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Geochemical background and threshold for 47 chemical elements in Slovenian topsoil

Geokemično ozadje in zgornja meja naravne variabilnosti 47 kemičnih elementov v zgornji plasti tal Slovenije

Mateja GOSAR[1], Robert ŠAJN[1], Špela BAVEC[1], Martin GABERŠEK[1], Valentina PEZDIR[2] & Miloš MILER[1]

[1]Geološki zavod Slovenije, Dimičeva ulica 14, SI–1000 Ljubljana, Slovenija; e-mail: mateja.gosar@geo-zs.si, robert.sajn@geo-zs.si, spela.bavec@geo-zs.si, martin.gabersek@geo-zs.si, milos.miler@geo-zs.si
[2]Breg pri Borovnici 46, SI-1353 Borovnica, Slovenija; e-mail: valentina.pezdir@gmail.com

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Abstract

Geochemical background and threshold values need to be established to identify areas with unusually high concentrations of elements. High concentrations are caused by natural or anthropogenic processes. The <2 mm fraction of 817 collected topsoil (0 – 10 cm) samples at a 5 × 5 km grid on the territory of Slovenia was analysed. Results are used here to establish the geochemical background variation and threshold values, derived statistically from the data set, in order to identify unusually high element concentrations for these elements in the soil samples. Geochemical threshold values were determined following different methods of calculation for (1) whole of Slovenia and (2) for 8 spatial units determined on the base of geological structure, lithology, relief, climate and vegetation. Medians and geochemical thresholds for whole of Slovenia were compared with data for Europe and for southern Europe separately, since large differences in the spatial distribution of many elements are observed between northern and southern Europe. Potentially toxic elements (PTEs), namely As, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Sb, and Zn, are of particular interest. Medians of these PTE elements are all higher in Slovenia than in southern Europe. Medians of Pb and Mo are 1.5 times higher and medians of Hg and Cd are even more than 2 times higher in Slovenia. Geochemical thresholds for As, Cr, Co, Ni, Sb and Zn are of similar values in both Slovenia and southern Europe and some lower for Cu and Ni. Up to 1.5 times higher are tresholds in Slovenia for Mo and Pb and more than 2.5 times higher for Cd and Hg. These values were then compared to existing Slovenian soil guideline values for these elements.

Izvleček

Kemični elementi so v okolju, torej tudi v tleh, naravno prisotni. Povišane vsebnosti le-teh so posledica naravnih danosti ali pa jih povzročijo človekove dejavnosti. Območja povišanih koncentracij elementov so opredeljena kot območja, na katerih vsebnosti elementov presegajo vrednosti geokemičnega praga (zgornjih mej naravne variabilnosti - MNV). Na podlagi kemičnih analiz 817 vzorcev zgornje plasti tal (0–10 cm), odvzetih v mreži 5 × 5 km na območju celotne Slovenije, smo izračunali mediane (geokemično ozadje) in zgornje meje naravne variabilnosti (MNV) po več metodah za celotno Slovenijo in za 8 manjših prostorskih enot, ki smo jih določili glede na geološko zgradbo, kamninsko sestavo, relief, podnebje in rastlinstvo. Znotraj posameznih manjših prostorskih enot se izračunane MNV po različnih metodah močno razlikujejo zaradi heterogenosti enot in majhnega števila vzorcev. Mediane in zgornje meje naravne variabilnosti za celotno Slovenijo smo primerjali s podatki za celotno Evropo in še posebej južno Evropo, ker se prostorske porazdelitve elementov med južno in severno Evropo močno razlikujejo. Zanimive so vsebnosti potencialno strupenih elementov (As, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Zn) in primerjava z mejnimi, opozorilnimi in kritičnimi vrednostmi za tla po slovenski zakonodaji. Mediane teh elementov so v Sloveniji višje kot v celotni Evropi in v južni Evropi. Primerjava z južno Evropo kaže, da sta mediani Pb in Mo 1,5 krat višji, mediani Cd in Hg pa celo več kot 2 krat višji v Sloveniji. V Sloveniji so MNV blizu vrednostim v južni Evropi za elemente As, Cr, Co, Ni, Sb in Zn, malo nižje za Cu in Ni, do 1,5 krat višje za elementa Mo in Pb ter več kot 2,5 krat višje za Cd in Hg.

Introduction

Chemical elements are in environment, as well as in soil, present naturally. High element concentrations in environment may be due to occurrence of mineralization, unusual rock types, such as serpentinite, black shale mudstone, etc., or may be caused by human activities (mining, metallurgy, industry, traffic, agriculture, etc.). Depending on bioavailability and stability of the material in which the chemical elements appear, their high concentration levels may present environmental risk due to element toxicity.

Anthropogenic chemical contamination is one of the most evident signals of human influence on the environment. The large amounts of industrially produced pollutants that have been introduced, over decades, into air, soil and water have caused modifications to natural elemental cycling (Gałuszka et al., 2014). Anthropogenic contamination usually leads to enrichment in many elements, particularly in industrial areas. Certain elements and their isotopes can therefore be used as geochemical indicators of anthropogenic impact. There are also secondary effects of the pollution, such as acidification, which causes increased geochemical mobility of elements in surficial deposits. Methods used in geochemistry to assess the scale of anthropogenic influence on the environment include determination of geochemical background and thresholds, calculation of enrichment and contamination factors, geoaccumulation index and pollution load index. The use of geochemical background levels to distinguish between natural and anthropogenic pollution is important (fig. 1 and 2) (Gałuszka et al., 2014).

To identify areas with unusually high (or low) concentrations of "potentially toxic elements" (PTEs), geochemical background and threshold values of these elements need to be determined.

Uvod

Kemični elementi (prvine) so v okolju, torej tudi v tleh, naravno prisotni. Njihove povišane vsebnosti v okolju so lahko posledica naravnih danosti (pojavljanje mineralizacij oziroma orudenj in kamnin z naravno visokimi vsebnostmi nekaterih elementov, kot so na primer serpentinit, črni skrilavi glinavci, itd.), ali pa jih povzročijo človekove dejavnosti (rudarstvo, metalurgija, industrija, promet, kmetijstvo, itd.). Odvisno od obstojnosti zvrsti, v katerih kemični elementi nastopajo, lahko njihove povišane vsebnosti predstavljajo okoljska tveganja zaradi biodostopnosti škodljivih elementov.

Antropogena kemična kontaminacija je eden najbolj očitnih znakov človekovega vpliva na okolje. Dolgoletno delovanje različnih industrij, prometa in drugih človekovih dejavnosti so povzročili povišanje vsebnosti nekaterih elementov v površinskih materialih (tla, sedimenti, itd.) in spremembe naravnega kroženja elementov (Gałuszka et al., 2014). Antropogeni vplivi navadno vodijo v obogatitev številnih elementov, še zlasti na industrijskih območjih. Nekateri elementi in njihovi izotopi se tako lahko uporabljajo kot geokemični indikatorji antropogenega vpliva. Poznamo tudi sekundarne učinke onesnaženja, kot je na primer zakisljevanje, ki povzroča povečano geokemično mobilnost elementov v površinskih materialih. Metode, ki jih geokemiki uporabljamo za oceno obsega antropogenega vpliva na okolje, vključujejo opredelitev ravni geokemičnega ozadja in mej naravne variacije, izračune obogatitvenih razmerij, geoakumulacijskih indeksov in indeksov onesnaženja. Še posebej pomembna je uporaba geokemičnih ravni ozadja za ločitev naravnega in antropogenega deleža onesnaženja (sl. 1 in 2) (Gałuszka et al., 2014).

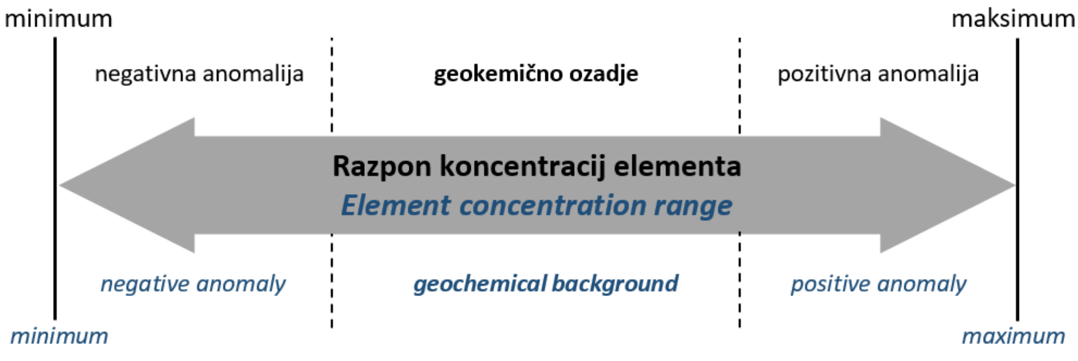

Fig. 1. Geochemical background and anomalies (after Gałuszka et al., 2014).
Sl. 1. Geokemično ozadje in anomalije (po Gałuszka et al., 2014).

Geochemical threshold values are used to identify locations with unusually high element concentrations. A lower threshold, determined in the lower part of the data distribution, is used to identify locations with unusually low element concentrations. Deficiency of certain elements in the soil can present a problem to living organisms in those environments (Reimann et al., 2018). In this work we focused solely on upper threshold and did not discuss the lower threshold.

After identification of areas with unusually high element concentrations, risk assessment must be determined in these areas. Risk assessment of soil determines whether the high element concentrations pose a threat to living organisms or the environment. It is dependent from elements, as certain elements are toxic at low concentrations and other elements are biologically essential, but harmful at higher concentration levels (Reimann et al., 2018). Proper risk assessment of soil includes comparison of determined element concentration values with effect thresholds for environmental and human health derived from (eco)toxicological data. This approach preferentially takes into account the effect of abiotic soil properties (such as mineral composition, structure and texture of the soil, water and air present in the soil) on bioavailability and toxicity of the element (examples in Smolders et al. (2009), Oorts & Schoeters (2014), Oorts et al. (2016) or Birke et al. (2016)). Proper risk assessment of certain location also requires

S pomočjo opredelitve vrednosti mej naravne variabilnosti za posamezne elemente se določa območja z nenavadno visoko (ali nizko) koncentracijo "potencialno strupenih elementov" (v nadaljevanju PTE – *potentially toxic elements*). Geokemični prag, ki je definiran kot zgornja meja naravne variabilnosti, se uporablja za določitev območij z nenavadno visoko koncentracijo elementov. Zanimiva je tudi spodnja meja naravne variabilnosti, ki je definirana v spodnjem delu porazdelitve geokemičnih podatkov in se uporablja za določitev območij z nenavadno nizko koncentracijo elementov, saj lahko tudi pomanjkanje nekaterih elementov v tleh povzroča težave živim bitjem (Reimann et al., 2018). Spodnja meja naravne variabilnosti ne sodi v vsebino tega dela, zato je v nadaljevanju ne bomo obravnavali.

Območja z nenavadno visokimi koncentracijami elementov v tleh je potrebno raziskati s posebno študijo, imenovano ocena tveganja, s katero ugotavljamo, ali te nenavadno visoke vsebnosti elementa lahko škodujejo okolju oz. živim bitjem. Nekateri elementi so namreč potencialno strupeni že v nižjih vsebnostih, drugi pa so biološko nujno potrebni, vendar njihove previsoke vsebnosti lahko škodujejo živim bitjem (Reimann et al., 2018). Pravilna ocena tveganja vključuje primerjavo izmerjenih koncentracij elementov z vrednostmi elementa, ki negativno učinkujejo na okolje in zdravje ljudi na podlagi ekotoksikoloških raziskav. Ta pristop prednostno upošteva

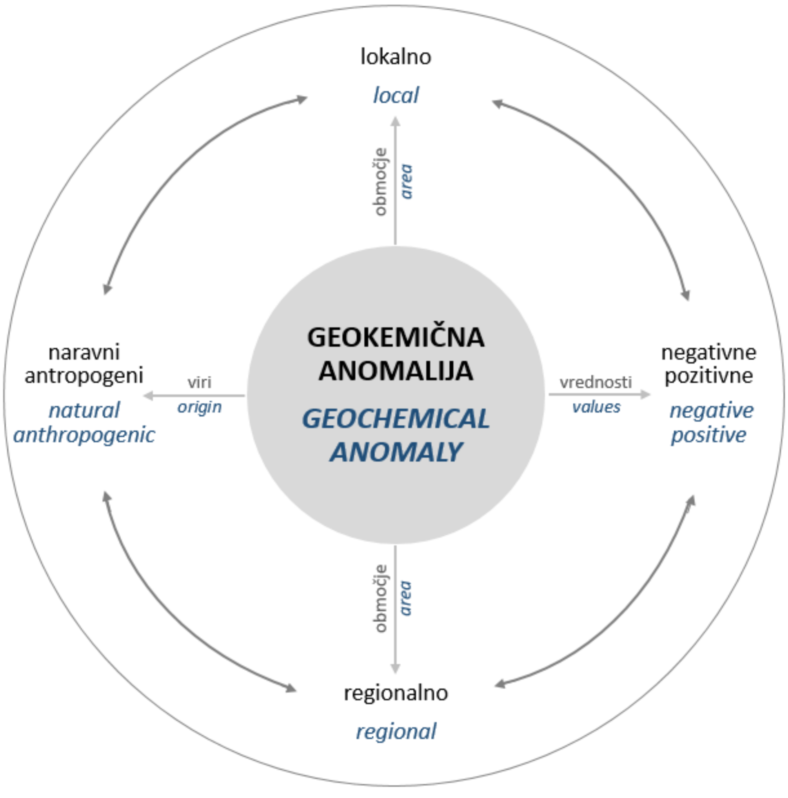

Fig. 2. Systematics of geochemical anomalies (after Gałuszka et al., 2014).

Sl. 2. Sistematika geokemičnih anomalij (po Gałuszka et al., 2014).

a substantial amount of additional data, such as bioavailability of elements, acidity (pH), grain size, cation exchange capacity and total organic carbon. Additional data must be available for each determined location with high element concentrations. Identifying geochemical (non-toxicological) threshold can simply be defined as a value above which the concentration of an element in a given data set is "unusually high". With this approach we separate locations that require attention and further analysis and studies (Reimann et al., 2018).

Unusually high element concentrations in the upper soil layer can be due to anthropogenic activities, such as urbanization, industrial activities, mining and agricultural practices. They may also be of natural origin and indicate areas with geochemically unusual rock types or areas having a high potential for the occurrence of mineral deposits (Reimann et al., 2018). The separation of these three distinct causes for high element concentrations in soil requires substantial expert knowledge about the location of possible contamination sources (cities, metal smelters, power plants, industry), climate, vegetation zones, geology, element dispersion processes, mineral deposits etc. (Reimann et al., 2018).

Materials and methods

Soil as sample material in geochemistry

Soils are an unique natural resource essential for food production and an irreplaceable component of natural ecosystems. Due to numerous environmental, economic, social and cultural functions (the multifunctionality of soils), soils are of crucial importance for life in terrestrial ecosystems (Vidic et al., 2015).

Soils represent the upper part of Earth's crust that consist of mineral particles, organic matter, water, air and living organisms (FitzPatric, 1986). They are indispensable to humanity and to maintaining a healthy natural environment.

Soil formation is a slow process. Soils form as a result of lithosphere weathering due to interactions of pedogenetic factors, which are lithological parent material, climate, relief, time and living organisms. Lithological parent material provides the original quantity of mineral material (with exception of carbonate rocks), from which soils are composed. It also influences thickness of the soil, physical, mineral and chemical attributes and further development of the soil (FitzPatrick, 1986). Climate influences soil development with solar radiation and dynamic processes in the atmosphere, which have an impact on humidity, heat

učinek abiotskih lastnosti tal (kot so mineralna sestava, tekstura in struktura tal ter voda in zrak v tleh) na biološko dostopnost (primeri v Smolders et al. (2009), Oorts & Schoeters (2014), Oorts et al. (2016) ali Birke et al. (2016)). Za določitev ocene tveganja na določenem območju so dodatno potrebni še drugi podatki o tleh, kot so biodostopni delež elementov, kislost (pH) in zrnavost tal, kationska izmenjevalna kapaciteta ter skupni organski ogljik. Tudi ti morajo biti na voljo za vsako obravnavano območje. Geokemično (ne toksikološko) zgornjo mejo naravne variabilnosti v obravnavanih tleh lahko preprosto določimo kot vrednost, nad katero je koncentracija elementa v tleh na podlagi danih podatkov "nenavadno visoka". S tako določenimi zgornjimi mejami naravne variacije izdvojimo območja tal, ki zahtevajo večjo pozornost in morda nadaljnje analize in študije (Reimann et al., 2018).

Nenavadno visoke koncentracije elementov v zgornjem sloju tal so lahko posledica antropogenih dejavnosti ali pa so naravnega izvora (Reimann et al., 2018). Za identifikacijo vzrokov visoke ravni elementov v tleh je potrebno zahtevno raziskovalno delo. Potrebno je izdelati kompleksno študijo, v kateri združujemo podatke o geoloških lastnostih (litološke značilnosti ozemlja, podatki o morebitnih orudenjih) in okoljskih značilnostih obravnavanega ozemlja, kot so npr. morebitni viri onesnaževanja (urbanizirana območja, kovinska industrija, termoelektrarne, druge vrste industrije) ter informacije o podnebju, talnih in vegetacijskih značilnostih in podobno (Reimann et al., 2018).

Materiali in metode

Tla kot vzorčni medij v geokemiji

Tla so edinstven naravni vir, ki je neposredno povezan s pridelavo hrane in splošno blaginjo, hkrati pa predstavljajo nenadomestljiv del naravnih ekosistemov. Zaradi številnih okoljskih, ekonomskih, socialnih in kulturnih funkcij so tla ključnega pomena za življenje v kopenskih ekosistemih (Vidic et al., 2015).

Tla predstavljajo zgornji del zemeljske skorje, ki ga sestavljajo mineralni delci, organska snov, voda, zrak in živi organizmi (FitzPatrick, 1986). So zelo pomembna za človeštvo in za vzdrževanje zdravega naravnega okolja.

Tvorba tal je počasen proces. Tla nastajajo ob preperevanju litosfere zaradi medsebojnega delovanja tlotvornih (pedogenetskih) dejavnikov, kot so matična podlaga, podnebje, relief, čas in organizmi. Matična podlaga zagotavlja osnovno and atmospheric deposition of particles. Organisms exchange substances and energy from lithological parent material and soils and thus directly affect soil development. The relief indirectly influences the formation of the soil by distribution of surface material and energy. Moving and retention potential of substances in the original location depend on the slope steepness. The relief also affects the thickness and humidity of the soil. Humans also have an influence on soil development, either directly by agriculture, infrastructure and urbanization or indirectly by changing relief, water regime, vegetation and pollution, which can be of point or dispersed type. Soils have a high buffering capacity which relates to stability of the soil system and the pH of the soil and to the soil retaining capacity. Thus, the content of water, mineral particles, gases as well as pollutants in the soil are regulated. However, the buffering capacity of the soil is not unlimited and therefore certain pollutants can exceed the retention or buffering capacity of the soil (FitzPatric, 1986).

Soil is a dynamic complex formation, in which biological, chemical and physical processes continuously take place. It represents a complex ecosystem that enables plant growth and biogeochemical circulation of elements. Physical processes include decomposition of rocks into smaller particles without changing their mineral and chemical composition. Physical decomposition is caused by temperature changes, frost, wind, glaciation, plant roots activity and water. Due to physical decomposition, the specific particle size increases, allowing for faster chemical decomposition. Chemical processes are dissolution, hydrolysis, hydration, oxidation or reduction, and the formation of clay and other minerals. Water, that contains dissolution of various gases and acids, plays an important role in all these processes. Most of the soil processes are of direct or indirect biological nature. Organisms are effective leaching factors in the dissolution of many elements. Due to the extremely high reproduction rate of microorganisms, their effect can be significant and can be important in the migration of elements in the soil (Siegel, 2002).

The unique characteristic of the soils is the distribution of their components and features in layers, that are dependent on the present landscape surface and that vary with depth. Migration processes of particles, chemical elements and humus substances take place due to weathering, water and organisms in the soil. Thus, soil layers are formed, which differ in morphological features: colour, density of the roots, humus

količino mineralnega gradiva (izjema je karbonatna podlaga), iz katerega sestoje tla, in vpliva na debelino, na fizikalne, mineralne in kemične lastnosti ter na nadaljnjo smer njihovega razvoja (FitzPatrick, 1986). Podnebje vpliva na razvoj s sončnim sevanjem in z dinamičnimi procesi v atmosferi, ki prenašajo vlago, toploto in vplivajo na atmosfersko odlaganje delcev. Živi svet izmenjuje z matično podlago in s tlemi snovi in energijo ter tako neposredno vpliva na razvoj tal. Relief posredno vpliva na oblikovanje tal s tem, da razporeja po površini snovi in energijo. Premeščanje ali zadrževanje snovi na prvotnem mestu je odvisno od strmine pobočja. Relief vpliva tudi na debelino in vlažnost tal. Na njihovo oblikovanje vpliva tudi človek. Neposredno z obdelovanjem, gradnjo infrastrukture in naselij, posredno pa s spreminjanjem reliefa, vodnega režima, rastlinstva in z onesnaževanjem, ki je lahko točkovno ali razpršeno. Tla imajo veliko puferno sposobnost, ki se nanaša na stabilnost talnega sistema in pH tal ter na zadrževalno sposobnost tal. Tako se uravnava vsebnost vode, mineralnih delcev, plinov kot tudi onesnaževal v tleh. Puferna sposobnost tal pa ni neomejena in zato lahko določena onesnaževala tudi presežejo zadrževalno oz. puferno sposobnost tal (FitzPatrick, 1986).

Tla so dinamična kompleksna tvorba, v kateri ves čas potekajo biološki, kemični in fizikalni procesi. Predstavljajo zapleten ekosistem, ki omogoča rast rastlin in biogeokemično kroženje elementov. Fizikalni procesi obsegajo razpadanje kamnine na manjše delce, pri čemer se njihova mineralna in kemična sestava ne spremenita. Fizikalno razpadanje povzročajo temperaturne spremembe, delovanje zmrzali, vetra, ledenikov, rastlinskih korenin in vode. Zaradi takega razpadanja se poveča specifična površina delcev, kar omogoča hitrejše kemično razpadanje. Kemični procesi so raztapljanje, hidroliza, hidratacija, oksidacija ali redukcija ter tvorba glinenih in drugih mineralov. Pri vseh teh procesih ima pomembno vlogo voda, v kateri so raztopljeni različni plini in kemične snovi. Večina talnih procesov je posredno ali neposredno biološke narave. Organizmi so učinkoviti dejavniki izluževanja in raztapljanja številnih elementov. Zaradi izredno velike razmnoževalne hitrosti mikroorganizmov je njihov skupni učinek lahko znaten in je lahko pomemben v migraciji elementov v tleh (Siegel, 2002).

Edinstvena značilnost tal je razporeditev njihovih sestavin in lastnosti v plasteh, ki so odvisne od sedanjega površja in se spreminjajo z globino. Zaradi preperevanja, delovanja vode ter organizmov v tleh potekajo procesi premeščanja delcev, content, grains, humidity and other. Individual layers are called soil horizons. They were created in the process of soil formation and interaction between the layers. They can be from few centimeters to several meters thick. Together, they form a soil profile (Siegel, 2002).

Trace elements in the soils occur in primary minerals that originate from lithological parent material, in secondary newly formed minerals, and bound to clay minerals and organic matter. In addition to geological and pedological features, soils also provide information on pollutants in the air, and are therefore a very useful and widespread sample medium.

A regional radiometric and geochemical survey was performed on the entire territory of Slovenia during the period 1990–1993 by the Geological Survey of Slovenia. Soil sampling was performed at a 5 × 5 km grid with a randomly selected starting point to ensure randomness of sampling (fig. 3) (Andjelov, 1994). In total, 817 topsoil (0–10 cm) samples were collected. The air dried samples were gently disaggregated in a ceramic mortar, sieved through a 2 mm sieve and stored. In 2012 the stored soil samples were taken out of the depot at the Geological Survey of Slovenia, pulverized in an agate mill to a fine-grain size (<0.075 mm) and submitted to chemical analysis in Bureau Veritas Mineral Laboratories at Vancouver, Canada. Samples were analysed with inductively coupled plasma (ICP) and mass spectrometry (MS) after digestion of an aliquot of 15 g sample material with aqua regia

kemičnih elementov in humusnih snovi. Tako nastanejo v tleh plasti, ki se razlikujejo po morfoloških lastnostih: barvi, prekoreninjenosti, deležu humusa, deležu skeleta, vlažnosti in drugem. Posamezne plasti imenujemo talni horizonti. Nastali so v procesu nastanka in razvoja tal v medsebojni odvisnosti. Debeli so od nekaj centimetrov do več metrov. Skupaj sestavljajo talni profil (Siegel, 2002).

Sledni elementi v tleh so vezani v obstojnih prvotnih mineralih, ki izvirajo iz matične kamnine, v drugotnih, novonastalih mineralih, ter vezani na glinene minerale in organsko snov. Ker pa poleg geoloških in pedoloških značilnosti dajejo tudi informacijo o onesnaževalih v zraku, so tla zelo uporaben in razširjen vzorčni medij.

V letih 1990–1993 je Geološki zavod Slovenije izvedel regionalno vzorčenje tal celotnega ozemlja Slovenije za potrebe izdelave karte naravne radioaktivnosti. Tla so bila sistematično vzorčena v mreži 5 × 5 km, v kateri je bila merjena tudi naravna radioaktivnost (sl. 3) (Andjelov, 1994). Skupno je bilo odvzetih 817 vzorcev zgornje plasti tal (0–10 cm), ki so bili posušeni in presejani na frakcijo <2 mm. Del vzorcev je bil arhiviran v depoju GeoZS. Leta 2012 so bili vzorci vzeti iz depoja, zmleti v ahatnem mlinčku (<0,075 mm) in posredovani v kemične analize v Bureau Veritas Mineral Laboratories (Vancouver, Kanada). Vzorci so bili analizirani z metodo induktivno vezane plazemske masne spektrometrije (ICP-MS) po razklopu z modificirano zlatotopko (15 g vzorca so raztopili v mešanici kislin $HCl : HNO_3 : H_2O = 1 : 1 : 1$).

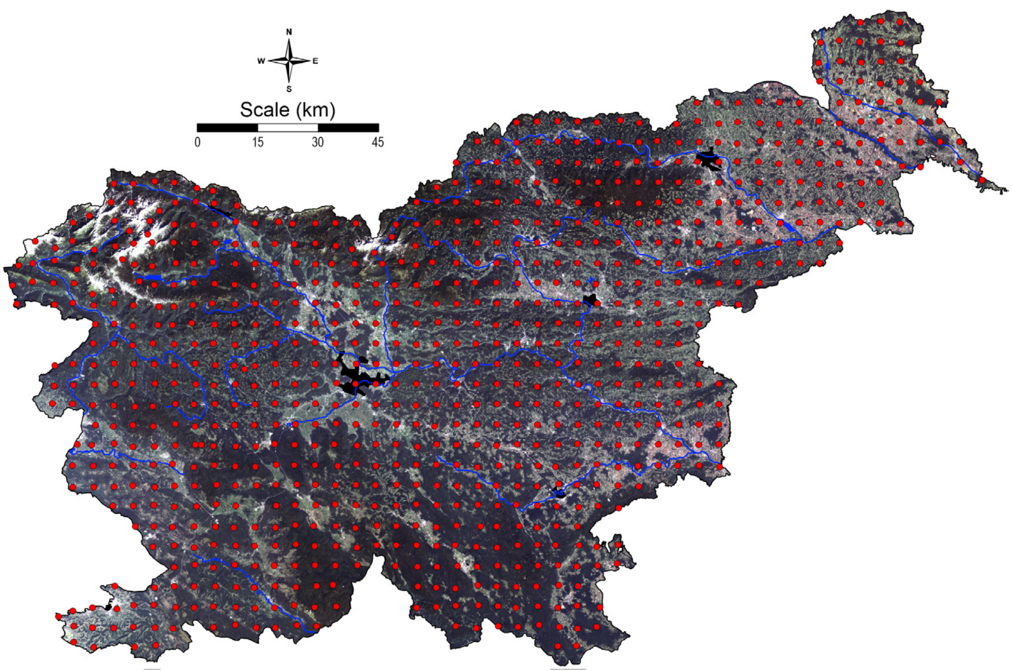

Fig. 3. Sampling locations.

Sl. 3. Prikaz vzorčnih lokacij.

(1 : 1 : 1 HCl : HNO_3 : H_2O). Concentrations of following 53 elements were determined: Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Pd, Pt, Rb, Re, S, Sb, Sc, Se, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, W, Y, Zn, Zr.

Quality control

The quality control of analyses was assured by several methods. Aliquots of Certified Reference Materials (CRM: OREAS 43P, OREAS 44P, OREAS 45P, OREAS 45CA), and sample replicates were included randomly into the sample batches to estimate accuracy and precision of chemical analyses. Analysed concentration values of standards were compared to the certified values, as well as the repetitions of analyses of standard materials and soil samples. With this we determined the accuracy (A) and precision (P) of used analytical methods for analysed chemical elements (figs. 4 and 5). Table 1 shows the numbers

Določene so bile vsebnosti naslednjih 53 elementov: Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Pd, Pt, Rb, Re, S, Sb, Sc, Se, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, W, Y, Zn, Zr.

Presoja kakovosti analitike

Kakovost analitike smo ocenili na podlagi rezultatov kemičnih analiz standardnih materialov (OREAS 43P, OREAS 44P, OREAS 45P, OREAS 45CA), katerih vsebnosti analiziranih elementov smo primerjali s priporočenimi vrednostmi, ter s ponovitvami analiz standardnih materialov in vzorcev tal. To je omogočilo oceno točnosti (A accuracy) in natančnosti (P precision) uporabljene analitske metode za analizirane kemične elemente (sl. 4 in 5). Naredili smo tudi pregled, v koliko vzorcih tal so vsebnosti obravnavanih kemičnih elementov pod mejo določljivosti (spodnja meja zaznavnosti) (tabela 1). Točnost (A accuracy) analitike ocenjujemo z relativno razliko med analit-

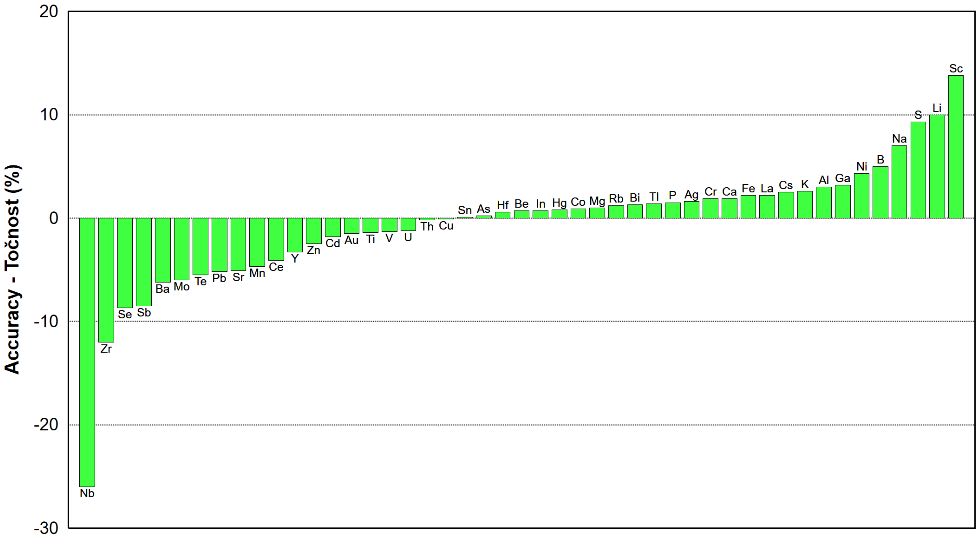

Fig. 4. Accuracy of analytical method.

Sl. 4. Točnost analitske metode.

