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At the crossroads of different fine sediment fingerprinting methods in the Jiu River Basin (SW Romania)

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INTRODUCTION

- Fine sediments in rivers hold the imprint of the lithological and geochemical features of their origin areas and sometimes intermediate storage, as well as of the influence of human activities.
- The quest for methods and techniques to identify the sources of fine sediments is gaining attention and it is viewed with growing interest in the context of European river basins' management, following the adoption of the Water Framework Directive (WFD 2000/60/EC).
- Knowledge of fine sediment sources may ensure compliance with the EU Water Directive, particularly with its provisions concerning the prioritization and inclusion of measures for controlling the mobilization and delivery of riverine sediments to the Danube River.
- To illustrate the systemic perspective on the geochemical elements of fine sediments, the study was carried out in the Jiu River Basin (10,070 km²), a major tributary of the Danube in Romania.

THE OBJECTIVE OF THE STUDY is to identify the most contributing sub-catchments in terms of sediment source areas, by trying and testing different conventional (heavy metals and lanthanides geochemistry) and alternative (colorimetry, image analysis and organic petrology) laboratory methods.

METHODOLOGY

Sampling strategy

A total of 88 samples (smps.) were collected from **2 types of locations**

- ***Raw coal smps (12)***
  - upstream sector – Petroşani coal basin
  - middle sector – Motru – Rovinari coal basin
- ***Environmental smps (66)***
  - Intermediary sources (55): Jiu river and its tributaries
  - Accumulation (11): alluvial deposition on Jiu riverbank

- Uneven no. of samples were used for each of the fingerprinting methods.

Laboratory analysis

- After drying in the oven (105°/24h), the were crushed and sieved to take out particles >1 mm.
- **The analyses made on coal** were: **a)** Coal speciation (lignite and bituminous coal) by means of the apparent density & b) To distinguish between the sources of bituminous coal from the Western and Eastern Jiu, volatile compounds were determined by means of calcination in the absence of air (capped crucible) at 959°C (ISO 562: 2010), and ash content by calcination at 850°C (ISO 1171: 2010)
- **Elemental analyses** were performed by X-ray fluorescence (XRF) spectrometry (SR EN 15309: 2007), for particles with ρ >2.8 g/l
- **Coal petrology** – After drying the samples at room temperature, polished blocks were prepared for microscopic analyses in reflected light: random reflectance measurements and determination of types of organic particles.

STUDY AREA

- Jiu River (L~340 km) springs in the Romanian Meridional Carpathians by its headwaters Western and Eastern Jiu and flows southward towards the Danube, from >2000 m to <50 m a.s.l.
- A geomorphologically and lithologically complex watershed overlapping a large variety of landforms and geologic units contributing to the high rate of suspended sediment load (> 10 t·ha^{-1}·yr^{-1})
- Coal mining areas present, both in the upper Jiu Valley, along Petroşani depression (bituminous coal mainly) and in the middle sector of the piedmont (lignite in Motru – Rovinari basin).

