishyna et al., 2010) correlated the Kaydaky unit with MIS 5e and the Dnipro unit with MIS 6, while others (Veklich, 1995; Gozhik et al., 2000; Lindner et al., 2004, 2006; Gozhyk, 2012) continued to correlate these units with MIS 7 and MIS 8.

According to Gozhyk (2012), the Pliocene/Pleistocene boundary is correlated with the lower part of the Siversk loess unit. However, according to the latest palaeomagnetic study (Tretyak and Vigilyanskaya, 2000), the GMB, and thus, the Pliocene/Pleistocene transition, lies within the upper part of the Bogdanivka soil unit.

MODERN PERIOD (2013-PRESENT)

A new stage of the magnetostratigraphic research in Ukraine was largely inspired by P. Gozhyk (see Gozhik, 2013) at the Ukrainian–Polish conference, held in Roksolany in 2013. At the conference, new preliminary palaeomagnetic results of the upper part of the Roksolany section were presented by Bakhmutov and Hlavatskyi (2013). In further studies, the lower part of the section was studied and the MBB was detected between two soils, interpreted by Gozhik et al. (1995, 2000, 2007) and Bogucki et al. (2013) as the Lubny and Martonosha units (Bakhmutov and Hlavatskyi, 2014a, b; Hlavatskyi and Bakhmutov, 2019). In parallel, detailed rock magnetic (Bakhmutov et al., 2017) studies of the Roksolany section and of the anisotropy of magnetic susceptibility (Nawrocki et al., 2018b) of its upper loess layers were published. As a result of compilation of AMS and U-Pb provenance studies of detrital zircons, a NW-SE transport direction and Carpathian primary sources of loess material were documented (Nawrocki et al., 2018b).

Extensive palaeomagnetic studies were conducted on the western Ukrainian loess sequences. The Pringle Falls palaeomagnetic event, dated at 212 kyr, was discovered at the archaeological site of Velykyi Hlybochok (Fig. 6) at the level of the Korshiv palaeosol unit (MIS 7; Łanczont et al., 2014). In addition, in the humus horizon of the lower Horokhiv soil (corresponding to the last interglacial) in the Palaeolithic section at Pronyatyn (Fig. 6), the Blake event was detected (Łanczont et al., 2015).

Subaerial Pleistocene deposits were studied palaeomagnetically in the Bukovynka Cave (Bondar and Ridush, 2015) and the Neporotove section (Bondar et al., 2019) within the Upper Dnister basin (Fig. 6). In the former, a geomagnetic inversion was interpreted as the Etrussia excursion, dated at 2.8 ka BP.

In the Volyn Upland, Hlavatskyi et al. (2016a) and Bakhmutov et al. (2017) studied the Boyanychi and Korshiv sections and did not detect geomagnetic events within the Brunhes chron. The authors noted that there is no clear dependence between magnetic susceptibility variations and loess-palaeosol lithology.

In the following study, Hlavatskyi et al. (2016b) described palaeomagnetic and rock magnetic data from the Vyazivok section. The MBB was detected in the upper part of the lowest soil (sh_{1b1}) of the Shyrokyne palaeosol unit (Fig. 7). Furthermore, a short zone of reversed polarity was detected in the lower part of the Lower Zavadivka subunit (zv_1), interpreted by Hlavatskyi and Bakhmutov (2020) as the Unnamed event estimated at 430 ka, by analogy to that in the Udvari-U2 section in Hungary (Sümegi et al., 2018).

In the Palaeolithic site of Korolevo (Transcarpathia), the MBB was recorded in the S7 illuvial soil horizon assigned to the Martonosha unit (Nawrocki et al., 2016). Research conducted previously showed that the MBB is located in the loess layer between palaeosols VIII and IX (Adamenko et al., 1989 *fide* Koulakovska and Usik, 2011) or in the lithological layer 21 (below the S7 palaeosol; Haesaerts and Koulakovska, 2006 *fide* Koulakovska and Usik, 2011). According to Nawrocki et al. (2016) the Jaramillo subchron was detected (based on two samples) in the S8 soil, correlated with the Lower Shyrokyne subunit. In the subsection studied by Nawrocki et al. (2016), the Martonosha soil (S7) is deformed by cracks and erosionally overlies the Shyrokyne unit.

In the Palaeolithic sites and loess-palaeosol sequences of Medzybizh and Holovchyntsi (Podilia Upland), which are underlain by the Shyrokyne and Illichivsk alluvial units, respectively, the MBB was not identified (Bakhmutov et al., 2018; Hlavatskyi, 2019). A reversed polarity zone in the lower part of the Lower Zavadivka subunit (zv_1) at Medzhybizh was correlated with the Unnamed event (at 430 ka) similar to that at Vyazivok (Hlavatskyi et al., 2021b).

A possible Hilina Pali excursion (c. 18 ka) was detected in the uppermost loess layer in the Rivne section (Nawrocki et al., 2018a). Furthermore, new AMS results were described from the Korshiv and Cherepyn sections which allowed the first detection of the timing of ice sheet advance and the appearance of katabatic winds (Nawrocki et al., 2019).

Based on rock magnetic proxies, Bradák et al. (2019) compared pedogenic and palaeoclimate changes recorded at four Ukrainian (Roksolany, Zahvizdya, Korolevo and Skala Podilska) and central–southeastern European loess sites. Magnetic data shows that the palaeosols – correlatives of MIS 19, MIS 15 and MIS 11 – are the most strongly developed palaeosol units, formed in a sub-Mediterranean climate in the south and a humid and temperate climate in the north.

Tecsa et al. (2020), based on optically stimulated luminescence dates, palaeopedological and magnetic susceptibility proxies, correlated the formerly designated Dofinivka palaeosol (MIS 2 interstadial) at Kurortne (Gozhik et al., 1995) with the Pryluky/Kaydaky palaeosol unit and MIS 5. Additional palaeomagnetic study of the 2 m thick lowermost part of the Kurortne section (Martonosha soil and Sula loess, below the excavation of Nawrocki et al., 1999) still did not detect the presence of Matuyama chron (Hlavatskyi and Bakhmutov, 2021).

In view of the magnetostratigraphic data from Vyazivok and similar lithopedological patterns at Roksolany, a new chronostratigraphic model (Fig. 7), partially supported by compilations of existing luminescence dates (Fedorowicz et al., 2012, 2013; Constantin et al., 2019, 2021) and magnetic susceptibility proxies was proposed (Hlavatskyi and Bakhmutov, 2020). The Lubny unit (according to Gozhik et al., 1995) with the detected MBB was reinterpreted as the Shyrokyne unit, correlated with MIS 19. The Martonosha unit was correlated with MIS 17 (Fig. 8, version 1). A reversed-polarity episode above the Martonosha unit was, thus, interpreted as a Stage 17 excursion (670 ka; Hlavatskyi and Bakhmutov, 2020).

The study of the Vyazivok and Roksolany sections was followed by palaeomagnetic and rock magnetic results with a new stratigraphic interpretation of the lower Middle Pleistocene deposits exposed at Stari Kaydaky (Hlavatskyi et al., 2021a; Gerasimenko et al., 2022) and the late Lower–Middle Pleistocene deposits studied at Dolynske (Hlavatskyi and Bakhmutov, 2021). At Stari Kaydaky, 11 m below the excavation of Buggle et al. (2008, 2009), the MBB was not detected (Fig. 7); however, the Martonosha unit and the Upper Shyrokyne subunit are characterised by normal polarity. It was suggested (Hlavatskyi et al., 2021a) that the well-developed red-brown palaeosol of the Martonosha unit should correspond to the warm MIS 15, and the vertisol of the Upper Shyrokyne subunit, formed in more temperate climatic conditions, may correspond to the colder

