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# Implications of the geochemistry of L1LL1 (MIS2) loess in Poland for paleoenvironment and new normalizing values for loess-focused multi-elemental analyses

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| **Abstract:** | Loess paleoenvironmental reconstructions on a (supra-)regional scale have recently gained much attention. Geochemistry comparisons in relation to a reference dataset such as UCC (Upper Continental Crust) data have helped understand the climatic and geomorphological conditions under which terrestrial sites have developed. However, UCC data differs from loess, thereby obscuring important features, and the existing “average loess” datasets also are not sufficient for modern investigations. In this study, we examine the youngest Polish loess (L1LL1=MIS2,~26–15ka) for its suitability as a new, loess-focused reference dataset. A total of 89 samples from seven sites were analyzed, using Inductively Coupled Plasma spectrometry. The loess had assumedly been homogenized during transportation and/or sedimentary recycling ($La_N/Sm_N$=3.34–4.06, median 3.78; Eu/Eu*=0.46–0.66, median 0.55; $Gd_N/Yb_N$=1.08–1.49, median 1.26), and weakly affected by pre- or post-depositional weathering (CIA=53.64–69.12, median 57.69). The statistically significant differences between sites in elemental medians were mostly conditioned by variations in grain-size and in the "fresh" to "re-deposited" sediment ratio. Nonetheless, the overall geochemical composition homogeneity provided a basis for the estimation of Polish Median Loess (PML) data, as determined for 41 chemical elements. When used, PML data highlight differences between loess regions in Europe, thereby providing a tool for cross-continental comparisons. |

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9th November 2023

Dear Editor,

We here submit the revised research article "**Implications of the geochemistry of L1LL1 (MIS2) loess in Poland for paleoenvironment and new normalizing values for loess-focused multi-elemental analyses**" for consideration by Quaternary Research. We confirm that this work is original and has not been published, nor is it under consideration for publication elsewhere.

This manuscript discuss the geochemical composition of Polish loess. We investigated a total number of 89 samples from seven sites, using Inductively Coupled Plasma – Emission Spectrometry (ICP-ES) and Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) after sample fusion with lithium borate (in a furnace) and a cooled alloy dissolution with ACS grade nitric acid.

We show that the statistically significant differences in medians of elements between research sites were mostly conditioned by variations in grain-size distribution, and the proportion between "fresh" and "re-deposited" material. However, despite regional differences, investigated loess is strongly homogenized during transportation and/or sedimentary recycling, and not significantly affected by pre- or post-depositional processes.

We also report the estimation of new reference dataset (PML - Polish Median Loess) for multi-elemental analyses. The PML, determined for 41 chemical elements, is the first dataset which can replace the UCC as the normalizing dataset for loess.

As such, we believe that this manuscript is highly appropriate for submission to Quaternary Research and is of interest to a broad audience of geochemistry and palaeoenvironment researchers. We have no conflicts of interest to disclose.

Thank you for your consideration of this manuscript.

Yours faithfully
On behalf of the authors

Dr Jacek Skurzyński

# Implications of the geochemistry of L1LL1 (MIS2) loess in Poland for paleoenvironment and new normalizing values for loess-focused multi-elemental analyses

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**ABSTRACT**

Loess paleoenvironmental reconstructions on a (supra-)regional scale have recently gained much attention. Geochemistry comparisons in relation to a reference dataset such as UCC (Upper Continental Crust) data have helped understand the climatic and geomorphological conditions under which terrestrial sites have developed. However, UCC data differs from loess, thereby obscuring important features, and the existing "average loess" datasets also are not sufficient for modern investigations. In this study, we examine the youngest Polish loess (L1LL1 = MIS2, ~26 – 15 ka) for its suitability as a new, loess-focused reference dataset. A total of 89 samples from seven sites were analyzed, using Inductively Coupled Plasma spectrometry. The loess had assumedly been homogenized during transportation and/or sedimentary recycling ($La_N/Sm_N$ = 3.34 – 4.06, median 3.78; Eu/Eu* = 0.46 – 0.66, median 0.55; $Gd_N/Yb_N$ = 1.08 – 1.49, median 1.26), and weakly affected by pre- or post-depositional weathering (CIA = 53.64 – 69.12, median 57.69). The statistically significant differences between sites in elemental medians were mostly conditioned by variations in grain-size and in the "fresh" to "re-deposited" sediment ratio. Nonetheless, the overall geochemical composition homogeneity provided a basis for the estimation of Polish Median Loess (PML) data, as determined for 41 chemical elements. When used, PML data highlight differences between loess regions in Europe, thereby providing a tool for cross-continental comparisons.

**Keywords:** Elemental composition; Inductively Coupled Plasma; Late Pleistocene; Aeolian; Central Europe, PML – Polish Median Loess.

## INTRODUCTION

Loess is a clastic mineral dust deposit which occurs as wind-laid sheets (Smalley, Vita-Finzi 1968), and is considered as one of the most investigated and best recognized terrestrial sediments (Schaetzl et al., 2018; Waroszewski et al., 2021). Its bulk properties (such as granulometric or mineralogical composition) show important variations with age, location, source area, topography, or depositional and post-depositional weathering history (Rousseau et al., 2018; Lehmkuhl et al., 2016, 2021; Pötter et al., 2023). At the same time, it is considered to be relatively homogeneous in terms of geochemical composition (Gallet et al., 1998; Wright, 1998; Tripathi and Rajamani, 1999; Újvári et al., 2008; Muhs, 2018; Fenn et al., 2022) due to its considerable spread and mixing during transport. Consequently, its chemical composition was initially used mainly for the stratigraphic location of the boundaries of individual layers (Sial et al., 2019), based on the assumption that soil processes lead to the re-deposition of mobile and retention of immobile elements (Buggle et al. 2011).

Contemporary chemostratigraphic studies of loess focus on specific causes of stratigraphic and spatial variation in chemical composition (Sial et al., 2019). However, they are limited by the lack of representative sets of geochemical data from potential source areas (Buggle et al., 2008; Újvári et al., 2008). Some authors have compared the chemical composition of loess with floodplain sediments (Buggle et al., 2008; Muhs and Budahn, 2006; Újvári et al., 2014; Skurzyński et al., 2020) which represent the average composition of large areas, and have been suggested as an immediate, up-wind, source of silty material (Smalley and Leach, 1978; Hao et al., 2010; Schaetzl and Attig, 2013; Stevens et al., 2013; Obreht et al., 2015; Fenn et al., 2022; Költringer et al., 2022). Other studies have compared the chemical signatures between loess-paleosol stratigraphic sequences (e.g. Buggle et al., 2008; Újvári et al., 2008; Skurzyński et al., 2019; Pötter et al., 2021). However, this approach may present different challenges due to the methodological differences of determining the chemical composition (e.g., Miyazaki et al., 2016; Pötter et al., 2021), which may result in significantly different values for the various chemical elements (Skurzyński and Fenn, 2022). One of the most common comparative approaches is the use of normalized multi-element diagrams (e.g., Gallet et al., 1998; Jahn et al., 2001; Buggle et al., 2008; Újvári et al., 2008, 2014; Rousseau et al., 2014; Campodonico et al., 2019; Bosq et al. 2020; Skurzyński et al., 2020). These so-called spider diagrams (or spidergrams) are constructed with respect to reference datasets such as the UCC (average composition of the Upper Continental Crust; Condie, 1993; Taylor and McLennan, 1985; McLennan, 2001; Rudnick and Gao, 2003) or PAAS (Post-

Archaean Australian Average Shale; Taylor and McLennan, 1985), and identify deviations in composition from the reference dataset (Rollinson, 2013). However, data reporting is poor, with some studies not providing information on source of the normalization dataset (e.g. the version of the UCC).

Crucially, as the chemical composition of loess differs significantly from, e.g., the UCC or PAAS, it causes strong positive or negative anomalies (e.g. Skurzyński et al., 2020) which obscures other changes between individual samples. Consequently, attempts have been made to create a set of normalizing values dedicated to loess, such as the Average Loess (Schnetger, 1992; presented later in the limited form as AVL$^{1}$ by Újvári et al., 2008) or Global Average Loess (GAL; Újvári et al., 2008). AVL was calculated using 24 samples taken from seven loess regions (Lukashev et al., 1965; Ebens et al., 1980; Taylor et al., 1983), and GAL was based on the mean of 17 averages from 11 loess regions (244 samples, including these used for AVL$^{1}$), with different quality of age control, and analyzed by different or even unreported methods (Lukashev et al.,1965). Although GAL data constitute a significant contribution to the understanding of the geochemistry of loess, they present data for only a limited number of chemical elements (even in relation to the original Average Loess by Schnetger, 1992) and lack most of trace elements and rare earth elements (REE), which are particularly important from a perspective of provenance studies, as major elements do not distinguish source contributions (e.g., Fenn and Prud'homme, 2022; Skurzyński et al., 2020). Consequently, both GAL and other existing "average chemical loess compositional data" are not sufficient for the comparative analysis of loess from different parts of Europe or the world, and alternative reference data sets (such as UCC) are not suited to the needs of loess research. Therefore, the old general assumption is valid - there is a need to introduce a set of consistent and universally accepted normalizing values (Rock, 1987; Rudnick, 2013).

This study tackles this dilemma by presenting a new dataset dedicated to loess, based on samples representing weakly weathered and relatively homogenous loess from areas with well-documented chronostratigraphy, and measured with similar, reliable and precise methods. The loess cover of Poland was chosen for this initial analysis, as it is thought to be representative of the whole Northern European Loess Belt. It reflects contemporary and Pleistocene features of European climate: continental in the east and more oceanic in the west (Cegła, 1972; Jersak, 1973; Maruszczak, 1991; Jary, 2007; Jary and Ciszek, 2013), and is lithologically diverse in relation to the latitudinal extent of the Pleistocene extra-glacial zone (Tutkovsky, 1899; Jahn, 1950). Consequently, we argue that the loess of eastern Poland shares many similarities (e.g. in the granulometric composition) with the East European loess cover, whilst the western part is similar to the western loesses (Maruszczak, 1991). Moreover, the Last Glacial Maximum loess in Poland (L1LL1 correlated to MIS 2, ~26 - 15 ka) was demonstrated to have been strongly homogenized during transportation and/or sedimentary recycling, and has not been significantly affected by pre- or post-depositional processes (Skurzyński et al., 2020). We thus analyzed 89 loess samples from seven research sites, for major, trace and rare earth element concentrations, to determine the factors influencing the chemical compositions of Polish loess, and to propose new reference values of loess geochemical composition.

## RESEARCH AREA AND MATERIALS

The loess cover of Poland relates to the very dynamic environment of Pleistocene glaciations (e.g., Tutkovsky, 1899; Jahn, 1950; Rousseau et al., 2014; Skurzyński et al., 2020) and was most likely sourced from glacigenic deposits, as homogenized by meltwater rivers (Smalley et al., 2009, Badura et al., 2013; Pańczyk et al., 2020; Baykal et al., 2021), with a variable proportion of local material (Pańczyk et al., 2020, Baykal et al., 2021). The loess sites selected for sampling represent the full variability of the loess in Poland (Fig. 1). They were divided into main and supplementary ones, considering the scope of geochemical analyses and the accuracy of age control. We used the "universal" stratigraphical labelling system for this loess, first introduced by Kukla and An (1989) and modified by Marković et al. (2008, 2015).

The L1LL1 loess units were sampled at these sites: Biały Kościół (Moska et al., 2019a), Złota (Moska et al., 2018; Skurzyński et al., 2020) and Tyszowce (Moska et al., 2017; Skurzyński et al., 2019). These sites have existing chronologies developed using Optically Stimulated Luminescence (OSL; Fig. 2) dating, and they have been analyzed at high resolution for geochemistry. The main sites (representing the variability of loess on the W-E axis, located at considerable distances from each other, and near the valleys of various large rivers) represent the domain of the Northern European Loess Belt (domain II; Lehmkuhl et al., 2021) but each likely formed under the different paleoenvironmental conditions (e.g., Maruszczak 1991). Biały Kościół belongs to the subdomain IIb (Western European continental subdomain), and the rest of the sections to the subdomain IIc (Central European continental subdomain) (Lehmkuhl et al., 2021). All of these loess sequences were formed during the last interglacial-glacial (Fig. 2), although there are notable differences in the thickness of individual loess covers (Fig. 2) which indicates different depositional rates. This further implies local influences on the development of each profile on a sub-orbital scale, as suggested by Fenn et al. (2021). The lithological features of the main research sites are also varied (Fig. 2). In the L1LL1 section at Biały Kościół (especially in the lower part), weak tundra-gley soils, indications of periglacial deformation, or horizons of initial gleying can be distinguished (Moska et al., 2019a). At Złota, the L1LL1 loess is more homogeneous, although several horizons of initial gleying and/or deformation are also present (Fig. 2). The lowest parts are deformed by cryogenic processes and show traces of slope redeposition (Moska et al., 2018; Skurzyński et al., 2020). At Tyszowce, the L1LL1 loess can be as much as 14 m thick (Fig. 2). In the upper part (up to a depth of ca. 5 m below ground level), sandy laminae are common (Fig. 2), suggesting short-term episodes of material transport from the nearby Huczwa river valley (Skurzyński et al., 2019). Two generations of ice wedge pseudomorphs in the L1LL1 loess indicate a double development cycle, and degradation of permafrost (Jary, 2007).

Four supplementary sites, i.e. Zaprężyn (Jary, 2007; Krawczyk et al., 2017; Skurzyński et al., 2017; Zöller et al., 2022), Strzyżów (Moska et al., 2019b), Branice (Jary, 2007; Moska and Bluszcz, 2013) and Odonów (Butrym, 1987; Jary, 2007) were also investigated to determine the spatial variability of the chemical composition in the context of hetero- or homogeneity of the source material. The sites at Zaprężyn and Strzyżów are located farther north than are Biały Kościół, Złota and Tyszowce, and the sections at Branice and Odonów represent the southern parts of the loess in Poland (Fig. 1).

In this work 70 L1LL1 (MIS 2) samples were subject to geochemical analysis (Biały Kościół – 19, Tyszowce – 32, Zaprężyn – 3, Strzyżów – 6, Odonów – 5, Branice – 5) following the methodology used previously for Złota loess-paleosol sequence (Skurzyński et al., 2020). A further 19 published samples for Złota's (Skurzyński et al., 2020) L1LL1 loess were also included, resulting in a total of 89 L1LL1 (MIS 2) loess samples under study.

## METHODS

The loess samples were collected in 2012 (Tyszowce, Złota and Zaprężyn), 2013 (Strzyżów), and 2018 (Biały Kościół). Samples from two of the sites (Branice and Odonów) are the result of earlier works (2002), although the methodology used at that time did not significantly differ from that developed for the new research sites (Jary, 2007). The air-dried samples were stored in plastic string bags.

Chemical analyses were performed in the commercial laboratory (Bureau Veritas, formerly ACME labs; LF200 package) using Inductively Coupled Plasma – Emission Spectrometry (ICP-ES) and Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) after sample fusion with lithium borate (in a furnace) and a cooled alloy dissolution with ACS grade nitric acid. Prior to the analysis, the material was passed through a 63 µm dry sieve to avoid the effect of grain-size differentiation on geochemical parameters values (e.g., Nesbitt and Young, 1982; Shao et al., 2012; Guan et al., 2016) and to minimalize the influence of very local sandy material (Skurzyński et al., 2019).

Analytical precision RSD (relative standard deviation) data were estimated separately for each of the measurement series, based on several measurements (Table S1) of the certified STD SO-19 standard. The average values for a given element were close to the expected value of the share of the analogous element in the STD SO-19 standard, and the differences between the average values from individual series were usually negligible (Table S1). The RSD is less than ± 5% for most of the elements determined, and the variation between measurement series is usually small (Table S1). For Cs, Ga, Hf and W, in some measurement series, the RSD was less than ± 10%. For Be (which is not significant in the context of this paper), the RSD was more variable, ranging from ± 4.79% to ± 34.41% in individual measurement series (Table S1).

The grain-size of the samples was determined by a Malvern Mastersizer 2000 laser grain-size analyzer, which has a measurement range of 0.02–2000 µm with a precision of ± 1%. The refractive and absorption indices used in the measurements were 1.544 and 0.1. Measurements were conducted after chemical pre-treatment. The samples were first treated with $H_2O_2$ and 10% HCl to remove organic matter and carbonate, respectively. Finally, the samples were dispersed with a 0.5 N sodium metaphosphate solution and ultrasonicated for 10 min before measuring (e.g. Song et al., 2014; Skurzyński et al., 2019). The clay-silt boundary assigned to the samples was 4 µm (e.g., Svensson et al., 2022), so the clay fraction may be underestimated in relation to the data from publications utilizing higher clay-silt boundary, e.g. 8 µm (Konert and Vandenberghe, 1997).

The concentrations of major (wt. %), trace elements and rare earths (ppm), as well as values of geochemical parameters and granulometry, are shown in the Table S2. Basic, descriptive statistics (median, average, minimum, maximum and standard deviation) are presented in Table S3. Throughout this article, the median (instead of the mean) is used because most proportions of chemical elements (except $Na_2O$, $K_2O$,

$TiO_2$, Ba, Sr, Y, and almost all of the rare earths are not normally distributed (tested using Shapiro-Wilk test; Table S4). Consequently, non-parametric Kruskal-Wallis test (Table S4) and the Spearman correlation were used for most analyses. The number of samples from supplementary sites was too limited for statistical analysis, therefore comparison of the whole dataset was performed by the geochemical diagrams.

## RESULTS

### Chemical composition and granulometric background of the main research sites

The Kruskal-Wallis test (Table S4), in which the null hypothesis is that the medians of each group are the same, showed that at least at one main research site the loess chemical composition differs significantly from the others, by the median of practically each of the determined chemical elements (except MgO, $P_2O_5$, MnO, Ni, and Zr).

Biały Kościół, as compared to the rest of main sites, is characterized by the highest median values for most chemical elements (except $SiO_2$, CaO and Sr), and the highest minimum values for many major element oxides ($Al_2O_3$, $Fe_2O_3$, $K_2O$, $TiO_2$, MnO) and all trace and rare earth elements (except Hf, Sr, and Zr). The maximum values from Biały Kościół also are the highest in the entire dataset scale for most oxides ($Al_2O_3$, $Fe_2O_3$, MgO, $K_2O$, and $TiO_2$) and trace elements (except Co, Ga, Hf, Nb, Sr, V, W, and Zr), and for all REEs (Table S3). Further, it is the only profile where Ni was found in most of the samples (Table S2). This site is characterized by the highest minimum values and the highest median of fine fractions (< 4 µm, 4-8 µm and 8-16 µm), with the lowest median of medium (16-31 µm) and coarse (31-63 µm) silt. The median of sand (> 63 µm) also is the highest, but maximum value is the lowest in relation to the rest of the main research sites (Table S3). The lower part (from a depth of approx. 4 m below ground level) is clearly enriched in fine fractions (Table S2).

Złota is poorer in trace elements and REEs than is Biały Kościół, and richer than Tyszowce (Table S3). However, the highest median of $SiO_2$, and (equals with Biały Kościół) Cr and W, were found in this profile, as well as the highest minimum values of $SiO_2$, MgO, $Na_2O$, $P_2O_5$, Hf, W, and Zr (Table S3). In terms of grain-size, Złota is characterized by the lowest median of fine fractions, and the only significant increase of fine material was found in the lowest part of the L1LL1 loess, just above the L1SS1 soil (Fig. S1). The median and minimum values of medium and coarse silt were the highest (Table S3). No significant enrichment in the sand fraction was found (Fig. S1).

Loess at the Tyszowce site is the most depleted in the chemical components (if one considers median values), with the exception of CaO and Sr, which reached the highest median values. However, the highest maximum values of $SiO_2$, CaO, $P_2O_5$, MnO, Hf, Sr, Ta, W, Zr and Lu were found in relation to the rest of main research sites (Table S3). Notably all the minimum values at Tyszowce (and the lowest minimum values of the whole dataset) are in the upper, ~5-meters thick, sandy part of loess L1LL1 (Table S2). At Tyszowce, the grain size variation is greater than in the other main sites (Fig. S1, Table S2). For example, the median share of the sand fraction is the lowest (8.73%), with the lowest minimum value (2.09%) and the highest maximum value (40.35%) - the standard deviation exceeds 9 (Table S3). Apart from the sand fraction, at Tyszowce there is more coarse silt than at Biały Kościół, but less than at Złota. The share of fine fractions is higher than at Złota, but lower than at Biały Kościół (Table S3). The fine material generally shows a clear upward trend with depth, reaching maximum values in the lower part of the L1LL1 unit, but in several places this trend is disturbed (Fig. S1).

**Chemical composition and granulometric background of the supplementary research sites**

Due to the limited number of samples from the supplementary sites Shepard's (1954) triangular diagram, based on Wentworth's (1922) classification, was used to interpret grain sizes (Fig. S2). The use of laser diffraction data could have caused the underestimation of the clay fraction (e.g. Konert and Vandenberghe, 1997; Miller and Schaetzl, 2012; Bitelli et al., 2019), however it clearly shows the overall diversity. The loess at Zaprężyn is enriched in the sand fraction in relation to the other supplementary research sites (Fig. S2, Table S2). Loess from Odonów and Strzyżów show more “pure silt” granulometric characteristics (Fig. S2). Loess at Strzyżów is not as variable in terms of grain size, although the samples represent the part of L1LL1 loess of considerable thickness, from 3.20 to 9.30 m b.g.l. (Table S2). The loess at Branice is distinguished by a significant amount of fine (<4 μm) fractions (Fig. S2, Table S2), with a low share of coarse silt (31-63 μm) and sand (Table S2). The share of medium silt (16-31 μm) is comparable to other supplementary sites (Table S2, Table S3). The results of the chemical composition of the supplementary research sites, summarized in Table S2 and S3, will be discussed later, to avoid unnecessary repetitions.

## DISCUSSION

### Stratigraphic variability of the main research sites' chemical composition

All profiles show minor fluctuations and clear peaks of mobile (e.g. MgO, CaO or $Fe_2O_3$; Kabata-Pendias and Pendias, 1999) and immobile (e.g. Zr, Hf or Nb; Sheldon and Tabor, 2009) oxides and elements (Fig. 3-5; Table S2). This variation could be related to the changes in the mineralogical and/or grain-size composition, e.g. at 11.95 m depths of Tyszowce profile, where the sharp decrease in content of REEs was found (Fig. 5). This transition was followed by the peaks of Hf, Zr, U, and W (Fig. 4), which may be explained by additions different from the main mass of sediment (as suggested by the strong increase in the coarse silt; Fig. S1), e.g. from local sources or from the sediments enriched in resistant mineral phases.

The variability in chemical composition may be related to the post-depositional processes, such as bioturbation, gleying, and weak weathering (e.g. Kemp, 2001; Jeong et al., 2008; Mroczek, 2013). However, no clear influence of the initial tundra-gley soils on the chemical composition was found, except for a few horizons at Tyszowce (Fig. 3). Even decalcification, one of the first pedogenetic process taking place in loess (Liu, 1985; Jahn et al., 2001; Finke and Hutson, 2008), is not clearly indicated, based on elements associated with carbonates (e.g. CaO or Sr). Conversely the lower parts of the L1LL1 are generally enriched in oxides of the major elements (Fig. 3-5) such as aluminum ($Al_2O_3$). The $Al_2O_3$ is strongly positively related to the iron ($Fe_2O_3$; Spearman's correlation coefficient is 0.63 at Złota; 0.93 at Biały Kościół, and 0.99 at Tyszowce), which is one of the most mobile elements in humid-climate soils. Nonetheless, it has to be noted that iron mobility varies with conditions such as redox potential, the presence of organic matter or the type of mineral phases (Kabata-Pendias and Pendias, 1999). Similar tendencies to $Al_2O_3$ and $Fe_2O_3$ shows also $TiO_2$ (Fig. 3; e.g. at Tyszowce the Spearman's correlation coefficient between $Al_2O_3$ and $TiO_2$ is 0.81). This is of particular interest as $TiO_2$ is unlikely to migrate due to the very low solubility of its compounds (e.g. Sheldon and Tabor, 2009), and is consequently transported passively, in the form of primary minerals or in secondary products of weathering (Kabata-Pendias and Pendias, 1999). In reducing and acidic environments and in the presence of organic matter, $TiO_2$ is partially mobile, and enters the structure of clay minerals (Kabata-Pendias and Pendias, 1999). The increases in the contents of $TiO_2$, $Al_2O_3$ and $Fe_2O_3$ with depth (or simply in the deeper parts of the L1LL1 units) is likely driven by a greater share of e.g. clay minerals or amorphous hydroxides (Kabata-Pendias and Pendias, 1999; Reeder et al., 2006) in the source material (likely the older loess, eroded and re-deposited e.g. from neighboring areas; e.g. Kemp, 2001; Jeong et al., 2008; Mroczek, 2013; Skurzyński et al., 2020), and not by post-depositional changes.

Interpretations based on correlations between oxides (in percentages) seem reasonable, however they may be faced with the closed-array compositional conundrum (Chayes, 1971; Templ et al., 2008; Rollinson, 2013; Andrews et al., 2023). That is, the increase in one oxide necessitates a decrease in at least one other element, resulting in spurious negative correlations. Therefore, further analyses were based on geochemical indicators and diagrams, which should not be significantly affected by the selective removal or enrichment effect (e.g. Buggle et al., 2008). One of them is CIA, i.e. Chemical Index of Alteration (Nesbitt and Young, 1982), which is illustrated (Fig. S3-S5) on the A-CN-K diagrams (Nesbitt and Young, 1984).

The CIA for entire loess-paleosol sequence at Złota (including majority of samples taken from loess L1LL2 and paleosol L1SS1, correlated to MIS 4 and MIS 3 respectively) ranges between 50 to 65 (Fig. S3; Skurzyński et al., 2020) with only some samples experienced moderate weathering (65 to 85). These data suggest that the site has undergone weak chemical weathering under a cold and dry climate (e.g., Song et al., 2014) and periodic warm and moist paleoclimatic conditions for some of the soil samples (Fig. S3). Considering only L1LL1 loess from Złota, the majority of samples are tightly clustered close to the CIA value of 50, which is characteristic for unweathered crustal rocks (Nesbitt and Young, 1982, 1984). Additionally, the lowermost part of the L1LL1 (6.35 – 6.75 m) is slightly more weathered (similarly to the L1LL2 unit) (Fig. S3; Fig. 6).

At Biały Kościół, samples from the L1LL1 unit (Fig. S4; Fig. 6) are less clustered than at Złota (Fig. S3; Fig. 6). The loess collected in the lowest part (4.73 - 5.3 m), above the L1SS1 soil, is the most weathered, and the highest of all the samples (1.36 m) is with the lowest CIA value (Fig. S4). These data illustrate the typical decreasing degree of chemical weathering upward the profile. However, there are some samples from higher parts of the profile (1.55 m and to a lesser extent, 1.81 and 2.06 m) which are relatively more weathered and enriched with $K_2O$ (Fig. S4, Table S2). It may suggest the downward penetration of the effects of pedogenesis (e.g., Han et al., 2019) and use of fertilizers, which are the main anthropogenic source of potassium (e.g. Reeder et al., 2006). The least weathered samples are poorer in $K_2O$ than other samples (Fig. S4). In turn, the lower part of the profile (3.8 – 5.3 m) is also rich is $K_2O$, which may be related to the enrichment in fine granulometric fractions (Table S2) - the very soluble simple cation $K^+$, derived e.g. from the weathered potassium feldspars, may be easily incorporated into the crystal lattice of clay minerals or adsorbed on them (e.g. Reeder et al., 2006). As K-bearing mineral phases (such as potassium feldspars) are quite resistant to chemical weathering (e.g. Wilson, 2004) the post-depositional processes cannot be the dominant factor determining its variability in the investigated profile. Given the environmental conditions this site experiences, feldspar breakdown is unlikely to be the key driver of potassium variability; a change in the source material is more likely cause. However, taking into account the range of infiltration (from 2 to 5 m; e.g. Tu et al., 2009; Zeng et al., 2016) and potential rapid transportation of rainwater through cracks (Derbyshire, 2001), secondary enrichment cannot be ruled out.

At Tyszowce (Fig. S5) the samples taken from the deformation levels and/or initial soil horizons (e.g. 11.35 m, 12.95 m, or 14.6 m b.g.l.) clearly deviate from "the freshest" loess within the L1LL1 unit (e.g. 1.4 m, 8.15 m, or 9.55 m b.g.l.). These data may indicate changing paleoenvironmental conditions ("pure loess" deposition vs post-depositional initial pedogenesis) during the formation of this very thick loess unit (e.g. Jary, 2007; Moska et al., 2017; Skurzyński et al., 2019). On the other hand, the lowest CIA values are associated with layers enriched with sand (Fig. S5; Skurzyński et al., 2019), suggesting that the chemical composition here is controlled by the mutual proportion of the finer and coarser materials.

**Factors controlling the spatial variability of Polish loess' chemical composition**

Most samples, representing the spatial variability of loess in Poland, are weakly weathered (Fig. 6). Only loess samples from Branice oscillate around the CIA value of 65 (Fig. 6), resembling the data from the L1SS1 soil at the Złota loess-paleosol sequence (Fig. S3). Considering that samples from Branice are characterized by the finest grain size among Polish loess (Jary, 2007; Table S3), the effect of granulometric sorting may be a better explanation than the different intensities of soil-forming processes (conditioned by different features of the paleoclimate) for variability of CIA values. This conclusion is demonstrated by the A-CN-K diagram, which reflects also the grain-size differentiation (Buggle et al., 2008) - the finest material is the closest to the apex of the $Al_2O_3$ axis (Nesbitt et al., 1996) such as the highest CIA values (Nesbitt and Young, 1984).

