Hydromorphology and sediment transport of Vjosa River

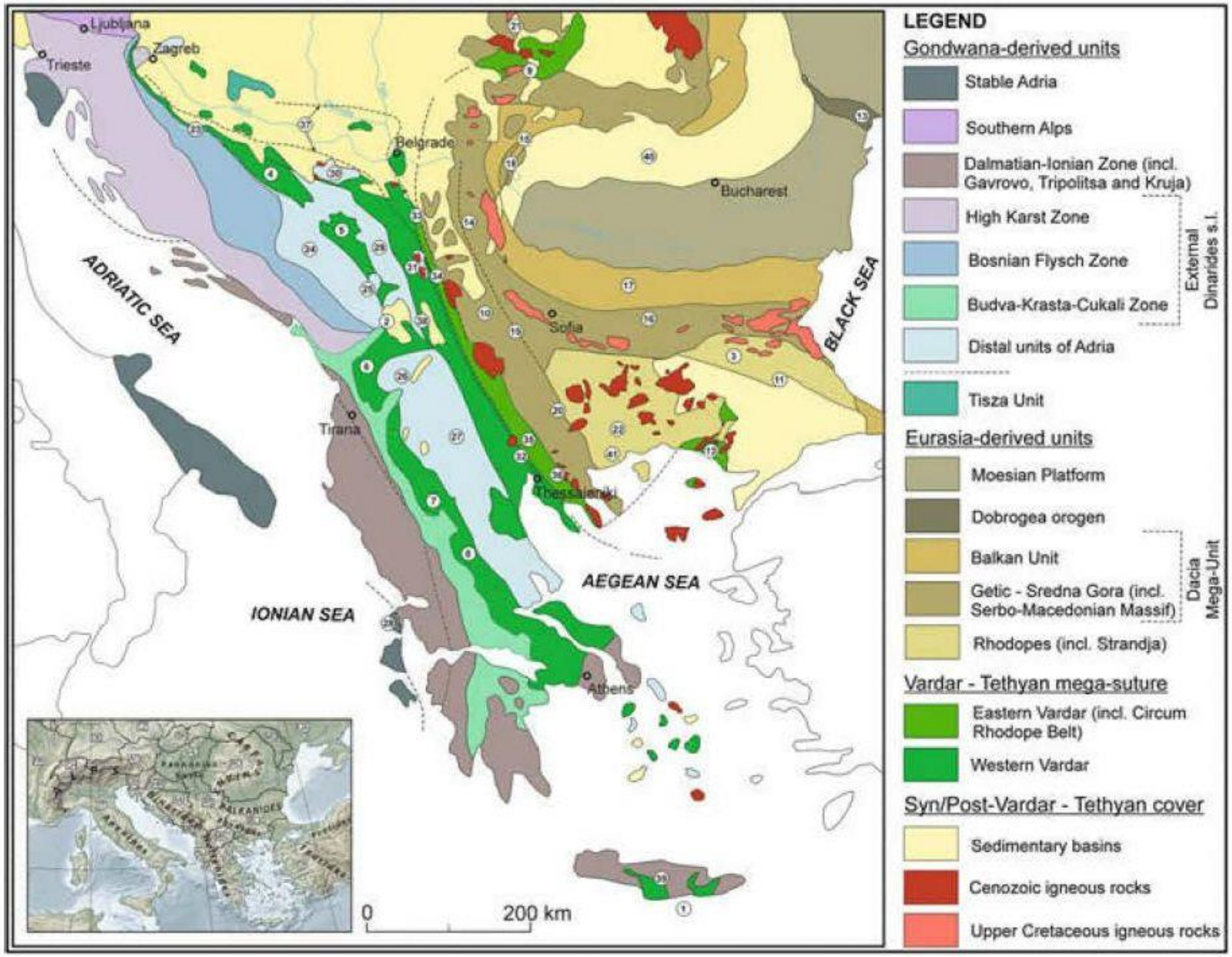
Skrame, K. & **Hauer, C.**,

with contributions of Pessenlehner, S., Holzapfel, P., Rindler, R., Aigner, H., Hinterleitner, M., Liedermann, M.