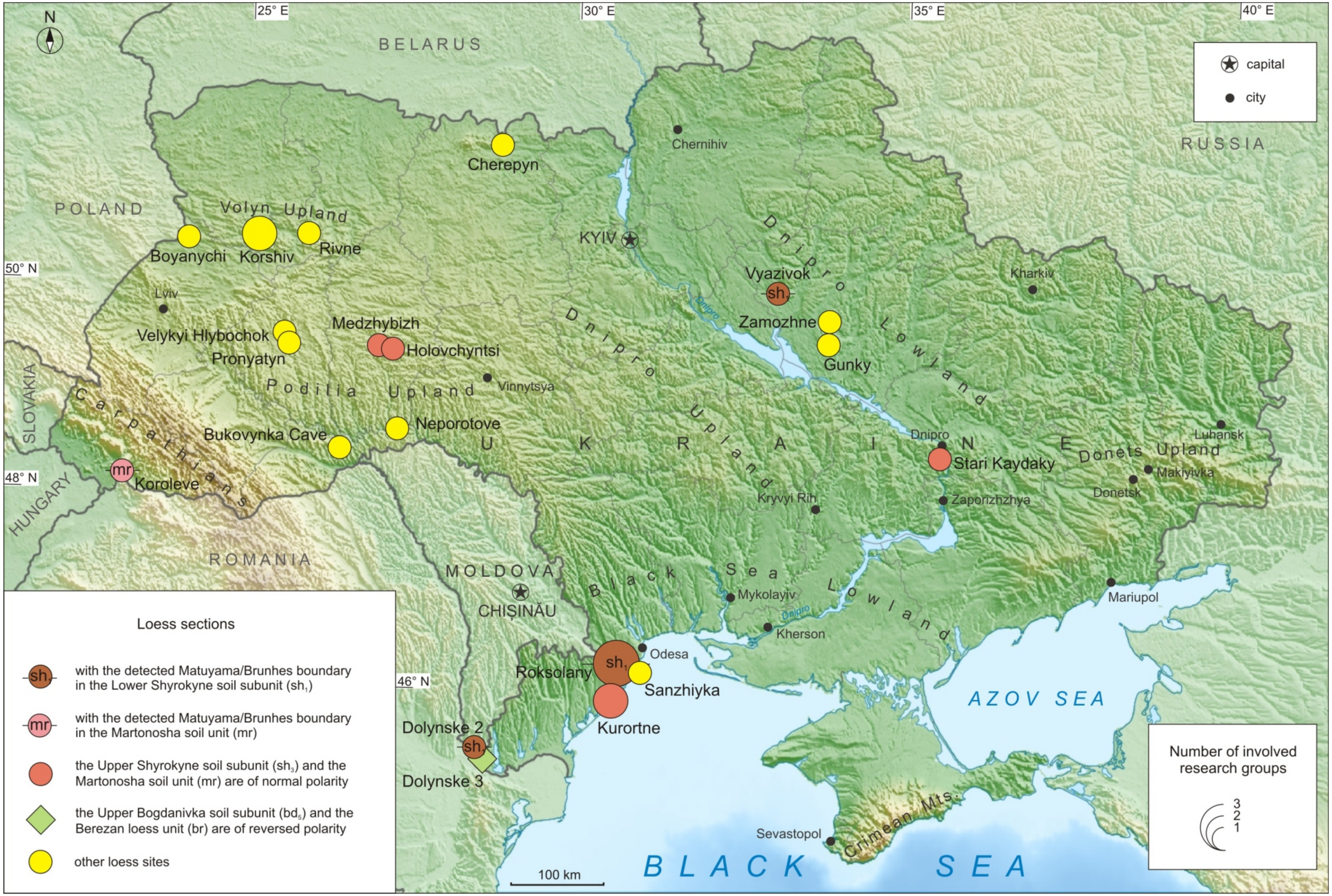

Fig. 6. Loess sites studied palaeomagnetically from 2013 to the present

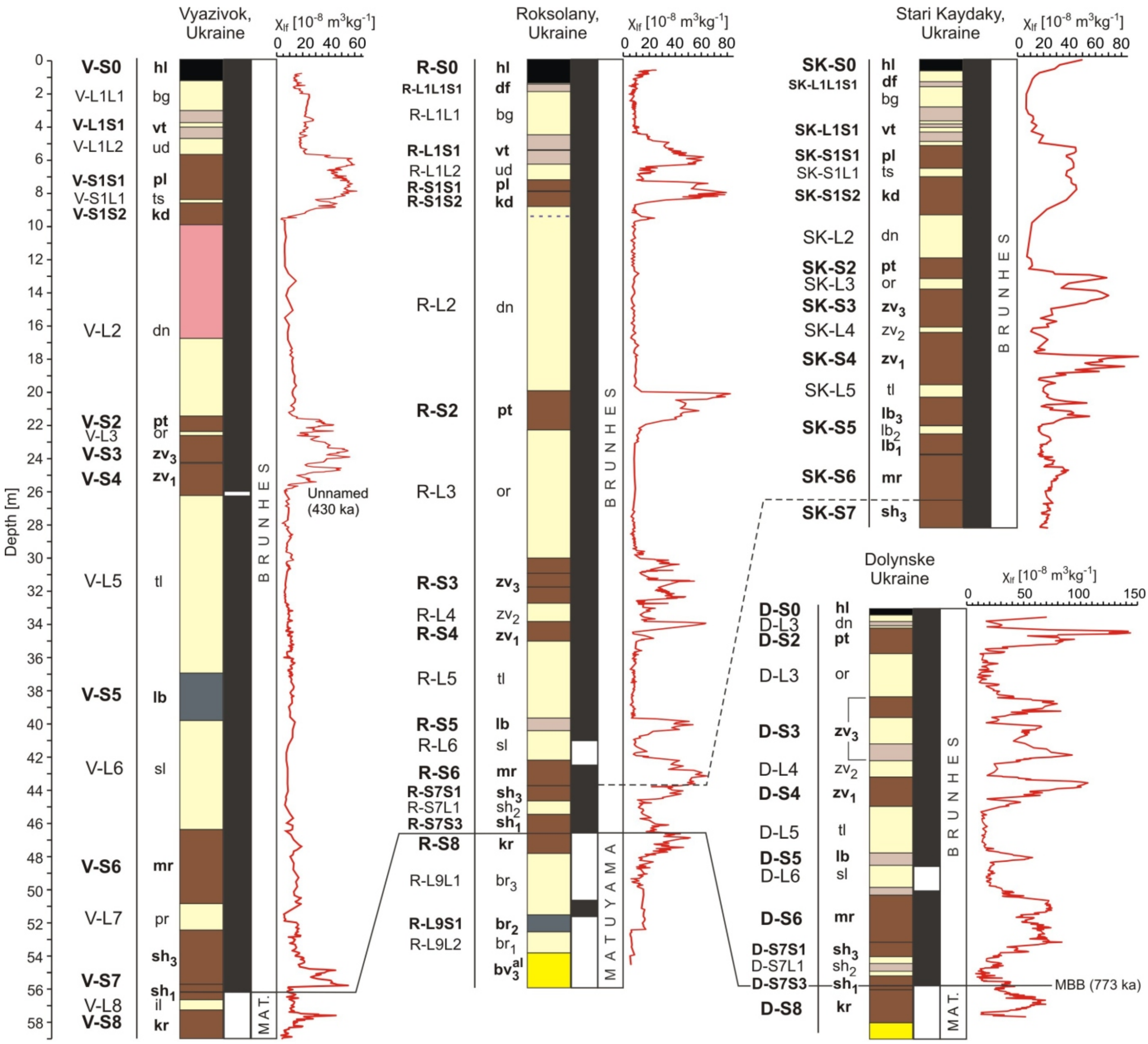

Fig. 7. Correlation chart of reference sections of Ukraine studied in recent years using magnetostratigraphy and low-field magnetic susceptibility $_{lf}$ (Hlavatskyi and Bakhmutov, 2020, 2021; Hlavatskyi et al., 2021a)

Loess-soil nomenclature of individual sites in Hlavatskyi and Bakhmutov (2020, 2021) and Hlavatskyi et al. (2021a) has been adapted from the Chinese (Heller and Liu, 1982; Kukla, 1987) and Danube loess studies (Buggle et al., 2008), in which added prefixes designate the location of the sections, i.e.; V – Vyazivok, R – Roksolany, SK – Stari Kaydaky, D – Dolynske; other explanation as on Figure 4

MIS 17 (Fig. 8, version 2) following regional (Sirenko and Turlo, 1986; Gerasimenko, 2010; Sirenko, 2019) and global (Shackleton et al., 1990; Lisiecki and Raymo, 2005; Varga, 2015; Sümegi et al., 2018) palaeoclimatic trends of the Middle Pleistocene.

At Dolynske, the former magnetostratigraphy and stratigraphic classification of the loess-palaeosol sequence (Bakhmutov et al., 2005) has been recently revised (see Bakhmutov et al., 2021). The MBB boundary was detected in the Lower Shyrokyne subunit (Fig. 7) separated from the Upper Shyrokyne subunit by loess-like loam similar to that in the Shyrokyne suite at Roksolany (Hlavatskyi and Bakhmutov, 2021). Therefore, the luvisol of the Lower Shyrokyne subunit was correlated with MIS 19. This allowed for the preliminary correlation of the southern Ukrainian loess deposits with those in the Danube Basin and Central Asia, as well as with the marine isotope stratigraphy (Hlavatskyi and Bakhmutov, 2021). The reversed-polarity zone in the Sula loess unit at Roksolany and Dolynske has been considered as the Big Lost event (540–580 ka), correlated with MIS 14 (Hlavatskyi and Bakhmutov, 2021; Bakhmutov and Hlavatskyi, 2022). In addition, Hlavatskyi et al. (2022a, c) studied a pilot collection of samples from the lower part of the Dolynske section, below the MBB, and did not find the GMB, at least above the Upper Bogdanivka subunit (bd_{5-3}).

The consequences of a Russia's full-scale invasion since 24 February 2022 for the magnetostratigraphic studies in Ukraine, events of the temporary occupation of our palaeomagnetic laboratory, and a return to work in wartime conditions, are described in detail in Hlavatskyi et al. (2023b). During