The highest values of CIA, and also the finest material, were found at Branice, and in the lowest parts of the Biały Kościół (4.73 - 5.3 m), Tyszowce (14.6 m) and Złota (6.75 m) (Fig. 6). The remaining, even the “freshest”, parts of L1LL1 at Biały Kościół (4.6 - 1.36 m) resemble the lower parts of L1LL1 at Tyszowce (14.25 - 10.45 m) or at Złota (6.05, 6.35, 6.9 m), similarly to the loess from Odonów (Fig. 6). In turn, the "freshest" loess in the whole dataset was found, in general terms, in the upper (and therefore the youngest) parts of loess L1LL1 at Złota (0.55 - 5.6 m), Tyszowce (1 – 10 m and 11.75 - 11.95 m), and at the “northern” sites i.e. Strzyżów and Zaprężyn (Fig. 6). The last one (Zaprężyn), located only approx. 60 km (straight-line distance) towards NNE from the profile at Biały Kościół (Fig. 1), is particularly important in this context, given that its weak weathering is likely not the direct result of different paleoclimatic conditions in relation to the Biały Kościół. The better explanation may be so-called loess-cannibalism (Van Loon, 2006; Licht et al., 2016), as a hiatus in loess deposition was found at Zaprężyn (from 56.8 ± 4.7 ka to 18.4 ± 1.2 ka; Zöller et al., 2022). The “lacking” loess deflated from Zaprężyn theoretically could have been transported southwards and re-deposited at Biały Kościół. It may further suggest that, similar to at Biały Kościół, the loess from “southern” loess covers (Branice, Odonów), as well as the lowermost parts of the L1LL1 units from “eastern” loess-paleosol sequences (Tyszowce and Złota) contain sediment eroded and reworked from paleosols or older loess covers, and mixed with fresh, incoming dust (e.g. Mroczek 2013). Consequently, the varying proportions of "older" and "fresher" material could explain the overall variability of the CIA values (Fig. 6), as the higher supply of "fresh" material would have led to smaller chemical weathering values (e.g. Varga et al., 2011). In this approach, the last phase of loess deposition in MIS 2 in the study area would have supplied the "fresh" material to the “northern” profiles like Zaprężyn (since 18.4 ± 1.2 ka; Zöller et al., 2022) and Strzyżów (substantial deposition since ~ 19 ka; Moska et al., 2019b). That supply of fresh sediment was likely provided mostly from the north, given that loess with higher weathering values occurs in the south. Given the > 6-meter thick layer of loess L1LL1 (3.20 - 9.30 m) at Strzyżów, and the lack of differentiation of the low CIA values there (Fig. 6), the supply was likely stable and substantial.

A “northern” source of the material is also suggested by the positive Zr and Hf anomalies (Fig. 7, Table S2), which in Europe are commonly found for the periglacial loess (Rousseau et al., 2014 and the references therein) and limited to material deposited near the Fenno-Scandinavian Ice Sheet (Scheib et al., 2014; Bosq et al., 2020). This confirms the relationship of Polish loess to glacigenic deposits, as the enrichment with elements related to the chemically resistant minerals, such as zircon (Zr and Hf), may be best attributed to the removal of more weatherable minerals during the processes of glacial grinding and post-depositional leaching in the sub- and proglacial environments of Poland (Lis and Pasieczna, 2006; Buggle et al., 2008). The data also strengthen the previous premise about the relationship between the chemical and grain-size compositions of the loess, as zircons are known to be preferentially concentrated in coarse silt and sand fractions in aeolian sediments (Muhs and Bettis, 2000, Yang et al., 2006). The results further demonstrate that all samples (collected both from the main and supplementary research sites) are arranged in accordance with the sedimentary recycling trend line in the Zr/Sc vs Th/Sc diagram (Fig. 8), whilst the finest material is the most depleted in zircons (Fig. 8).

We conclude that Polish loess can be considered to be generally unweathered sediment, with slight variations in granulometry or weathering history. Therefore, the variability of chemical compositions is mostly influenced by the enrichment and depletion of the silica, carbonates and secondary weathering products (Gallet et al., 1998). In essence, the duration of post-depositional processes has not been long and intense enough to mask the chemical signature of the loess parent material (Campodonico et al., 2019; Skurzyński et al., 2020). Of course, admixtures of local material also may be important, e.g. the highest share of carbonates at Tyszowce probably relates local bedrock, limestones (Maruszczak, 1991).

**General homogeneity of Polish loess' chemical composition**

The overall homogeneity of Polish loess is suggested by the very similar shape of the UCC-normalized diagrams for all of the investigated sites (Fig. 7). Particularly important is the slight variation in REE curves, as the magmatic or metamorphic rocks (the protolith of all the loess sediments) have a much greater diversity, and the only way to "average" all these to a near-constant pattern is by recycling and mixing during at least one cycle of sedimentary processes (Gallet et al., 1998). The statistically significant differences (Table S4) of absolute abundances of chemical elements and oxides are not particularly important for the geochemical indices, based on the trace element composition, e.g. Th/U (2.96–4.63; median 3.56), the lack of distinct Ce anomaly (0.96–1.08; median 1.00), or the relatively stable values of $La_N/Sm_N$ (3.34–4.06; median 3.78), $La_N/Yb_N$ (5.48–8.10; median 6.69) and $Gd_N/Yb_N$ (1.08–1.49; median 1.26). These all suggest an indistinguishable REE fractionation between "unweathered" and "weathered" loess, due to relatively greater mobilization of HREE (heavy rare earths) than LREE (light rare earths). The significant weathering would lead to a decrease in $La_N/Sm_N$ values, and an increase in $La_N/Yb_N$ and $Gd_N/Yb_N$ values (Nesbitt, 1979; Hao et al., 2010; Han et al., 2019; Skurzyński et al., 2020).

**PML – Polish Median Loess**

The weakly weathered (Fig. 6) Polish loess is geochemically homogeneous, relative to published data on loess around the world (e.g., Pye, 1984; Rousseau et al., 2014; Bosq et al., 2020). Thus, it may be of importance for paleoenvironmental interpretations, as trace elements and rare earths are widely used to infer the provenance of sediments (Li et al., 2021; Shi et al., 2023), but the differences may be relatively minor, and for the different loess deposits e.g. the REE patterns in the normalized diagrams are hardly distinguishable (Guo, 2010). For example, the HREE patterns may be a good overall indicator of loess diversity in Europe (Skurzyński et al., 2020). Thus, $Gd_N/Yb_N$ values of Polish loess were tested against the background of samples from various European loess areas (Fig. 9). To avoid comparing differences related to adopted research methodology (Skurzyński and Fenn, 2022) only studies which used similar approaches were utilized (Rousseau et al., 2014; Bosq et al., 2020). Additionally, a cross-analysis of the $Gd_N/Yb_N$ was carried out (for Tyszowce and Złota: this study vs Bosq et al., 2020; and for Surduk: Bosq et al., 2020 vs Rousseau et al., 2014). For the loess sample from Tyszowce analyzed by Bosq et. al. (2020), the value of $Gd_N/Yb_N$ was 1.13 (this study: median 1.18, min. 1.08, max. 1.35) and for Złota, it was 1.17 (this study: median 1.26, min. 1.18, max. 1.34). The $Gd_N/Yb_N$ for the Surduk profile (located in Serbia) was 1.43 according to Bosq et al. (2020), and 1.55 according to Rousseau et al. (2014). For Polish loess, the values of $Gd_N/Yb_N$ are visibly lower than the loess in Surduk, which is understandable, as these loess deposits have different sources. Similarly, low values like in Polish loess were found (Fig. 9) e.g. in the English Channel, Ukraine (Stayky, Korshiv), E Germany (Ostrau, Zeuchfeld) or Aquitaine (Pomarez). Even for the most weathered Polish loess (Branice; Fig. 9) the median of $Gd_N/Yb_N$ is lower than in the publication by Bosq et al. (2020), comparable to the median from Rousseau et al. (2014).

As evidenced, even relatively small differences in the values of the appropriately chosen parameters between Polish loess and loess from other regions can be detected, and therefore infer important information about the source of the material. However, these kinds of minor differences are often imperceptible due to the UCC normalization, which is very common in the literature. This set of chemical data is unsuited to the specificity of loess. For this reason, many elements create very clear positive or negative anomalies on the UCC-normalized diagrams (Fig. 7). Therefore, a set of normalization data dedicated to loess could be used, such as AVL[1] (Schnetger, 1992; modified by Újvári et al., 2008) or GAL (Újvári et al., 2008). However, these normalizing sets are based on the results obtained using variable methods, from samples representing diverse worldwide loess regions, and showing values for limited number of elements (most trace elements and REEs are omitted). An additional complication is the fact that even in a not very large group of "loess normalization data sets", the same "average loess" may be presented in different scope and under different names. A good example is the "average loess" introduced by Schnetger (1992) and cited later as AVL[1] by Újvári et al (2008) in the way limited to the selected chemical elements. This may cause some confusion, so the name AVL[1] has been consistently used in this work (Újvári et al., 2008), however, Table 1 presents the complete set of elements from the original "average loess" (Schnetger, 1992). The relevant information can be found in the caption of Table 1.

Therefore, we propose a new parameter (PML – Polish Median Loess), based on data obtained by same methods, from one loess region with a homogeneous and "fresh" chemical composition, i.e., Poland. Moreover, the PML dataset represents a near complete range of variability of chemical composition of loess deposited at a similar time (MIS 2, as shown by numerous OSL ages) although differing in granulometric composition. The PML is based on medians of individual elements, not average values – for this reason, it is insensitive to outlier values remained in the data set (the paleoenvironmental information related to them was not lost).

The PML is determined in wt.%, on a volatile-free basis, for oxides of major elements, and in ppm for trace elements and rare earths. Its values are clearly different from previously published average loess compositions (GAL and AVL[1]; Table 1), but show some similar trends to them, such as higher values of elements related to chemically and mechanically resistant mineral phases (e.g. $SiO_2$, Hf, Zr), in relation to the UCC (Table 1). The differences between PML and UCC (Table 1) seem more important, because the latter is widely used. We next tested the new loess-dedicated normalization data set against two loess samples from different regions (Ukraine and Serbia; Bosq et al., 2020) and compared with UCC-normalized data via multielemental spidergrams (Fig. 10).

The UCC-normalization of the Korshiv (Ukraine) section shows numerous positive and negative anomalies, while PML-normalization illustrates that loess from Korshiv is only slightly enriched in MnO, MgO, CaO and Sr, as compared to Polish loess (Fig. 10). Conversely, Serbian loess has higher values of almost all elements and oxides in relation to the Polish loess - it is much more visible than in the case of UCC-normalization (Fig. 10). This suggests that the use of PML may highlight even the barely noticeable differences between loess regions in Europe. It may also facilitate the cross-continental comparative analysis of loess geochemical compositions. We note that, for this type of analysis, the focus has traditionally been on Asian and North American loess (e.g., Muhs, 2018).

By developing the PML we hope that other regional reference datasets (for e.g. China, USA, Argentina) will be next developed, using similar methods, which will allow for further geochemical comparisons. Until then, PML remains a reliable and comprehensive dataset for loess normalization elsewhere.

## CONCLUSIONS

The geochemical composition of the youngest (MIS 2) Polish loess units (L1LL1) are clearly differentiated in vertical profiles. However, the classic chemostratigraphy, based on the analysis of the variability of individual elements (or their correlations) with depth, is not always suitable for loess deposited in a dynamic periglacial environment. The more effective way to examine this loess is to use geochemical diagrams, which should not be significantly affected by the selective removal or enrichment effect, and by the effect of closed-array compositional conundrum, which may result in spurious negative correlations.

The analysis of chemical weathering in the loess showed that the most weathered sites are located in the southern part of Poland, as well as the lowest parts of the sections in the north. The "freshest" loess was found, in general terms, in the upper (and therefore the youngest) parts of the L1LL1 loess at Złota, Tyszowce, Strzyżów and Zaprężyn. The comparatively weak weathering data for loess at Zaprężyn changes the earlier assumptions about the clear division of the Polish loess area into more weathered loess of western Poland and relatively fresh loess of eastern Poland. The profiles located in the northern part of the research area (both in the east and in the west) are much "fresher" than the profiles representing the southern sector of Poland. The most reasonable explanation seems to be the deflation and transportation of the older material southwards and later depositing it, for example, at the Biały Kościół or Branice areas. As a consequence, there is no "older" material more to the north, e.g. at Zaprężyn, where the "fresh" material was deposited.

Nonetheless, despite statistically significant differences in the degree of chemical weathering, as well as in the other geochemical parameters and indices, the general homogeneity (or the well-mixed nature) of Polish loess is clearly visible and has been demonstrated for each of the research sites. The loess is relatively “fresh”, strongly mixed and homogenized during transportation and/or sedimentary recycling, and not significantly affected by post-depositional processes, or the admixtures of the local material.

The overall homogeneity of the Polish loess studied here has allowed for the calculation of a new, loess-normalizing dataset named PML (Polish Median Loess). These data may be of particular importance for comparative analyses of loess from different parts of the world. The PML may also constitute the basis for further work on a pan-European or even global reference dataset - in this case, the condition is to maintain rigor in the research methodology used and in the selection of research sites and samples.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at

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**Figures:**

Fig. 1. Location of the research sites on a map of loess distribution in Poland (A) and Europe (B) (loess distribution after Lehmkuhl et al, 2021).

Fig. 2. Schemes of the main research sites. Abbreviations: STR – stratigraphy, L + S – lithology + samples, A – ages (expressed as ka). Stratigraphical labelling system after Kukla and An (1989), modified by Marković et al. (2008, 2015): S0 – recent soil, L1LL1 – loess correlated to MIS 2, L1SS1 – paleosol correlated to MIS 3, L1LL2 – loess correlated to MIS 4, S1 – paleosol complex correlated to MIS 5. U.M.* means “underlying material”. Lithological legend: dark grey rectangles – soil units; pale grey

rectangles – horizons with signs of gley processes or deformations; pale grey rectangle with black curves – loess with gley and humic intercalations. Black spots – geochemical samples. Ages after Moska et al. (2017, 2018, 2019a) – Post-IR IRSL polymineral fraction (4–11 μm).

Fig. 3. The variability of the main elements (100 wt.% without the volatile components) at the research sites. Vertical grey dashed lines represent GAL values (Újvári et al., 2008) for individual oxides. The main pedo- and lithostratigraphic units are also drawn. Legend of lithological markings according to Fig. 2.

Fig. 4. The variability of the trace elements (ppm) at the research sites. The main pedo- and lithostratigraphic units are also drawn. Legend of lithological markings according to Fig. 2.

Fig. 5. The variability of the rare earth elements (ppm) at the research sites. The main pedo- and lithostratigraphic units are also drawn. Legend of lithological markings according to Fig. 2.

Fig. 6. A-CN-K ternary diagram (Nesbitt and Young, 1984) of the Polish loess samples. CaO* (Ca in silicates) was calculated according to McLennan (1993). Dashed lines – CIA values of 65 and 85. Stratigraphical labelling system after Kukla and An (1989), modified by Marković et al. (2008, 2015).

Fig. 7. UCC-normalized multielemental spidergrams for Polish loess. Each curve represents one sample. Ni is not shown because of its presence only in some samples. The UCC values used are from Rudnick and Gao (2003).

Fig. 8. Th/Sc vs Zr/Sc discrimination diagram of sedimentary recycling (McLennan et al., 1993) for Polish loess. Explanations: A – BK 3.8 - 5.3; ZŁ 6.05 - 6.9; TY 10.45 - 11.35, 12.95 and 13.9 - 14.6; OD 2.5 m. B – BK 1.36 - 3.6 (except 2.06 and 2.25); ZŁ 2.6 and 5.25; OD 3.3 m. C – BK 2.06 and 2.25; ZŁ 1.75 and 4.65; TY 6 - 6.65 m, 8.8, 9.55 - 10, 12.25 - 12.55, 13.35; ST - 5; ZA - 1.2 m, D – ZŁ 0.55 - 1.4, 2.2, 3.3 - 4, 5.05, 5.45 - 5.6; OD 0.9 - 1.8; ST 3.2 - 3.8; ZA - 1.5 m. E – TY 1 - 5.35, 7.15 8.15, 9.1, 11.75 - 11.95; ST 4.4, 7.3 - 9.3; ZA - 1.65 m. Zoomed area is not in the scale.

Fig. 9. Box plots of $Gd_N/Yb_N$ values of Polish and European loess. Explanations: signature of red square - median, whiskers - range of values, frame - 25-75% of values. Explanations for the data from literature (colored polygons): – red rectangle (the data from Bosq et al., 2020) shows the samples from Rhine (Achenheim, Nussloch) and Rhône (Baix, Bouzil, Brillanne, Collias, Cuges les Pins, Donnat, Lautagne, Mauves, Pact, Serezin du Rhône, Saint Julien de Peyrolas, Saint Paul les Durance, Vaise); yellow rectangle (the data from Bosq et al., 2020) shows the samples form N France (Quesnoy,

Hauteville), Germany - Saxony (Rottewitz), Rhine (Schaffhouse), Serbia (Surduk), Rhône (Feyzin, Garons, Lautagne, Ledenon, Montanay, Saint-Péray, Sathonay, Saint Cyr au Mont d'Or, Saint-Désirat, Saint Georges les Bains, Soyons, Tain l'Hermitage); green rectangle (the data from Bosq et al., 2020) shows the samples from N France (Beutin, Glos, Nisy le Comte, Sourdon, Verlinghem, Chaudon, Havrincourt, Renancourt, Villers Carbonnel), Aquitaine (Pomarez, Romentères), Belgium (Harmignies), Ukraine (Korshiv), E Germany (Ostrau), Poland (Tyszowce, Złota); blue rectangle (the data from Rousseau et al., 2014) shows the samples from W Germany (Nussloch; samples from following depths: 5, 6, 7.9, 9.5, 10.3, 12, 14.1, 17.8 m), W Europe (Pleneuf Val Andre, Languevoisin, Serbia (Surduk); grey rectangle (the data from Rousseau et al., 2014) shows the samples from W Europe (English Channel, Villers Carbonel, Harmignies), E Germany (Gleina, Leippen, Ostrau, Seilitz, Zehren, Zeuchfeld), Ukraine (Stayky).

Fig. 10. UCC-normalized and PML-normalized multielemental spidergrams for loess samples from Korshiv (Ukraine) and Surduk (Serbia) – geochemical data used for normalization after Bosq et al. (2020). Each curve represents one sample. Ni is not shown because of its presence only in some samples. The UCC values used are from Rudnick and Gao (2003), PML – this study.

Table 1. Polish Median Loess (PML – this study) versus UCC (Rudnick and Gao, 2003), AVL[1] (Schnetger, 1992; Újvári et al., 2008 - the AVL[1] presented by Újvári et al., 2008, lacks the values for Co, Cs, Hf, Ta, U, W, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu, so these elements are cited after original "average loess" presented by Schnetger, 1992) and GAL (Újvári et al., 2008). Major elements (wt.%) are recalculated on a volatile-free basis. Total iron is expressed as $Fe_2O_3$ ($Fe_2O_3$ value of AVL[1] in this study was recalculated from $FeO_{(tot)}$ = 2.78% as presented by Újvári et al. (2008). Schnetger (1992) presented separately FeO = 0.8%, and $Fe_2O_3$ = 2.2%). Trace elements and REE are in ppm. The color scale was developed using the Conditional Formatting function of MS Excel - the red-yellow-green color scale indicates the position of a given value in the entire range of values in a given column (red = high values, green = low values). N/D means “no data”.

Dear Editors,

thank you for your really kind words and constructive comments. We have not mentioned most of the Editor's comments in this document - they have been unquestionably accepted. Comments that required clarification are presented below.

1. RS proposition: “At the same time, it is considered to be relatively homogeneous in terms of geochemical composition (Gallet et al., 1998; Wright, 1998; Tripathi and Rajamani, 1999; Újvári et al., 2008; Muhs, 2018; Fenn et al., 2022) due to its considerable spread and mixing during aeolian transport”. It is not only aeolian, as shown later [lines 121-125]: “The loess cover of Poland relates to the very dynamic environment of Pleistocene glaciations (e.g., Tutkovsky, 1899; Jahn, 1950; Rousseau et al., 2014; Skurzyński et al., 2020) and was most likely sourced from glacigenic deposits, as homogenized by meltwater rivers (Smalley et al., 2009, Badura et al., 2013; Pańczyk et al., 2020; Baykal et al., 2021), with a variable proportion of local material (Pańczyk et al., 2020, Baykal et al., 2021)”.

2. RS proposition: “Three supplementary sites, i.e. Zaprężyn (Jary, 2007; Krawczyk et al., 2017; Skurzyński et al., 2017; Zöller et al., 2022), Strzyżów (Moska et al., 2019b), Branice (Jary, 2007; Moska and Bluszcz, 2013) and Odonów (Butrym, 1987; Jary, 2007) were also investigated to determine the spatial variability of the chemical composition in the context of hetero- or homogeneity of the source material”. We have four supplementary sites, not three…

3. RS proposition: “Move this paragraph down, to the Methods section? → In this work 70 L1LL1 (MIS 2) samples were subject to geochemical analysis (Biały Kościół – 19, Tyszowce – 32, Zaprężyn – 3, Strzyżów – 6, Odonów – 5, Branice – 5) following the methodology used previously for Złota loess-palaeosol sequence (Skurzyński et al., 2020). A further 19 published samples for Złota’s (Skurzyński et al., 2020) L1LL1 loess were also included, resulting in a total of 89 L1LL1 (MIS 2) loess samples under study.” It is placed in the chapter “research area and materials”. We believe that it is OK.

4. “The share of medium dust (RS proposition loess → I believe that we only call it dust when it is in the air; otherwise it is loess) (16-31 µm) is comparable to other supplementary sites (Table S2, Table S3). Of course we thought silt, as a granulometric fraction… It is modified.

5. RS comment: “Suggest citing a paper here, which uses this value and which also justifies its use. Other clay-silt boundaries have been used by other researchers, so please justify this”. Original phrase: “The clay-silt boundary assigned to the samples was 4 µm”. Modified phrase: “The clay-silt boundary assigned to the samples was 4 µm (e.g., Svensson et al., 2022), so the clay fraction may be underestimated in relation to the data from publications utilizing higher clay-silt boundary, e.g. 8 µm (Konert and Vandenberghe, 1997)”.

6. RS comment: “Do you want to mention which one? And what the implications of this might be?”. Original phrase: “The Kruskal-Wallis test (Table S4), in which the null hypothesis is that the medians of each group are the same, showed that at least one main research site the loess chemical composition differs significantly from the others, by the median of practically each of the determined chemical elements (except MgO, $P_2O_5$, MnO, Ni, and Zr)”. The entire rest of this chapter is actually a response to this comment, so we left it as it is.

7. RS comment: “I like this - good justification”. Authors response: thank you! ☺

Table 1

| | PML | UCC | AVL[1] * | GAL |
|---|---|---|---|---|
| $SiO_2$ | 78.64 | 66.00 | 76.50 | 70.71 |
| $Al_2O_3$ | 8.19 | 15.20 | 12.50 | 11.74 |
| $Fe_2O_3$ | 2.41 | 5.00 | 3.09 | 3.75 |
| MgO | 1.32 | 2.20 | 1.00 | 2.15 |
| CaO | 4.81 | 4.20 | 1.30 | 6.67 |
| $Na_2O$ | 1.07 | 3.90 | 2.10 | 1.68 |
| $K_2O$ | 2.25 | 3.40 | 2.30 | 2.22 |
| $TiO_2$ | 0.68 | 0.50 | 0.63 | 0.71 |
| $P_2O_5$ | 0.10 | 0.40 | N/D | 0.14 |
| MnO | 0.04 | 0.08 | 0.06 | 0.07 |
| Cr | 68.42 | 62.00 | 43.00 | 67.00 |
| Ba | 360.00 | 628.00 | 582.00 | 427.00 |
| Ni | 22.00 | 47.00 | 18.00 | 27.00 |
| Sc | 6.00 | 14.00 | 8.00 | N/D |
| Co | 5.50 | 17.30 | 9.00 | N/D |
| Cs | 2.40 | 4.90 | 3.70 | N/D |
| Ga | 7.90 | 17.50 | 13.00 | 12.00 |
| Hf | 14.60 | 5.30 | 12.00 | N/D |
| Nb | 12.80 | 12.00 | 18.00 | 14.00 |
| Rb | 69.20 | 84.00 | 81.00 | 79.00 |
| Sr | 131.10 | 320.00 | 246.00 | 208.00 |
| Ta | 0.90 | 0.90 | 1.30 | N/D |
| Th | 9.50 | 10.50 | 10.00 | 9.00 |
| U | 2.70 | 2.70 | 2.60 | N/D |
| V | 46.00 | 97.00 | 66.00 | N/D |
| W | 1.4 | 1.90 | 1.30 | N/D |
| Zr | 576.2 | 193.00 | 387.00 | 322 |
| Y | 27.8 | 21.00 | 25.00 | 26 |
| La | 30.8 | 31.00 | 35.00 | 29 |
| Ce | 59.8 | 63.00 | 78.00 | 61 |
| Pr | 6.86 | 7.10 | 8.40 | N/D |
| Nd | 26.3 | 27.00 | 33.00 | N/D |
| Sm | 5.01 | 4.70 | 6.40 | N/D |
| Eu | 0.88 | 1.00 | 1.20 | N/D |
| Gd | 4.69 | 4.00 | 4.80 | N/D |
| Tb | 0.75 | 0.70 | 0.80 | N/D |
| Dy | 4.68 | 3.90 | 4.70 | N/D |
| Ho | 0.99 | 0.83 | 1.00 | N/D |
| Er | 3.06 | 2.30 | 2.80 | N/D |
| Tm | 0.45 | 0.30 | N/D | N/D |
| Yb | 3.08 | 1.96 | 2.70 | N/D |
| Lu | 0.48 | 0.31 | N/D | N/D |

