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Palaeoseismic deformations in the Eastern Baltic region (Kaliningrad District of Russia)

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Abstract. The article presents new data on sedimentological structures, which have been discovered at the Ryadino archaeological excavation in the northeast of the Kaliningrad District of Russia (the Šešupė River Valley). Tongue-shaped and dome-shaped diapir-like structures indicate liquefaction-induced features. As the most plausible reason, the earthquake-induced shaking is discussed. A preliminary estimation of the time interval for the seismic event covers the period from the early up to the late Holocene. The reasons for seismic activity in this region can be related to neotectonic movements (including glacio-isostatic rebound) as recorded in the southeastern Baltic Sea area of the Fennoscandian ice sheet margin zone. The relation between a palaeoseismic event and the essential changes in the hydrographic network in the region is also discussed.

Key words: palaeoseismicity, liquefaction, soft-sediment deformation structures, glacio-isostatic rebound, Šešupė River valley.

INTRODUCTION

Palaeoseismological investigations have a long tradition in many European regions affected by glaciations. Successful attempts have been made in studies aimed at extending the seismic catalogues, identifying the causes of recent and past seismic activity, estimating the maximum possible magnitudes, earthquake recurrence intervals, etc. (Mörner 1985, 2003, 2011; Stewart et al. 2000; Hoffmann & Reicherter 2012; Nikonov 2013; Van Loon & Pisarska-Jamroży 2014; Sandersen & Jørgensen 2015; Grützner et al. 2016; Van Loon et al. 2016).

Most of the palaeoseismic events identified are dated to the late Pleistocene and early Holocene and have led to a conclusion about the relationship existing between postglacial rebound and seismic activity (Stewart et al. 2000; Mörner 2003; Houtgast et al. 2005). The Fennoscandian postglacial rebound and glacial forebulge in relation to the underlying tectonic stress have engendered a pattern of alternating regions of higher and lower seismicity, whereas evidences of active faulting and seismicity are mostly connected to the areas where ice sheets reached their maximum thickness, including the marginal regions (Mörner 2003; Steffen & Wu 2011; Hoffmann & Reicherter 2012; Brandes et al. 2015). According to Stewart et al. (2000) and Sandersen & Jørgensen (2015), the loading and unloading of ice sheets, which covered large areas of northern Europe, can affect areas hundreds of kilometres outside the former ice-sheet margins and the areas that could potentially be affected by deglaciation tectonics. These areas may therefore have considerable size and include wide territories from the British Isles to the Baltic region and further to the east.

High seismic activity in the Fennoscandian shield area and the adjacent Baltic Sea territories (including evidence of tsunamis in the Baltic Sea) during the late glacial and the Holocene has been documented in a number of studies (e.g. Mörner 2003, 2011, 2013; Nikonov 2004; Bitinas & Lazauskienė 2011; Bitinas 2012; Mörner & Dawson 2012; Rotnicki et al. 2016). Seismic activity in the Eastern Baltic Sea region (including Baltic states and Kaliningrad District of Russia) is significantly lower than the seismicity in the Fennoscandian shield. Nevertheless, a considerable number (>40) of seismic events with magnitudes (M) up to 5, including those, which produced surface ruptures, have been recorded in the area (Nikonov 2008a, 2008b; Bitinas & Lazauskienė 2011; Van Loon et al. 2016). Historical data on earthquakes on the territories of former Prussia (1302) and

Lithuania (1328) both with M ~5, Latvia (in 1616, M 4.8), a tsunami event in 1779 on the Baltic Sea coast near Trzebiatów (Poland), recent earthquakes in Estonia (in 1976, M 4.78) and the Kaliningrad District (Russia) (in 2004, M 5.2) provide evidence of seismic activity in this part of Subbalticum (Nikonov 2008a, 2008b, 2010).

Palaeoseismological studies of the Eastern Baltic area have a relatively short history. However, recent detailed analysis of the Quaternary deposits of this territory based on modern state-of-the-art palaeoseismology has led to considerable advancements in the understanding of some important aspects of regional seismic geology. Many of the soft-sediment deformed structures (SSDS), earlier interpreted as cryoturbations, glaciotectonic features or so-called water-escape structures, could be the liquefaction-induced sediment deformations. Such structures have been found and described in a number of locations in Estonia, Latvia, Lithuania, Poland and Belarus. The majority of these seismite-type structures were formed during the late glacial and Holocene periods, and several of them are related to the middle Pleistocene, Eemian interglacial and early Weichselian strata (Bitinas & Lazauskienė 2011; Bitinas 2012; Van Loon & Pisarska-Jamroży 2014; Van Loon et al. 2016).