Politechnical University Tirana

BOKU – University of Natural Resources and Life Sciences

Lets talk about rivers and geology…

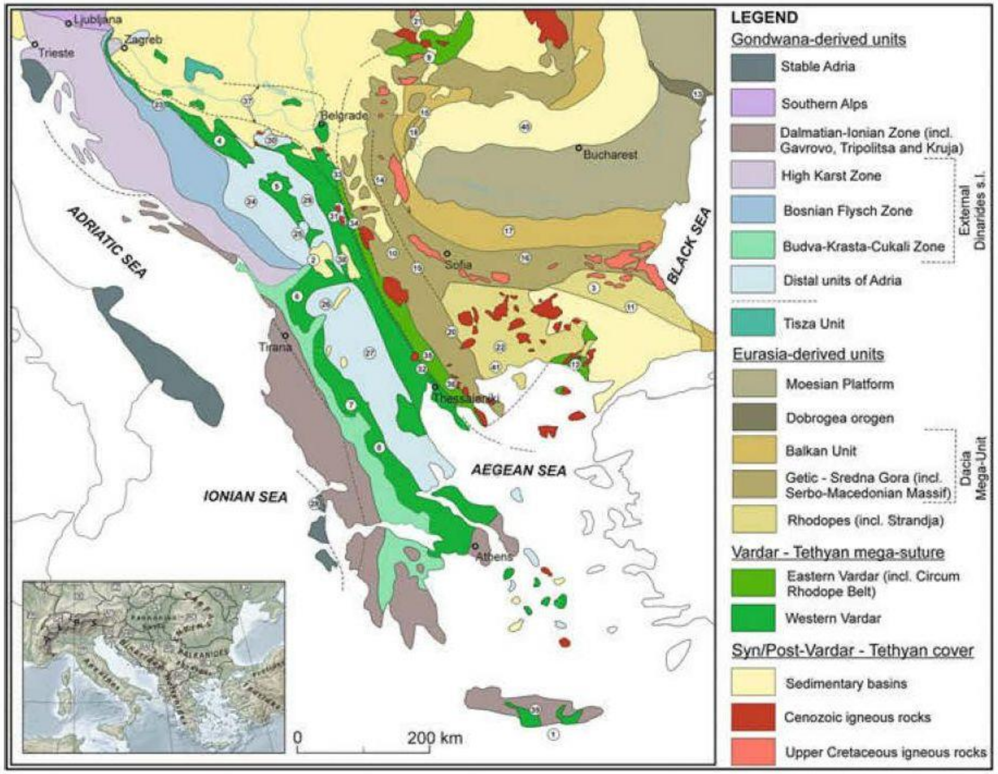


A simplified geological sketch of South–Eastern Europe (Cvetkovic et al., 2015)

