Instrumental neutron activation analysis of river sediments of Danube (Romania), Nile (Egypt) and Zarafshon (Tajikistan): a comparative investigation

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Introduction

Why sediments?

Sediments represent naturally occurring materials, broken down by weathering and erosion, and subsequently transported by the action of water, wind, ice as the main constituent of glaciers, every time the gravity acting as an active on the constituent particles

Introduction

Although sediments are ubiquitous, the fluvial ones are associated with rivers and streams as well as with the deposits and landforms created by these in the development of floodplains and the occurrence of flash floods.

In typical rivers, the carried sediments are of sand and gravel size, but larger floods can carry cobbles and even boulders.

Introduction

Nile floodplain

https://www.insidescience.org/news/volcanic-eruptions-may-have-contributed-unrest-ancient-egypt

Introduction

Although sediments are ubiquitous, the fluvial ones are associated with rivers and streams as well as with the deposits and landforms created by these in the development of floodplains and the occurrence of flash floods.

In typical rivers, sediments consist of silt, sand or gravel size, but larger floods can carry cobbles and even boulders while fluvial processes include sediments motion and erosion or deposition on river beds.

Introduction

A common characteristics of the all type of sediments consists of their close chemical and mineralogical correlation with the parent rock lithology.

Indeed, sedimentary material consists of fragments of preexisting rocks produced during weathering and subsequently transported and deposited as unconsolidated sediments.

Introduction

Therefore, a detailed investigation of the sediments elemental composition can furnish valuable information concerning the nature of parent rocks as well as the diagenetic processes which take place after transport and during deposition.

Often, by crossing human agglomeration, sediments are enriched in various anthropogenic organic and inorganic contaminants, most of them harmful for human health.

Introduction

While the weathering, transport of weathered material and deposition processes are universal, the local sediments formation can be quite different especially due to the nature of parent rocks.

For this reason, a comparative study of sediments accumulated under different conditions concerning the parent rock and local climate could be of interest for any environmental study.

Materials and Methods

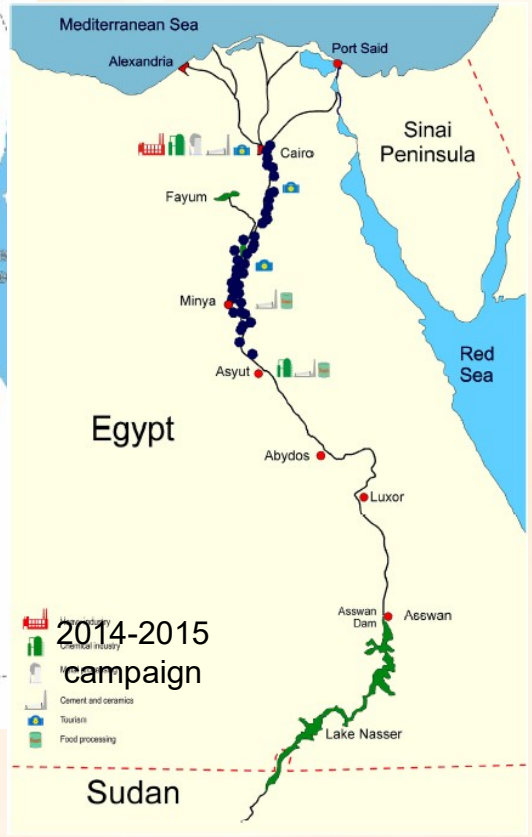
Under these circumstances, between 2012 and 2020 about 369 samples of unconsolidated sediments were collected along the Nile sector between the Aswan Lake and Mediterranean Sea including Nile Delta main branches, Serbian sector of the Danube river between Belgrade and Iron Gate II dam as well as the Zarafshon River from the sources to Tajik—Uzbek border including its main tributaries.

Materials and Methods

In this regard it worth mentioning that in the case of Nile and Zarafshon Rivers, we took the opportunity to collect an equal number of soil samples in order to evidence to what extent the sediments and soil elemental chemistry is closer.