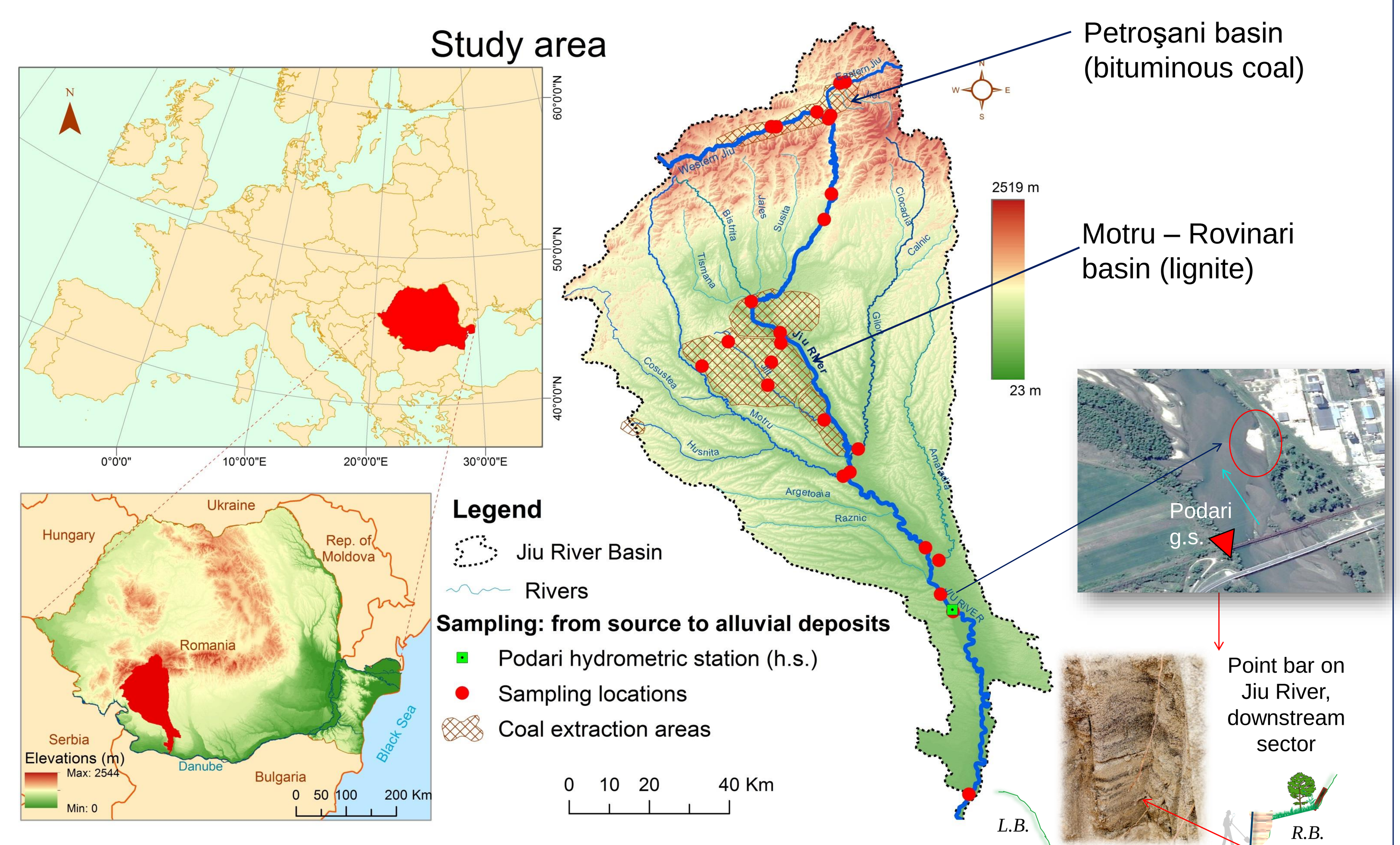


Fig. 1 – *Location map of the Jiu River Basin and sampling points*

RESULTS & DISCUSSION

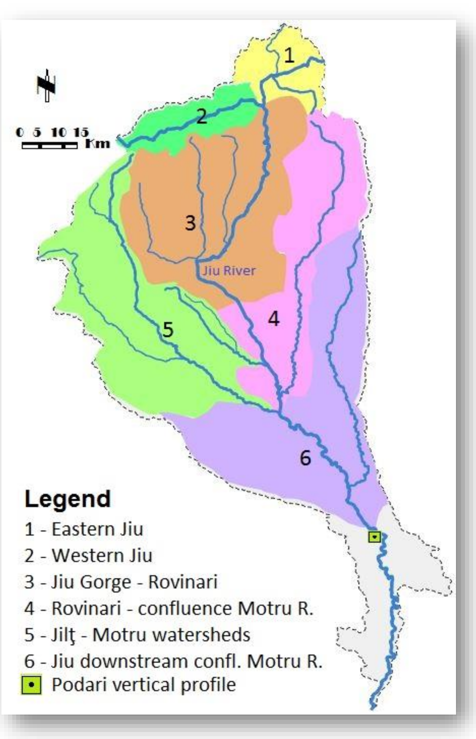


Fig. 2 - Illustration of the 6 sub-catchments where the samples' location (reflecting the main sediment source areas) were organized. Downstream, Podari site, the vertical profile of the alluvial deposits was investigated