Figure 1

Click here to access/download;Figure;Fig. 1_JS et al_QR.jpg

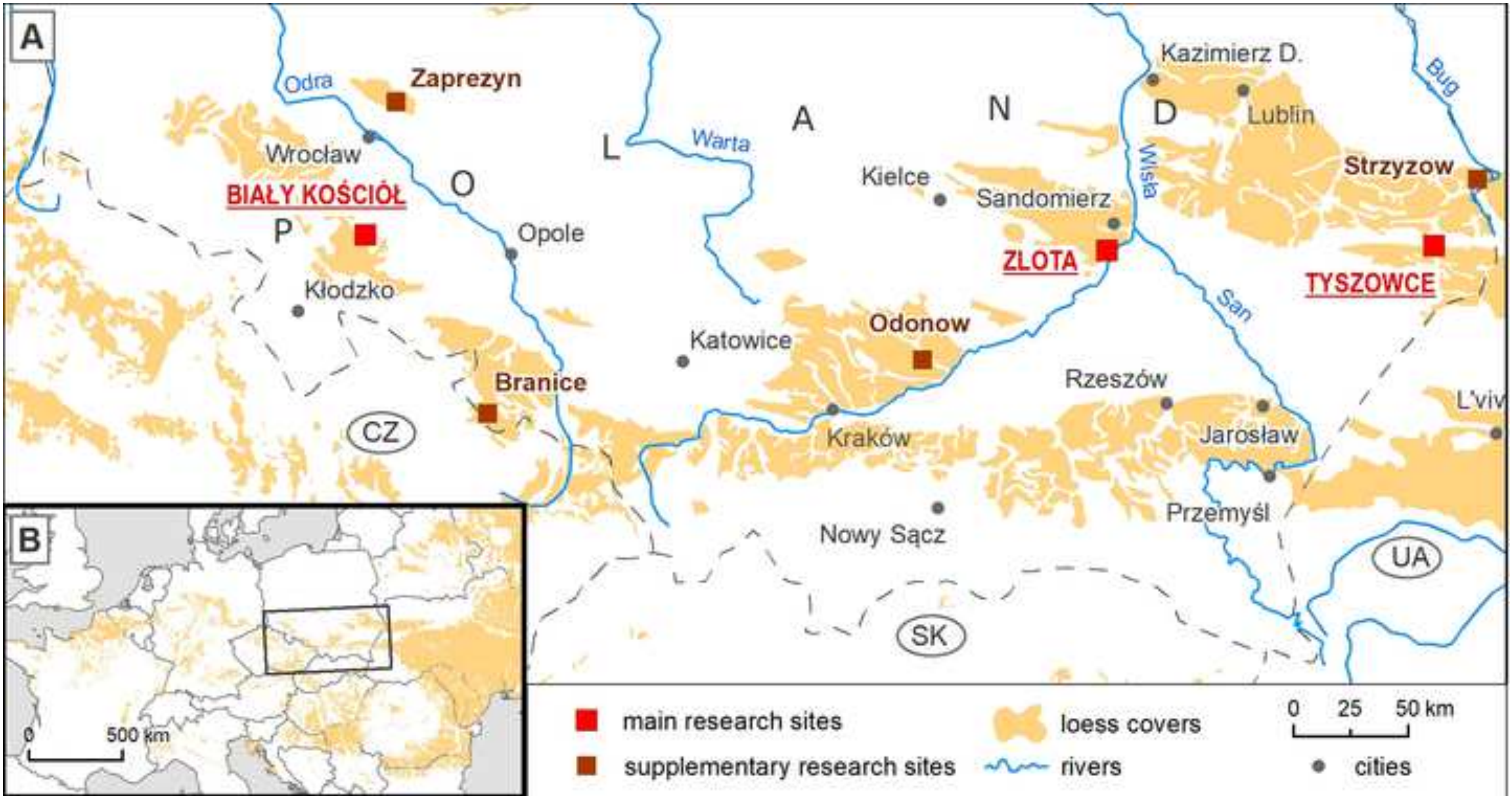

Figure 2 Click here to access/download;Figure;Fig. 2_JS et al_QR.tif

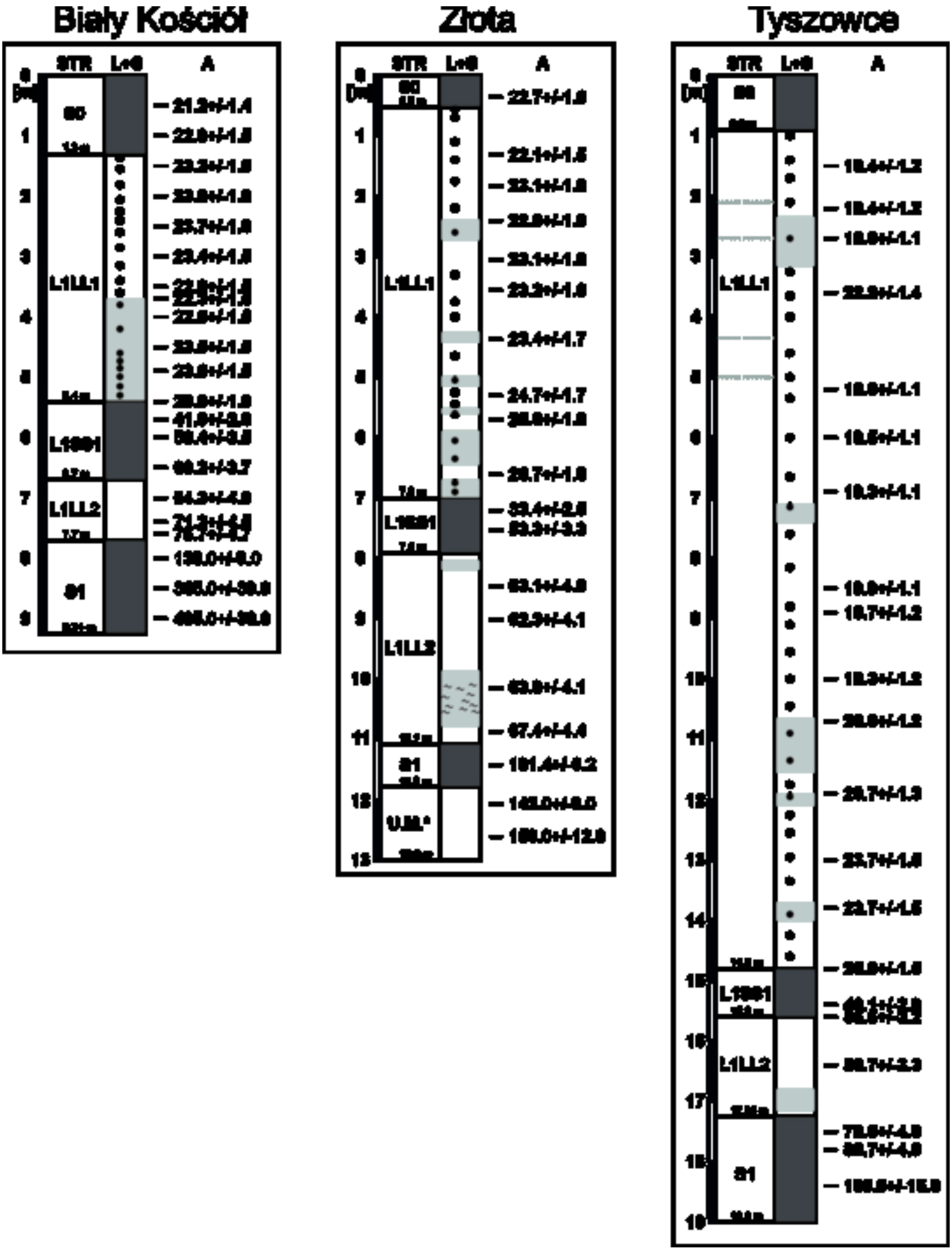

Figure 3

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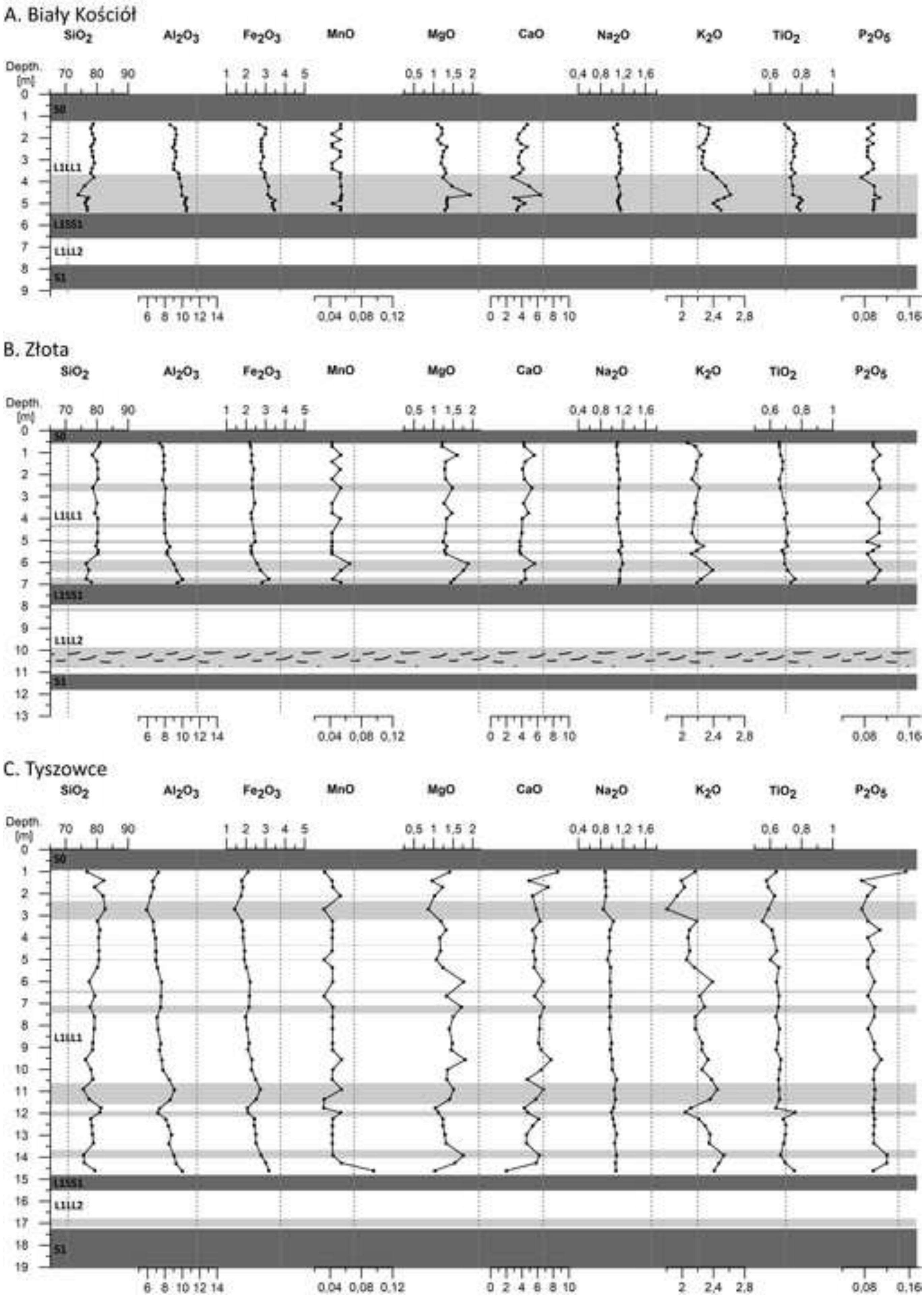

Figure 4

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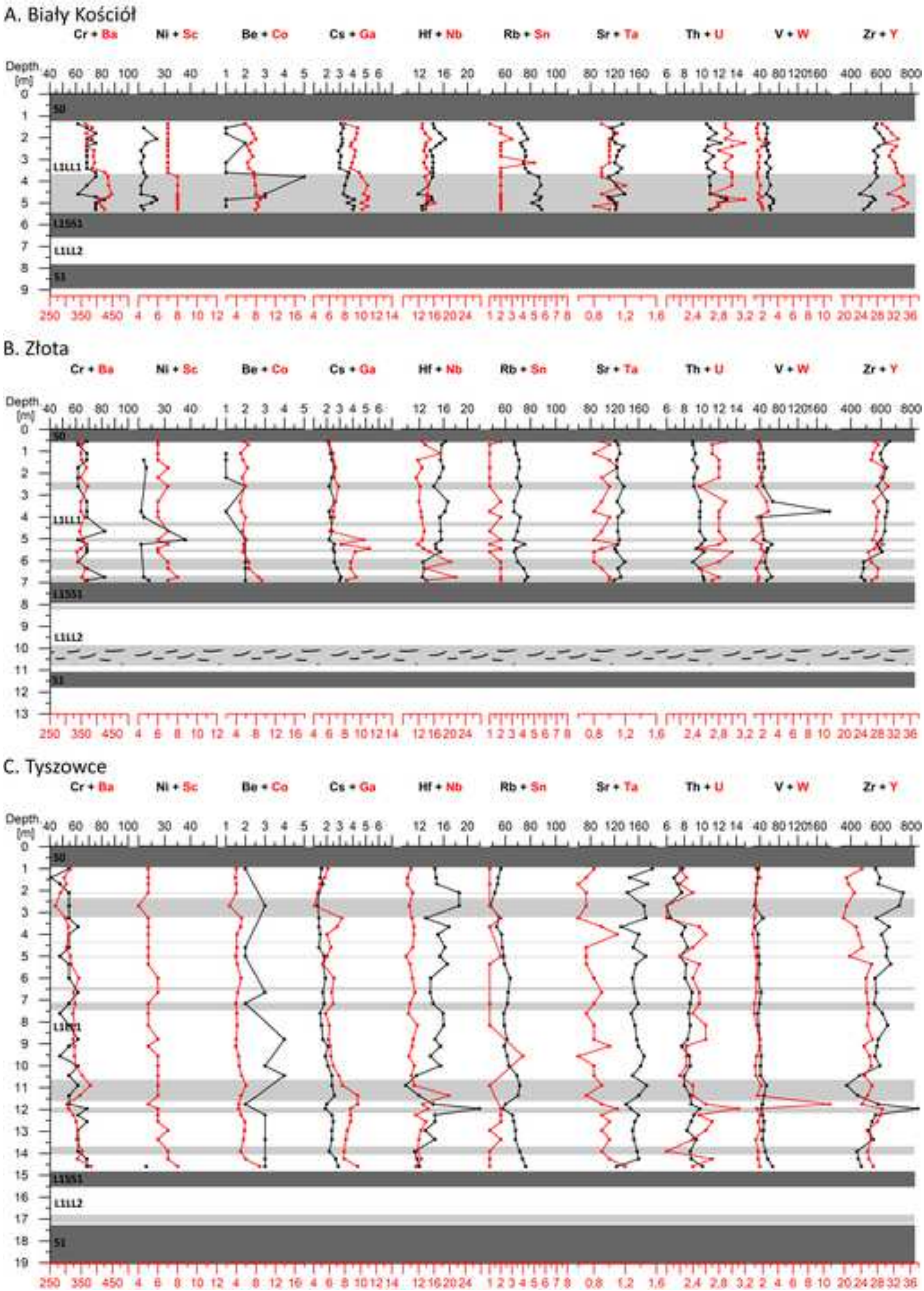

Figure 5

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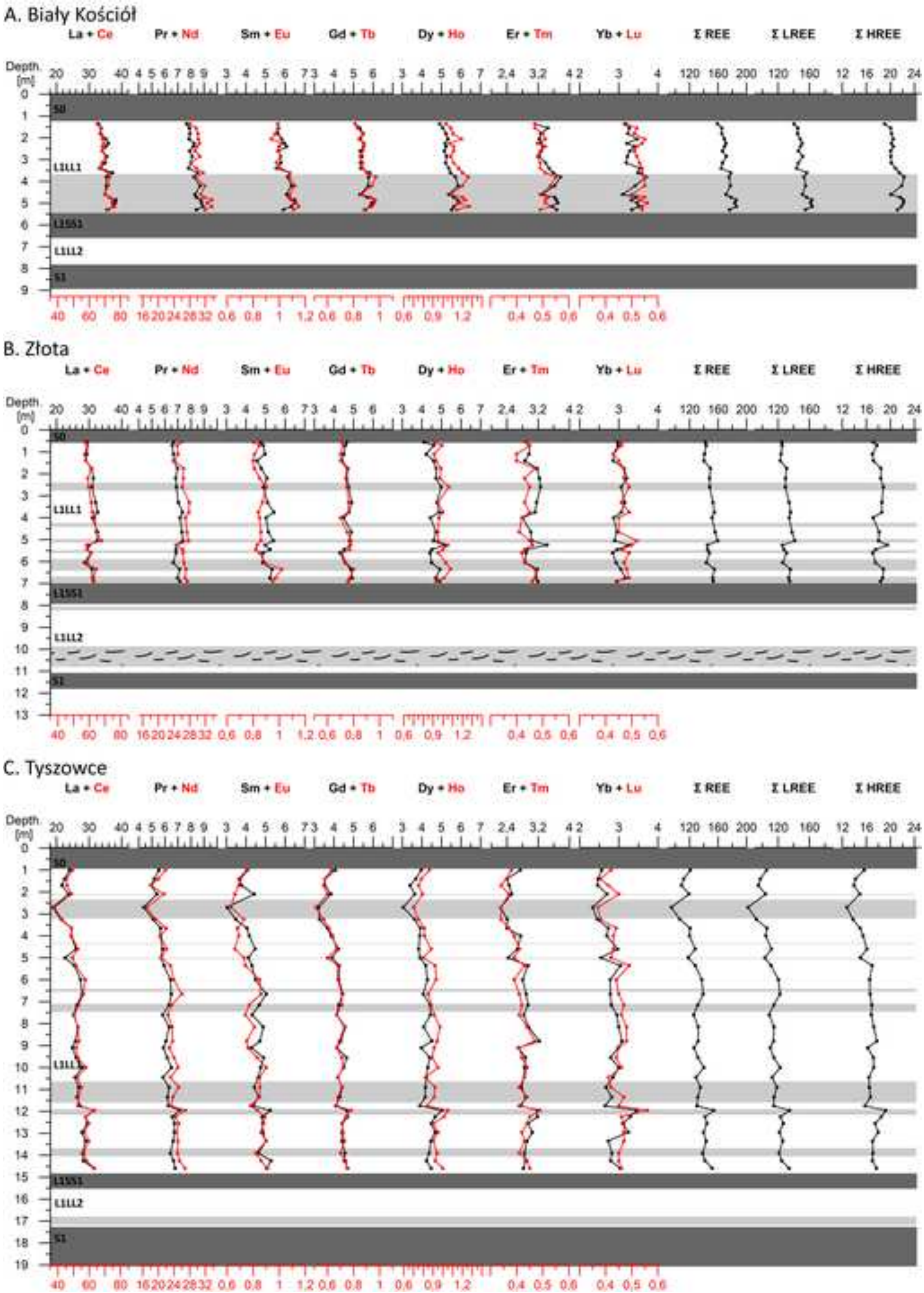

Figure 6

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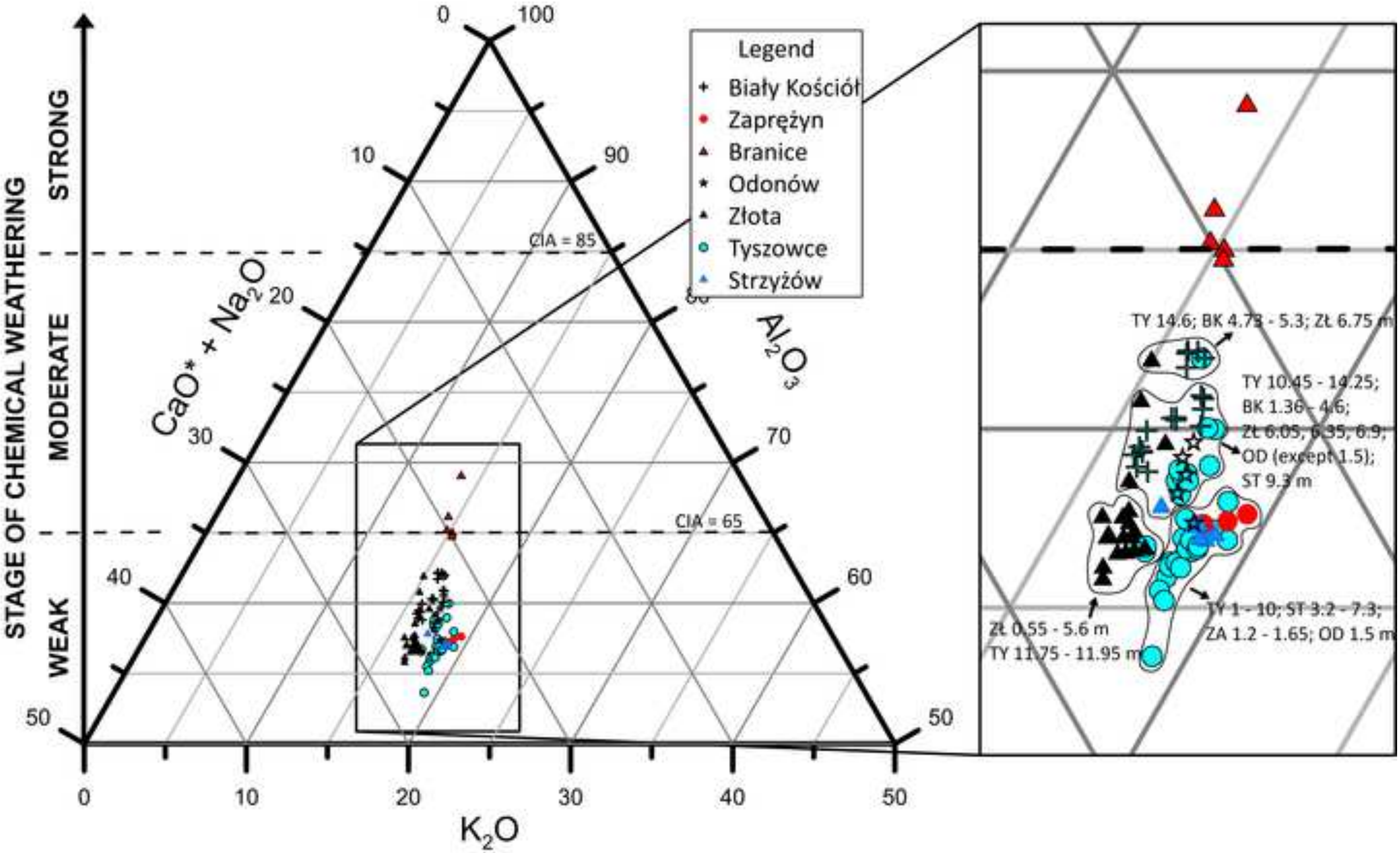

Figure 7 Click here to access/download;Figure;Fig. 7_JS et al_QR.tif

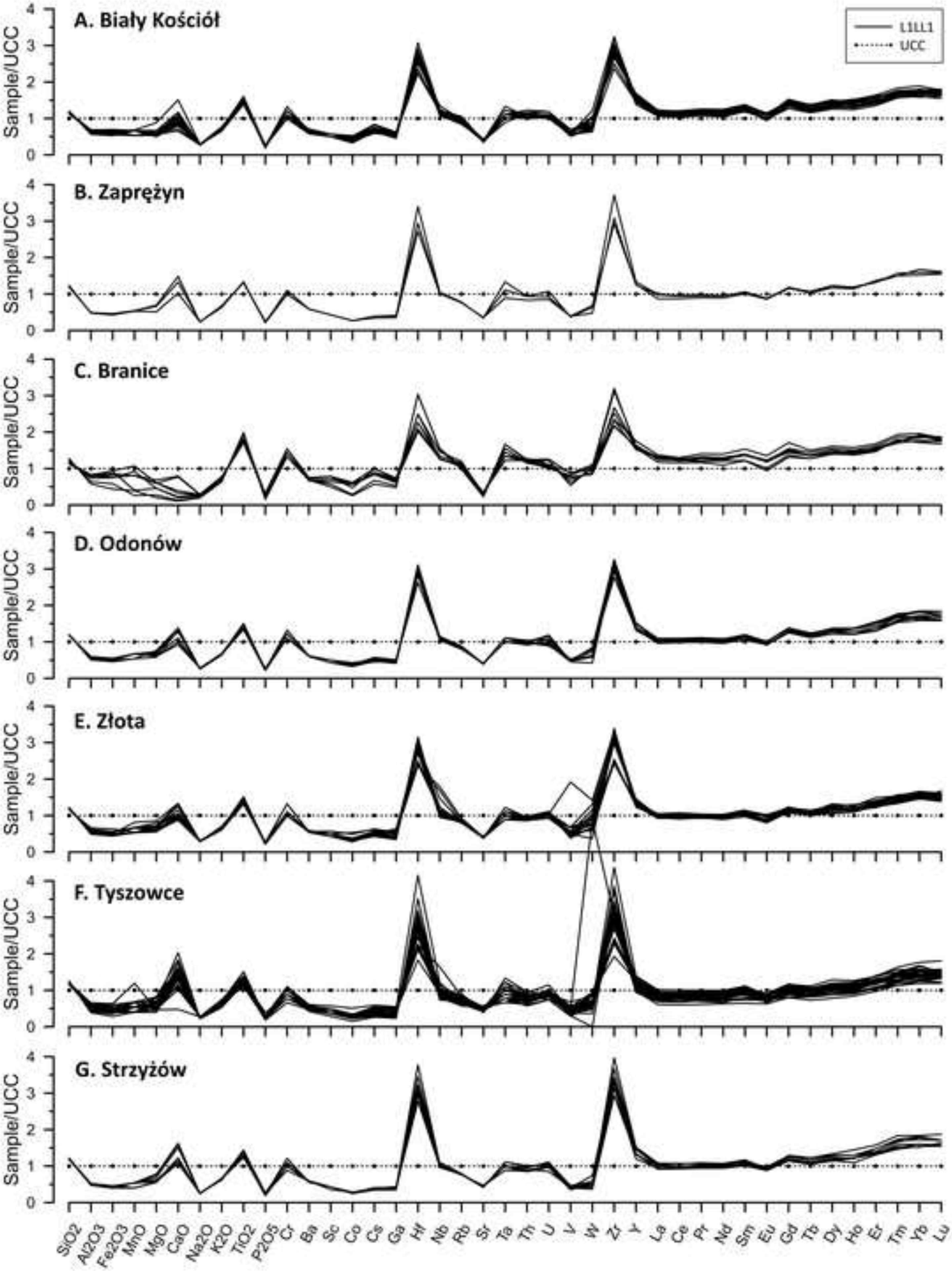

Figure 8

Click here to access/download;Figure;Fig. 8_JS et al_QR.tif

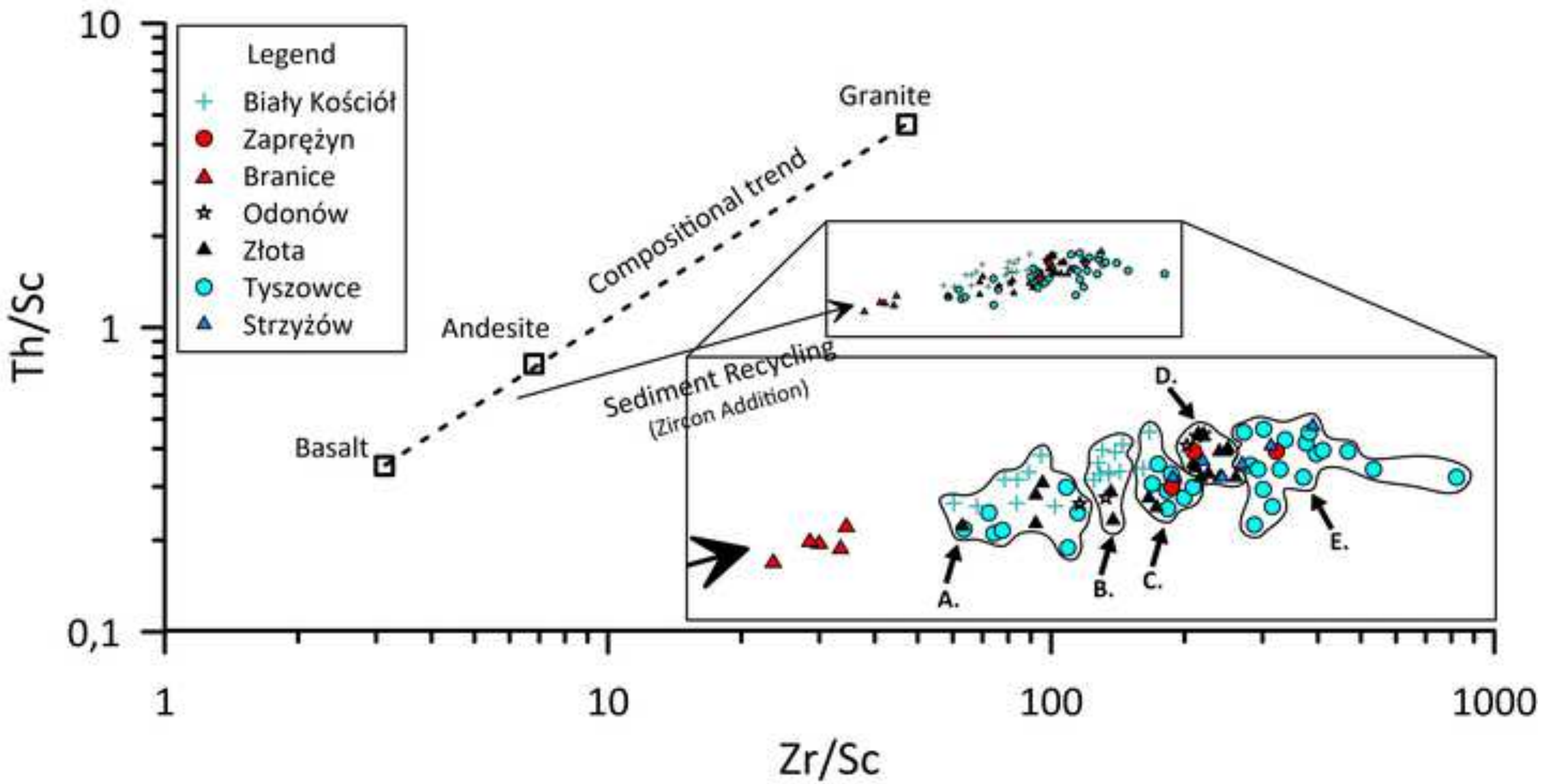

Figure 9

Click here to access/download;Figure;Fig. 9_JS et al_QR.tif

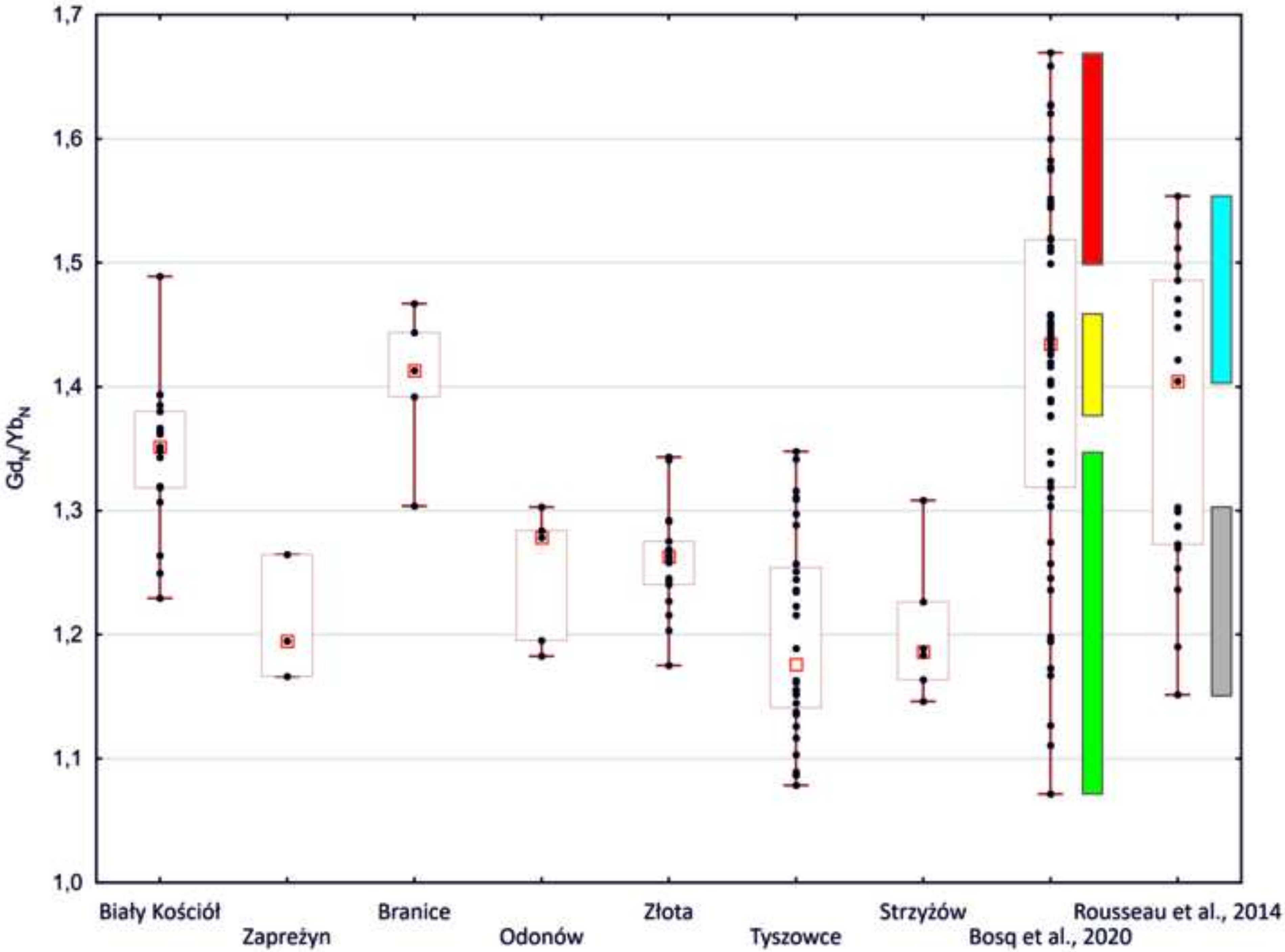

Figure 10

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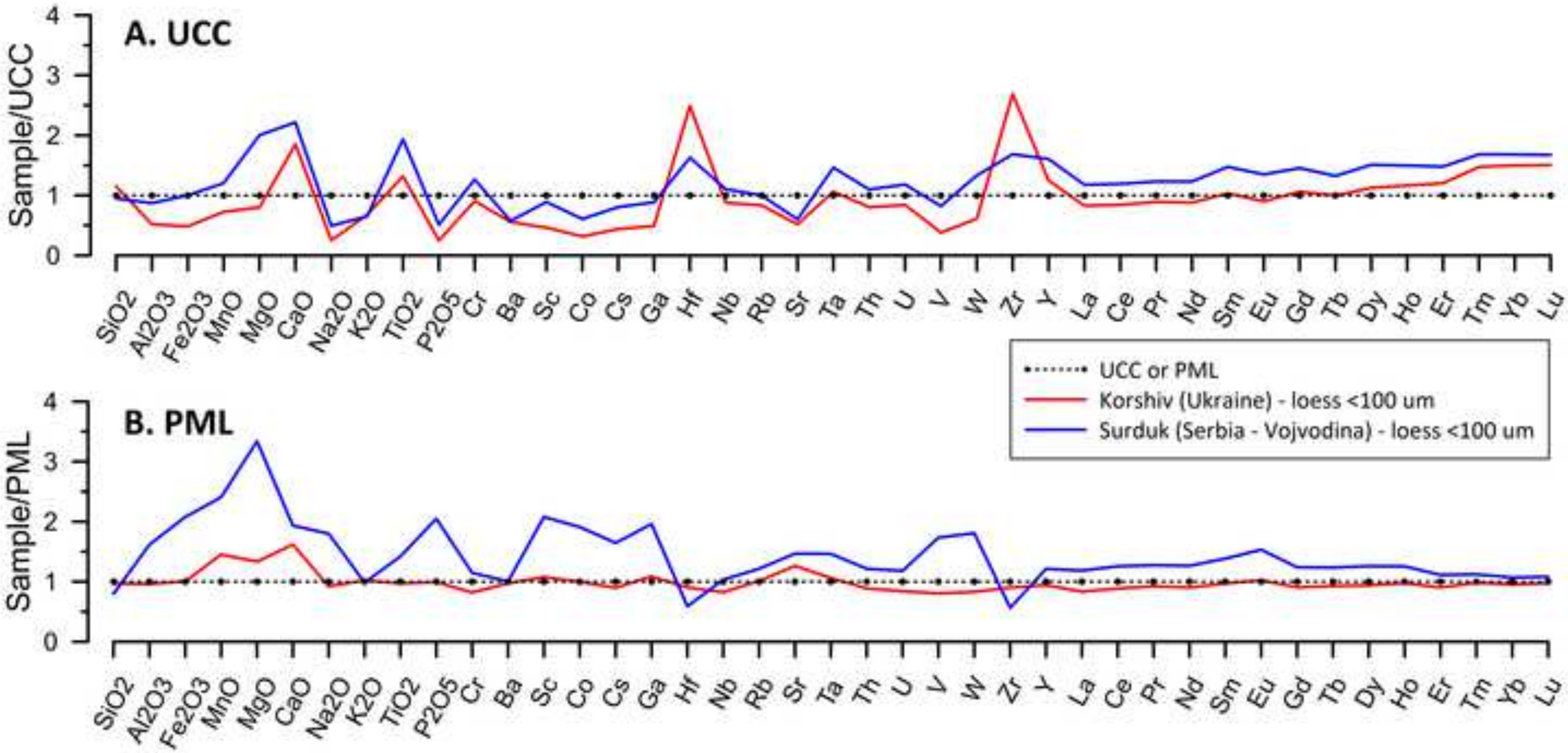


# Implications of the geochemistry of L1LL1 (MIS2) loess in Poland for paleoenvironment and new normalizing values for loess-focused multi-elemental analyses

## Supplementary figures

**Fig. S1**. The variability of granulometric composition (divided into individual fractions) at Biały Kościół (A), Złota (B) and Tyszowce (C). The main pedo- and lithostratigraphic units are shown. Legend of lithological markings consistent with Fig. 2.