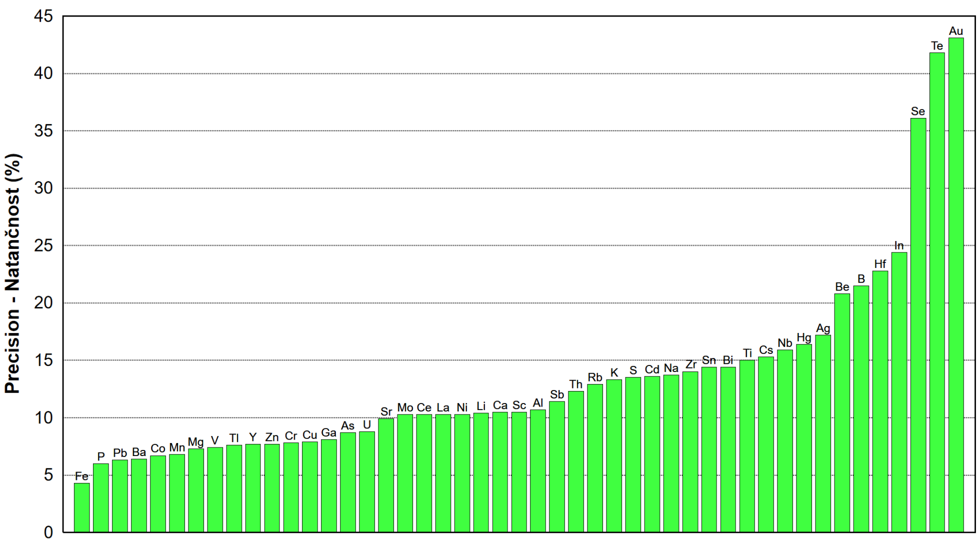

Fig. 5. Precision of analitical method.

Sl. 5. Natančnost analitske metode.

of soil samples having individual element concentrations below the lower detection limit. Accuracy (A) of analytics is evaluated as a relative difference between the analytical value of the element and its certified value. Analytical values of geological standard materials are compared with their certified values (Abbey, 1983; Reimann et al., 2009). Individual standards and their replicates were randomly distributed among the soil samples. Calculated relations between replicated values and their certified values are in fact the correction factor, by which analysed values could be divided in order to approach the certified values (Gosar, 2007).

Precision (P) of analytical methods is a measure of repeatability of determining a parameter in the same sample standard material, regardless of deviation from the certified value (Rose et al., 1979; Reimann et al., 2009).

Chemical elements Ge, Pd, Pt, Re, Ta and W were eliminated from further discussion, because their concentrations in more than 30 % of the samples were below detection limit of the analytical methods (table 1). For other chemical elements, sensitivity, accuracy (A) and precision (P) of analytical methods were satisfactory (table 1). They were included in further statistical processing.

Based on the findings described above, the following 47 chemical elements were discussed in statistical analyses: Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Hf, Hg, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, S, Sb, Sc, Se, Sn, Sr, Te, Th, Ti, Tl, U, V, Y, Zn, Zr.

Methods for determination of geochemical threshold values

In scientific literature can be found several methods for calculating the geochemical threshold which is needed for recognizing the unusually high element concentrations. We summarize a selection of the most commonly used methods.

The original and most simple approach to calculate the geochemical threshold is "Mean + 2 × standard deviations (SD)" (abr. **X2S**) of a given data set. The method was developed in exploration geochemistry to detect data outliers and to determine the threshold between geochemical background and unusually high element concentrations that can indicate areas of mineralization (Matschullat et al., 2000; Reimann & Garrett, 2005; Reimann et al., 2018). The approach has many shortcomings, among which the most important one is that the method does not consider the multimodal nature of geochemical data sets (Reimann & Filzmoser, 2000).

sko vrednostjo elementa v vzorcu in njeno priporočeno vrednostjo. Navadno primerjamo analitske vrednosti geoloških standardnih materialov z njihovimi priporočenimi vrednostmi (Abbey, 1983; Reimann et al., 2009). Posamezni standardi so bili pod laboratorijskimi številkami naključno porazdeljeni med ostale vzorce in večkrat analizirani. Izračunana razmerja med ponovitvami analiz in priporočenimi vrednostmi so pravzaprav popravni količnik, s katerim bi morali deliti analizirane vrednosti, da bi se bolje približali priporočenim vsebnostim v vzorcih (Gosar, 2007).

Natančnost (P *precision*) analitike predstavlja mero ponovljivosti določanja nekega parametra v istem vzorcu ali v standardnem materialu ne glede na odstopanje od priporočene vrednosti (Rose et al., 1979; Reimann et al., 2009).

Kemične elemente Ge, Pd, Pt, Re, Ta in W smo izločili iz nadaljnje obdelave, ker je bila njihova vsebnost v več kot 30 % vzorcev nižja od spodnje meje zaznavnosti analitike (tabela 1). Za ostale elemente smo ugotovili, da so občutljivost, točnost (A *accuracy*) in natančnost (P *precision*) analitike zadovoljivi (tabela 1), zato smo rezultate vključili v nadaljnjo statistično obdelavo.

Na podlagi zgoraj navedenih ugotovitev smo v nadaljnjih statističnih obdelavah obravnavali naslednjih 47 elementov: Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Hf, Hg, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, S, Sb, Sc, Se, Sn, Sr, Te, Th, Ti, Tl, U, V, Y, Zn, Zr.

Pregled metod za opredelitev zgornje meje naravne variabilnosti

V znanstveni literaturi najdemo več metod za določanje geokemičnih zgornjih mej naravne variabilnosti za določitev anomalno visokih vsebnosti elementov. V nadaljevanju povzemamo izbor najpogosteje uporabljenih metod.

Prvi in najpreprostejši pristop, pri katerem izračunamo zgornjo mejo naravne variabilnosti, temelji na izračunu "aritmetična sredina + 2 × standardni odklon (SD)" (okrajšano: **X2S**) za dane podatke. S tem izračunom so v preteklih geokemičnih raziskavah za iskanje mineralnih surovin računali vsebnost za definiranje meje med vsebnostmi, ki sodijo v geokemično ozadje in anomalno visokimi vsebnostmi, ki lahko nakazujejo območja mineralizacije (Matschullat et al., 2000; Reimann & Garrett, 2005; Reimann et al., 2018). Ta metoda ima več pomanjkljivosti, med katerimi je najpomembnejša neupoštevanje večmodalne narave geokemičnih podatkov (Reimann & Filzmoser, 2000).

Geokemični podatki so prostorsko variabilni, na njihove vrednosti vplivajo številni dejavniki

Table 1. Quality control of analytical method.
Tabela 1. Ocena kakovosti analitske metode.

	Unit	DL	UL	N(DL)	A (%)	P (%)
Ag	µg/kg	2	100000	817	1.6	17.2
Al	%	0.01	10	817	3.0	10.7
As	mg/kg	0.1	10000	817	0.2	8.7
Au	mg/kg	0.2	100000	797	–1.5	43.1
B	mg/kg	1	2000	631	5.0	21.5
Ba	mg/kg	0.5	10000	817	–6.2	6.4
Be	mg/kg	0.1	1000	814	0.7	20.8
Bi	mg/kg	0.02	2000	817	1.3	14.4
Ca	%	0.01	40	813	1.9	10.5
Cd	mg/kg	0.01	2000	813	–1.8	13.6
Ce	mg/kg	0.1	2000	817	–4.1	10.3
Co	mg/kg	0.1	2000	817	0.9	6.7
Cr	mg/kg	0.5	10000	817	1.9	7.8
Cs	mg/kg	0.02	2000	817	2.5	14.3
Cu	mg/kg	0.01	10000	817	–0.1	7.9
Fe	%	0.01	40	817	2.2	4.3
Ga	mg/kg	0.1	1000	817	3.2	8.1
Ge	mg/kg	0.1	100	**31**	–13.9	1.0
Hf	mg/kg	0.02	1000	658	0.6	22.8
Hg	mg/kg	0.005	50	817	0.8	16.4
In	mg/kg	0.02	1000	709	0.7	24.4
K	%	0.01	10	816	2.6	13.3
La	mg/kg	0.5	10000	817	2.2	10.3
Li	mg/kg	0.1	2000	817	10.0	10.4
Mg	%	0.01	30	817	1.0	7.3
Mn	mg/kg	1	10000	817	–4.7	6.8
Mo	mg/kg	0.01	2000	817	–6.0	10.3
Na	%	0.001	5	806	7.0	13.7
Nb	mg/kg	0.02	2000	816	–26.0	14.9
Ni	mg/kg	0.1	10000	817	4.3	10.3
P	%	0.001	5	817	1.5	6.0
Pb	mg/kg	0.01	10000	817	–5.2	6.3
Pd	µg/kg	10	100000	**10**	14.6	–
Pt	µg/kg	2	100000	**47**	3.2	6.0
Rb	mg/kg	0.1	2000	817	1.2	12.9
Re	µg/kg	1	100	**255**	1.6	18.9
S	%	0.02	5	668	9.3	13.5
Sb	mg/kg	0.02	2000	817	–8.5	11.4
Sc	mg/kg	0.1	100	817	13.8	10.5
Se	mg/kg	0.1	100	778	–8.7	36.1
Sn	mg/kg	0.1	100	817	0.1	14.4
Sr	mg/kg	0.5	10000	817	–5.1	9.9
Ta	mg/kg	0.05	2000	**0**	–	–
Te	mg/kg	0.02	1000	607	–5.5	41.8
Th	mg/kg	0.1	2000	816	–0.2	12.3
Ti	%	0.001	5	782	–1.4	15.0
Tl	mg/kg	0.02	1000	817	1.4	7.6
U	mg/kg	0.05	2000	817	–1.2	8.8
V	mg/kg	2	10000	817	–1.3	7.4
W	mg/kg	0.05	100	**335**	–38.6	10.5
Y	mg/kg	0.01	2000	817	–3.3	7.7
Zn	mg/kg	0.1	10000	817	–2.5	7.7
Zr	mg/kg	0.1	2000	800	–12.0	14.0

DL – spodnja meja detekcije analiz/lower detection limit; UL – zgornja meja detekcije analiz/upper detection limit; N(DL) – število vzorcev nad DL/number of values above DL; A (%) – točnost/accuracy; P (%) – natančnost/precision

Geochemical data have a high spatial variability, are influenced by many factors and are often imprecise due to unavoidable sampling errors, sample preparation and analytical errors. Due to these properties of geochemical data, Reimann et al. (2005) suggested to replace the earlier **X2S** approach by using "Median + 2 × median absolute deviations (abr. MAD)" (abr. **MD2MAD**), where the median is defined for a sample x_1, … …, x_n as $median_j(x_j)$. $Median_i(x_i)$ is then defined for a new data set, that is determined from absolute values obtained by subtracting the $median_j(x_j)$ from each original value in the sample. MAD is therefore determined as:

$$MAD_i(x_i) = 1.48 \times median_i|x_i - median_j(x_j)|$$

In case of normal data distribution, a constant 1.48 is added to MAD definition for approximation to standard deviation (SD) (Rousseeuw & Croux, 1993; Reimann et al., 2018). The approach **MD2MAD** is much more efficient in exposing the anomalously high element concentrations, while the approach **X2S** only determines extreme values that are not necessarily the anomalous high values. The disadvantage of the **MD2MAD** method, if applied to raw, untransformed data, is that it delivers very conservative (low) threshold values (quite often around the 90^{th} percentile), i.e., it produces a lot of sites that need to be checked (Reimann et al., 2018). The reason is that geochemical data distributions are most often strongly right-skewed, while, when using the above formula, the underlying assumption is of a symmetrical (not necessarily normal) data distribution. The correct approach to using this formula would thus be to calculate "Median + 2 × MAD" (**MD2MAD**) on the log-transformed data (e.g., using log base 10) and then to back-transform the result and use these values as threshold according to the formula (Reimann et al., 2018). Geochemical threshold is therefore determined according to formula:

$$\text{Threshold (after MD2MAD approach)} = \mathbf{10^b}$$

where

$$\mathbf{b} = (median_i\ (\log_{10}(x_i)) + 2 \times MAD_j\ (\log_{10}(x_j))$$

Values calculated using this approach are often comparable with the **TIF** (Tukey inner (upper) fence or upper whisker in a boxplot) method (Reimann et al., 2018). This method is based on the boxplot, an exploratory data analysis tool that depends solely on the symmetry of data dis-

in so pogosto nenatančni zaradi neizogibnih napak pri vzorčenju, pripravi vzorcev in analizah. Reimann in sodelavci (2005) so glede na naštete lastnosti geokemičnih podatkov predlagali zamenjavo prej omenjenega pristopa z izračunom "mediana + 2 × mediana absolutnih standardnih odklonov od mediane (okrajšano MAD)" (okrajšano: **MD2MAD**), kjer je mediana definirana za podatke x_1, … …, x_n kot $mediana_j(x_j)$. Nato se določi $mediana_i(x_i)$ iz novega seta podatkov, ki se ga določi kot absolutna vrednost razlike med posamezno vrednostjo novega vzorca in $mediane_j(x_j)$. MAD je tako definiran kot:

$$MAD_i(x_i) = 1{,}48 \times mediana_i|x_i - mediana_j(x_j)|$$

V primeru normalne porazdelitve podatkov je definicija MAD s konstanto 1,48 približek osnovnemu standardnemu odklonu (SD) (Rousseeuw & Croux, 1993; Reimann et al., 2018). Ta metoda veliko bolje izpostavi anomalno visoke vsebnosti. Metoda **X2S** ugotovi predvsem samo ekstremne vrednosti, ki ne predstavljajo vedno tudi anomalno visokih vsebnosti. Pomanjkljivost metode **MD2MAD** je, da je ne smemo uporabiti na surovih, netransformiranih podatkih (Reimann et al., 2018). Pogoj za uporabo je namreč simetrična (in zlasti normalna) porazdeljenost podatkov. Če jo uporabimo za netransformirane podatke, dobimo kot rezultat zelo konzervativne (nizke) vrednosti zgornjih mej naravne variabilnosti, pogosto okoli 90. percentila. To je posledica desne asimetričnosti porazdelitve geokemičnih podatkov, ki je v geoloških materialih zelo pogosta. Obrazec za izračun predpostavlja osnovno simetrično (ne nujno normalno) porazdelitev podatkov. Zato je pravilen pristop k uporabi te metode izračun "mediana + 2 × MAD" (**MD2MAD**) s transformiranimi podatki (npr. z uporabo logaritemske transformacije) ter ponovno re-transformacijo rezultata izračuna (Reimann et al., 2018). V zadnjem primeru torej mejno vrednost za anomalno visoke vsebnosti z logaritemsko transformacijo izračunamo po obrazcu:

$$\text{Zgornja meja naravne variacije (po metodi MD2MAD)} = \mathbf{10^b}$$

kjer je

$$\mathbf{b} = (mediana_i\ (\log_{10}(x_i)) + 2 \times MAD_j\ (\log_{10}(x_j))$$

Vrednosti, ki jih pridobimo s tem pristopom, so pogosto primerljive z metodo **TIF** (Tukeyeva notranja meja; ang. Tukey Inner Fence) (Reitribution. It allows the definition of a threshold for outliers even if none are present in the data set (i.e., Max < TIF), as it extrapolates from the robust inner core (25^{th} to 75^{th} percentiles) of the data structure. TIF is calculated as follows:

TIF = Q3 + 1.5 × IQR

Where Q3 stands for the 3^{rd} quartile (equivalent to the 75^{th} percentile), and IQR is the interquartile range (75^{th} – 25^{th} percentile). The multiplying factor of 1.5 in the formula is based on the assumption of a symmetrical data distribution. All values higher than TIF are therefore labeled as anomalously high values. With this approach TIF also presents a geochemical threshold value (Reimann et al., 2005). When dealing with geochemical data, which are most often right-skewed, **TIF** must be calculated on the log- (or otherwise) transformed data to achieve "symmetry". The TIF can be considered as one of the most reliable tools to calculate meaningful threshold values for any given data set (Reimann & Caritat, 2017; Reimann et al., 2018).

Reimann et al. (2005) compared methods discussed above by using normal distribution and log-normal distribution data sets. The results showed that the boxplot gives the best results when samples with anomalously high concentrations are **less than 10 %.** In case when samples with anomalously high concentrations **exceed 15 %** or even more than half of all data, only "Median + 2 × MAD" (**MD2MAD**) gives useful results (Reimann et al., 2005). Approach "Mean + 2 × standard deviation" (**X2S**) exposes only extreme values. It is only meaningful when all samples with anomalously high concentrations also represent extreme values.

Another approach, which again stems from exploration geochemistry, is to study data distributions in a cumulative probability (CP) diagram (Reimann et al., 2018). A CP diagram shows statistical distributions of data and can detect processes that cause deviation from general data distribution (Reimann et al., 2005; Reimann et al., 2018). It allows detection of samples with anomalously high element concentrations and their distance from other data. Values above threshold are most often detected as a break of the distribution in the cumulative probability diagrams.

Geochemical threshold can also be determined by using the percentile-based approach (Reimann et al., 2018). It is a simplistic method with the 90^{th}, 95^{th}, 97.5^{th} or 98^{th} percentile of a given data set defining the threshold (abr. **P90, P95, P97.5** and

mann et al., 2018). Ta metoda temelji na diagramu škatla z brki, ki omogoča določanje zgornjih mej naravne variabilnosti, tudi če med podatki ni vzorcev z anomalno visokimi vsebnostmi (torej je max < TIF). Izračuna se po sledečem obrazcu z ekstrapolacijo iz medkvartilnega razpona (25. do 75. percentil) vseh podatkov, kar predstavlja centralno "škatlo":

TIF = Q3 + 1,5 × IQR

Q3 je 3. kvartil (ekvivalent 75. percentilu) in IQR (Interquartile range) predstavlja medkvartilni razpon (75.–25. percentil). Faktor množenja 1,5 v formuli temelji na domnevi o simetrični porazdelitvi podatkov. Vse vrednosti, ki so večje od tako postavljene meje, so anomalno visoke vsebnosti. S tem pristopom TIF predstavlja mejo naravne variabilnosti (Reimann et al., 2005). Tudi **TIF** mora biti v primeru desno asimetričnih geokemičnih podatkov izračunan preko log- (ali drugače) transformiranih podatkov, da se ti približajo "simetričnosti". TIF je ena najbolj zanesljivih metod za izračun meje naravne variabilnosti za kakršnekoli podatke (Reimann & Caritat, 2017; Reimann et al., 2018).

Reimann s sodelavci (2005) je primerjal navedene metode v primeru normalne porazdelitve in logaritemsko normalne porazdelitve. Rezultati so pokazali, da diagram škatla z brki poda najboljše rezultate v primeru, da je vzorcev z anomalno visokimi vsebnostmi **manj kot 10 %**. V primeru, da je vzorcev z anomalno visokimi vsebnostmi **več kot 15 %** ali celo več kot polovica vseh podatkov, da uporabne rezultate le metoda "mediana + 2 × MAD" (**MD2MAD**) (Reimann et al., 2005). Metoda "aritmetična sredina + 2 × standardni odklon (**X2S**)" izpostavi le ekstremne vrednosti. Smiselna je le v primeru, ko vsi vzorci z anomalno visokimi vsebnostmi predstavljajo hkrati tudi ekstreme.

Za določitev vzorcev z anomalno visokimi vsebnostmi se uporablja tudi grafični prikaz porazdelitve podatkov v diagramu kumulativne verjetnosti (CP) (Reimann et al., 2018). Diagram prikazuje statistične porazdelitve podatkov, iz katerih je mogoče zaznati procese, ki povzročajo odstopanje od splošne porazdelitve podatkov (Reimann et al., 2005; Reimann et al., 2018). Omogoča določitev vzorcev z anomalno visokimi vsebnostmi ter njihovo oddaljenost od ostalih podatkov. Vrednosti nad zgornjo mejo naravne variacije se najpogosteje zazna kot prelom v porazdelitveni krivulji podatkov na teh diagramih.

P98, see also Ander et al., 2013). The 98th percentile, which identifies 2 % of all samples as upper outliers, comes closest to the original method of calculating the "mean + 2 SD" in the case of a normal distribution, which would result in 2.3 % of upper outliers. A common feature of all these statistical methods is that it will not necessarily be possible to establish a meaningful single threshold valid for the whole country, because the background varies spatially. Furthermore, there exists no valid scientific reason why 2, 5 or 10 % of the samples should be considered as "anomalous" regardless of the statistical data distribution. It will only determine the highest values in a data set that may also be anomalous. Though the method is very practical due to its simplicity and as there is no need for normal data distribution and with it, for transformations.

Zgornjo mejo naravne variabilnosti lahko določimo tudi z uporabo pristopa, ki temelji na percentilih (Reimann et al., 2018). Mejo lahko postavimo pri 90., 95., 97,5. ali 98. percentilu danih podatkov (okrajšano: **P90, P95, P97.5** ter **P98**, glej tudi Ander et al., 2013). Osemindevetdeseti percentil, ki predstavlja 2 % najvišjih vrednosti, je najbližje izvirni metodi računanja **X2S** v primeru normalne porazdelitve, ki bi v tem primeru določila 2,3 % vrednosti nad zgornjo mejo naravne variabilnosti. S tem pristopom se lahko odkrije nesmiselno visoke mejne vrednosti naravne variabilnosti na zelo velikih območjih, saj ne upoštevajo vpliva ozadja, ki se prostorsko spreminja. Prav tako ne obstaja znanstveni razlog, zakaj bi moralo biti 2, 5 ali 10 % vzorcev določenih za "anomalne". S temi metodami se najenostavneje določi le najvišje vrednosti podatkov, ki so seveda lahko tudi anomalne. Meto-

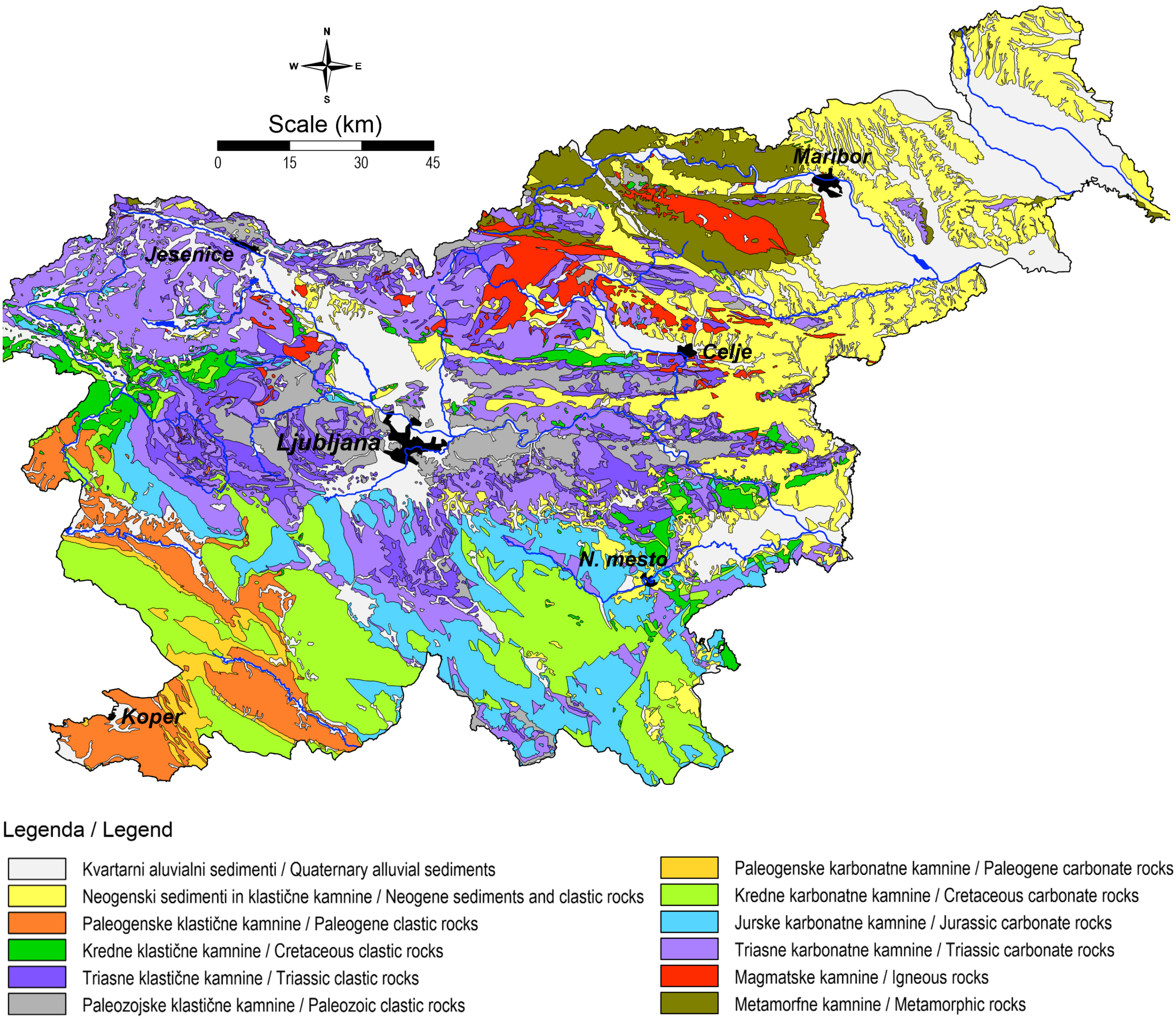

Fig. 6. Basic lithological units (after data from Bavec et al. (2016) and Novak et al. (2016)).

Sl. 6. Osnovne litološke enote (po podatkih iz Bavec et al. (2016) in Novak et al. (2016)).

In Great Britain, cumulative probability diagrams and percentiles (most frequently the 95th percentile) have been used to detect samples deviating from the "normal background deviation" and to identify a case-specific threshold (e.g. Cave et al., 2012; Johnson et al., 2012; Ander et al., 2013).

Geological and pedological settings and smaller spatial units in Slovenia

Geological diversity of Slovenia is a result of a contact between 3 larger geotectonic units in Slovenia. Most of Slovenia is composed of clastic rocks and sediments that comprise around half of Slovenian area and carbonates (limestone and dolomites), that comprise around 40 % of the area. Metamorphic rocks cover around 4 % of the area, pyroclastic rocks are less than 2 % and around 1.5 % of Slovenian area is comprised of igneous rocks (Komac, 2005, fig. 6). There are many soil types in Slovenia, as soil forming factors (lithology, relief, climate, hy-

da je vsekakor zelo praktična, ker je enostavna in ni potrebno, da so podatki normalno porazdeljeni. Zato podatkov tudi ni potrebno transformirati.

V Veliki Britaniji pogosto uporabljajo diagrame kumulativne verjetnosti in percentile (najpogosteje 95. percentil – **P95**) za ugotavljanje vzorcev, ki odstopajo od "normalne variacije v definiranem ozadju" in za določitev geokemičnega praga (zgornjih mej naravne variabilnosti) na določenem območju (npr. Cave et al., 2012; Johnson et al., 2012; Ander et al., 2013).

Geološke in pedološke značilnosti Slovenije in razmejitev na manjše prostorske enote

Slovenija leži na ozemlju stika 3 velikih geotektonskih enot in je zato geološko zelo pestra. Velik del Slovenije sestavljajo klastične kamnine in sedimenti, ki obsegajo približno polovico površine ozemlja Slovenije ter karbonati (apnenci in dolomiti), ki jih je okoli 40 %. Metamorfne kamnine obsegajo približno 4 % površine slovenskega ozemlja, piroklastičnih kamnin je manj kot 2 %, najmanj

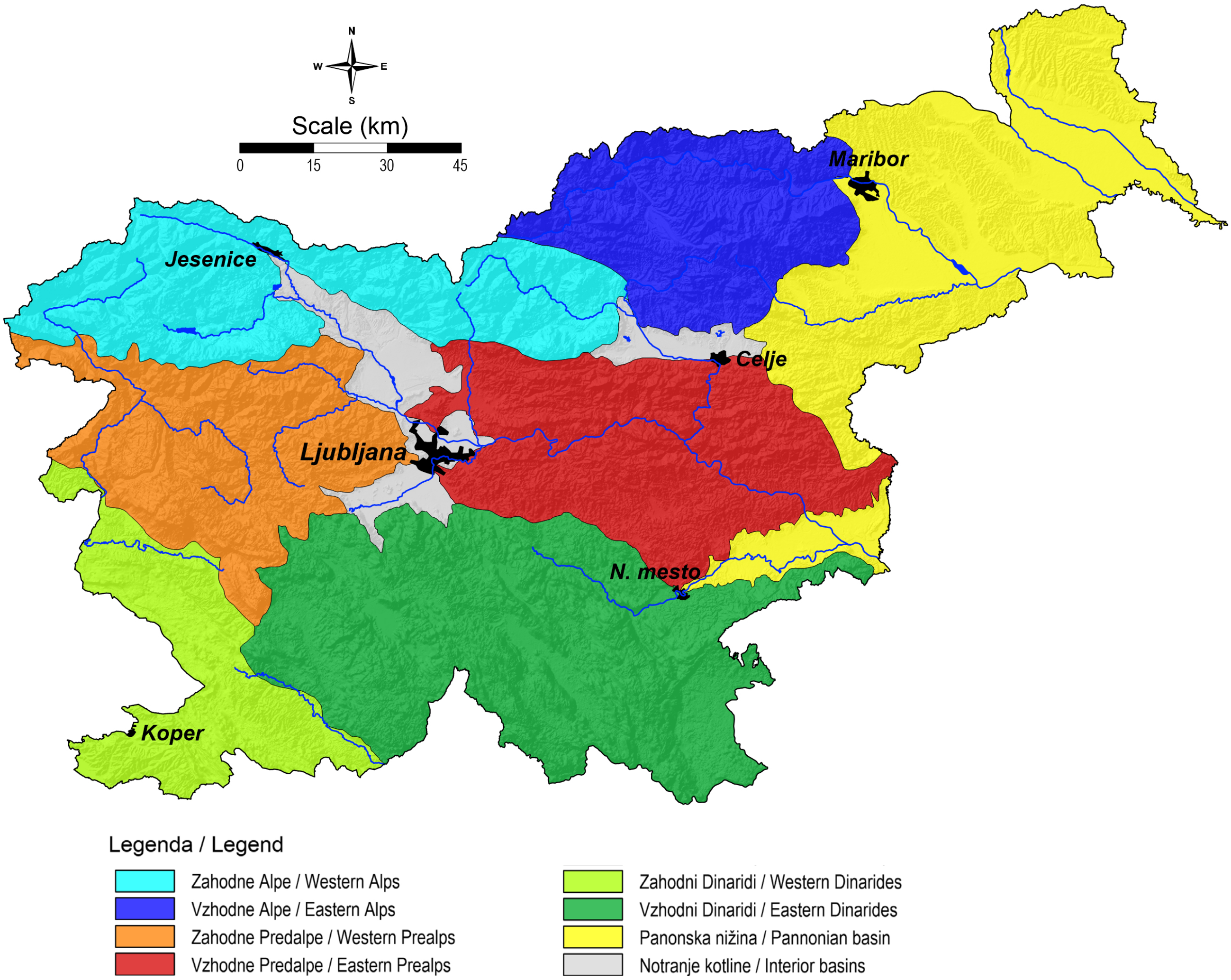

Fig. 7. Smaller spatial units in Slovenija (addapted after Poljak, 1987).

Sl. 7. Prikaz opisanih prostorskih enot v Sloveniji (prirejeno po Poljaku, 1987).

drology, vegetation, organisms and human influence) have a large spatial variability (Vidic et al., 2015). In Slovenia, lithology and relief have the greatest impact on soil formation (Vidic et al., 2015). Most of Slovenia is comprised of carbonate rocks, (including sediments and clastic rocks with carbonate clasts or cement) and soils that forms on these rocks. Lithosols and shallow rendzinas are present on steep slopes in mountain terrains. In areas with gentle slopes, brown soils on limestone and dolomite and rendzinas are present (Vidic et al., 2015). On carbonate flysch in western Slovenia and marlstones in eastern Slovenia are rendzinas and eutric brown soils. Rendzinas are also common on other clastic carbonate sediments as gravel and sand in river valleys (Vidic et al., 2015). Dystric rankers, dystric brown soils and leached soils are present on other noncarbonate clastic rocks and most of metamorphic and igneous rocks. On noncarbonate sediments in valleys of eastern Slovenia (Drava and Ptuj plains, Prekmurje), dystric soils are formed (Vidic et al., 2015).