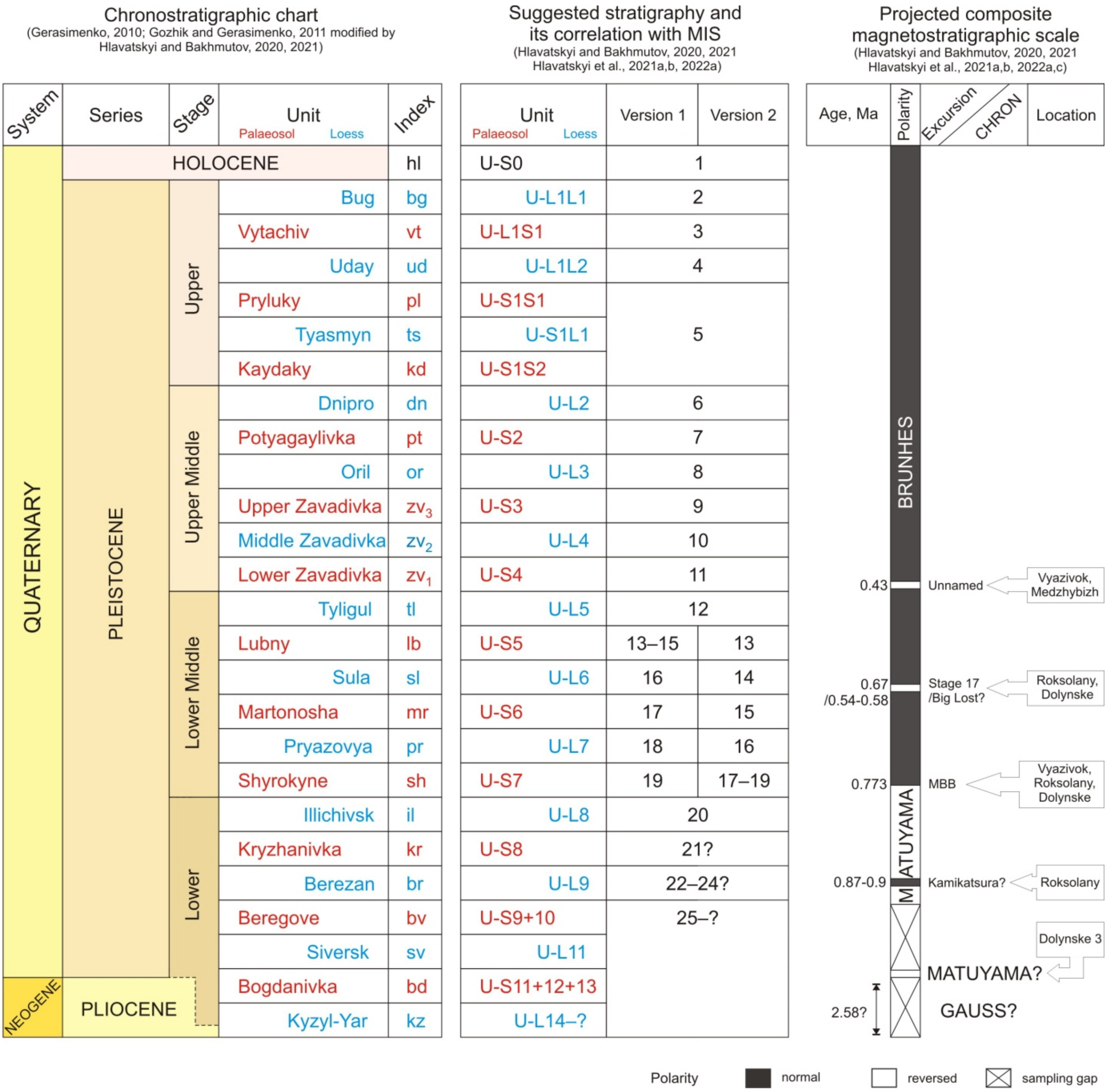

Fig. 8. Modified stratigraphic framework of the Quaternary deposits of Ukraine, proposed correlation with marine isotope stratigraphy and geomagnetic polarity scale in the interpretation of the authors

Magnetostratigraphic data are not shown for Moldova as no Moldovan section was studied by the authors of this paper (nor since 2010 by any research teams). For the Ukrainian loess-palaeosol stratigraphic units the prefix U was proposed (Hlavatskyi and Bakhmutov, 2020), referring to the standard pedostratigraphic frameworks of Vojvodina, Serbia (Marković et al., 2011) and Hungary (Sümegi et al., 2018), which use the prefixes V and H, respectively

this time, results on previously sampled loess sections including Sanzhiyka, Zamozhne and Gunky were published as extended abstracts at international conferences (Bakhmutov et al., 2022; Gerasimenko et al., 2022; Hlavatskyi et al., 2022b, 2023a; Melnyk et al., 2022).

Regarding the magnetostratigraphic research in Moldova, we have not found any materials on studies of the Moldovan loess in this third stage of work.

CONCLUSIONS

Loess-palaeosol sites investigated by modern rock magnetic and palaeomagnetic methods are located mainly in the north-western part of Ukraine and in the western Black Sea region (see Fig. 6). This is partly due to the deployment of multi-proxy studies of the loess-soil succession of Ukraine in recent decades in these areas. On the other hand, this provides the task of focusing magnetostratigraphic investigation on at least the central Ukrainian loess sections (the Middle Dnipro region), especially given that the stratotype sections of the Vytachiv, Uday, Pryluky, Tyasmyn, Kaydaky, Dnipro, Potyagaylivka, Oril, Zavadivka, Lubny, Sula and Martonosha units are located there. The well-developed Moldovan loess sequences, which have not been palaeomagnetically studied for the past decade, are also very promising for magnetostratigraphic study.

One of the important methodological tasks for future studies is the clarification of the stratigraphic position of the "golden benchmark" of the Pleistocene, the Matuyama–Brunhes reversal, and the mechanism of acquisition of characteristic magnetic remanence. In the stratigraphic scheme of the Quaternary deposits, Veklich (1982) initially positioned the MBB in the uppermost part of the Martonosha soil unit; however, in subsequent studies, Veklich (1987, 1995) pointed out the ambiguity of the determination of its position by different authors in different sections: from the Lubny unit of the Lower Neopleistocene to the Shyrokyne unit of the Eopleistocene. At the moment, in most stratigraphic schemes of the Quaternary of Ukraine (Gerasimenko, 2010; Gozhik and Gerasimenko, 2011; Gozhyk, 2012), its position is placed at the base of the Martonosha soil unit. This concept disregards, however, the significant palaeomagnetic studies contributed by another Ukrainian research team (Tretyak et al., 1987, 1989; Tretyak and Vigilyanskaya, 1994; Vigilyanskaya and Tretyak, 2000; Vigilyanskaya, 2001, 2002), in which the MBB was interpreted at the base of the older Shyrokyne soil unit.

The results of early palaeomagnetic research, due to the lack of accurate magnetometers and some methodological issues, led in some cases (in particular, in southern regions) to misinterpretations. An example is the contrasting definitions of the MBB in the Roksolany section by different scientific teams (discussed in Hlavatskyi and Bakhmutov, 2020). Furthermore, numerous geomagnetic excursions, which were prominent in the Ukrainian magnetostratigraphy in the 1970–1990s, were, in our view, confused with the strong influence of the viscous component of magnetisation due to measurements made without magnetic shielding.

During the last two decades, there has been a fundamental improvement in the methodology of extracting the characteristic remanent magnetisation signal from loess-soil samples both by western European researchers (Nawrocki et al., 2002, 2016) and by Ukrainian palaeomagnetologists (Bakhmutov and Hlavatskyi, 2016). Since 2000, in two-thirds of the reference sections, the MBB was determined in the lower part of the Shyrokyne unit or below it; in one-third (mainly in western Ukraine) it was detected in the Martonosha unit or Pryazovya unit (Figs. 5 and 6). This contradiction may be caused by a different approach to the stratigraphic subdivision of sections; alternatively, diagenesis may have influenced the preservation of remanent magnetisation in these loess-soil deposits. Also, the possibility of stratigraphic gaps should not be excluded from consideration.

Solving this issue is urgent for the development of reliable palaeoclimatic correlation of Pleistocene events reflected in the structure and properties of the loess-soil formation of Ukraine, as shown by the studies of Hlavatskyi and Bakhmutov (2020, 2021). A central task is the determination the position of the MBB in the stratotype section of the entire loess-soil succession of Ukraine, Stari Kaydaky, as well as in the stratotype sections of the Martonosha and Shyrokyne units (Fig. 1). The Shyrokyne section is currently impossible to study due to the Russian invasion, but a new palaeomagnetic study of the Kryzhanivka stratotype section, where the position of the Shyrokyne unit above the Kryzhanivka unit was determined by the founders of the stratigraphic framework of Quaternary deposits of Ukraine (Veklych and Sirenko, 1972; Veklich, 1982), is needed.

An important task is the determination of the stratigraphic position of the GMB and, thus, the boundary between the Pliocene and Pleistocene in the Ukrainian loess stratigraphic system.

Another promising area of activity of palaeomagnetic specialists might be the study of loess sections in neighbouring countries (Poland, Hungary, Romania, Bulgaria etc.), with the aim of exchanging magnetostratigraphic interpretation and correlating Quaternary deposits on a regional scale. A shift to international and integrative research combining multiple methods is needed to correlate the still-contradictory Lower to Middle Pleistocene stratigraphies, an important issue in central, eastern and south-eastern Europe (Sümegi et al., 2018; Zeeden et al., 2018; Łanczont et al., 2019).

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REFERENCES

Adamenko, O.M., Golbert, A.V., Osiyuk, V.A., Matviishina, Z.N., Medyanik, S.I., Motok, V.E., Sirenko, N.A., Chernyuk, A.V., 1996. Chetvertichnaya paleogeografiya ekosistemy Nizhnego i Srednego Dnestra (in Russian). Feniks, Kyiv.

Bakhmutov, V., Hlavatskyi, D., 2013. Paleomagnetic studies of Roxolany section: review of previous works and new preliminary results (in Russian with English summary). In: Loess cover of the North Black Sea Region. Proceeding of the XVIII Ukrainian-Polish Workshop 8–13 September 2013 (eds. A. Bogucki, P. Gozhik, M. Łanczont, T. Madejska and J. Yelovicheva): 72–83. KARTPOL s.c. Lublin, Lublin.

Bakhmutov, V.G., Hlavatskyi, D.V., 2014a. Identification of the Matuyama–Brunhes boundary by paleomagnetic studies of the Roxolany profile (Western Black Sea region) (in Russian with English summary). Dopovidi Natsionalnoy Akademii Nauk Ukrayiny, **10**: 92–98; http://doi.org/10.15407/dopovidi2014.10.092

Bakhmutov, V.G., Hlavatskyi, D.V., 2014b. New data about Matuyama-Brunhes boundary in Roxolany section (in Russian with English summary). Geological Journal, **2**: 73–84; http://doi.org/10.30836/igs.1025-6814.2014.2.139072

Bakhmutov, V.G., Hlavatskyi, D.V., 2016. Problems of magnetostratigraphy of Pleistocene loess-soil deposits in the South of Ukraine (in Russian with English summary). Geofizicheskiy Zhurnal, **38**: 59–75; https://doi.org/10.24028/gzh.0203-3100.v38i4.2016.107801

Bakhmutov, V., Hlavatskyi, D., 2022. On the reliability of a stratigraphic interpretation that overlooks geophysical techniques and results when determining the age of loess-soil deposits – Comment on "A remarkable last glacial loess sedimentation at Roxolany in the Dniester Liman (Southern Ukraine)." Quaternary Science Reviews, **297**: 107668; https://doi.org/10.1016/j.quascirev.2022.107668

Bakhmutov, V.G., Mokriak, I.N., Skarboviychuk, T.V., Yakukhno, V.I., 2005. Results of palaeomagnetic studies of Danube terraces sections and problems of Pleistocene magnetostratigraphy of the west Black Sea region (in Russian with English summary). Geofizicheskiy Zhurnal, **25**: 980–991.