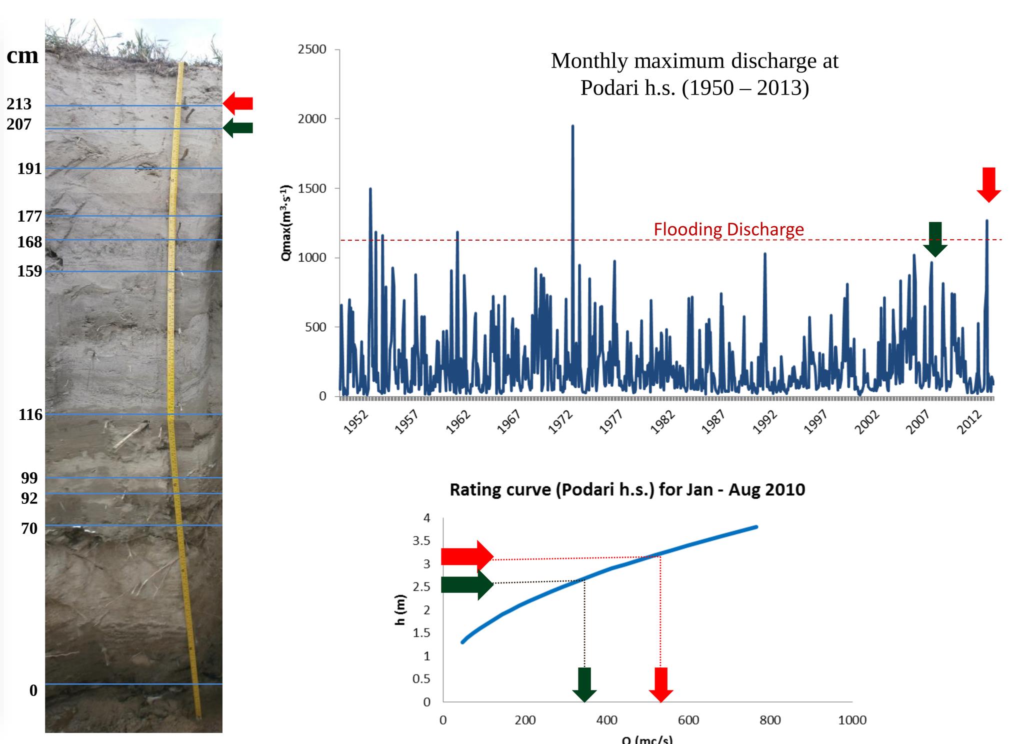


Fig. 3 – Relationship between water stage ~ layer depth ~ flooding discharge on the basis of the rating curve at Podari hydrometric station (h.s.). The layers were considered homogeneous in terms of granulometry and colorimetry, thus assuming that each flood responsible for the deposition of a sediment layer is geochemically different, according to the main coal/ heavy mineral tracers of the contributing sub-catchments

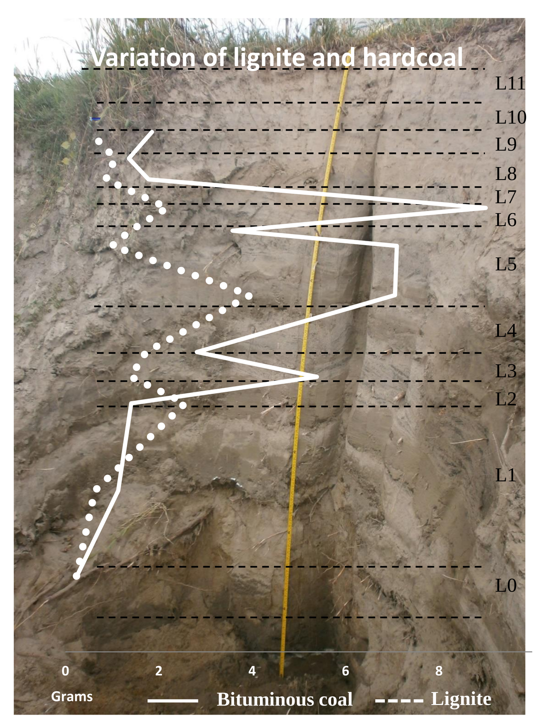


Fig. 4 - Variation with depth of the coal content (g) of the two species represented. Assumption: each layer corresponds to an overflowing flood which has contributed in the sediment accumulation. Large variation with depths → different catchment sources