Next, we present the spatial distribution of Slovenia, that is based on geological structure, lithology, relief, climate and vegetation acocording to suggestions from Poljak (1987). Slovenia was divided into 8 smaller spatial units (Western Alps, Eastern Alps, Western Prealps, Eastern Prealps. Western Dinarides, Eastern Dinarides, Pannonian basin and Interior basins, fig. 7), that we discuss later. Naming of spatial units is valid only for Slovenia and is not related to other units' names in Europe or in the entire Alps. Geological settings are summarized after Geology of Slovenia (Pleničar et al., 2009) and pedological settings after monograph Soils of Slovenia with soil map 1 : 250,000 (Vidic et al., 2015).

(1,5 %) pa je magmatskih kamnin (Komac, 2005, sl. 6). Ker so v Sloveniji tlotvorni dejavniki, torej matična osnova, relief, klima, vodne razmere, rastlinske združbe, dejavnost organizmov in aktivnosti človeka, močno spremenljivi in se pojavljajo v različnih kombinacijah, je tudi talna odeja zelo pestra (Vidic et al., 2015). Največji vpliv na nastajanje tal, in s tem tudi na pestrost talnih tipov v Sloveniji, imata matična podlaga in relief (Vidic et al., 2015). Za Slovenijo je najbolj značilna karbonatna podlaga (karbonatne kamnine ter sedimenti in sedimentne kamnine, ki vsebujejo karbonatna zrna ali vezivo) ter tla, ki se tam razvijajo. V visokogorskih območjih in na strmih pobočjih najdemo litosole in plitve rendzine. V nižjih predelih in na manj strmih pobočjih pa nastopajo skupaj z rendzinami tudi rjava pokarbonatna tla (Vidic et al., 2015). Na karbonatnem flišu zahodne Slovenije in laporovcih vzhodne Slovenije prevladujejo rendzine in evtrična rjava tla. Rendzine se pojavljajo tudi na drugih klastičnih karbonatnih sedimentih, kot so prodi in peski v nekaterih rečnih dolinah (Vidic et al., 2015). Na drugih nekarbonatnih klastičnih kamninah, na večini metamorfnih in magmatskih kamnin so distrični rankerji, distrična rjava tla in rjava izprana tla. V nižinah vzhodne Slovenije (Dravsko, Ptujsko polje, Prekmurje) so na nekarbonatnih sedimentih razvita distrična tla (Vidic et al., 2015).

V nadaljevanju povzemamo prostorsko razdelitev Slovenije, ki smo jo izvedli na podlagi geološke zgradbe, kamninske sestave (litologije), reliefa, podnebja in rastlinstva skladno s predlogi Poljaka (1987). Slovenijo smo razdelili na 8 manjših prostorskih enot (Zahodne Alpe, Vzhodne Alpe, Zahodne Predalpe, Vzhodne Predalpe, Zahodni Dinaridi, Vzhodni Dinaridi, Panonska nižina, Notranje kotline, sl. 7), katerih značilnosti podajamo v nadaljevanju. Prostorske enote smo določili in poimenovali samo za Slovenijo in poimenovanje nima enakega pomena kot v Evropi in celotnih Alpah. Geološke značilnosti so povzete iz monografi-

Table 2. Smaller spatial units in Slovenia and number of samples for each unit (N).
Tabela 2. Prostorske enote v Sloveniji in število pripadajočih vzorcev tal (N).

Prostorske enote – Spatial units	**N**
Zahodne Alpe (Western Alps)	99
Vzhodne Alpe (Eastern Alps)	80
Zahodne Predalpe (Western Prealps)	98
Vzhodne Predalpe (Eastern Prealps)	116
Zahodni Dinaridi (Western Dinarides)	66
Vzhodni Dinaridi (Eastern Dinarides)	163
Panonska nižina (Pannonian basin)	157
Notranje kotline (Interior basins)	38

Samples were collected at a grid of 5 × 5 km and assigned to spatial units according to their spatial distribution in Slovenia. Number of samples (N) in each spatial unit is presented in table 2.

Western Alps

Western Alps cover the area of the Julian Alps, Kamnik Savinja Alps and Karavanke Alps (Karawanks) in which are the highest peaks of Slovenia. Most of this spatial unit comprises area above the tree line, which is reflected in almost no vegetation and shallow (rendzinas) or undeveloped soils. Julian and Kamnik Savinja Alps are predominantly composed of carbonate rocks. The area developed from glacial processes and is influenced by dissolution of limestone in karstic areas. Due to lithology and dissolution of limestone, this area is also called "high or Alpine karst". The Karavanke Alps are a long mountain range along Austrian border which ends near Mežica in the east. Their lithology is diverse, with carbonate rocks, which predominate, clastic and igneous rocks.

The Julian Alps are mostly composed of limestone and dolomite (Dozet & Buser, 2009). Limestone with chert, clay marlstone and limestone with manganese nodules are also present (Buser & Dozet, 2009). Larger areas containing iron ore are in the vicinity of Pokljuka, Bohinj and Jelovica (Ogorelec et al., 2006; Pirc & Herlec, 2009). There are smaller areas of Cretaceous flysch marlstone, located in southern part of the Julian Alps (Pleničar, 2009).

The Kamnik Savinja Alps consist of mostly carbonate rocks and less clastic rocks (Dozet and Buser, 2009). Carbonate conglomerates that transit to marly clay called "sivica" are present on larger area of Smrekovec and Gornji Grad. There are Oligocene volcaniclastic rocks on Smrekovec area and other smaller areas in the Kamnik Savinja Alps (Pavšič & Horvat, 2009).

Carbonate rocks (limestones and dolomites) predominate in the Karavanke Alps. Clastic rocks are also common. Iron, lead, zinc, and antimony ores often occur at the contact of clastic rocks and carbonate rocks (Ramovš & Buser, 2009; Novak & Skaberne, 2009). Igneous rocks, limestone with chert and shales are also present in the Karavanke Alps. Also found in the Karavanke Alps are traces of manganese ore, that was mined in this area.

je Geologija Slovenije (Pleničar et al., 2009), pedološke pa po monografiji Tla Slovenije s pedološko karto v merilu 1 : 250 000 (Vidic et al., 2015).

Vzorčna mesta tal, ki so bila vzorčena v mreži 5 × 5 km, smo v skladu s prikazano prostorsko porazdelitvijo Slovenije, pripisali posameznim prostorskim enotam. V tabeli 2 je navedeno število vzorcev tal (N), odvzetih v posamezni prostorski enoti.

Zahodne Alpe

Zahodne Alpe obsegajo Julijske Alpe, Kamniško Savinjske Alpe in Karavanke, ki reliefno predstavljajo najvišje vrhove v Sloveniji. Večji del te prostorske enote obsega območja nad gozdno mejo, torej je vegetacija skromna, tla so večinoma plitva (rendzine) ali nerazvita. Območje Julijskih in Kamniško Savinjskih Alp je zgrajeno pretežno iz karbonatnih kamnin. To območje se je oblikovalo z ledeniškim delovanjem in je podvrženo recentni kraški eroziji. Zaradi litološke sestave in kraške erozije se območje Alp imenuje tudi "visoki ali alpski kras". Karavanke predstavlja dolg gorski greben, ki se vleče v ozkem pasu ob avstrijski meji do Mežice na vzhodu. Litološka sestava je pestra. Prevladujejo čiste karbonatne kamnine. Najdemo pa tudi raznovrstne klastične in magmatske kamnine.

Julijske Alpe so v večini sestavljene iz apnencev in dolomitov (Dozet & Buser, 2009). Mestoma najdemo apnence z roženci, glinene laporovce ter apnence z manganovimi gomolji (Buser & Dozet, 2009). V okolici Pokljuke – Bohinja ter Jelovice so pomembnejša orudenja železa (Ogorelec et al., 2006; Pirc & Herlec, 2009). V južnem delu Julijskih Alp so manjša območja krednega flišnega laporovca (Pleničar, 2009).

Kamniško Savinjske Alpe sestavljajo večinoma karbonatne kamnine, mestoma izdanjajo tudi klastiti (Dozet & Buser, 2009). Na širšem območju Smrekovca in Gornjega Grada ležijo karbonatni konglomerati, ki prehajajo v laporasto glino ali sivico. Na območju Smrekovca ter v manjših območjih znotraj Kamniško Savinjskih Alp najdemo oligocenske vulkanoklastične kamnine (Pavšič & Horvat, 2009).

V Karavankah prevladujejo karbonatne kamnine (apnenci in dolomiti) različnih starosti. Pogoste so tudi klastične kamnine, kjer se mestoma na njihovem stiku z apnencem pojavljajo orudenja železa, svinca, cinka in antimona (Ramovš & Buser, 2009; Novak & Skaberne, 2009). V Karavankah se mestoma pojavljajo magmatske kamnine. Ponekod najdemo apnence z roženci, skrilave glinavce in sledove manganove rude, ki so jo v preteklosti kratek čas tudi izkoriščali.

Rendzinas (profile A-C or A-R) predominates on carbonate rocks at higher altitudes and steep slopes. Rarely, brown soils (A-B-C) have formed. Dystric brown soils have formed on clastic and volcaniclastic rocks (Vidic et al., 2015).

Eastern Alps

Eastern Alps cover the area of Pohorje, a large massif that is distinctly separated from other areas.

This area is predominantly composed of igneous and metamorphic rocks. Weathering of these rocks causes forming of dystric brown soils and rankers on steeper slopes (Vidic et al., 2015). Pohorje is covered with dense vegetation with conifers, mixed forests and meadows due to fertile soils, wet climate and impermeable lithology.

Central part of the Pohorje range is composed of granodiorite batholith, that is surrounded with metamorphic rocks, of which most special are eclogite and garnet peridotite. In northern part of Pohorje there are mostly mica schists, gneisses, amphibolite and less eclogite and marble. Amphibolite that includes chlorite and epidote is found in southwestern part of Pohorje (Hinterlechner-Ravnik & Trajanova, 2009).

Phyllitic schists with quartzite, metakeratophyre, marble, graphitic slates and amphibole schists with chlorite and epidote represent the transit from lower grade metamorphic rocks to higher metamorphic grade, found west of Kobansko. Mineral garnet is more common (Hinterlechner-Ravnik & Trajanova, 2009). Miocene conglomerate with dacite tuff is present in the Ribnica-Selnica tectonic graben and on Mt. Kozjak (Pavšič & Horvat, 2009).

Quartz sandstones, conglomerates and siltstones compose western part of Eastern Alps. Dolomites, limestones, marlstones and claystone are present in smaller areas (Dozet & Buser, 2009; Buser & Dozet, 2009). In the area around Stranice and Zreče are dolomites with layers of black coal, claystone, siltstones and marlstones. In Velenje valley predominate Plio-Quaternary clastic rocks and sediments that include carbonates and pyroclastic rocks with andesite and dacite. Here are layers of lignite between clastic rocks (Markič, 2009).

Igneous rocks of Pohorje are divided into two groups: Magdalensberg series and Železna Kapla magmatic zone. Magdalensberg series passes along river Meža, via Slovenj Gradec to northwestern Pohorje and area of Remšnik. Central part of the series is composed of felsic igneous

Na karbonatnih kamninah v višjih legah z nekoliko strmejšim reliefom je prevladujoči talni tip rendzina (profil A-C ali A-R), ki le mestoma prehaja v rjava pokarbonatna tla (A-B-C). Na klastičnih in vulkanoklastičnih kamninah so distrična rjava tla (Vidic et al., 2015).

Vzhodne Alpe

Vzhodne Alpe obsegajo Pohorje, velik masiv, ki se ostro loči od sosednjih ozemelj.

Gradijo ga pretežno magmatske in metamorfne kamnine, iz katerih pri preperevanju nastajajo na strmejših delih rankerji, bolj pogosto pa distrična rjava tla (Vidic et al., 2015). Večinoma so to rodovitna tla, ki omogočajo ob obilju padavin in nepropustni geološki podlagi gost vegetacijski pokrov iglavcev, mešanega gozda in travnikov.

Na osrednjem delu grebena Pohorja je granodioritni batolit, ki ga obdajajo metamorfne kamnine. Posebnosti sta eklogit in granatov peridotit. Na severnem delu Pohorja najdemo predvsem blestnik, gnajs in amfibolit, manj je eklogita in marmorja. Amfibolit je tudi na jugozahodnem delu Pohorja, ki tu vključuje klorit in epidot (Hinterlechner-Ravnik & Trajanova, 2009).

Zahodno od Kobanskega so razvite manj metamorfozirane kamnine, ki prehajajo v močneje metamorfozirane kamnine, ki jih predstavljajo filitni skrilavci s kvarcitom, metakeratofir, marmor in grafitni skrilavec ter amfibolovi skrilavci s kloritom in epidotom. Na nekaterih območjih je zelo pogost mineral granat (Hinterlechner-Ravnik & Trajanova, 2009). Na Kozjaku ter v Ribniško-selniškem tektonskem jarku so miocenski konglomerati, ki vsebujejo tudi dacitne tufe (Pavšič & Horvat, 2009).

Na zahodnem območju Vzhodnih Alp so kremenovi peščenjaki, konglomerati in meljevci. Mestoma se pojavljajo dolomiti, apnenci, laporovci in glinavci (Dozet & Buser, 2009; Buser & Dozet, 2009). V okolici Stranic in Zreč so dolomiti s plastmi črnega premoga ter glinavci, meljevci in laporovci. V Velenjski kotlini je veliko plio-kvartarnih klastitov, ki izvirajo iz podlage in jih zastopajo karbonati ter piroklastične kamnine z andezitom in dacitom, med njimi pa je prisoten lignit (Markič, 2009).

Magmatske kamnine na Pohorju izdanjajo na območju štalenskogorske serije in železnokapelske magmatske cone. Štalenskogorska serija poteka vzdolž reke Meže preko Slovenj Gradca na severozahodno Pohorje ter na območje Remšnika. Kisle magmatske kamnine sestavljajo osrednji del serije, na severnem delu serije pa so bazične magmatske kamnine (Trajanova, 2009). Železnorocks and northern part of the series is composed of mafic igneous rocks (Trajanova, 2009). Železna Kapla magmatic zone is exposed along Periadriatic lineament, passes south of Peca, via Koprivna and Črna na Koroškem and plunges beneath the sediments in the vicinity of Mt. Plešivec. Magmatic zone is mostly composed of felsic igneous rocks. Northern part of the magmatic zone is composed of syenogranitic massif and in southern part is a tonalite belt. Syenogranitic massif includes gabbro, monzogabbro, monzodiorite and monzonite (Dobnikar & Zupančič, 2009; Trajanova et al., 2009). Tonalitic belt is composed mostly of hornblende-biotite and biotite tonalite that can transit to granodiorite (Trajanova et al., 2009).

Western Prealps

Prealps have very heterogeneous lithology composed of carbonates, carbonate-clastic rocks and siliciclastic rocks (fig. 6). Lithology has an impact on erosion rate and vegetation. Western Prealps represent the area of central Slovenia, west of Ljubljana basin and comprise the Idrija-Žiri area, Tolmin area, Bača and Selška Sora area, Polhov Gradec hills, Škofja Loka hills, Poljane-Vrhnika area and Trnovski Gozd, Nanos, Hrušica and Javorniki area. Polhov Gradec-Vrhnika area is composed mainly of clastic rocks, such as quartz sandstone and quartz conglomerates (Novak & Skaberne, 2009). Sandstones, conglomerates and siltstones are found in a belt between Cerkno and Smrečje. This area is known for its copper ore and uranium deposit. Limestones, dolomites, marlstones and siltstones predominate in Polhov Gradec hills and Cerkno-Idrija area. In area around Idrija are claystone and sandstones that are rich in mercury ore (Dozet & Buser, 2009). Area between Petrovo Brdo and Železniki is composed of shale mudstones, sandstones, limestones with chert and breccias (Pleničar, 2009). Mafic igneous rocks are found in some places in Škofja Loka hills (Hinterlechner-Ravnik & Trajanova, 2009).

Trnovski gozd, Banjšice, Hrušica, Javorniki and Nanos are composed of carbonate rocks (limestones and dolomites). Bauxite loam and bauxite are present in a belt from Nanos, Hrušica to Žužemberk (Buser & Dozet, 2009).

Limestones with chert are common in the Tolmin area and Škofja Loka hills (Dozet & Buser, 2009). There are manganese deposits and iron manganese nodules between Perbla and Tolminske Ravne (Buser & Dozet, 2009). In some places in the area of Soča river valley are limestone breccias, on top of them occurs marlstone that transits

kapelska magmatska cona poteka vzdolž Periadriatskega prelomnega sistema, južno od Pece, preko Koprivne in Črne na Koroškem in tone pod sedimente v okolici Plešivca. Cono v večini sestavljajo kisle magmatske kamnine. Na severnem delu je sienogranitni masiv, na južnem pa tonalitni. V sienogranitnem masivu so prisotni gabro, monzogabro, monzodiorit in monzonit (Dobnikar & Zupančič, 2009; Trajanova et al., 2009). Tonalitni pas pa sestavlja v večini rogovačno-biotitni in biotitni tonalit, ki ponekod prehaja v granodiorit (Trajanova et al., 2009).

Zahodne Predalpe

Na sliki 6 je razvidno, da imajo Predalpe zelo heterogeno litološko zgradbo. Sestavljajo jo karbonati, karbonatno-klastične in siliciklastične kamnine. Litološka sestava močno vpliva na erozijo in vegetacijo. Zahodne Predalpe zavzemajo osrednji del Slovenije, ki leži zahodno od Ljubljanske kotline in obsegajo Idrijsko-Žirovsko ozemlje s hribovjem okoli Tolmina, ob Bači in Selški Sori, Polhograjsko hribovje, Škofjeloško hribovje, Poljansko-Vrhniško ozemlje ter Trnovski gozd, Nanos, Hrušico in Javornike. Na Polhograjsko-Vrhniškem območju najdemo klastične kamnine, predvsem kremenove peščenjake in kremenove konglomerate (Novak & Skaberne, 2009). V širokem pasu med Cerknim in Smrečjem se pojavljajo peščenjaki, konglomerati in muljevci. V tem območju je veliko rudišč bakra in uranovo rudišče. Obsežno območje Polhograjskega hribovja, Cerkljanskega in Idrijskega sestavljajo apnenci, dolomiti, laporovci in meljevci. Na Idrijskem se menjavajo glinavci in peščenjaki, ki so bogato orudeni s cinabaritom (Dozet & Buser, 2009). Na območju med Petrovim Brdom in Železniki so navzoči skrilavi glinavci, peščenjaki, apnenci z roženci in breče (Pleničar, 2009). V Škofjeloškem hribovju mestoma najdemo bazične magmatske kamnine (Hinterlechner-Ravnik & Trajanova, 2009).

Na območju Trnovskega gozda, Banjške planote, Hrušice, Javornikov ter Nanosa izdanjajo karbonatne kamnine (apnenci in dolomiti). V pasu od Nanosa in Hrušice proti Žužemberku najdemo boksitno ilovico in boksit (Buser & Dozet, 2009).

Na območju Tolmina se pojavljajo ploščati apnenci z roženci, ki jih najdemo tudi na Škofjeloškem hribovju (Dozet & Buser, 2009). Med Perblo in Tolminskimi Ravnami je veliko manganovega orudenja in železovo manganovih gomoljev (Buser & Dozet, 2009). Na območju Posočja se ponekod pojavlja apnenčeva breča, na kateri leži laporovec, ki prehaja v flišne plasti (Pleničar, 2009). Kredne into flysch (Pleničar, 2009). Cretaceous and Paleocene carbonate flysch is composed of red or grey marlstone (Drobne et al., 2009). Lacustrine sediments with predominant carbonate component are sparsely found in upper Soča river valley (Bavec & Pohar, 2009).

Eutric brown soils on flysch are found in westernmost part of Western Prealps. On carbonate rocks of western part of Western Prealps are rendzinas (profile A-C or A-R) on steeper slopes and in more favorable conditions brown soils (A-B-C). In central and eastern part of this spatial unit, clastic rocks and dystric brown soils predominate (Vidic et al., 2015).

Eastern Prealps

Eastern Prealps represent the area of the Sava Folds east of Ljubljana basin. The area consists of ridges and valleys in east–west direction. Similar as Western Prealps, this spatial unit has a very heterogeneous lithology, where clastic rocks predominate. Lithology has an impact on erosion rate and vegetation, that is mostly dense with mixed forest and arable land.

Southern part of the Sava Folds is composed of marlstone, siltstone, claystone, limestone and sandstones. There are more shale mudstones, siltstones, claystone and dolomite in northern part of the Sava Folds, and in central part, limestone and dolomite predominate. Both limestone and dolomite are also sparsely found in southern and northern part of the Sava Folds. Limestone with chert is also present in some areas (Dozet & Buser, 2009). Limestone and dolomite occur in the area of Tuhinj valley and Mirna and south from Sevnica (Buser & Dozet, 2009). Sandstones, conglomerates and siltstones are found in the Radeče area. There are also smaller copper deposits (Skaberne et al., 2009). Clastic sedimentary rocks with vein deposits of Pb, Zn, Hg, Cu, Ba and Sb are sparsely located east of Ljubljana (Novak & Skaberne, 2009).

Clastic flysch rocks can be found in Litija overthrust (Pleničar, 2009). In the area of Bohor are igneous rocks, that can be enriched with Pb and Zn (Trajanova & Grafenauer, 2009).

Northwestern part of the Sava Folds is composed of more conglomerate, followed by clay, marlstone and sandstone. Same rocks with addition of pyroclastic rocks and coal in the area from Laško to Zagorje, are found in eastern part of the Sava Folds. Coal was mined in collieries Zagorje, Trbovlje, Hrastnik, Laško and Senovo (Markič, 2007). Limestone sandstones, quartz sand and clayey marl are present in the areas

in paleocenske karbonatne fliše sestavljajo plasti rdečega ali sivega laporovca (Drobne et al., 2009). Na manjših območjih v zgornjem Posočju najdemo jezerske sedimente, v katerih prevladuje karbonatna komponenta (Bavec & Pohar, 2009).

Na skrajnem zahodnem delu Zahodnih Predalp, kjer so večinoma flišne kamnine, so prevladujoč talni tip evtrična rjava tla. V zahodnem delu, kjer je več karbonatnih kamnin, so na strmejših območjih rendzine (profil A-C ali A-R), ki ob ugodnih pogojih za razvoj tal prehajajo v rjava pokarbonatna tla (A-B-C). V centralnem in vzhodnem delu Zahodnih Predalp prevladujejo klastične kamnine, na katerih so distrična rjava tla (Vidic et al., 2015).

Vzhodne Predalpe

Vzhodne Predalpe obsegajo območje Posavskih gub vzhodno od Ljubljanske kotline, ki predstavljajo vrsto grebenov in dolin v smeri vzhod-zahod. Podobno kot Zahodne Predalpe imajo tudi Vzhodne zelo heterogeno litološko zgradbo. Območje je zgrajeno pretežno iz klastičnih kamnin. Litološka sestava močno vpliva na stopnjo erozije in vegetacijo, ki je večinoma bujna s prevladujočim mešanim gozdom in obdelanimi površinami.

V južnem delu Posavskih gub so laporovci, meljevci, glinavci, apnenci in peščenjaki. V severnem delu je več skrilavega glinavca, meljevca in dolomita, v osrednjem delu Posavskih gub pa prevladujeta apnenec in dolomit, ki se mestoma pojavljata tudi v južnem in severnem delu Posavskih gub. Ponekod se pojavlja tudi apnenec z rožencem (Dozet & Buser, 2009). Več apnenca in dolomita je tudi na območju Tuhinjske doline in Mirne ter južno od Sevnice (Buser & Dozet, 2009). Na območju Radeč izdanjajo peščenjaki, konglomerati in meljevci. Na tem območju so prisotna tudi manjša bakrova orudenja (Skaberne et al., 2009). Vzhodno od Ljubljane se mestoma pojavljajo klastične sedimentne kamnine, v katerih so žilna rudišča Pb, Zn, Hg, Cu, Ba in Sb (Novak & Skaberne, 2009).

V Litijskem narivu so flišne klastične kamnine (Pleničar, 2009). V okolici Bohorja najdemo magmatske kamnine, ki so mestoma obogatene s Pb in Zn (Trajanova & Grafenauer, 2009).

Na severozahodnem delu Posavskih gub najdemo konglomerate, ki jim sledijo glina, laporovec in peščenjak, na vzhodnem delu pa poleg teh še piroklastite ter malo premoga, ki ga več najdemo od Laškega do Zagorja. Premog so izkoriščali v premogovnikih Zagorje, Trbovlje, Hrastnik, Laško in Senovo (Markič, 2007). Na območju of Celje, Senovo and Laško synclines (Pavšič & Horvat, 2009).

Dystric brown soils and rankers predominate in southern and northern part of the Sava Folds, where there are more clastic rocks. Eutric brown soils are present on carbonate clastic rocks in eastern part of this spatial unit. Rendzinas (profile A-C or A-R) and brown soils (A-B-C) are most common on carbonate rocks in the central part of the Sava Folds (Vidic et al., 2015).

Western Dinarides

Western Dinarides are represented with wide valleys (Vipava valley, Matarsko podolje), hills and the large Karst plateau (in Slovene: Kras) that have a typical Dinaric northwest–southeast direction. Climate and vegetation are submediterranean.

Kras plateau, Čičarija and Matarsko podolje are composed mainly of limestone and dolomite with breccia with bauxite clay. In some areas, limestones include nodules and sheets of chert. Around Lipica and Sečovlje area are layers of coal (Pleničar, 2009).

Large area of Western Dinarides is covered with flysch (layers of marl, sandstone and carbonate turbidite). Red and grey marlstones are present in Vipava valley, Goriška Brda and Koper hills (Drobne et al., 2009). Flysch in Goriška Brda is of Cretaceous age (Pleničar, 2009). There is also limestone in the area of Goriška Brda (Drobne et al., 2009).

Boundary between Cretaceous and Tertiary rocks is best visible on Kras plateau between Sežana and Kozina. Rocks from the area of the boundary have increased contents of iridium, mercury and rare earth elements (Pleničar, 2009). On the boundary is also an increase in content of Ga, Sm, Zr, Co, Ni and V (Drobne et al., 2009). Limestone sparsely occurs in the area of flysch rocks.

Brown soils and rendzinas predominate on carbonate rocks (limestones and dolomites). Variation of brown soils, brown and red brown soils called also terra rossa is found on Kras plateau. Terra rossa forms on hard limestones and dolomites in submediterranean climate. Cambic horizon is brown-red to red. Organic (A) horizon is thin and poor in humus as organic matter quickly decays and mineralizes due to warm and dry climate. Contact with rocks is not straight, pockets of soil are common. Eutric brown soils predominate in the area of carbonate flysch rocks (Vipava valley, Goriška Brda and Koper hills). Dystric brown soils are present on flysch rocks in southeastern part of Western Dinarides (Vidic et al., 2015).

Celjske, Senovške in Laške sinklinale so apnenčevi peščenjaki, kremenov pesek in glinast lapor (Pavšič & Horvat, 2009).

Na južnem in severnem delu območja, kjer je več klastičnih kamnin, so distrična rjava tla in rankerji. Na karbonatnih klastičnih kamninah predvsem v vzhodnem delu Vzhodnih Predalp so evtrična rjava tla. V osrednjem delu so na karbonatnih kamninah rendzine (profil A-C ali A-R) in rjava pokarbonatna tla (A-B-C) (Vidic et al., 2015).

Zahodni Dinaridi

Zahodne Dinaride sestavljajo široke doline (Vipavska dolina, Matarsko podolje), gričevja in obsežna planota Kras, ki se raztezajo v smeri severozahod–jugovzhod. Podnebje in rastlinstvo sta submediteranska.

Na planoti Kras najdemo apnenec in dolomit ter nekaj breče z boksitno glino. Podobno je tudi v Čičariji in Matarskem podolju. Ponekod apnenec vsebuje leče in pole roženca. V okolici Lipice in v Sečovljah najdemo plasti premoga (Pleničar, 2009).

Velik del območja Zahodnih Dinaridov obsega fliš (plasti laporja, peščenjaka in karbonatnega turbidita). V Vipavski dolini, Goriških Brdih in Koprskem gričevju najdemo rdeče in sive laporovce (Drobne et al., 2009). Na območju Goriških Brd najdemo kredni fliš (Pleničar, 2009) in apnenec (Drobne et al., 2009).

Meja med krednimi in terciarnimi plastmi je najbolje vidna na Krasu med Sežano in Kozino in je zaznamovana s povišanjem iridija, kamnine vsebujejo tudi več živega srebra (Hg) in redkih zemelj (Pleničar, 2009). Na meji kreda/terciar so povišane tudi vsebnosti nekaterih drugih elementov: Ga, Sm, Zr, Co, Ni, V (Drobne et al., 2009). Mestoma se apnenec nahaja tudi na območju flišnih kamnin.

Na karbonatnih kamninah (apnenci in dolomiti) prevladujejo rjava pokarbonatna tla in rendzine. Na Krasu večkrat najdemo poseben različek rjavih pokarbonatnih tal, imenovan jerovica (terra rossa). Jerovice nastajajo na trdih apnencih in dolomitih, kjer se pojavlja submediteransko podnebje. Kambični horizont je izrazito rdeče barve. Horizont A je slabo izražen in zato slabo opazen, saj organska snov zaradi toplega in suhega podnebja hitro razpade in se mineralizira. Stik z matično podlago je izrazito neenakomeren, žepast. Na območju karbonatnih flišnih kamnin (Vipavska dolina, Goriška Brda in Koprsko gričevje) so evtrična rjava tla, na flišnih kamninah v jugovzhodnem delu Zahodnih Dinaridov pa so distrična rjava tla (Vidic et al., 2015).

Eastern Dinarides

Eastern Dinarides represent hilly karstic landscape with altitudes to 1000 meters with typical vegetation of mixed to broadleaf forests and meadows. Similar as Western Dinarides, hill ridges have a northwest–southeast direction. Bela Krajina plateau in the east represents the transition to the Pannonian basin. Limestones and dolomites predominate in this area. The area of Eastern Dinarides is also called “low or Dinaric karst”. Brown soils predominate as soil type (Vidic et al., 2015).

Most of the Eastern Dinarides area is composed of limestones and dolomites and in some areas also marlstone, claystone and sandstone. Bituminous dolomite and limestone are found in the area of Cerknica lake, Logatec hills, Kočevje and Bela Krajina, where also coal can be present. Dolomite and bituminous dolomite predominate in Krim hills area, where limestone is also present. Bauxite loam and bauxite are present in a belt from Nanos, Hrušica, via Rakek, Vrhnika, Grosuplje, Krka to Žužemberk. Snežnik area is composed of limestone and breccia with bauxite clay. Area between Tržišče, Škocjan and Krško hills and Gorjanci area is comprised of clayey and marly shales with chert and limestone (Pleničar, 2009).

Marly limestone, limestone marlstone or claystone, tuffs and tuffite compose the area of Dolenjska around Mišji Dol and Primskovo (Dozet & Buser, 2009). Quartz conglomerates and quartz sandstones appear in the area around Ortnek and south of Kočevje (Novak & Skaberne, 2009). Flysch with red and grey marlstone is found in Pivka valley (Drobne et al., 2009).

Around Ilirska Bistrica is grey clay, lying on top of lignite. Coal was found south of Črnomelj and in Kočevje area. Red and brown clay spreads from Šmarje and Grosuplje via Ivančna Gorica to Trebnje and Mirna valley and in Mirna Peč and Novo mesto area. These rocks can include chert (Markič, 2009).

Most of the area of Eastern Dinarides is covered with brown soils and less rendzinas on carbonate rocks. Eutric brown soils formed on carbonate flysch rocks and dystric brown soils formed on siliciclastic rocks. The area of Bela Krajina is covered with leached soils and in some places with terra rossa, that does not form in this area any longer (Vidic et al., 2015).

Pannonian basin

Pannonian basin in Slovenia is known for its wide river valleys (Mura, Drava and Krško basin) and low hills (Goričko, Slovenske gorice and

Vzhodni Dinaridi

V Vzhodnih Dinaridih prevladuje hribovit kraški svet, ki leži na nadmorski višini do 1000 metrov, z vegetacijo mešanega do listnatega gozda s travniki. Podobno kot v Zahodnih Dinaridih se hribovja raztezajo v smeri severozahod–jugovzhod. Na vzhodu je Belokranjska planota, ki predstavlja prehod v Panonsko nižino. Ozemlje je v večini sestavljeno iz apnencev in dolomitov. Vzhodni Dinaridi se imenujejo tudi “nizki ali dinarski kras”. Prevladujoči talni tip so rjava pokarbonatna tla (Vidic et al., 2015).