Bakhmutov, V.G., Kazanskii, A.Yu., Matasova, G.G., Glavatskii, D.V., 2017. Rock Magnetism and Magnetostratigraphy of the Loess-Sol Series of Ukraine (Roksolany, Boyanychi, and Korshev Sections). Izvestiya, Physics of the Solid Earth, **53**: 65–86; http://doi.org/10.1134/S106935131705002

Bakhmutov, V., Hlavatskyi, D., Stepanchuk, V., Poliachenko, Ie., 2018. Rock Magnetism and Magnetostratigraphy of Loess-Palaesol Sections – Lower Paleolithic Sites of Podolian Upland (Medzhybizh, Holovchintsi). 12th International Conference on Monitoring of Geological Processes and Ecological Condition of the Environment, Kyiv, Ukraine.

Bakhmutov, V.G., Hlavatskyi, D.V., Veklych, Y.M., Shpyra, V.V., Yakukhno, V.I. 2021. The Matuyama–Brunhes boundary in the loess-palaeosol sequence of Dolynske, southern Ukraine (in Russian with English summary). Geofizicheskiy Zhurnal, **43**: 95–110; https://doi.org/10.24028/gzh.v43i5.244065

Bakhmutov, V., Hlavatskyi, D., Melnyk, G., Mychak, S., Cherkes, S., 2022. Pleistocene Climate Fluctuations Recorded in the Magnetic Susceptibility of the Longest LPSs of Ukraine. International Conference of Young Professionals «GeoTerrace-2022», European Association of Geoscientists & Engineers, Lviv, Ukraine; https://doi.org/10.3997/2214-4609.2022590035

Boguckyj, A.B., Łanczont, M., Łącka, B., Madeyska, T., Nawrocki, J., 2009. Quaternary sediment sequence at Skala Podil'ska, Dniester River basin (Ukraine): Preliminary results of multi-proxy analyses. Quaternary International, **198**: 173–194; https://doi.org/10.1016/j.quaint.2008.05.010

Bogucki, A., Łanczont, M., Gozhik, P., Komar, M., 2013. Roksolany loess section: location, research history and characteristics of deposits (in Polish and Ukrainian with English summary). In: Loess cover of the North Black Sea Region. Proceeding of the XVIII Ukrainian-Polish Workshop 8–13 September 2013 (eds. A. Bogucki, P. Gozhik, M. Łanczont, T. Madejska and J. Yelovicheva): 34–58. KARTPOL s.c. Lublin, Lublin.

Bokhorst, M.P., Beets, C.J., Marković, S.B., Gerasimenko, N.P., Matviishina, Z.N., Frechen, M., 2009. Pedo-chemical climate proxies in Late Pleistocene Serbian–Ukrainian loess sequences. Quaternary International, **198**: 113–123; https://doi.org/10.1016/j.quaint.2008.09.003

Bolikhovskaya, N.S., Molodkov, A.N., 2006. East European loess-palaeosol sequences: Palynology, stratigraphy and correlation. Quaternary International, **149**: 24–36; https://doi.org/10.1016/j.quaint.2005.11.015

Bonchkovskyi, O., 2020. The loess-palaeosol sequence of Novyi Tik: a new Middle and Upper Pleistocene record for Volyn' Upland (north-west Ukraine). Quaternaire, **31**, 281–308; https://doi.org/10.4000/quaternaire.14308

Bonchkovskyi, O.S., 2019. Changes in pedogenic processes during Pryluky times (Late Pleistocene) in the central part of the Volyn Upland. Journal of Geology, Geography and Geoecology, **28**: 230–240; https://doi.org/10.15421/111924

Bondar, K., Ridush, B., 2015. Rockmagnetic and palaeomagnetic studies of unconsolidated sediments of Bukovynka Cave (Chernivtsi region, Ukraine). Quaternary International, **357**: 125–135; http://doi.org/10.1016/j.quaint.2014.04.025

Bondar, K., Ridush, B., Baryshnikova, M., Popiuk, Y., 2019. On palaeomagnetic dating of fluvial deposits in the section of Neporotove gravel quarry on the Middle Dniester. Journal of Geology, Geography and Geoecology, **28**: 241–249; http://doi.org/10.1016/j.quaint.2014.04.025

Bradák, B., Seto, Y., Nawrocki, J., 2019. Significant pedogenic and palaeoenvironmental changes during the early Middle Pleistocene in Central Europe. Palaeogeography, Palaeoclimatology, Palaeoecology, **534**: 109335; https://doi.org/10.1016/j.palaeo.2019.109335

Buggle, B., Glaser, B., Zöller, L., Hambach, U., Marković, S., Glaser, I., Gerasimenko, N., 2008. Geochemical characterization and origin of Southeastern and Eastern European loesses (Serbia, Romania, Ukraine). Quaternary Science Reviews, **27**: 1058–1075; http://doi.org/10.1016/j.quascirev.2008.01.018

Buggle, B., Hambach, B., Glaser, B., Gerasimenko, N., Marković, S., Glaser, I., Zöller, L., 2009. Stratigraphy, and spatial and temporal paleoclimatic trends in Southeastern/Eastern European loess–paleosol sequences. Quaternary International, **196**: 86–106; https://doi.org/10.1016/j.quaint.2008.07.013

Channell, J.E.T., Singer, B.S., Jicha, B.R., 2020. Timing of Quaternary geomagnetic reversals and excursions in volcanic and sedimentary archives. Quaternary Science Reviews, **228**: 106114; https://doi.org/10.1016/j.quascirev.2019.106114

Constantin, D., Veres, D., Panaiotu, C., Anechitei-Deacu, V., Groza, S.M., Begy, R., Kelemen, S., Buylaert, J.-P., Hambach, U., Marković, S.B., Gerasimenko, N., Timar-Gabor, A., 2019. Luminescence age constraints on the Pleistocene-Holocene transition recorded in loess sequences across SE Europe. Quaternary Geochronology, **49**: 71–77; https://doi.org/10.1016/j.quageo.2018.07.011

Constantin, D., Mason, J.A., Veres, D., Hambach, U., Panaiotu, C., Zeeden, C., Zhou, L., Marković, S.B., Gerasimenko, N., Avram, A., Tecsa, V., Groza-Sacaciu, S.M., del Valle Villalonga, L., Begy, R., Timar-Gabor, A., 2021. OSL-dating of the Pleistocene-Holocene climatic transition in loess from China, Europe and North America, and evidence for accretionary pedogenesis. Earth-Science Reviews, **221**: 103769;https://doi.org/10.1016/j.earscirev.2021.103769

Cox, A., 1969. Geomagnetic reversals. Science, **163**: 3864; https://doi.org/10.1126/science.163.3864.237

Dodonov, A.E., Zhou, L.P., Markova, A.K., Tchepalyga, A.L., Trubikin, V.M., Aleksandrowski, A.L., Simakova, A.N., 2006. Middle-Upper Pleistocene bio-climatic and magnetic records of the Northern Black Sea Coastal Area. Quaternary International, **149**: 44–54; http://doi.org/10.1016/j.quaint.2005.11.017

Dudkin, V.P., 1983. Vydelenie magnitokhronologicheskikh reperov v pozdnepleystotsenovykh otlozheniyakh Severo-Zapadnogo Prichernomorya (in Russian). In: Paleomagnitnye issledovaniya donnykh i beregovykh obrazovaniy vnutri kontinentalnykh morey i okeanov (eds. A.N. Tretyak and A.Yu.Mytropolskiy): 48–58. Institute of Geological Sciences AS USSR, Kyiv.

Ehlers, J., Gibbard, P.L., Hughes, P.D., 2011. Quaternary Glaciations – Extent and Chronology. Elsevier, Amsterdam.

Evans, M., Heller, F., 2003. Environmental Magnetism: Principles and Applications of Enviromagnetics. Academic Press.

Faustov, S.S., Virina, E.I., 1989. Problems of paleomagnetic stratigraphy of loess-soil formation in Ukraine and Moldova (in Russian with English summary). In: Quaternary Period. Stratigraphy (eds. M.N. Alekseev and K.V. Nikiforova): 96–102. Nauka, Moscow.

Fedorowicz, S., Woźniak, P.P., Hałas, S., Łanczont, M., Paszkowski, M., Wójtowicz, A., 2012. Challenging K-Ar dating of the Quaternary tephra from Roxolany. Mineralogia, **39**: 102–105.

Fedorowicz, S., Łanczont, M., Bogucki, A., Woźniak, P.P., Wróblewski, R., Adamiec, G., Bluszcz, A., Moska, P., 2013. Isotope dating in Roksolany loess profile (in Polish with English summary). In: Loess cover of the North Black Sea Region. Proceeding of the XVIII Ukrainian-Polish Workshop 8–13 September 2013 (eds. (eds. A. Bogucki, P. Gozhik, M. Łanczont, T. Madejska and J. Yelovicheva): 65–68. KARTPOL s.c. Lublin, Lublin.

Gendler, T.S., Heller, F., Tsatskin, A., Spassov, S., Du Pasquier, J., Faustov, S.S., 2006. Roxolany and Novaya Etuliya – key sections in the western Black Sea loess area: magnetostratigraphy, rock magnetism, and paleopedology. Quaternary International, **152–153**: 78–93; https://doi.org/10.1016/j.quaint.2006.01.001

Gerasimenko, N.P., 2004. Quaternary Evolution of Zonal Paleoecosystems in Ukraine (in Ukrainian with English summary). Institute of Geography NASU, Kyiv.

Gerasimenko, N., 2006. Upper Pleistocene loess–palaeosol and vegetational successions in the Middle Dnieper Area, Ukraine. Quaternary International, **149**: 55–66; https://doi.org/10.1016/j.quaint.2005.11.018

Gerasimenko, N.P., 2010. On the correlation of palaeogeographic stages of the Pleistocene of Ukraine with global benchmarks and chronostratigraphy of Western and Eastern Europe (in Ukrainian). In: Spatio-temporal correlation of Quaternary palaeogeographic conditions on the territory of Ukraine (eds. Zh.M. Matviishyna, N.P. Gerasimenko, V.I. Peredii, A.M> Bragin, A.S. Ivchenko, S.P. Karmazynenko, V.M. Nahirnyi and O.G. Parkhomenko): 94–104. Naukova Dumka, Kyiv.