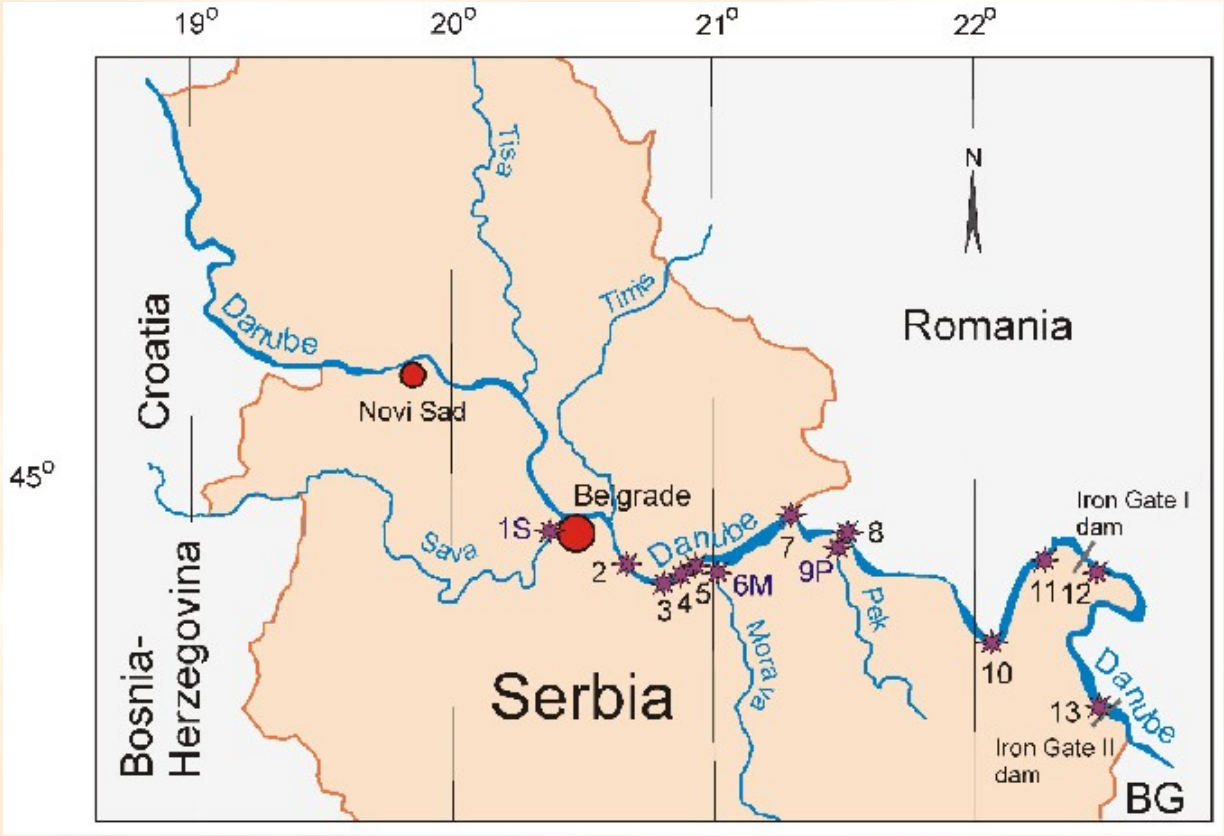
Materials and Methods - samples

The Nile River sediments and soil were collected from the Aswan lake to the Nile Delta, totally 2 x **240** samples in two campaigns

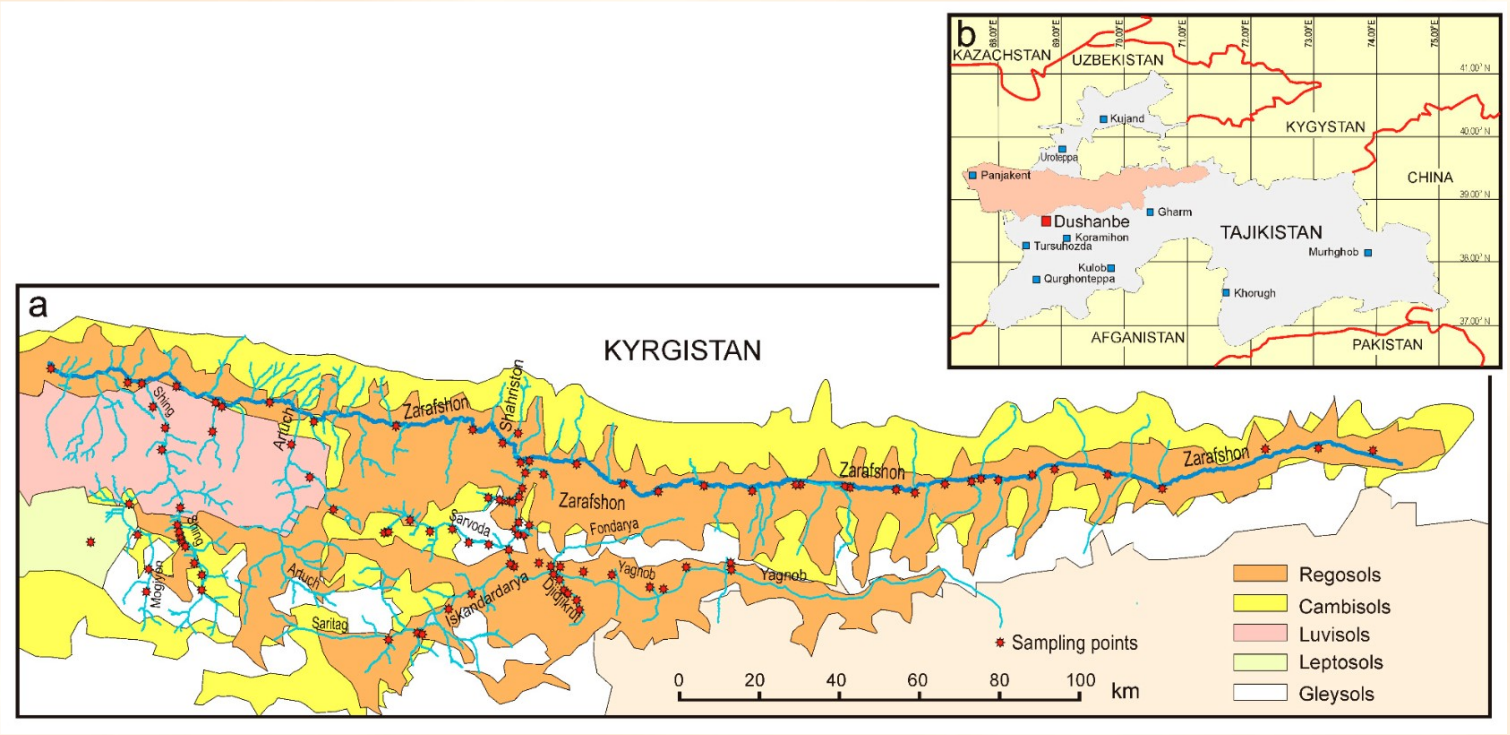


Materials and Methods - samples

13 unconsolidated superficial sediments were collected between Belgrade and Iron gate II dam Danube River