Apnenec in dolomit (mestoma tudi laporovec, glinavec in peščenjak) gradita večino območja Vzhodnih Dinaridov. Na območju Cerkniškega jezera, Logaške planote, Kočevskega in Bele Krajine izdanja bituminozni dolomit, ki ponekod prehaja v apnence. Pojavljajo se tudi leče premoga. V Krimskem pogorju in v njegovi okolici je apnenec, prevladujeta pa dolomit in bituminozen dolomit. V pasu Nanos, Hrušica, Rakek, Vrhnika, Grosuplje, Krka, Žužemberk sta prisotna boksitna ilovica in boksit. Območje Snežnika je zgrajeno iz apnenca in breče z boksitno glino. Na območju med Tržiščem in Škocjanom ter proti Krškem hribovju in na Gorjancih so razviti glinasti in laporasti skrilavci z rožencem in apnencem (Pleničar, 2009).

Na Dolenjskem v okolici Mišjega Dola in Primskovega so črni laporasti apnenci, apnenčevi laporovci ali glinavci, tufi in tufiti (Dozet & Buser, 2009). V okolici Ortneka in južno od Kočevja so kremenovi konglomerati in kremenovi peščenjaki (Novak & Skaberne, 2009). V Pivški kotlini izdanjajo flišne kamnine s plastmi rdečega in sivega laporovca (Drobne et al., 2009).

V okolici Ilirske Bistrice najdemo sivo glino nad lignitom. Premog so odkrili tudi južno od Črnomlja ter v okolici Kočevja. Rdeče in rjave gline se razširjajo od Šmarja in Grosupljega preko Ivančne Gorice do Trebnjega ter v Mirnski dolini in v okolici Mirne Peči in Novega mesta. Ponekod vsebujejo veliko rožence (Markič, 2009).

Na večini ozemlja Vzhodnih Dinaridov so rjava pokarbonatna tla in redkeje rendzine na karbonatnih kamninah. Na karbonatnih flišnih kamninah so evtrična rjava tla, na siliciklastičnih kamninah pa distrična rjava tla. Na območju Bele Krajine so izprana tla, najdemo pa tudi jerovice (terra rosse), ki danes na tem območju ne nastajajo več (Vidic et al., 2015)

Panonska nižina

Panonsko nižino v Sloveniji zaznamujejo široke rečne doline (Murski, Dravski in Krški bazen) in nizka hribovja (Goričko, Slovenske gorice in

Haloze with Kozjansko). River valleys are filled with gravel, sand and clay. Higher altitudes comprise clastic rocks and sediments, such as sandstone and marl. Due to the lithology, this area has a rugged terrain with intensive erosion and hydrogeological regime that is in favor to forming fertile soils, suitable for intensive agriculture.

Larger areas of Pannonian basin are composed of clastic rocks and sediments with vein quartz gravel and less chert, mica schists, diabase and andesite. Between these, lignite can be present. In some areas are coal, clay or "sivica" clay. Sandy and clayey marl, sandstone, sand, gravel and conglomerate and less limestone are present in the area of Štajerska basin and Mura basin. In Mura and Drava basin area are deposits of oil and gas (Pavšič & Horvat, 2009).

Gravel, sand and clay that originate from carbonate and metamorphic rocks from Central Alps are found in the area of Goričko, Ljutomerske and Lendavske gorice and river valleys between them. In Goričko, traces of vulcanism can also be seen. Clays can contain iron or manganese oxides and hydroxides. Most of them are found in Krško basin and Bizeljsko where they are also limonitized (Markič, 2009). Marlstones, calcarenites and other carbonate rocks, mainly limestone comprise the area in Krško basin around Čatež (Pavšič & Horvat, 2009).

Eutric brown soils formed on carbonate sediments (gravel, sand, marl and flysch) on low relief. They are more common in Krško basin. Dystric brown soils have formed on noncarbonate sediments, mostly in Drava and Mura basin. Weakly-developed soils, such as rendzinas and rankers are scarce. Alluvial soils and hypogleys formed on extensive river plains (Drava, Mura). Pseudogleys developed on hill slopes (Vidic et al., 2015).

Interior basins

Larger valleys are located within Alps, Prealps and Dinarides. The largest ones are Ljubljana-Kranj and Celje basin. They represent densely populated plains. Ljubljana-Kranj basin is filled with sediments of glacial, fluvio-glacial and lacustrine-glacial origin. Celje basin is a fertile valley filled with river sediments. In older river terraces, sediments have formed rocks (conglomerate, sandstone, tillite).

Celje basin is filled with sediments from gravel to clay. Gravel is mainly composed of carbonates, sandstone, keratophyre, diabase and chert (Markič, 2009).

Haloze s Kozjanskim). Rečne doline so zapolnjene s prodom, peskom in glino. Višji predeli so iz klastičnih kamnin in sedimentov, kot so peščenjaki in laporji. Zaradi tovrstne litološke sestave je razvit razčlenjen relief z intenzivnimi erozijskimi pojavi in hidrogeološkim režimom, ki je ugoden za nastanek rodovitnih tal, primernih za intenzivno poljedelstvo.

Večji del Panonske nižine gradijo klastične kamnine in sedimenti s prodniki žilnega kremena in manj rožencа ter zelo malo blestnika, diabaza in andezita. Vmes se pojavlja tudi lignit. Mestoma se pojavljajo vložki premoga in gline ali sivice. Na območju Štajerskega bazena in Murskega bazena so peščeni in glinasti lapor, peščenjak, pesek, prod in konglomerat ter malo apnenca. Na območju Murskega in Dravskega bazena so nahajališča nafte in zemeljskega plina (Pavšič & Horvat, 2009).

Na območju Goričkega, Ljutomerskih in Lendavskih goric in v vmesnih rečnih dolinah najdemo prod, pesek in glino iz karbonatnih in metamorfnih kamnin, ki izvirajo iz Centralnih Alp. Na Goričkem so sledovi vulkanizma. Gline ponekod vsebujejo več železovih in manganovih oksidov in hidroksidov. Veliko teh kamnin najdemo tudi v Krškem bazenu in na Bizeljskem, kjer so tudi limonitizirane (Markič, 2009). V Krškem bazenu v okolici Čateža se menjavajo laporovci, kalkareniti ter druge karbonatne kamnine, predvsem apnenci (Pavšič & Horvat, 2009).

Zaradi blagega reliefa so na podlagi iz karbonatnih sedimentov (prod, pesek, lapor, fliš) razvita evtrična rjava tla, ki se pogosteje pojavljajo v Krškem bazenu, na nekarbonatnih pa distrična rjava tla predvsem v Dravskem in Murskem bazenu. Manj razvita tla, kot so rendzine in rankerji, so zelo redka. Na obsežnih ravninah ob rekah (Drava, Mura) so razvita obrečna tla in hipogleji, na pobočjih gričevij so ponekod psevdogleji (Vidic et al., 2015).

Notranje kotline

Znotraj Alp, Predalp in Dinaridov so večje kotline. Največji sta Ljubljansko-Kranjska in Celjska kotlina. Predstavljata gosto naseljeni nižini. Ljubljansko-Kranjska kotlina je zapolnjena s sedimenti ledeniškega, rečno-ledeniškega in jezersko-ledeniškega nastanka. Celjska kotlina je rodovitna dolina, ki sestoji iz rečnih sedimentov. V starejših terasah so sedimenti sprijeti v kamnine (konglomerat, peščenjak, tilit).

V Celjski kotlini najdemo sedimente velikosti od prodov do gline. Prode sestavljajo karbonati, peščenjaki, keratofir, diabaz in roženec (Markič, 2009).

Ljubljana basin is filled with gravel, sand and clay. In Bled lake and Radovljica area are carbonate sediments (silt and clay). Ljubljana moor is filled with gravels, sandy gravels and silty gravels with lacustrine and paludal sediments (Bavec & Pohar, 2009).

Juvenile soils, that formed on alluvial plains, predominate in Interior basins. In some areas, the soils are affected by streams that accumulate recent material. Brown soils formed on sediments and alluvial soils formed next to rivers. Leached soils appear in northwestern part of Ljubljana-Kranj basin. In Ljubljana moor area, topogenic peat soils have formed (Vidic et al., 2015).

Results and discussion

Table 3 shows basic statistical parameters, that were determined by parametric and nonparametric statistical methods for chemical elements Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Hf, Hg, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, S, Sb, Sc, Se, Sn, Sr, Te, Th, Ti, Tl, U, V, Y, Zn, Zr. The basic statistical parameters are mean, geometric mean, median, maximum and minimum, quartiles and percentiles (Q1 (=P25), Q2 (=P50=Md), Q3 (=P75)), skewness and kurtosis. Basic statistical parameters are shown for whole of Slovenia (table 3) and separately for smaller spatial units in appendix 1/1-8.

Box and whiskers diagrams were made for 9 major elements and for 11 trace elements (figs. 8 and 9). Box represent interquartile range (lower boundary of the box represents 1st quartile, upper boundary represents 3rd quartile) and whiskers represent Tukey inner fence (TIF). Concentration value axis scale is logarithmic.

Table 4 shows calculated geochemical threshold values (X2S, MD2MAD, TIF, P95, P97.5) for 47 chemical elements (Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Hf, Hg, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, S, Sb, Sc, Se, Sn, Sr, Te, Th, Ti, Tl, U, V, Y, Zn, Zr) for whole of Slovenia.

In appendix 2/1-8 geochemical threshold values (X2S, MD2MAD, TIF, P95, P97.5) for smaller spatial units in Slovenia are presented.

Due to nature of geochemical data, which is generally applicable for the data set in question, logarithmic data transformation is required. Skewness and kurtosis values imply that our data set does not have a normal data distribution. Therefore, we calculated geochemical thresholds using log-transformed data (labeled L). Results were afterwards back transformed.

Na območju Ljubljanske kotline so prodi, peski in glina. V Blejskem jezeru je karbonatni sediment (melj in glina), ki ga najdemo tudi v širši okolici Radovljice. Na Ljubljanskem barju so prodni, meljasti in peščeno prodni nanosi z jezerskimi in močvirskimi sedimenti (Bavec & Pohar, 2009).

V kotlinah prevladujejo mlada tla, razvita na aluvialnih ravninah, ki so mestoma še pod vplivom vodotokov, ki stalno prinašajo material. Na sedimentih so razvita rjava tla, ob rekah pa obrečna tla. V severozahodnem delu Ljubljansko-Kranjske kotline so pogosta izprana tla. Na Ljubljanskem barju so šotna tla (Vidic et al., 2015).

Rezultati in diskusija

V tabeli 3 so prikazani osnovni statistični parametri, ki smo jih določili na osnovi parametričnih in neparametričnih statističnih metod za naštete kemične elemente Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Hf, Hg, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, S, Sb, Sc, Se, Sn, Sr, Te, Th, Ti, Tl, U, V, Y, Zn, Zr. Izraženi so kot aritmetična srednja vrednost, geometrijska srednja vrednost, mediana, najmanjša in največja vrednost, kvartili oziroma percentili (Q1 (=P25), Q2 (=P50=Md), Q3 (=P75)), asimetričnost in sploščenost. Izsledki statističnih obdelav so prikazani tabelarično za celotno Slovenijo (tabela 3) in za manjše prostorske enote v prilogi 1/1-8.

Za 9 glavnih prvin in 11 slednih prvin smo izdelali diagrame škatel z brki (sl. 8 in 9), kjer škatla predstavlja medkvartilni razpon (spodnja meja je 1. kvartil, zgornja meja pa 3. kvartil), brki pa predstavljajo Tukeyevo notranjo mejo (TIF). Naj opozorimo, da je merilo osi, ki prikazuje vsebnosti elementov, logaritemsko.

V tabeli 4 navajamo izračunane vrednosti zgornje meje naravne variabilnosti (X2S, MD-2MAD, TIF, P95, P97.5) za 47 elementov (Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Hf, Hg, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, S, Sb, Sc, Se, Sn, Sr, Te, Th, Ti, Tl, U, V, Y, Zn, Zr) za celotno Slovenijo.

V prilogi 2/1-8 podajamo izračunane vrednosti zgornje meje naravne variabilnosti (X2S, MD-2MAD, TIF, P95, P97.5) manjših prostorskih enot v Sloveniji.

Zaradi narave porazdelitve geokemičnih podatkov, ki velja na splošno in za obravnavani set podatkov, je potrebna logaritemska transformacija podatkov. Vrednosti asimetričnosti in sploščenosti sta pokazali, da podatki nimajo normalne porazdelitve. Zato v nadaljevanju razpravljamo o mejah naravne variabilnosti, ki smo jih izračuna-

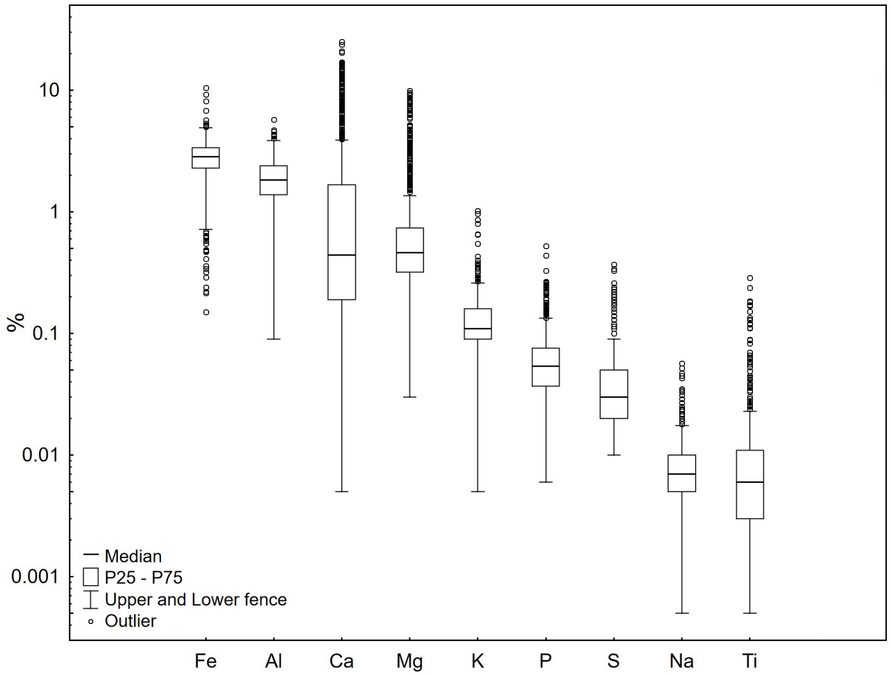

Fig. 8. Box and whiskers plot for major elements.

Sl. 8. Diagrami škatle z brki za glavne prvine.

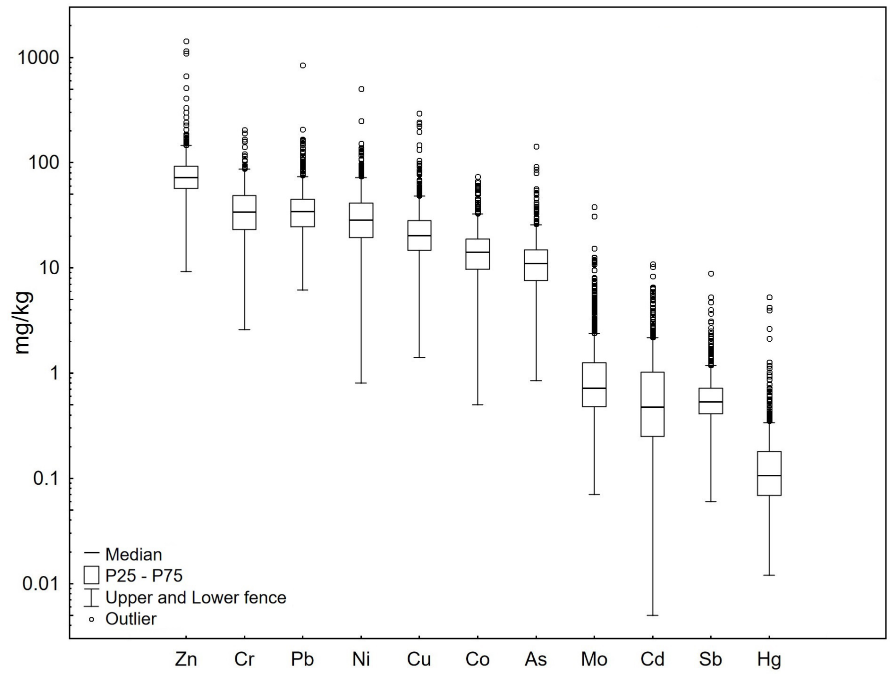

Fig. 9. Box and whiskers plot for PTEs (As, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Sb and Zn).

Sl. 9. Diagrami škatle z brki za PTE (As, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Sb in Zn).

In Europe, most of the element distributions clearly show the differences between the composition of the northern and southern parts of Europe. In northern Europe, influence of glaciation is obvious for most elements (Reimann et al., 2018). Reimann et al. (2018) showed soil composition data separately for northern and southern Europe, of which Slovenia is a part of. Therefore, the Slovenian soil element concentrations were compared with the soil concentrations of Europe and of southern Europe. Comparison of the element concentration in Slovenia with Europe shows that most of element concentrations are higher in Slovenia than in the whole Europe and also in the southern Europe.

li z logaritmiranimi podatki (oznaka L). Končni rezultati so antilogaritmirani.

V Evropi večina porazdelitev elementov jasno kaže razlike med sestavo severnega in južnega dela Evrope. Zelo opazen je vpliv poledenitve v severnem delu Evrope (Reimann et al., 2018). Zato je Reimann s sodelavci (2018) prikazal ločene podatke o sestavi tal za severno in južno Evropo, v katero je bila vključena tudi Slovenija. Zato naše podatke v nadaljevanju primerjamo z južno in celotno Evropo. Primerjava vsebnosti elementov v Sloveniji in južni Evropi kaže, da so vsebnosti večine elementov v Sloveniji večje kot v južni Evropi. Mediane večine elementov v Sloveniji prese-

Table 3. Basic statistical parameters for Slovenia.
Tabela 3. Osnovni statistični parametri za Slovenijo.

	Unit	$\bar{X}$	X(G)	Md	Min	Max	P25	P75	A	E	A(L)	E(L)
Ag	µg/kg	78	63	62	1.0	1200	43	93	7.75	95.39	−0.17	2.95
Al	%	1.9	1.7	1.8	0.090	5.7	1.4	2.4	0.53	0.74	−1.39	4.06
As	mg/kg	13	11	11	0.85	140	7.6	15	5.67	56.73	−0.25	1.94
Au	µg/kg	2.5	1.7	1.7	0.10	110	1.1	2.7	14.62	274.70	−0.36	3.12
B	mg/kg	2.8	1.9	2.0	0.50	36	1.0	4.0	3.90	31.11	−0.07	−0.68
Ba	mg/kg	83	71	75	3.2	820	55	100	5.36	61.52	−0.89	3.52
Be	mg/kg	1.0	0.89	0.90	0.050	3.5	0.60	1.3	0.98	0.86	−0.78	2.17
Bi	mg/kg	0.36	0.32	0.33	0.020	1.3	0.24	0.43	1.28	2.53	−0.49	1.79
Ca	%	2.0	0.55	0.44	0.0050	25	0.19	1.7	2.74	8.07	0.16	−0.37
Cd	mg/kg	0.85	0.50	0.47	0.0050	11	0.25	1.0	3.86	21.40	−0.16	1.32
Ce	mg/kg	39	33	38	1.8	130	24	52	0.50	0.61	−1.22	1.88
Co	mg/kg	15	13	14	0.50	74	9.7	19	1.95	7.02	−1.12	3.34
Cr	mg/kg	38	32	34	2.6	210	23	49	2.40	11.35	−0.56	1.01
Cs	mg/kg	1.5	1.3	1.4	0.050	7.0	0.88	2.0	1.26	2.89	−0.90	1.73
Cu	mg/kg	25	21	20	1.4	300	15	28	6.14	54.76	0.07	2.41
Fe	%	2.8	2.6	2.9	0.15	10	2.3	3.4	0.85	7.03	−2.16	7.63
Ga	mg/kg	5.3	4.8	5.2	0.20	19	3.8	6.7	0.75	1.84	−1.33	3.66
Hf	mg/kg	0.071	0.047	0.050	0.010	0.37	0.020	0.10	1.44	2.38	−0.29	−0.95
Hg	mg/kg	0.17	0.12	0.11	0.012	5.3	0.069	0.18	10.38	135.24	0.84	2.09
In	mg/kg	0.039	0.033	0.040	0.010	0.25	0.030	0.050	2.31	15.37	−0.57	0.06
K	%	0.13	0.12	0.11	0.0050	1.0	0.090	0.16	4.58	34.47	0.03	3.18
La	mg/kg	18	15	17	1.0	82	11	24	1.16	4.01	−1.05	1.43
Li	mg/kg	20	17	19	0.30	150	13	24	4.27	37.31	−1.36	5.22
Mg	%	0.98	0.54	0.46	0.030	9.9	0.32	0.74	3.40	12.11	0.81	1.31
Mn	mg/kg	960	760	790	17	7200	520	1200	2.42	12.41	−0.75	2.10
Mo	mg/kg	1.4	0.84	0.72	0.070	38	0.48	1.3	7.83	92.88	0.81	1.05
Na	%	0.0079	0.0063	0.0070	0.0005	0.057	0.0050	0.010	3.03	16.49	−0.72	1.75
Nb	mg/kg	0.75	0.54	0.60	0.025	7.8	0.31	1.0	2.95	20.64	−0.44	0.05
Ni	mg/kg	34	27	29	0.80	500	20	41	6.58	90.17	−0.57	1.99
P	%	0.063	0.053	0.054	0.0060	0.52	0.037	0.076	3.57	23.20	0.01	0.82
Pb	mg/kg	40	34	34	6.2	850	25	45	13.93	294.78	0.39	2.38
Rb	mg/kg	19	17	18	0.40	94	13	23	1.79	9.53	−1.29	4.85
S	%	0.043	0.032	0.030	0.010	0.37	0.020	0.050	3.49	17.45	0.13	0.00
Sb	mg/kg	0.64	0.54	0.53	0.060	8.9	0.41	0.72	7.11	84.55	0.22	2.42
Sc	mg/kg	4.2	3.7	3.9	0.20	19	2.8	5.3	1.27	3.97	−0.86	2.11
Se	mg/kg	0.44	0.35	0.40	0.050	2.6	0.28	0.55	2.19	8.38	−0.69	1.03
Sn	mg/kg	1.3	1.1	1.1	0.10	25	0.80	1.6	11.77	215.39	0.30	2.37
Sr	mg/kg	30	16	14	1.6	940	8.5	25	7.58	76.43	0.95	1.59
Te	mg/kg	0.049	0.035	0.040	0.010	0.24	0.020	0.070	1.39	2.18	−0.14	−1.09
Th	mg/kg	4.3	3.6	4.1	0.050	17	2.7	5.7	0.59	0.91	−1.50	3.85
Ti	%	0.012	0.0057	0.0060	0.0005	0.29	0.0030	0.011	6.26	49.64	0.25	0.63
Tl	mg/kg	0.32	0.26	0.23	0.050	1.3	0.16	0.43	1.56	2.63	0.24	−0.57
U	mg/kg	1.1	0.96	1.0	0.10	10	0.70	1.4	3.69	28.00	−0.11	0.91
V	mg/kg	49	40	40	3.0	230	28	60	2.07	5.43	−0.11	0.68
Y	mg/kg	14	11	11	0.78	110	7.1	16	3.67	21.09	−0.09	0.86
Zn	mg/kg	83	72	72	9.2	1400	57	92	11.10	152.99	0.52	6.37
Zr	mg/kg	2.4	1.5	1.8	0.050	12	0.80	3.4	1.44	2.18	−0.85	0.79

$\bar{X}$ – aritmetična sredina/arithmetic mean; X(G) – geometrijska sredina/geometric mean; Md – mediana/median (Q2); Min – minimium/minimum; Max – maksimum/maximum; P25 – 25. percentil/ 25th percentile (Q1), P75 – 75. percentil/75th percentile (Q3); A – asimetričnost/skewness; E – sploščenost/kurtosis; A(L) – asimetričnost (logaritmirane vrednosti)/skewness (logarithmic values); E(L) – sploščenost (logaritmirane vrednosti)/kurtosis (logarithmic values)

Table 4. Determined thresholds for Slovenia.
Tabela 4. Zgornje meje naravne variabilnosti za Slovenijo.

	Unit	P95	P97.5	X2S	X2S(L)	MD2MAD	MD2MAD(L)	TIF	TIF(L)
Ag	µg/kg	170	210	220	230	130	190	170	300
Al	%	3.3	3.5	3.5	4.6	3.3	4.1	3.9	5.4
As	mg/kg	25	34	32	34	22	30	26	40.9
Au	µg/kg	5.8	8.1	13	9.2	3.8	6.2	5.1	10.4
B	mg/kg	8.0	9.5	8.4	11	5.0	16	8.5	32.0
Ba	mg/kg	150	200	190	220	140	180	170	250
Be	mg/kg	2.1	2.4	2.1	2.8	1.8	3.0	2.4	4.1
Bi	mg/kg	0.68	0.80	0.69	0.83	0.60	0.80	0.72	1.0
Ca	%	11	14	9.4	15	1.4	7.3	3.9	44.2
Cd	mg/kg	2.7	4.0	3.1	4.0	1.3	3.6	2.2	8.4
Ce	mg/kg	71	80	78	120	80	110	94	160
Co	mg/kg	30	38	34	47	28	39	32	50.7
Cr	mg/kg	75	89	85	110	71	100	88	150
Cs	mg/kg	3.3	3.7	3.4	5.0	3.0	4.6	3.7	7.0
Cu	mg/kg	53	68	70	69	40	54	49	75.6
Fe	%	4.3	4.5	4.8	6.5	4.4	5.0	5.0	6.0
Ga	mg/kg	9.4	10	10	14	9.3	12	11	15.7
Hf	mg/kg	0.20	0.23	0.19	0.33	0.17	0.39	0.22	1.1
Hg	mg/kg	0.44	0.66	0.82	0.54	0.24	0.41	0.35	0.76
In	mg/kg	0.070	0.090	0.083	0.11	0.070	0.094	0.080	0.11
K	%	0.25	0.32	0.31	0.32	0.20	0.28	0.27	0.38
La	mg/kg	34	39	38	57	36	51	43	76.5
Li	mg/kg	36	43	44	58	35	44	40	58.1
Mg	%	4.5	6.5	4.1	3.7	0.99	1.5	1.4	2.6
Mn	mg/kg	2200	2700	2330	3200	1800	2900	2300	4600
Mo	mg/kg	4.8	6.8	6.3	5.0	1.7	2.9	2.4	5.3
Na	%	0.018	0.021	0.020	0.026	0.016	0.020	0.018	0.028
Nb	mg/kg	1.9	2.3	2.0	3.0	1.5	3.2	2.0	5.8
Ni	mg/kg	78	94	92	110	60	87	74	130
P	%	0.13	0.18	0.15	0.17	0.11	0.15	0.13	0.22
Pb	mg/kg	82	110	110	96	64	84	75	110
Rb	mg/kg	34	39	36	47	31	39	37	51.8
S	%	0.11	0.17	0.12	0.14	0.060	0.10	0.095	0.20
Sb	mg/kg	1.4	1.7	1.7	1.6	0.97	1.2	1.2	1.7
Sc	mg/kg	7.8	9.1	8.4	11	7.5	10	9.1	13.8
Se	mg/kg	1.0	1.2	1.1	1.5	0.84	1.0	0.96	1.6
Sn	mg/kg	2.5	3.0	3.7	3.2	2.3	2.8	2.8	4.5
Sr	mg/kg	96	180	160	110	34	69	50	130
Te	mg/kg	0.13	0.15	0.13	0.20	0.13	0.31	0.15	0.46
Th	mg/kg	8.1	8.8	8.6	14	8.2	11	10	17.5
Ti	%	0.038	0.066	0.059	0.053	0.018	0.047	0.023	0.077
Tl	mg/kg	0.77	0.88	0.76	0.93	0.53	0.82	0.83	1.9
U	mg/kg	2.4	3.0	2.7	3.1	1.9	2.9	2.4	4.0
V	mg/kg	120	150	120	140	84	130	110	190
Y	mg/kg	34	45	37	43	23	36	30	55.3
Zn	mg/kg	140	170	250	190	120	150	150	190
Zr	mg/kg	6.6	7.7	6.5	13	5.4	14	7.3	29.8

P95 – 95. percentil/95th percentile, P97.5 – 97,5. percentil/97.5th percentile; X2S – srednja vrednost+2×standardni odklon/mean+2×standard deviation; MD2MAD – mediana+2×absolutna deviacija mediane/median+2×median absolute deviation; TIF – Tukeyeva zgornja meja/Tukey upper fence; (L) – izračun na osnovi logaritemskih vrednosti/(calculated based on logarithmic values)

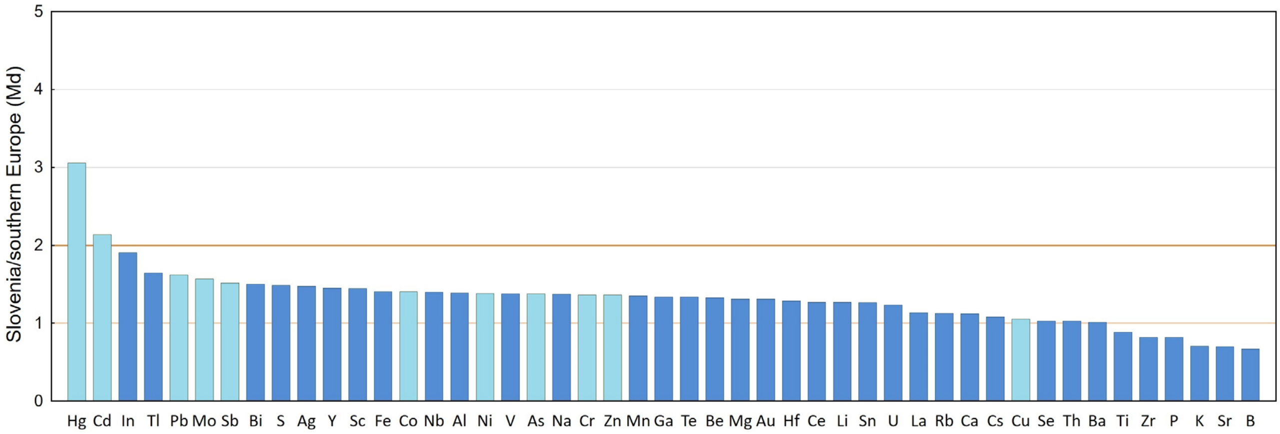

Fig. 10. Ratios of medians between Slovenia and southern Europe. Light blue colour mark PTEs, orange lines represent 1 time and 2 times higher values in Slovenia.

Sl. 10. Razmerja median med Slovenijo in južno Evropo. S svetlo modro so označeni PTE, oranžni črti predstavljata 1 krat in 2 krat višje vrednosti v Sloveniji.