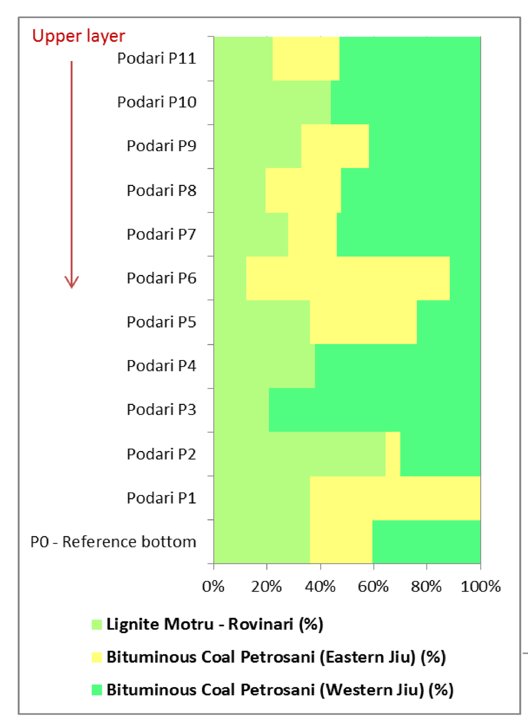


Fig. 6 - Variation with depth of the total content (%) of lignite and bituminous coal (from the Western and Eastern Jiu) in the vertical profile of the alluvial deposits at Podari h.s. (*Color scheme from Fig. 2*)

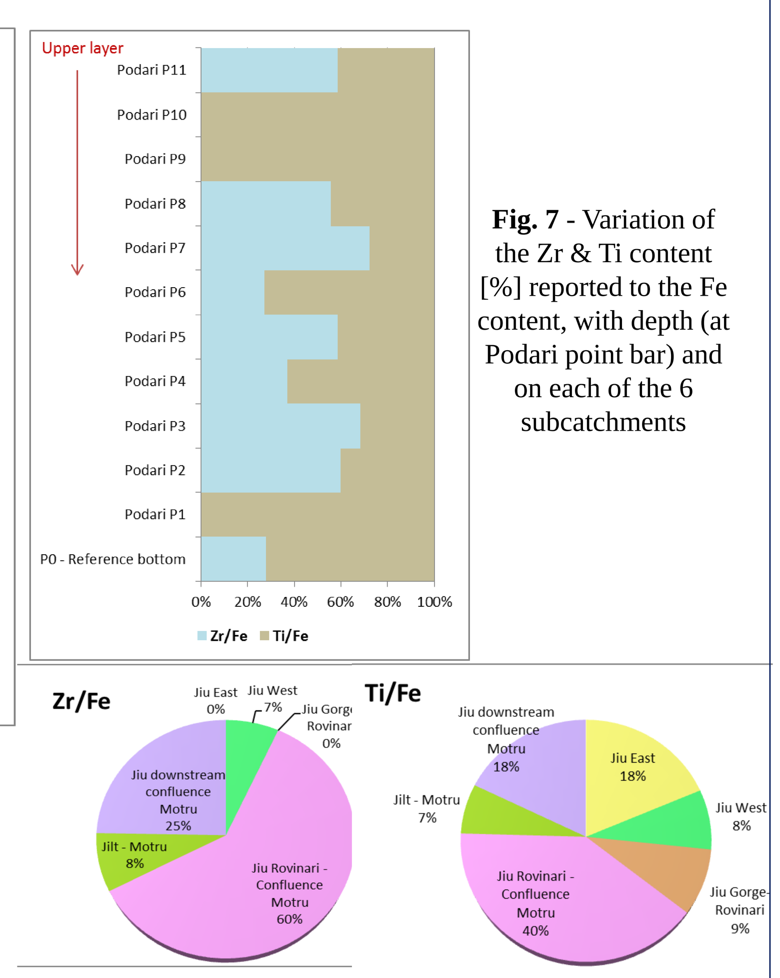
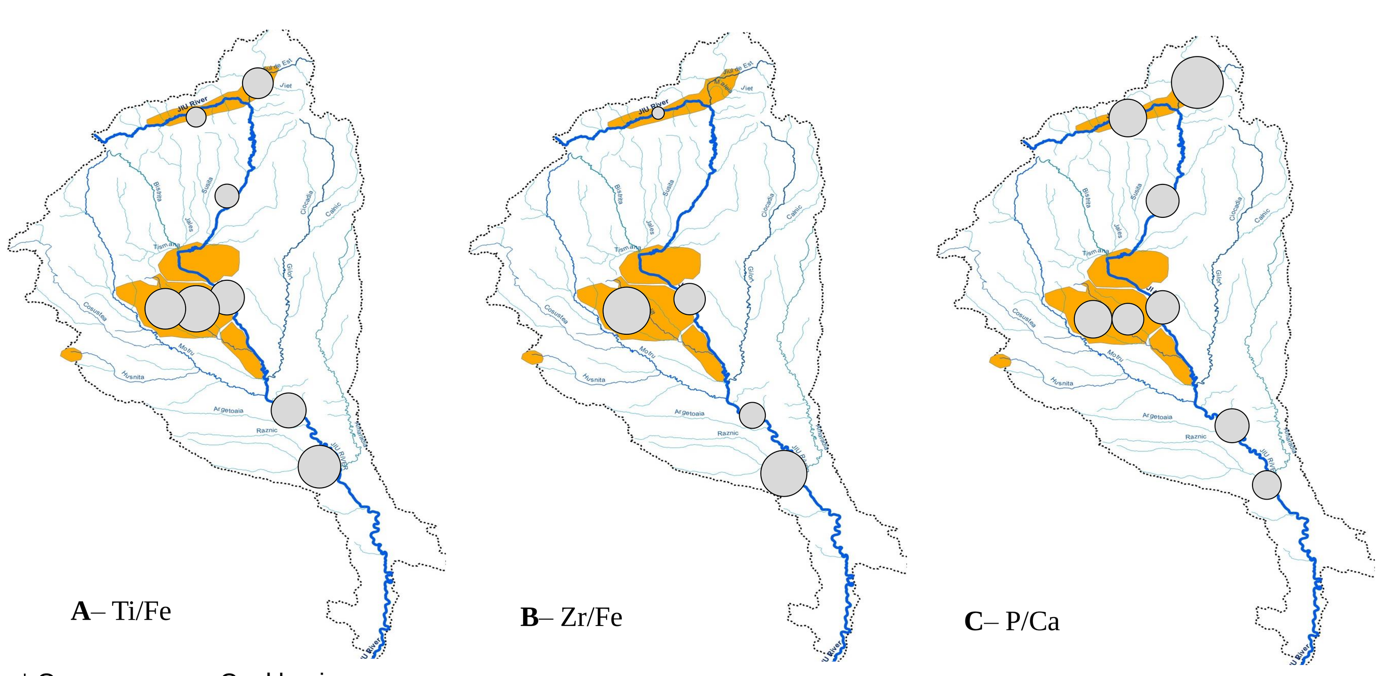