The territory of the Kaliningrad District (Fig. 1) was for many years considered as seismically inactive, and no evidence of palaeoseismicity has been recorded before 2004. The situation changed after the Kaliningrad earthquake in 2004 with M 5.2, which led to the destruction of 1046 buildings and surface ruptures (Nikonov 2010). The location of the causative faults is

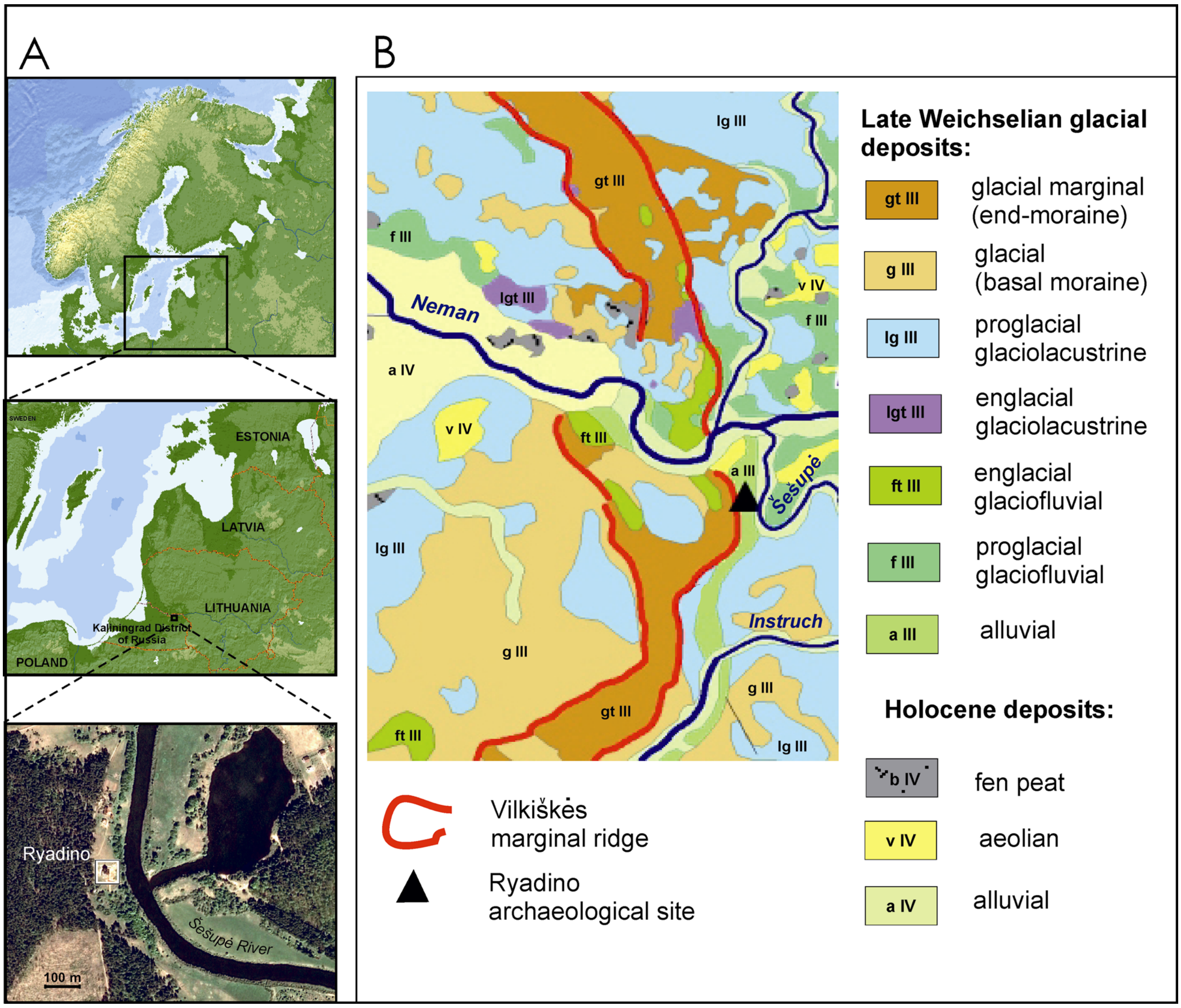

Fig. 1. A, location of the study area; **B**, the geological and geomorphological situation at the Ryadino archaeological site and its surroundings (after Bitinas et al. 2017).

disputable, but could probably be related to two zones at a depth of about 20 km: a meridional active fault along the western coast and a latitudinal one along the northern coast of the Sambian Peninsula (Nikonov 2008a, 2010) (Fig. 2). The earthquake of 2004 gave an impulse to investigations of recent and historical seismicity in the region. A number of SSDS, interpreted as palaeoseismic deformations, have been identified and described in several locations in the Sambian Peninsula. On the new map of seismic activity published in 2013, the Eastern Baltic region is shown as one of the seismically most active regions of the East European Plain (Nikonov 2013).