Materials and Methods - samples



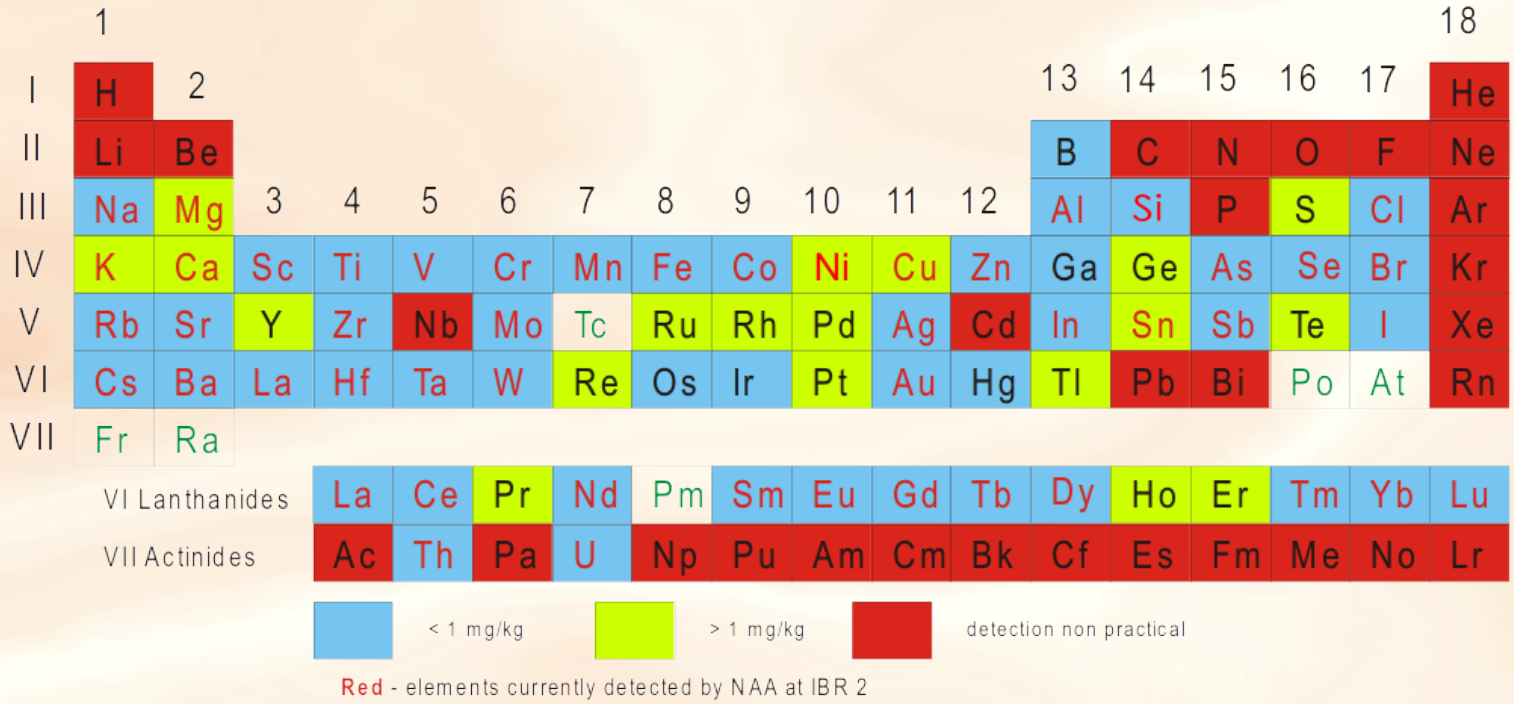
2 x 116 soil and unconsolidated superficial sediments were collected along the Zarafshon River

Materials and Methods - INAA

For a better precision and accuracy, the mass fractions of 38 elements were determined using Instrumental Neutron Activation Analysis (INAA), in both its thermal and epithermal variants.

INAA was chosen due its capacity to determine the mass fractions of up to 40 elements, without any preliminary processing prone to induce systematic errors.

Materials and Methods - INAA



INAA at FLNP IBR 2 reactor

Materials and Methods – Statistical Data Analysis

Beside basic statistical analysis, more multivariate techniques such as Cluster and Principal Component Analysis or multiple ANOVA together with graphical analysis such as bi – or ternary discriminant diagrams were currently used.

As reference, Upper Continental Crust (UCC), North American Shale Composite (NASC), Average World Suspended Sediment (AWSS) as well as different National Regulations concerning Presumably Contaminating Elements (PCE) were used.

Principal objectives

i - to evidence to what extent the geochemistry of sediments can be related to crustal material, better approximated by UCC, and NASC as well as AWSS for sediments.

ii – to evidence any correlation between sediments and soil concerning the distribution of major and trace elements.

iii - to evidence and quantify the magnitude of sediments contamination with some of the most perilous PCE, with the exception of Cd and Pb.