Fig. 7 - Variation of the Zr & Ti content [%] reported to the Fe content, with depth (at Podari point bar) and on each of the 6 subcatchments



* Orange areas – Coal basins

Fig 8. Some examples for the distribution of heavy minerals composition as sediment sources

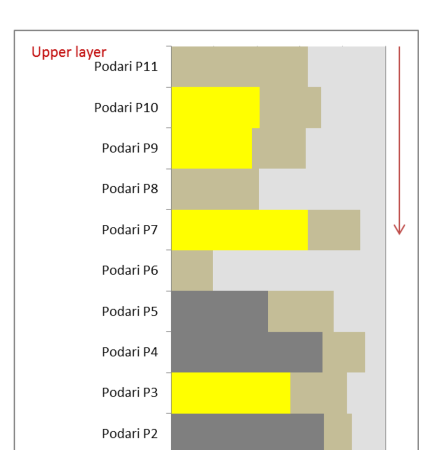


Fig. 9 - Variation with depth of the Au & associated minerals at Podari vertical profile (content [%])

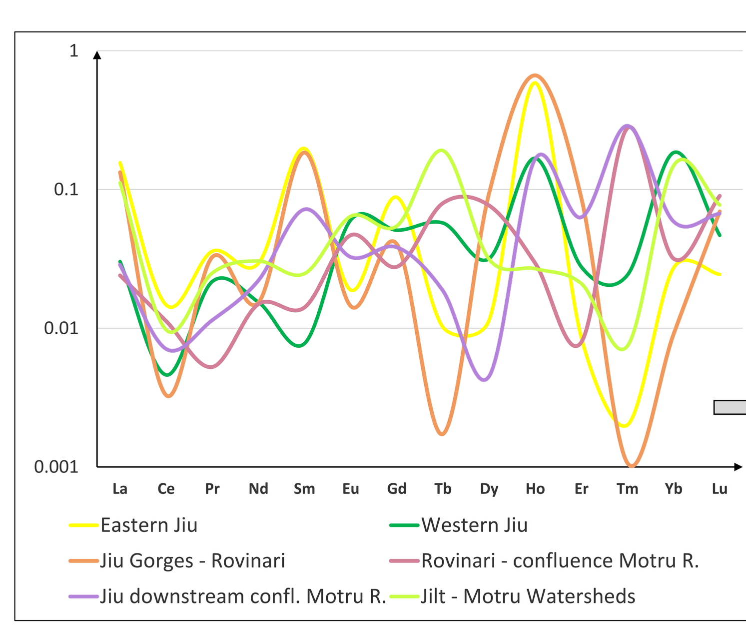


Fig. 10. Nomalized distribution of lanthanides for the 6 sources areas

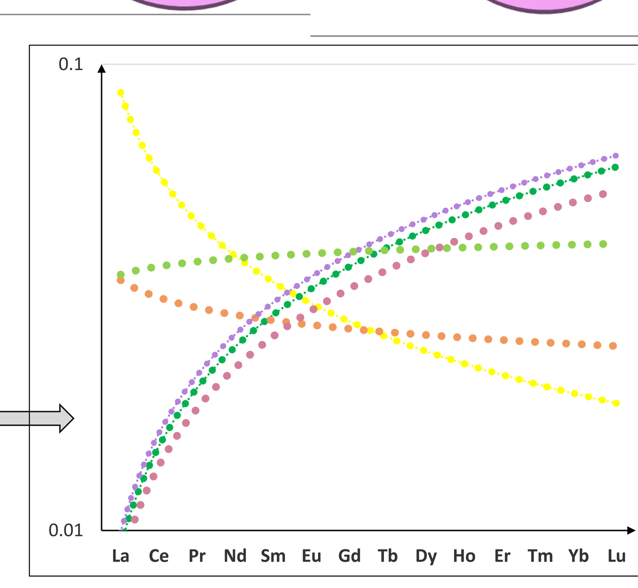