The present article provides new data on SSDS demonstrating the liquefaction features, which were identified in the northeast of the Kaliningrad District of Russia (the Šešupė River Valley) during the archaeological excavation of the Ryadino Palaeolithic site in 2009–2010 (Fig. 1). The goal of this study is to link the inferred liquefaction structures to a palaeoseismic event and to contribute to the understanding of the palaeoseismicity of the area under consideration in the context of regional and continental tectonic history.

GEOLOGICAL SETTING

The Eastern Baltic area belongs to the Baltic syncline in the west of the East European Platform. After the deglaciation, during the late Pleistocene and Holocene, the southeastern part of the Baltic Sea region (vicinity of Klaipėda) was uplifting due to glacio-isostatic rebound at a rate of up to 6.8 mm per year, whereas at the present time the subsidence up to 0.5–2.0 mm per year is prevailing (Šliaupa et al. 2005). Recent studies of Holocene vertical crustal movements have revealed that against the background of the overall subsidence of the Baltic syncline there exist several stable or slightly uplifting blocks, probably followed by active faults – the Łeba, Sambian and Klaipeda tectonic blocks (Aizberg et al. 2001; Nikonov et al. 2009).

The study area is located at the confluence of the Šešupė and the Neman rivers. The present relief and the uppermost part of the sediments were formed at the very end of the last (Weichselian) glaciation (Fig. 1).

According to geological-geomorphological data, part of the Šešupė River valley was a part of the main channel

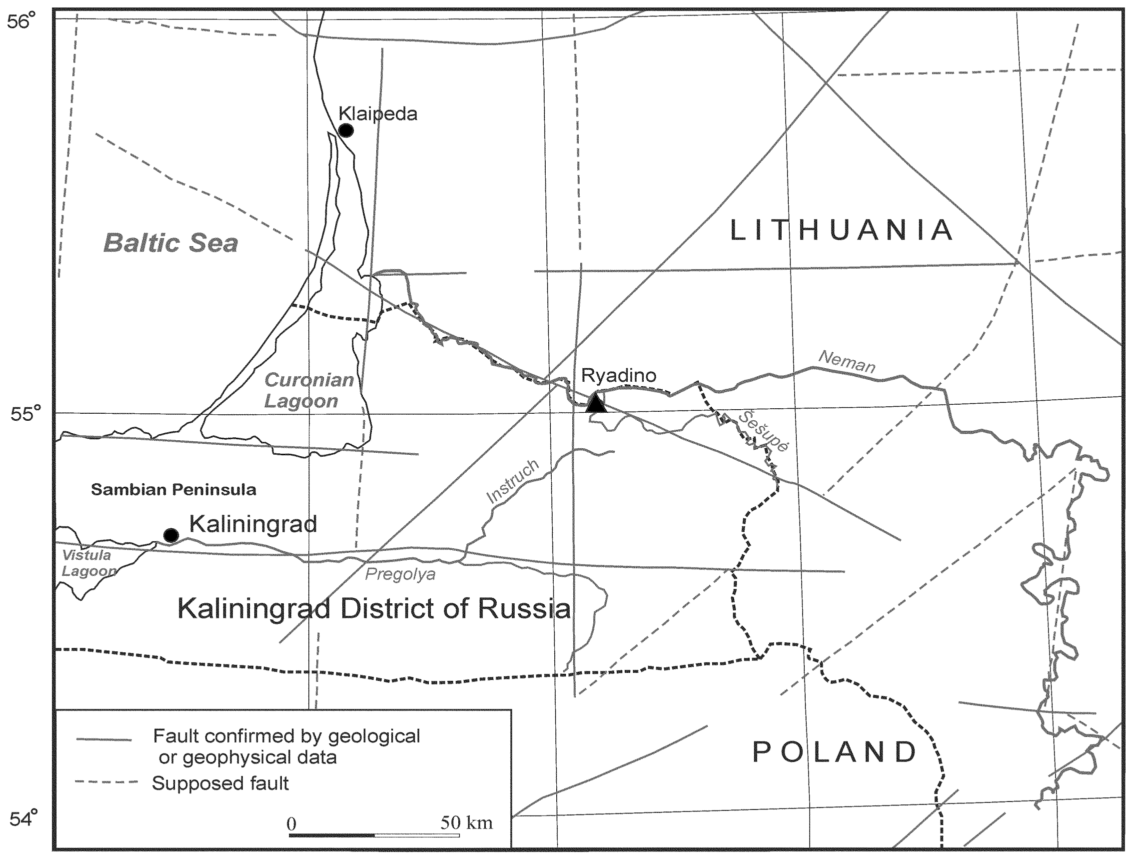

Fig. 2. Map showing the main tectonic faults on the territory of the Kaliningrad District (Russia), Lithuania and Poland (after Aizberg et al. 2001).