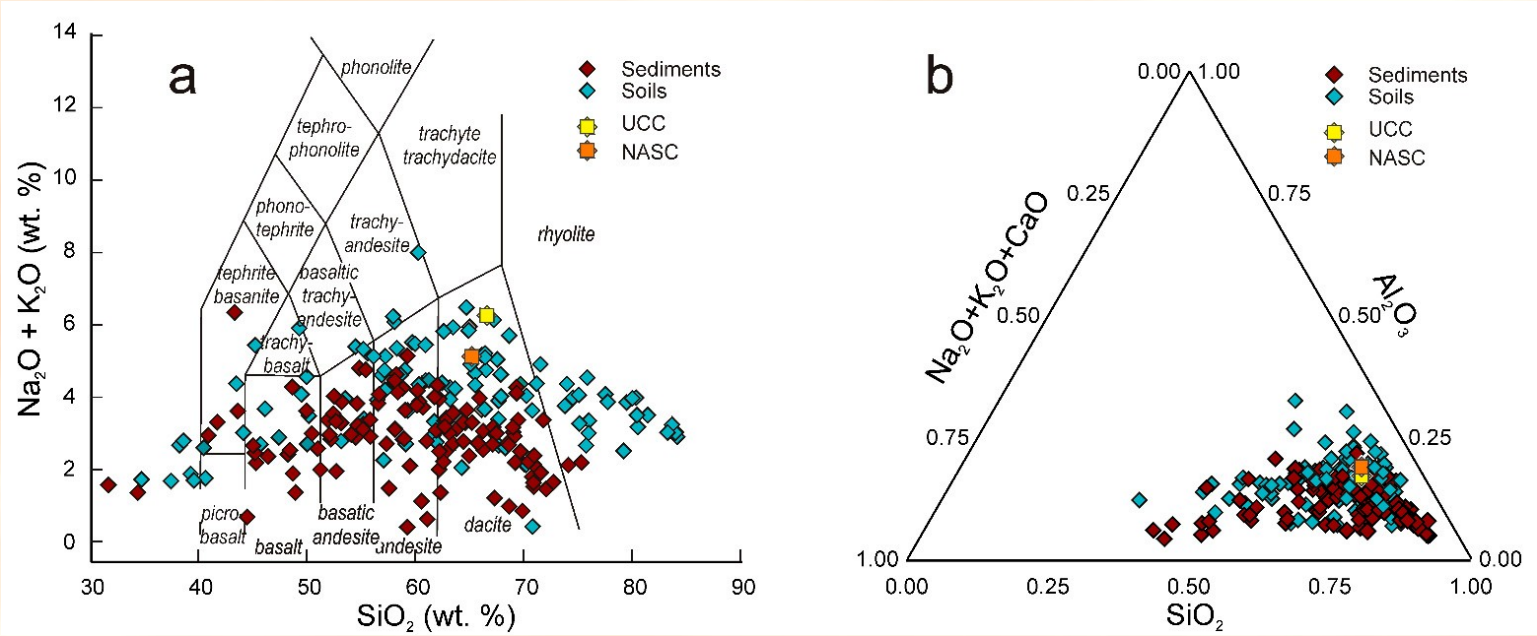
Results and Discussion

As a rule, the elements which constitute the sediments and subsequently soils can be classified, according to their abundance in major, rock forming elements of which mass fractions, as oxides, are on the order of percents to tens of percent such as Mg, Na, Al, Si, K, Ca, Ti, Mn and Fe while the others of which mass fractions varies between thousandths of mg/kg to hundreds of mg/kg represents the trace ones.

Results and Discussion

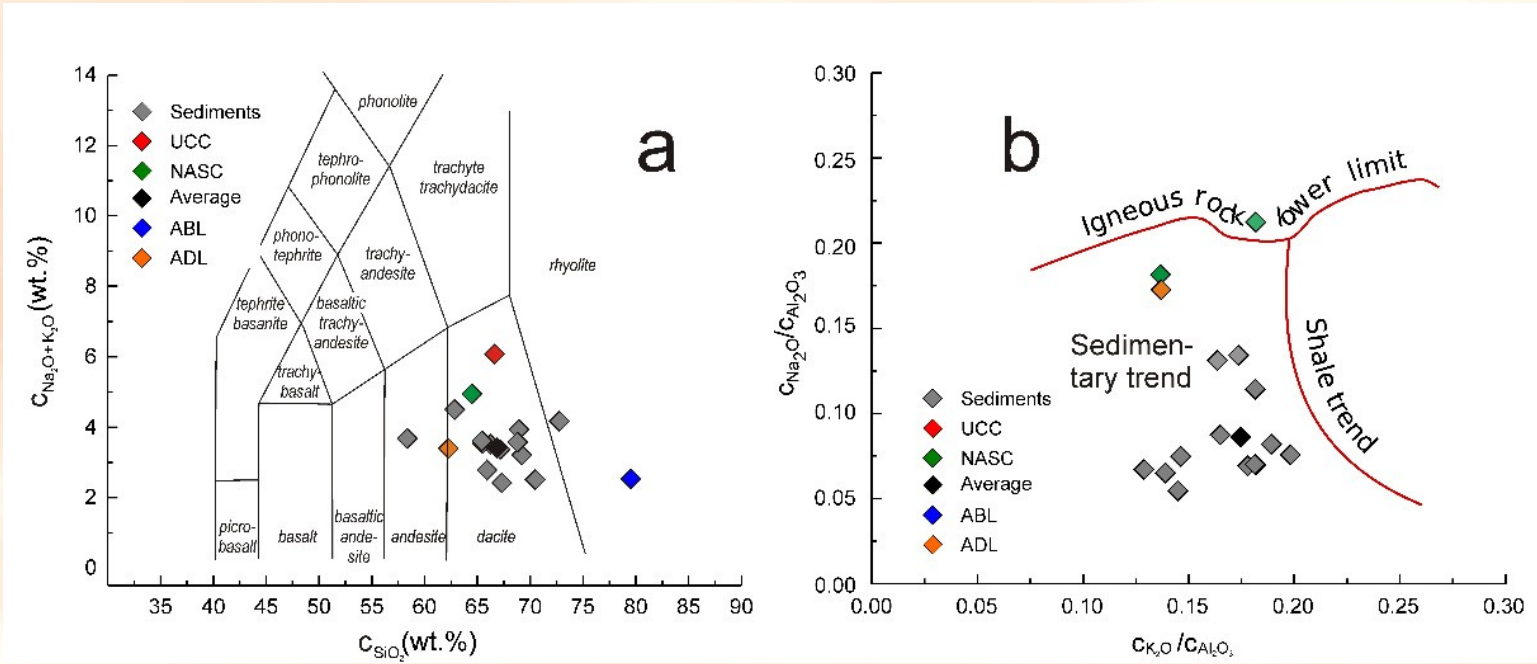
Their amount, regardless being major or trace, are deeply influenced by the nature of parent rock as well as by the influence of weathering and depositional processes, so that their geochemistry are very useful in elucidating these facts.