Fig. 11. Correspondent trendlines of the normalized lanthanide distribution for the 6 sources areas

	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11
Normalized distribution	4 and 5	3 and 1	nothing	nothing	nothing	1 and 3	2	nothing	4	nothing	nothing
Trendlines of the normalized distribution	6	1	1	2, 4 and 5	1	2, 4 and 5	2	1	3	1	6

Table 1. Possible sources of the 11 alluvial layers from Podari, based on the distribution of lanthanides for the 6 sources areas (numbers from 1 to 6 correspond to the six regions described in the methodology)

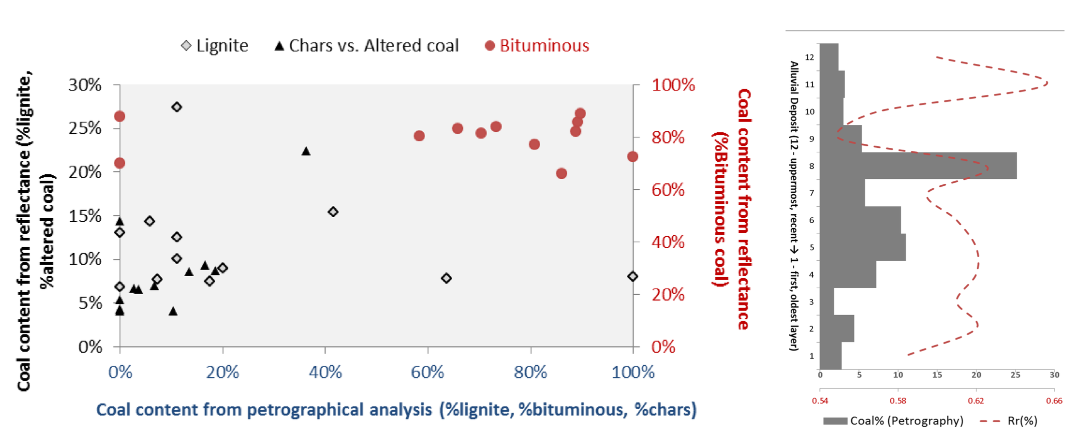
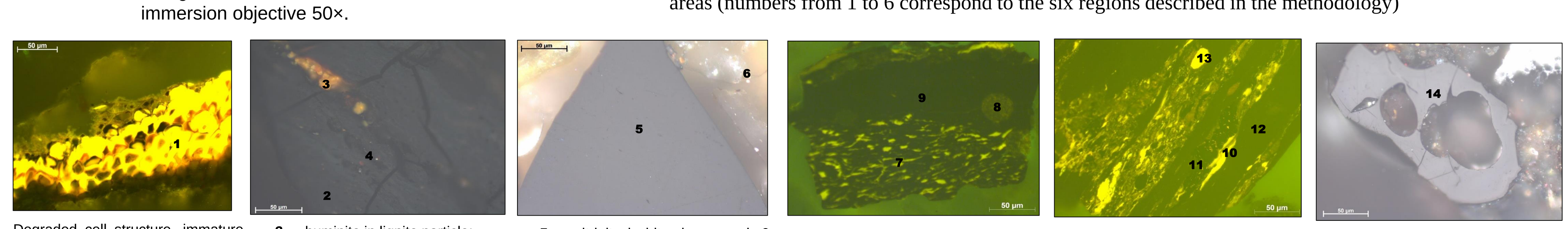


