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PALEO-STORM INDICATORS WITHIN SASYK LIMAN BAYMOUTH BARRIER, UKRAINE

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Sedimentary sequences along continental and insular margins serve as archives of coastal erosion by storms and tsunamis. In areas where overwash is limited or precluded by barrier width and height, such as prograded beach-ridge plains (strandplains), geomorphological (scarps) and lithological (heavy-mineral concentrations) indicators provide the only means of assessing the extent and timing of erosional events. This research presents geological evidence of buried erosional scarps along the Black Sea coast of southwestern Ukraine. A distinct paleo-scarp imaged in shore-normal georadar profile and the associated heavy-mineral horizon (magnetic susceptibility >1,700 SI) indicate a storm event that impacted the shoreline of Sasyk Liman baymouth barrier in historical times. Optical dating offers a more reliable chronology of erosional events, whereas radiocarbon-dated reworked early Holocene shells aid in determining the sources of bioclastic material.

Key words: georadar, heavy-mineral concentration, magnetic susceptibility.

Diagnostic geological indicators of storms include not only depositional features (washovers), but also a suite of erosional indicators (breaches, dune and berm scarps, and mineralogical lag deposits) [2, 3, 5, 10, 12, 13, 17]. The scarps are steep erosional features of variable longshore extent and are typically generated by wave erosion during storms, with subordinate mechanisms that include increased wave activity during spring high tides, ice scour, and tsunamis [11, 14]. Therefore, the ability to identify and map past erosional indicators, such as paleo-scarps and heavy-mineral concentrations (HMCs) are crucial for reconstructing past storm activity, particularly in prograded coastal regions where overwash is precluded by barrier width or dune height [1, 3, 13, 18]. The prograded baymouth barriers of the northwest Black Sea coast (Odessa region, Ukraine; Fig. 1) provide an ideal opportunity for paleotempestological research in a non-tidal basin with a long history of documented meteorological events [6, 7, 16, 20].

The aim of the study is the identification and characterization of geological indicators of erosion, with emphasis on their morphology and recognition in the sedimentary record. In addition, the chronological value of radiocarbon and optical dating are addressed.

Research subject – 1) recent erosional indicators and 2) buried paleo-scarps along a mixed siliciclastic-bioclastic shoreline of the Black Sea (Fig. 1). This is the first study that focuses on paleo-storm signatures along this part of the Black Sea basin.

Geological setting. Erosional geoindicators were investigated along the mixed siliciclastic-bioclastic shoreline of the Sasyk (Kunduk) Liman baymouth barrier, Odessa region, Ukraine (Fig. 1). The northwest Black Sea coast is non-tidal, with fair-weather waves dominating accumulation of berm/beachface successions. Intense storms produce a variety of erosional features such as dune and berm scarps, as well as breaches (prorvas) of thin barriers fronting coastal bays (limans) [9, 16, 20]. Aeolian action dominates the upper dry portion of the berm, producing both deflation lag (shell fragments, heavy-mineral concentrations [2, 3, 5]) and depositional features (incipient coppice dunes, wind-ripple lamination and aeolian ramps extending onto foredune ridges).

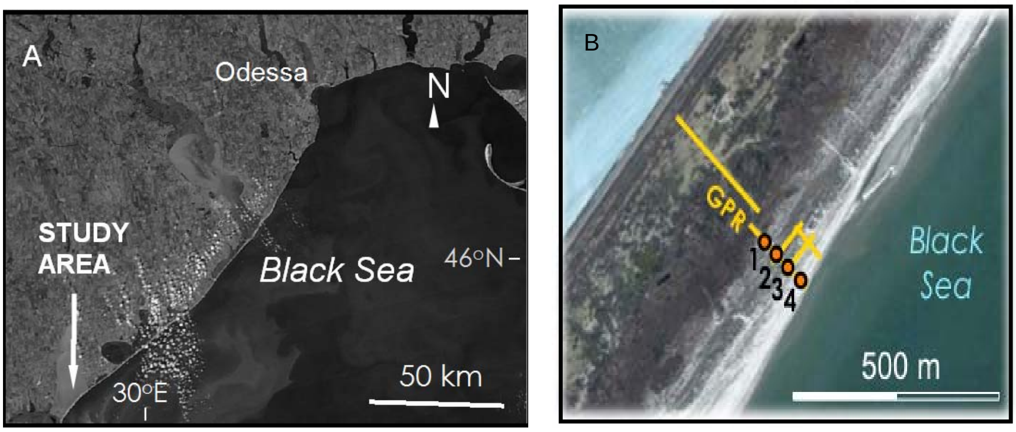

Fig. 1. A – Location of the study site along the northwestern Black Sea coast of Ukraine, just north of the Danube River delta; B – Aerial view of the central Sasyk (Kunduk) baymouth barrier showing geophysical (GPR) transects and sampling trenches.