Results and Discussion – Major elements



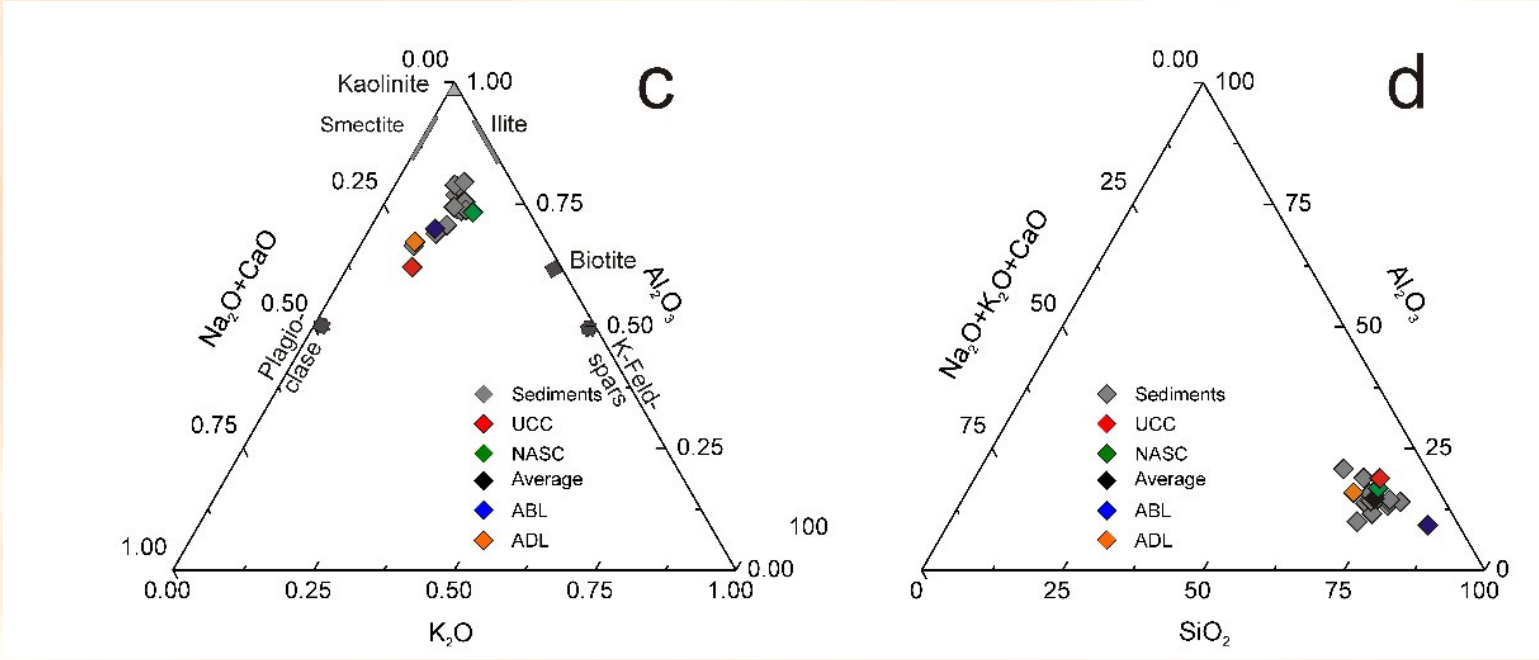
Discriminating total alkali metal oxides vs. SiO2 biplot (**a**)and ternary SiO2-Al2O3-Na2O + K2O + CaO (**b**)diagrams illustrating the preponderance of felsic material in Zarafshon sediments and soil

Results and Discussion – Major elements



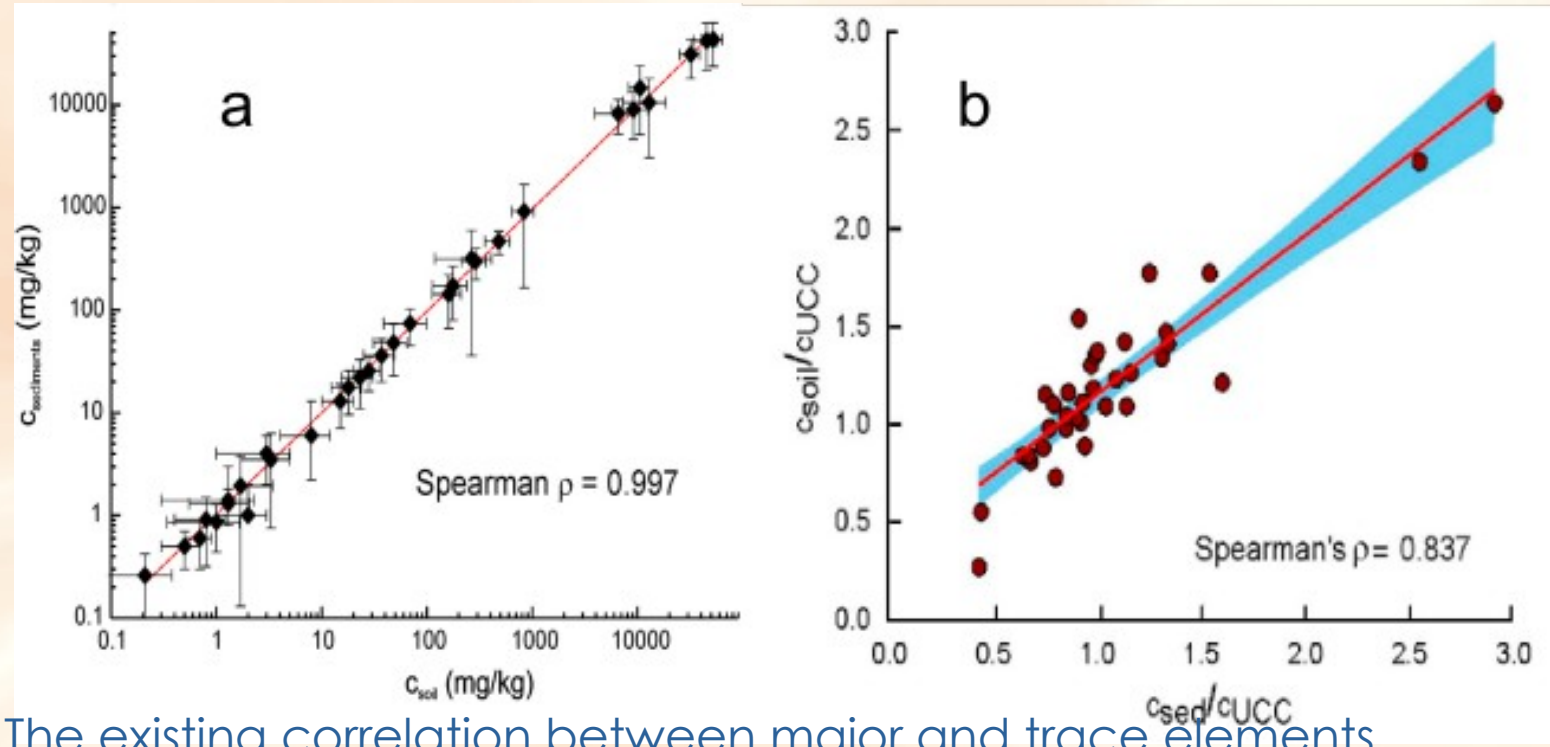
The $Na_2O + K_2O$ vs SiO_2 (a) and Na_2O/Al_2O_3 vs. K_2O/Al_2O_3 (b) discriminating diagrams illustrating more the preponderance of felsic material in the Danube River sediments.