Fig. 12. Vertical profile from Podari alluvial deposits:
a. ***Correlogram between lignite, chars vs. altered coal & bituminous coal in petrographic/ reflectance analyses; b. Total content of coal (%) & average*** R$_r$***(%)***

Fig. 13. *Optical microscopy photomicrographs. Examples of macerals identified in some source (upstream: bulk coal, riverbed/ environmental) and alluvial deposit (downstream: Podari riverbank profile) samples .* The photomicrographs were taken in reflected white light and fluorescence mode with oil immersion objective 50×.



Degraded cell structure, immature lignite particle: *1* → textinite; *2* → huminite in lignite particle; *3* → resinite; *4* → sporinite; *5* → vitrinite in bituminous coal; *6* → mineral matter (clay, quartz); *7* → liptodetrinite; *8* → framboidal pyrite; *9* → inertinite; *10* → sporinite; *11* → macrinite; *12* → collotelinite; *13* → resinite; *14* → Altered coal particle (strong heat, devolatilisation)

CONCLUSIONS & PERSPECTIVES

- The main indicators (**Zr/Si, Ti/Fe, Cu/Fe, Cu/S, Ca/Mg, Na/K, different Lanthanides/P ratios**) were further correlated with the underlying lithology by means of nonparametric statistical tests.
- We have reported Ti and Zr primarily to Fe, conformly to the their occurrence in the geological background of the watershed. It can be seen that Zr appears predominantly in the areas from downstream (with few exceptions) and that Ti enriches downstream, with the Ti/Fe ratio noticeably higher for sediments collected from the Motru and Jilț tributaries. This distribution corresponds to the composition of the heavy sand fraction (frequent in sterile heaps interlining in the Motru - Rovinari mining area).
- The study also focused on the elements grouped around Au and lanthanides. In terms of their origin, gold appears in the Jiet River and in the rest of the Easter Jiu sub-catchment upstream the confluence with Jiet, but also in the ash of the coal mines from Petrosani mining basin (upper Jiu river). Lanthanides occur all over the sands, but their distribution differentiates the source.
- To link the geochemical composition of the upstream (source areas) samples with those from the downstream riverbank deposit, information gathered from the geochemical indicators may further help associating the sediment layers with historical hydrological events.
- In our study, the reflectance and petrographic measurements led to identify particles of the two coal species (lignite and bituminous coal) in the downstream, alluvial layers from the downstream sector of Jiu River, reflecting the natural erosion, artificial occurrence and drainage processes characterizing the coaly and inorganic particles transport and deposition. A variable content of chars and altered coal particles was found, with generally high reflectance (Rr >0.8%).
- The origin of the coaly matter appeared to be nonuniform, as shown by the sparse distribution of the average reflectance among samples, as well as by the different, huminite/vitrinite and other maceral groups proportion. There is a general agreement between petrographic and reflectance analyses in estimating the lignite and bituminous coal content, except for the confusions between the sub-bituminous coal from the Eastern Jiu river basin and from the lignite coal extraction areas, given their similar reflectance values (Rr <0.5%).

ACKNOWLEDGMENTS

REFERENCES