for meltwater discharge from north to south, and further to the west, along the valley of the present-day Pregolya River, during the final stage of the Weichselian glaciation (Guobytė & Jusienė 2007; Bitinas et al. 2017). It happened when large territories of Lithuania and the Kaliningrad District were partly deglaciated, but the area of the Neman Delta and the northern part of the Sambian Peninsula were still occupied by dead ice (Guobytė & Jusienė 2007). At that time the periglacial lake, dammed by the end-moraine ridge, named as the Vilkiškės marginal ridge, extended along the entire western margin of the study area. A few metres of glaciolacustrine, in some areas glaciofluvial sand accumulated in this basin. After the reservoir drained, its topography was partially reshaped by the wind to form a 'wavy-hilly' plain with a height of 20–35 m, cut through by the Šešupė River. The terraces of the river were formed as a result of past erosion processes, caused by changes in the base level of erosion, i.e. water level fluctuations in the Baltic Sea. Water level in the former Baltic Sea basins (Yoldia Sea or Ancylus Lake) during the formation of the terraces was a few tens of metres lower than the recent one (Veski et al. 2005; Damušytė 2011). Most probably, oscillatory movements of the Earth's crustal blocks also influenced this process.

The Ryadino site is situated on the second overbank terrace of the river (23 m a.s.l.), the surface of which is covered by well-developed aeolian forms (Fig. 1).

METHODS

Investigations of the Ryadino Palaeolithic site were conducted in 2009–2011 (Druzhinina et al. 2016). After removing the plough layer during excavation in a part (ca 28 m^2) of the site, oval and oblong spots of light grey and reddish-brown sand were observed on the surface of alluvial sand. Such geological structures are not characteristic of alluvial sediments of this region. So, together with traditional archaeological studies, a few additional investigations (geochemical, chronological) have been carried out due to the reconstruction of palaeo-sedimentological conditions.

Geochemical studies were conducted at the Herzen State Pedagogical University (St. Petersburg, Russia). Investigations of the vertical sequence of the deposits, aimed to analyse the environmental and archaeological development of the settlement area, were also carried out (Druzhinina 2012). Sediment samples were taken from the surface down to a depth of 100 cm (including deposits, beneath the culture-bearing layer): samples were spaced at 2–5 cm at a depth between 0 and 70 cm, and at 10 cm between 70 and 100 cm. Chemical analysis of the deposits inside and outside the settlement was carried out by the X-ray fluorescence method using a SPECTROSCAN-MAKC spectrometer. Statistical processing was performed using Statistica 6.0 software. Fine-grained fraction (0.25–0.50 mm) was used for the reconstruction of palaeoenvironmental conditions by using the geochemical indicating method. The environmental conditions of sedimentation (relative humidity, relative temperature, anthropogenic influence) were evaluated using several geochemical indicators such as MnO/Fe_2O_3 and SiO_2/Al_2O_3 ratios. The identified geological structures were sampled to confirm or refute their anthropogenic origin by estimating the values of chemical components such as P_2O_5, CaO, MnO and K_2O (Druzhinina 2012).

Radiocarbon age determinations were performed at the Radioisotope Laboratory, Institute of History of Material Culture, Russian Academy of Science (St. Petersburg, Russia). Two samples of charcoal were taken for ^{14}C analysis. For the calibration of dates, OxCal v4.2.4 (Bronk Ramsey & Lee 2013) was used. Moreover, the IR-OSL dating of six samples was conducted at the Research Laboratory for Quaternary Geochronology, Department of Geology, Tallinn University of Technology (Molodkov & Bitinas 2006; Druzhinina et al. 2016).

Preliminary estimation of the magnitude of the Ryadino seismic event was made using the Magnitude-Bound Method (Obermeier & Pond 1998). The method is based on the correlation between the minimum magnitudes necessary for the formation of liquefaction features and the distance to the causative tectonic faults.

RESULTS

Lithological composition of the section

The investigation results allowed the division of the sediment sequence at the Ryadino archaeological site into five units, or lithofacies (Fig. 3). Under the modern topsoil and plough layer (from the surface to 0.25 m depth) there is a layer of light yellow medium- and fine-grained alluvial sand (between 0.25 and 0.50 m). It has a differentiated structure, from top to bottom as follows. The upper part of the layer is composed of light yellow silty sand, predominantly fine- and medium-grained, with gravels and an admixture of scattered ash. It is followed by light greyish-yellow silty sand, which is also fine- and medium-grained, with a very small amount of fine gravel and an admixture of scattered ash and organic matter. Spotting in colour is observed. The lowest part of the alluvial layer is composed of brownish-yellow medium- and coarse-grained sand, with sharp-edged grains of irregular shape. This part of the alluvial layer contains some amount of angular gravel. This overlies the sediment unit (0.50–0.60 m) of very dense, reddish-