Gerasimenko, N.P., Kovalchuk, I.P., 2019. The Late Pleistocene soils as indicators of the impact of environmental changes on development of pedogenic processes. Journal of Geology, Geography and Geoecology, **28**: 262–274; https://doi.org/10.15421/111927

Gerasimenko, N., Hlavatskyi, D., Bakhmutov, V., Wimbledon, W.A.P., Poliachenko, I., Bonchkovskyi, O., 2022.

Enviromagnetic Study of the Reference Ukrainian Loess-Palaeosol Sequence at Stari Kaydaky. 16th International Conference Monitoring of Geological Processes and Ecological Condition of the Environment, Kyiv, Ukraine; https://doi.org/10.3997/2214-4609.2022580069

Gozhik, P.F., 1976. Putevoditel' VIII Mezhdunarodnogo simpoziuma po lessovym porodam (in Russian) (eds. Gozhik P.F., Chugunnyi Yu.G., Melnik V.I.). 71 p. Naukova Dumka, Kyiv.

Gozhyk, P.F., 2012. Stratigraphic Code of Ukraine (in Ukrainian with English summary) (eds. Gozhyk P.F.). Kyiv, National Stratigraphic Committee of Ukraine.

Gozhik, P., 2013. Research problems of the Roksolany section (in Ukrainian with English summary). In: Loess cover of the North Black Sea Region. Proceeding of the XVIII Ukrainian-Polish Workshop 8–13 September 2013 (eds. A. Bogucki, P. Gozhik, M. Łanczont, T. Madejska and J. Yelovicheva): 17–33. KARTPOL s.c. Lublin, Lublin.

Gozhik, P.F., Gerasimenko, N.P., 2011. The lower and middle Pleistocene of Ukraine. In: Quaternary studies in Ukraine (eds. N.P. Gerasimenko, P.F. Gozhik, N.I. Dykan, Zh.M. Matviishyna, V.M. Shelkoplyas and B.D. Vozgrin): 9–26. Institute of Geological Sciences NASU, Kyiv.

Gozhik, P., Shelkoplyas, V., Khristoforova, T., 1995. Development stages of loessial and facial formation in Ukraine (Stratigraphy of loess in Ukraine). Annales Universitae Mariae Curie-Sklodowska (B), **50**: 65–74.

Gozhik, P.F., Shelkoplyas, V.N., Komar, M.S., Matviishyna, Z.M., Perederiy, V.I., 2000. Putivnyk X polsko-ukrayinskoho seminaru "Korelyatsiya lesiv i lodovykovykh vidkladiv Polshchi i Ukrayiny" (in Ukrainian). Kyiv.

Gozhik, P., Komar, M., Krokhmal, O., Shovkoplias, V., Khrystoforova, T., Dykan, N., Prylypko, S., 2007. The key section of Neopleistocene subaerial deposits near Roxolany village (Odessa region) (in Ukrainian with English summary). In: Problems of Middle Pleistocene interglacial. Proceeding of the XIV Ukrainian-Polish Workshop 12–16 September 2007 (eds. A. Bogucki, P. Gozhik, M. Łanczont, L. Lindner and J. Yelovicheva): 109–128. Vydavnychyi tsentr LNU imeni Ivana Franka, Lviv.

Haase, D., Fink, J., Haase, G., Ruske, R., Pesci, M., Richter, H., Altermann, M., Jager, K.-D., 2007. Loess in Europe – Its spatial distribution based on a European Loess Map, scale 1:2,500,000. Quaternary Science Reviews, **26**: 1301–1312; https://doi.org/10.1016/j.quascirev.2007.02.003

Haesaerts, P., Damblon, F., Gerasimenko, N., Spagna, P., Pirson, S., 2016. The Late Pleistocene loess-palaeosol sequence of Middle Belgium. Quaternary International, **411**: 25–43; https://doi.org/10.1016/j.quaint.2016.02.012

Haesaerts, P., Gerasimenko, N., Damblon, F., Yurchenko, T., Kulakovska, L., Usik, V., Ridush, B., 2020. The Upper Palaeolithic site Doroshivtsi III: A new chronostratigraphic and environmental record of the Late Pleniglacial in the regional context of the Middle Dniester-Prut loess domain (Western Ukraine).Quaternary International, **546**: 196–215; https://doi.org/10.1016/j.quaint.2019.12.018

Head, M.J., Gibbard, P.L., 2015. Early–Middle Pleistocene transitions: linking terrestrial and marine realms. Quaternary International, **389**: 7–46; http://doi.org/10.1016/j.quaint.2015.09.042

Heller, F., Liu, T.S., 1982. Magnetostratigraphical dating of loess deposits in China. Nature, **300**: 431–433; https://doi.org/10.1038/300431a0

Heller, F., Liu, T.S., 1984. Magnetism of Chinese loess deposits. Geophysical Journal of the Royal Astronomical Society, **77**: 125–141; https://doi.org/10.1111/j.1365-246X.1984.tb01928.x

Heller, F., Sartori, M., Hus, J., Geeraerts, R., Hailwood, E., Montgomery, P., Gendler, T., Bagin, V., Virina, E., Tsatskin, A., 1996. Paleoenvironmental change documented by magnetic investigations at Roxolany, a loess type section near Odessa (Ukraine). Geologica Carpatica, **47**: 208–209.

Hlavatskyi, D.V., 2019. Refined magnetostratigraphic position of the Shyrokyne unit in loess sequences from Central Ukraine. Journal of Geology, Geography and Geoecology, **28** (2): 301–312; http://doi.org/10.15421/111930

Hlavatskyi, D.V., Bakhmutov, V.G., 2019. Magnetostratigraphy of the key loess-palaesol sequence at Roxolany (Western Black Sea region). In: Recent Advances in Rock Magnetism, Environmental Magnetism and Paleomagnetism. Springer Geophysics (eds. D. Nurgaliev, V. Shcherbakov, A. Kosterov and S. Spassov): 371–382. Springer, Cham; http://doi.org/10.1007/978-3-319-90437-5_26

Hlavatskyi, D.V., Bakhmutov, V.G., 2020. Magnetostratigraphy and magnetic susceptibility of the best developed Pleistocene loess-palaeosol sequences of Ukraine: implications for correlation and proposed chronostratigraphic models. Geological Quarterly, **64**: 723–753; http://doi.org/10.7306/gq.1544

Hlavatskyi, D., Bakhmutov, V., 2021. Early–Middle Pleistocene magnetostratigraphic and rock magnetic records of the Dolynske Section (Lower Danube, Ukraine) and their application to the correlation of loess–palaeosol sequences in Eastern and South-Eastern Europe. Quaternary, **4**: 43; http://doi.org/10.3390/quat4040043

Hlavatskyi, D., Bakhmutov, V., Bogucki, A., Voloshyn, P., 2016a. Petromagnetism and paleomagnetism of subaerial deposits of Boyanychi and Korshiv sections (Volhynian Upland) (in Ukrainian with English summary). Visnyk of Taras Shevchenko National University of Kyiv: Geology, **72**: 43–51; http://doi.org/10.17721/1728-2713.72.06

Hlavatskyi, D.V., Kuzina, D.M., Gerasimenko, N.P., Bakhmutov, V.G., 2016b. Petromagnetism and paleomagnetism of Quaternary loess-soil sediments of Vyazivok section (Dnieper Lowland) (in Russian with English summary). Geofizicheskiy Zhurnal, **38**: 186–193; http://doi.org/10.24028/gzh.0203-3100.v38i6.2016.91903

Hlavatskyi, D., Gerasimenko, N., Bakhmutov, V., Bonchkovskyi, O., Poliachenko, I., Shpyra, V., Mychak, S., Kravchuk, I., Cherkes, S., 2021a. Significance of the Ukrainian loess-palaeosol sequences for Pleistocene climate reconstructions: rock magnetic, palaeosol and pollen proxies. Geofizicheskiy Zhurnal, **43**: 3–26; http://doi.org/10.24028/gzh.v43i3.236378

Hlavatskyi, D., Stepanchuk, V., Kuzina, D., Poliachenko, I., Shpyra, V., Skarboviychuk, T., Yakukhno, V., Bakhmutov, V., 2021b. Rock magnetic and palaeomagnetic studies of loess-palaesol sections – Lower Palaeolithic sites within the Southern Bug Valley (Medzhybizh, Holovchyntsi) (in Russian with English summary). Geofizicheskiy Zhurnal, **43**: 3–37; http://doi.org/10.24028/gzh.0203-3100.v43i1.2021.225539

Hlavatskyi, D., Bakhmutov, V., Veklych, Yu., Shpyra, V., Poliachenko, Ie., 2022a. Danube Loess Magnetostratigraphy: a Perspective from Ukraine. International Conference of Young Professionals «GeoTerrace-2022», European Association of Geoscientists & Engineers, Lviv, Ukraine; http://doi.org/10.3997/2214-4609.2022590007

Hlavatskyi, D., Gerasimenko, N., Bakhmutov, V., Wimbledon, W., Bonchkovskyi, O., Cherkes, S., Kravchuk, I., Poliachenko, I., Shpyra, V., 2022b. A detailed Middle and Late Pleistocene cyclostratigraphic record using rock magnetism and palaeosol proxies in the Middle Dnieper basin loess domain. EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022, EGU22-4682; http://doi.org/10.5194/egusphere-egu22-4682

Hlavatskyi, D., Veklych, Y., Bakhmutov, V., Shpyra, V., Skarboviychuk, T., Yakukhno, V., Poliachenko, I. 2022c. Palaeomagnetic suitability of a new section with a potential lower boundary for the Quaternary on the left bank of the lower River Danube (in Ukrainian with English summary). Geofizicheskiy Zhurnal, **44**: 38–50; http://doi.org/10.24028/gj.v44i4.264840

Hlavatskyi, D., Bonchkovskyi, O., Bakhmutov, V., Gerasimenko, N., Poliachenko, I., Shpyra, V., Cherkes, S., Kravchuk, I., Mychak, S., 2023a. Pedo-, magneto- and rock magnetic stratigraphy for the late Middle-Upper Pleistocene interval of the Sanzhiyka loess-palaeosol sequence in southern Ukraine, EGU General Assembly 2023, Vienna, Austria, 24–28 April 2023, EGU23-2416; http://doi.org/10.5194/egusphere-egu23-2416