Methodology. Surficial and subsurface indicators of erosion were identified, measured, and photographed. Because it is often challenging to identify event horizons in sediment cores and short trenches, the identification and mapping of buried storm paleo-indicators was conducted using ground-penetrating radar (GPR). Georadar uses electromagnetic impulses to provide rapid continuous imaging of the shallow subsurface [2, 4, 10, 11, 13, 14, 19]. The surveys were collected in 2012 across the landward sections of selected study sites with a digital MALÅ Geoscience system. Within the upper 1.0–1.5 m, the monostatic 800 MHz antenna provided vertical resolution of 4–5-cm in unsaturated sand (signal velocity ~12cm/ns), with higher resolution below the water table. Field data were post-processed using the RadExplorer v1.41 software package and rendered as two-dimensional sections (2D radargrams). In situ bulk low-field magnetic susceptibility was measured on trench walls using MS2K Bartington sensor. The first radiocarbon (mollusk shell) and optically stimulated luminescence (sand exposure and burial) datasets are presented to discuss their potential in establishing the chronology of coastal events.

Results and Discussion. Trenches through modern beach (berm and beachface) sections along the Sasyk baymouth barrier show a suite of bioclastic accumulations (largely shell hash), as well as thin layers of heavy-mineral concentrations (HMCs; Fig. 2). The latter have a distinct magnetic susceptibility signal (>50 μSI), which is substantially higher than that of background quartz-feldspar/carbonate sands (negative to ~10 μSI). Based on observations, such mineralogical anomalies are produced by moderate wave or wind action or persistent winnowing action in a regime of slow deposition and are typically 1–2 mm in thickness [15].

Fig. 2. Trench across the modern berm along the seaward segment of the main stratigraphic transect (beach location seaward of trench 4 in Fig. 1). Concentration of bioclastic fragments and heavy-mineral concentration (HMC) are the result of winnowing of lighter fraction, likely by moderate waves. Note the anomalously high magnetic susceptibility value of the HMC, compared to slightly negative (diamagnetic) background quartz-rich sand.

Shore-normal GPR images across four ridges of the Sasyk baymouth barrier (Fig. 1B) reveal several distinct reflections along the seaward portions of the ridges. These reflections truncate the gently dipping berm horizons and exhibit 8–12° dip angles (second oldest ridge SKO-2; Fig. 3). They are interpreted as oversteepened upper berm scarps related to major storm erosion [2, 3, 6]. In siliciclastic settings, heavy-mineral concentrations accentuate the scarps, enhancing their visual recognition in trenches and cores and producing sharp signal response in GPR records [3, 10, 11, 14, 19]. These lithological anomalies (HMCs) often have sufficiently high concentrations of paramegnetic and ferrimagnetic fraction to produce anomalously high magnetic susceptibility values (<1,700 μSI; Fig. 4). The HMCs in the SKO-2 paleo-scarp is much thicker than the modern analogue (Fig. 2), likely resulting from prolonged reworking by waves during the waning stage s of the storm [3, 17].

The potential role of buried berm scarps as high-energy indicators emphasizes their value in paleotempestological research, albeit largely understudied [3, 12, 17]. In coastal accumulation forms that are too wide or high to prevent overwash into backbarrier wetlands, these features provide the only geological evidence of past storm or tsunami impact [2, 3, 11, 12, 14, 18]. Although they represent the minimum number of events due to the potential for episodes of net erosion, paleo-scarps act as mappable anomalies in prograded depositional systems. This work will ultimately complement the beach-texture research along the Pontic basin aimed at reconstructing the late Holocene wave climate [1]. In addition to serving as storm indicators, the relatively limited vertical range of berm scarps can be utilized to constrain past sea-level positions [8, 18].

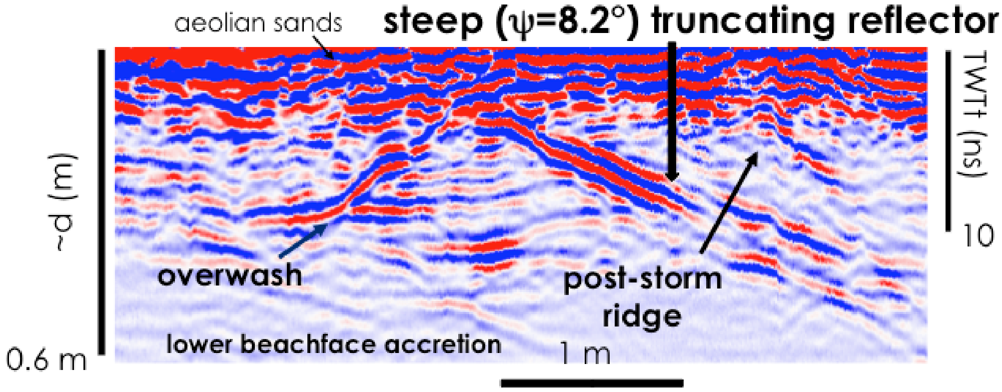

Fig. 3. Georadar image (frequency: 800 MHz; TwTt – two-way travel time in nanoseconds; Black Sea is to the right; see Fig. 1B for location). The paleo-scarp SKO-2 is shown as a prominent seaward-dipping reflection truncating older berm strata. Note the landward-dipping reflection, likely related to overwash deposition.