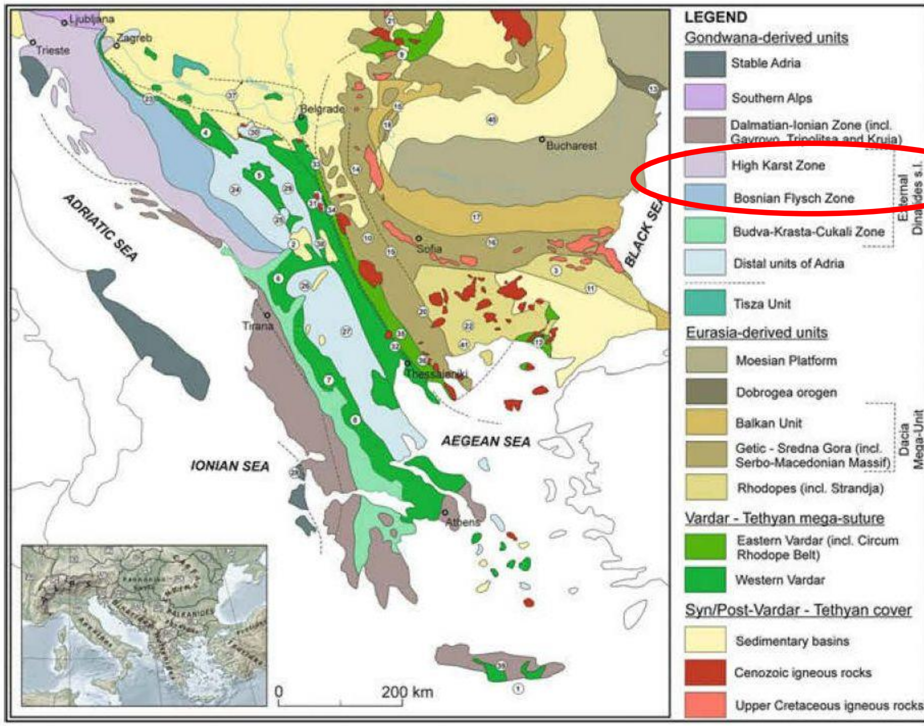
THE RIVER SYSTEMS OF THE BALKANS

by two mountain ranges:

1. Outer- and Inner Dinaric Mountains
2. so-called “Prokletije”, part of the Southern Dinarden



THE RIVER SYSTEMS OF THE BALKANS



1. Outer- and Inner Dinaric Mountains

600 km long mountain range running along the Adriatic Sea

i. Kupa River,
ii. Una River,
iii. Sana River,
iv. Vrbas River,
v. Bosna River,
vi. Drina River

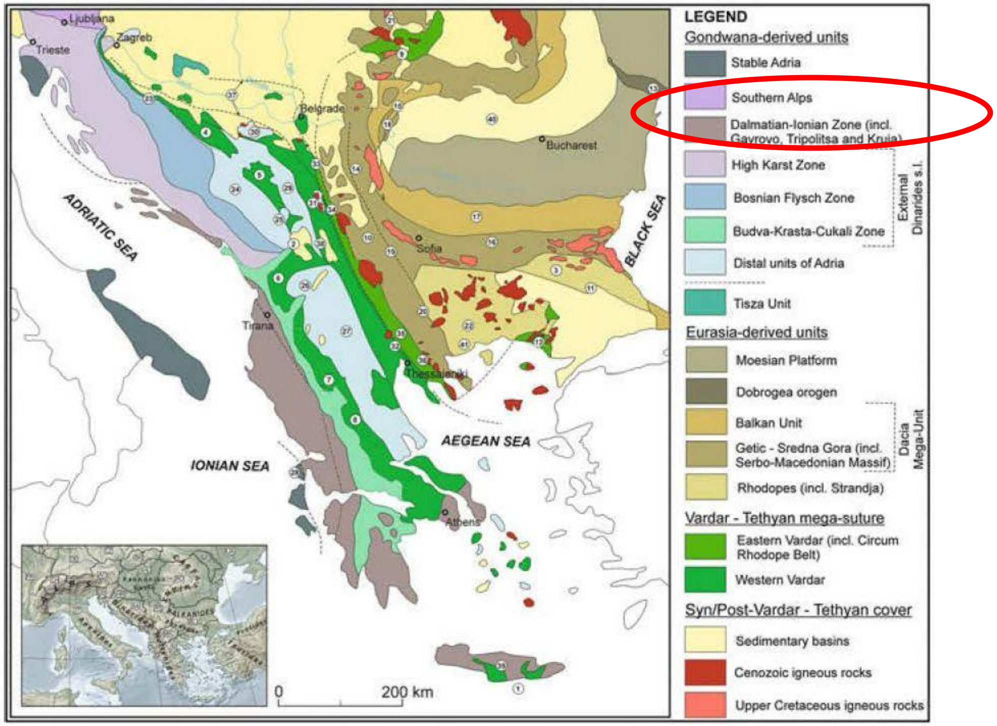
lead into the Black Sea

i. Krka River,
ii. Cetina River,
iii. Neretva River,
iv. Moraca River

lead into the Adriatic Sea

For all rivers of the Dinarden, **gorges and canyons** are dominant in most of the draining systems