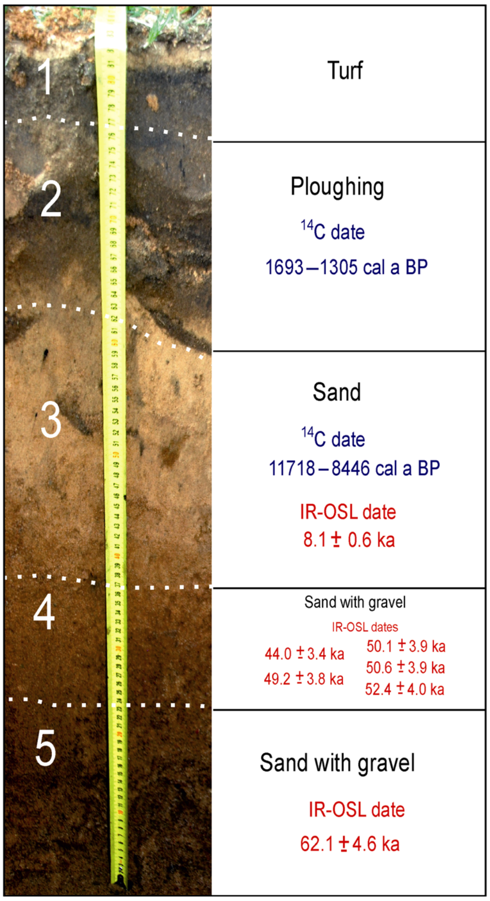

Fig. 3. Undisturbed cross section of the sediment layers at the Ryadino archaeological site. Dating results are from different sampling points and demonstrate sediment chronology of the Ryadino site (after Druzhinina et al. 2016).

brown, ferruginous unsorted loamy sand with a high gravel content. The layer of coarse- and medium-grained light grey sand, with an admixture of gravel forms the lowest part of the section (0.60 m and deeper) (Fig. 3).

After removing the plough layer, oval and oblong spots of light grey and reddish-brown sand were observed on the surface of the alluvial sand (Fig. 4). The excavation and detailed study of these spots, which were at first interpreted as 'pits', revealed that their geological structure did not confirm the anthropogenic origin and, moreover, was out of stratigraphic order.

One of the disturbances of stratigraphy was the sedimentological structure which had tongue-shaped ('flame structures' after Neuwerth et al. 2006) or dome-shaped forms (diapir-like structures), caused by the penetration of light grey sand into the overlying layers (Figs 5–8). This resulted in breaking the boundaries of the overlying layers or their uplift. These deformations had different sizes and 'heights'. The top of the highest discovered one reached the lower limit of the plough layer (Fig. 4). Some of the identified structures had a significant elongation in the uppermost part. Upper elongated 'tongues' of light grey sand had an SE–NW and SW–NE orientation. Lamination of light grey sand was not observed in the majority of tongue-shaped and dome-shaped forms, although it was visible in several structures.

Another example of disturbed stratigraphy was the presence of a 'mixed' layer – spotted unsorted sand. It consisted of inclusions of light yellow, dark and brown sand (Fig. 4).

Fig. 4. The surface of the alluvial sand after removing the plough layer. The tops of the diapir-like structures, which appeared as oval and oblong spots of light grey and reddish-brown sand, are visible in the different parts of the excavation (long arrows). The 'spotted sand' is transpired in the centre (short arrows). The length of the measuring stick is 2 m.

Fig. 5. Soft-sediment deformation structures: light grey sand (contours are marked by a dotted line) is squeezing up into the overlying layers. The length of the measuring stick is 2 m.

Fig. 6. Cross-sectional view of the deformation structure (natural image).

Chronology of the site sediments

Two radiocarbon (^{14}C) dates are available for the site sediments (Table 1). An age of 1580 ± 90 a BP (1693–1305 cal a BP at the 95.4% confidence level) for charcoal sample Le-6340 indicates the lower temporal limit of the plough zone. The sample of charcoal (Le-9049, 8800 ± 600 a BP, calibrated at the 95.4% level to 11 718–8446 cal a BP) is related to the lower part of the alluvial sand. The radiocarbon age obtained is roughly in line with the IR-OSL date for sediment sample RLQG 2114-122 (8.1 ± 0.6 ka) taken from the same layer (Figs 3, 7, 8). The IR-OSL dates for the sediment units underlying the alluvial sand allow us to attribute them to the middle Weichselian (Druzhinina et al. 2016). The ages obtained show that during its formation the Šešupė River incised the sediments until the middle of the Weichselian layers, which are at present lying in the base of the river terraces.

Geochemical investigations

Factor analysis revealed a group of indicator elements of human activities in the area of settlement (Druzhinina 2012). Comparison with the control samples showed that the settlement zone contained higher values of chemical components such as P_2O_5, CaO, MnO and K_2O, which were almost twice the concentration of these elements in the areas outside the settlement (Druzhinina 2012).