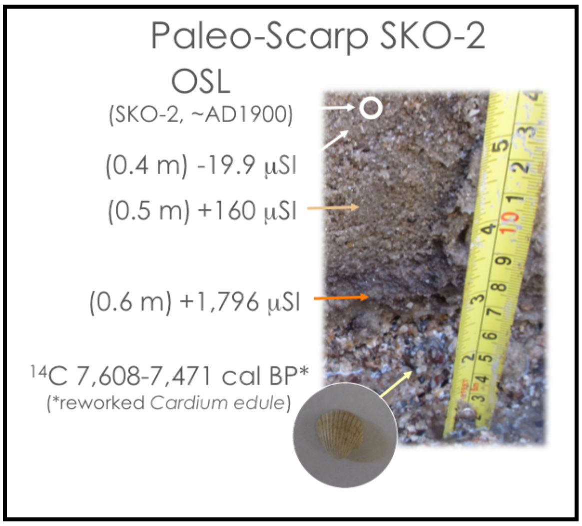

Fig. 4. Trench through paleo-scarp SKO-2 (right side of profile in Fig. 3) shows an extreme concentration of heavy minerals with MS values nearly 20x higher than that of the recent beach (see Fig. 2). Such anomalies not only serve as prominent reflections in GPR images (Fig. 3), helping locate, map, and characterize HMCs geometry, but can provide quantitative information about near-surface shear stress of the flow responsible for their formation. Note the early Holocene age of the reworked mollusk, which provides information on the nearshore sediment source, but not the erosional event. The optical age of ~100 years likely post-dates the scarp, but is much closer to the age of the storm event.

Our research is one of the first attempts at chronological control of erosional events in the absence of associated archaeological or historical documents. The optical (OSL) age of ~100–200 years for overlying beach/dune sands offers a more reliable date than > 7 ka age of the associated mollusk valve (Fig. 4). Based on the general chronology of coastal evolution in this region, including similar buried scarps at nearby locations along the Bessarabian coast [7, 9]. Most baymouth barriers have prograded within the past 500 years [9, 16, 20]. Still, the latter may provide useful information about the source of bioclastic material, including different paleo-shoreline deposits within the Black Sea basin.

Conclusions.

1. Georadar imaging provides a rapid and effective means of locating and characterizing buried erosional indicators along the mixed-sediment coast of southeastern Ukriane.

2. Mineralogical anomalies (>1,700 μSI) aid in accentuating electromagnetic GPR signal response and can provide information about hydrodynamic conditions.

3. Optical dating of overlying beach/dune sediments (100–200 years) is a more reliable indicator than mollusk shells associated with erosional scarps. The latter, however, can provide important information about the source of bioclastic material.

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ІНДИКАТОРИ ДАВНІХ ШТОРМІВ У ПЕРЕСИПІ САСИКСЬКОГО ЛИМАНУ, УКРАЇНА

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Послідовність осадових відкладів вздовж материкових і острівних берегів є свідченням абразії узбережжя штормами та цунамі. В областях, де заплеск хвиль є обмежений або неможливий через ширину та висоту бар'єрів, таких як берегові вали, геоморфологічні (ескарпи, уступи, обриви) та літологічні (вміст важких мінералів) індикатори є єдиними засобами для оцінки масштабів та хронології етапів абразії. У цьому дослідженні наведені геологічні дані щодо похованих ерозійних ескарпів (уступів) вздовж чорноморського узбережжя південно-західної України. Чіткий палео-ескарп (уступ) виявлений у профілі георадару та відповідному горизонті важких мінералів (магнітна сприйнятливість > 1,700и.8I) вказує ' на те, що протягом історичного часу, шторми значне впливали на берегову лінію гирлового бару Сасикського лиману. Оптичне датування забезпечує більш вірогідну реконструкцію хронології абразійних етапів, тоді як датування радіо вуглецевим методом перевідкладених мушель ранньоголоценових молюсків дозволяє визначити джерела біокластичного матеріалу.

Ключові слова: георадар, шліх, магнітна сприйнятливість.