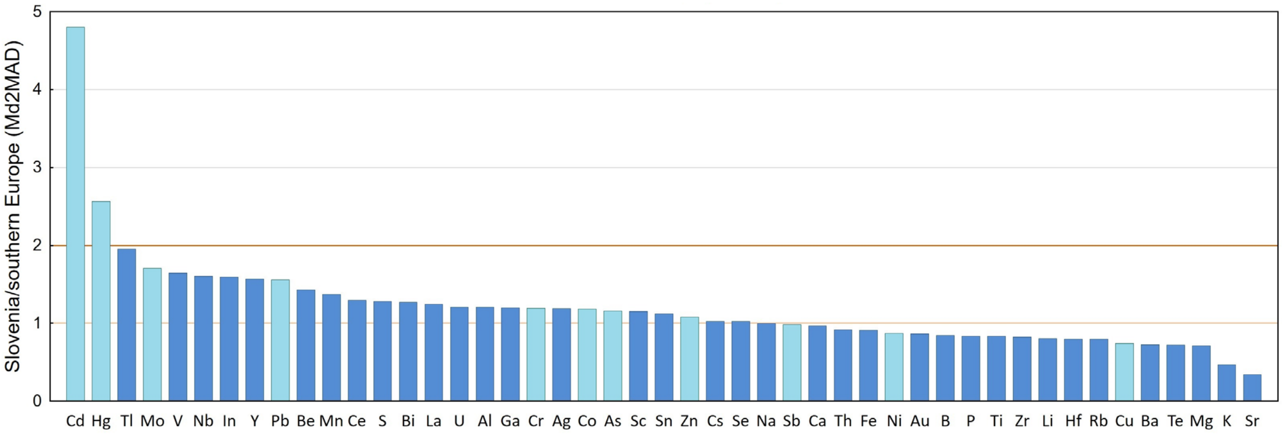

Fig. 11. Ratios of threshold (MD2MAD) between Slovenia and southern Europe. Light blue colour mark PTEs, orange lines represent 1 time and 2 times higher values in Slovenia.

Sl. 11. Razmerja zgornje meje naravne variabilnosti (MD2MAD) med Slovenijo in južno Evropo. S svetlo modro so označeni PTE, oranžni črti predstavljata 1 krat in 2 krat višje vrednosti v Sloveniji.

In Slovenia most of median element concentrations exceed median values in southern Europe (fig. 10). Mercury (Hg) and Cd medians are 2 times higher in Slovenia than in southern Europe, while the concentration of In is almost 2 times higher. Several elements (Tl, Pb, Mo, Sb, Bi, S, Ag, Y, Sc) have around 1.5 times higher median values in Slovenia. Only Ti, Zr, P, K, Sr and B have lower median concentration values in Slovenia, compared to southern Europe.

Comparison between determined MD2MAD values in Slovenia and southern Europe (fig. 11) shows that more elements in Slovenia have lower MD2MAD values than in the case of median values. MD2MAD values in southern Europe are close to Slovenian threshold values for elements Sb, Na, Se and Cs. Lead (Pb), Y, In, Nb, V and Mo have around 1.5 times higher thresholds values in Slovenia and Tl has almost 2 times higher values in Slovenia, compared to southern Europe. Compared to the median values ... Com-

gajo mediane v južni Evropi (sl. 10). Živo srebro (Hg) in Cd imata v Sloveniji več kot 2 krat višje vsebnosti kot v južni Evropi, blizu 2 krat višja je tudi vsebnost In. Več elementov (Tl, Pb, Mo, Sb, Bi, S, Ag, Y, Sc) ima v Sloveniji okoli 1,5 krat višje vsebnosti mediane kot v južni Evropi. Samo Ti, Zr, P, K, Sr in B imajo nižjo mediano v Sloveniji kot v južni Evropi.

Razmerja vrednosti MD2MAD v Sloveniji in južni Evropi (sl. 11) kažejo, da ima več elementov v Sloveniji nižje vrednosti MD2MAD, kot v primeru razmerja median. Vrednosti MD2MAD so si v Sloveniji in južni Evropi blizu za elemente Sb, Na, Se in Cs. Okoli 1,5 krat so v Sloveniji višje vrednosti MD2MAD za Pb, Y, In, Nb, V in Mo. Skoraj 2 krat je v Sloveniji višja vrednost Tl. V primerjavi z južno Evropo, v Sloveniji najbolj izstopata Hg in Cd, ki imata v Sloveniji več kot 2,5 krat višje vrednosti MD2MAD.

pared to southern Europe, Hg and Cd stand out the most, with more than 2.5 times higher threshold values in Slovenia.

Most of Slovenian territory is represented by rendzinas and brown soils that have formed on carbonate rocks (Vidic et al., 2015; Zupančič et al., 2018). It took a long time for the soil to develop due to these soils forming on limestone and dolomites with 1–2 % insoluble rock residue. During soil development, the soil could also be under the influence of eolian and other deposits (Gosar, 2007). Soils on carbonate rocks often have higher concentrations of As, Bi, Co, Cr, Cu, Hg, Li, Mn, Nb, Ni, Pb, Sb, Th, U, V, Zn and Zr than Slovenian average concentration values (Gosar, 2007). Large differences in geochemical composition between soils in Slovenia and Europe can therefore be a consequence of prevailing carbonate lithology in Slovenia.

For easier understanding of medians and calculated threshold values (X2S (L), MD2MAD (L), TIF (L) and P97.5) selected elements are shown in fig. 12 to 15. Medians and geochemical threshold values are shown for smaller spatial units (left part of the graph), for whole of Slovenia and in comparison, also for southern, northern and entire Europe (right part of the graph, according to the GEMAS project, Reimann et al. (2018)). On the graph, limit value is marked with the orange dash line, warning value is marked with red dash line and critical value is marked with red full line according to Decree on limit values, alert thresholds and critical levels of dangerous substances in the soil (Official Gazette RS, 1996). Reimann et al. (2018) used 98th percentile for European data, while in Slovenia we used 97.5th percentile, as in case of an ideal normal distribution, values of X2S, MD2MAD and 97.5th percentile coincide in the same value.

Median values of individual spatial units in Slovenia are similar for elements As, Pb, Sb and Zn. In case of Co and Cr, there are higher median values in Dinarides. Higher median values for Mo are in Eastern Dinarides. Of significance are higher median values for Cu and Ni in Western Dinarides, where Ni median value exceeds the limit value (50 mg/kg) according to Official Gazette RS, 1996 (fig. 14). Large median value differences are apparent for Cd, with highest values in Western Alps, where median value also exceeds the limit value (1 mg/kg) according to Official Gazette RS, 1996 (fig. 12). Somewhat higher median values of Cd are also in Eastern Dinarides and Interior basins. Among the spatial units in Slovenia, there are large differences between median values for Hg. Mercury (Hg) median value is much higher in Western Prealps (0.270 mg/kg), compared to other spatial units (fig. 13).

V Sloveniji večji delež ozemlja predstavljajo rendzine in rjava pokarbonatna tla, ki nastajajo na karbonatnih kamninah (Vidic et al., 2015; Zupančič et al., 2018). Ker nastajajo ta tla na apnencih in dolomitih z 1–2 % netopnega ostanka kamnin, je bilo potrebno dolgo časovno obdobje, da so se tla razvila. V času razvoja tal so bila tla lahko tudi pod vplivom eolskih in drugih nanosov (Gosar, 2007). Tla na karbonatnih kamninah imajo zato pogoste višje vsebnosti As, Bi, Co, Cr, Cu, Hg, Li, Mn, Nb, Ni, Pb, Sb, Th, U, V, Zn in Zr od slovenskega povprečja (Gosar, 2007). Velike razlike med Slovenijo in Evropo so torej lahko posledica obsežnih območij karbonatnih kamnin v Sloveniji, ki pa v Evropi predstavljajo manjši delež.

Za lažje razumevanje median in izračunanih zgornjih mej naravne variabilnosti (X2S(L), MD2MAD(L), TIF(L) in P97.5) smo le-te za izbrane elemente prikazali na slikah od 12 do 15. Mediane in zgornje meje naravne variabilnosti so prikazane za prostorske enote v Sloveniji (levi del grafa), za celotno Slovenijo in primerjalno tudi za severni in južni del Evrope ter za celotno Evropo (desni del grafa, po podatkih projekta GEMAS, Reimann et al. (2018)). Na grafih smo z oranžno črtkano črto označili mejno vrednost, z rdečo prekinjeno črto opozorilno vrednost in s polno rdečo črto kritično vrednost po Uredbi o mejnih, opozorilnih in kritičnih imisijskih vrednostih nevarnih snovi v tleh (Uradni list RS, 1996). Pri podatkih o Evropi so Reimann in sodelavci (2018) uporabili vrednosti za 98. percentil, v Sloveniji pa smo uporabili 97,5. percentil. Uporabili smo ga, ker v primeru idealne normalne porazdelitve vrednosti X2S, MD2MAD in 97,5. percentil sovpadajo v isti vrednosti.

Mediane posameznih prostorskih enot v Sloveniji so si blizu za As, Pb, Sb in Zn. Pri Co in Cr opažamo višje vrednosti median v Dinaridih, pri Mo pa višje vrednosti v Vzhodnih Dinaridih. Značilnost Cu in Ni so višje vrednosti median v Zahodnih Dinaridih, kjer mediana Ni presega mejno vrednost (50 mg/kg) po Uradnem listu RS, 1996 (sl. 14). Večje razlike med medianami posameznih prostorskih enot so v primeru Cd, ki močno izstopa v Zahodnih Alpah, kjer mediana tudi presega mejno vrednost (1 mg/kg) po Uradnem listu RS, 1996 (sl. 12). Nekoliko višje vrednosti median Cd so tudi v Vzhodnih Dinaridih in Notranjih kotlinah. Med prostorskimi enotami v Sloveniji so velike razlike tudi med medianami za Hg. Mediana Hg v Zahodnih Predalpah je veliko višja (0,270 mg/kg), kot v drugih prostorskih enotah (sl. 13).

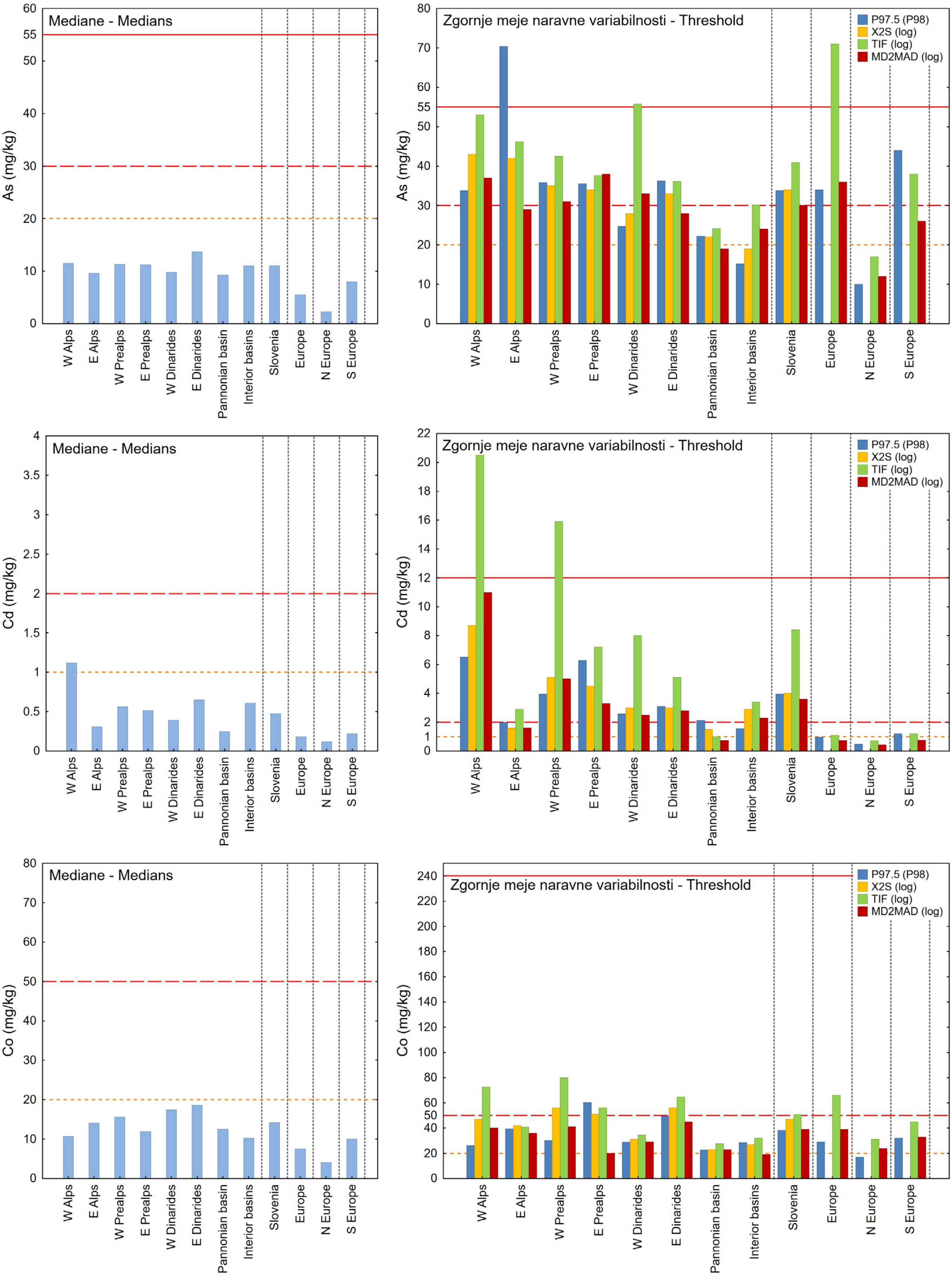

Fig. 12. Medians and thresholds calculated by different methods for arsenic (As), cadmium (Cd) and cobalt (Co). European data are after Reimann et al. (2018). Markings: orange dotted line – limit soil value, red dotted line – warning soil value, red line – critical soil value (Official Gazette RS, 1996).

Sl. 12. Prikaz median in izračunanih zgornjih mej naravne variabilnosti po izbranih metodah za arzen (As), kadmij (Cd) in kobalt (Co). Podatki za Evropo po Reimann et al. (2018). Oznake na sliki: oranžna črtkana črta – mejna vrednost, rdeča prekinjena črta – opozorilna vrednost, polna rdeča črta – kritična vrednosti (Uradni list RS, 1996).

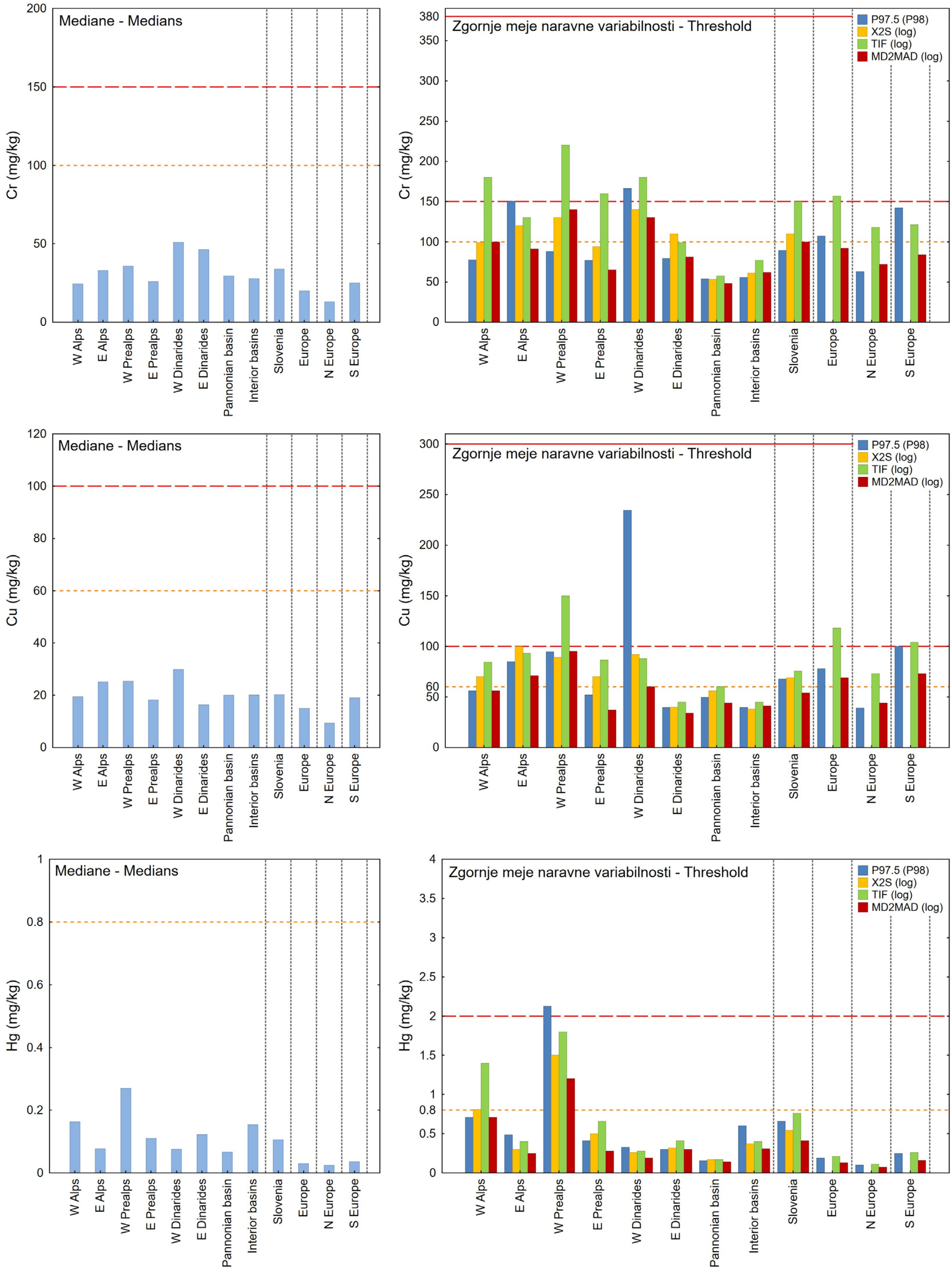

Fig. 13. Medians and thresholds calculated by different methods for chromium (Cr), copper (Cu) and mercury (Hg). European data are after Reimann et al. (2018). Markings: orange dotted line – limit soil value, red dotted line – warning soil value, red line – critical soil value (Official Gazette RS, 1996).

Sl. 13. Prikaz median in izračunanih zgornjih mej naravne variabilnosti po izbranih metodah za krom (Cr), baker (Cu) in živo srebro (Hg). Podatki za Evropo po Reimann et al. (2018). Oznake na sliki: oranžna črtkana črta – mejna vrednost, rdeča prekinjena črta – opozorilna vrednost, polna rdeča črta – kritična vrednosti (Uradni list RS, 1996).

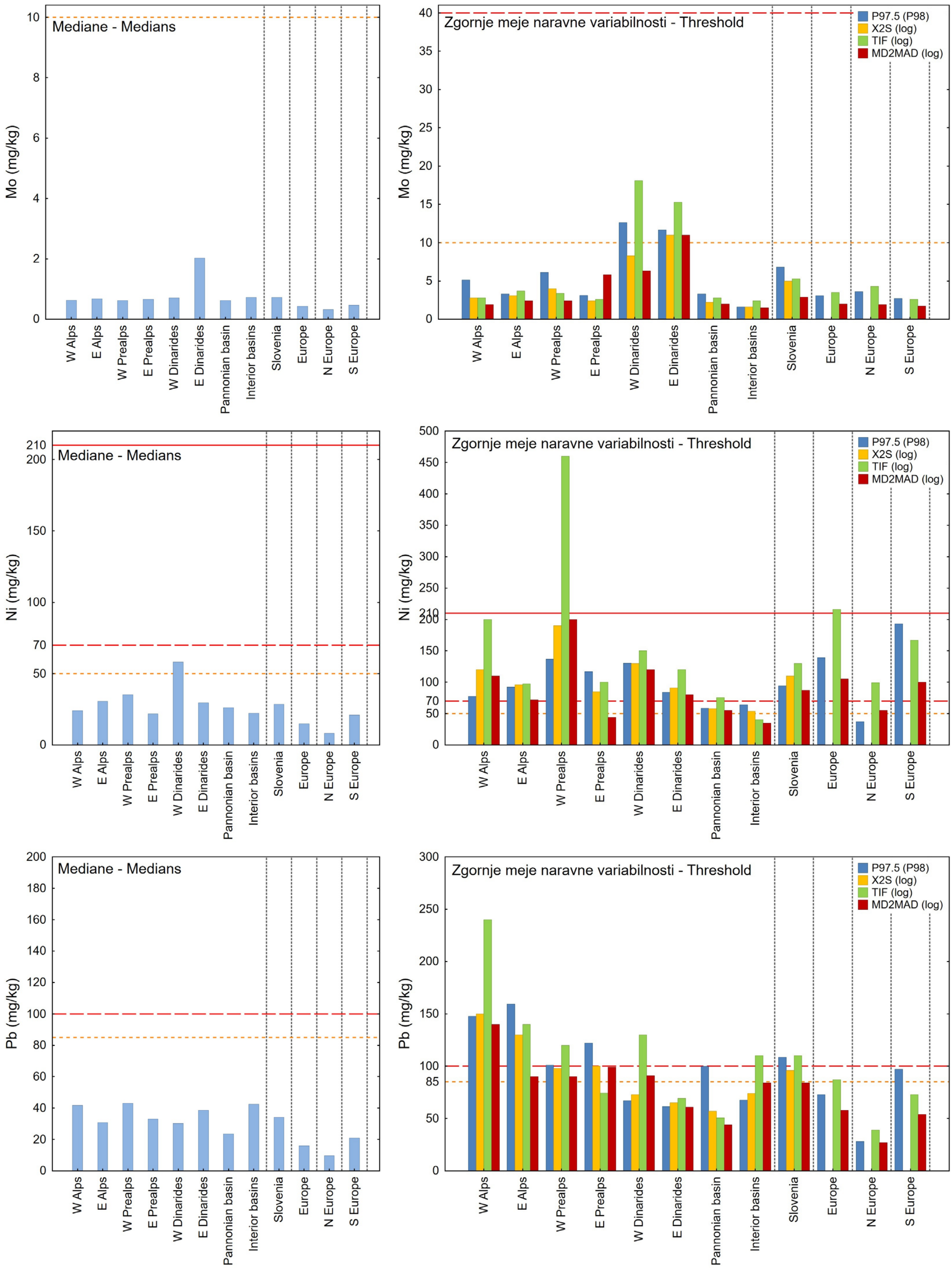

Fig. 14. Medians and thresholds calculated by different methods for molybdenum (Mo), nickel (Ni) and lead (Pb). European data are after Reimann et al. (2018). Markings: orange dotted line – limit soil value, red dotted line – warning soil value, red line – critical soil value (Official Gazette RS, 1996).

Sl. 14. Prikaz median in izračunanih zgornjih mej naravne variabilnosti po izbranih metodah za molibden (Mo), nikelj (Ni) in svinec (Pb). Podatki za Evropo po Reimann et al. (2018). Oznake na sliki: oranžna črtkana črta – mejna vrednost, rdeča prekinjena črta – opozorilna vrednost, polna rdeča črta – kritična vrednosti (Uradni list RS, 1996).

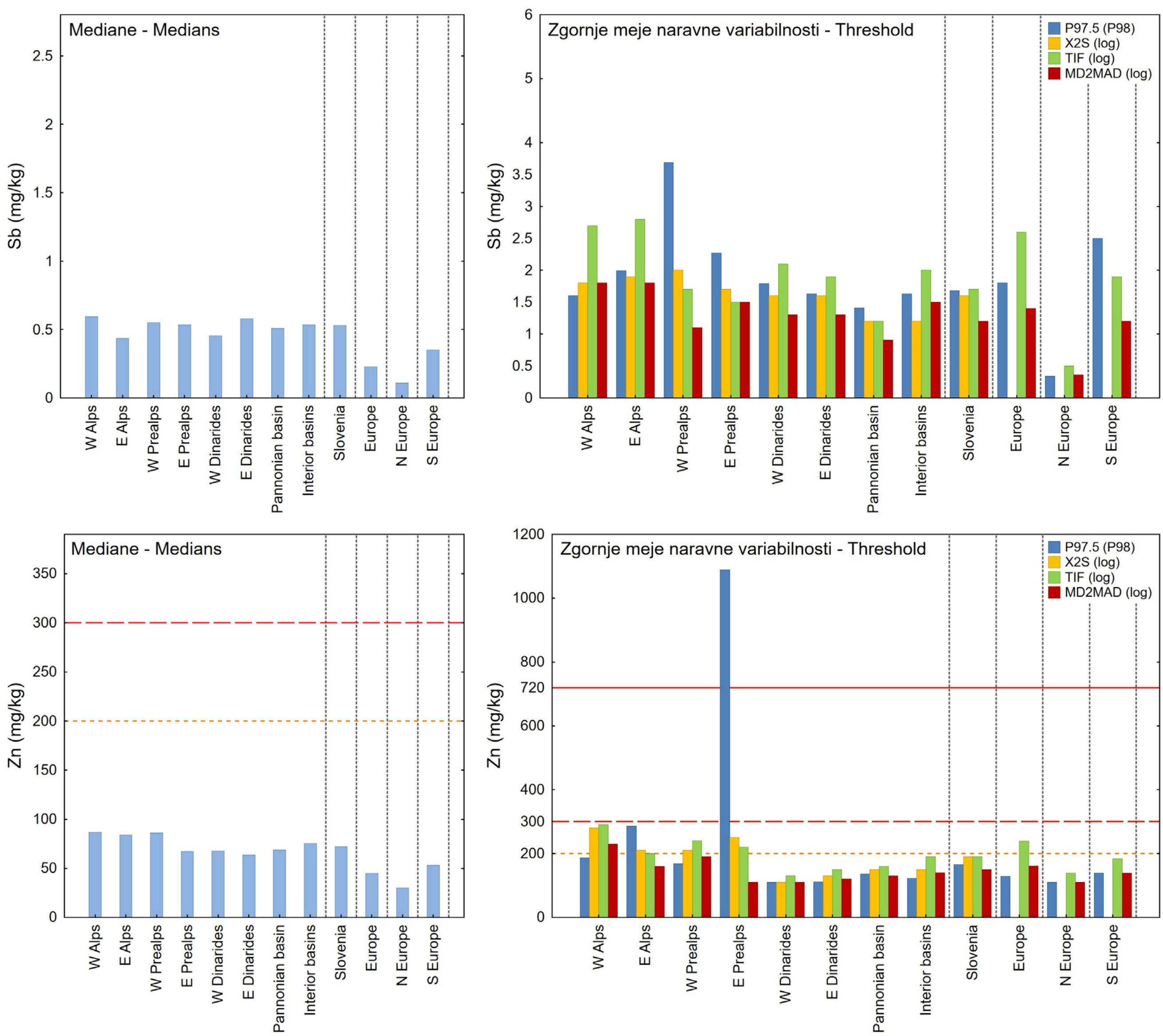

Fig. 15. Medians and thresholds calculated by different methods for antimony (Sb) and zinc (Zn). European data are after Reimann et al. (2018). Markings: orange dotted line – limit soil value, red dotted line – warning soil value, red line – critical soil value (Official Gazette RS, 1996).

Sl. 15. Prikaz median in izračunanih zgornjih mej naravne variabilnosti po izbranih metodah za antimon (Sb) in cink (Zn). Podatki za Evropo po Reimann et al. (2018). Oznake na sliki: oranžna črtkana črta – mejna vrednost, rdeča prekinjena črta – opozorilna vrednost, polna rdeča črta – kritična vrednosti (Uradni list RS, 1996).

Comparison with southern Europe shows that Cu median value in Slovenia (20 mg/kg) and southern Europe (19 mg/kg) are similar (fig. 13). Median values for As, Co, Cr, Mo, Ni, Pb, Sb and Zn are from 1.4 to 1.6 times higher in Slovenia than in southern Europe. Large differences between median values in Slovenia and southern Europe are for Cd (0.48 mg/kg in Slovenia and 0.22 mg/kg in southern Europe (Reimann et al., 2018)) and Hg (0.106 mg/kg in Slovenia (Gosar et al., 2016) and 0.036 mg/kg in southern Europe (Reimann et al., 2018)).

Calculated geochemical threshold values are similar between spatial units in Slovenia only for Sb (fig. 15). Smaller differences between spatial units are in case of As and Cr, where the thresh-

Primerjava z južno Evropo pokaže, da so si mediane Cu v Sloveniji (20 mg/kg) in južni Evropi (19 mg/kg) blizu (sl. 13). Vrednosti median As, Co, Cr, Mo, Ni, Pb, Sb in Zn so v Sloveniji od 1,4 krat do 1,6 krat višje kot v južni Evropi. Velike razlike med medianama Slovenije in južne Evrope smo ugotovili za Cd (0,48 mg/kg v Sloveniji in 0,22 mg/kg v južni Evropi (Reimann et al., 2018)) in Hg (0,106 mg/kg v Sloveniji (Gosar et al., 2016) in 0,036 mg/kg v južni Evropi (Reimann et al., 2018)).

Izračunane vrednosti zgornjih mej naravne variabilnosti so si med vsemi prostorskimi enotami v Sloveniji podobne le za Sb (sl. 15). Manjše razlike so pri As in Cr, kjer so vrednosti nižje le v Panonski nižini in Notranjih kotlinah. Nižje old values are lower only in the Pannonian basin and Interior basins. Lower geochemical threshold values in Pannonian basin and Interior basins are also for elements Co, Cu and Ni. Cobalt have lower values in Western Dinarides and Cu in Eastern Dinarides. Nickel has higher threshold values in also Western Prealps and Western Dinarides. In case of Zn, there are higher geochemical threshold values in Alps and Prealps. Large differences between spatial units are visible for Pb, where there are higher threshold values in Alps and lower values in Eastern Dinarides and Pannonian basin. Molybdenum threshold values are very high in Dinarides, compared to other spatial units. Greatest differences between spatial units are in case of Cd and Hg. Cadmium has higher geochemical threshold values in western Alps and Prealps (fig. 12) and Hg has higher values in Western Alps and highest threshold values in Western Prealps (fig. 13).

For comparison of geochemical threshold values between Slovenia and southern Europe we compared threshold values calculated using MD-2MAD approach, since TIF values are very high due to wide interquartile range and percentile threshold values are too dependent on number of samples. For As, Co, Cr, Sb and Zn, MD2MAD values are similar or up to 20 % higher in Slovenia than in southern Europe. MD2MAD values for Ni and Cu are lower in Slovenia (Ni: 87 kg/kg, Cu: 54 mg/kg) than in southern Europe (Ni: 100 mg/kg, Cu: 73 mg/kg (Reimann et al. 2018)). For Mo and Pb, MD2MAD values in Slovenia are 1.5 to 1.7 times higher than in southern Europe. In Slovenia MD2MAD values for Hg are 2.6 times higher than in southern Europe, while threshold valued for Cd are 4.8 times higher than in southern Europe.

Conclusion

Slovenia was divided into smaller spatial units as homogeneous as possible. Spatial units are still very heterogeneous due to the high variability of the lithological parent material and soil type. Heterogeneity within an individual spatial unit is expressed by very different values of geochemical threshold, calculated by using different methods. Differences between calculated geochemical threshold values reflect the different concentrations of elements among spatial units and especially the high variability within individual units. Calculation of geochemical threshold using TIF method, that is based on the interquartile range (IQR), generally gives much higher values than other methods we used. This shows a high data variability between the first and third quartiles, which means a very high interquartile range (IQR).

vrednosti zgornjih mej naravne variabilnosti v Panonski nižini in Notranjih kotlinah so tudi pri Co, Cu in Ni. Kobalt ima nižje vrednosti tudi v Zahodnih Dinaridih, Cu pa v Vzhodnih Dinaridih. Ni ima višje vrednosti zgornjih mej naravne variabilnosti v Zahodnih Predalpah in Zahodnih Dinaridih. V primeru Zn so višje vrednosti zgornjih mej naravne variabilnosti v Alpah in Predalpah. Večje razlike med vrednostmi so pri Pb, kjer so višje vrednosti v Alpah ter nižje vrednosti v Vzhodnih Dinaridih in Panonski nižini. Zgornje meje naravne variabilnosti za Mo so v primerjavi z ostalimi prostorskimi enotami zelo visoke v Dinaridih. Največje razlike med prostorskimi enotami so v primeru Cd in Hg. Cd ima višje vrednosti zgornjih mej naravne variabilnosti v Zahodnih Alpah in Predalpah (sl. 12), Hg pa v Zahodnih Alpah ter najvišje v Zahodnih Predalpah (sl. 13).