Results and Discussion – Major elements



Ternary discriminating diagrams (c) K-A-CN and $SiO_2 - Al_2O_3 - Na_2O + K_2O + CaO$ (d) illustrating the origin of sedimentary material that composed the Danube River sediments.

Results and Discussion – Major and trace elements



The existing correlation between major and trace elements distribution in sediments and adjacent soils in the case of Nile (a) and Zarafshon (b) Rivers

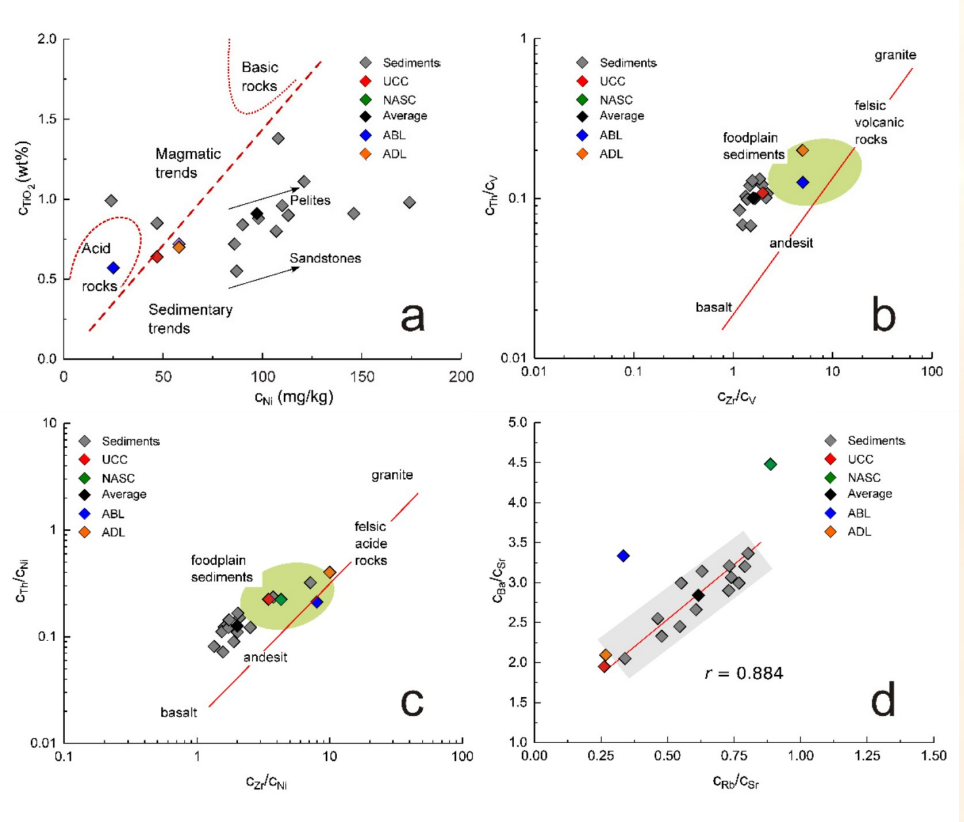
Results and Discussion – Trace elements

Much numerous than the major ones, trace elements due to their diversity could furnish a more detailed information concerning both parent rocks and evolutionary processes during sediments transport and deposition.

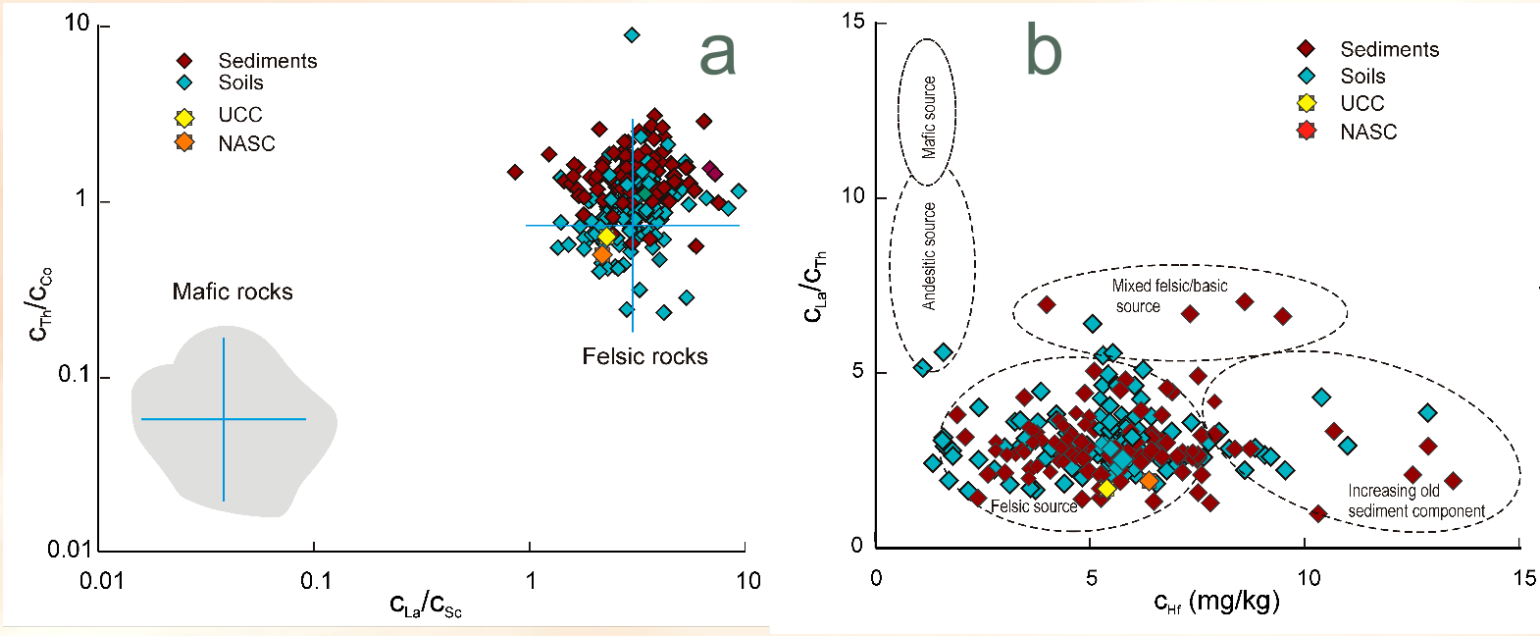
Among them, the so-called incompatible elements showed to be very useful for such type of studies