THE RIVER SYSTEMS OF THE BALKANS



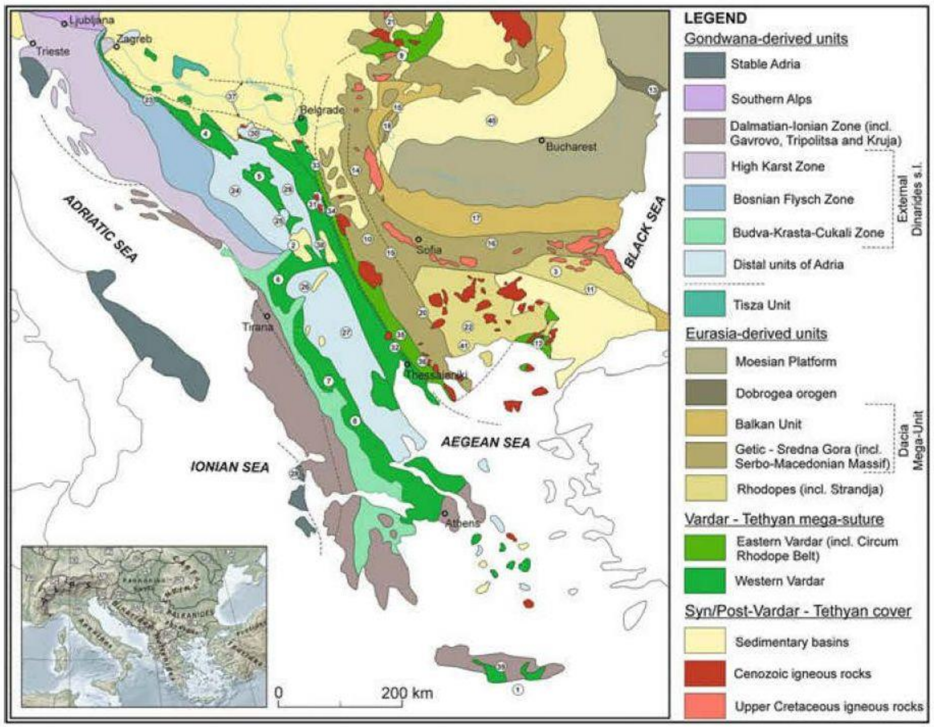
2. so-called “Prokletije”,
part of the Southern Dinarden

running from Eastern Montenegro to Northern Albania

High mountain altitudes accompanied with glacier shaped valleys give this particular mountain range alpine characteristics which are very special for the Balkan region.

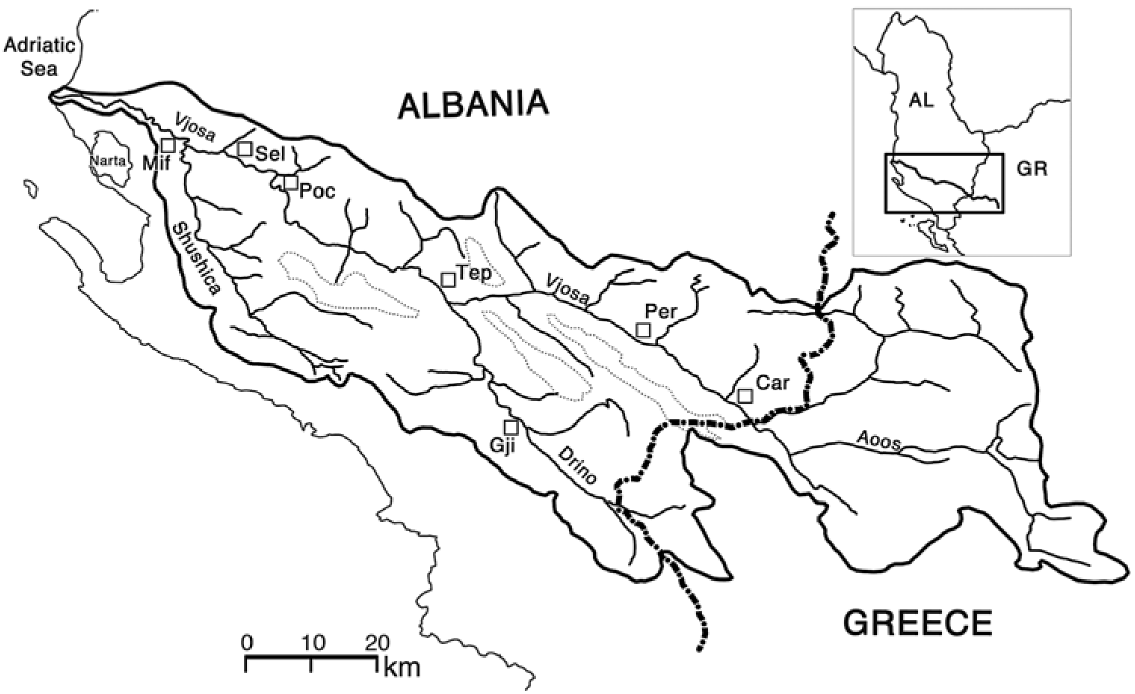
Ropojani River,
Grbaja River
Valbona River