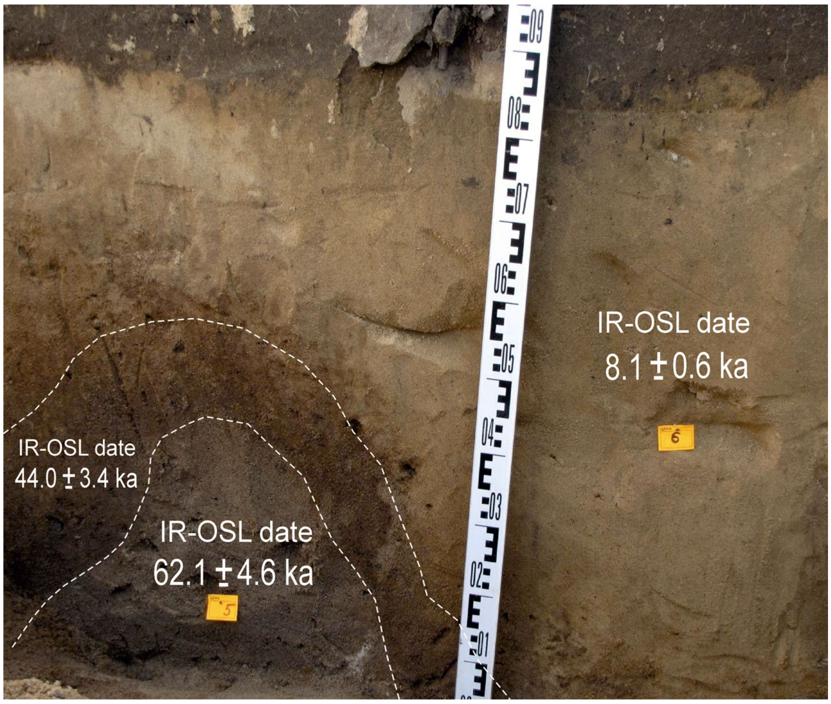

Fig. 7. Diapir-like liquefaction structures (contours are marked by a dotted line) in the profile of the excavation. IR-OSL dates are also shown (after Druzhinina et al. 2016).

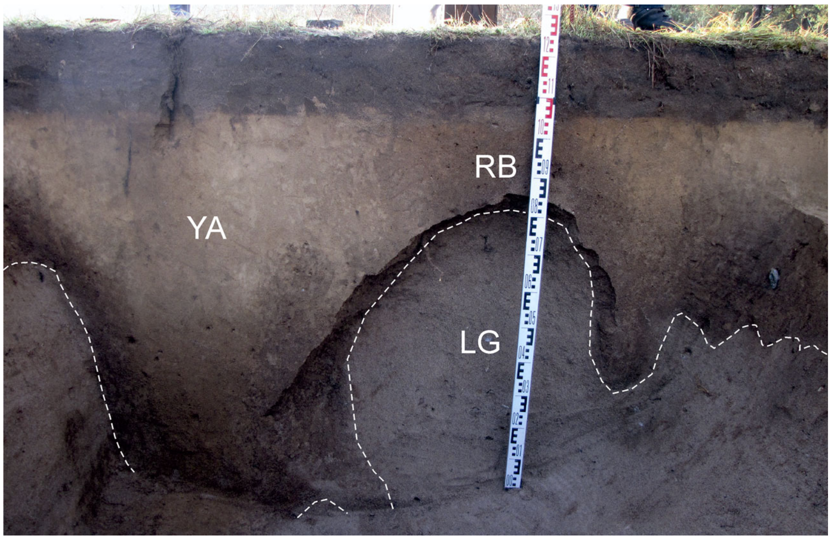

Fig. 8. Diapir-like liquefaction structures (contours are marked by a dotted line) in the profile of the excavation. Light grey (LG) sand has been squeezed up into the overlying layer of reddish-brown (RB) sand. Yellow alluvial (YA) sand is 'sinking' between two diapir-like structures.

Table 1. Results of ^{14}C dating for the sediment samples from the Ryadino archaeological site

No.	Lab No.	Dated material	Depth below surface (m)	^{14}C a BP	Calibrated age (cal a BP, 95.4%)
1	Le-6340	Charcoal	0.23	1580 ± 90	1693–1305
2	Le-9049	Ash	0.45	8800 ± 600	11718–8446

Analysis of samples taken from the investigated geological structures did not reveal any chemical elements in concentrations indicating anthropogenic origin.

Changes in water level were characterized by indicators MnO/Fe_2O_3 and SiO_2/Al_2O_3 in the context of other data. An increase in the MnO/Fe_2O_3 ratio reflected an increase in the oxidative potential of the environment, while SiO_2/Al_2O_3 showed the degree of silica or alumina enrichment of the 0.25–0.50 mm sediment fraction. Increasing values of this index were associated with a change in sedimentation features, and could also be associated with the inflow of well-sorted quartz sand. Such conditions may correspond to the formation of deposits in water streams. Geochemical investigations showed that the formation of sediments at a depth of 0.2–0.5 m occurred in a dynamic river system regime with periodic rises and falls in the water level (Druzhinina 2012).