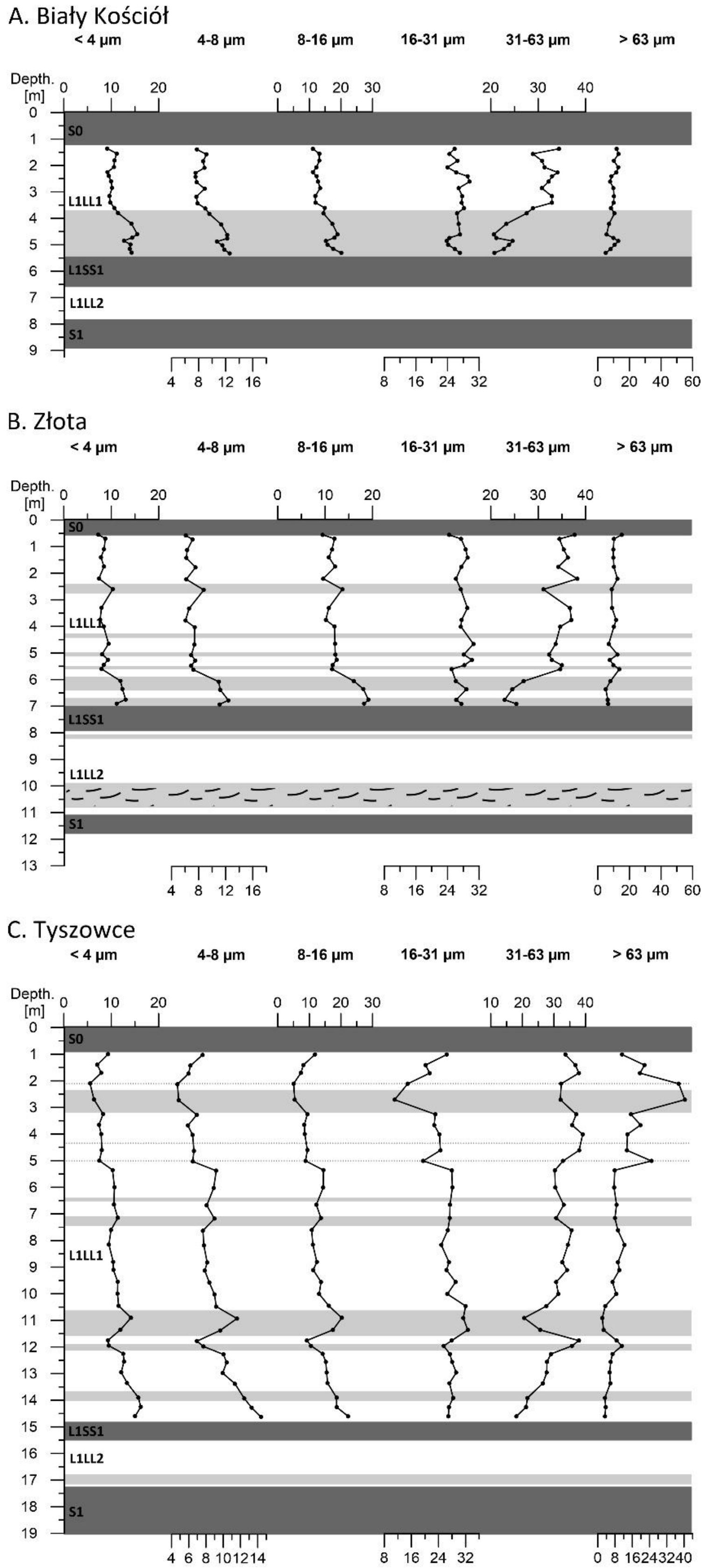
**Fig. S2**. Shepard's (1954) triangular diagram, based on Wentworth's (1922) classification, for the supplementary research sites.

**Fig. S3**. A-CN-K ternary diagram (Nesbitt and Young, 1984) of the Złota loess-palaeosol samples (after Skurzyński et al., 2020, modified). CaO* (Ca in silicates) was calculated according to McLennan (1993). Dashed lines – CIA values of 65 and 85. Stratigraphical labelling system after Kukla and An (1989), modified by Marković et al. (2008, 2015). U.M.* means “underlying material”.

**Fig. S4**. A-CN-K ternary diagram (Nesbitt and Young, 1984) of the Biały Kościół samples. Only L1LL1 loess is shown. CaO* (Ca in silicates) was calculated according to McLennan (1993). Dashed lines – CIA values of 65 and 85. Stratigraphical labelling system after Kukla and An (1989), modified by Marković et al. (2008, 2015).

**Fig. S5**. A-CN-K ternary diagram (Nesbitt and Young, 1984) of the Tyszowce samples. Only L1LL1 loess is shown. CaO* (Ca in silicates) was calculated according to McLennan (1993). Dashed lines – CIA values of 65 and 85. Stratigraphical labelling system after Kukla and An (1989), modified by Marković et al. (2008, 2015).

**Table S1.** Method detection limits (MDL) and precision (RSD – relative standard deviation) for investigated elements and oxides. RSD was presented separately for each of the four independent measurement series, based on the analysis of the same standard STD SO-19 (Biały Kościół, i.e. BK - 6; Złota, i.e. ZŁ - 5; Tyszowce, i.e. TY - 10; Zaprężyn, Strzyżów, Odonów and Branice, i.e. Z+S+O+B - 3 markings). The RSD value should be understood as the percentage average deviation from the mean value (e.g. 60.40 ± 0.18 means that the standard deviation is ± 0.18% of the mean value of 60.40%). The results are presented in the form obtained from an external laboratory, i.e. major elements and chromium are converted to oxides and expressed in wt%, trace elements and rare earth elements are presented in ppm.

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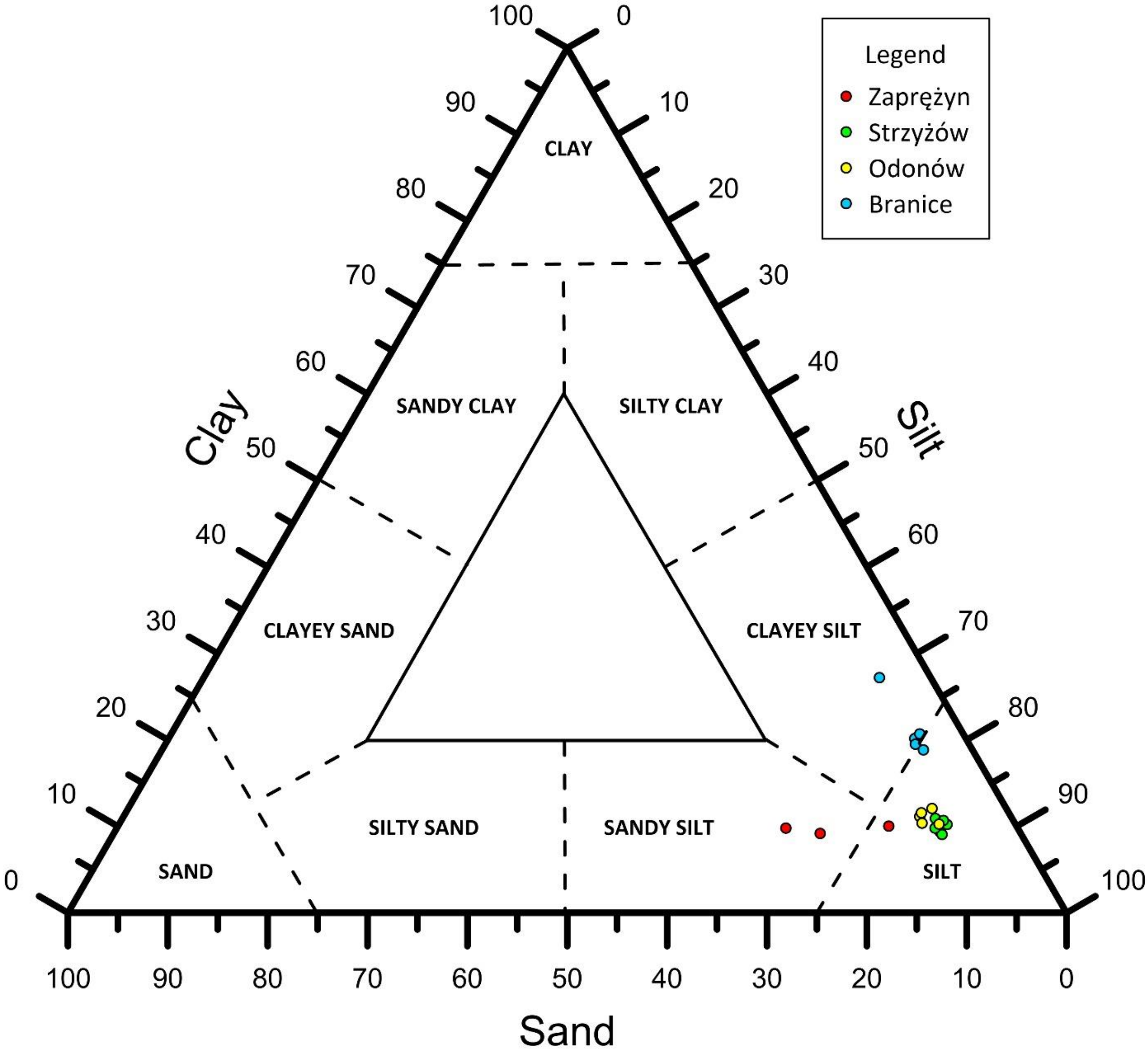


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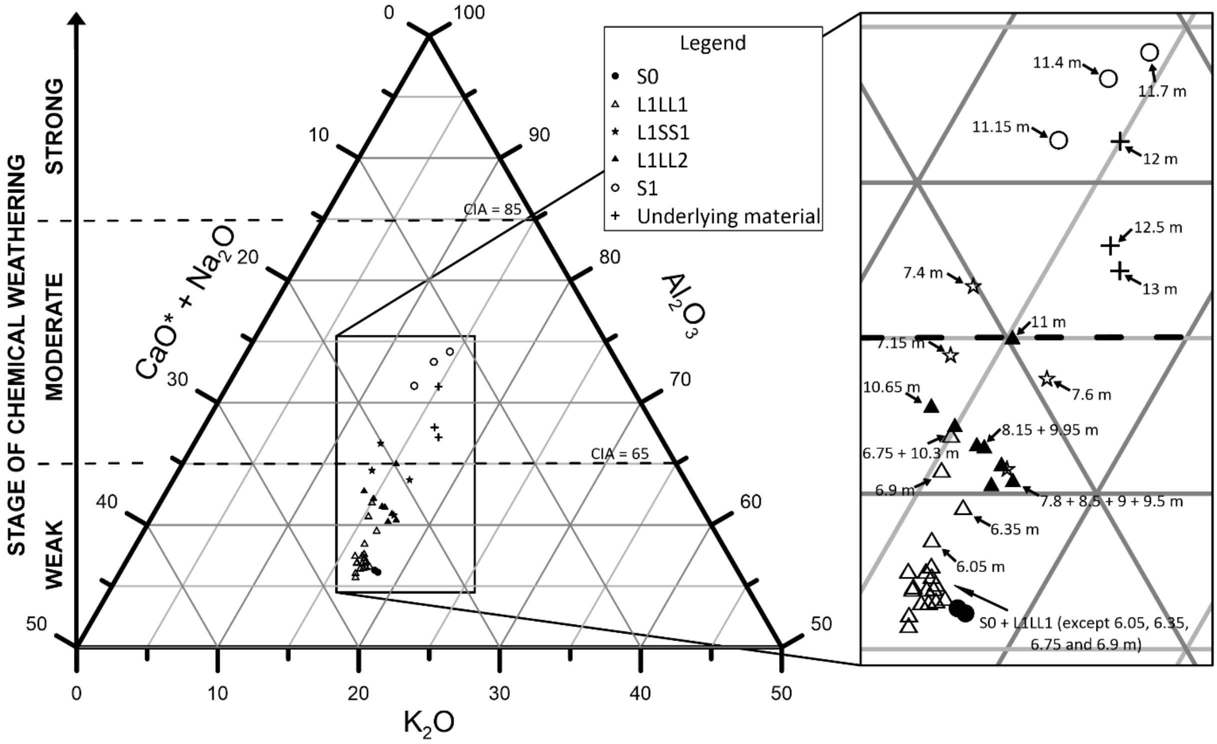


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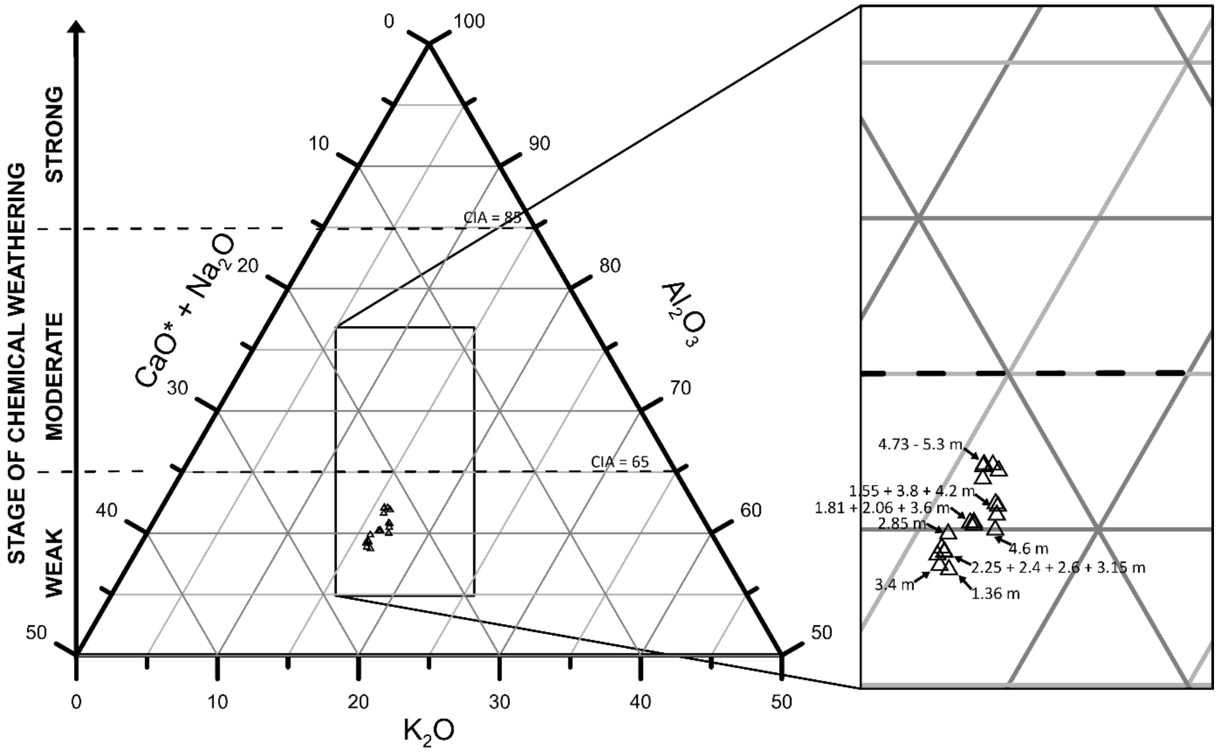


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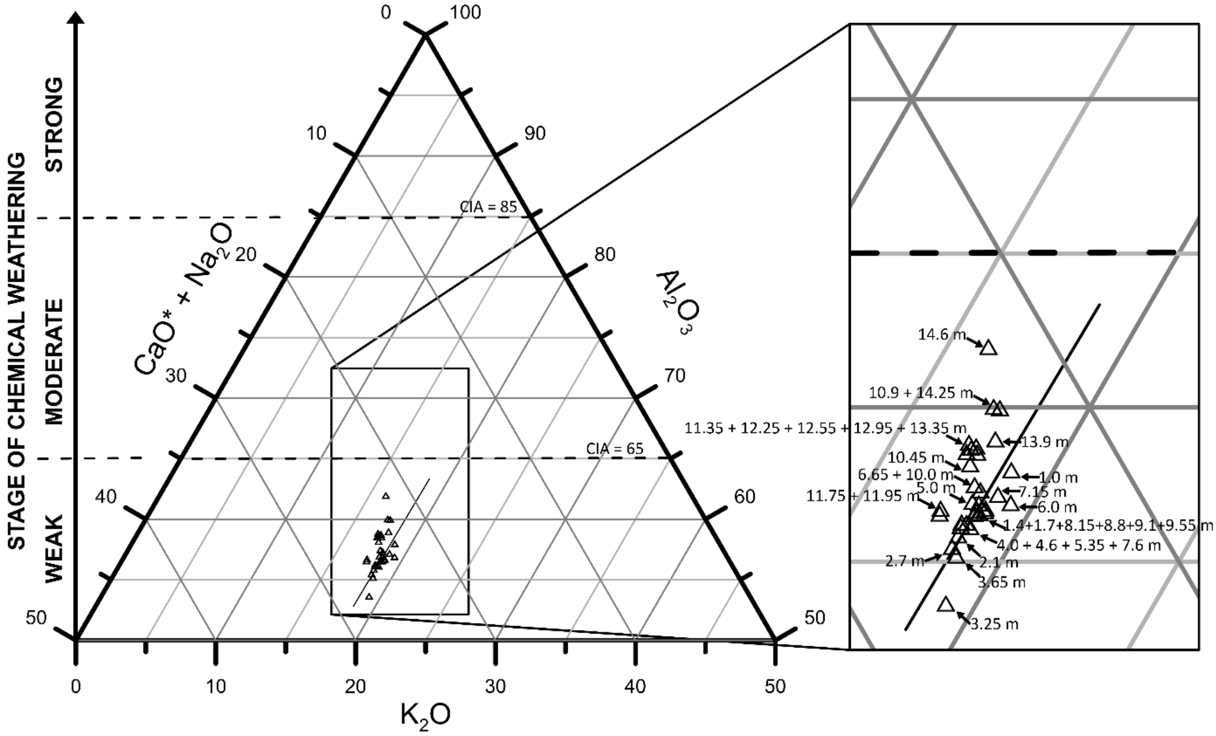


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| | | | AVERAGE VALUE ± RSD (%) | | | |
|---|---|---|---|---|---|---|
| | MDL | STD SO-19 | BK | ZŁ | TY | Z+S+O+B |
| $SiO_2$ % | 0,010 | 61,13 | 60,56 ± 0,12 | 60,30 ± 0,22 | 60,40 ± 0,18 | 60,31 ± 0,09 |
| $Al_2O_3$ % | 0,010 | 13,95 | 13,91 ± 0,35 | 13,98 ± 0,57 | 14,00 ± 0,41 | 14,03 ± 0,06 |
| $Fe_2O_3$ % | 0,040 | 7,47 | 7,45 ± 0,80 | 7,50 ± 0,82 | 7,45 ± 0,58 | 7,51 ± 0,70 |
| MnO % | 0,010 | 0,13 | 0,13 ± 0,00 | 0,13 ± 0,00 | 0,13 ± 0,00 | 0,13 ± 0,00 |
| MgO % | 0,010 | 2,88 | 2,93 ± 1,31 | 2,92 ± 0,59 | 2,91 ± 1,04 | 2,92 ± 0,28 |
| CaO % | 0,010 | 6,00 | 5,97 ± 0,72 | 5,97 ± 0,84 | 5,92 ± 0,82 | 5,95 ± 0,00 |
| $Na_2O$ % | 0,010 | 4,11 | 4,01 ± 1,50 | 4,07 ± 1,29 | 4,09 ± 1,56 | 4,04 ± 0,84 |
| $K_2O$ % | 0,010 | 1,29 | 1,26 ± 3,21 | 1,32 ± 1,14 | 1,31 ± 0,77 | 1,30 ± 0,73 |
| $TiO_2$ % | 0,010 | 0,69 | 0,70 ± 0,00 | 0,70 ± 0,70 | 0,70 ± 0,64 | 0,70 ± 0,00 |
| $P_2O_5$ % | 0,010 | 0,32 | 0,32 ± 3,32 | 0,32 ± 3,70 | 0,33 ± 2,06 | 0,32 ± 1,46 |
| $Cr_2O_3$ % | 0,002 | 0,50 | 0,49 ± 0,43 | 0,50 ± 1,21 | 0,50 ± 0,87 | 0,51 ± 0,16 |
| Ba | 1,000 | 486,00 | 470,83 ± 1,53 | 460,80 ± 1,40 | 458,30 ± 2,13 | 471,67 ± 1,39 |
| Ni | 20,000 | 470,00 | 471,50 ± 1,56 | 475,00 ± 1,58 | 462,60 ± 1,32 | 482,33 ± 0,54 |
| Sc | 1,000 | 27,00 | 26,33 ± 1,79 | 26,80 ± 3,66 | 26,50 ± 2,53 | 27,00 ± 0,00 |
| Be | 1,000 | 20,00 | 13,50 ± 34,41 | 19,80 ± 26,80 | 17,80 ± 16,27 | 19,67 ± 4,79 |
| Co | 0,200 | 24,00 | 23,85 ± 4,59 | 23,70 ± 2,96 | 23,56 ± 2,71 | 23,97 ± 2,75 |
| Cs | 0,100 | 4,50 | 4,45 ± 4,81 | 4,32 ± 8,33 | 4,14 ± 7,88 | 4,60 ± 3,07 |
| Ga | 0,500 | 17,50 | 16,48 ± 6,23 | 15,80 ± 3,90 | 16,47 ± 6,29 | 15,93 ± 1,48 |
| Hf | 0,100 | 3,10 | 3,12 ± 6,79 | 3,08 ± 2,43 | 3,05 ± 5,34 | 3,23 ± 3,86 |
| Nb | 0,100 | 68,50 | 70,87 ± 2,39 | 68,24 ± 1,67 | 68,66 ± 1,58 | 71,83 ± 1,93 |
| Rb | 0,100 | 19,50 | 19,35 ± 3,10 | 20,20 ± 4,78 | 19,67 ± 2,35 | 20,00 ± 2,55 |
| Sn | 1,000 | 19,00 | 17,83 ± 3,85 | 17,80 ± 2,25 | 17,80 ± 4,90 | 19,33 ± 2,44 |
| Sr | 0,50 | 317,10 | 314,08 ± 3,29 | 316,46 ± 0,96 | 324,11 ± 1,29 | 315,27 ± 2,16 |
| Ta | 0,10 | 4,90 | 4,42 ± 4,79 | 4,86 ± 3,59 | 4,73 ± 4,83 | 5,03 ± 1,87 |
| Th | 0,20 | 13,00 | 13,42 ± 2,84 | 13,28 ± 2,10 | 12,85 ± 3,60 | 13,97 ± 2,43 |
| U | 0,10 | 19,40 | 19,53 ± 1,44 | 19,56 ± 2,18 | 20,11 ± 2,13 | 20,87 ± 2,16 |
| V | 8,00 | 165,00 | 165,17 ± 1,90 | 170,40 ± 2,31 | 167,70 ± 3,04 | 169,67 ± 2,00 |
| W | 0,50 | 9,80 | 9,93 ± 5,92 | 10,54 ± 9,40 | 9,66 ± 5,88 | 9,77 ± 3,38 |
| Zr | 0,10 | 112,00 | 112,53 ± 2,59 | 109,34 ± 1,31 | 109,44 ± 1,71 | 113,47 ± 2,73 |
| Y | 0,10 | 35,50 | 36,32 ± 3,81 | 35,00 ± 2,04 | 35,38 ± 2,04 | 37,13 ± 3,30 |
| La | 0,10 | 71,30 | 71,35 ± 1,78 | 72,42 ± 2,31 | 71,53 ± 1,94 | 74,43 ± 2,91 |
| Ce | 0,10 | 161,00 | 157,52 ± 1,01 | 158,66 ± 1,34 | 159,78 ± 1,37 | 166,43 ± 3,10 |
| Pr | 0,02 | 19,40 | 19,40 ± 2,28 | 19,06 ± 1,44 | 18,99 ± 1,52 | 20,34 ± 2,40 |
| Nd | 0,30 | 75,70 | 74,40 ± 2,67 | 74,30 ± 1,15 | 74,33 ± 2,91 | 78,67 ± 2,73 |
| Sm | 0,05 | 13,70 | 13,12 ± 2,78 | 12,89 ± 1,71 | 12,95 ± 1,50 | 13,44 ± 2,80 |
| Eu | 0,02 | 3,81 | 3,64 ± 2,56 | 3,58 ± 2,86 | 3,61 ± 2,18 | 3,82 ± 2,14 |
| Gd | 0,05 | 10,53 | 10,60 ± 1,56 | 10,13 ± 1,39 | 10,19 ± 1,70 | 10,81 ± 1,70 |
| Tb | 0,01 | 1,41 | 1,39 ± 1,55 | 1,34 ± 1,60 | 1,34 ± 1,79 | 1,43 ± 2,82 |
| Dy | 0,05 | 7,50 | 7,40 ± 1,82 | 7,26 ± 2,09 | 7,17 ± 2,26 | 7,53 ± 1,79 |
| Ho | 0,02 | 1,39 | 1,36 ± 2,61 | 1,34 ± 1,11 | 1,33 ± 2,69 | 1,41 ± 2,98 |
| Er | 0,03 | 3,78 | 3,88 ± 2,28 | 3,75 ± 3,51 | 3,77 ± 3,45 | 4,04 ± 1,34 |
| Tm | 0,01 | 0,55 | 0,52 ± 3,29 | 0,51 ± 3,61 | 0,52 ± 3,26 | 0,56 ± 2,92 |
| Yb | 0,05 | 3,55 | 3,38 ± 4,56 | 3,36 ± 3,06 | 3,36 ± 3,91 | 3,55 ± 2,13 |
| Lu | 0,01 | 0,53 | 0,51 ± 3,84 | 0,50 ± 4,56 | 0,50 ± 3,27 | 0,55 ± 2,57 |