Results and Discussion – Trace elements

For instance, in the case of Danube River bottom sediments more discriminating bi-plots pointed toward a felsic origin food plain sediments

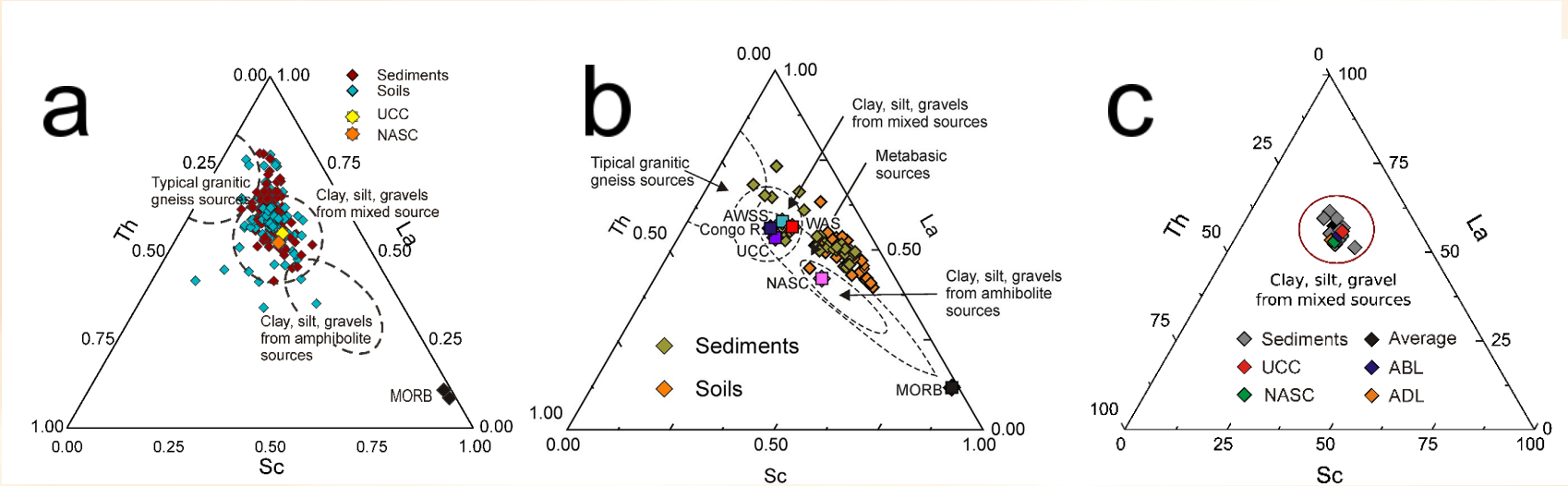


Results and Discussion – Trace elements



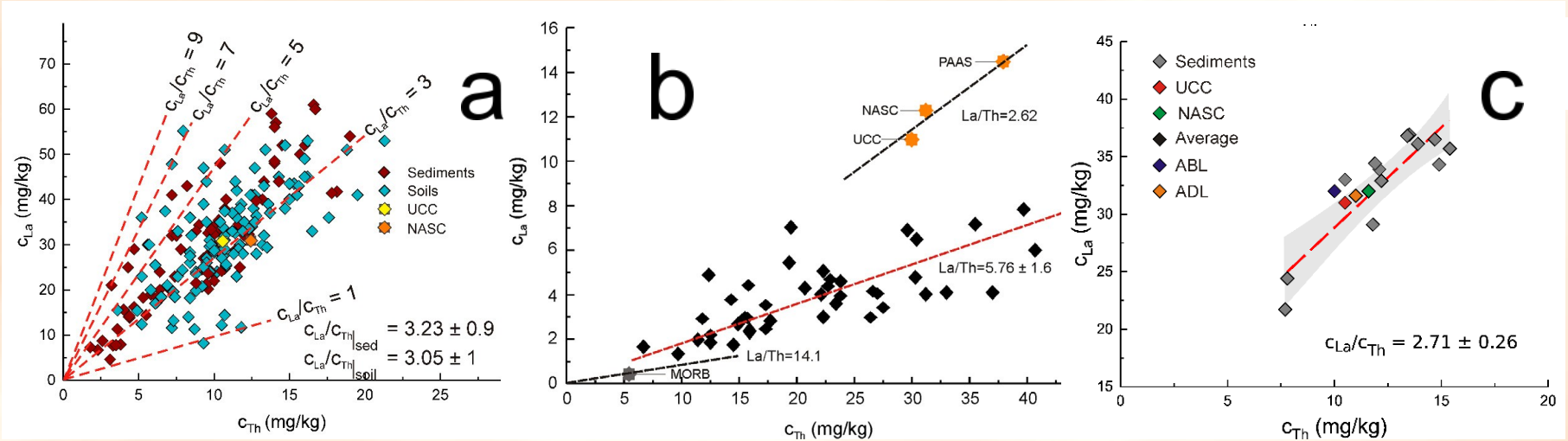
The Co/Th vs. La/Sc (a) and La/Th vs. Hf (b) discriminating diagrams illustrating felsic origin of Zarafshon River sediments and soil.