THE RIVER SYSTEMS OF THE BALKANS



Moreover, meandering channel patterns may be found at high altitudes in alluvial basins and incised, straight patterns close to mouth.

THE RIVER SYSTEMS OF THE BALKANS



(Schiemer et al., 2018)

The Vjosa River contains almost all channel types found in Balkan rivers:

- **incision and formation of gorges in the upper parts,**
- **braiding / anabranching channel patterns in areas of valley widening,**
- **sinuous / meandering characteristics close to the mouth.**

Geological Overview of the Vjosa Basin

3 Sections of the Vjosa River

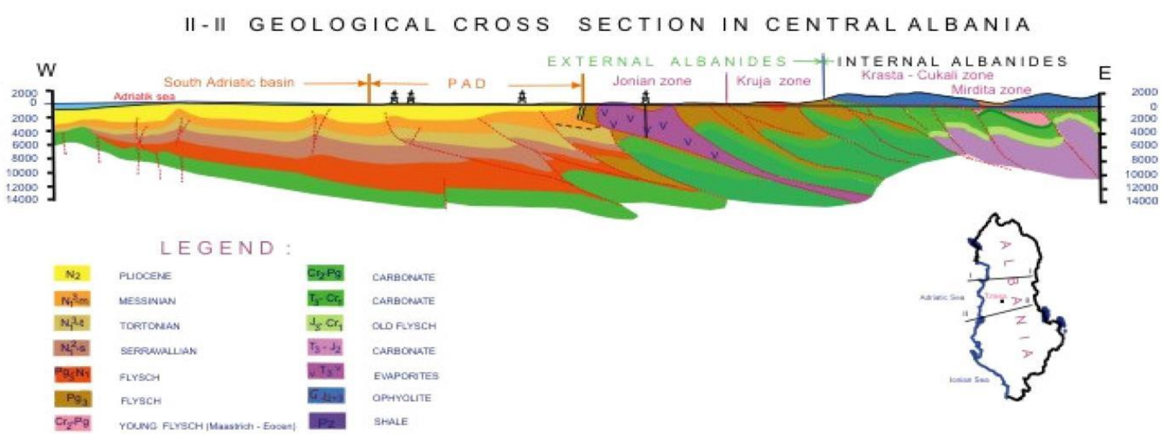
I. The Upstream Section

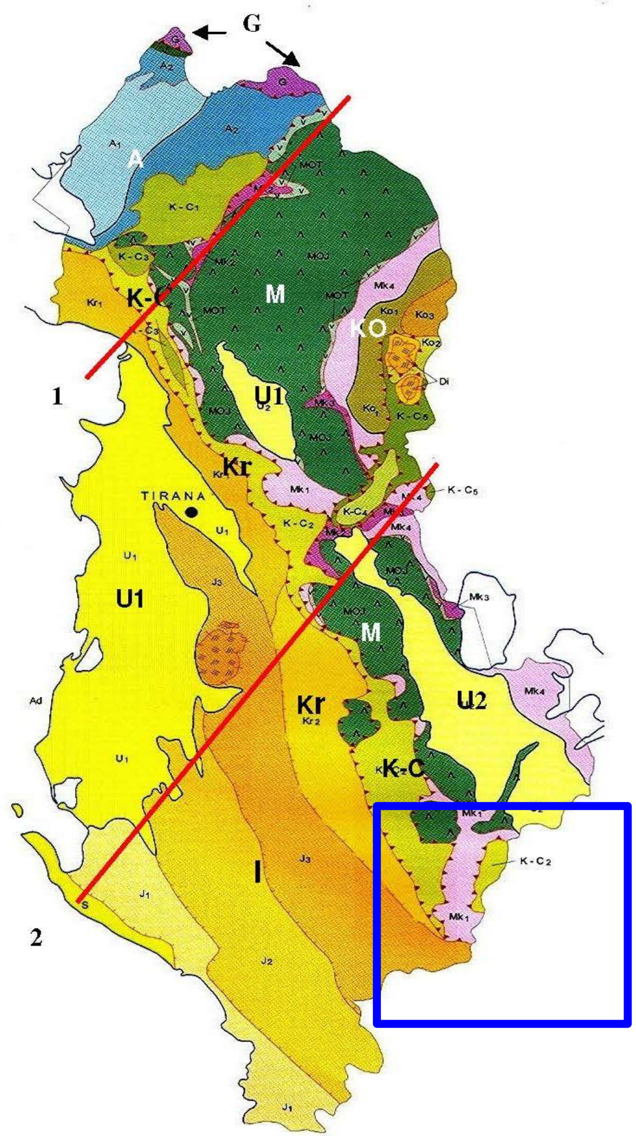
II. The Midstream Section

III. The Downstream Section

The Upstream Section

extends from the mountains of Pindos in North-Western Greece to Dragot in Albania