Hlavatskyi, D., Poliachenko, I., Melnyk, G., Bakhmutov, V., 2023b. Impact of war on geophysical research in Ukraine: An eyewitness report from the formerly occupied palaeomagnetic lab. Contributions to Geophysics and Geodesy, **53**/Special report: 85–95; http://doi.org/10.31577/congeo.2023.sp.1

Jordanova, D., Petersen, N., 1999. Paleoclimatic record from a loess-soil profile in northeastern Bulgaria II. Correlation with global climatic events during the Pleistocene. Geophysical Journal International, **138**: 533–540; https://doi.org/10.1046/j.1365-246X.1999.00874.x

Karmazinenko, S., 2019. Pleistocene soils of the Azov Lowland, Ukraine. Journal of Geology, Geography and Geoecology, **28**: 313–326; https://doi.org/10.15421/111931

Komar, M., Łanczont, M., Fedorowicz, S., Gozhik, P., Mroczek, P., Bogucki, A., 2018. Stratigraphic interpretation of loess in the marginal zone of the Dnieper I Ice Sheet and the evolution of its landscape after deglaciation (Dnieper Upland, Ukraine). Geological Quarterly, **62** (3): 536–552; https://doi.org/10.7306/gq.1434

Koulakovska, L.V., Usik, V.I., 2011. The Paleolithic of Transcarpathian region (Ukraine): chronology and cultural variability. In: Quaternary Studies in Ukraine (eds. N.P. Gerasimenko, P.F. Gozhik, N.I. Dykan, Zh.M. Matviishyna, V.M. Shelkoplyas and B.D. Vozgrin): 129–139. Institute of Geological Sciences NASU, Kyiv.

Krokos, V.I., 1926. Kratkiy ocherk chetvertichnykh otlozheniy Ukrainy (in Russian). Bulletin MOIP Section Geology, **4**: 214–264.

Kukla, G.J., 1987. Loess stratigraphy in Central China. Quaternary Science Reviews, **6**: 191–219.

Kukla, G., Heller, F., Liu, X.M., Xu, T.C., Liu, T.S., An, Z.S., 1988. Pleistocene climates in China dated by magnetic susceptibility. Geology, **16**: 811–814.

Kulikova, L.S., 1980. Vydelenie magnitokhronologicheskikh reperov po rezultatam paleomagnitnogo izucheniya pozdnepleystotsenovykh otlozheniy razrezov Moldova V i Korman IV (in Russian). In: Geokhronologiya chetvertichnogo perioda: 116–130. Nauka, Moscow.

Łanczont, M., Boguckyj, A., 2007. High-resolution archive of climatic oscillations during Oxygen Isotope Stages 5–2 in the loess-palaeosol sequence at Kolodiiv (East Carpathian Foreland, Ukraine). Geological Quarterly, **51** (2): 105–126.

Łanczont, M., Madeyska, T., Bogucki, A., Sytnyk, O., Kusiak, J., Frankowski, Z., Komar, M., Nawrocki, J., Żogała, B., 2014. Stratigraphic position and natural environment of the oldest Middle Palaeolithic in central Podolia, Ukraine: New data from the Velykyi Glybochok site. Quaternary International, **326–327**: 191–212; https://doi.org/10.1016/j.quaint.2013.08.045

Łanczont, M., Madeyska, T., Sytnyk, O., Bogucki, A., Komar, M., Nawrocki, J., Hołub, B., Mroczek, P., 2015. Natural environment of MIS 5 and soil catena sequence along a loess slope in the Seret River valley: Evidence from the Pronyatyn Palaeolithic site (Ukraine). Quaternary International, **365**: 74–97; https://doi.org/10.1016/j.quaint.2014.05.035

Łanczont, M., Bogucki, A., Yatsyshyn, A., Terpiłowski, S., Mroczek, P., Orłowska, A., Hołub, B., Zieliński, P., Komar, M., Woronko, B., Kulesza, P., Dmytruk, R., Tomeniuk, O., 2019. Stratigraphy and chronology of the periphery of the Scandinavian ice sheet at the foot of the Ukrainian Carpathians. Palaeogeography, Palaeoclimatology, Palaeoecology, **530**: 59–77; https://doi.org/10.1016/j.palaeo.2019.05.024

Łanczont, M., Mroczek, P., Komar, M., Fedorowicz, S., Woronko, B., Nawrocki, J., Frankowski, Z., Standzikowski, K., 2022. A remarkable last glacial loess sedimentation at Roxolany in the Dniester Liman (Southern Ukraine). Quaternary Science Reviews, **285**: 107521; https://doi.org/10.1016/j.quascirev.2022.107521

Lehmkuhl, F., Nett, J.J., Pötter, S., Schulte, P., Sprafke, T., Jary, Z., Antoine, P., Wacha, L., Wolf, D., Zerboni, A., Hošek, J., Marković, S.B., Obreht, I., Sümegi, P., Veres, D., Zeeden, C., Boemke, B.J., Schaubert, V., Viehweger, J., Hambach, U., 2021. Loess landscapes of Europe - mapping, geomorphology, and zonal differentiation. Earth-Science Reviews, **215**: 103496; https://doi.org/10.1016/j.earscirev.2020.103496

Lindner, L., Gozhik, P., Marciniak, B., Marks, L., Yelovicheva, Y., 2004. Main climatic changes in the Quaternary of Poland, Belarus and Ukraine. Geological Quarterly, **48** (2): 97–114.

Lindner, L., Bogutsky, A., Gozhik, P., Marks, L., Łanczont, M., Wojtanowicz, J., 2006. Correlation of Pleistocene deposits in the area between the Baltic and Black Sea, Central Europe. Geological Quarterly, **50** (1): 195–210.

Lisiecki, L.E., Raymo, M.E., 2005. A Pliocene–Pleistocene stack of 57 globally distributed benthic ^{18}O records. Paleoceanography, **20**: PA1003; https://doi.org/10.1029/2004PA001071

Liu, Q., Chunsheng, J., Pengxiang, H., Zhaoxia, J., Kunpeng, G., Roberts, A., 2015. Magnetostratigraphy of Chinese loess–paleosol sequences. Earth-Science Reviews, **150**: 139–167; http://doi.org/10.1016/j.earscirev.2015.07.009

Manyuk, V., 2021. New data on geology of the Rybalsky Quarry, unique object of geological heritage of global significance. Journal of Geology, Geography and Geoecology, **30**: 100–121; https://doi.org/10.15421/112110

Marković, S.B., Hambach, U., Stevens, T., Kukla, G.J., Heller, F., McCoy, W.D., Oches, E.A., Buggle, B., Zöller, L., 2011. The last million years recorded at the Stari Slankamen loess–palaeosol sequence: revised chronostratigraphy and long-term environmental trends. Quaternary Science Reviews, **30**: 1142–1154; https://doi.org/10.1016/j.quascirev.2011.02.004

Marković, S.B., Stevens, T., Kukla, G.J., Hambach, U., Fitzsimmons, K.E., Gibbard, P., Buggle, B., Zech, M., Guo, Z., Hao, Q., Wu, H., O'Hara Dhand, K., Smalley, I.J., Újvári, G., Sümegi, P., Timar-Gabor, A., Veres, D., Sirocko, F., Vasiljević, D.A., Jary, Z., Svensson, A., Jović, V., Lehmkuhl, F., Kovács, J., Svirčev, Z., 2015. Danube loess stratigraphy – Towards a pan-European loess stratigraphic model. Earth-Science Reviews, **148**: 228–258; https://doi.org/10.1016/j.earscirev.2015.06.005

Matoshko, A., 2021. Loess and its derivatives in a common sedimentary and geomorphic evolution of the East European Plain. Aeolian Research, **53**: 100750; https://doi.org/10.1016/j.aeolia.2021.100750

Matoshko, A., Matoshko, A., de Leeuw, A., 2019. The Plio-Pleistocene demise of the East Carpathian Foreland fluvial system and arrival of the Paleo-Danube to the Black Sea. Geologica Carpathica, **70**: 91–112; https://doi.org/10.2478/geoca-2019-0006

Matviishina, Zh.M., 2011. Micromorphology and pedogenesis of the Pleistocene loess-soil section in Pobuzhye (Ukraine) and its palaeoenvironment implication. In: Quaternary Studies in Ukraine (eds. N.P. Gerasimenko, P.F. Gozhik, N.I. Dykan, Zh.M. Matviishina, V.M. Shelkoplyas and B.D. Vozgri): 55–66. Institute of Geological Sciences NASU, Kyiv.

Matviishyna, Zh.M., Doroshkevych, S.P., 2019. Micromorphological peculiarities of the Pleistocene soils in the Middle Pobuzhzhya (Ukraine) and their significance for palaeogeographic reconstructions. Journal of Geology, Geography and Geoecology, **28**: 327–347. https://doi.org/10.15421/111932

Matviishina, Zh., Mel'nichuk, I., Perederyi, V., Gerasimenko, N., 2001. Vyazivok section. In: The Ukraine Quaternary explored: the Middle and Upper Pleistocene of the Middle Dnieper area and its importance for the East-West European correlation. Excursion guide of the SEQS 2001 conference, Ukraine: 23–36. Institute of Geological Sciences NASU, Kyiv.

Matviishyna, Zh.M., Gerasimenko, N.P., Perederyi, V.I., Bragin, A.M., Ivchenko, A.S., Karmazinenko, S.P., Nagirnyi, V.M., Parkhomenko, O.G., 2010. Spatio-temporal correlation of Quaternary palaeogeographic conditions on the territory of Ukraine (in Ukrainian with English summary). Naukova Dumka, Kyiv.