Table S2. Geochemical composition of the Polish loess. Major elements (wt%) are recalculated on a volatile-free b

| Research Site | Depth (m b.g.l) | LOI | OXIDES OF MAJOR ELEMENTS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | CaO | $Na_2O$ | $K_2O$ | $TiO_2$ |
| BIAŁY KOŚCIÓŁ | 1.36 | 6.20 | 78.81 | 8.60 | 2.65 | 1.10 | 4.68 | 1.10 | 2.22 | 0.69 |
| | 1.55 | 6.30 | 78.11 | 9.19 | 3.01 | 1.21 | 4.26 | 1.03 | 2.34 | 0.72 |
| | 1.81 | 5.60 | 78.56 | 9.31 | 2.98 | 1.21 | 3.61 | 1.09 | 2.34 | 0.75 |
| | 2.06 | 5.30 | 79.26 | 9.16 | 2.78 | 1.10 | 3.42 | 1.08 | 2.31 | 0.75 |
| | 2.25 | 5.70 | 78.77 | 9.11 | 2.77 | 1.18 | 3.85 | 1.15 | 2.27 | 0.76 |
| | 2.40 | 6.40 | 78.10 | 8.91 | 2.77 | 1.34 | 4.65 | 1.14 | 2.21 | 0.75 |
| | 2.60 | 5.80 | 78.48 | 9.23 | 2.79 | 1.26 | 3.92 | 1.16 | 2.28 | 0.75 |
| | 2.85 | 5.60 | 78.75 | 9.26 | 2.89 | 1.22 | 3.59 | 1.14 | 2.26 | 0.75 |
| | 3.15 | 5.60 | 79.17 | 9.03 | 2.75 | 1.19 | 3.60 | 1.14 | 2.25 | 0.73 |
| | 3.40 | 6.00 | 78.43 | 9.03 | 2.76 | 1.28 | 4.17 | 1.16 | 2.28 | 0.74 |
| | 3.60 | 6.10 | 78.01 | 9.58 | 2.96 | 1.31 | 3.72 | 1.13 | 2.39 | 0.76 |
| | 3.80 | 5.20 | 79.02 | 9.66 | 2.95 | 1.24 | 2.76 | 1.08 | 2.44 | 0.73 |
| | 4.20 | 7.00 | 75.99 | 9.90 | 3.15 | 1.47 | 4.93 | 1.12 | 2.55 | 0.74 |
| | 4.60 | 8.50 | 73.97 | 9.95 | 3.12 | 1.94 | 6.35 | 1.15 | 2.62 | 0.74 |
| | 4.73 | 6.10 | 77.29 | 10.49 | 3.27 | 1.36 | 2.99 | 1.12 | 2.54 | 0.79 |
| | 4.85 | 6.40 | 76.68 | 10.32 | 3.48 | 1.34 | 3.67 | 1.10 | 2.45 | 0.80 |
| | 4.99 | 6.90 | 76.25 | 10.27 | 3.35 | 1.33 | 4.36 | 1.11 | 2.40 | 0.79 |
| | 5.15 | 6.40 | 76.77 | 10.47 | 3.36 | 1.35 | 3.53 | 1.14 | 2.45 | 0.77 |
| | 5.30 | 6.00 | 76.87 | 10.46 | 3.46 | 1.29 | 3.34 | 1.15 | 2.50 | 0.79 |
| ZAPRĘŻYN | 1.20 | 7.30 | 78.51 | 7.42 | 2.30 | 1.52 | 6.24 | 0.90 | 2.31 | 0.66 |
| | 1.50 | 6.70 | 79.35 | 7.42 | 2.21 | 1.46 | 5.57 | 0.92 | 2.28 | 0.66 |
| | 1.65 | 5.50 | 81.36 | 7.21 | 2.14 | 1.12 | 4.29 | 0.92 | 2.15 | 0.67 |
| BRANICE | 1.26 | 7.10 | 74.71 | 11.92 | 4.12 | 1.31 | 3.24 | 1.10 | 2.57 | 0.87 |
| | 1.54 | 7.50 | 74.37 | 12.18 | 3.79 | 1.51 | 3.34 | 1.14 | 2.65 | 0.87 |
| | 1.75 | 6.50 | 75.42 | 12.61 | 4.27 | 1.33 | 1.64 | 1.12 | 2.53 | 0.91 |
| | 1.96 | 6.30 | 75.36 | 12.41 | 4.70 | 1.34 | 1.35 | 1.16 | 2.59 | 0.89 |
| | 2.38 | 6.50 | 76.50 | 12.65 | 4.61 | 1.01 | 0.85 | 0.98 | 2.32 | 0.96 |
| ODONÓW | 0.90 | 7.00 | 78.59 | 8.19 | 2.47 | 1.27 | 5.51 | 0.97 | 2.18 | 0.70 |
| | 1.50 | 7.10 | 78.51 | 7.69 | 2.28 | 1.67 | 5.80 | 0.99 | 2.26 | 0.67 |
| | 1.80 | 6.80 | 78.29 | 8.30 | 2.45 | 1.52 | 5.41 | 1.01 | 2.21 | 0.68 |
| | 2.50 | 7.40 | 77.53 | 8.41 | 2.52 | 1.56 | 5.80 | 1.04 | 2.31 | 0.68 |
| | 3.30 | 6.90 | 77.99 | 8.38 | 2.43 | 1.60 | 5.35 | 1.07 | 2.32 | 0.70 |
| ZŁOTA | 0.55 | 5.50 | 80.99 | 7.40 | 2.20 | 1.22 | 4.22 | 1.10 | 2.07 | 0.66 |
| | 0.70 | 5.60 | 80.52 | 7.70 | 2.23 | 1.21 | 4.29 | 1.08 | 2.17 | 0.66 |
| | 1.10 | 6.60 | 78.50 | 7.88 | 2.30 | 1.60 | 5.56 | 1.09 | 2.24 | 0.67 |
| | 1.40 | 5.60 | 80.03 | 7.85 | 2.27 | 1.31 | 4.42 | 1.12 | 2.19 | 0.68 |
| | 1.75 | 5.40 | 80.21 | 7.92 | 2.39 | 1.28 | 4.08 | 1.10 | 2.18 | 0.68 |
| | 2.20 | 5.60 | 80.26 | 7.72 | 2.32 | 1.31 | 4.32 | 1.14 | 2.12 | 0.66 |
| | 2.60 | 6.60 | 78.66 | 8.09 | 2.33 | 1.48 | 5.28 | 1.12 | 2.22 | 0.67 |
| | 3.30 | 5.70 | 80.04 | 7.96 | 2.44 | 1.26 | 4.20 | 1.12 | 2.17 | 0.69 |
| | 3.75 | 6.10 | 79.36 | 7.90 | 2.27 | 1.46 | 4.85 | 1.13 | 2.18 | 0.70 |
| | 4.00 | 5.80 | 80.28 | 7.98 | 2.29 | 1.33 | 4.03 | 1.10 | 2.15 | 0.69 |
| | 4.65 | 5.60 | 80.19 | 7.99 | 2.41 | 1.31 | 3.98 | 1.14 | 2.12 | 0.71 |
| | 5.05 | 5.40 | 80.17 | 8.22 | 2.46 | 1.24 | 3.74 | 1.17 | 2.18 | 0.70 |
| | 5.25 | 5.50 | 79.71 | 8.57 | 2.26 | 1.34 | 3.81 | 1.18 | 2.27 | 0.71 |
| | 5.45 | 5.20 | 80.40 | 8.26 | 2.27 | 1.28 | 3.67 | 1.12 | 2.19 | 0.68 |
| | 5.60 | 5.40 | 80.25 | 8.25 | 2.29 | 1.31 | 3.81 | 1.15 | 2.12 | 0.69 |
| | 6.05 | 7.40 | 76.55 | 9.05 | 2.56 | 1.88 | 5.61 | 1.19 | 2.31 | 0.69 |
| | 6.35 | 6.90 | 77.37 | 9.35 | 2.74 | 1.77 | 4.37 | 1.14 | 2.39 | 0.71 |
| | 6.75 | 7.50 | 76.56 | 10.02 | 3.18 | 1.53 | 4.43 | 1.14 | 2.24 | 0.76 |
| | 6.90 | 6.90 | 78.23 | 9.44 | 2.82 | 1.44 | 3.87 | 1.13 | 2.20 | 0.73 |
| | 1.00 | 8.80 | 76.86 | 7.22 | 2.10 | 1.41 | 8.54 | 0.88 | 2.17 | 0.64 |
| | 1.40 | 5.90 | 82.19 | 6.59 | 1.78 | 0.96 | 4.92 | 0.88 | 1.99 | 0.57 |
| | 1.70 | 7.70 | 79.26 | 6.68 | 1.84 | 1.23 | 7.35 | 0.89 | 2.03 | 0.59 |
| | 2.10 | 5.80 | 81.94 | 6.37 | 1.74 | 1.02 | 5.34 | 0.89 | 1.93 | 0.63 |
| | 2.70 | 6.30 | 82.65 | 5.90 | 1.41 | 0.87 | 5.83 | 0.84 | 1.81 | 0.59 |
| | 3.25 | 7.10 | 80.19 | 6.65 | 1.78 | 1.19 | 6.30 | 1.02 | 2.19 | 0.55 |
| | 3.65 | 6.60 | 80.95 | 6.71 | 1.86 | 1.32 | 5.35 | 0.97 | 2.09 | 0.61 |
| | 4.00 | 6.40 | 80.54 | 6.93 | 1.84 | 1.16 | 5.76 | 0.95 | 2.08 | 0.62 |
| | 4.60 | 6.30 | 80.62 | 6.96 | 1.93 | 1.18 | 5.48 | 0.96 | 2.10 | 0.64 |
| | 5.00 | 6.50 | 80.66 | 6.95 | 1.91 | 1.07 | 5.71 | 0.92 | 2.06 | 0.60 |
| | 5.35 | 6.60 | 80.15 | 7.13 | 2.02 | 1.23 | 5.56 | 0.98 | 2.16 | 0.65 |
| | 6.00 | 7.70 | 77.56 | 7.61 | 2.20 | 1.77 | 6.73 | 0.97 | 2.39 | 0.64 |
| | 6.65 | 6.80 | 79.36 | 7.56 | 2.17 | 1.32 | 5.62 | 0.98 | 2.22 | 0.66 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| TYSZOWCE | 7.15 | 7.90 | 77.78 | 7.51 | 2.15 | 1.71 | 6.81 | 0.96 | 2.29 | 0.65 |
| | 7.60 | 7.10 | 79.23 | 7.09 | 1.97 | 1.50 | 6.30 | 0.97 | 2.17 | 0.64 |
| | 8.15 | 7.10 | 79.18 | 7.20 | 2.05 | 1.40 | 6.26 | 0.96 | 2.17 | 0.66 |
| | 8.80 | 7.20 | 78.66 | 7.53 | 2.16 | 1.48 | 6.13 | 0.99 | 2.26 | 0.65 |
| | 9.10 | 7.30 | 78.64 | 7.37 | 2.10 | 1.45 | 6.45 | 0.97 | 2.25 | 0.64 |
| | 9.55 | 8.40 | 76.37 | 7.65 | 2.30 | 1.81 | 7.70 | 1.01 | 2.33 | 0.67 |
| | 10.00 | 7.40 | 78.07 | 7.77 | 2.28 | 1.35 | 6.46 | 1.01 | 2.25 | 0.66 |
| | 10.45 | 6.40 | 78.73 | 8.52 | 2.49 | 1.34 | 4.68 | 1.08 | 2.38 | 0.65 |
| | 10.90 | 8.30 | 75.62 | 9.09 | 2.73 | 1.51 | 6.74 | 1.04 | 2.45 | 0.66 |
| | 11.35 | 7.40 | 77.49 | 8.60 | 2.52 | 1.41 | 5.77 | 1.06 | 2.36 | 0.66 |
| | 11.75 | 5.60 | 81.29 | 7.39 | 2.07 | 1.04 | 4.31 | 1.03 | 2.11 | 0.64 |
| | 11.95 | 6.10 | 80.93 | 7.18 | 2.10 | 1.12 | 4.73 | 0.99 | 2.04 | 0.76 |
| | 12.25 | 7.60 | 78.01 | 8.12 | 2.43 | 1.24 | 6.15 | 1.02 | 2.21 | 0.68 |
| | 12.55 | 6.90 | 78.38 | 8.41 | 2.42 | 1.24 | 5.37 | 1.04 | 2.29 | 0.70 |
| | 12.95 | 6.40 | 78.60 | 8.74 | 2.49 | 1.28 | 4.62 | 1.08 | 2.36 | 0.70 |
| | 13.35 | 6.40 | 78.90 | 8.46 | 2.51 | 1.32 | 4.59 | 1.05 | 2.35 | 0.69 |
| | 13.90 | 8.20 | 75.75 | 9.05 | 2.77 | 1.76 | 6.22 | 1.08 | 2.53 | 0.67 |
| | 14.25 | 8.00 | 75.93 | 9.29 | 3.02 | 1.55 | 5.81 | 1.07 | 2.47 | 0.70 |
| | 14.60 | 5.60 | 79.37 | 10.00 | 3.16 | 1.03 | 2.01 | 1.07 | 2.41 | 0.75 |
| STRZYŻÓW | 3.20 | 6.10 | 80.68 | 7.39 | 2.01 | 1.22 | 4.81 | 0.95 | 2.20 | 0.64 |
| | 3.80 | 7.60 | 78.36 | 7.27 | 2.07 | 1.66 | 6.73 | 0.94 | 2.22 | 0.62 |
| | 4.40 | 7.40 | 79.03 | 7.22 | 1.98 | 1.53 | 6.35 | 0.94 | 2.19 | 0.63 |
| | 5.00 | 7.90 | 77.96 | 7.40 | 2.13 | 1.70 | 6.84 | 0.95 | 2.27 | 0.62 |
| | 7.30 | 7.90 | 77.83 | 7.55 | 2.15 | 1.72 | 6.72 | 0.98 | 2.23 | 0.67 |
| | 9.30 | 6.70 | 79.78 | 7.63 | 2.27 | 1.26 | 5.16 | 1.00 | 2.11 | 0.70 |

*Implications of the geochemistry of L1LL1 (MIS2) loess in Poland for paleoenvironment and new normalizing values for loess-focused multi-elem

The color scale was developed using the Conditional Formatting function of MS Excel - the red-yellow-green color scale indicates the position of a

**Table S3. Basic statistics of geochemical composition of the Polish loess. Major elements (wt%) are recalculated o**

| Basic Statistic | Research Site | LOI | OXIDES OF MAJOR ELEMENTS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | CaO | $Na_2O$ | $K_2O$ | $TiO_2$ |
| MEDIAN | Biały Kościół | 6.10 | 78.11 | 9.31 | 2.96 | 1.28 | 3.72 | 1.13 | 2.34 | 0.75 |
| | Złota | 5.60 | 80.04 | 7.99 | 2.32 | 1.31 | 4.22 | 1.13 | 2.18 | 0.69 |
| | Tyszowce | 7.00 | 79.04 | 7.45 | 2.13 | 1.32 | 5.79 | 0.99 | 2.22 | 0.65 |
| | Zaprężyn | 6.70 | 79.35 | 7.42 | 2.21 | 1.46 | 5.57 | 0.92 | 2.28 | 0.66 |
| | Branice | 6.50 | 75.36 | 12.41 | 4.27 | 1.33 | 1.64 | 1.12 | 2.57 | 0.89 |
| | Odonów | 7.00 | 78.29 | 8.30 | 2.45 | 1.56 | 5.51 | 1.01 | 2.26 | 0.68 |
| | Strzyżów | 7.50 | 78.69 | 7.39 | 2.10 | 1.59 | 6.54 | 0.95 | 2.21 | 0.63 |
| AVERAGE | Biały Kościół | 6.16 | 77.75 | 9.58 | 3.01 | 1.30 | 3.97 | 1.12 | 2.37 | 0.75 |
| | Złota | 6.02 | 79.38 | 8.29 | 2.42 | 1.40 | 4.34 | 1.13 | 2.20 | 0.69 |
| | Tyszowce | 6.99 | 79.06 | 7.63 | 2.20 | 1.32 | 5.80 | 0.99 | 2.21 | 0.65 |
| | Zaprężyn | 6.50 | 79.74 | 7.35 | 2.22 | 1.37 | 5.37 | 0.91 | 2.25 | 0.66 |
| | Branice | 6.78 | 75.27 | 12.35 | 4.30 | 1.30 | 2.08 | 1.10 | 2.53 | 0.90 |
| | Odonów | 7.04 | 78.18 | 8.19 | 2.43 | 1.52 | 5.57 | 1.02 | 2.26 | 0.69 |
| | Strzyżów | 7.27 | 78.94 | 7.41 | 2.10 | 1.51 | 6.10 | 0.96 | 2.20 | 0.65 |
| MINIMUM | Biały Kościół | 5.20 | 73.97 | 8.60 | 2.65 | 1.10 | 2.76 | 1.03 | 2.21 | 0.69 |
| | Złota | 5.20 | 76.55 | 7.40 | 2.20 | 1.21 | 3.67 | 1.08 | 2.07 | 0.66 |
| | Tyszowce | 5.60 | 75.62 | 5.90 | 1.41 | 0.87 | 2.01 | 0.84 | 1.81 | 0.55 |
| | Zaprężyn | 5.50 | 78.51 | 7.21 | 2.14 | 1.12 | 4.29 | 0.90 | 2.15 | 0.66 |
| | Branice | 6.30 | 74.37 | 11.92 | 3.79 | 1.01 | 0.85 | 0.98 | 2.32 | 0.87 |
| | Odonów | 6.80 | 77.53 | 7.69 | 2.28 | 1.27 | 5.35 | 0.97 | 2.18 | 0.67 |
| | Strzyżów | 6.10 | 77.83 | 7.22 | 1.98 | 1.22 | 4.81 | 0.94 | 2.11 | 0.62 |
| MAXIMUM | Biały Kościół | 8.50 | 79.26 | 10.49 | 3.48 | 1.94 | 6.35 | 1.16 | 2.62 | 0.80 |
| | Złota | 7.50 | 80.99 | 10.02 | 3.18 | 1.88 | 5.61 | 1.19 | 2.39 | 0.76 |
| | Tyszowce | 8.80 | 82.65 | 10.00 | 3.16 | 1.81 | 8.54 | 1.08 | 2.53 | 0.76 |
| | Zaprężyn | 7.30 | 81.36 | 7.42 | 2.30 | 1.52 | 6.24 | 0.92 | 2.31 | 0.67 |
| | Branice | 7.50 | 76.50 | 12.65 | 4.70 | 1.51 | 3.34 | 1.16 | 2.65 | 0.96 |
| | Odonów | 7.40 | 78.59 | 8.41 | 2.52 | 1.67 | 5.80 | 1.07 | 2.32 | 0.70 |
| | Strzyżów | 7.90 | 80.68 | 7.63 | 2.27 | 1.72 | 6.84 | 1.00 | 2.27 | 0.70 |
| STANDARD DEV. | Biały Kościół | 0.72 | 1.33 | 0.59 | 0.26 | 0.17 | 0.79 | 0.03 | 0.12 | 0.03 |
| | Złota | 0.71 | 1.31 | 0.67 | 0.24 | 0.18 | 0.57 | 0.03 | 0.07 | 0.03 |
| | Tyszowce | 0.84 | 1.83 | 0.94 | 0.38 | 0.23 | 1.14 | 0.06 | 0.16 | 0.04 |
| | Zaprężyn | 0.75 | 1.19 | 0.10 | 0.07 | 0.18 | 0.81 | 0.01 | 0.07 | 0.01 |
| | Branice | 0.45 | 0.73 | 0.27 | 0.33 | 0.16 | 1.02 | 0.06 | 0.12 | 0.04 |
| | Odonów | 0.21 | 0.39 | 0.26 | 0.08 | 0.14 | 0.19 | 0.03 | 0.06 | 0.01 |
| | Strzyżów | 0.66 | 1.02 | 0.14 | 0.10 | 0.20 | 0.81 | 0.02 | 0.05 | 0.03 |
| MEDIAN | POLAND (n=89**) | 6.50 | 78.64 | 8.19 | 2.41 | 1.32 | 4.81 | 1.07 | 2.25 | 0.68 |
| AVERAGE | | 6.60 | 78.60 | 8.46 | 2.54 | 1.36 | 4.88 | 1.05 | 2.27 | 0.70 |
| MINIMUM | | 5.20 | 73.97 | 5.90 | 1.41 | 0.87 | 0.85 | 0.84 | 1.81 | 0.55 |
| MAXIMUM | | 8.80 | 82.65 | 12.65 | 4.70 | 1.94 | 8.54 | 1.19 | 2.65 | 0.96 |
| STANDARD DEV. | | 0.86 | 1.78 | 1.41 | 0.61 | 0.21 | 1.38 | 0.09 | 0.15 | 0.07 |

*Implications of the geochemistry of L1LL1 (MIS2) loess in Poland for paleoenvironment and new normalizing values for loess-focused multi-elem

**The number of samples for Ni and W is lower (n = 33 and 88, respectively).
The color scale was developed using the Conditional Formatting function of MS Excel - the red-yellow-green color scale indicates the position of a

## Table S4. P-values of Shapiro-Wilk and Kruskal-Wallis tests for Polish loess.

| Test | Research Site | LOI | OXIDES OF MAJOR ELEMENTS (P-values) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | CaO | $Na_2O$ | $K_2O$ | $TiO_2$ |
| SHAPIRO-WILK* | Biały Kościół (n=19) | 0.0086 | 0.01944 | 0.07583 | 0.07556 | 0.00015 | 0.04779 | 0.08360 | 0.31756 | 0.85000 |
| | Złota (n=19***) | 0.0042 | 0.00317 | 0.00635 | 0.00032 | 0.00340 | 0.01091 | 0.66501 | 0.26247 | 0.20185 |
| | Tyszowce (n=32***) | 0.5611 | 0.74385 | 0.23784 | 0.34668 | 0.58346 | 0.07445 | 0.17621 | 0.98553 | 0.27104 |
| KRUSKAL-WALLIS** | Main Sites**** | | 0.00480 | 0.00000 | 0.00000 | 0.25320 | 0.00000 | 0.00000 | 0.00010 | 0.00000 |

*P-values above 0.05 (marked in black) mean that the given variable has a distribution close to normal in a given main research site.
**P-values below 0.05 (marked in red) mean that at least one main research site differs significantly from the others in terms of the median of th
***Except the Ni (n = 15 in Biały Kościół, n = 8 in Złota, and n=1 in Tyszowce), and W (n=31 in Tyszowce).
****Main Sites i.e. Biały Kościół, Złota and Tyszowce. In the remaining research sites, the number of samples was less than the minimum require

asis. Total iron is expressed as $Fe_2O_3$. Trace elements and REE are in ppm. The granulometric composition and the values

| | | TRACE ELEMENTS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $P_2O_5$ | MnO | Cr | Ba | Ni | Sc | Co | Cs | Ga | Hf | Nb | Rb | Sr | Ta |
| 0.10 | 0.05 | 61.58 | 364.00 | <20 | 7.00 | 5.70 | 3.10 | 8.00 | 14.30 | 13.00 | 70.50 | 133.40 | 0.90 |
| 0.09 | 0.05 | 68.42 | 386.00 | 22.00 | 7.00 | 6.90 | 3.30 | 9.60 | 14.50 | 12.90 | 72.80 | 116.90 | 1.00 |
| 0.10 | 0.04 | 75.27 | 365.00 | <20 | 7.00 | 7.40 | 3.10 | 9.50 | 15.40 | 13.70 | 75.20 | 119.10 | 1.10 |
| 0.08 | 0.05 | 68.42 | 385.00 | 27.00 | 7.00 | 8.00 | 3.20 | 9.30 | 16.30 | 15.00 | 77.90 | 116.40 | 1.00 |
| 0.10 | 0.04 | 75.27 | 368.00 | 23.00 | 7.00 | 7.00 | 3.20 | 8.80 | 15.40 | 13.90 | 72.30 | 121.60 | 1.00 |
| 0.09 | 0.04 | 68.42 | 366.00 | <20 | 7.00 | 6.20 | 3.10 | 8.70 | 14.80 | 13.80 | 73.70 | 134.90 | 1.00 |
| 0.09 | 0.05 | 68.42 | 391.00 | 21.00 | 7.00 | 6.70 | 2.90 | 9.30 | 13.80 | 13.40 | 75.90 | 127.90 | 1.00 |
| 0.08 | 0.05 | 68.42 | 389.00 | 22.00 | 7.00 | 7.40 | 3.10 | 9.20 | 14.20 | 14.10 | 76.20 | 124.20 | 1.00 |
| 0.10 | 0.04 | 68.42 | 393.00 | 21.00 | 7.00 | 6.30 | 3.00 | 8.90 | 14.30 | 13.40 | 74.60 | 120.80 | 1.00 |
| 0.10 | 0.04 | 68.42 | 386.00 | <20 | 7.00 | 6.60 | 3.00 | 8.70 | 14.20 | 14.00 | 75.90 | 131.70 | 0.90 |
| 0.09 | 0.05 | 75.27 | 427.00 | 22.00 | 7.00 | 7.60 | 3.70 | 9.80 | 14.30 | 15.10 | 78.70 | 125.20 | 0.90 |
| 0.07 | 0.05 | 75.27 | 436.00 | 23.00 | 8.00 | 7.70 | 3.60 | 10.10 | 14.20 | 13.60 | 86.40 | 110.50 | 0.90 |
| 0.10 | 0.05 | 68.42 | 438.00 | 21.00 | 8.00 | 7.90 | 3.40 | 10.90 | 13.50 | 14.60 | 88.10 | 123.20 | 1.20 |
| 0.10 | 0.05 | 61.58 | 447.00 | 21.00 | 8.00 | 8.00 | 3.30 | 10.40 | 11.80 | 14.30 | 83.50 | 137.20 | 0.90 |
| 0.11 | 0.05 | 75.27 | 438.00 | 26.00 | 8.00 | 9.10 | 3.60 | 11.00 | 14.00 | 14.70 | 88.40 | 109.50 | 1.00 |
| 0.10 | 0.05 | 82.11 | 407.00 | 27.00 | 8.00 | 8.90 | 4.10 | 10.90 | 14.10 | 14.20 | 86.90 | 116.50 | 1.00 |
| 0.10 | 0.04 | 75.27 | 406.00 | 25.00 | 8.00 | 8.20 | 3.60 | 10.10 | 13.30 | 16.20 | 81.30 | 120.30 | 1.10 |
| 0.10 | 0.05 | 75.27 | 417.00 | 21.00 | 8.00 | 8.50 | 4.10 | 10.90 | 12.40 | 13.90 | 86.70 | 122.90 | 0.80 |
| 0.10 | 0.05 | 75.27 | 425.00 | 22.00 | 8.00 | 7.90 | 4.00 | 10.20 | 12.50 | 13.80 | 88.70 | 122.10 | 1.00 |
| 0.10 | 0.04 | 61.58 | 367.00 | <20 | 6.00 | 4.70 | 1.70 | 6.20 | 14.40 | 12.10 | 63.80 | 114.20 | 0.80 |
| 0.09 | 0.04 | 68.42 | 369.00 | <20 | 6.00 | 4.70 | 1.90 | 7.20 | 15.60 | 12.20 | 64.80 | 111.30 | 1.20 |
| 0.08 | 0.04 | 61.58 | 372.00 | 21.00 | 6.00 | 4.60 | 1.90 | 6.40 | 18.00 | 12.60 | 65.10 | 109.60 | 1.00 |
| 0.10 | 0.06 | 88.95 | 420.00 | 33.00 | 10.00 | 10.00 | 4.40 | 12.40 | 12.00 | 15.00 | 92.10 | 109.20 | 1.10 |
| 0.10 | 0.06 | 82.11 | 425.00 | 30.00 | 10.00 | 10.60 | 4.20 | 11.50 | 10.70 | 15.20 | 94.00 | 108.80 | 1.30 |
| 0.10 | 0.06 | 88.95 | 453.00 | 26.00 | 11.00 | 10.30 | 4.30 | 12.20 | 11.10 | 15.30 | 93.30 | 98.50 | 1.20 |
| 0.13 | 0.09 | 95.79 | 473.00 | 31.00 | 11.00 | 10.70 | 4.90 | 12.20 | 12.00 | 16.10 | 96.80 | 104.30 | 1.20 |
| 0.11 | 0.03 | 95.79 | 463.00 | 31.00 | 11.00 | 8.10 | 4.90 | 12.90 | 13.20 | 17.50 | 100.70 | 87.30 | 1.50 |
| 0.09 | 0.04 | 68.42 | 377.00 | 25.00 | 6.00 | 6.20 | 2.70 | 8.00 | 15.60 | 13.00 | 70.30 | 122.90 | 1.00 |
| 0.09 | 0.04 | 68.42 | 383.00 | <20 | 6.00 | 5.60 | 2.30 | 7.20 | 15.80 | 12.50 | 67.00 | 129.80 | 0.90 |
| 0.09 | 0.05 | 75.27 | 376.00 | 22.00 | 6.00 | 6.40 | 2.20 | 8.00 | 15.00 | 12.80 | 70.10 | 128.90 | 0.90 |
| 0.10 | 0.05 | 75.27 | 379.00 | <20 | 7.00 | 6.20 | 2.50 | 8.70 | 13.90 | 13.10 | 70.00 | 130.50 | 0.90 |
| 0.11 | 0.05 | 75.27 | 375.00 | 21.00 | 7.00 | 6.40 | 2.50 | 8.20 | 15.20 | 12.40 | 70.50 | 131.20 | 1.00 |
| 0.10 | 0.04 | 68.42 | 337.00 | <20 | 6.00 | 5.50 | 2.10 | 6.00 | 16.30 | 13.00 | 67.00 | 122.30 | 0.90 |
| 0.10 | 0.04 | 61.58 | 353.00 | <20 | 6.00 | 6.50 | 2.20 | 6.00 | 15.70 | 13.70 | 67.50 | 126.30 | 1.00 |
| 0.11 | 0.05 | 68.42 | 349.00 | <20 | 6.00 | 4.90 | 2.30 | 6.50 | 15.50 | 17.60 | 68.80 | 129.20 | 0.80 |
| 0.10 | 0.04 | 68.42 | 351.00 | 22.00 | 6.00 | 5.40 | 2.40 | 6.50 | 15.50 | 11.80 | 70.90 | 123.90 | 1.00 |
| 0.10 | 0.05 | 61.58 | 366.00 | 23.00 | 7.00 | 6.30 | 2.60 | 6.80 | 15.90 | 12.90 | 71.10 | 123.90 | 1.10 |
| 0.11 | 0.04 | 61.58 | 348.00 | <20 | 6.00 | 5.20 | 2.40 | 6.60 | 15.30 | 11.40 | 69.20 | 125.40 | 0.90 |
| 0.11 | 0.05 | 61.58 | 371.00 | <20 | 7.00 | 5.80 | 2.20 | 7.20 | 14.40 | 12.40 | 72.20 | 135.40 | 1.00 |
| 0.08 | 0.04 | 68.42 | 349.00 | <20 | 6.00 | 4.80 | 2.60 | 6.80 | 16.70 | 12.10 | 67.20 | 124.60 | 0.90 |
| 0.10 | 0.04 | 68.42 | 349.00 | 21.00 | 6.00 | 5.10 | 2.20 | 6.50 | 16.20 | 12.60 | 66.80 | 134.20 | 0.80 |
| 0.11 | 0.05 | 68.42 | 360.00 | 22.00 | 6.00 | 5.90 | 2.30 | 6.60 | 15.40 | 12.80 | 71.90 | 125.80 | 1.00 |
| 0.11 | 0.04 | 82.11 | 345.00 | <20 | 7.00 | 5.30 | 2.40 | 6.10 | 15.50 | 13.50 | 69.60 | 125.70 | 0.90 |
| 0.08 | 0.04 | 61.58 | 355.00 | 38.00 | 6.00 | 6.10 | 2.20 | 10.40 | 15.60 | 13.00 | 66.80 | 128.10 | 0.80 |
| 0.11 | 0.04 | 68.42 | 366.00 | 21.00 | 7.00 | 5.50 | 2.60 | 7.50 | 14.70 | 11.80 | 75.40 | 125.80 | 1.10 |
| 0.10 | 0.04 | 68.42 | 348.00 | <20 | 6.00 | 5.60 | 2.50 | 11.10 | 14.80 | 13.30 | 68.50 | 120.60 | 0.90 |
| 0.08 | 0.04 | 68.42 | 336.00 | <20 | 6.00 | 5.40 | 2.60 | 9.30 | 15.50 | 14.80 | 67.20 | 123.40 | 0.80 |
| 0.10 | 0.06 | 61.58 | 342.00 | <20 | 7.00 | 6.60 | 2.60 | 8.70 | 12.60 | 20.20 | 69.90 | 137.10 | 0.80 |
| 0.11 | 0.05 | 68.42 | 363.00 | <20 | 7.00 | 6.60 | 2.80 | 8.70 | 12.80 | 13.70 | 74.70 | 125.90 | 0.90 |
| 0.10 | 0.04 | 82.11 | 352.00 | 22.00 | 8.00 | 8.50 | 3.10 | 9.40 | 12.50 | 21.50 | 77.90 | 131.00 | 1.00 |
| 0.09 | 0.05 | 68.42 | 362.00 | 24.00 | 7.00 | 9.20 | 3.00 | 8.20 | 13.20 | 13.90 | 75.60 | 119.00 | 1.00 |
| 0.15 | 0.03 | 54.74 | 314.00 | <20 | 5.00 | 4.00 | 1.60 | 5.80 | 14.60 | 10.00 | 56.40 | 182.80 | 0.80 |
| 0.07 | 0.04 | 41.05 | 296.00 | <20 | 5.00 | 3.80 | 1.50 | 5.40 | 14.80 | 9.20 | 54.20 | 144.90 | 0.70 |
| 0.10 | 0.04 | 47.90 | 302.00 | <20 | 5.00 | 4.00 | 1.70 | 4.80 | 14.90 | 9.10 | 53.80 | 174.80 | 0.60 |
| 0.09 | 0.05 | 54.74 | 284.00 | <20 | 5.00 | 4.00 | 1.40 | 4.50 | 18.60 | 10.50 | 51.50 | 140.90 | 0.70 |
| 0.07 | 0.03 | 54.74 | 267.00 | <20 | 4.00 | 2.60 | 1.30 | 4.10 | 18.60 | 9.60 | 48.20 | 169.10 | 0.70 |
| 0.09 | 0.04 | 54.74 | 300.00 | <20 | 5.00 | 5.10 | 1.40 | 7.60 | 13.10 | 10.30 | 55.30 | 172.10 | 0.60 |
| 0.11 | 0.04 | 61.58 | 309.00 | <20 | 5.00 | 4.90 | 1.40 | 7.00 | 16.90 | 10.80 | 52.90 | 131.10 | 0.90 |
| 0.09 | 0.04 | 54.74 | 310.00 | <20 | 5.00 | 4.10 | 1.50 | 5.70 | 15.10 | 10.80 | 56.90 | 160.40 | 1.10 |
| 0.10 | 0.04 | 54.74 | 303.00 | <20 | 5.00 | 4.10 | 1.40 | 6.20 | 16.20 | 10.50 | 57.60 | 150.90 | 0.70 |
| 0.09 | 0.03 | 47.90 | 315.00 | <20 | 5.00 | 3.90 | 1.80 | 5.70 | 15.40 | 8.80 | 58.50 | 171.60 | 0.70 |
| 0.09 | 0.04 | 54.74 | 317.00 | <20 | 5.00 | 4.20 | 1.70 | 5.20 | 16.60 | 9.80 | 59.30 | 156.00 | 0.70 |
| 0.10 | 0.04 | 54.74 | 342.00 | <20 | 6.00 | 5.00 | 1.90 | 6.60 | 13.90 | 10.40 | 63.80 | 149.80 | 0.80 |
| 0.09 | 0.03 | 61.58 | 325.00 | <20 | 6.00 | 4.30 | 1.70 | 6.30 | 13.80 | 11.10 | 62.20 | 153.30 | 0.90 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.10 | 0.04 | 54.74 | 330.00 | <20 | 5.00 | 3.90 | 1.80 | 6.50 | 14.30 | 9.80 | 61.70 | 158.90 | 0.80 |
| 0.10 | 0.04 | 47.90 | 323.00 | <20 | 5.00 | 4.10 | 1.50 | 5.50 | 15.90 | 9.40 | 58.70 | 147.70 | 0.70 |
| 0.09 | 0.04 | 54.74 | 329.00 | <20 | 5.00 | 4.20 | 1.60 | 6.00 | 16.00 | 11.70 | 59.10 | 153.90 | 0.80 |
| 0.10 | 0.04 | 61.58 | 323.00 | <20 | 6.00 | 4.00 | 1.70 | 5.90 | 14.60 | 10.60 | 61.20 | 156.90 | 0.80 |
| 0.10 | 0.04 | 54.74 | 328.00 | <20 | 5.00 | 3.90 | 2.10 | 6.10 | 15.50 | 10.40 | 59.10 | 159.30 | 1.00 |
| 0.11 | 0.05 | 47.90 | 328.00 | <20 | 6.00 | 4.50 | 1.90 | 6.20 | 13.80 | 9.50 | 61.40 | 169.20 | 0.60 |
| 0.10 | 0.04 | 61.58 | 332.00 | <20 | 6.00 | 4.60 | 2.10 | 6.50 | 15.50 | 10.90 | 63.00 | 163.70 | 0.80 |
| 0.10 | 0.04 | 54.74 | 353.00 | <20 | 6.00 | 5.10 | 2.40 | 7.20 | 11.50 | 10.20 | 69.40 | 149.80 | 0.80 |
| 0.10 | 0.05 | 61.58 | 379.00 | <20 | 6.00 | 6.00 | 2.40 | 7.70 | 9.70 | 10.90 | 71.50 | 173.70 | 0.90 |
| 0.10 | 0.03 | 54.74 | 345.00 | <20 | 6.00 | 5.00 | 2.60 | 9.60 | 11.90 | 19.70 | 70.10 | 160.40 | 0.70 |
| 0.10 | 0.03 | 54.74 | 305.00 | <20 | 5.00 | 4.50 | 2.00 | 9.60 | 14.30 | 13.10 | 60.00 | 138.80 | 0.90 |
| 0.10 | 0.05 | 68.42 | 310.00 | <20 | 6.00 | 4.50 | 1.90 | 8.70 | 22.00 | 14.50 | 58.00 | 146.70 | 1.10 |
| 0.10 | 0.04 | 61.58 | 325.00 | <20 | 6.00 | 5.00 | 2.40 | 8.70 | 14.60 | 11.30 | 65.60 | 159.60 | 0.90 |
| 0.10 | 0.04 | 68.42 | 333.00 | <20 | 6.00 | 5.80 | 2.50 | 8.70 | 14.60 | 13.90 | 66.70 | 153.60 | 1.00 |
| 0.10 | 0.04 | 61.58 | 339.00 | <20 | 7.00 | 5.70 | 2.40 | 8.30 | 13.00 | 12.60 | 68.20 | 150.00 | 0.90 |
| 0.10 | 0.04 | 61.58 | 335.00 | <20 | 6.00 | 5.50 | 2.40 | 8.10 | 14.60 | 12.10 | 68.00 | 152.10 | 1.00 |
| 0.12 | 0.04 | 61.58 | 353.00 | <20 | 7.00 | 4.90 | 2.20 | 7.90 | 11.20 | 11.70 | 71.50 | 157.50 | 0.90 |
| 0.12 | 0.05 | 68.42 | 337.00 | <20 | 7.00 | 5.90 | 2.70 | 7.90 | 11.60 | 12.70 | 73.80 | 160.00 | 1.00 |
| 0.10 | 0.10 | 68.42 | 381.00 | 23.00 | 8.00 | 8.80 | 2.90 | 9.60 | 12.00 | 11.40 | 76.30 | 123.50 | 1.20 |
| 0.07 | 0.03 | 61.58 | 373.00 | <20 | 6.00 | 4.70 | 1.90 | 7.60 | 16.10 | 12.40 | 65.30 | 139.30 | 0.90 |
| 0.09 | 0.04 | 61.58 | 373.00 | <20 | 6.00 | 4.30 | 1.70 | 6.30 | 15.60 | 11.60 | 64.60 | 146.20 | 0.80 |
| 0.10 | 0.04 | 54.74 | 370.00 | <20 | 5.00 | 4.90 | 1.70 | 6.10 | 17.00 | 11.60 | 64.80 | 145.10 | 0.90 |
| 0.09 | 0.04 | 61.58 | 361.00 | <20 | 6.00 | 4.50 | 1.70 | 7.00 | 14.70 | 11.80 | 63.80 | 150.60 | 0.80 |
| 0.10 | 0.04 | 61.58 | 363.00 | <20 | 6.00 | 4.70 | 1.80 | 6.80 | 16.80 | 12.10 | 64.20 | 149.50 | 0.90 |
| 0.09 | 0.03 | 75.27 | 351.00 | <20 | 6.00 | 4.90 | 1.90 | 7.30 | 18.30 | 12.80 | 63.80 | 147.00 | 0.90 |