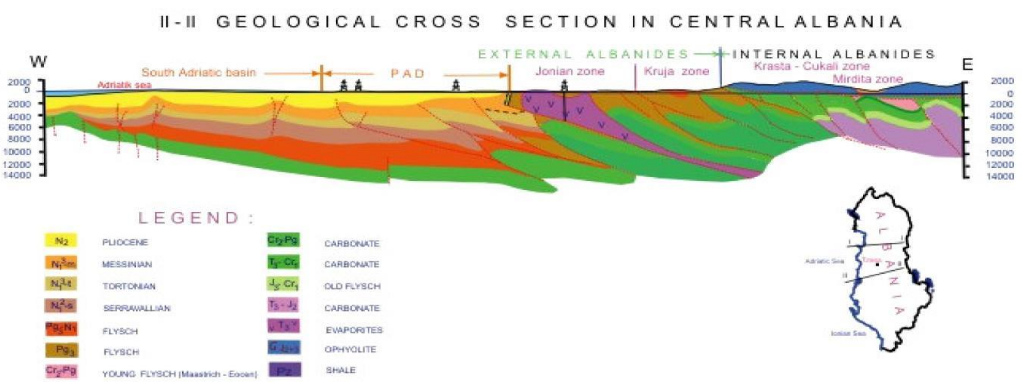


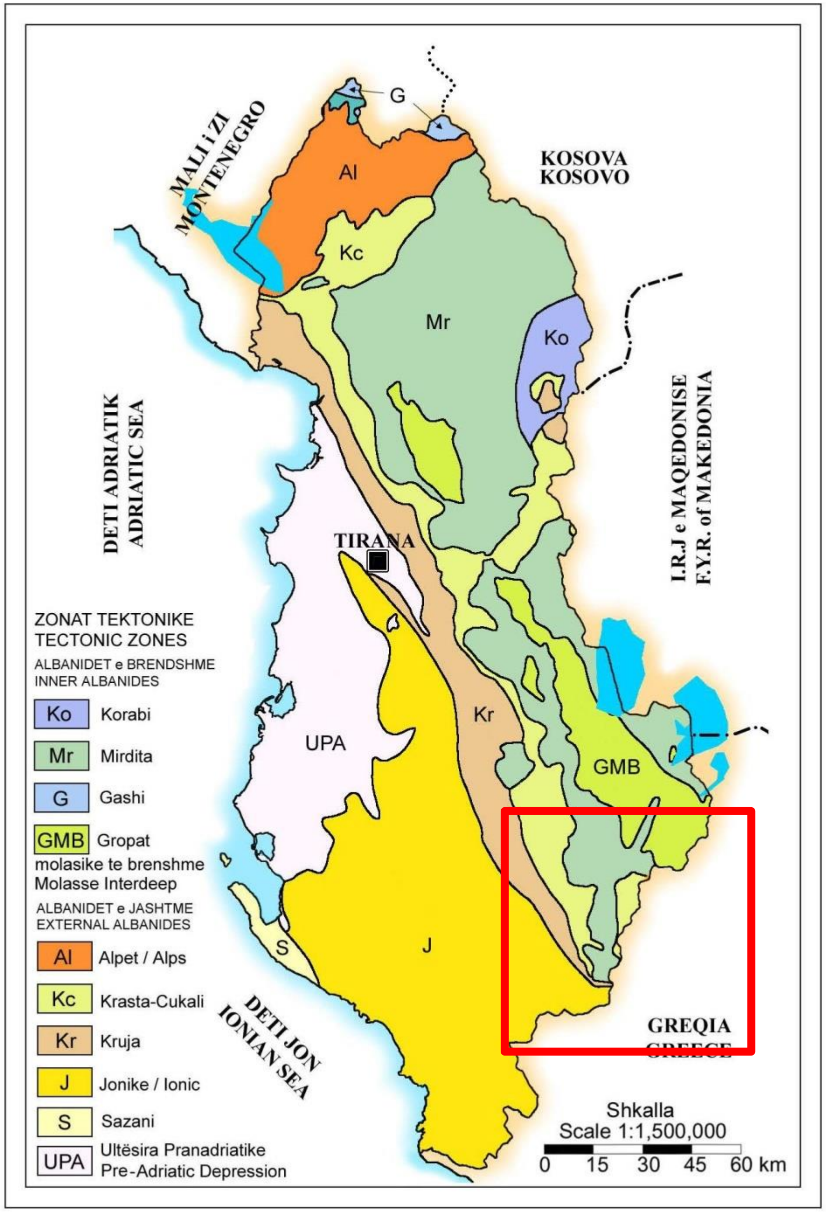
(Geology of Albania, 2002)