Results and Discussion – Trace elements



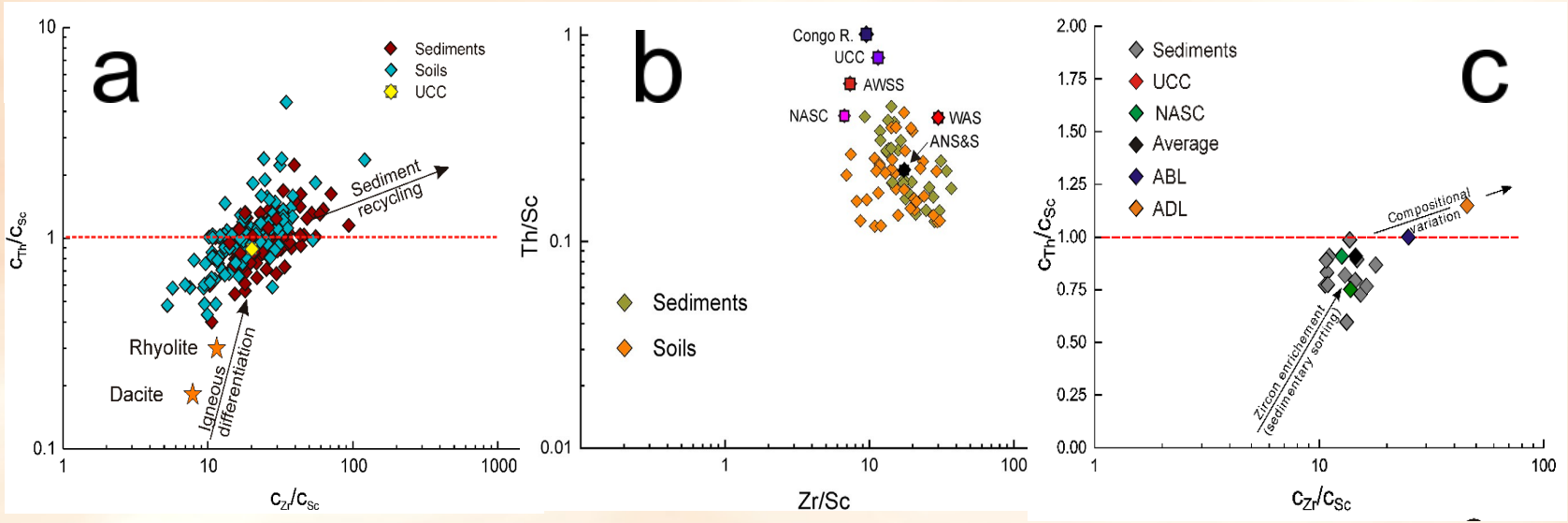
The Sc-La-Th ternary discriminating diagram for Zarafshon (a), Nile (b) and Danube (c) sediments and soils

Results and Discussion – Trace elements



The La vs Th discriminating bi-plot for Zarafshon (a), Nile (b) and Danube (c) sediments and soils. La/Sc ratio > 3 suggests the presence of mafic material, as the case of Nile sedimentary material.

Results and Discussion – Trace elements



The Th/Sc vs. Zr/Sc discriminating bi-plot for Zarafshon (a), Nile (b) and Danube (c) sediments and soils proving a weak or total absent material recycling

Results and Discussion - Presumably Contaminating Elements

Two indices, Enrichment factor (EF) and Pollution Load Index (PLI) were calculated for all investigated sediments and soils.

Results and Discussion - Presumably Contaminating Elements

Zarafshon River (Tajikistan)

- $PLI_{sediments}$: 0.5 - 5.0; V,As, Sb, W, Hg **EF** up to 14
- PLI_{soil}: 1.0 - 9.0; V, Cr, Co, Ni, As, Sb, W, Hg **EF** up to 14

Significantly contaminated

Nile River (Egypt)

- $PLI_{sediments}$: 0.74 ; Cr, Co **EF** up to 2.8
- PLI_{soil}: 1.01 ; Cr, Co **EF** up to 2.8

Almost noncontaminated

Danube River (Serbia)

- $PLI_{sediments}$: 2.0 - 4.5 ; Z, Sb **EF** up to 10

Significantly contaminated

Concluding Remarks

The comparative investigation of major and trace elements distribution in three different depositional continental regions: North-East Africa, Central Asia and Central Europe permitted evidencing not only the natural factors related to the geology of considered regions, but also the influence of human factors.

Concluding Remarks

Consequently, it was possible to differentiate the redominantly mafic origin of Nile River sediments, and subsequently soil with respect to the felsic one of both Danube and Zarafshon ones.

Also, our results evidenced a significant anthropogenic contamination with PCE in the case of Zarafshon and Danube River, different from the clean, almost uncontaminated Nile River sediments and soil.

Acknowledgments

The results I have presented are due to a continuous and fruitful cooperation with my colleagues from JINR Dubna - Daler Abdusamadzoda, Djamshed Abdushukurov, Wael Badawy, Otilia Culicov, Marina Frontasieva, Pavel Nekhoroshkov, Tatjana Trtić-Petrović, Hussein El Samman, Inga Zinicovscaia to whom I am deeply grateful and honored for their friendship

Thank you for attention and to the hosts of this seminary شـكرا for hospitality