Primerjavo zgornjih mej naravne variabilnosti med Slovenijo in južno Evropo smo naredili s primerjanjem vrednosti izračunanih po metodi MD2MAD, saj so vrednosti TIF zaradi velikega medkvartilnega razpona zelo visoke, vrednosti percentilov pa so zelo odvisne od števila vzorcev. Pri As, Co, Cr, Sb in Zn so si vrednosti MD2MAD podobne ali do 20 % višje kot v južni Evropi. Vrednosti MD2MAD za Ni in Cu sta nižji v Sloveniji (Ni: 87 mg/kg, Cu: 54 mg/kg) kot v južni Evropi (Ni: 100 mg/kg, Cu: 73 mg/kg (Reimann et al. 2018)). Pri Mo in Pb so vrednosti MD2MAD v Sloveniji 1,5 krat do 1,7 krat višje kot v južni Evropi. V Sloveniji so vrednosti MD-2MAD za Hg 2,6 krat višje kot v južni Evropi, vrednosti za Cd pa so 4,8 krat višje v Sloveniji kot v južni Evropi.

Zaključek

Slovenijo smo poskušali razdeliti na čim bolj homogene prostorske enote, kar pa se je zaradi velike spremenljivosti v matični podlagi in talnem tipu izkazalo za praktično nemogoče. Heterogenost znotraj posameznih enot se izraža v zelo različnih vrednostih zgornjih mej naravne variabilnosti, izračunanih z različnimi metodami. V razlikah med izračunanimi zgornjimi mejami naravne variabilnosti se zrcalijo različne vsebnosti elementov po prostorskih enotah in še posebej velika spremenljivost znotraj posameznih enot. Izračun zgornje meje naravne variabilnosti z metodo TIF, ki temelji na medčetrtinskem razmiku (IQR), večinoma daje mnogo višje vrednosti kot druge uporabljene metode. V tem se kaže velika variabilnost podatkov že med prvim in tretjim kvartilom, torej zelo velik medčetrtinski razmik (IQR).

We conclude that in most cases TIF(L) values are very high, which is due to the already mentioned large interquartile range (IQR). Therefore, we focused on calculations based on methods X2S(L), MD2MAD(L) and P97.5. In case of an ideal normal distribution, all three of these methods give the same value. In smaller spatial units, calculated threshold values using methods X2S(L), MD2MAD(L) and P97.5 result in large differences. However, if we compare their values with the results that were calculated with data for whole of Slovenia, we see that they are much closer. This shows that the data set for whole Slovenia is more suitable for geostatistical analysis (larger number of samples) than data for individual spatial units. Whole Slovenia and smaller spatial units discussed in the present work are lithologically and consequently pedologically heterogeneous. More homogeneous units could be established by considering the geochemical features of the soil on a single lithology, which would be extremely demanding and time-consuming. The fragmentation of units and their number would not be appropriate.

Geochemical maps are suitable for showing spatial variability of chemical elements in the soil and for identifying areas with higher element concentrations. Geochemical maps are multilayer maps that are formed by connecting geochemical analyses and geographic-information systems. With geochemical maps, we identify spatial connections, for example, between higher element concentrations in soil and geogenic sources (lithological parent material) or anthropogenic sources (industry, traffic). At the Geological Survey of Slovenia, we

Ugotavljamo, da so vrednosti TIF(L) v večini primerov zelo visoke, kar je posledica že prej omenjenega velikega medčetrtinskega razmika (IQR). Zato smo se osredotočili na izračune po metodah X2S(L), MD2MAD(L) in P97.5. V primeru idealne normalne porazdelitve vse 3 omenjene metode dajo podobne vrednosti. V manjših prostorskih enotah so razlike med izračunanimi vrednostmi po metodah X2S(L), MD2MAD(L) in P97.5 večinoma velike. Če pa primerjamo te vrednosti z rezultati, ki so bili izračunani s podatki za celotno Slovenijo, vidimo, da so si le-te precej bliže. To kaže, da je set podatkov za celo Slovenijo primernejši za geostatistično obravnavo (večje število vzorcev) kot podatki po posameznih prostorskih enotah. Slovenija je namreč litološko in posledično še zlasti pedološko močno heterogena tudi v manjših prostorskih enotah. Bolj homogene enote bi morda lahko vzpostavili na podlagi geokemičnih lastnosti tal na enotni litološki podlagi, kar bi bilo izjemno zahtevno in zamudno. Razdrobljenost enot in njihovo število pa bi bila neustrezno velika.

Za pregled prostorske variabilnosti kemičnih elementov v tleh Slovenije in za identifikacijo območij s povišanimi vsebnostmi so zelo primerne tudi geokemične karte. Geokemične karte spadajo med večslojne zemljevide, ki jih tvorimo s povezovanjem geokemičnih analiz in geografsko-informacijskim sistemom v celoto. Z njimi ugotavljamo prostorske povezave, npr. med povišanimi koncentracijami elementov v tleh in geogenimi viri (matična kamninska podlaga) ali antropogenimi viri (industrija, promet). Na Geološkem zavodu Slovenije smo v preteklih

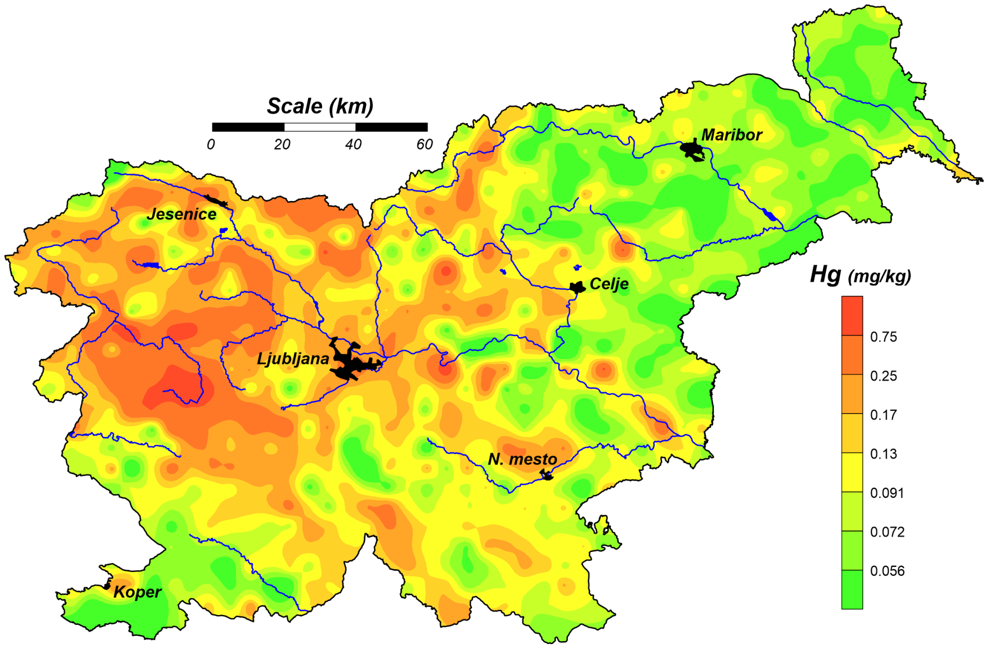

Fig. 16. Geochemical map of spatial mercury (Hg) distribution in Slovenian soil (after Gosar et al., 2016).

Sl. 16. Geokemična karta porazdelitve živega srebra (Hg) v tleh Slovenije (po Gosar et al., 2016) have produced a number of geochemical maps at different scales and participated in the preparing of geochemical atlases of Europe (Reimann et al., 2014; Salminen et al., 2005). We studied mercury concentrations in the Slovenian soil and published a geochemical map of mercury distribution in Slovenian soil (fig. 16) (Gosar et al., 2016). In the continuation of the presented work, it would be useful to create geochemical maps for 47 elements based on data set presented in this paper.

letih izdelali kar nekaj geokemičnih kart različnih meril in sodelovali pri izdelavi geokemičnih atlasov Evrope (Reimann et al., 2014; Salminen et al., 2005). Raziskovali smo vsebnosti živega srebra v tleh Slovenije in izdelali karto porazdelitve živega srebra v tleh Slovenije (sl. 16) (Gosar et al., 2016). V nadaljevanju predstavljenega dela bi bilo koristno na podlagi predstavljenih podatkov izdelati karte porazdelitev vseh obravnavanih elementov.

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Appendix 1/1. Basic statistical parameters for Western Alps.
Priloga 1/1. Osnovni statistični parametri za Zahodne Alpe.

	Unit	$\bar{X}$	X(G)	Md	Min	Max	P25	P75	A	E	A(L)	E(L)
Ag	µg/kg	84	70	67	12	410	51	110	2.43	11.34	-0.39	0.79
Al	%	1.8	1.4	1.7	0.090	4.6	0.99	2.5	0.31	-0.45	-1.27	1.46
As	mg/kg	13	11	12	0.85	80	7.2	16	3.51	19.21	-0.64	2.10
Au	µg/kg	1.9	1.2	1.3	0.10	34	0.70	2.3	8.04	73.47	-0.46	1.43
B	mg/kg	4.1	2.9	3.0	0.50	19	2.0	5.0	1.83	4.01	-0.39	-0.20
Ba	mg/kg	61	48	63	3.2	200	32	80	0.76	1.48	-1.21	1.32
Be	mg/kg	1.0	0.80	0.80	0.050	3.0	0.60	1.4	0.82	0.30	-1.04	1.52
Bi	mg/kg	0.43	0.38	0.39	0.050	1.1	0.29	0.56	0.96	1.12	-0.74	1.65
Ca	%	4.1	1.4	1.6	0.020	25	0.35	7.0	1.83	3.46	-0.23	-0.90
Cd	mg/kg	1.8	1.1	1.1	0.11	10	0.52	2.3	1.93	4.14	-0.00	-0.68
Ce	mg/kg	30	22	28	1.8	81	13	43	0.49	-0.69	-0.84	0.10
Co	mg/kg	11	8.5	11	0.50	32	5.3	15	0.58	0.17	-1.13	1.05
Cr	mg/kg	30	24	24	2.7	86	15	40	0.97	0.25	-0.40	-0.12
Cs	mg/kg	1.3	0.95	1.1	0.050	5.6	0.53	1.9	1.29	2.62	-0.93	0.88
Cu	mg/kg	22	18	19	1.4	86	13	28	1.72	5.02	-0.91	2.01
Fe	%	2.4	1.9	2.6	0.15	5.3	1.4	3.3	-0.25	-0.74	-1.44	1.43
Ga	mg/kg	4.6	3.6	4.4	0.20	14	2.3	6.3	0.57	0.22	-1.11	1.07
Hf	mg/kg	0.084	0.062	0.070	0.010	0.31	0.035	0.11	1.51	2.50	-0.34	-0.26
Hg	mg/kg	0.25	0.18	0.16	0.022	2.6	0.11	0.31	5.91	45.33	0.29	0.95
In	mg/kg	0.044	0.038	0.040	0.010	0.11	0.030	0.060	0.26	0.30	-1.12	0.60
K	%	0.12	0.098	0.11	0.0050	0.40	0.070	0.15	1.35	2.70	-1.09	3.35
La	mg/kg	15	10	11	1.0	62	5.7	20	1.31	1.85	-0.51	-0.18
Li	mg/kg	15	11	15	0.30	41	6.6	21	0.48	-0.09	-1.31	1.89
Mg	%	1.6	0.76	0.57	0.030	9.3	0.33	2.3	1.87	2.64	0.45	-0.31
Mn	mg/kg	910	650	770	31	5700	400	1300	2.78	14.40	-0.74	0.74
Mo	mg/kg	0.90	0.64	0.63	0.070	6.4	0.41	0.89	3.51	12.71	0.96	2.40
Na	%	0.0083	0.0068	0.0070	0.0010	0.052	0.0050	0.010	4.02	20.73	0.32	1.78
Nb	mg/kg	0.67	0.45	0.45	0.040	3.2	0.22	0.79	1.75	3.13	-0.14	-0.35
Ni	mg/kg	27	19	24	0.80	79	12	36	0.94	0.61	-0.98	0.97
P	%	0.079	0.062	0.056	0.011	0.33	0.043	0.095	1.90	3.60	0.14	0.14
Pb	mg/kg	53	44	42	8.5	150	30	70	1.20	0.94	-0.12	-0.17
Rb	mg/kg	14	11	13	0.40	49	7.6	19	0.91	2.03	-1.30	2.39
S	%	0.069	0.046	0.050	0.010	0.34	0.030	0.090	1.86	3.45	-0.02	-0.55
Sb	mg/kg	0.68	0.57	0.59	0.070	3.1	0.42	0.89	2.53	11.05	-0.32	1.33
Sc	mg/kg	3.8	2.9	3.4	0.20	12	1.8	5.3	0.91	0.47	-0.76	0.45
Se	mg/kg	0.59	0.46	0.40	0.050	2.5	0.30	0.80	1.97	4.99	-0.19	0.48
Sn	mg/kg	1.4	1.2	1.3	0.10	3.7	0.90	1.8	0.89	0.59	-0.98	2.12
Sr	mg/kg	25	18	18	2.8	97	9.5	35	1.49	1.90	0.08	-0.75
Te	mg/kg	0.060	0.040	0.050	0.010	0.23	0.015	0.090	1.27	1.07	-0.14	-1.11
Th	mg/kg	2.8	1.9	2.4	0.050	9.9	1.1	3.9	1.15	0.94	-0.87	1.19
Ti	%	0.011	0.0039	0.0030	0.0005	0.19	0.0020	0.0070	4.81	24.50	0.90	1.82
Tl	mg/kg	0.36	0.30	0.31	0.060	1.1	0.18	0.53	0.92	0.46	-0.20	-0.74
U	mg/kg	0.75	0.67	0.70	0.10	1.9	0.50	1.0	1.00	0.98	-0.53	1.33
V	mg/kg	37	30	39	3.0	150	21	48	1.51	6.23	-0.91	0.77
Y	mg/kg	16	10	9.7	0.78	100	6.3	19	2.44	7.54	-0.17	0.10
Zn	mg/kg	94	80	87	9.2	510	62	110	3.62	23.28	-1.05	2.85
Zr	mg/kg	2.4	1.8	2.0	0.20	8.9	1.0	3.2	1.52	2.38	-0.35	-0.03

$\bar{X}$ – aritmetična sredina/arithmetic mean; X(G) – geometrijska sredina/geometric mean; Md – mediana/median (Q2); Min – minimium/minimum; Max – maksimum/maximum; P25 – 25. percentil/ 25th percentile (Q1), P75 – 75. percentil/75th percentile (Q3); A – asimetričnost/skewness; E – sploščenost/kurtosis; A(L) – asimetričnost (logaritmirane vrednosti)/skewness (logarithmic values); E(L) – sploščenost (logaritmirane vrednosti)/kurtosis (logarithmic values)

Appendix 1/2. Basic statistical parameters for Eastern Alps.
Priloga 1/2. Osnovni statistični parametri za Vzhodne Alpe.

	Unit	$\bar{X}$	X(G)	Md	Min	Max	P25	P75	A	E	A(L)	E(L)
Ag	μg/kg	90	61	60	1.0	580	37	120	2.85	11.44	−0.90	3.58
Al	%	2.2	2.1	2.2	0.34	5.7	1.7	2.7	0.77	2.80	−1.23	3.31
As	mg/kg	12	7.5	7.2	1.6	140	4.6	12	5.05	29.90	0.73	1.35
Au	μg/kg	3.1	1.4	1.3	0.10	58	0.95	2.5	6.04	40.84	0.12	1.78
B	mg/kg	2.3	1.6	2.0	0.50	9.5	0.50	3.0	1.62	2.99	0.03	−1.19
Ba	mg/kg	91	78	78	14	310	59	110	1.68	3.68	−0.41	1.12
Be	mg/kg	0.92	0.84	0.90	0.20	2.2	0.70	1.1	0.93	1.83	−0.84	2.00
Bi	mg/kg	0.30	0.26	0.27	0.020	1.3	0.19	0.38	2.28	9.18	−0.96	3.48
Ca	%	1.1	0.29	0.23	0.020	17	0.12	0.52	4.41	20.27	0.70	0.71
Cd	mg/kg	0.44	0.31	0.31	0.040	2.2	0.17	0.54	2.44	6.56	0.21	0.06
Ce	mg/kg	34	31	33	5.4	65	25	44	0.13	−0.60	−1.17	1.69
Co	mg/kg	15	13	14	2.1	55	9.6	17	1.81	4.93	−0.53	1.14
Cr	mg/kg	40	32	33	6.3	210	23	46	3.05	12.13	0.02	0.72
Cs	mg/kg	2.0	1.7	1.8	0.34	7.0	0.96	2.6	1.23	2.19	−0.30	−0.36
Cu	mg/kg	30	23	25	1.7	220	17	33	4.59	29.73	−0.58	2.13
Fe	%	3.4	3.1	3.3	0.41	10	2.7	3.9	1.92	8.13	−1.47	6.17
Ga	mg/kg	6.7	6.1	6.5	0.90	19	4.8	8.1	1.16	2.96	−0.97	2.70
Hf	mg/kg	0.025	0.017	0.010	0.010	0.19	0.010	0.030	3.13	11.99	1.31	0.72
Hg	mg/kg	0.10	0.080	0.078	0.012	0.67	0.056	0.12	4.29	21.39	0.31	2.22
In	mg/kg	0.037	0.031	0.030	0.010	0.15	0.025	0.040	2.41	9.30	−0.23	0.66
K	%	0.19	0.16	0.16	0.040	1.0	0.11	0.21	3.45	13.80	0.49	1.50
La	mg/kg	16	14	16	2.1	30	11	20	0.04	−0.59	−1.27	2.00
Li	mg/kg	27	23	25	3.6	130	19	33	3.10	16.70	−0.74	1.85
Mg	%	1.2	0.81	0.69	0.090	9.3	0.53	1.1	4.05	16.87	1.04	2.97
Mn	mg/kg	720	620	630	150	2800	460	840	2.39	7.41	0.16	0.68
Mo	mg/kg	0.93	0.69	0.68	0.13	7.9	0.50	1.1	4.76	29.94	0.08	0.87
Na	%	0.014	0.011	0.012	0.0010	0.057	0.0070	0.018	1.78	4.64	−0.79	1.12
Nb	mg/kg	1.1	0.67	0.73	0.060	7.8	0.31	1.3	2.85	11.80	−0.15	−0.34
Ni	mg/kg	32	27	31	3.7	130	20	38	2.22	8.74	−0.86	1.43
P	%	0.072	0.065	0.063	0.028	0.19	0.049	0.085	1.45	2.44	0.25	−0.22
Pb	mg/kg	41	32	31	6.2	170	23	47	2.29	5.44	0.24	0.41
Rb	mg/kg	23	19	19	5.1	94	14	25	2.19	6.30	0.16	0.48
S	%	0.031	0.025	0.030	0.010	0.090	0.010	0.040	0.85	0.61	−0.27	−1.14
Sb	mg/kg	0.59	0.44	0.44	0.070	4.7	0.27	0.69	4.51	27.48	0.22	0.83
Sc	mg/kg	4.6	3.9	4.0	0.70	19	2.7	5.7	2.24	8.18	−0.08	0.61
Se	mg/kg	0.40	0.32	0.35	0.050	1.2	0.20	0.50	1.02	1.02	−0.85	0.67
Sn	mg/kg	1.4	0.94	0.90	0.20	25	0.70	1.3	8.05	68.54	1.68	8.02
Sr	mg/kg	22	14	13	3.2	390	8.8	24	7.95	67.75	0.92	3.17
Te	mg/kg	0.030	0.023	0.022	0.010	0.090	0.010	0.040	0.93	0.18	0.10	−1.46
Th	mg/kg	3.9	3.2	3.6	0.40	9.2	2.4	5.5	0.37	−0.56	−1.18	1.23
Ti	%	0.041	0.016	0.016	0.0020	0.29	0.0040	0.058	2.25	5.65	0.12	−1.21
Tl	mg/kg	0.23	0.21	0.21	0.060	0.64	0.16	0.30	1.24	2.29	−0.25	0.06
U	mg/kg	1.2	1.0	0.90	0.10	5.0	0.70	1.5	2.26	5.64	0.07	1.42
V	mg/kg	51	43	39	6.0	190	30	59	2.29	5.70	0.31	1.75
Y	mg/kg	9.0	7.8	8.3	2.4	33	5.5	11	1.79	5.41	−0.00	−0.12
Zn	mg/kg	95	85	84	17	410	68	110	3.25	13.66	0.34	3.24
Zr	mg/kg	0.75	0.41	0.50	0.050	4.7	0.20	0.97	2.43	7.10	−0.24	−0.59

$\bar{X}$ – aritmetična sredina/arithmetic mean; X(G) – geometrijska sredina/geometric mean; Md – mediana/median (Q2); Min – minimium/minimum; Max – maksimum/maximum; P25 – 25. percentil/ 25th percentile (Q1), P75 – 75. percentil/75th percentile (Q3); A – asimetričnost/skewness; E – sploščenost/kurtosis; A(L) – asimetričnost (logaritmirane vrednosti)/skewness (logarithmic values); E(L) – sploščenost (logaritmirane vrednosti)/kurtosis (logarithmic values)

Appendix 1/3. Basic statistical parameters for Western Prealps.
Priloga 1/3. Osnovni statistični parametri za Zahodne Predalpe.

	Unit	$\bar{X}$	X(G)	Md	Min	Max	P25	P75	A	E	A(L)	E(L)
Ag	µg/kg	91	78	83	11	570	57	110	4.47	30.62	-0.21	1.89
Al	%	2.0	1.8	1.9	0.41	3.9	1.5	2.5	0.10	-0.68	-0.90	0.67
As	mg/kg	13	11	11	1.1	52	8.0	16	2.23	7.79	-0.64	2.21
Au	µg/kg	2.6	1.9	2.0	0.10	17	1.4	2.7	3.47	16.32	-0.60	2.84
B	mg/kg	2.9	2.2	2.0	0.50	9.0	1.0	4.0	0.81	0.23	-0.52	-0.65
Ba	mg/kg	78	67	71	9.1	230	50	100	1.02	1.50	-0.69	0.98
Be	mg/kg	1.1	0.89	1.0	0.050	3.5	0.70	1.5	0.90	1.23	-1.44	3.54
Bi	mg/kg	0.47	0.43	0.45	0.16	1.1	0.32	0.57	0.81	0.42	-0.21	-0.31
Ca	%	1.5	0.51	0.52	0.020	13	0.20	1.3	2.70	7.46	-0.12	-0.33
Cd	mg/kg	0.94	0.59	0.56	0.0050	4.6	0.28	1.4	1.85	3.82	-0.86	2.82
Ce	mg/kg	36	29	32	2.4	110	19	48	0.78	0.72	-0.88	0.69
Co	mg/kg	15	12	16	0.50	36	8.2	20	0.20	-0.36	-1.81	4.71
Cr	mg/kg	37	29	36	2.6	120	19	51	0.84	1.35	-0.91	0.56
Cs	mg/kg	1.5	1.2	1.4	0.060	4.1	0.74	2.1	0.61	-0.22	-0.93	1.40
Cu	mg/kg	30	24	25	3.4	100	15	37	1.62	3.04	-0.12	0.02
Fe	%	2.9	2.7	2.9	0.24	4.9	2.5	3.5	-0.55	0.38	-2.60	9.95
Ga	mg/kg	5.1	4.6	5.0	1.2	9.5	3.8	6.6	0.08	-0.72	-0.76	-0.09
Hf	mg/kg	0.091	0.069	0.080	0.010	0.36	0.050	0.12	1.51	3.03	-0.69	0.41
Hg	mg/kg	0.44	0.28	0.27	0.046	5.3	0.16	0.42	5.32	31.96	0.76	1.60
In	mg/kg	0.044	0.039	0.040	0.010	0.11	0.030	0.050	0.73	1.20	-0.99	1.23
K	%	0.13	0.12	0.12	0.040	0.29	0.090	0.16	0.87	0.49	-0.20	-0.04
La	mg/kg	17	13	15	1.1	82	7.8	22	2.26	7.36	-0.49	0.20
Li	mg/kg	23	19	20	1.0	69	14	29	1.16	1.54	-1.25	3.08
Mg	%	0.87	0.51	0.45	0.030	8.0	0.33	0.75	3.55	13.44	0.36	1.51
Mn	mg/kg	1200	850	1000	17	7200	560	1500	3.22	18.68	-1.59	4.62
Mo	mg/kg	1.1	0.68	0.62	0.10	12	0.39	0.93	4.03	20.29	0.91	1.41
Na	%	0.0061	0.0050	0.0060	0.0010	0.017	0.0030	0.0080	0.97	0.77	-0.47	-0.19
Nb	mg/kg	0.65	0.42	0.44	0.040	2.8	0.20	0.97	1.30	1.24	-0.15	-0.70
Ni	mg/kg	42	30	35	1.4	250	15	58	2.44	10.20	-0.64	0.67
P	%	0.072	0.059	0.064	0.0090	0.22	0.039	0.098	1.24	1.76	-0.48	0.22
Pb	mg/kg	46	42	43	14	110	32	54	1.21	1.81	-0.04	0.06
Rb	mg/kg	18	16	16	4.1	39	13	23	0.65	0.04	-0.53	0.42
S	%	0.048	0.040	0.040	0.010	0.17	0.030	0.060	1.67	4.98	-0.54	0.17
Sb	mg/kg	0.80	0.61	0.55	0.21	8.9	0.45	0.76	5.84	39.54	1.78	5.26
Sc	mg/kg	4.2	3.6	4.2	0.50	13	2.8	5.3	0.82	2.10	-0.92	1.00
Se	mg/kg	0.55	0.48	0.50	0.10	1.5	0.30	0.70	1.12	0.88	-0.08	-0.29
Sn	mg/kg	1.5	1.3	1.3	0.37	5.6	0.80	2.0	1.76	5.10	0.13	-0.49
Sr	mg/kg	19	12	12	1.6	230	7.4	22	5.63	41.28	0.34	0.75
Te	mg/kg	0.063	0.047	0.060	0.010	0.20	0.030	0.080	0.94	0.74	-0.59	-0.60
Th	mg/kg	3.9	3.5	3.5	0.60	8.8	2.6	4.9	0.72	-0.02	-0.63	0.92
Ti	%	0.0042	0.0027	0.0030	0.0005	0.026	0.0010	0.0060	2.23	6.56	-0.11	-0.67
Tl	mg/kg	0.33	0.28	0.25	0.080	1.1	0.18	0.45	1.33	1.44	0.28	-0.68
U	mg/kg	1.0	0.81	0.75	0.20	5.2	0.50	1.3	2.29	7.89	0.18	-0.25
V	mg/kg	46	37	41	6.0	160	24	57	1.52	2.95	-0.43	0.02
Y	mg/kg	17	11	13	1.0	110	6.4	19	3.67	15.31	-0.20	0.74
Zn	mg/kg	88	80	86	11	190	64	110	0.46	0.02	-1.11	2.63
Zr	mg/kg	2.7	2.1	2.1	0.30	11	1.3	3.6	1.63	2.95	-0.18	-0.14

$\bar{X}$ – aritmetična sredina/arithmetic mean; X(G) – geometrijska sredina/geometric mean; Md – mediana/median (Q2); Min – minimium/minimum; Max – maksimum/maximum; P25 – 25. percentil/ 25th percentile (Q1), P75 – 75. percentil/75th percentile (Q3); A – asimetričnost/skewness; E – sploščenost/kurtosis; A(L) – asimetričnost (logaritmirane vrednosti)/skewness (logarithmic values); E(L) – sploščenost (logaritmirane vrednosti)/kurtosis (logarithmic values)

Appendix 1/4. Basic statistical parameters for Eastern Prealps.
Priloga 1/4. Osnovni statistični parametri za Vzhodne Predalpe.

	Unit	$\bar{X}$	X(G)	Md	Min	Max	P25	P75	A	E	A(L)	E(L)
Ag	µg/kg	71	55	55	15	1000	42	73	8.00	74.60	1.01	4.13
Al	%	1.6	1.4	1.6	0.26	3.5	1.1	1.9	0.66	0.31	−0.80	1.42
As	mg/kg	13	11	11	2.0	50	8.4	15	2.23	7.75	−0.51	1.24
Au	µg/kg	2.4	1.7	1.6	0.20	41	1.2	2.5	8.42	80.99	0.59	3.78
B	mg/kg	2.9	1.9	2.0	0.50	18	1.0	4.0	2.10	5.75	0.12	−0.94
Ba	mg/kg	88	70	70	17	820	47	100	5.73	44.76	0.49	1.43
Be	mg/kg	0.93	0.79	0.70	0.20	2.6	0.60	1.2	1.27	1.04	0.12	−0.42
Bi	mg/kg	0.31	0.29	0.30	0.090	0.75	0.23	0.39	0.72	1.06	−0.57	0.36
Ca	%	2.4	0.48	0.36	0.0050	17	0.15	2.4	1.99	2.91	0.04	−0.65
Cd	mg/kg	0.96	0.53	0.52	0.030	11	0.28	1.0	4.20	22.35	0.09	0.27
Ce	mg/kg	35	30	33	5.3	93	23	46	0.67	0.59	−0.87	0.42
Co	mg/kg	16	12	12	2.3	74	8.0	17	2.32	6.21	0.06	0.26
Cr	mg/kg	33	27	26	5.7	210	16	40	3.43	20.96	0.12	−0.08
Cs	mg/kg	1.4	1.2	1.4	0.14	5.2	0.79	2.0	1.12	2.23	−0.75	0.52
Cu	mg/kg	24	19	18	3.9	300	13	28	7.07	59.93	0.43	2.43
Fe	%	2.6	2.4	2.5	0.47	4.8	2.1	3.2	0.07	−0.30	−1.23	1.99
Ga	mg/kg	4.4	3.9	4.1	0.60	10	2.9	5.5	0.67	−0.04	−0.69	0.76
Hf	mg/kg	0.064	0.047	0.050	0.010	0.30	0.030	0.090	1.73	4.29	−0.31	−0.45
Hg	mg/kg	0.17	0.12	0.11	0.015	3.9	0.076	0.18	9.36	94.46	0.91	4.35
In	mg/kg	0.038	0.030	0.030	0.010	0.25	0.020	0.050	3.98	21.25	0.11	0.50
K	%	0.13	0.11	0.11	0.040	0.65	0.080	0.15	3.39	15.22	0.84	1.52
La	mg/kg	17	14	15	2.1	46	10	22	0.74	0.36	−0.83	0.59
Li	mg/kg	17	15	16	2.6	64	11	20	1.73	5.20	−0.52	0.87
Mg	%	1.2	0.47	0.38	0.040	9.9	0.22	0.73	2.71	6.54	0.83	0.41
Mn	mg/kg	940	680	720	54	3300	410	1100	1.50	1.67	−0.28	0.02
Mo	mg/kg	0.83	0.65	0.65	0.095	6.0	0.46	0.93	3.88	20.29	0.21	1.64
Na	%	0.0082	0.0065	0.0070	0.0005	0.043	0.0050	0.011	2.50	11.91	−1.01	2.62
Nb	mg/kg	0.53	0.40	0.45	0.025	1.7	0.26	0.71	1.21	1.51	−0.77	0.74
Ni	mg/kg	30	22	22	4.7	500	15	32	8.50	82.15	0.87	3.59
P	%	0.064	0.050	0.050	0.010	0.52	0.033	0.075	4.67	30.84	0.40	1.07
Pb	mg/kg	43	33	33	6.2	850	27	40	9.70	99.95	1.22	9.13
Rb	mg/kg	16	14	15	3.1	37	11	21	0.59	−0.14	−0.59	0.06
S	%	0.036	0.029	0.030	0.010	0.20	0.020	0.040	2.76	13.75	−0.18	−0.31
Sb	mg/kg	0.63	0.53	0.54	0.13	4.0	0.40	0.68	3.84	19.80	0.32	1.71
Sc	mg/kg	3.8	3.3	3.1	1.0	12	2.3	4.4	1.58	2.43	0.33	−0.12
Se	mg/kg	0.36	0.29	0.30	0.050	0.90	0.20	0.50	0.45	−0.55	−0.90	0.31
Sn	mg/kg	1.1	0.97	1.0	0.25	6.0	0.70	1.4	3.14	15.43	0.32	0.72
Sr	mg/kg	44	16	13	1.7	940	7.8	34	5.75	38.59	0.98	1.22
Te	mg/kg	0.055	0.037	0.040	0.010	0.24	0.020	0.080	1.42	1.98	−0.06	−1.08
Th	mg/kg	4.4	3.8	4.3	0.50	11	3.1	5.6	0.32	0.29	−1.54	3.26
Ti	%	0.0055	0.0039	0.0050	0.0005	0.019	0.0020	0.0080	1.11	0.89	−0.61	−0.20
Tl	mg/kg	0.24	0.20	0.21	0.050	1.2	0.15	0.28	2.39	9.95	−0.01	0.10
U	mg/kg	1.1	0.93	0.90	0.10	4.6	0.70	1.2	2.56	8.32	−0.03	2.13
V	mg/kg	36	30	29	7.0	150	21	43	1.94	5.15	0.26	−0.14
Y	mg/kg	13	9.7	9.1	1.2	57	5.4	18	1.79	3.28	0.13	−0.50
Zn	mg/kg	99	68	67	16	1400	48	88	5.98	36.09	1.97	8.74
Zr	mg/kg	2.2	1.7	1.6	0.30	7.4	1.1	3.0	1.17	0.88	−0.12	−0.53

$\bar{X}$ – aritmetična sredina/arithmetic mean; X(G) – geometrijska sredina/geometric mean; Md – mediana/median (Q2); Min – minimium/minimum; Max – maksimum/maximum; P25 – 25. percentil/ 25th percentile (Q1), P75 – 75. percentil/75th percentile (Q3); A – asimetričnost/skewness; E – sploščenost/kurtosis; A(L) – asimetričnost (logaritmirane vrednosti)/skewness (logarithmic values); E(L) – sploščenost (logaritmirane vrednosti)/kurtosis (logarithmic values)

Appendix 1/5. Basic statistical parameters for Western Dinarides.
Priloga 1/5. Osnovni statistični parametri za Zahodne Dinaride.