Melnyk, G., Hlavatskyi, D., Poliachenko, I., Bakhmutov, V., Shenderovska, O., Yakukhno, V., 2022. Current State of Knowledge of the Brunhes Chron Geomagnetic Excursions. 16th International Conference Monitoring of Geological Processes and Ecological Condition of the Environment, Kyiv, Ukraine; http://doi.org/10.3997/2214-4609.2022580137

Moska, P., Sokołowski, R.J., Jary, Z., Zieliński, P., Raczyk, J., Szymak, A., Krawczyk, M., Skurzyński, J., Poręba, G., Łopuch, M., Tudyka, K., 2022. Stratigraphy of the Late Glacial and Holocene aeolian series in different sedimentary zones related to the Last Glacial maximum in Poland. Quaternary International, **630**: 65–83; https://doi.org/10.1016/j.quaint.2021.04.004

Nawrocki, J., Wojcik, A., Bogucki, A., 1996. The magnetic susceptibility record in the Polish and western Ukrainian loess-palaeosol sequences conditioned by paleoclimate. Boreas, **25**: 161–169; https://doi.org/10.1111/j.1502-3885.1996.tb00845.x

Nawrocki, J., Bakhmutov, V., Bogucki, A., Dolecki, L. 1999. The paleo- and petromagnetic record in the Polish and Ukrainian loess-paleosol sequences. Physics and Chemistry of the Earth (A), **24**: 773–777; https://doi.org/10.1016/S1464-1895(99)00113-1

Nawrocki, J., Bogucki, A., Łanczont, M., Nowaczyk, N., 2002. The Matuyama-Brunhes boundary and the nature of magnetic remanence aquisition in the loess-paleosol sequences from the western part of the East European Loess province. Palaeogeography, Palaeoclimatology, Palaeoecology, **188**: 39–50; http://doi.org/10.1016/S0031-0182(02)00528-X

Nawrocki, J., Polechońska, O., Boguckij, A., Łanczont, M., 2006. Palaeowind directions recorded in the youngest loess in Poland and western Ukraine as derived from anisotropy of magnetic susceptibility measurements. Boreas, **35**: 266–271; http://doi.org/10.1111/j.1502-3885.2006.tb01156.x

Nawrocki, J., Boguckyj, A., Łanczont, M., 2007. Palaeomagnetic studies of the loess-palaeosol sequence from the Kolodiiv section (East Carpathian Foreland, Ukraine). Geological Quarterly, **51** (2): 161–166.

Nawrocki, J., Łanczont, M., Rosowiecka, O., Bogucki, A.B., 2016. Magnetostratigraphy of the loess-palaeosol key Palaeolithic section at Korolevo (Transcarpathia, W Ukraine). Quaternary International, **399**: 72–85; https://doi.org/10.1016/j.quaint.2014.12.063

Nawrocki, J., Bogucki, A., Łanczont, M., Werner, T., Standzikowski, K., Pańczyk, M., 2018a. The Hilina Pali palaeomagnetic excursion and possible self-reversal in the loess from western Ukraine. Boreas, **47**: 954–966; https://doi.org/10.1111/bor.12305

Nawrocki, J., Gozhik, P., Łanczont, M., Pańczyk, M., Komar, M., Bogucki, A., Williams, J.S., Czupy, Z., 2018b. Palaeowind directions and sources of detrital material archived in the Roxolany loess section (southern Ukraine). Palaeogeography, Palaeoclimatology, Palaeoecology, **496**: 121–135; https://doi.org/10.1016/j.palaeo.2018.01.028

Nawrocki, J., Bogucki, A.B., Gozhik, P., Łanczont, M., Pańczyk, M., Standzikowski, K., Komar, M., Rosowiecka, O., Tomeniuk, O., 2019. Fluctuations of the Fennoscandian Ice Sheet recorded in the anisotropy of magnetic susceptibility of periglacial loess from Ukraine. Boreas, **48**: 940–952; https://doi.org/10.1111/bor.12400

Necula, C., Dimofte, D., Panaiotu, C., 2015. Rock magnetism of a loess-palaeosol sequence from the western Black Sea shore (Romania). Geophysical Journal International, **202**: 1733–1748. https://doi.org/10.1093/gji/ggv250

Petrova, G.N., Pospelova, G.A., 1990. Excursions of the magnetic field during the Brunhes chron. Physics of the Earth and Planetary Interiors, **63**: 135–143; https://doi.org/10.1016/0031-9201(90)90067-8

Petrova, G.N., Nechaeva. T.B., Pospelova, G.A., 1992. Kharakter izmeneniya geomagnitnogo polya v proshlom (in Russian). Nauka, Moscow.

Pevzner, M.A., 1970. Paleomagnitnye issledovaniya pliotsen-chetvertichnykh terras Dnestra (in Russian). Materialy VIII konferentsii po postoyannomu magnitnomu polyu I paleomagnetizmu. 2. Naukova Dumka, Kyiv.

Pilipenko, O.V., Sharonova, Z.V., Trubikhin, V.M., Didenko, A.N., 2005. Fine structure and evolution of the geomagnetic field recorded in the Roksolany (Ukraine) loess-soil section 75–10 ka (in Russian with English summary). Fizika Zemli, **1**: 66–73.

Popiuk, Y., Ridush, B., Solovey, T., 2021. Middle and Late Pleistocene terrestrial snails from the Middle Dniester area, Ukraine (based on Mykola Kunytsia's collections). Geological Quarterly, **65**: 1–12; http://doi.org/10.7306/gq.1575

Pospelova, G.A., Gnibidenko, Z.N., 1972. Paleomagnetic studies of the Pliocene-Quaternary deposits of Southern Transnistria (in Russian with English summary). Geofizicheskiy Sbornik, **47**: 55–65.

Rousseau, D.-D., Gerasimenko, N., Matviischina, Zh., Kukla, G., 2001. Late Pleistocene environments of the Central Ukraine. Quaternary Research, **56**: 349–356; http://doi.org/10.1006/qres.2001.2270

Sartori, M., 2000. The Quaternary climate in loess sediments: Evidence from rock and mineral magnetic and geochemical analysis. PhD thesis. 231 p. Swiss Federal Institute of Technology, Zurich.

Shackleton, N.J., Berger, A., Peltier, W.R., 1990. An alternative astronomical calibration of the lower Pleistocene timescale based on ODP Site 677. Transactions of the Royal Society of Edinburgh Earth Sciences, **81**: 251–261; https://doi.org/10.1017/S0263593300020782

Sharonova, Z.V., Pilipenko, O.V., Trubikhin, V.M., Didenko, A.N., Feyn, A.G., 2004. Restoration of geomagnetic field according to paleomagnetic records in loess-soil section Roxolany (Dnestr river, Ukraine) for last 75 000 years (in Russian with English summary). Fizika Zemli, **1**: 4–13.

Sirenko, O., 2019. Changes in Pleistocene vegetation and climate of Ukraine in the range of 1.8-0.4 million years. Journal of Geology, Geography and Geoecology, **28**: 355–366; https://doi.org/10.15421/111934

Sirenko, N.A., Turlo, S.I., 1986. Razvitiye pochv i rastitel'nosti Ukrainy v pliotsene i pleystotsene (in Russian). Naukova Dumka, Kyiv.

Sirenko, N.A., Vozgrin, B.D., Tretyak, A.N. et al., 1993. Palaeopedological, detailed lithological and stratigraphic subdivision of sections of Upper Cenozoic deposits and their correlation across the area of a large-scale geological survey in the interfluve of the Vorskla and Seversky Donets (sheets: M-86-95, 108-B, M-37-96-B, 97-A): A report of the Institute of Geography of the Academy of Sciences of Ukraine. 200 p. Kyiv.

Sirenko, O.A., Bahmutov, V.G., Nikitchenko, ¸.M., 2008. New data for studying Neopleistocene deposits of Nonglacial zone of the Ukrainian Shield (in Ukrainian with English summary). Geologichnyi Zhurnal, **325**: 113–122.

Smalley, I., O'Hara-Dhand, K., Wynn, P., 2008. Two types of loess – two sets of origins: the Danubian and Ukrainian loesses compared. Abhandlungen der Geologischen Bundesanstalt, **62S**: 221-222.

Song, Y., Guo, Z., Marković, S., Hambach, U., Deng, C., Chang, L., Wu, J., Hao, Q., 2018. Magnetic stratigraphy of the Danube loess: a composite Titel-Stari Slankamen loess section over the last one million years in Vojvodina, Serbia. Journal of Asian Earth Sciences, **155**: 68–80; https://doi.org/10.1016/j.jseaes.2017.11.012

Suc, J.-P., Bertini, A., Leroy, S.A.G., Suballyova, D., 1997. Towards the lowering of the Pliocene/Pleistocene boundary to the Gauss-Matuyama reversal. Quaternary International, **40**: 37–42; https://doi.org/10.1016/S1040-6182(96)00059-6

Sümegi, P., Gulyás, S., Molnár, D., Sümegi, B.P., Almond, P.C., Vandenberghe, J., Zhou, L., Pál-Molnár, E., Törőcsik, T., Hao, Q., Smalley, I., Molnár, M., Marsi, I., 2018. New chronology of the best developed loess/paleosol sequence of Hungary capturing the past 1.1 ma: Implications for correlation and proposed pan-Eurasian stratigraphic schemes. Quaternary Science Reviews, **191**: 144–166; https://doi.org/10.1016/j.quascirev.2018.04.012

Sümegi, P., Molnár, D., Gulyás, S., Stevens, T., Makó, L., Cseh, P., Molnár, M., Fitzsimmons, K., Nett, J.J., Hlavatskyi, D., Lehmkuhl, F., 2022. Comparison of high-resolution ^{14}C and luminescence-based chronologies of the MIS 2 Madaras loess/paleosol sequence, Hungary: implications for chronological studies. Quaternary, **5**: 47; https://doi.org/10.3390/quat5040047

Tauxe, L., Herbert, T., Shackleton, N.J., Kok, Y.S., 1996. Astronomical calibration of the Matuyama–Brunhes boundary: consequences for magnetic remanence acquisition in marine carbonates and the Asian loess sequences. Earth and Planetary Science Letters, **140**: 133–146; https://doi.org/10.1016/0012-821X(96)00030-1

Tecsa, V., Gerasimenko, N., Veres, D., Hambach, U., Lehmkuhl, F., Schulte, P., Timar-Gabor, A., 2020. Revisiting the chronostratigraphy of Late Pleistocene loess-paleosol sequences in southwestern Ukraine: OSL dating of Kurortne section. Quaternary International, **542**: 65–79; https://doi.org/10.1016/j.quaint.2020.03.001

Tretyak, A.N., 1967. Paleomagnetism of late Tertriary and Quaternary sediments of the Ukrainian SSR (in Russian with English summary). Geofizicheskiy Sbornik, **21**: 73–81.