ental analyses

given value in the entire range of values in a given column, including all main and supplementary research sites (red = high values, green = low values)

a volatile-free basis. Total iron is expressed as $Fe_2O_3$. Trace elements and REE are in ppm. The granulometric compositi

| | | TRACE ELEMENTS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $P_2O_5$ | MnO | Cr | Ba | Ni | Sc | Co | Cs | Ga | Hf | Nb | Rb | Sr | Ta |
| 0.10 | 0.05 | 68.42 | 393.00 | 22.00 | 7.00 | 7.60 | 3.30 | 9.60 | 14.20 | 13.90 | 77.90 | 122.10 | 1.00 |
| 0.10 | 0.04 | 68.42 | 351.00 | 22.00 | 6.00 | 5.60 | 2.40 | 6.80 | 15.50 | 13.00 | 69.60 | 125.80 | 0.90 |
| 0.10 | 0.04 | 54.74 | 325.00 | 23.00 | 5.50 | 4.50 | 1.85 | 6.50 | 14.60 | 10.70 | 60.60 | 156.45 | 0.80 |
| 0.09 | 0.04 | 61.58 | 369.00 | 21.00 | 6.00 | 4.70 | 1.90 | 6.40 | 15.60 | 12.20 | 64.80 | 111.30 | 1.00 |
| 0.10 | 0.06 | 88.95 | 453.00 | 31.00 | 11.00 | 10.30 | 4.40 | 12.20 | 12.00 | 15.30 | 94.00 | 104.30 | 1.20 |
| 0.09 | 0.05 | 75.27 | 377.00 | 22.00 | 6.00 | 6.20 | 2.50 | 8.00 | 15.20 | 12.80 | 70.10 | 129.80 | 0.90 |
| 0.09 | 0.04 | 61.58 | 366.50 | N/D | 6.00 | 4.70 | 1.75 | 6.90 | 16.45 | 11.95 | 64.40 | 146.60 | 0.90 |
| 0.09 | 0.05 | 71.30 | 401.79 | 22.93 | 7.42 | 7.47 | 3.39 | 9.70 | 14.07 | 14.08 | 79.67 | 122.86 | 0.98 |
| 0.10 | 0.05 | 67.70 | 352.74 | 24.13 | 6.47 | 6.01 | 2.48 | 7.63 | 14.95 | 14.00 | 70.43 | 126.72 | 0.93 |
| 0.10 | 0.04 | 57.09 | 324.13 | 23.00 | 5.63 | 4.68 | 1.93 | 6.86 | 14.66 | 11.17 | 61.68 | 156.03 | 0.83 |
| 0.09 | 0.04 | 63.86 | 369.33 | 21.00 | 6.00 | 4.67 | 1.83 | 6.60 | 16.00 | 12.30 | 64.57 | 111.70 | 1.00 |
| 0.11 | 0.06 | 90.32 | 446.80 | 30.20 | 10.60 | 9.94 | 4.54 | 12.24 | 11.80 | 15.82 | 95.38 | 101.62 | 1.26 |
| 0.09 | 0.05 | 72.53 | 378.00 | 22.67 | 6.40 | 6.16 | 2.44 | 8.02 | 15.10 | 12.76 | 69.58 | 128.66 | 0.94 |
| 0.09 | 0.04 | 62.72 | 365.17 | N/D | 5.83 | 4.67 | 1.78 | 6.85 | 16.42 | 12.05 | 64.42 | 146.28 | 0.87 |
| 0.07 | 0.04 | 61.58 | 364.00 | 21.00 | 7.00 | 5.70 | 2.90 | 8.00 | 11.80 | 12.90 | 70.50 | 109.50 | 0.80 |
| 0.08 | 0.04 | 61.58 | 336.00 | 21.00 | 6.00 | 4.80 | 2.10 | 6.00 | 12.50 | 11.40 | 66.80 | 119.00 | 0.80 |
| 0.07 | 0.03 | 41.05 | 267.00 | 23.00 | 4.00 | 2.60 | 1.30 | 4.10 | 9.70 | 8.80 | 48.20 | 123.50 | 0.60 |
| 0.08 | 0.04 | 61.58 | 367.00 | 21.00 | 6.00 | 4.60 | 1.70 | 6.20 | 14.40 | 12.10 | 63.80 | 109.60 | 0.80 |
| 0.10 | 0.03 | 82.11 | 420.00 | 26.00 | 10.00 | 8.10 | 4.20 | 11.50 | 10.70 | 15.00 | 92.10 | 87.30 | 1.10 |
| 0.09 | 0.04 | 68.42 | 375.00 | 21.00 | 6.00 | 5.60 | 2.20 | 7.20 | 13.90 | 12.40 | 67.00 | 122.90 | 0.90 |
| 0.07 | 0.03 | 54.74 | 351.00 | 0.00 | 5.00 | 4.30 | 1.70 | 6.10 | 14.70 | 11.60 | 63.80 | 139.30 | 0.80 |
| 0.11 | 0.05 | 82.11 | 447.00 | 27.00 | 8.00 | 9.10 | 4.10 | 11.00 | 16.30 | 16.20 | 88.70 | 137.20 | 1.20 |
| 0.11 | 0.06 | 82.11 | 371.00 | 38.00 | 8.00 | 9.20 | 3.10 | 11.10 | 16.70 | 21.50 | 77.90 | 137.10 | 1.10 |
| 0.15 | 0.10 | 68.42 | 381.00 | 23.00 | 8.00 | 8.80 | 2.90 | 9.60 | 22.00 | 19.70 | 76.30 | 182.80 | 1.20 |
| 0.10 | 0.04 | 68.42 | 372.00 | 21.00 | 6.00 | 4.70 | 1.90 | 7.20 | 18.00 | 12.60 | 65.10 | 114.20 | 1.20 |
| 0.13 | 0.09 | 95.79 | 473.00 | 33.00 | 11.00 | 10.70 | 4.90 | 12.90 | 13.20 | 17.50 | 100.70 | 109.20 | 1.50 |
| 0.11 | 0.05 | 75.27 | 383.00 | 25.00 | 7.00 | 6.40 | 2.70 | 8.70 | 15.80 | 13.10 | 70.50 | 131.20 | 1.00 |
| 0.10 | 0.04 | 75.27 | 373.00 | 0.00 | 6.00 | 4.90 | 1.90 | 7.60 | 18.30 | 12.80 | 65.30 | 150.60 | 0.90 |
| 0.01 | 0.01 | 5.12 | 26.78 | 2.14 | 0.49 | 0.90 | 0.37 | 0.86 | 1.05 | 0.77 | 6.09 | 7.43 | 0.09 |
| 0.01 | 0.01 | 5.83 | 9.54 | 5.33 | 0.60 | 1.11 | 0.27 | 1.51 | 1.25 | 2.70 | 3.31 | 4.69 | 0.10 |
| 0.01 | 0.01 | 6.54 | 23.60 | 0.00 | 0.82 | 1.04 | 0.44 | 1.50 | 2.37 | 2.04 | 6.75 | 12.54 | 0.15 |
| 0.01 | 0.00 | 3.23 | 2.05 | 0.00 | 0.00 | 0.05 | 0.09 | 0.43 | 1.50 | 0.22 | 0.56 | 1.90 | 0.16 |
| 0.01 | 0.02 | 5.12 | 20.88 | 2.32 | 0.49 | 0.95 | 0.30 | 0.45 | 0.86 | 0.92 | 3.08 | 8.14 | 0.14 |
| 0.01 | 0.01 | 3.35 | 2.83 | 1.70 | 0.49 | 0.29 | 0.17 | 0.48 | 0.66 | 0.27 | 1.30 | 2.98 | 0.05 |
| 0.01 | 0.01 | 6.14 | 7.84 | N/D | 0.37 | 0.21 | 0.09 | 0.53 | 1.14 | 0.44 | 0.54 | 3.64 | 0.05 |
| 0.10 | 0.04 | 68.42 | 360.00 | 22.00 | 6.00 | 5.50 | 2.40 | 7.90 | 14.60 | 12.80 | 69.20 | 131.10 | 0.90 |
| 0.10 | 0.05 | 65.73 | 361.02 | 24.24 | 6.54 | 5.94 | 2.52 | 7.99 | 14.62 | 12.84 | 70.01 | 135.94 | 0.92 |
| 0.07 | 0.03 | 41.05 | 267.00 | 21.00 | 4.00 | 2.60 | 1.30 | 4.10 | 9.70 | 8.80 | 48.20 | 87.30 | 0.60 |
| 0.15 | 0.10 | 95.79 | 473.00 | 38.00 | 11.00 | 10.70 | 4.90 | 12.90 | 22.00 | 21.50 | 100.70 | 182.80 | 1.50 |
| 0.01 | 0.01 | 10.24 | 41.16 | 4.10 | 1.36 | 1.74 | 0.83 | 1.94 | 1.91 | 2.33 | 10.56 | 19.35 | 0.16 |

ental analyses

given value in the entire range of values in a given column, separately for each statistical indicator (red = high values, green = low values).

| | | TRACE ELEMENTS (P-values) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $P_2O_5$ | MnO | Cr | Ba | Ni | Sc | Co | Cs | Ga | Hf | Nb | Rb | Sr | Ta |
| 0.01258 | 0.00002 | 0.01060 | 0.13428 | 0.00379 | 0.00001 | 0.95570 | 0.04058 | 0.41560 | 0.40916 | 0.25792 | 0.03959 | 0.68093 | 0.02275 |
| 0.00935 | 0.00007 | 0.00012 | 0.61260 | 0.00008 | 0.00008 | 0.00145 | 0.10613 | 0.01536 | 0.01197 | 0.00018 | 0.04109 | 0.14643 | 0.02189 |
| 0.00002 | 0.00000 | 0.00682 | 0.59518 | N/D | 0.00023 | 0.00018 | 0.05876 | 0.26552 | 0.14154 | 0.00002 | 0.75142 | 0.78224 | 0.08105 |
| 0.14980 | 0.10130 | 0.00000 | 0.00000 | 0.83220 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.04610 | 0.00000 | 0.00000 | 0.00000 | 0.00050 |

e given chemical element or oxide.

d to carry out the tests under consideration.

s of geochemical parameters used in the paper* are also shown.

| | | | | | | | | | | | | | RARE EARTH ELEMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Th | U | V | W | Zr | Y | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb |
| 10.60 | 2.90 | 49.00 | 1.4 | 570.8 | 29.1 | 32.9 | 65.1 | 7.65 | 28 | 5.63 | 0.99 | 5.08 | 0.81 |
| 11.00 | 2.90 | 55.00 | 1.2 | 556.8 | 30.4 | 33.7 | 67.4 | 7.89 | 29.6 | 5.66 | 0.99 | 5.32 | 0.83 |
| 11.70 | 3.00 | 54.00 | 1.3 | 589.1 | 31.5 | 33.6 | 66.9 | 7.92 | 30.1 | 5.63 | 0.97 | 5.5 | 0.87 |
| 10.80 | 2.90 | 52.00 | 1.5 | 617.5 | 33.1 | 35.2 | 68.5 | 7.85 | 30.2 | 5.82 | 0.94 | 5.35 | 0.84 |
| 12.20 | 3.20 | 58.00 | 2.3 | 626.2 | 30.2 | 35.9 | 69.3 | 8.24 | 30.5 | 5.97 | 1.02 | 5.52 | 0.88 |
| 10.70 | 3.00 | 53.00 | 1.9 | 585.3 | 32.7 | 35.2 | 68.4 | 8.18 | 29.9 | 6.08 | 1 | 5.52 | 0.88 |
| 10.40 | 2.80 | 56.00 | 1.3 | 551.7 | 31.6 | 34 | 68.2 | 7.9 | 29.4 | 5.66 | 0.99 | 5.34 | 0.87 |
| 11.40 | 3.00 | 60.00 | 1.6 | 578.7 | 30.9 | 35.5 | 70.5 | 8.09 | 30.6 | 5.77 | 1.01 | 5.43 | 0.85 |
| 10.60 | 2.90 | 52.00 | 1.4 | 559.1 | 32.3 | 34.9 | 68.2 | 7.97 | 28.3 | 5.78 | 0.98 | 5.36 | 0.87 |
| 10.70 | 2.90 | 62.00 | 1.5 | 571.1 | 32.6 | 33.4 | 66.3 | 7.82 | 29.7 | 5.55 | 1.01 | 5.37 | 0.87 |
| 11.50 | 3.00 | 56.00 | 1.3 | 562.4 | 32.8 | 37.2 | 71.9 | 8.51 | 31.5 | 6.23 | 1.08 | 5.82 | 0.9 |
| 10.90 | 3.00 | 55.00 | 1.3 | 576.7 | 34.1 | 35.3 | 73 | 8.21 | 29.5 | 6.13 | 1.08 | 5.77 | 0.97 |
| 11.00 | 3.00 | 62.00 | 1.7 | 528.4 | 34.4 | 35.3 | 72.1 | 8.7 | 31.9 | 6.33 | 1.12 | 5.75 | 0.94 |
| 11.00 | 2.70 | 53.00 | 1.4 | 457.9 | 30.6 | 34.9 | 69.9 | 8.3 | 30.8 | 6.07 | 1.08 | 5.33 | 0.86 |
| 12.20 | 2.90 | 61.00 | 1.9 | 543 | 33.5 | 36.3 | 72.9 | 8.41 | 31.7 | 6.19 | 1.08 | 5.7 | 0.93 |
| 12.90 | 3.20 | 68.00 | 1.4 | 559 | 34.2 | 38.2 | 75 | 8.76 | 33.7 | 6.49 | 1.09 | 6.1 | 0.96 |
| 11.90 | 2.80 | 68.00 | 1.7 | 529.3 | 35.4 | 38 | 74.6 | 8.8 | 32.5 | 6.49 | 1.13 | 5.93 | 0.96 |
| 11.90 | 2.80 | 60.00 | 1.9 | 514.2 | 34.4 | 37.5 | 76.2 | 8.93 | 33.7 | 6.32 | 1.15 | 5.84 | 0.94 |
| 10.90 | 2.70 | 62.00 | 2 | 483 | 31.9 | 35.5 | 72.2 | 8.41 | 31.9 | 5.91 | 1.11 | 5.61 | 0.88 |
| 8.70 | 2.30 | 38.00 | 1.3 | 564.9 | 26.6 | 27 | 55 | 6.38 | 24.1 | 4.73 | 0.86 | 4.6 | 0.75 |
| 9.80 | 2.50 | 38.00 | 0.9 | 594.1 | 26.2 | 30.3 | 59.4 | 6.76 | 25.5 | 4.98 | 0.88 | 4.65 | 0.72 |
| 9.80 | 2.90 | 36.00 | 1.2 | 716.8 | 28 | 30.8 | 60.2 | 6.96 | 25.7 | 4.89 | 0.86 | 4.72 | 0.74 |
| 12.80 | 2.90 | 75.00 | 1.6 | 448 | 31.9 | 40.3 | 77.6 | 9.09 | 33.6 | 6.4 | 1.2 | 5.77 | 0.95 |
| 12.10 | 2.80 | 75.00 | 1.6 | 421.1 | 33.4 | 39.9 | 76.2 | 8.96 | 33.2 | 6.5 | 1.23 | 6.1 | 0.95 |
| 12.50 | 2.70 | 79.00 | 2 | 417 | 33.8 | 39.9 | 80.1 | 9.12 | 33 | 6.52 | 1.18 | 6.05 | 0.94 |
| 13.40 | 3.00 | 87.00 | 1.8 | 453.4 | 36.9 | 42.6 | 81.8 | 9.97 | 37.7 | 7.21 | 1.35 | 6.84 | 1.05 |
| 13.10 | 3.40 | 84.00 | 2.1 | 486.3 | 33.7 | 41.1 | 80.4 | 9.17 | 34 | 6.5 | 1.18 | 5.92 | 0.96 |
| 10.30 | 3.20 | 46.00 | 1.2 | 597.2 | 31.8 | 32 | 63.5 | 7.31 | 27.4 | 5.22 | 0.94 | 5.18 | 0.84 |
| 10.40 | 2.50 | 44.00 | 0.8 | 607.3 | 28.4 | 31.2 | 62.3 | 7.29 | 27.7 | 5.5 | 0.94 | 5 | 0.79 |
| 10.00 | 2.60 | 46.00 | 1.1 | 584.6 | 29.6 | 32.3 | 63.6 | 7.28 | 27.7 | 5.4 | 0.91 | 5.18 | 0.81 |
| 9.60 | 2.70 | 45.00 | 1.4 | 534.3 | 28.2 | 29.8 | 61.8 | 7.04 | 25.9 | 4.99 | 0.94 | 5 | 0.79 |
| 9.80 | 2.90 | 44.00 | 1.4 | 566.5 | 27.5 | 31.3 | 61.9 | 7.25 | 26.9 | 4.94 | 0.92 | 5 | 0.78 |
| 9.00 | 2.90 | 37.00 | 1.3 | 653.6 | 27.3 | 29.3 | 57.3 | 6.68 | 25.9 | 4.76 | 0.8 | 4.65 | 0.71 |
| 9.00 | 2.70 | 41.00 | 1.7 | 629.9 | 28.2 | 29.5 | 58.8 | 6.57 | 24.8 | 4.89 | 0.85 | 4.58 | 0.72 |
| 9.30 | 2.70 | 46.00 | 1.5 | 596.3 | 26.9 | 29.3 | 57.1 | 6.65 | 25 | 4.97 | 0.81 | 4.5 | 0.7 |
| 9.00 | 2.80 | 46.00 | 1.5 | 603.2 | 26.5 | 29 | 57.8 | 6.67 | 24.1 | 4.56 | 0.8 | 4.39 | 0.7 |
| 9.50 | 2.80 | 49.00 | 1.5 | 636.6 | 29.7 | 30.8 | 61.2 | 6.97 | 26.4 | 4.78 | 0.81 | 4.71 | 0.75 |
| 9.10 | 2.80 | 42.00 | 2 | 613.8 | 28.9 | 31.3 | 59.2 | 6.82 | 26.4 | 5.08 | 0.85 | 4.64 | 0.74 |
| 9.10 | 2.50 | 47.00 | 1.2 | 576.2 | 30.6 | 30.9 | 59.8 | 6.89 | 26.1 | 4.89 | 0.9 | 4.75 | 0.75 |
| 9.90 | 2.90 | 66.00 | 2.5 | 642.3 | 27.1 | 32 | 61.3 | 7.02 | 27.9 | 5.09 | 0.87 | 4.9 | 0.76 |
| 9.80 | 2.80 | 186.00 | 2.7 | 639.2 | 28.3 | 32.6 | 62.1 | 7.36 | 27.8 | 5.42 | 0.84 | 4.77 | 0.76 |
| 9.80 | 2.80 | 42.00 | 1.3 | 629.6 | 27.8 | 31 | 63.5 | 7.15 | 26.9 | 5.02 | 0.85 | 4.49 | 0.7 |
| 9.80 | 2.80 | 46.00 | 2 | 625.2 | 27.7 | 32.6 | 64.4 | 7.3 | 27.3 | 5.14 | 0.86 | 4.88 | 0.75 |
| 10.40 | 2.90 | 48.00 | 0.7 | 600.4 | 26.8 | 32.5 | 67.7 | 7.37 | 27.7 | 5.4 | 0.86 | 4.79 | 0.78 |
| 10.00 | 2.80 | 65.00 | 1.8 | 573.2 | 29.4 | 30 | 58.5 | 6.85 | 24.5 | 4.98 | 0.83 | 4.84 | 0.77 |
| 9.40 | 2.50 | 56.00 | 1.8 | 592.5 | 27.2 | 29.4 | 58.9 | 6.86 | 26.3 | 5.22 | 0.82 | 4.53 | 0.77 |
| 10.30 | 3.00 | 54.00 | 2.2 | 607.7 | 25.8 | 30.6 | 61.3 | 6.86 | 26.3 | 4.87 | 0.85 | 4.3 | 0.71 |
| 9.00 | 2.80 | 50.00 | 1.7 | 482.8 | 26.5 | 28.6 | 58.6 | 6.64 | 26.5 | 4.84 | 0.89 | 4.57 | 0.74 |
| 9.90 | 2.50 | 54.00 | 1.1 | 482.9 | 28.2 | 30.9 | 64.4 | 7.13 | 27.1 | 5.34 | 1.02 | 4.86 | 0.8 |
| 10.20 | 2.80 | 64.00 | 1.5 | 467 | 27.9 | 31.1 | 62.7 | 6.97 | 26.8 | 5.22 | 0.97 | 4.94 | 0.77 |
| 10.30 | 2.70 | 54.00 | 1.4 | 490.4 | 26.6 | 31.4 | 62.5 | 7.14 | 27.4 | 5.37 | 0.95 | 4.72 | 0.76 |
| 7.80 | 2.20 | 37.00 | 1.1 | 563.2 | 24.2 | 24 | 49.2 | 5.54 | 21.8 | 4.08 | 0.75 | 4.07 | 0.63 |
| 6.80 | 2.30 | 36.00 | 1.6 | 592.1 | 20.5 | 22.5 | 45.5 | 5.18 | 20 | 3.7 | 0.69 | 3.54 | 0.58 |
| 7.20 | 2.20 | 33.00 | 1.1 | 579.9 | 21 | 21.7 | 45.7 | 4.95 | 18 | 3.76 | 0.69 | 3.53 | 0.57 |
| 7.70 | 2.40 | 32.00 | 1.1 | 745.7 | 22.4 | 23.7 | 48.6 | 5.38 | 21.4 | 4.41 | 0.66 | 3.84 | 0.6 |
| 6.00 | 2.00 | 28.00 | 1.1 | 721.2 | 20.5 | 18.9 | 37.7 | 4.37 | 17 | 3.03 | 0.63 | 3.21 | 0.51 |
| 6.40 | 2.00 | 46.00 | 0.9 | 568.4 | 19.8 | 21.4 | 42.5 | 5.1 | 19.3 | 3.47 | 0.73 | 3.26 | 0.57 |
| 8.10 | 2.50 | 29.00 | <0.5 | 654.3 | 22.8 | 24.6 | 48.8 | 5.67 | 22 | 4.05 | 0.68 | 3.66 | 0.61 |
| 7.70 | 2.60 | 36.00 | 0.7 | 602.6 | 23.3 | 24.5 | 48.7 | 5.64 | 20.6 | 4.17 | 0.69 | 3.86 | 0.64 |
| 8.40 | 2.40 | 36.00 | 1 | 639.4 | 24.3 | 26 | 52.6 | 5.82 | 22.1 | 4.46 | 0.66 | 4.22 | 0.67 |
| 7.50 | 2.20 | 37.00 | 1.1 | 635.6 | 21.3 | 22.6 | 49.3 | 5.7 | 20.7 | 4.12 | 0.73 | 3.9 | 0.6 |
| 8.20 | 2.50 | 39.00 | 1.3 | 664.4 | 26.6 | 25.5 | 51.4 | 5.92 | 23.1 | 4.3 | 0.74 | 4.26 | 0.68 |
| 8.10 | 2.40 | 36.00 | 1.1 | 559.7 | 25.2 | 27.4 | 57.5 | 6.42 | 23.9 | 4.48 | 0.85 | 4.24 | 0.68 |
| 8.90 | 2.50 | 42.00 | 1.2 | 566.9 | 25.3 | 27.9 | 56.2 | 6.48 | 26 | 5.03 | 0.86 | 4.45 | 0.71 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8.70 | 2.50 | 39.00 | 0.9 | 554.6 | 25.7 | 26.3 | 53.1 | 6.32 | 23.4 | 4.67 | 0.77 | 4.24 | 0.71 |
| 8.50 | 2.40 | 36.00 | 0.9 | 609.6 | 25.9 | 25.2 | 50.3 | 5.83 | 22.4 | 4.31 | 0.74 | 4.14 | 0.67 |
| 8.70 | 2.60 | 37.00 | 1.2 | 644.3 | 25.5 | 26.6 | 52.7 | 6.33 | 23.5 | 4.88 | 0.81 | 4.57 | 0.73 |
| 8.40 | 2.60 | 40.00 | 1.6 | 580.8 | 26.8 | 25.8 | 53.4 | 6.09 | 23.6 | 4.71 | 0.75 | 4.35 | 0.69 |
| 7.70 | 2.30 | 40.00 | 1.6 | 573.3 | 24.7 | 24.9 | 51.4 | 5.89 | 22.8 | 4.28 | 0.76 | 4.14 | 0.67 |
| 8.60 | 2.30 | 42.00 | 1.2 | 558.3 | 26.1 | 26 | 52.7 | 6.17 | 24 | 4.9 | 0.83 | 4.64 | 0.71 |
| 8.70 | 2.30 | 41.00 | 1 | 592.8 | 26.5 | 27.9 | 57.8 | 6.5 | 25 | 4.75 | 0.9 | 4.5 | 0.72 |
| 8.00 | 2.20 | 41.00 | 1.1 | 456.1 | 24.8 | 25.7 | 52.4 | 5.85 | 23.1 | 4.62 | 0.85 | 4.18 | 0.68 |
| 8.00 | 2.40 | 53.00 | 1.8 | 371.9 | 26.7 | 26.8 | 55 | 6.31 | 25.2 | 4.42 | 0.85 | 4.42 | 0.71 |
| 8.70 | 2.40 | 48.00 | 1.3 | 444.1 | 25.6 | 26.3 | 53.1 | 6.2 | 23.7 | 4.64 | 0.85 | 4.3 | 0.68 |
| 8.80 | 2.60 | 45.00 | 10.8 | 580.3 | 24.2 | 27.2 | 52.7 | 6.27 | 23.2 | 4.37 | 0.78 | 4.09 | 0.67 |
| 9.80 | 3.10 | 43.00 | 1.2 | 844 | 29.2 | 31.4 | 63.3 | 7.12 | 26.9 | 5.23 | 0.83 | 4.65 | 0.78 |
| 9.10 | 2.50 | 45.00 | 1.7 | 563.8 | 28.7 | 28.9 | 57.7 | 6.56 | 24.4 | 4.81 | 0.89 | 4.69 | 0.74 |
| 8.80 | 2.70 | 48.00 | 1.4 | 540.1 | 28 | 29.5 | 59.7 | 6.74 | 25.2 | 4.85 | 0.88 | 4.42 | 0.71 |
| 8.30 | 2.60 | 47.00 | 1.7 | 519.6 | 25.5 | 27.8 | 56.9 | 6.71 | 24.6 | 4.86 | 0.86 | 4.41 | 0.72 |
| 9.40 | 2.40 | 45.00 | 1.1 | 547.4 | 26.5 | 28.9 | 59.7 | 6.64 | 25 | 5.01 | 0.9 | 4.41 | 0.73 |
| 8.70 | 2.00 | 51.00 | 1.4 | 439.2 | 25.6 | 28 | 56.5 | 6.41 | 24.9 | 4.63 | 0.82 | 4.56 | 0.7 |
| 8.80 | 2.70 | 56.00 | 1.4 | 447.6 | 25.9 | 28.3 | 58.2 | 6.67 | 25.4 | 5.28 | 0.86 | 4.53 | 0.74 |
| 10.10 | 2.40 | 66.00 | 1.6 | 468.8 | 27 | 31.5 | 63.2 | 6.78 | 26.8 | 5.05 | 0.91 | 4.7 | 0.75 |
| 9.00 | 2.60 | 40.00 | 0.9 | 633.9 | 28.3 | 28.4 | 58.5 | 6.74 | 25.5 | 4.83 | 0.89 | 4.57 | 0.77 |
| 9.50 | 2.30 | 41.00 | 0.8 | 606.6 | 25.2 | 29.1 | 58.5 | 6.83 | 25.6 | 4.79 | 0.88 | 4.57 | 0.73 |
| 8.90 | 2.60 | 34.00 | 1 | 649.3 | 27.9 | 31 | 59.8 | 6.88 | 25.8 | 5.14 | 0.89 | 4.81 | 0.78 |
| 9.00 | 2.80 | 39.00 | 0.7 | 566.1 | 27.7 | 28.5 | 58.3 | 6.68 | 25.4 | 4.75 | 0.88 | 4.62 | 0.76 |
| 9.40 | 2.70 | 40.00 | 1.4 | 662.7 | 30.5 | 31.1 | 61.8 | 7.13 | 26.9 | 5.02 | 0.91 | 5.02 | 0.82 |
| 10.00 | 3.00 | 44.00 | 1 | 708.3 | 30.5 | 32.7 | 62.1 | 7.34 | 27.2 | 5.4 | 0.92 | 5.01 | 0.82 |