Schematic Tectonic Zonation Map of Albania

The Upstream Section

1. Mirdita Zone (Mr)
2. Krasta – Cukali Zone (Kc)
3. Kruja Zone (Kr)
4. Ionian Zone (J)



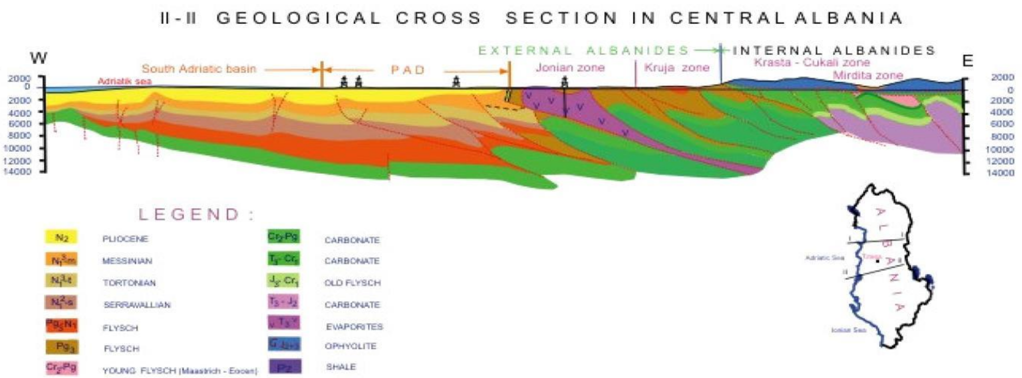