Tretyak, A.N., 1972. Principles of paleomagnetic stratigraphy (in Russian with English summary). Geofizicheskiy Sbornik, **45**: 9–19.

Tretyak, A.N., 1980. Regim of the Pleistocene geomagnetic field and structure of the Brunhes geomagnetic epoch (in Russian with English summary). Geofizicheskiy Zhurnal, **5**: 75–87.

Tretyak, A.N., 1983. Estestvennaya ostatochnaya namagnichennost' i problema paleomagnitnoy stratifikatsii osadochnykh tolshh (in Russian). Naukova Dumka, Kyiv.

Tretyak, A.N., Volok, Z.E., 1974. An experiment of paleomagnetic stratification of the Pliocene–Quaternary deposits in the territory of the Ukrainian SSR (in Russian with English summary). Geofizicheskiy Sbornik, **58**: 50–55.

Tretyak, A.N., Volok, Z.E., 1975. Paleomagnetic section of the upper Cenozoic deposits in the south-west of the Ukraine and Moldavia (in Russian with English summary). Geofizicheskiy Sbornik, **64**: 43–46.

Tretyak, A.N., Volok, Z.E., 1976. Paleomagnitnaya stratigrafiya pliotsen-chetvertichnykh osadochnykh tolshch Ukrainy (in Russian). 88 p. Naukova Dumka, Kyiv.

Tretyak, A.N., Volok, Z.E., 1982. Paleomagnitnaya stratigrafiya pliotsen-chetvertichnykh otlozheniy Pridnestrovya i yugo-zapada Moldavii (in Russian). In: Paleomagnitnaya stratigrafiya kaynozoyskikh otlozheniy: 31–47. Naukova Dumka, Kyiv.

Tretyak, A.N., Vigilyanskaya, L.I., 1994. Magnetostratigraphic scale of Pleistocene of Ukraine (in Russian with English summary). Geofizicheskiy Zhurnal, **16**: 3–14.

Tretyak, A.N., Shevchenko, A.I., Dudkin, V.P., Vigilyanskaya, L.I., 1987. Paleomagnitnaya stratigrafiya opornykh razrezov pozdnego kaynozoya yuga Ukrainy (in Russian). Institute of Geological Sciences AS USSR, Kyiv.

Tretyak, A.N., Vigilyanskaya, L.I., Makarenko, V.N., Dudkin, V.P., 1989. Tonkaya struktura geomagnitnogo polya v pozdnem kaynozoye (in Russian). Naukova Dumka, Kyiv.

Tsatskin, A., Heller, F., Hailwood, E.A., Gendler, T.S., Hus, J., Montgomery, P., Sartori, M., Virina, E.I., 1998. Pedosedimentary division, rock magnetism and chronology of the loess/palaesol sequence at Roxolany (Ukraine). Palaeogeography, Palaeoclimatology, Palaeoecology, **143**: 111–133; https://doi.org/10.1016/S0031-0182(98)00073-X

Tsatskin, A., Heller, F., Gendler, T.S., Virina, E.I., Spassov, S., Du Pasquier, J., Hus, J., Hailwood, E.A., Bagin, V.I., Faustov, S.S., 2001. A new scheme of terrestrial paleoclimate evolution during the last 1.5 Ma in the western Black Sea region: integration of soil studies and loess magmatism. Physics and Chemistry of the Earth, **26**: 911–916; https://doi.org/10.1016/S1464-1895(01)00141-7

Tsatskin, A., Gendler, T.S., Heller, F., 2008. Improved paleopedological reconstruction of vertic paleosols at Novaya Etuliya, Moldova via integration of soil micromorphology and environmental magnetism. In: New Trends in Soil Micromorphology (eds. S. Kapur and G. Stoops): 91–110. Springer-Verlag, Berlin Heidelberg.

Varga, G., 2015. Changing nature of Pleistocene interglacials - is it recorded by paleosoils in Hungary (Central Europe)? Hungarian Geographical Bulletin, **64**: 317–326; https://doi.org/10.15201/hungeobull.64.4.6

Veklich, M.F., 1968. Stratigrafiya lessovoy formatsii Ukrainy i sosednikh stran (in Russian). 238 p. Naukova Dumka, Kyiv.

Veklich, M.F., 1982. Paleoetapnost' i stratotipy pochvennykh formatsiy verkhnego kaynozoya (in Russian). 202 p. Naukova Dumka, Kyiv.

Veklich, M.F., 1987. Problemy paleoklimatologii (in Russian). 190 p. Naukova Dumka, Kyiv.

Veklich, M.F., 1995. Correlation of the Pleistocene paleogeographical stages: ocean–loess areas–the Black Sea (in Russian with English summary). In: Correlation of Paleogeographical Events: Continent–Shelf–Ocean (ed. A.A. Svitoch): 27–33. Moscow University Press, Moscow.

Veklich, M.F., Sirenko, N.A., 1972. Opornyye geologicheskiye razrezy antropogena Ukrainy. Ch. III (in Russian): 225 p. Naukova Dumka, Kyiv.

Veklich, M.F., Veklich, Y.M., 1993. Stage and stratoregion of the estuary-marine Pleistocene of the Azov–Black Sea Basin (in Russian with English summary). 186 p. Publ. by the Institute of Geography of NAS of Ukraine, Kyiv.

Veklich, M.F., Artyushenko, A.T., Sirenko, N.A., Dubnyak, V.A., Mel'nichuk, I.V., Parishkura, S.I., 1967. Opornyye geologicheskiye razrezy antropogena Ukrainy (in Russian): 13–50. Naukova Dumka, Kyiv.

Veklich, M.F., Sirenko, N.A., Matviyishina, Zh.N., 1984. Paleogeograficheskiye etapy i detal'noye stratigraficheskoye raschleneniye pleystotsena Ukrainy (in Russian). 32 p. Naukova Dumka, Kyiv.

Veklich, M.F., Sirenko, N.A., Matviishina, Z.N., Gerasimenko, N.P., Perederiy, V.I., Turlo, S.I., 1993. Stratigraficheskaya skhema chetvertichnykh otlozheniy Ukrainy (in Russian). In: Stratigraficheskiye skhemy fanerozoya i dokembriya. Goskomgeologia of Ukraine, Kyiv.

Veklych, Y., 2019. Map of Quaternary formations of Ukraine in scale 1:2,500,000. Journal of Geology, Geography and Geoecology, **28**: 367–376; https://doi.org/10.15421/111935

Velichko, A.L., Morozova, T.D., Pevzner, M.L., 1973a. Stroenie i vozrast gorizontov lyossov i iskopaemykh pochv na glavnykh terrasovykh urovnyakh Severnogo Priazovya (in Russian). In: Paleomagnitnyi analiz pri izuchenii chetvertichnykh otlozheniy i vulkanitov: 48–70. Nauka, Moscow.

Velichko, A.L., Morozova, T.D., Pevzner, M.L., 1973b. Korrelyatsiya kontinentalnykh i morskikh otlozheniy v Severnom Priazovye pri pomoschi paleomagnitnogo metoda (in Russian). In: Khronologiya pleystotsena i klimaticheskaya stratigrafiya: 23–27. Nedra, Leningrad.

Vigilyanskaya, L.I., 2001. Paleomagnetic section and magnetic properties of Quaternary deposits of the Viazivok site. In: The Ukraine Quaternary explored: the Middle and Upper Pleistocene of the Middle Dnieper area and its importance for the East-West European correlation. Abstracts of the SEQS 2001 conference: 97. Institute of Geological Sciences NASU, Kyiv.

Vigilyanskaya, L.I., 2002. Palaeomagnetic studies of Pliocene-Pleistocene deposits of loess-palaeosol stratum in Middle Dnieper region (in Russian with English summary). Geofizicheskiy Zhurnal, **24**: 36–42.

Vigilyanskaya, L.I., Tretyak, A.N., 2000. Palaeomagnetism of key Pliocene-Pleistocene sections in North-Western Donbass (in Russian with English summary). Geofizicheskiy Zhurnal, **22**: 96–104.

Virina, E.I., Dobrodeev, O.P., Faustov, S.S., 1971. Paleomagnetizm i korrelatsiya noveyshikh otlozheniy juga Russkoy ravniny (in Russian). In: Problemy pleistocena: 258–262. Leningrad, Geograficheskoe soobschestvo SSSR.

Vozgrin, B.D., 2001. Problemy stratyhrafichnoho rozchlenuvannya ta korelyatsii kontynentalnykh vidkladiv antropohenu Ukrayiny (in Ukrainian). In: Rehionalni heolohichni doslidzhennya v Ukrayini i pytannya stvorennya Derzhheolkarty – 2001. The State Geological Survey, Ukrainian State Research Institute for Geological Survey, Kyiv.

Wulf, S., Fedorowicz, S., Veres, D., Łanczont, M., Karátson, D., Gertisser, R., Bormann, M., Magyari, E., Appelt, O., Hambach, U., Gozhik, P.F., 2016. The 'Roxolany Tephra' (Ukraine) – new evidence for an origin from Ciomadul volcano, East Carpathians. Journal of Quaternary Science, **31**: 565–576; https://doi.org/10.1002/jqs.2879

Zeeden, C., Hambach, U., Obreht, I., Hao, Q., Abels, H.A., Lehmkuhl, F., Gavrilov, M.B., Marković, S.B., 2018. Patterns and timing of loess-paleosol transitions in Eurasia: Constraints for paleoclimate studies. Global and Planetary Change, **162**: 1–7; https://doi.org/10.1016/j.gloplacha.2017.12.021

Zubakov, V.A., Pisarevskiy, S.A., Bogatina, N.V., 1982. O stratigraficheskom polozhenii zon obratnoy i anomalnoy polyarnosti ortomagnetema Bryunes v opornykh razrezakh pleystotsena Kerch-Tamanskogo rayona (in Russian). In: Paleomagnitnaya stratigrafiya mezo-kaynozoyskikh otlozheniy: 50–56. Naukova Dumka, Kyiv.