	Unit	$\bar{X}$	X(G)	Md	Min	Max	P25	P75	A	E	A(L)	E(L)
Ag	µg/kg	81	74	74	21	170	55	110	0.49	–0.58	–0.46	0.07
Al	%	2.1	1.9	1.9	0.62	4.7	1.4	2.5	1.06	0.93	0.00	0.01
As	mg/kg	12	10	9.8	4.3	27	6.6	16	0.83	–0.29	0.14	–1.04
Au	µg/kg	2.7	2.1	2.5	0.10	14	1.6	3.1	3.30	17.01	–1.29	4.38
B	mg/kg	2.7	2.3	2.5	0.50	8.0	2.0	4.0	0.79	0.96	–0.84	0.23
Ba	mg/kg	99	90	95	31	310	67	120	1.69	6.07	–0.11	0.15
Be	mg/kg	1.2	0.99	0.93	0.40	2.6	0.60	1.6	0.63	–0.87	0.08	–1.35
Bi	mg/kg	0.40	0.35	0.37	0.090	0.82	0.24	0.52	0.52	–0.64	–0.38	–0.36
Ca	%	3.4	1.2	0.86	0.040	17	0.44	4.5	1.50	0.83	0.31	–0.77
Cd	mg/kg	0.73	0.48	0.40	0.060	2.8	0.23	0.95	1.47	1.07	0.30	–0.75
Ce	mg/kg	34	28	29	9.2	75	19	50	0.46	–1.10	–0.14	–1.27
Co	mg/kg	18	18	17	9.0	29	15	21	0.34	–0.31	–0.31	–0.24
Cr	mg/kg	62	55	51	21	190	39	72	1.82	3.36	0.67	0.04
Cs	mg/kg	1.2	0.96	0.95	0.29	3.9	0.60	1.5	1.52	1.88	0.16	–0.60
Cu	mg/kg	40	33	30	14	240	24	41	4.52	21.98	1.83	5.24
Fe	%	3.0	2.9	3.1	1.5	4.8	2.3	3.6	0.08	–0.92	–0.35	–0.78
Ga	mg/kg	5.9	5.4	5.5	2.1	13	4.0	7.5	0.82	0.15	–0.02	–0.66
Hf	mg/kg	0.11	0.084	0.085	0.010	0.26	0.050	0.16	0.58	–0.94	–0.33	–0.41
Hg	mg/kg	0.096	0.080	0.076	0.016	0.40	0.058	0.11	2.48	7.53	0.28	1.04
In	mg/kg	0.043	0.037	0.040	0.010	0.090	0.030	0.060	0.19	–0.65	–0.86	0.05
K	%	0.16	0.15	0.15	0.050	0.37	0.12	0.19	0.94	1.35	–0.22	0.08
La	mg/kg	16	13	14	3.3	37	7.2	23	0.62	–0.86	–0.14	–1.14
Li	mg/kg	19	18	19	8.3	33	15	22	0.49	–0.46	–0.16	–0.47
Mg	%	0.50	0.40	0.39	0.15	4.3	0.31	0.48	5.40	31.14	1.86	7.49
Mn	mg/kg	1200	1100	980	400	2600	790	1300	1.10	0.49	0.25	–0.38
Mo	mg/kg	1.8	0.94	0.71	0.17	15	0.39	1.8	3.13	11.39	0.67	–0.32
Na	%	0.0061	0.0053	0.0060	0.0005	0.015	0.0040	0.0070	0.55	0.82	–1.85	4.92
Nb	mg/kg	0.78	0.42	0.30	0.050	2.9	0.14	1.5	0.95	–0.33	0.15	–1.50
Ni	mg/kg	64	60	58	22	130	50	78	0.94	0.73	–0.08	0.11
P	%	0.050	0.045	0.046	0.013	0.14	0.036	0.059	1.33	3.51	–0.40	0.78
Pb	mg/kg	33	30	30	13	68	21	44	0.41	–0.65	–0.22	–1.00
Rb	mg/kg	19	18	17	9.7	44	15	22	1.44	1.63	0.66	0.03
S	%	0.049	0.037	0.040	0.010	0.21	0.020	0.060	2.11	5.48	–0.11	–0.34
Sb	mg/kg	0.55	0.45	0.46	0.060	2.7	0.30	0.65	2.94	12.25	–0.06	1.47
Sc	mg/kg	5.2	4.8	4.7	2.1	9.5	3.8	6.7	0.37	–0.70	–0.27	–0.75
Se	mg/kg	0.48	0.40	0.40	0.050	1.7	0.30	0.60	2.07	6.58	–0.89	2.65
Sn	mg/kg	1.4	1.2	1.2	0.30	9.4	0.80	2.0	4.90	32.27	0.37	1.59
Sr	mg/kg	57	27	21	2.9	450	12	55	2.46	7.07	0.67	–0.42
Te	mg/kg	0.076	0.068	0.080	0.010	0.14	0.050	0.10	–0.21	–0.61	–1.37	1.89
Th	mg/kg	4.1	3.7	3.8	1.5	10	2.4	5.6	1.01	0.64	0.07	–0.80
Ti	%	0.0054	0.0035	0.0030	0.0005	0.028	0.0020	0.0080	2.00	4.19	0.23	–0.61
Tl	mg/kg	0.29	0.23	0.20	0.080	0.81	0.13	0.42	0.93	–0.27	0.31	–1.31
U	mg/kg	0.76	0.65	0.60	0.20	1.9	0.40	1.1	0.88	–0.29	0.13	–1.01
V	mg/kg	76	58	46	16	230	31	110	1.17	0.14	0.48	–1.09
Y	mg/kg	15	13	13	2.4	45	9.1	20	1.29	2.11	–0.45	0.60
Zn	mg/kg	70	68	68	39	120	58	81	0.62	0.18	–0.01	–0.34
Zr	mg/kg	3.6	2.7	2.3	0.70	12	1.4	5.8	1.06	0.24	0.22	–1.34

$\bar{X}$ – aritmetična sredina/arithmetic mean; X(G) – geometrijska sredina/geometric mean; Md – mediana/median (Q2); Min – minimium/minimum; Max – maksimum/maximum; P25 – 25. percentil/ 25th percentile (Q1), P75 – 75. percentil/75th percentile (Q3); A – asimetričnost/skewness; E – sploščenost/kurtosis; A(L) – asimetričnost (logaritmirane vrednosti)/skewness (logarithmic values); E(L) – sploščenost (logaritmirane vrednosti)/kurtosis (logarithmic values)

Appendix 1/6. Basic statistical parameters for Eastern Dinarides.
Priloga 1/6. Osnovni statistični parametri za Vzhodne Dinaride.

	Unit	$\bar{X}$	X(G)	Md	Min	Max	P25	P75	A	E	A(L)	E(L)
Ag	µg/kg	64	55	54	12	240	39	79	1.91	5.34	–0.07	0.32
Al	%	2.2	2.1	2.2	0.35	4.3	1.8	2.7	–0.00	0.40	–1.74	4.89
As	mg/kg	15	14	14	2.9	56	11	18	2.26	8.41	–0.22	1.79
Au	µg/kg	1.9	1.5	1.6	0.10	8.2	1.0	2.4	2.02	6.00	–1.02	2.42
B	mg/kg	2.6	1.6	2.0	0.50	36	1.0	3.0	5.97	47.54	0.35	–0.03
Ba	mg/kg	80	74	77	15	200	58	97	1.28	3.69	–0.75	2.37
Be	mg/kg	1.4	1.2	1.4	0.20	3.3	1.0	1.7	0.28	0.31	–1.21	2.30
Bi	mg/kg	0.39	0.37	0.37	0.10	0.86	0.30	0.47	0.61	0.49	–0.69	1.39
Ca	%	1.7	0.61	0.57	0.0050	14	0.23	1.7	2.76	7.92	–0.01	0.03
Cd	mg/kg	0.86	0.64	0.65	0.060	5.9	0.42	1.1	3.03	13.71	–0.17	0.56
Ce	mg/kg	55	50	56	5.7	130	46	66	0.14	1.91	–1.93	4.83
Co	mg/kg	20	18	19	2.0	65	14	26	1.34	2.92	–0.96	2.08
Cr	mg/kg	47	44	46	6.9	110	39	57	0.16	1.41	–1.69	3.93
Cs	mg/kg	2.0	1.7	2.0	0.23	6.4	1.3	2.6	0.68	1.80	–1.09	1.15
Cu	mg/kg	18	17	16	3.6	99	13	21	3.90	23.05	0.35	2.61
Fe	%	3.0	2.8	3.0	0.48	5.7	2.7	3.5	–0.43	1.64	–2.39	7.95
Ga	mg/kg	6.5	6.0	6.4	1.0	13	5.4	7.6	0.05	1.14	–1.86	4.98
Hf	mg/kg	0.10	0.085	0.090	0.010	0.37	0.055	0.13	1.35	2.36	–0.34	0.23
Hg	mg/kg	0.13	0.12	0.12	0.025	0.45	0.086	0.16	1.63	4.09	–0.16	0.43
In	mg/kg	0.046	0.042	0.040	0.010	0.10	0.030	0.060	0.53	0.63	–1.20	2.63
K	%	0.12	0.10	0.10	0.020	0.86	0.080	0.12	5.66	41.51	0.95	4.48
La	mg/kg	24	22	24	2.8	65	19	30	0.35	1.86	–1.64	3.69
Li	mg/kg	21	19	20	2.7	150	15	25	6.21	48.20	–0.15	4.21
Mg	%	1.0	0.55	0.43	0.10	9.2	0.30	0.74	2.97	9.31	1.10	0.71
Mn	mg/kg	1200	1000	1100	170	4200	680	1600	1.28	2.28	–0.32	–0.21
Mo	mg/kg	3.1	2.0	2.0	0.31	38	1.1	3.1	5.24	35.43	0.49	0.52
Na	%	0.0060	0.0047	0.0060	0.0005	0.019	0.0030	0.0080	0.96	1.24	–1.08	1.09
Nb	mg/kg	1.1	0.93	1.0	0.070	2.5	0.72	1.3	0.50	0.21	–1.48	3.49
Ni	mg/kg	35	31	30	5.4	150	22	44	1.84	6.28	–0.22	0.58
P	%	0.048	0.039	0.038	0.0060	0.44	0.027	0.060	5.56	42.85	0.47	1.96
Pb	mg/kg	38	37	39	13	78	32	44	0.40	1.33	–0.84	1.84
Rb	mg/kg	22	20	22	3.3	52	18	26	0.36	1.38	–1.39	3.16
S	%	0.042	0.033	0.030	0.010	0.23	0.020	0.050	2.63	9.58	–0.01	–0.21
Sb	mg/kg	0.68	0.60	0.58	0.13	3.0	0.46	0.81	2.51	11.21	–0.07	1.35
Sc	mg/kg	4.8	4.4	4.8	0.60	11	3.6	5.9	0.38	0.74	–1.44	3.40
Se	mg/kg	0.44	0.36	0.40	0.050	1.6	0.30	0.50	1.64	3.81	–0.96	1.86
Sn	mg/kg	1.4	1.3	1.3	0.30	5.0	1.0	1.7	2.09	11.11	–0.51	1.93
Sr	mg/kg	21	13	12	2.6	240	7.5	20	4.18	21.95	0.80	0.80
Te	mg/kg	0.057	0.045	0.050	0.010	0.17	0.030	0.070	0.93	0.80	–0.72	–0.14
Th	mg/kg	5.7	5.1	5.6	0.30	17	4.6	7.1	0.45	2.37	–2.03	5.65
Ti	%	0.0076	0.0064	0.0070	0.0005	0.021	0.0040	0.010	0.74	0.37	–0.84	1.25
Tl	mg/kg	0.53	0.46	0.48	0.10	1.3	0.34	0.68	0.80	0.56	–0.59	0.21
U	mg/kg	1.6	1.4	1.4	0.30	6.2	1.1	2.0	2.06	9.77	–0.53	1.65
V	mg/kg	74	67	70	13	200	54	87	1.25	2.52	–0.63	1.41
Y	mg/kg	16	13	14	2.1	59	9.0	20	1.90	4.96	–0.20	0.52
Zn	mg/kg	65	62	64	17	130	50	76	0.53	0.38	–0.64	1.08
Zr	mg/kg	4.0	3.5	3.5	0.60	11	2.6	4.9	0.93	0.77	–0.60	0.74

$\bar{X}$ – aritmetična sredina/arithmetic mean; X(G) – geometrijska sredina/geometric mean; Md – mediana/median (Q2); Min – minimium/minimum; Max – maksimum/maximum; P25 – 25. percentil/ 25th percentile (Q1), P75 – 75. percentil/75th percentile (Q3); A – asimetričnost/skewness; E – sploščenost/kurtosis; A(L) – asimetričnost (logaritmirane vrednosti)/skewness (logarithmic values); E(L) – sploščenost (logaritmirane vrednosti)/kurtosis (logarithmic values)

Appendix 1/7. Basic statistical parameters for Pannonian basin.
Priloga 1/7. Osnovni statistični parametri za Panonsko nižino.

	Unit	$\bar{X}$	X(G)	Md	Min	Max	P25	P75	A	E	A(L)	E(L)
Ag	µg/kg	67	57	57	11	280	39	79	2.00	4.92	0.05	0.44
Al	%	1.6	1.5	1.6	0.57	2.9	1.3	1.8	0.20	0.42	-0.82	1.30
As	mg/kg	10	9.3	9.3	3.5	92	7.2	12	7.94	83.02	0.77	4.07
Au	µg/kg	3.2	2.1	2.1	0.30	110	1.4	3.1	11.72	142.89	1.20	6.48
B	mg/kg	2.5	1.7	2.0	0.50	11	1.0	3.0	1.85	3.61	-0.02	-0.80
Ba	mg/kg	84	79	81	27	230	64	100	1.16	3.55	-0.23	0.37
Be	mg/kg	0.76	0.72	0.70	0.30	2.5	0.60	0.90	1.91	9.49	-0.22	0.93
Bi	mg/kg	0.26	0.25	0.25	0.080	0.69	0.21	0.31	1.21	5.25	-0.45	1.61
Ca	%	1.1	0.33	0.25	0.020	17	0.16	0.55	4.28	19.94	0.90	0.91
Cd	mg/kg	0.38	0.25	0.25	0.0050	2.9	0.18	0.36	3.59	14.25	-0.94	6.28
Ce	mg/kg	39	37	39	13	80	31	46	0.43	0.32	-0.49	0.26
Co	mg/kg	13	12	13	4.7	32	9.9	15	1.15	3.21	-0.16	0.64
Cr	mg/kg	30	29	29	8.9	65	25	35	1.09	2.36	-0.30	1.55
Cs	mg/kg	1.3	1.2	1.3	0.30	4.4	1.0	1.5	2.04	11.44	-0.39	2.14
Cu	mg/kg	24	21	20	3.2	200	16	27	5.99	46.94	0.53	4.06
Fe	%	2.7	2.6	2.6	1.1	9.3	2.3	3.0	3.72	30.30	-0.00	4.48
Ga	mg/kg	4.6	4.4	4.5	1.5	8.6	3.8	5.3	0.28	0.65	-0.81	1.58
Hf	mg/kg	0.030	0.020	0.015	0.010	0.15	0.010	0.040	1.85	3.18	0.68	-0.89
Hg	mg/kg	0.081	0.069	0.067	0.026	0.96	0.054	0.086	8.28	79.68	1.66	7.85
In	mg/kg	0.025	0.022	0.025	0.010	0.080	0.010	0.030	1.06	1.80	-0.17	-0.94
K	%	0.13	0.12	0.12	0.040	0.35	0.090	0.15	1.51	2.99	0.26	0.34
La	mg/kg	18	17	18	5.1	32	14	21	0.18	-0.22	-0.75	0.85
Li	mg/kg	18	17	19	5.0	37	14	22	0.20	0.21	-0.89	1.10
Mg	%	0.57	0.46	0.46	0.040	5.0	0.34	0.59	4.90	32.38	0.30	3.33
Mn	mg/kg	700	640	670	140	2100	510	810	1.24	3.63	-0.51	0.83
Mo	mg/kg	0.80	0.63	0.61	0.18	6.6	0.41	0.89	4.55	25.48	0.95	1.85
Na	%	0.0086	0.0076	0.0080	0.0020	0.023	0.0050	0.011	0.93	0.64	-0.32	-0.02
Nb	mg/kg	0.57	0.52	0.57	0.11	1.5	0.41	0.69	0.52	0.84	-0.76	0.61
Ni	mg/kg	28	26	26	8.7	66	21	35	0.95	0.96	-0.16	0.06
P	%	0.061	0.057	0.058	0.022	0.13	0.044	0.074	0.85	0.79	-0.16	-0.11
Pb	mg/kg	27	24	23	11	210	19	28	5.58	40.63	1.70	5.55
Rb	mg/kg	18	17	18	9.1	39	14	21	0.89	1.55	0.03	-0.17
S	%	0.030	0.024	0.030	0.010	0.21	0.020	0.030	4.20	25.34	0.27	0.58
Sb	mg/kg	0.58	0.53	0.51	0.16	1.7	0.43	0.65	1.96	4.96	0.24	1.47
Sc	mg/kg	3.7	3.5	3.5	1.4	11	2.8	4.4	1.54	5.64	0.07	0.61
Se	mg/kg	0.34	0.27	0.30	0.050	1.5	0.20	0.40	1.62	4.65	-0.67	0.34
Sn	mg/kg	0.95	0.88	0.90	0.40	5.1	0.70	1.1	4.75	37.66	0.87	2.57
Sr	mg/kg	33	16	13	2.6	750	9.4	21	6.34	46.06	1.62	3.76
Te	mg/kg	0.025	0.019	0.020	0.010	0.15	0.010	0.030	2.59	11.07	0.49	-0.81
Th	mg/kg	4.3	4.0	4.2	1.1	8.9	3.1	5.3	0.48	0.07	-0.63	0.36
Ti	%	0.015	0.010	0.012	0.0005	0.14	0.0050	0.020	4.30	32.05	-0.31	-0.01
Tl	mg/kg	0.19	0.18	0.17	0.090	0.81	0.14	0.21	3.58	16.73	1.29	3.35
U	mg/kg	1.1	1.0	1.0	0.30	3.7	0.85	1.2	2.48	10.12	0.39	1.91
V	mg/kg	34	32	32	15	76	26	39	1.27	2.61	0.14	0.40
Y	mg/kg	10	9.5	9.8	2.6	64	7.9	12	5.89	55.02	-0.05	3.11
Zn	mg/kg	77	70	69	32	660	57	86	7.97	78.25	1.60	8.20
Zr	mg/kg	0.90	0.60	0.60	0.050	4.4	0.30	1.1	1.90	3.89	-0.43	0.24

$\bar{X}$ – aritmetična sredina/arithmetic mean; X(G) – geometrijska sredina/geometric mean; Md – mediana/median (Q2); Min – minimium/minimum; Max – maksimum/maximum; P25 – 25. percentil/ 25th percentile (Q1), P75 – 75. percentil/75th percentile (Q3); A – asimetričnost/skewness; E – sploščenost/kurtosis; A(L) – asimetričnost (logaritmirane vrednosti)/skewness (logarithmic values); E(L) – sploščenost (logaritmirane vrednosti)/kurtosis (logarithmic values)

Appendix 1/8. Basic statistical parameters for Interior basins.
Priloga 1/8. Osnovni statistični parametri za Notranje kotline.

	Unit	$\bar{X}$	X(G)	Md	Min	Max	P25	P75	A	E	A(L)	E(L)
Ag	μg/kg	120	88	93	18	1200	55	140	5.57	33.04	0.97	4.28
Al	%	1.8	1.8	1.9	0.60	2.9	1.5	2.3	−0.05	−0.37	−1.04	2.00
As	mg/kg	11	10	11	5.6	15	7.8	13	−0.03	−1.30	−0.37	−1.09
Au	μg/kg	2.6	2.0	1.9	0.60	12	1.2	2.7	2.51	7.36	0.48	0.10
B	mg/kg	2.6	1.9	2.0	0.50	7.0	1.0	4.0	0.63	−0.55	−0.39	−1.12
Ba	mg/kg	95	78	83	21	560	51	110	4.46	24.05	0.38	2.10
Be	mg/kg	0.88	0.83	0.90	0.30	1.6	0.70	1.0	0.45	0.08	−0.63	0.71
Bi	mg/kg	0.33	0.32	0.35	0.18	0.56	0.24	0.40	0.03	−0.44	−0.45	−0.81
Ca	%	2.1	0.54	0.60	0.0050	20	0.17	2.9	3.65	16.81	−0.34	−0.52
Cd	mg/kg	0.70	0.55	0.61	0.050	1.6	0.42	0.98	0.41	−0.53	−1.42	2.11
Ce	mg/kg	33	30	35	7.4	56	24	42	−0.10	−0.84	−1.14	1.19
Co	mg/kg	11	10	10	2.8	29	8.2	12	1.15	1.66	−0.33	0.45
Cr	mg/kg	28	26	28	8.3	56	20	35	0.57	0.49	−0.71	0.82
Cs	mg/kg	1.4	1.2	1.4	0.24	2.7	0.96	1.8	0.22	−0.36	−1.11	1.73
Cu	mg/kg	21	20	20	8.2	40	16	24	0.97	1.11	−0.04	0.34
Fe	%	2.6	2.5	2.7	1.2	4.5	2.2	3.1	−0.04	0.01	−0.79	0.04
Ga	mg/kg	5.0	4.7	5.0	1.6	8.0	3.8	6.1	−0.02	−0.43	−1.01	1.98
Hf	mg/kg	0.091	0.074	0.080	0.010	0.24	0.050	0.12	0.95	0.51	−0.93	1.38
Hg	mg/kg	0.17	0.15	0.15	0.057	0.60	0.12	0.19	3.05	13.64	0.42	1.73
In	mg/kg	0.038	0.036	0.040	0.010	0.060	0.030	0.050	−0.41	0.17	−1.71	3.73
K	%	0.12	0.11	0.10	0.050	0.34	0.090	0.14	1.75	3.83	0.57	0.17
La	mg/kg	15	13	15	2.7	30	11	18	0.45	0.07	−1.10	1.89
Li	mg/kg	18	16	18	4.3	38	14	22	0.32	0.55	−1.12	1.31
Mg	%	0.89	0.54	0.41	0.030	4.7	0.29	0.80	2.13	4.17	0.18	1.27
Mn	mg/kg	800	640	820	100	1600	350	1200	0.22	−1.03	−0.81	−0.21
Mo	mg/kg	0.79	0.73	0.72	0.31	1.6	0.56	1.0	0.52	0.08	−0.31	−0.52
Na	%	0.0074	0.0066	0.0065	0.0020	0.022	0.0050	0.010	1.70	4.48	−0.22	0.84
Nb	mg/kg	0.60	0.50	0.54	0.12	1.2	0.36	0.82	0.42	−0.90	−0.67	−0.13
Ni	mg/kg	24	21	22	7.2	64	20	26	1.64	4.73	−0.48	1.33
P	%	0.073	0.063	0.067	0.0080	0.20	0.050	0.10	0.83	1.80	−1.16	2.27
Pb	mg/kg	44	42	42	21	67	33	53	0.05	−0.65	−0.55	−0.06
Rb	mg/kg	18	17	18	5.4	45	14	22	0.84	1.97	−0.60	0.13
S	%	0.060	0.044	0.040	0.010	0.37	0.030	0.060	3.75	14.17	0.58	2.75
Sb	mg/kg	0.58	0.54	0.54	0.26	1.6	0.40	0.76	1.93	5.71	0.55	0.27
Sc	mg/kg	3.5	3.3	3.3	1.4	6.1	2.8	4.4	0.20	−0.81	−0.43	−0.51
Se	mg/kg	0.54	0.44	0.40	0.10	2.6	0.30	0.60	3.01	10.74	0.60	1.44
Sn	mg/kg	1.7	1.4	1.4	0.40	11	1.0	1.8	4.88	27.09	1.08	4.10
Sr	mg/kg	23	14	12	2.9	210	6.9	27	4.37	21.67	0.62	0.69
Te	mg/kg	0.037	0.029	0.035	0.010	0.090	0.010	0.060	0.59	−0.45	−0.39	−1.15
Th	mg/kg	3.6	3.3	3.8	0.90	7.0	2.6	4.5	0.04	−0.27	−1.13	0.98
Ti	%	0.0051	0.0040	0.0050	0.0005	0.014	0.0030	0.0070	0.95	1.39	−0.97	0.72
Tl	mg/kg	0.27	0.25	0.26	0.090	0.60	0.20	0.33	0.85	1.10	−0.37	0.19
U	mg/kg	1.4	1.1	1.1	0.30	10	0.80	1.5	4.53	22.66	1.33	4.42
V	mg/kg	39	36	40	13	89	30	44	0.93	2.59	−0.48	0.52
Y	mg/kg	12	10	9.8	2.0	30	7.6	15	1.08	1.28	−0.47	0.45
Zn	mg/kg	78	74	75	29	120	63	99	0.03	−0.48	−0.86	0.86
Zr	mg/kg	2.5	2.3	2.3	1.1	5.8	1.5	3.2	1.07	0.57	0.26	−0.82

$\bar{X}$ – aritmetična sredina/arithmetic mean; X(G) – geometrijska sredina/geometric mean; Md – mediana/median (Q2); Min – minimium/minimum; Max – maksimum/maximum; P25 – 25. percentil/ 25th percentile (Q1), P75 – 75. percentil/75th percentile (Q3); A – asimetričnost/skewness; E – sploščenost/kurtosis; A(L) – asimetričnost (logaritmirane vrednosti)/skewness (logarithmic values); E(L) – sploščenost (logaritmirane vrednosti)/kurtosis (logarithmic values)

Appendix 2/1. Determined thresholds for Western Alps.
Priloga 2/1. Zgornje meje naravne variabilnosti za Zahodne Alpe.

	Unit	P95	P97.5	X2S	X2S(L)	MD2MAD	MD2MAD(L)	TIF	TIF(L)
Ag	µg/kg	180	180	190	250	140	190	200	350
Al	%	3.6	3.7	3.7	6.8	3.9	6.2	4.7	9.6
As	mg/kg	30	34	34	43	24	37	29	53.0
Au	µg/kg	4.8	5.2	8.8	8.9	3.4	8.0	4.7	13.7
B	mg/kg	12	14	11	17	6.0	10	9.5	19.8
Ba	mg/kg	130	140	130	240	130	150	150	310
Be	mg/kg	2.3	2.3	2.2	3.7	2.0	3.2	2.6	5.0
Bi	mg/kg	0.86	0.94	0.84	1.1	0.70	0.99	0.97	1.5
Ca	%	16	21	15	42	5.8	130	17	620
Cd	mg/kg	6.4	6.5	5.7	8.7	3.2	11	4.9	20.5
Ce	mg/kg	67	70	69	130	73	160	89	270
Co	mg/kg	25	26	25	47	25	40	30	72.6
Cr	mg/kg	67	78	69	99	57	100	78	180
Cs	mg/kg	3.3	3.6	3.3	6.3	3.0	6.4	4.0	13.1
Cu	mg/kg	49	56	49	70	40	56	49	84.4
Fe	%	4.2	4.3	4.8	9.2	4.9	6.1	6.1	11.9
Ga	mg/kg	8.8	10	10	18	10	17	12	28.6
Hf	mg/kg	0.22	0.27	0.21	0.32	0.17	0.37	0.22	0.61
Hg	mg/kg	0.56	0.71	0.83	0.81	0.42	0.71	0.60	1.4
In	mg/kg	0.070	0.090	0.085	0.13	0.070	0.094	0.11	0.17
K	%	0.24	0.28	0.26	0.37	0.23	0.33	0.27	0.47
La	mg/kg	39	39	38	65	31	68	42	140
Li	mg/kg	29	38	33	70	35	61	43	120
Mg	%	7.2	8.1	6.0	8.4	1.4	3.1	5.2	40.5
Mn	mg/kg	2100	2400	2440	4000	2000	3900	2700	7700
Mo	mg/kg	3.6	5.1	3.1	2.8	1.3	1.9	1.6	2.8
Na	%	0.017	0.024	0.023	0.023	0.013	0.019	0.018	0.028
Nb	mg/kg	1.9	2.4	1.9	2.8	1.2	3.1	1.6	5.4
Ni	mg/kg	71	77	64	120	61	110	73	200
P	%	0.24	0.25	0.20	0.25	0.12	0.17	0.17	0.31
Pb	mg/kg	130	150	120	150	90	140	130	240
Rb	mg/kg	27	33	31	54	31	45	37	79.1
S	%	0.23	0.24	0.20	0.29	0.14	0.23	0.18	0.47
Sb	mg/kg	1.3	1.6	1.5	1.8	1.2	1.8	1.6	2.7
Sc	mg/kg	8.7	9.3	8.8	14	8.4	15	11	26.8
Se	mg/kg	1.4	2.1	1.5	1.9	0.99	1.7	1.6	3.5
Sn	mg/kg	3.2	3.4	3.0	4.3	2.8	3.9	3.2	5.1
Sr	mg/kg	75	82	67	93	49	110	73	240
Te	mg/kg	0.17	0.20	0.17	0.28	0.15	0.39	0.20	1.3
Th	mg/kg	7.6	8.1	7.1	13	6.5	13	8.1	26.0
Ti	%	0.056	0.12	0.066	0.042	0.009	0.014	0.014	0.046
Tl	mg/kg	0.77	0.88	0.82	1.1	0.75	1.5	1.1	2.7
U	mg/kg	1.5	1.7	1.5	1.8	1.3	1.9	1.8	2.8
V	mg/kg	73	79	81	120	80	130	89	170
Y	mg/kg	58	60	49	71	24	52	37	95.6
Zn	mg/kg	180	190	210	280	160	230	190	290
Zr	mg/kg	6.8	7.7	6.0	8.6	5.0	8.8	6.5	18.3

P95 – 95. percentil/95th percentile, P97.5 – 97,5. percentil/97.5th percentile; X2S – srednja vrednost+2×standardni odklon/mean+2×standard deviation; MD2MAD – mediana+2×absolutna deviacija mediane/median+2×median absolute deviation; TIF – Tukeyeva zgornja meja/Tukey upper fence; (L) – izračun na osnovi logaritemskih vrednosti/(calculated based on logarithmic values)

Appendix 2/2. Determined thresholds for Eastern Alps.
Priloga 2/2. Zgornje meje naravne variabilnosti za Vzhodne Alpe.