**on and the values of geochemical parameters used in the paper* are also shown.**

| | | | | | | RARE EARTH ELEMENT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Th | U | V | W | Zr | Y | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb |
| 11.00 | 2.90 | 56.00 | 1.50 | 559.10 | 32.60 | 35.30 | 69.90 | 8.21 | 30.50 | 5.97 | 1.02 | 5.52 | 0.88 |
| 9.80 | 2.80 | 49.00 | 1.50 | 603.20 | 27.70 | 30.90 | 61.20 | 6.89 | 26.40 | 5.02 | 0.85 | 4.71 | 0.75 |
| 8.40 | 2.40 | 40.50 | 1.20 | 570.85 | 25.50 | 26.15 | 52.70 | 6.19 | 23.45 | 4.55 | 0.80 | 4.25 | 0.68 |
| 9.80 | 2.50 | 38.00 | 1.20 | 594.10 | 26.60 | 30.30 | 59.40 | 6.76 | 25.50 | 4.89 | 0.86 | 4.65 | 0.74 |
| 12.80 | 2.90 | 79.00 | 1.80 | 448.00 | 33.70 | 40.30 | 80.10 | 9.12 | 33.60 | 6.50 | 1.20 | 6.05 | 0.95 |
| 10.00 | 2.70 | 45.00 | 1.20 | 584.60 | 28.40 | 31.30 | 62.30 | 7.28 | 27.40 | 5.22 | 0.94 | 5.00 | 0.79 |
| 9.20 | 2.65 | 40.00 | 0.95 | 641.60 | 28.10 | 30.05 | 59.15 | 6.86 | 25.70 | 4.93 | 0.89 | 4.72 | 0.78 |
| 11.28 | 2.93 | 57.68 | 1.58 | 555.80 | 32.41 | 35.39 | 70.35 | 8.24 | 30.71 | 5.98 | 1.04 | 5.56 | 0.89 |
| 9.62 | 2.76 | 57.53 | 1.65 | 586.46 | 27.76 | 30.67 | 60.90 | 6.94 | 26.38 | 5.04 | 0.86 | 4.67 | 0.74 |
| 8.27 | 2.41 | 41.56 | 1.55 | 575.94 | 24.88 | 26.05 | 52.92 | 6.05 | 23.09 | 4.48 | 0.79 | 4.19 | 0.67 |
| 9.43 | 2.57 | 37.33 | 1.13 | 625.27 | 26.93 | 29.37 | 58.20 | 6.70 | 25.10 | 4.87 | 0.87 | 4.66 | 0.74 |
| 12.78 | 2.96 | 80.00 | 1.82 | 445.16 | 33.94 | 40.76 | 79.22 | 9.26 | 34.30 | 6.63 | 1.23 | 6.14 | 0.97 |
| 10.02 | 2.78 | 45.00 | 1.18 | 577.98 | 29.10 | 31.32 | 62.62 | 7.23 | 27.12 | 5.21 | 0.93 | 5.07 | 0.80 |
| 9.30 | 2.67 | 39.67 | 0.97 | 637.82 | 28.35 | 30.13 | 59.83 | 6.93 | 26.07 | 4.99 | 0.90 | 4.77 | 0.78 |
| 10.40 | 2.70 | 49.00 | 1.20 | 457.90 | 29.10 | 32.90 | 65.10 | 7.65 | 28.00 | 5.55 | 0.94 | 5.08 | 0.81 |
| 9.00 | 2.50 | 37.00 | 0.70 | 467.00 | 25.80 | 28.60 | 57.10 | 6.57 | 24.10 | 4.56 | 0.80 | 4.30 | 0.70 |
| 6.00 | 2.00 | 28.00 | 0.70 | 371.90 | 19.80 | 18.90 | 37.70 | 4.37 | 17.00 | 3.03 | 0.63 | 3.21 | 0.51 |
| 8.70 | 2.30 | 36.00 | 0.90 | 564.90 | 26.20 | 27.00 | 55.00 | 6.38 | 24.10 | 4.73 | 0.86 | 4.60 | 0.72 |
| 12.10 | 2.70 | 75.00 | 1.60 | 417.00 | 31.90 | 39.90 | 76.20 | 8.96 | 33.00 | 6.40 | 1.18 | 5.77 | 0.94 |
| 9.60 | 2.50 | 44.00 | 0.80 | 534.30 | 27.50 | 29.80 | 61.80 | 7.04 | 25.90 | 4.94 | 0.91 | 5.00 | 0.78 |
| 8.90 | 2.30 | 34.00 | 0.70 | 566.10 | 25.20 | 28.40 | 58.30 | 6.68 | 25.40 | 4.75 | 0.88 | 4.57 | 0.73 |
| 12.90 | 3.20 | 68.00 | 2.30 | 626.20 | 35.40 | 38.20 | 76.20 | 8.93 | 33.70 | 6.49 | 1.15 | 6.10 | 0.97 |
| 10.40 | 3.00 | 186.00 | 2.70 | 653.60 | 30.60 | 32.60 | 67.70 | 7.37 | 27.90 | 5.42 | 1.02 | 4.94 | 0.80 |
| 10.10 | 3.10 | 66.00 | 10.80 | 844.00 | 29.20 | 31.50 | 63.30 | 7.12 | 26.90 | 5.28 | 0.91 | 4.70 | 0.78 |
| 9.80 | 2.90 | 38.00 | 1.30 | 716.80 | 28.00 | 30.80 | 60.20 | 6.96 | 25.70 | 4.98 | 0.88 | 4.72 | 0.75 |
| 13.40 | 3.40 | 87.00 | 2.10 | 486.30 | 36.90 | 42.60 | 81.80 | 9.97 | 37.70 | 7.21 | 1.35 | 6.84 | 1.05 |
| 10.40 | 3.20 | 46.00 | 1.40 | 607.30 | 31.80 | 32.30 | 63.60 | 7.31 | 27.70 | 5.50 | 0.94 | 5.18 | 0.84 |
| 10.00 | 3.00 | 44.00 | 1.40 | 708.30 | 30.50 | 32.70 | 62.10 | 7.34 | 27.20 | 5.40 | 0.92 | 5.02 | 0.82 |
| 0.67 | 0.13 | 5.17 | 0.29 | 40.05 | 1.66 | 1.49 | 3.07 | 0.36 | 1.55 | 0.30 | 0.06 | 0.25 | 0.05 |
| 0.49 | 0.13 | 31.31 | 0.47 | 58.59 | 1.20 | 1.22 | 2.77 | 0.24 | 1.09 | 0.24 | 0.06 | 0.18 | 0.03 |
| 0.87 | 0.22 | 7.78 | 1.71 | 93.08 | 2.34 | 2.75 | 5.55 | 0.60 | 2.33 | 0.50 | 0.08 | 0.40 | 0.06 |
| 0.52 | 0.25 | 0.94 | 0.17 | 65.81 | 0.77 | 1.69 | 2.29 | 0.24 | 0.71 | 0.10 | 0.01 | 0.05 | 0.01 |
| 0.45 | 0.24 | 4.82 | 0.20 | 25.06 | 1.63 | 1.02 | 2.03 | 0.36 | 1.73 | 0.29 | 0.06 | 0.37 | 0.04 |
| 0.30 | 0.25 | 0.89 | 0.22 | 25.74 | 1.51 | 0.87 | 0.78 | 0.10 | 0.68 | 0.22 | 0.01 | 0.09 | 0.02 |
| 0.38 | 0.21 | 2.98 | 0.22 | 44.44 | 1.82 | 1.58 | 1.58 | 0.23 | 0.71 | 0.23 | 0.02 | 0.19 | 0.03 |
| 9.50 | 2.70 | 46.00 | 1.40 | 576.20 | 27.80 | 30.80 | 59.80 | 6.86 | 26.30 | 5.01 | 0.88 | 4.69 | 0.75 |
| 9.66 | 2.67 | 50.49 | 1.52 | 572.49 | 28.15 | 30.54 | 61.01 | 7.04 | 26.54 | 5.13 | 0.90 | 4.80 | 0.77 |
| 6.00 | 2.00 | 28.00 | 0.70 | 371.90 | 19.80 | 18.90 | 37.70 | 4.37 | 17.00 | 3.03 | 0.63 | 3.21 | 0.51 |
| 13.40 | 3.40 | 186.00 | 10.80 | 844.00 | 36.90 | 42.60 | 81.80 | 9.97 | 37.70 | 7.21 | 1.35 | 6.84 | 1.05 |
| 1.51 | 0.29 | 18.80 | 1.07 | 77.08 | 3.62 | 4.70 | 8.75 | 1.06 | 3.80 | 0.76 | 0.14 | 0.67 | 0.11 |

| | | | | | | RARE EARTH ELEMENTS (P-v | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Th | U | V | W | Zr | Y | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb |
| 0.07446 | 0.09598 | 0.33457 | 0.04953 | 0.45053 | 0.92746 | 0.38833 | 0.70633 | 0.42917 | 0.59829 | 0.23668 | 0.16196 | 0.57522 | 0.19261 |
| 0.04336 | 0.00790 | 0.00000 | 0.80090 | 0.00257 | 0.50836 | 0.27276 | 0.30440 | 0.32002 | 0.21634 | 0.69068 | 0.01125 | 0.70311 | 0.17342 |
| 0.26190 | 0.07430 | 0.11499 | 0.00000 | 0.16729 | 0.08796 | 0.83915 | 0.57709 | 0.25880 | 0.21729 | 0.16002 | 0.07652 | 0.01291 | 0.06209 |
| 0.00000 | 0.00000 | 0.00000 | 0.00090 | 0.07030 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |

| S | | | | | | GEOCHEMICAL INDICES | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dy | Ho | Er | Tm | Yb | Lu | CIA | Th/Sc | Zr/Sc | Th/U | Eu/Eu* | $La_N/Yb_N$ | $La_N/Sm_N$ | $Gd_N/Yb_N$ |
| 4.91 | 1.03 | 3.11 | 0.47 | 3.15 | 0.48 | 58.8 | 1.51 | 81.54 | 3.66 | 0.57 | 7.06 | 3.68 | 1.31 |
| 5.08 | 1.08 | 3.45 | 0.47 | 3.27 | 0.52 | 60.8 | 1.57 | 79.54 | 3.79 | 0.55 | 6.96 | 3.75 | 1.32 |
| 5.23 | 1.1 | 3.26 | 0.5 | 3.23 | 0.51 | 60.3 | 1.67 | 84.16 | 3.90 | 0.53 | 7.03 | 3.76 | 1.38 |
| 5.33 | 1.19 | 3.23 | 0.51 | 3.47 | 0.55 | 60.2 | 1.54 | 88.21 | 3.72 | 0.51 | 6.85 | 3.81 | 1.25 |
| 5.19 | 1.07 | 3.27 | 0.48 | 3.21 | 0.54 | 59.3 | 1.74 | 89.46 | 3.81 | 0.54 | 7.56 | 3.79 | 1.39 |
| 5.24 | 1.11 | 3.32 | 0.51 | 3.39 | 0.52 | 59.3 | 1.53 | 83.61 | 3.57 | 0.53 | 7.02 | 3.64 | 1.32 |
| 5.15 | 1.11 | 3.28 | 0.49 | 3.28 | 0.51 | 59.5 | 1.49 | 78.81 | 3.71 | 0.55 | 7.00 | 3.78 | 1.32 |
| 5.27 | 1.08 | 3.22 | 0.48 | 3.22 | 0.52 | 59.9 | 1.63 | 82.67 | 3.80 | 0.55 | 7.45 | 3.87 | 1.37 |
| 5.21 | 1.11 | 3.39 | 0.49 | 3.19 | 0.53 | 59.4 | 1.51 | 79.87 | 3.66 | 0.54 | 7.39 | 3.80 | 1.36 |
| 5.38 | 1.16 | 3.48 | 0.49 | 3.54 | 0.54 | 58.9 | 1.53 | 81.59 | 3.69 | 0.57 | 6.38 | 3.79 | 1.23 |
| 5.46 | 1.2 | 3.58 | 0.51 | 3.49 | 0.54 | 60.3 | 1.64 | 80.34 | 3.83 | 0.55 | 7.20 | 3.76 | 1.35 |
| 5.72 | 1.26 | 3.77 | 0.55 | 3.7 | 0.55 | 60.9 | 1.36 | 72.09 | 3.63 | 0.55 | 6.45 | 3.62 | 1.26 |
| 5.86 | 1.2 | 3.62 | 0.53 | 3.42 | 0.55 | 60.6 | 1.38 | 66.05 | 3.67 | 0.57 | 6.97 | 3.51 | 1.36 |
| 5.37 | 1.08 | 3.3 | 0.49 | 3.1 | 0.5 | 60.1 | 1.38 | 57.24 | 4.07 | 0.58 | 7.61 | 3.62 | 1.39 |
| 5.64 | 1.2 | 3.62 | 0.52 | 3.44 | 0.55 | 62.0 | 1.53 | 67.88 | 4.21 | 0.56 | 7.13 | 3.69 | 1.34 |
| 5.83 | 1.23 | 3.66 | 0.51 | 3.32 | 0.53 | 62.2 | 1.61 | 69.88 | 4.03 | 0.53 | 7.78 | 3.70 | 1.49 |
| 5.9 | 1.15 | 3.7 | 0.51 | 3.47 | 0.56 | 62.2 | 1.49 | 66.16 | 4.25 | 0.56 | 7.40 | 3.69 | 1.39 |
| 5.64 | 1.27 | 3.56 | 0.53 | 3.51 | 0.54 | 62.1 | 1.49 | 64.28 | 4.25 | 0.58 | 7.22 | 3.73 | 1.35 |
| 5.52 | 1.14 | 3.67 | 0.49 | 3.33 | 0.54 | 61.7 | 1.36 | 60.38 | 4.04 | 0.59 | 7.20 | 3.78 | 1.37 |
| 4.81 | 0.98 | 3.03 | 0.47 | 3.12 | 0.49 | 57.6 | 1.45 | 94.15 | 3.78 | 0.56 | 5.85 | 3.59 | 1.19 |
| 4.57 | 0.95 | 3.15 | 0.45 | 2.98 | 0.48 | 57.4 | 1.63 | 99.02 | 3.92 | 0.56 | 6.87 | 3.83 | 1.26 |
| 4.59 | 0.99 | 3.06 | 0.45 | 3.28 | 0.5 | 57.3 | 1.63 | 119.47 | 3.38 | 0.55 | 6.35 | 3.96 | 1.17 |
| 5.52 | 1.14 | 3.37 | 0.54 | 3.36 | 0.52 | 65.1 | 1.28 | 44.80 | 4.41 | 0.60 | 8.10 | 3.96 | 1.39 |
| 5.87 | 1.18 | 3.48 | 0.54 | 3.37 | 0.55 | 64.8 | 1.21 | 42.11 | 4.32 | 0.60 | 8.00 | 3.86 | 1.47 |
| 5.64 | 1.23 | 3.54 | 0.51 | 3.47 | 0.54 | 66.2 | 1.14 | 37.91 | 4.63 | 0.57 | 7.77 | 3.85 | 1.41 |
| 6.29 | 1.31 | 3.86 | 0.58 | 3.84 | 0.57 | 65.3 | 1.22 | 41.22 | 4.47 | 0.59 | 7.50 | 3.72 | 1.44 |
| 5.85 | 1.19 | 3.46 | 0.53 | 3.68 | 0.58 | 69.1 | 1.19 | 44.21 | 3.85 | 0.58 | 7.55 | 3.98 | 1.30 |
| 5.25 | 1.14 | 3.47 | 0.51 | 3.55 | 0.53 | 59.6 | 1.72 | 99.53 | 3.22 | 0.55 | 6.09 | 3.86 | 1.18 |
| 4.97 | 1.01 | 3.02 | 0.48 | 3.39 | 0.52 | 57.4 | 1.73 | 101.22 | 4.16 | 0.55 | 6.22 | 3.57 | 1.20 |
| 5.02 | 1.01 | 3.18 | 0.47 | 3.27 | 0.5 | 59.2 | 1.67 | 97.43 | 3.85 | 0.53 | 6.67 | 3.76 | 1.28 |
| 5.1 | 1.07 | 3.18 | 0.5 | 3.17 | 0.5 | 58.7 | 1.37 | 76.33 | 3.56 | 0.58 | 6.35 | 3.76 | 1.28 |
| 4.74 | 1 | 2.98 | 0.46 | 3.11 | 0.49 | 58.2 | 1.40 | 80.93 | 3.38 | 0.57 | 6.80 | 3.99 | 1.30 |
| 4.12 | 0.91 | 2.89 | 0.44 | 2.97 | 0.46 | 55.78 | 1.50 | 108.93 | 3.10 | 0.52 | 6.67 | 3.87 | 1.27 |
| 4.61 | 0.99 | 2.97 | 0.45 | 2.98 | 0.46 | 56.58 | 1.50 | 104.98 | 3.33 | 0.55 | 6.69 | 3.80 | 1.25 |
| 4.22 | 0.91 | 2.97 | 0.4 | 2.86 | 0.43 | 56.64 | 1.55 | 99.38 | 3.44 | 0.52 | 6.92 | 3.71 | 1.28 |
| 4.6 | 0.93 | 2.86 | 0.4 | 2.86 | 0.45 | 56.52 | 1.50 | 100.53 | 3.21 | 0.55 | 6.85 | 4.00 | 1.24 |
| 4.73 | 0.98 | 3.17 | 0.47 | 3.14 | 0.47 | 56.96 | 1.36 | 90.94 | 3.39 | 0.52 | 6.63 | 4.06 | 1.22 |
| 4.72 | 0.97 | 3.23 | 0.43 | 3.2 | 0.47 | 56.12 | 1.52 | 102.30 | 3.25 | 0.54 | 6.61 | 3.88 | 1.18 |
| 4.99 | 1.06 | 3.26 | 0.45 | 3.06 | 0.49 | 57.11 | 1.30 | 82.31 | 3.64 | 0.57 | 6.82 | 3.98 | 1.26 |
| 4.77 | 0.95 | 3.16 | 0.43 | 3.15 | 0.46 | 56.95 | 1.65 | 107.05 | 3.41 | 0.53 | 6.86 | 3.96 | 1.26 |
| 4.89 | 1 | 3.12 | 0.45 | 3.06 | 0.49 | 56.51 | 1.63 | 106.53 | 3.50 | 0.50 | 7.20 | 3.79 | 1.26 |
| 4.44 | 0.96 | 2.8 | 0.42 | 2.87 | 0.45 | 57.36 | 1.63 | 104.93 | 3.50 | 0.55 | 7.30 | 3.89 | 1.27 |
| 4.72 | 0.95 | 3.01 | 0.41 | 2.95 | 0.45 | 56.95 | 1.40 | 89.31 | 3.50 | 0.52 | 7.47 | 3.99 | 1.34 |
| 4.6 | 0.95 | 3.03 | 0.45 | 2.89 | 0.52 | 57.02 | 1.73 | 100.07 | 3.59 | 0.52 | 7.60 | 3.79 | 1.34 |
| 5.15 | 1.05 | 3.43 | 0.46 | 3.26 | 0.5 | 57.51 | 1.43 | 81.89 | 3.57 | 0.52 | 6.22 | 3.79 | 1.20 |
| 4.51 | 1 | 2.9 | 0.43 | 2.96 | 0.46 | 57.69 | 1.57 | 98.75 | 3.76 | 0.52 | 6.71 | 3.55 | 1.24 |
| 4.42 | 0.95 | 2.89 | 0.42 | 2.84 | 0.49 | 57.53 | 1.72 | 101.28 | 3.43 | 0.57 | 7.28 | 3.95 | 1.23 |
| 4.49 | 1.03 | 2.87 | 0.43 | 2.93 | 0.47 | 58.52 | 1.29 | 68.97 | 3.21 | 0.58 | 6.60 | 3.72 | 1.26 |
| 4.92 | 1.08 | 3.18 | 0.47 | 3.05 | 0.48 | 59.57 | 1.41 | 68.99 | 3.96 | 0.61 | 6.85 | 3.64 | 1.29 |
| 4.72 | 1.01 | 3.14 | 0.47 | 3.17 | 0.49 | 61.89 | 1.28 | 58.38 | 3.64 | 0.58 | 6.63 | 3.75 | 1.26 |
| 4.91 | 0.93 | 3.19 | 0.46 | 2.96 | 0.44 | 60.76 | 1.47 | 70.06 | 3.81 | 0.58 | 7.17 | 3.68 | 1.29 |
| 3.97 | 0.86 | 2.74 | 0.38 | 2.56 | 0.42 | 58.0 | 1.56 | 112.64 | 3.55 | 0.56 | 6.34 | 3.70 | 1.29 |
| 3.69 | 0.78 | 2.4 | 0.36 | 2.47 | 0.38 | 56.6 | 1.36 | 118.42 | 2.96 | 0.58 | 6.16 | 3.83 | 1.16 |
| 3.4 | 0.75 | 2.46 | 0.34 | 2.46 | 0.41 | 56.6 | 1.44 | 115.98 | 3.27 | 0.58 | 5.96 | 3.63 | 1.16 |
| 3.64 | 0.79 | 2.52 | 0.37 | 2.7 | 0.45 | 55.9 | 1.54 | 149.14 | 3.21 | 0.49 | 5.93 | 3.38 | 1.15 |
| 3.05 | 0.7 | 2.24 | 0.34 | 2.33 | 0.37 | 55.5 | 1.50 | 180.30 | 3.00 | 0.62 | 5.48 | 3.93 | 1.12 |
| 3.63 | 0.75 | 2.41 | 0.34 | 2.45 | 0.38 | 53.6 | 1.28 | 113.68 | 3.20 | 0.66 | 5.90 | 3.88 | 1.08 |
| 3.92 | 0.81 | 2.4 | 0.37 | 2.73 | 0.44 | 55.2 | 1.62 | 130.86 | 3.24 | 0.54 | 6.09 | 3.82 | 1.09 |
| 3.89 | 0.81 | 2.75 | 0.39 | 2.69 | 0.43 | 56.3 | 1.54 | 120.52 | 2.96 | 0.53 | 6.15 | 3.70 | 1.16 |
| 3.84 | 0.88 | 2.67 | 0.41 | 2.97 | 0.43 | 56.2 | 1.68 | 127.88 | 3.50 | 0.46 | 5.92 | 3.67 | 1.15 |
| 3.9 | 0.8 | 2.43 | 0.39 | 2.54 | 0.42 | 56.9 | 1.50 | 127.12 | 3.41 | 0.56 | 6.01 | 3.45 | 1.24 |
| 4.2 | 0.92 | 2.94 | 0.43 | 3.04 | 0.49 | 56.3 | 1.64 | 132.88 | 3.28 | 0.53 | 5.67 | 3.73 | 1.14 |
| 4.28 | 0.93 | 2.8 | 0.39 | 2.78 | 0.44 | 56.9 | 1.35 | 93.28 | 3.38 | 0.60 | 6.66 | 3.85 | 1.24 |
| 4.07 | 0.85 | 2.89 | 0.41 | 2.78 | 0.45 | 57.3 | 1.48 | 94.48 | 3.56 | 0.56 | 6.78 | 3.49 | 1.30 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.42 | 0.88 | 2.94 | 0.42 | 2.81 | 0.47 | 57.2 | 1.74 | 110.92 | 3.48 | 0.53 | 6.32 | 3.54 | 1.22 |
| 4.44 | 0.91 | 2.83 | 0.41 | 2.95 | 0.46 | 56.1 | 1.70 | 121.92 | 3.54 | 0.54 | 5.77 | 3.68 | 1.14 |
| 4.09 | 0.97 | 2.95 | 0.44 | 3 | 0.48 | 56.7 | 1.74 | 128.86 | 3.35 | 0.52 | 5.99 | 3.43 | 1.23 |
| 4.51 | 0.94 | 3.23 | 0.47 | 3.08 | 0.48 | 56.9 | 1.40 | 96.80 | 3.23 | 0.51 | 5.66 | 3.45 | 1.14 |
| 3.97 | 0.91 | 2.69 | 0.41 | 2.98 | 0.45 | 56.6 | 1.54 | 114.66 | 3.35 | 0.55 | 5.65 | 3.66 | 1.13 |
| 4.4 | 0.89 | 2.88 | 0.42 | 2.79 | 0.44 | 56.7 | 1.43 | 93.05 | 3.74 | 0.53 | 6.30 | 3.34 | 1.35 |
| 4.3 | 0.95 | 2.85 | 0.44 | 3 | 0.46 | 57.5 | 1.45 | 98.80 | 3.78 | 0.59 | 6.28 | 3.70 | 1.22 |
| 4.23 | 0.82 | 2.84 | 0.43 | 2.85 | 0.41 | 58.2 | 1.33 | 76.02 | 3.64 | 0.59 | 6.09 | 3.50 | 1.19 |
| 4.18 | 0.92 | 2.77 | 0.41 | 2.67 | 0.42 | 60.0 | 1.33 | 61.98 | 3.33 | 0.59 | 6.78 | 3.82 | 1.34 |
| 4.17 | 0.91 | 2.88 | 0.44 | 2.82 | 0.47 | 58.7 | 1.45 | 74.02 | 3.63 | 0.58 | 6.30 | 3.57 | 1.24 |
| 3.89 | 0.84 | 2.76 | 0.41 | 2.65 | 0.45 | 56.6 | 1.76 | 116.06 | 3.38 | 0.56 | 6.94 | 3.92 | 1.25 |
| 5.03 | 1.05 | 3.18 | 0.49 | 3.46 | 0.56 | 56.7 | 1.63 | 140.67 | 3.16 | 0.51 | 6.13 | 3.78 | 1.09 |
| 4.67 | 1.01 | 3.18 | 0.45 | 3.29 | 0.46 | 58.6 | 1.52 | 93.97 | 3.64 | 0.57 | 5.94 | 3.78 | 1.16 |
| 4.48 | 0.9 | 2.94 | 0.44 | 3.1 | 0.47 | 58.7 | 1.47 | 90.02 | 3.26 | 0.58 | 6.43 | 3.83 | 1.16 |
| 4.68 | 0.95 | 3.05 | 0.42 | 3.24 | 0.47 | 58.9 | 1.19 | 74.23 | 3.19 | 0.57 | 5.80 | 3.60 | 1.10 |
| 4.46 | 0.9 | 2.91 | 0.43 | 2.73 | 0.47 | 58.5 | 1.57 | 91.23 | 3.92 | 0.59 | 7.15 | 3.63 | 1.31 |
| 4.37 | 0.94 | 2.85 | 0.41 | 2.82 | 0.45 | 59.0 | 1.24 | 62.74 | 4.35 | 0.55 | 6.71 | 3.81 | 1.31 |
| 4.24 | 0.92 | 2.88 | 0.44 | 2.79 | 0.45 | 60.0 | 1.26 | 63.94 | 3.26 | 0.54 | 6.85 | 3.37 | 1.32 |
| 4.47 | 1 | 2.82 | 0.45 | 3.03 | 0.46 | 62.0 | 1.26 | 58.60 | 4.21 | 0.57 | 7.03 | 3.93 | 1.26 |
| 4.42 | 1.01 | 3.06 | 0.48 | 3.13 | 0.49 | 57.3 | 1.50 | 105.65 | 3.46 | 0.58 | 6.13 | 3.70 | 1.18 |
| 4.49 | 0.91 | 3.01 | 0.44 | 3.02 | 0.48 | 56.9 | 1.58 | 101.10 | 4.13 | 0.57 | 6.51 | 3.82 | 1.23 |
| 4.68 | 1.02 | 3.15 | 0.46 | 2.98 | 0.51 | 56.9 | 1.78 | 129.86 | 3.42 | 0.55 | 7.03 | 3.80 | 1.31 |
| 4.55 | 1.01 | 3.11 | 0.45 | 3.15 | 0.48 | 57.0 | 1.50 | 94.35 | 3.21 | 0.57 | 6.11 | 3.78 | 1.19 |
| 5.07 | 1.08 | 3.4 | 0.52 | 3.55 | 0.53 | 57.3 | 1.57 | 110.45 | 3.48 | 0.55 | 5.92 | 3.90 | 1.15 |
| 5.04 | 1.08 | 3.21 | 0.5 | 3.49 | 0.53 | 57.8 | 1.67 | 118.05 | 3.33 | 0.54 | 6.33 | 3.81 | 1.16 |