DISCUSSION

As ice sheets were a major factor in defining the surface morphology of the deposits in the Eastern Baltic area, and because palaeoseismic studies in the region were not initiated until recently, the genesis of many geological structures is still a matter of discussion. According to Pisarska-Jamroży & Weckwerth (2013), such factors as a high sedimentation rate, erosion (by wave action or meltwater currents), ice-sheet loading and seasonal changes in the ablation rate triggered the processes of fluidization and liquefaction of the rapidly deposited, water saturated sediments, which resulted in the formation of a wide range of SSDS. Nevertheless, in some localities among those structures, which have been interpreted as cryoturbations, glaciotectonic features or so-called water-escape structures, sedimentary deformations classified as seismites have been identified (Bitinas & Lazauskienė 2011; Bitinas 2012). According to the resent analysis of SSDS, it is possible to distinguish up to 21 triggering mechanisms of their formation, including for example earthquakes, meteorite impacts, tsunamis, sediment loading (Shanmugam 2016). The most common SSDS for the Southeastern Baltic Region are linked with glaciotectonic deformations, slope processes and cryoturbations. Because SSDS at the Ryadino site are linked with alluvial sediments formed on the flat surface of the highest river terrace during the Holocene climate, the above-mentioned triggers influencing the sedimentary structures are excluded. Thus, a possible reason for SSDS at the Ryadino site could be a palaeoseismic event, which influenced the process of liquefaction and formation of SSDS, referred to as seismites. The term 'seismite' was introduced to describe the various co-seismic effects of earthquakes on sediments that range from principally brittle deformation (e.g. neptunian dykes, hydrofracturing) to soft-sediment deformation (e.g. liquefaction, convolution, seismoslumps) (Seilacher 1969; Michetti et al. 2005; Montenat et al. 2007; Shanmugam 2016). Until recently such structures have been identified and described in a number of locations in Estonia, Latvia, Lithuania, Poland, Germany and Belarus. The majority of these seismite-type structures were formed during the late Pleistocene and Holocene (Bitinas & Lazauskienė 2011; Bitinas 2012; Van Loon & Pisarska-Jamroży 2014; Van Loon et al. 2016).

The sediment deformations observed at Ryadino indicate the upward movement of the underlying light grey sand into overlying yellow alluvial sand (Figs 5, 7, 8). To our opinion, the identified tongue-shaped ('flame structures') and dome-shaped forms (diapir-like structures) with a thinning of the topmost strata clearly demonstrate liquefaction- and fluidization-induced features, which could be caused by earthquake-induced shaking of water saturated sediments (Obermeier & Pond 1998; Obermeier et al. 2002, 2005; Mörner 2003). The sedimentary deformations observed display similarities with seismic deformations studied in Sweden, NW Russia and other regions (Obermeier et al. 2002, 2005; Mörner 2003, 2011; Biske et al. 2006). Liquefaction takes place when unconsolidated sediment experiences a sudden loss of shearing resistance and an increase in pore-fluid pressure, resulting in sedimentary structures that give evidence of upward-directed hydraulic force (Obermeier & Pond 1998; Hoffmann & Reicherter 2012). The geochemical investigations indicate conditions suitable for sediment saturation on the higher terrace. The studies carried out revealed that deposit formation occurred during the Holocene in the dynamic river system regime with periodic rises and falls of the water level. Even in the present day, significant periodic rises in the water level can be observed, leading to the flooding of the first terrace of the river. This is caused by a sharp rise in the water level of the Šešupė River and the neighbouring Neman River during stormy western winds, combined with extremely high precipitation and melting snow. Thus, the formation of palaeoseismic sedimentary deformations on the river terraces could be explained by a combination of extremely high stand of water level and a seismic event at the particular moment of the Holocene.

As evidenced by field observations, the top of the highest diapir reaches the lower part of the plough layer (Fig. 4), dated to 1693–1305 cal a BP (Le-6340). However, it is hard to make a precise correlation between the dated base and the top of the diapir as the charcoal used for dating was taken from a post hole, and was partly contained in the yellow sand but with the upper part ‘distributed’ in the ploughing. Taking into account that most large-magnitude earthquakes in Scotland, Ireland, Germany and Scandinavia happened during a relatively short interval after deglaciation during glacio-isostatic rebound of the crust there approximately 9–12 ka ago (Mörner 2003; Hoffmann & Reicherter 2012; Van Loon & Pisarska-Jamroży 2014; Van Loon et al. 2016; Sandersen & Jørgensen 2015), the Ryadino seismic event probably accompanied the faulting affected by deglaciation tectonics in the early Holocene (after 8.1 ± 0.6 ka (IR-OSL) or 11 718–8446 cal a BP). But with respect to the evidences of the recent seismic activity in the region, we should not exclude that the earthquake under consideration happened later, during the middle or late Holocene. The seismic event could be linked to the system of still active tectonic faults (Fig. 2) along the Sambian Peninsula, the Neman fault and several faults stretching in a NE–SW direction (Aizberg et al. 2001; Gosudarstvennaya... 2011). These known faults and mapped lineaments extend over several tens of kilometres and are capable of inducing liquefaction over great distances (Obermeier & Pond 1998; Michetti et al. 2005). In this instance, we are able to narrow down the time frame of the related seismic activity to a period from the early Holocene (after 8.1 ± 0.6 ka or 11 718–8446 cal a BP) up to the late Holocene (approximately 1693–1305 cal a BP).