	Unit	P95	P97.5	X2S	X2S(L)	MD2MAD	MD2MAD(L)	TIF	TIF(L)
Ag	µg/kg	250	340	270	410	140	270	240	660
Al	%	3.5	3.7	3.9	4.8	3.7	4.3	4.2	5.5
As	mg/kg	39	70	50	42	19	29	22	46.2
Au	µg/kg	10	22	18	14	3.4	7.6	4.9	11.2
B	mg/kg	7.0	9.0	6.3	9.4	6.4	16	6.8	44.1
Ba	mg/kg	220	240	200	250	140	200	190	290
Be	mg/kg	1.6	1.9	1.6	2.0	1.5	1.6	1.7	2.2
Bi	mg/kg	0.64	0.74	0.66	0.86	0.54	0.75	0.67	1.1
Ca	%	4.9	13	6.9	5.4	0.67	2.0	1.1	4.7
Cd	mg/kg	1.3	2.0	1.3	1.6	0.75	1.6	1.1	2.9
Ce	mg/kg	60	61	63	86	64	81	74	110
Co	mg/kg	35	39	33	42	27	36	29	40.9
Cr	mg/kg	88	150	100	120	64	91	80	130
Cs	mg/kg	4.2	4.7	4.5	6.0	4.2	7.0	5.1	11.6
Cu	mg/kg	63	85	85	100	49	71	58	93.0
Fe	%	5.1	7.5	6.3	7.7	5.1	5.6	5.6	6.7
Ga	mg/kg	12	14	13	16	11	14	13	17.5
Hf	mg/kg	0.085	0.11	0.086	0.080	0.010	0.010	0.060	0.16
Hg	mg/kg	0.21	0.49	0.31	0.30	0.15	0.25	0.22	0.40
In	mg/kg	0.075	0.10	0.081	0.096	0.060	0.070	0.063	0.081
K	%	0.41	0.89	0.53	0.54	0.31	0.44	0.35	0.52
La	mg/kg	25	28	29	40	31	41	35	53.0
Li	mg/kg	55	64	61	77	45	57	54	76.0
Mg	%	3.1	8.9	4.5	3.7	1.4	2.0	1.9	3.1
Mn	mg/kg	1600	2300	1630	1800	1200	1600	1400	2100
Mo	mg/kg	2.4	3.3	2.9	3.1	1.5	2.4	2.0	3.7
Na	%	0.034	0.040	0.033	0.051	0.028	0.047	0.035	0.074
Nb	mg/kg	3.4	4.0	3.5	5.3	2.0	7.2	2.8	11.5
Ni	mg/kg	54	92	71	96	58	72	65	97.4
P	%	0.15	0.18	0.14	0.16	0.12	0.14	0.14	0.19
Pb	mg/kg	130	160	110	130	64	90	84	140
Rb	mg/kg	51	67	54	62	34	44	42	61.5
S	%	0.065	0.075	0.068	0.095	0.060	0.10	0.085	0.32
Sb	mg/kg	1.4	2.0	1.8	1.9	1.0	1.8	1.3	2.8
Sc	mg/kg	9.8	12	10	12	7.7	12	10	17.1
Se	mg/kg	0.90	1.1	0.90	1.4	0.79	1.0	0.95	2.0
Sn	mg/kg	2.5	4.4	7.0	3.5	1.6	2.0	2.2	3.3
Sr	mg/kg	49	59	110	67	32	62	46	100
Te	mg/kg	0.070	0.085	0.073	0.10	0.059	0.24	0.085	0.32
Th	mg/kg	7.9	8.2	8.2	14	8.0	12	10	19.1
Ti	%	0.17	0.21	0.15	0.29	0.052	0.85	0.14	3.3
Tl	mg/kg	0.44	0.55	0.46	0.56	0.39	0.57	0.52	0.81
U	mg/kg	3.2	4.8	3.2	3.7	1.8	3.0	2.7	4.7
V	mg/kg	140	170	120	130	73	94	100	160
Y	mg/kg	18	22	19	22	17	23	20	31.9
Zn	mg/kg	200	290	210	210	140	160	160	200
Zr	mg/kg	2.5	3.7	2.5	4.4	1.4	7.5	2.1	10.5

P95 – 95. percentil/95th percentile, P97.5 – 97,5. percentil/97.5th percentile; X2S – srednja vrednost+2×standardni odklon/mean+2×standard deviation; MD2MAD – mediana+2×absolutna deviacija mediane/median+2×median absolute deviation; TIF – Tukeyeva zgornja meja/Tukey upper fence; (L) – izračun na osnovi logaritemskih vrednosti/(calculated based on logarithmic values)

Appendix 2/3. Determined thresholds for Western Prealps.
Priloga 2/3. Zgornje meje naravne variabilnosti za Zahodne Predalpe.

	Unit	P95	P97.5	X2S	X2S(L)	MD2MAD	MD2MAD(L)	TIF	TIF(L)
Ag	µg/kg	170	200	220	240	160	210	180	280
Al	%	3.3	3.4	3.5	4.5	3.5	4.5	4.2	5.9
As	mg/kg	27	36	28	35	22	31	27	42.5
Au	µg/kg	6.5	10	7.4	9.2	3.9	5.7	4.7	7.2
B	mg/kg	7.0	7.0	6.8	11	5.0	16	8.5	32.0
Ba	mg/kg	150	180	160	210	140	210	190	320
Be	mg/kg	2.3	2.5	2.4	3.9	2.2	3.3	2.7	4.7
Bi	mg/kg	0.85	0.92	0.86	1.0	0.83	1.1	0.94	1.4
Ca	%	8.7	9.2	6.6	12	1.6	8.5	3.0	22.8
Cd	mg/kg	3.2	4.0	2.8	5.1	1.6	5.0	3.1	15.9
Ce	mg/kg	74	81	78	120	76	130	93	200
Co	mg/kg	27	30	30	56	31	41	39	80.0
Cr	mg/kg	69	88	81	130	82	140	98	220
Cs	mg/kg	3.1	3.2	3.2	5.2	3.3	6.3	4.1	10.0
Cu	mg/kg	78	94	70	89	58	95	71	150
Fe	%	4.1	4.4	4.6	6.5	4.6	5.1	5.2	6.1
Ga	mg/kg	8.5	8.9	9.1	12	9.3	11	11	15.3
Hf	mg/kg	0.24	0.27	0.22	0.35	0.18	0.32	0.22	0.45
Hg	mg/kg	1.2	2.1	1.8	1.5	0.63	1.2	0.81	1.8
In	mg/kg	0.080	0.10	0.084	0.11	0.070	0.094	0.080	0.11
K	%	0.24	0.27	0.24	0.28	0.21	0.28	0.27	0.38
La	mg/kg	44	55	45	66	36	65	44	110
Li	mg/kg	54	61	52	81	42	60	51	86.8
Mg	%	4.0	5.8	3.5	3.5	0.97	1.4	1.4	2.6
Mn	mg/kg	2700	2900	3000	5400	2400	3900	2900	6400
Mo	mg/kg	4.8	6.1	4.6	4.0	1.3	2.4	1.7	3.4
Na	%	0.013	0.016	0.013	0.019	0.015	0.020	0.016	0.035
Nb	mg/kg	1.7	2.2	1.8	3.0	1.2	4.5	2.1	10.4
Ni	mg/kg	97	140	120	190	98	200	120	460
P	%	0.17	0.21	0.16	0.22	0.15	0.23	0.19	0.39
Pb	mg/kg	85	100	86	98	76	90	87	120
Rb	mg/kg	32	36	33	41	31	41	38	53.5
S	%	0.10	0.12	0.11	0.14	0.099	0.13	0.11	0.17
Sb	mg/kg	1.9	3.7	2.9	2.0	0.93	1.1	1.2	1.7
Sc	mg/kg	7.6	8.3	8.3	11	8.1	11	9.1	13.8
Se	mg/kg	1.3	1.3	1.2	1.4	1.1	1.9	1.3	2.5
Sn	mg/kg	2.9	3.7	3.2	3.8	2.9	4.7	3.8	7.9
Sr	mg/kg	61	72	72	70	30	62	44	110
Te	mg/kg	0.16	0.17	0.15	0.26	0.15	0.23	0.16	0.35
Th	mg/kg	7.6	8.0	7.6	9.6	6.5	8.7	8.4	12.7
Ti	%	0.014	0.015	0.013	0.019	0.009	0.023	0.014	0.088
Tl	mg/kg	0.78	0.84	0.75	0.90	0.52	0.78	0.85	1.8
U	mg/kg	2.4	3.3	2.6	3.1	1.8	3.0	2.5	5.5
V	mg/kg	110	140	110	150	89	150	110	210
Y	mg/kg	43	98	55	67	32	48	38	98.6
Zn	mg/kg	160	170	160	210	150	190	170	240
Zr	mg/kg	7.4	8.4	6.7	9.0	4.8	8.7	7.0	16.6

P95 – 95. percentil/95th percentile, P97.5 – 97,5. percentil/97.5th percentile; X2S – srednja vrednost+2×standardni odklon/mean+2×standard deviation; MD2MAD – mediana+2×absolutna deviacija mediane/median+2×median absolute deviation; TIF – Tukeyeva zgornja meja/Tukey upper fence; (L) – izračun na osnovi logaritemskih vrednosti/(calculated based on logarithmic values)

Appendix 2/4. Determined thresholds for Eastern Prealps.
Priloga 2/4. Zgornje meje naravne variabilnosti za Vzhodne Predalpe.

	Unit	P95	P97.5	X2S	X2S(L)	MD2MAD	MD2MAD(L)	TIF	TIF(L)
Ag	µg/kg	130	220	270	190	100	150	120	170
Al	%	3.1	3.3	2.9	3.7	2.8	3.5	3.2	4.6
As	mg/kg	26	36	28	34	22	38	26	37.6
Au	µg/kg	5.5	10	10	7.1	3.6	4.2	4.5	7.5
B	mg/kg	9.0	12	8.8	13	5.3	3.6	8.5	32.0
Ba	mg/kg	200	300	260	250	150	170	180	320
Be	mg/kg	2.2	2.4	2.0	2.4	1.6	3.5	2.1	3.4
Bi	mg/kg	0.53	0.62	0.56	0.68	0.54	1.1	0.63	0.86
Ca	%	13	14	10	25	1.3	8.3	5.9	170
Cd	mg/kg	3.6	6.3	3.8	4.5	1.4	3.3	2.1	7.2
Ce	mg/kg	67	80	73	110	70	150	81	130
Co	mg/kg	45	60	42	51	25	20	32	56.2
Cr	mg/kg	72	77	81	94	58	65	77	160
Cs	mg/kg	3.0	3.4	3.1	4.6	3.1	5.2	3.7	7.6
Cu	mg/kg	47	52	85	70	39	37	50	86.6
Fe	%	4.3	4.6	4.6	5.9	4.3	4.6	5.0	6.4
Ga	mg/kg	8.6	9.3	8.6	11	7.8	10	9.5	14.7
Hf	mg/kg	0.16	0.17	0.16	0.25	0.11	0.33	0.18	0.47
Hg	mg/kg	0.36	0.41	0.92	0.50	0.26	0.28	0.34	0.66
In	mg/kg	0.070	0.14	0.10	0.11	0.060	0.10	0.095	0.20
K	%	0.28	0.43	0.31	0.30	0.20	0.22	0.26	0.39
La	mg/kg	33	37	35	50	31	87	38	65.1
Li	mg/kg	35	48	37	46	29	33	34	49.9
Mg	%	7.7	8.2	5.4	5.5	0.93	0.70	1.5	4.4
Mn	mg/kg	2900	3100	2480	3600	1800	1500	2200	5300
Mo	mg/kg	2.6	3.1	2.3	2.4	1.3	5.8	1.6	2.6
Na	%	0.017	0.023	0.019	0.028	0.016	0.016	0.020	0.036
Nb	mg/kg	1.4	1.7	1.3	2.0	1.1	8.2	1.4	3.3
Ni	mg/kg	66	120	130	85	45	44	59	100
P	%	0.16	0.25	0.18	0.19	0.11	0.10	0.14	0.26
Pb	mg/kg	69	120	200	100	53	99	60	74.3
Rb	mg/kg	32	34	32	41	30	26	37	58.9
S	%	0.090	0.10	0.088	0.11	0.060	0.10	0.070	0.11
Sb	mg/kg	1.7	2.3	1.6	1.7	0.96	1.5	1.1	1.5
Sc	mg/kg	9.2	9.7	8.1	9.1	6.1	8.1	7.5	11.4
Se	mg/kg	0.70	0.80	0.76	1.2	0.60	0.70	0.95	2.0
Sn	mg/kg	2.4	3.3	2.6	2.8	1.9	3.3	2.4	4.0
Sr	mg/kg	180	410	270	170	36	86	74	320
Te	mg/kg	0.14	0.19	0.15	0.23	0.13	0.077	0.17	0.64
Th	mg/kg	7.5	8.0	8.1	12	7.9	14	9.3	13.5
Ti	%	0.015	0.016	0.014	0.025	0.014	0.030	0.017	0.064
Tl	mg/kg	0.51	0.62	0.56	0.66	0.40	0.86	0.48	0.71
U	mg/kg	2.3	3.5	2.6	2.9	1.8	3.0	2.0	2.7
V	mg/kg	80	110	82	94	62	110	76	130
Y	mg/kg	39	51	37	49	23	27	37	110
Zn	mg/kg	140	1100	480	250	120	110	150	220
Zr	mg/kg	5.1	6.1	5.2	7.1	3.9	10	5.9	14.5

P95 – 95. percentil/95th percentile, P97.5 – 97,5. percentil/97.5th percentile; X2S – srednja vrednost+2×standardni odklon/mean+2×standard deviation; MD2MAD – mediana+2×absolutna deviacija mediane/median+2×median absolute deviation; TIF – Tukeyeva zgornja meja/Tukey upper fence; (L) – izračun na osnovi logaritemskih vrednosti/(calculated based on logarithmic values)

Appendix 2/5. Determined thresholds for Western Dinarides.
Priloga 2/5. Zgornje meje naravne variabilnosti za Zahodne Dinaride.

	Unit	P95	P97.5	X2S	X2S(L)	MD2MAD	MD2MAD(L)	TIF	TIF(L)
Ag	µg/kg	140	140	150	180	140	200	190	300
Al	%	4.0	4.3	3.8	4.3	3.4	4.3	4.2	5.9
As	mg/kg	24	25	23	28	21	33	29	55.8
Au	µg/kg	6.1	6.6	6.6	9.5	5.0	6.3	5.3	8.4
B	mg/kg	5.0	6.0	5.8	8.9	4.0	4.6	7.0	11.3
Ba	mg/kg	160	200	190	220	180	230	210	310
Be	mg/kg	2.3	2.4	2.4	3.0	2.2	4.7	3.1	7.0
Bi	mg/kg	0.71	0.80	0.77	0.97	0.75	1.3	0.94	1.7
Ca	%	14	15	13	23	2.6	20	11	150
Cd	mg/kg	2.4	2.6	2.2	3.0	0.97	2.5	2.0	8.0
Ce	mg/kg	66	69	71	95	76	130	97	220
Co	mg/kg	28	29	28	31	27	29	30	34.5
Cr	mg/kg	160	170	130	140	95	130	120	180
Cs	mg/kg	3.2	3.7	3.0	3.7	2.3	3.7	2.8	5.8
Cu	mg/kg	81	230	120	92	51	60	65	88.0
Fe	%	4.2	4.4	4.6	5.0	5.1	5.7	5.5	6.9
Ga	mg/kg	12	12	11	13	10	14	13	19.3
Hf	mg/kg	0.21	0.24	0.24	0.35	0.22	0.56	0.33	0.92
Hg	mg/kg	0.24	0.33	0.23	0.26	0.15	0.19	0.19	0.28
In	mg/kg	0.080	0.090	0.085	0.12	0.099	0.13	0.11	0.17
K	%	0.26	0.30	0.28	0.32	0.25	0.30	0.30	0.38
La	mg/kg	35	37	36	51	36	79	48	140
Li	mg/kg	31	33	31	35	31	40	34	42.6
Mg	%	0.90	3.0	1.7	1.2	0.64	0.72	0.73	0.92
Mn	mg/kg	2300	2400	2210	2500	1800	2100	2200	3000
Mo	mg/kg	6.7	13	7.3	8.3	2.0	6.3	3.9	18.1
Na	%	0.011	0.013	0.012	0.019	0.012	0.014	0.012	0.016
Nb	mg/kg	2.2	2.6	2.4	4.4	0.85	5.4	3.5	50.9
Ni	mg/kg	120	130	110	130	98	120	120	150
P	%	0.089	0.097	0.095	0.11	0.079	0.096	0.094	0.12
Pb	mg/kg	53	67	61	73	63	91	78	130
Rb	mg/kg	37	40	35	37	27	30	34	42.6
S	%	0.13	0.19	0.13	0.17	0.099	0.13	0.12	0.31
Sb	mg/kg	1.0	1.8	1.4	1.6	0.94	1.3	1.2	2.1
Sc	mg/kg	8.5	9.3	9.0	10	9.0	12	11	15.7
Se	mg/kg	0.90	1.6	1.1	1.4	0.70	0.94	1.0	1.7
Sn	mg/kg	2.5	3.1	3.8	3.8	2.4	4.0	3.8	7.9
Sr	mg/kg	220	280	220	280	53	130	120	530
Te	mg/kg	0.13	0.13	0.14	0.20	0.14	0.15	0.18	0.28
Th	mg/kg	8.0	10	8.3	9.9	8.3	13	10	20.0
Ti	%	0.019	0.021	0.017	0.023	0.009	0.018	0.017	0.064
Tl	mg/kg	0.64	0.71	0.67	0.85	0.43	0.81	0.85	2.4
U	mg/kg	1.6	1.7	1.6	2.0	1.5	2.0	2.2	5.0
V	mg/kg	200	220	190	240	97	170	230	740
Y	mg/kg	29	40	32	42	26	38	36	65.6
Zn	mg/kg	110	110	110	110	100	110	120	130
Zr	mg/kg	9.8	11	9.3	13	5.8	14	12	48.9

P95 – 95. percentil/95th percentile, P97.5 – 97,5. percentil/97.5th percentile; X2S – srednja vrednost+2×standardni odklon/mean+2×standard deviation; MD2MAD – mediana+2×absolutna deviacija mediane/median+2×median absolute deviation; TIF – Tukeyeva zgornja meja/Tukey upper fence; (L) – izračun na osnovi logaritemskih vrednosti/(calculated based on logarithmic values)

Appendix 2/6. Determined thresholds for Eastern Dinarides.
Priloga 2/6. Zgornje meje naravne variabilnosti za Vzhodne Dinaride.

	Unit	P95	P97.5	X2S	X2S(L)	MD2MAD	MD2MAD(L)	TIF	TIF(L)
Ag	µg/kg	130	160	140	170	110	150	140	230
Al	%	3.5	3.7	3.7	4.7	3.5	3.9	4.0	4.9
As	mg/kg	27	36	30	33	23	28	28	36.1
Au	µg/kg	4.1	5.6	4.6	7.0	3.4	5.3	4.5	8.9
B	mg/kg	8.0	11	9.9	9.9	5.0	16	6.0	15.6
Ba	mg/kg	120	150	140	170	130	160	150	210
Be	mg/kg	2.2	2.4	2.4	3.1	2.6	2.9	2.8	3.8
Bi	mg/kg	0.65	0.68	0.67	0.78	0.61	0.70	0.72	0.92
Ca	%	7.2	11	7.1	11	1.8	8.4	3.9	33.2
Cd	mg/kg	2.0	3.1	2.4	3.0	1.5	2.8	2.2	5.1
Ce	mg/kg	83	87	94	130	85	94	96	110
Co	mg/kg	40	50	42	56	34	45	43	64.7
Cr	mg/kg	75	79	81	110	72	81	83	99.1
Cs	mg/kg	3.5	3.7	3.9	5.8	3.8	5.1	4.5	7.0
Cu	mg/kg	32	40	40	40	28	34	34	44.8
Fe	%	4.2	4.4	4.7	6.0	4.1	4.4	4.6	5.1
Ga	mg/kg	9.9	11	11	14	9.7	11	11	12.7
Hf	mg/kg	0.22	0.25	0.22	0.29	0.21	0.30	0.24	0.47
Hg	mg/kg	0.28	0.30	0.27	0.32	0.23	0.30	0.27	0.41
In	mg/kg	0.080	0.090	0.080	0.10	0.070	0.094	0.11	0.17
K	%	0.21	0.27	0.29	0.25	0.16	0.19	0.18	0.22
La	mg/kg	39	39	42	58	39	46	46	58.5
Li	mg/kg	33	35	53	51	34	41	39	52.2
Mg	%	4.4	6.0	4.1	3.8	0.90	1.5	1.4	2.9
Mn	mg/kg	2600	3100	2640	3500	2400	4000	2900	5600
Mo	mg/kg	11	12	12	11	5.0	11	6.1	15.3
Na	%	0.013	0.015	0.013	0.023	0.012	0.020	0.016	0.035
Nb	mg/kg	2.1	2.2	2.1	3.1	1.9	2.4	2.2	3.3
Ni	mg/kg	72	84	76	91	58	80	77	120
P	%	0.094	0.14	0.14	0.13	0.079	0.12	0.11	0.20
Pb	mg/kg	56	61	59	65	56	61	61	69.3
Rb	mg/kg	34	38	37	46	34	39	38	44.9
S	%	0.11	0.14	0.11	0.14	0.060	0.10	0.095	0.20
Sb	mg/kg	1.2	1.6	1.4	1.6	1.0	1.3	1.3	1.9
Sc	mg/kg	8.1	8.7	8.5	11	8.2	9.6	9.4	12.4
Se	mg/kg	1.0	1.2	0.99	1.4	0.70	0.94	0.80	1.1
Sn	mg/kg	2.3	2.4	2.5	2.8	2.2	2.8	2.8	3.8
Sr	mg/kg	71	110	80	74	28	49	39	86.0
Te	mg/kg	0.13	0.15	0.13	0.20	0.11	0.14	0.13	0.25
Th	mg/kg	9.4	9.9	10	16	9.2	11	11	13.6
Ti	%	0.015	0.017	0.016	0.022	0.016	0.020	0.019	0.040
Tl	mg/kg	1.1	1.2	1.1	1.4	0.95	1.3	1.2	1.9
U	mg/kg	2.7	3.0	3.0	3.6	2.6	3.5	3.3	4.9
V	mg/kg	130	170	140	170	120	140	140	180
Y	mg/kg	36	40	36	44	29	44	37	69.0
Zn	mg/kg	100	110	110	130	100	120	120	150
Zr	mg/kg	7.9	8.9	8.0	10	6.8	8.9	8.4	12.7

P95 – 95. percentil/95th percentile, P97.5 – 97,5. percentil/97.5th percentile; X2S – srednja vrednost+2×standardni odklon/mean+2×standard deviation; MD2MAD – mediana+2×absolutna deviacija mediane/median+2×median absolute deviation; TIF – Tukeyeva zgornja meja/Tukey upper fence; (L) – izračun na osnovi logaritemskih vrednosti/(calculated based on logarithmic values)

Appendix 2/7. Determined thresholds for Pannonian basin.
Priloga 2/7. Zgornje meje naravne variabilnosti za Panonsko nižino.

	Unit	P95	P97.5	X2S	X2S(L)	MD2MAD	MD2MAD(L)	TIF	TIF(L)
Ag	µg/kg	180	210	160	180	120	160	140	230
Al	%	2.3	2.5	2.4	2.7	2.3	2.6	2.6	3.0
As	mg/kg	18	22	26	22	16	19	18	24.2
Au	µg/kg	6.5	8.9	21	8.5	4.2	6.7	5.6	9.9
B	mg/kg	7.0	9.0	6.9	9.7	5.0	16	6.0	15.6
Ba	mg/kg	140	150	140	160	130	170	160	210
Be	mg/kg	1.2	1.2	1.3	1.5	1.3	1.5	1.4	1.7
Bi	mg/kg	0.37	0.43	0.42	0.46	0.40	0.43	0.46	0.56
Ca	%	5.6	10	6.3	4.8	0.63	1.4	1.1	3.6
Cd	mg/kg	1.2	2.1	1.3	1.5	0.52	0.74	0.64	1.0
Ce	mg/kg	61	66	63	70	61	67	68	82.4
Co	mg/kg	20	23	21	23	20	23	22	27.5
Cr	mg/kg	51	54	49	53	44	48	50	57.7
Cs	mg/kg	2.1	2.2	2.2	2.4	2.0	2.3	2.3	2.7
Cu	mg/kg	44	50	63	56	35	44	44	60.3
Fe	%	3.7	4.0	4.3	4.4	3.7	4.0	4.1	4.6
Ga	mg/kg	6.6	7.6	7.0	7.8	6.7	7.2	7.5	8.7
Hf	mg/kg	0.10	0.11	0.088	0.11	0.030	0.050	0.085	0.32
Hg	mg/kg	0.14	0.16	0.25	0.17	0.11	0.14	0.13	0.17
In	mg/kg	0.050	0.060	0.053	0.067	0.040	0.048	0.060	0.16
K	%	0.24	0.29	0.23	0.25	0.21	0.26	0.24	0.32
La	mg/kg	28	29	29	33	28	33	32	38.9
Li	mg/kg	27	29	30	35	31	36	34	43.2
Mg	%	1.6	2.2	1.6	1.6	0.82	1.0	0.96	1.3
Mn	mg/kg	1200	1400	1280	1500	1100	1300	1300	1600
Mo	mg/kg	1.7	3.3	2.4	2.2	1.3	2.0	1.6	2.8
Na	%	0.018	0.020	0.017	0.021	0.017	0.027	0.020	0.036
Nb	mg/kg	0.94	1.0	1.0	1.3	1.0	1.3	1.1	1.5
Ni	mg/kg	52	59	51	58	46	55	56	75.6
P	%	0.11	0.12	0.11	0.12	0.10	0.12	0.12	0.16
Pb	mg/kg	51	100	69	57	37	44	42	50.6
Rb	mg/kg	27	30	28	30	27	30	31	36.4
S	%	0.060	0.080	0.078	0.082	0.060	0.10	0.045	0.055
Sb	mg/kg	1.1	1.4	1.1	1.2	0.81	0.91	0.97	1.2
Sc	mg/kg	6.1	6.4	6.2	6.7	5.6	6.8	6.7	8.5
Se	mg/kg	0.70	0.90	0.78	1.2	0.60	1.0	0.70	1.1
Sn	mg/kg	1.6	1.9	1.9	1.8	1.5	1.9	1.7	2.2
Sr	mg/kg	83	300	200	100	26	40	38	68.6
Te	mg/kg	0.060	0.070	0.065	0.075	0.050	0.16	0.060	0.16
Th	mg/kg	7.3	8.5	7.6	9.2	7.3	8.8	8.6	11.8
Ti	%	0.036	0.043	0.043	0.060	0.034	0.079	0.042	0.16
Tl	mg/kg	0.39	0.54	0.39	0.37	0.26	0.30	0.31	0.39
U	mg/kg	1.9	2.4	2.0	2.1	1.6	1.8	1.8	2.1
V	mg/kg	55	69	56	59	50	59	59	71.6
Y	mg/kg	17	19	22	22	16	18	18	22.3
Zn	mg/kg	120	140	190	150	110	130	130	160
Zr	mg/kg	2.7	3.7	2.6	4.2	1.5	4.7	2.4	8.6

P95 – 95. percentil/95th percentile, P97.5 – 97,5. percentil/97.5th percentile; X2S – srednja vrednost+2×standardni odklon/mean+2×standard deviation; MD2MAD – mediana+2×absolutna deviacija mediane/median+2×median absolute deviation; TIF – Tukeyeva zgornja meja/Tukey upper fence; (L) – izračun na osnovi logaritemskih vrednosti/(calculated based on logarithmic values)

Appendix 2/8. Determined thresholds for Interior basins.
Priloga 2/8. Zgornje meje naravne variabilnosti za Notranje kotline.

	Unit	P95	P97.5	X2S	X2S(L)	MD2MAD	MD2MAD(L)	TIF	TIF(L)
Ag	µg/kg	200	1200	480	350	210	330	270	570
Al	%	2.7	2.9	2.9	3.3	3.0	3.4	3.4	4.3
As	mg/kg	15	15	17	19	19	24	22	30.2
Au	µg/kg	8.1	12	7.3	8.4	4.4	6.1	5.0	9.1
B	mg/kg	6.5	7.0	6.3	11	6.4	16	8.5	32.0
Ba	mg/kg	170	560	270	260	180	240	200	370
Be	mg/kg	1.5	1.6	1.5	1.7	1.5	1.8	1.5	1.7
Bi	mg/kg	0.44	0.56	0.51	0.57	0.55	0.58	0.64	0.86
Ca	%	7.1	20	9.4	27	2.2	43	7.1	210
Cd	mg/kg	1.5	1.6	1.5	2.9	1.4	2.3	1.8	3.4
Ce	mg/kg	55	56	60	82	67	79	69	99.2
Co	mg/kg	21	29	22	27	17	19	19	23.1
Cr	mg/kg	53	56	50	61	49	62	56	77.0
Cs	mg/kg	2.5	2.7	2.5	3.4	2.7	3.9	3.0	4.6
Cu	mg/kg	39	40	35	38	33	41	36	44.7
Fe	%	3.8	4.5	4.2	4.8	4.0	4.3	4.4	5.1
Ga	mg/kg	7.3	8.0	7.8	9.0	8.4	9.7	9.5	12.4
Hf	mg/kg	0.22	0.24	0.20	0.31	0.17	0.32	0.22	0.45
Hg	mg/kg	0.28	0.60	0.35	0.37	0.27	0.31	0.30	0.40
In	mg/kg	0.060	0.060	0.062	0.079	0.070	0.077	0.080	0.11
K	%	0.23	0.34	0.24	0.26	0.17	0.21	0.22	0.27
La	mg/kg	28	30	28	38	24	30	28	35.4
Li	mg/kg	33	38	33	44	32	40	35	45.3
Mg	%	3.4	4.7	3.0	3.9	0.86	1.5	1.6	3.7
Mn	mg/kg	1600	1600	1710	2800	1900	3200	2400	7200
Mo	mg/kg	1.3	1.6	1.4	1.6	1.3	1.5	1.7	2.4
Na	%	0.016	0.022	0.015	0.018	0.011	0.014	0.018	0.028
Nb	mg/kg	1.1	1.2	1.2	1.8	1.2	1.8	1.5	2.8
Ni	mg/kg	50	64	45	54	33	35	36	40.4
P	%	0.13	0.20	0.15	0.21	0.14	0.20	0.18	0.28
Pb	mg/kg	64	67	67	74	71	84	83	110
Rb	mg/kg	32	45	34	43	30	36	34	44.8
S	%	0.33	0.37	0.20	0.19	0.070	0.094	0.11	0.17
Sb	mg/kg	1.1	1.6	1.1	1.2	1.0	1.5	1.3	2.0
Sc	mg/kg	5.5	6.1	5.9	6.8	6.0	7.4	6.9	8.9
Se	mg/kg	1.6	2.6	1.5	1.5	0.70	0.94	1.0	1.7
Sn	mg/kg	3.5	11	5.1	4.3	2.5	3.2	3.0	4.3
Sr	mg/kg	100	210	96	91	33	90	57	210
Te	mg/kg	0.085	0.090	0.084	0.13	0.11	0.18	0.14	0.88
Th	mg/kg	6.3	7.0	6.6	9.0	6.6	8.2	7.3	10.2
Ti	%	0.013	0.014	0.011	0.018	0.011	0.016	0.013	0.025
Tl	mg/kg	0.50	0.60	0.49	0.58	0.46	0.55	0.53	0.70
U	mg/kg	5.2	10	4.8	3.8	1.8	2.3	2.5	3.9
V	mg/kg	59	89	68	79	68	89	66	80.1
Y	mg/kg	29	30	24	32	22	29	27	42.8
Zn	mg/kg	120	120	130	150	120	140	150	190
Zr	mg/kg	5.5	5.8	5.0	5.8	4.8	7.0	5.8	10.0

P95 – 95. percentil/95th percentile, P97.5 – 97,5. percentil/97.5th percentile; X2S – srednja vrednost+2×standardni odklon/mean+2×standard deviation; MD2MAD – mediana+2×absolutna deviacija mediane/median+2×median absolute deviation; TIF – Tukeyeva zgornja meja/Tukey upper fence; (L) – izračun na osnovi logaritemskih vrednosti/(calculated based on logarithmic values)