| S | | | | | | GEOCHEMICAL INDICES | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dy | Ho | Er | Tm | Yb | Lu | CIA | Th/Sc | Zr/Sc | Th/U | Eu/Eu* | $La_N/Yb_N$ | $La_N/Sm_N$ | $Gd_N/Yb_N$ |
| 5.37 | 1.14 | 3.45 | 0.50 | 3.33 | 0.54 | 60.30 | 1.53 | 79.54 | 3.80 | 0.55 | 7.13 | 3.75 | 1.35 |
| 4.72 | 0.97 | 3.03 | 0.44 | 2.97 | 0.47 | 57.02 | 1.50 | 99.38 | 3.50 | 0.54 | 6.85 | 3.80 | 1.26 |
| 4.19 | 0.90 | 2.84 | 0.41 | 2.80 | 0.45 | 56.90 | 1.49 | 111.78 | 3.36 | 0.56 | 6.14 | 3.69 | 1.18 |
| 4.59 | 0.98 | 3.06 | 0.45 | 3.12 | 0.49 | 57.42 | 1.63 | 99.02 | 3.78 | 0.56 | 6.35 | 3.83 | 1.19 |
| 5.85 | 1.19 | 3.48 | 0.54 | 3.47 | 0.55 | 65.27 | 1.21 | 42.11 | 4.41 | 0.59 | 7.77 | 3.86 | 1.41 |
| 5.02 | 1.01 | 3.18 | 0.48 | 3.27 | 0.50 | 58.71 | 1.67 | 97.43 | 3.56 | 0.55 | 6.35 | 3.76 | 1.28 |
| 4.62 | 1.02 | 3.13 | 0.47 | 3.14 | 0.50 | 57.14 | 1.58 | 108.05 | 3.44 | 0.56 | 6.23 | 3.80 | 1.19 |
| 5.42 | 1.15 | 3.45 | 0.50 | 3.35 | 0.53 | 60.45 | 1.52 | 75.46 | 3.86 | 0.55 | 7.14 | 3.72 | 1.34 |
| 4.66 | 0.98 | 3.06 | 0.44 | 3.01 | 0.47 | 57.58 | 1.50 | 91.87 | 3.49 | 0.54 | 6.90 | 3.83 | 1.26 |
| 4.14 | 0.88 | 2.78 | 0.41 | 2.83 | 0.45 | 57.33 | 1.48 | 105.80 | 3.44 | 0.56 | 6.22 | 3.67 | 1.20 |
| 4.66 | 0.97 | 3.08 | 0.46 | 3.13 | 0.49 | 57.46 | 1.57 | 104.21 | 3.69 | 0.56 | 6.35 | 3.80 | 1.21 |
| 5.83 | 1.21 | 3.54 | 0.54 | 3.54 | 0.55 | 66.09 | 1.21 | 42.05 | 4.34 | 0.59 | 7.78 | 3.88 | 1.40 |
| 5.02 | 1.05 | 3.17 | 0.48 | 3.30 | 0.51 | 58.62 | 1.58 | 91.09 | 3.63 | 0.55 | 6.43 | 3.79 | 1.25 |
| 4.71 | 1.02 | 3.16 | 0.48 | 3.22 | 0.50 | 57.20 | 1.60 | 109.91 | 3.51 | 0.56 | 6.34 | 3.80 | 1.20 |
| 4.91 | 1.03 | 3.11 | 0.47 | 3.10 | 0.48 | 58.80 | 1.36 | 57.24 | 3.57 | 0.51 | 6.38 | 3.51 | 1.23 |
| 4.12 | 0.91 | 2.80 | 0.40 | 2.84 | 0.43 | 55.78 | 1.28 | 58.38 | 3.10 | 0.50 | 6.22 | 3.55 | 1.18 |
| 3.05 | 0.70 | 2.24 | 0.34 | 2.33 | 0.37 | 53.64 | 1.19 | 58.60 | 2.96 | 0.46 | 5.48 | 3.34 | 1.08 |
| 4.57 | 0.95 | 3.03 | 0.45 | 2.98 | 0.48 | 57.34 | 1.45 | 94.15 | 3.38 | 0.55 | 5.85 | 3.59 | 1.17 |
| 5.52 | 1.14 | 3.37 | 0.51 | 3.36 | 0.52 | 64.80 | 1.14 | 37.91 | 3.85 | 0.57 | 7.50 | 3.72 | 1.30 |
| 4.74 | 1.00 | 2.98 | 0.46 | 3.11 | 0.49 | 57.36 | 1.37 | 76.33 | 3.22 | 0.53 | 6.09 | 3.57 | 1.18 |
| 4.42 | 0.91 | 3.01 | 0.44 | 2.98 | 0.48 | 56.87 | 1.50 | 94.35 | 3.21 | 0.54 | 5.92 | 3.70 | 1.15 |
| 5.90 | 1.27 | 3.77 | 0.55 | 3.70 | 0.56 | 62.18 | 1.74 | 89.46 | 4.25 | 0.59 | 7.78 | 3.87 | 1.49 |
| 5.15 | 1.08 | 3.43 | 0.47 | 3.26 | 0.52 | 61.89 | 1.73 | 108.93 | 3.96 | 0.61 | 7.60 | 4.06 | 1.34 |
| 5.03 | 1.05 | 3.23 | 0.49 | 3.46 | 0.56 | 61.97 | 1.76 | 180.30 | 4.35 | 0.66 | 7.15 | 3.93 | 1.35 |
| 4.81 | 0.99 | 3.15 | 0.47 | 3.28 | 0.50 | 57.61 | 1.63 | 119.47 | 3.92 | 0.56 | 6.87 | 3.96 | 1.26 |
| 6.29 | 1.31 | 3.86 | 0.58 | 3.84 | 0.58 | 69.12 | 1.28 | 44.80 | 4.63 | 0.60 | 8.10 | 3.98 | 1.47 |
| 5.25 | 1.14 | 3.47 | 0.51 | 3.55 | 0.53 | 59.62 | 1.73 | 101.22 | 4.16 | 0.58 | 6.80 | 3.99 | 1.30 |
| 5.07 | 1.08 | 3.40 | 0.52 | 3.55 | 0.53 | 57.81 | 1.78 | 129.86 | 4.13 | 0.58 | 7.03 | 3.90 | 1.31 |
| 0.28 | 0.07 | 0.19 | 0.02 | 0.15 | 0.02 | 1.10 | 0.10 | 9.34 | 0.21 | 0.02 | 0.35 | 0.08 | 0.06 |
| 0.25 | 0.05 | 0.16 | 0.02 | 0.12 | 0.02 | 1.54 | 0.14 | 15.16 | 0.21 | 0.03 | 0.34 | 0.13 | 0.04 |
| 0.40 | 0.08 | 0.24 | 0.04 | 0.25 | 0.04 | 1.60 | 0.15 | 27.59 | 0.31 | 0.04 | 0.43 | 0.17 | 0.08 |
| 0.11 | 0.02 | 0.05 | 0.01 | 0.12 | 0.01 | 0.12 | 0.09 | 10.97 | 0.23 | 0.01 | 0.42 | 0.15 | 0.04 |
| 0.26 | 0.06 | 0.17 | 0.02 | 0.19 | 0.02 | 1.59 | 0.05 | 2.45 | 0.26 | 0.01 | 0.24 | 0.09 | 0.06 |
| 0.17 | 0.05 | 0.17 | 0.02 | 0.16 | 0.01 | 0.79 | 0.16 | 10.35 | 0.34 | 0.02 | 0.27 | 0.14 | 0.05 |
| 0.26 | 0.06 | 0.13 | 0.03 | 0.22 | 0.02 | 0.32 | 0.10 | 11.56 | 0.29 | 0.01 | 0.36 | 0.06 | 0.05 |
| 4.68 | 0.99 | 3.06 | 0.45 | 3.08 | 0.48 | 57.69 | 1.50 | 93.28 | 3.56 | 0.55 | 6.69 | 3.78 | 1.26 |
| 4.72 | 1.00 | 3.08 | 0.45 | 3.08 | 0.48 | 58.61 | 1.50 | 92.17 | 3.61 | 0.56 | 6.68 | 3.75 | 1.26 |
| 3.05 | 0.70 | 2.24 | 0.34 | 2.33 | 0.37 | 53.64 | 1.14 | 37.91 | 2.96 | 0.46 | 5.48 | 3.34 | 1.08 |
| 6.29 | 1.31 | 3.86 | 0.58 | 3.84 | 0.58 | 69.12 | 1.78 | 180.30 | 4.63 | 0.66 | 8.10 | 4.06 | 1.49 |
| 0.63 | 0.13 | 0.33 | 0.05 | 0.31 | 0.05 | 2.59 | 0.15 | 25.59 | 0.36 | 0.03 | 0.59 | 0.15 | 0.09 |

| alues) | | | | | |
|---|---|---|---|---|---|
| Dy | Ho | Er | Tm | Yb | Lu |
| 0.50371 | 0.44466 | 0.24411 | 0.35292 | 0.77842 | 0.15132 |
| 0.95296 | 0.37400 | 0.37796 | 0.22069 | 0.20239 | 0.70845 |
| 0.70890 | 0.81224 | 0.08915 | 0.25342 | 0.86275 | 0.04013 |
| 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |

| | | | | GRAIN-SIZE | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Ce/Ce* | ΣREE | ΣLREE | ΣHREE | < 4um | 4-8 um | 8-16 um | 16-31 um | 31-63 um | > 63 um |
| 1.00 | 159.31 | 140.27 | 19.04 | 9.17 | 7.73 | 11.11 | 25.76 | 34.34 | 11.89 |
| 1.00 | 165.26 | 145.24 | 20.02 | 11.18 | 9.15 | 13.15 | 24.49 | 28.86 | 13.17 |
| 0.99 | 165.32 | 145.12 | 20.20 | 10.68 | 8.67 | 13.18 | 26.56 | 30.80 | 10.12 |
| 0.98 | 168.98 | 148.51 | 20.47 | 10.59 | 8.87 | 12.26 | 24.01 | 31.35 | 12.92 |
| 0.98 | 171.09 | 150.93 | 20.16 | 9.22 | 7.55 | 11.16 | 26.20 | 34.08 | 11.79 |
| 0.99 | 169.25 | 148.76 | 20.49 | 9.48 | 7.54 | 12.31 | 29.07 | 32.93 | 8.67 |
| 1.01 | 166.18 | 146.15 | 20.03 | 9.98 | 7.69 | 12.75 | 29.59 | 32.19 | 7.80 |
| 1.00 | 171.54 | 151.47 | 20.07 | 10.20 | 8.89 | 13.42 | 26.81 | 30.77 | 9.91 |
| 1.01 | 166.28 | 146.13 | 20.15 | 9.63 | 7.66 | 11.91 | 27.71 | 32.86 | 10.22 |
| 0.99 | 164.61 | 143.78 | 20.83 | 9.77 | 7.83 | 11.96 | 27.58 | 32.90 | 9.96 |
| 0.98 | 177.92 | 156.42 | 21.50 | 10.66 | 9.01 | 14.89 | 28.21 | 28.90 | 8.33 |
| 1.05 | 175.51 | 153.22 | 22.29 | 11.44 | 9.58 | 14.44 | 26.43 | 27.55 | 10.56 |
| 1.01 | 177.32 | 155.45 | 21.87 | 14.25 | 11.34 | 17.29 | 26.79 | 23.26 | 7.06 |
| 1.00 | 171.08 | 151.05 | 20.03 | 15.50 | 12.23 | 18.93 | 27.18 | 20.62 | 5.53 |
| 1.01 | 178.18 | 156.58 | 21.60 | 14.40 | 12.24 | 17.94 | 24.45 | 21.16 | 9.80 |
| 0.98 | 185.38 | 163.24 | 22.14 | 12.70 | 10.70 | 15.27 | 23.78 | 24.60 | 12.95 |
| 0.99 | 183.70 | 161.52 | 22.18 | 14.05 | 11.49 | 15.74 | 24.12 | 23.82 | 10.78 |
| 1.01 | 185.63 | 163.80 | 21.83 | 13.90 | 11.80 | 17.57 | 25.86 | 22.74 | 8.13 |
| 1.01 | 176.21 | 155.03 | 21.18 | 14.32 | 12.59 | 20.08 | 27.15 | 20.77 | 5.10 |
| 1.02 | 136.32 | 118.07 | 18.25 | 9.80 | 6.45 | 9.43 | 17.37 | 33.73 | 23.21 |
| 1.00 | 145.77 | 127.82 | 17.95 | 9.17 | 6.12 | 9.63 | 19.54 | 35.47 | 20.07 |
| 1.00 | 147.74 | 129.41 | 18.33 | 10.03 | 6.36 | 11.00 | 24.33 | 35.48 | 12.80 |
| 0.98 | 189.36 | 168.19 | 21.17 | 20.14 | 13.23 | 20.49 | 23.86 | 17.16 | 5.12 |
| 0.97 | 188.03 | 165.99 | 22.04 | 20.68 | 13.80 | 22.15 | 23.83 | 15.15 | 4.37 |
| 1.03 | 191.74 | 169.82 | 21.92 | 19.51 | 13.62 | 21.02 | 23.95 | 16.54 | 5.37 |
| 0.96 | 204.97 | 180.63 | 24.34 | 18.83 | 13.06 | 21.80 | 25.00 | 16.39 | 4.93 |
| 1.00 | 194.52 | 172.35 | 22.17 | 27.21 | 14.77 | 17.68 | 19.72 | 15.47 | 5.14 |
| 1.00 | 156.84 | 136.37 | 20.47 | 11.16 | 6.56 | 13.32 | 28.06 | 31.77 | 9.12 |
| 1.00 | 154.11 | 134.93 | 19.18 | 10.37 | 5.89 | 12.77 | 28.27 | 33.43 | 9.27 |
| 0.99 | 156.63 | 137.19 | 19.44 | 11.55 | 6.84 | 14.82 | 27.90 | 30.12 | 8.77 |
| 1.04 | 149.78 | 130.47 | 19.31 | 12.05 | 7.87 | 15.91 | 27.94 | 28.76 | 7.46 |
| 1.00 | 151.77 | 133.21 | 18.56 | 10.25 | 6.59 | 15.12 | 29.43 | 30.97 | 7.64 |
| 0.98 | 141.89 | 124.74 | 17.15 | 7.26 | 6.09 | 9.47 | 24.38 | 37.66 | 15.13 |
| 1.01 | 143.17 | 125.41 | 17.76 | 8.76 | 7.12 | 11.98 | 27.46 | 34.45 | 10.23 |
| 0.99 | 140.82 | 123.83 | 16.99 | 8.49 | 6.32 | 11.45 | 28.61 | 35.37 | 9.76 |
| 1.02 | 140.12 | 122.93 | 17.19 | 7.84 | 6.19 | 10.80 | 29.06 | 36.27 | 9.84 |
| 1.00 | 149.38 | 130.96 | 18.42 | 8.46 | 7.54 | 12.11 | 27.47 | 34.26 | 10.17 |
| 0.96 | 148.05 | 129.65 | 18.40 | 7.41 | 6.18 | 9.61 | 26.15 | 38.22 | 12.42 |
| 0.98 | 148.29 | 129.48 | 18.81 | 10.33 | 8.77 | 13.63 | 27.36 | 31.08 | 8.83 |
| 0.96 | 152.76 | 134.18 | 18.58 | 7.93 | 6.59 | 10.77 | 29.03 | 36.69 | 8.99 |
| 0.96 | 154.66 | 136.12 | 18.54 | 7.67 | 6.06 | 10.13 | 27.54 | 37.01 | 11.59 |
| 1.03 | 151.55 | 134.42 | 17.13 | 8.39 | 7.41 | 11.97 | 27.39 | 34.64 | 10.20 |
| 1.01 | 155.72 | 137.60 | 18.12 | 9.43 | 7.40 | 12.08 | 30.55 | 33.66 | 6.89 |
| 1.05 | 159.54 | 141.53 | 18.01 | 8.06 | 6.92 | 12.13 | 28.13 | 32.30 | 12.45 |
| 1.00 | 145.12 | 125.66 | 19.46 | 9.34 | 7.52 | 12.45 | 30.15 | 32.89 | 7.66 |
| 1.00 | 145.06 | 127.50 | 17.56 | 8.38 | 6.92 | 11.56 | 28.24 | 34.98 | 9.91 |
| 1.01 | 147.80 | 130.78 | 17.02 | 7.97 | 7.21 | 11.49 | 25.05 | 34.66 | 13.62 |
| 1.01 | 143.60 | 126.07 | 17.53 | 11.94 | 10.97 | 16.06 | 26.11 | 26.94 | 7.98 |
| 1.05 | 154.73 | 135.89 | 18.84 | 12.36 | 11.18 | 18.07 | 28.78 | 24.55 | 5.05 |
| 1.02 | 152.47 | 133.76 | 18.71 | 13.03 | 12.40 | 19.12 | 26.20 | 22.93 | 6.31 |
| 1.00 | 153.13 | 134.76 | 18.37 | 11.16 | 11.09 | 18.24 | 27.48 | 25.37 | 6.65 |
| 1.02 | 121.00 | 105.37 | 15.63 | 9.34 | 7.59 | 11.83 | 26.46 | 33.58 | 11.20 |
| 1.01 | 111.77 | 97.57 | 14.20 | 7.06 | 6.20 | 8.11 | 20.16 | 36.77 | 21.70 |
| 1.08 | 108.72 | 94.80 | 13.92 | 7.90 | 5.97 | 7.32 | 21.41 | 37.86 | 19.53 |
| 1.02 | 119.06 | 104.15 | 14.91 | 5.53 | 4.69 | 5.02 | 14.92 | 32.27 | 37.57 |
| 0.99 | 94.38 | 81.63 | 12.75 | 6.36 | 4.83 | 5.40 | 11.03 | 32.02 | 40.35 |
| 0.99 | 106.29 | 92.50 | 13.79 | 8.29 | 6.93 | 9.37 | 23.04 | 37.00 | 15.37 |
| 0.99 | 120.74 | 105.80 | 14.94 | 7.41 | 5.90 | 8.42 | 22.71 | 35.71 | 19.84 |
| 1.01 | 119.76 | 104.30 | 15.46 | 7.89 | 6.45 | 8.58 | 24.28 | 39.06 | 13.74 |
| 1.03 | 127.73 | 111.64 | 16.09 | 8.02 | 6.60 | 9.38 | 24.57 | 37.95 | 13.48 |
| 1.08 | 118.13 | 103.15 | 14.98 | 7.50 | 6.46 | 8.80 | 19.49 | 32.87 | 24.89 |
| 1.00 | 127.92 | 110.96 | 16.96 | 10.28 | 9.19 | 14.48 | 27.92 | 30.26 | 7.87 |
| 1.05 | 137.09 | 120.55 | 16.54 | 10.68 | 8.89 | 14.42 | 28.09 | 30.39 | 7.53 |
| 0.99 | 139.08 | 122.47 | 16.61 | 10.56 | 8.09 | 12.21 | 27.39 | 33.07 | 8.69 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1.01 | 131.45 | 114.56 | 16.89 | 11.39 | 8.98 | 13.68 | 27.32 | 30.69 | 7.94 |
| 1.00 | 125.59 | 108.78 | 16.81 | 9.96 | 7.65 | 10.74 | 26.75 | 35.61 | 9.29 |
| 0.99 | 132.05 | 114.82 | 17.23 | 9.51 | 7.75 | 11.12 | 24.80 | 34.41 | 12.41 |
| 1.02 | 132.10 | 114.35 | 17.75 | 10.41 | 8.14 | 12.37 | 27.09 | 32.60 | 9.38 |
| 1.02 | 126.25 | 110.03 | 16.22 | 10.45 | 7.86 | 11.23 | 26.38 | 34.09 | 9.98 |
| 1.00 | 131.77 | 114.60 | 17.17 | 11.37 | 8.39 | 13.72 | 29.05 | 30.69 | 6.79 |
| 1.03 | 140.07 | 122.85 | 17.22 | 11.34 | 8.99 | 13.10 | 26.62 | 31.39 | 8.55 |
| 1.01 | 128.96 | 112.52 | 16.44 | 11.55 | 9.19 | 16.18 | 32.00 | 27.64 | 3.45 |
| 1.01 | 135.08 | 118.58 | 16.50 | 14.18 | 11.59 | 20.26 | 31.33 | 20.56 | 2.09 |
| 1.00 | 131.46 | 114.79 | 16.67 | 11.96 | 9.64 | 17.49 | 32.63 | 25.63 | 2.66 |
| 0.98 | 130.28 | 114.52 | 15.76 | 9.30 | 6.95 | 9.24 | 27.90 | 37.85 | 8.77 |
| 1.02 | 153.98 | 134.78 | 19.20 | 9.48 | 7.71 | 10.56 | 25.51 | 35.64 | 11.10 |
| 1.01 | 141.75 | 123.26 | 18.49 | 12.55 | 10.03 | 14.21 | 27.36 | 29.06 | 6.79 |
| 1.02 | 144.33 | 126.87 | 17.46 | 12.69 | 10.39 | 15.21 | 27.99 | 27.76 | 5.96 |
| 1.02 | 139.67 | 121.73 | 17.94 | 12.10 | 9.93 | 15.48 | 29.25 | 27.73 | 5.51 |
| 1.04 | 143.19 | 126.15 | 17.04 | 13.35 | 11.36 | 15.77 | 27.24 | 26.46 | 5.82 |
| 1.01 | 138.36 | 121.26 | 17.10 | 15.73 | 12.43 | 18.63 | 28.31 | 21.63 | 3.27 |
| 1.02 | 141.70 | 124.71 | 16.99 | 16.22 | 13.30 | 18.63 | 27.04 | 21.14 | 3.67 |
| 1.02 | 151.92 | 134.24 | 17.68 | 15.05 | 14.38 | 22.30 | 26.92 | 18.06 | 3.29 |
| 1.02 | 142.79 | 124.86 | 17.93 | 9.38 | 7.98 | 12.68 | 28.18 | 33.82 | 7.98 |
| 1.01 | 143.35 | 125.70 | 17.65 | 9.06 | 7.47 | 12.51 | 28.72 | 34.28 | 7.96 |
| 0.98 | 147.90 | 129.51 | 18.39 | 10.92 | 8.43 | 12.25 | 27.65 | 33.08 | 7.67 |
| 1.02 | 142.64 | 124.51 | 18.13 | 10.24 | 8.13 | 13.27 | 29.12 | 32.38 | 6.87 |
| 1.00 | 152.85 | 132.86 | 19.99 | 10.69 | 8.83 | 13.59 | 28.18 | 31.72 | 6.99 |
| 0.97 | 155.34 | 135.66 | 19.68 | 9.79 | 8.18 | 11.99 | 27.41 | 34.35 | 8.28 |

| | | | | GRAIN-SIZE | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Ce/Ce* | ΣREE | ΣLREE | ΣHREE | < 4um | 4-8 um | 8-16 um | 16-31 um | 31-63 um | > 63 um |
| 1.00 | 171.09 | 151.05 | 20.49 | 10.68 | 9.01 | 13.42 | 26.56 | 28.90 | 9.96 |
| 1.00 | 148.29 | 130.78 | 18.12 | 8.46 | 7.21 | 11.98 | 27.48 | 34.45 | 9.84 |
| 1.01 | 131.46 | 114.54 | 16.64 | 10.43 | 8.12 | 12.29 | 26.98 | 32.15 | 8.73 |
| 1.00 | 145.77 | 127.82 | 18.25 | 9.80 | 6.36 | 9.63 | 19.54 | 35.47 | 20.07 |
| 0.98 | 191.74 | 169.82 | 22.04 | 20.14 | 13.62 | 21.02 | 23.86 | 16.39 | 5.12 |
| 1.00 | 154.11 | 134.93 | 19.31 | 11.16 | 6.59 | 14.82 | 28.06 | 30.97 | 8.77 |
| 1.00 | 145.63 | 127.61 | 18.26 | 10.01 | 8.16 | 12.59 | 28.18 | 33.45 | 7.81 |
| 1.00 | 172.57 | 151.72 | 20.85 | 11.64 | 9.61 | 14.49 | 26.41 | 28.13 | 9.72 |
| 1.00 | 148.83 | 130.80 | 18.03 | 9.17 | 7.89 | 12.80 | 27.64 | 32.84 | 9.67 |
| 1.02 | 129.74 | 113.38 | 16.35 | 10.48 | 8.51 | 12.60 | 25.72 | 31.17 | 11.52 |
| 1.00 | 143.28 | 125.10 | 18.18 | 9.67 | 6.31 | 10.02 | 20.41 | 34.89 | 18.69 |
| 0.99 | 193.72 | 171.40 | 22.33 | 21.27 | 13.70 | 20.63 | 23.27 | 16.14 | 4.99 |
| 1.01 | 153.83 | 134.43 | 19.39 | 11.08 | 6.75 | 14.39 | 28.32 | 31.01 | 8.45 |
| 1.00 | 147.48 | 128.85 | 18.63 | 10.01 | 8.17 | 12.71 | 28.21 | 33.27 | 7.62 |
| 0.98 | 159.31 | 140.27 | 19.04 | 9.17 | 7.54 | 11.11 | 23.78 | 20.62 | 5.10 |
| 0.96 | 140.12 | 122.93 | 16.99 | 7.26 | 6.06 | 9.47 | 24.38 | 22.93 | 5.05 |
| 0.98 | 94.38 | 81.63 | 12.75 | 5.53 | 4.69 | 5.02 | 11.03 | 18.06 | 2.09 |
| 1.00 | 136.32 | 118.07 | 17.95 | 9.17 | 6.12 | 9.43 | 17.37 | 33.73 | 12.80 |
| 0.96 | 188.03 | 165.99 | 21.17 | 18.83 | 13.06 | 17.68 | 19.72 | 15.15 | 4.37 |
| 0.99 | 149.78 | 130.47 | 18.56 | 10.25 | 5.89 | 12.77 | 27.90 | 28.76 | 7.46 |
| 0.97 | 142.64 | 124.51 | 17.65 | 9.06 | 7.47 | 11.99 | 27.41 | 31.72 | 6.87 |
| 1.05 | 185.63 | 163.80 | 22.29 | 15.50 | 12.59 | 20.08 | 29.59 | 34.34 | 13.17 |
| 1.05 | 159.54 | 141.53 | 19.46 | 13.03 | 12.40 | 19.12 | 30.55 | 38.22 | 15.13 |
| 1.08 | 153.98 | 134.78 | 19.20 | 16.22 | 14.38 | 22.30 | 32.63 | 39.06 | 40.35 |
| 1.02 | 147.74 | 129.41 | 18.33 | 10.03 | 6.45 | 11.00 | 24.33 | 35.48 | 23.21 |
| 1.03 | 204.97 | 180.63 | 24.34 | 27.21 | 14.77 | 22.15 | 25.00 | 17.16 | 5.37 |
| 1.04 | 156.84 | 137.19 | 20.47 | 12.05 | 7.87 | 15.91 | 29.43 | 33.43 | 9.27 |
| 1.02 | 155.34 | 135.66 | 19.99 | 10.92 | 8.83 | 13.59 | 29.12 | 34.35 | 8.28 |
| 0.02 | 7.32 | 6.53 | 0.92 | 2.06 | 1.78 | 2.67 | 1.64 | 4.74 | 2.28 |
| 0.03 | 5.45 | 5.15 | 0.71 | 1.71 | 1.94 | 2.84 | 1.55 | 4.47 | 2.54 |
| 0.02 | 12.92 | 11.63 | 1.40 | 2.63 | 2.29 | 4.14 | 4.43 | 5.39 | 9.02 |
| 0.01 | 4.98 | 5.01 | 0.16 | 0.36 | 0.14 | 0.70 | 2.91 | 0.82 | 4.36 |
| 0.02 | 6.04 | 5.06 | 1.06 | 3.03 | 0.60 | 1.58 | 1.83 | 0.73 | 0.34 |
| 0.02 | 2.74 | 2.40 | 0.62 | 0.69 | 0.64 | 1.17 | 0.57 | 1.57 | 0.76 |
| 0.02 | 5.05 | 4.23 | 0.89 | 0.67 | 0.42 | 0.56 | 0.58 | 0.98 | 0.52 |
| 1.00 | 147.90 | 129.51 | 18.25 | 10.33 | 7.98 | 12.75 | 27.18 | 32.19 | 8.83 |
| 1.01 | 149.56 | 131.17 | 18.39 | 11.03 | 8.71 | 13.52 | 26.27 | 30.29 | 10.18 |
| 0.96 | 94.38 | 81.63 | 12.75 | 5.53 | 4.69 | 5.02 | 11.03 | 15.15 | 2.09 |
| 1.08 | 204.97 | 180.63 | 24.34 | 27.21 | 14.77 | 22.30 | 32.63 | 39.06 | 40.35 |
| 0.02 | 21.20 | 19.09 | 2.21 | 3.40 | 2.36 | 3.69 | 3.37 | 5.92 | 6.14 |