Supposing that the earthquake could be caused by the activity of one of the regional faults, the characteristics of the liquefaction observed at the Ryadino site allow us to suggest a magnitude of about 5.5–6.5 (Obermeier & Pond 1998; N.-A. Mörner, pers. comm. 2015).

This study is the first stage of broader comprehensive research, which should be done concerning the Ryadino sedimentary deformations. The newly developed techniques and modelling are necessary for proper palaeoseismic analysis. As a result, solutions to some essential problems of regional palaeogeography could be found out.

One of such issues concerns the major changes in the hydrographic network in the early Holocene. As mentioned above, the Neman and Šešupė rivers during the deglaciation were parts of the huge meltwater runoff system, which transported waters from the Neman and tributaries into the Instruch River and further to the Pregolya River and the Vistula Lagoon (Bitinas et al. 2017). But at a particular moment in the past, the Neman River eroded the Vilkiškes marginal ridge, changed direction and started to flow into the Baltic Sea basin to the north from the Sambian Peninsula. This event led to the formation of two independent hydrographic river systems of the Baltic Sea basin: the Pregolya (flowing into the Vistula Lagoon) and the Neman (flowing into the Curonian Lagoon). The reason for this change in the river flow direction is a matter of debate. In accordance with the data of corresponding investigations and palaeogeographic reconstructions carried out, abrupt changes in the hydrographic network happened at a particular moment of time before 9.5 ka (Bitinas et al. 2017). According to Sirocko et al. (2002), Bregman (2015), Sandersen & Jørgensen (2015) and others, rivers and streams have high sensitivity to tectonic movements and will respond very quickly to vertical changes in morphology. The research of Sandersen & Jørgensen (2015) indicated that streams in the study area followed the lineaments to such a degree that it became evident that the existing stream pattern evolved after the tectonic event. Undoubtedly, the earthquake in the Ryadino environment and the related tectonic processes can be considered among those triggering factors, which could affect the morphology of the area and influence the development of the hydrographic network.

CONCLUSIONS

The new data on the SSDS were obtained in the northeast of the Kaliningrad District of Russia (the Šešupė River Valley). The sediment deformations, observed at the Ryadino archaeological site, indicate the upward movement of the underlying light grey sand into the overlying strata. Detailed geological-geomorphological studies complemented by geochemical and chronological analysis allow us to conclude that the identified tongue-shaped (‘flame structures’) and dome-shaped forms (diapir-like structures) demonstrate liquefaction- and fluidization-induced features, which could be caused by earthquake-induced shaking of water saturated sediments. Geochemical investigations indicate the existence of conditions suitable for sediment saturation on the higher terrace. At present, it is possible to conclude that the seismic event related to the formation of SSDS (seismites) happened later than 8.1 ± 0.6 ka (IR-OSL) or 11 718–8446 cal a BP (^{14}C). Regarding the evidence of recent seismic activity in the region (Kaliningrad earthquakes of 2004), we should not exclude that the earthquake under consideration happened during the middle or late Holocene and could be caused by the structural movements of the Earth crust blocks. The characteristics of the liquefaction observed at the Ryadino site suggest a magnitude of about 5.5–6.5.

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Setete paleoseismilised deformatsioonid Ida-Baltikumis (Kaliningradi oblast, Venemaa)

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Artikkel sisaldab uut teavet Kaliningradi oblasti kirdeosas Šešupe jõe orus asuva Rjadino arheoloogilise leiukoha geoloogilise ehituse kohta. Sealsetes keele- ja kuplikujulistes struktuurides esineb setete veeldumisega (*liquefaction*) seotud nähtusi, mille kõige tõenäolisemateks põhjustajateks olid maavärinad. Seismiline aktiivsus selles piirkonnas võib seotud olla maakoore neotektoonilise liikumise või/ja Läänemere edelaosas Fennoskandia mandriliustiku serva-alal registreeritud jääajajärgse isostaatilise kerkega. Esialgsetel andmetel toimus see seismiline sündmus ajavahemikus Vara-Holotseenist varase keskajani. On arutletud ka paleoseismiliste sündmuste ja hüdrograafilise võrgu oluliste muutuste vahelise seose üle antud piirkonnas.