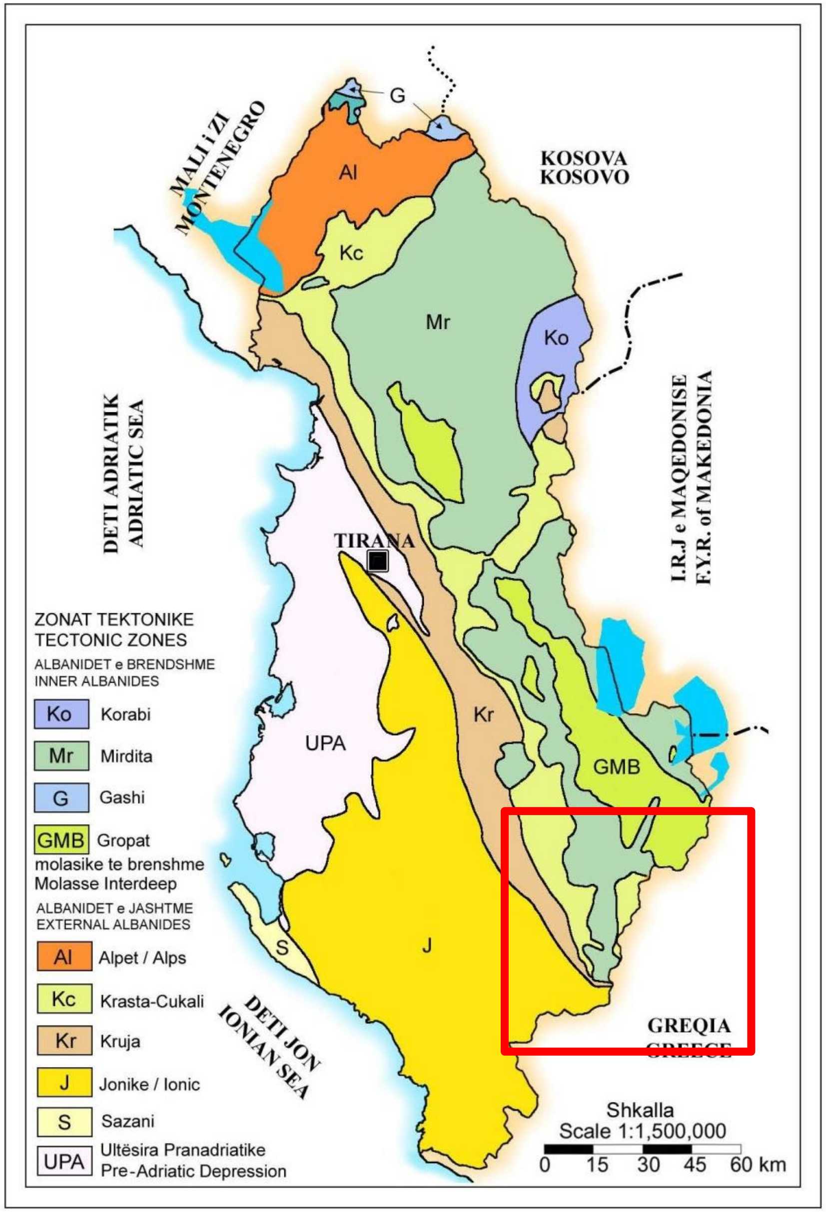
(Frasheri et al., 2002)

The Upstream Section

1. Mirdita Zone (Mr)

composed of ophiolitic formations



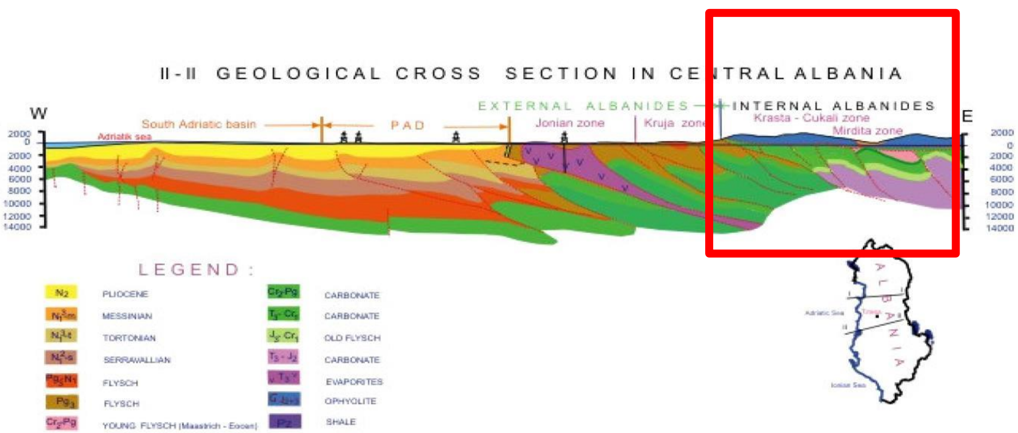


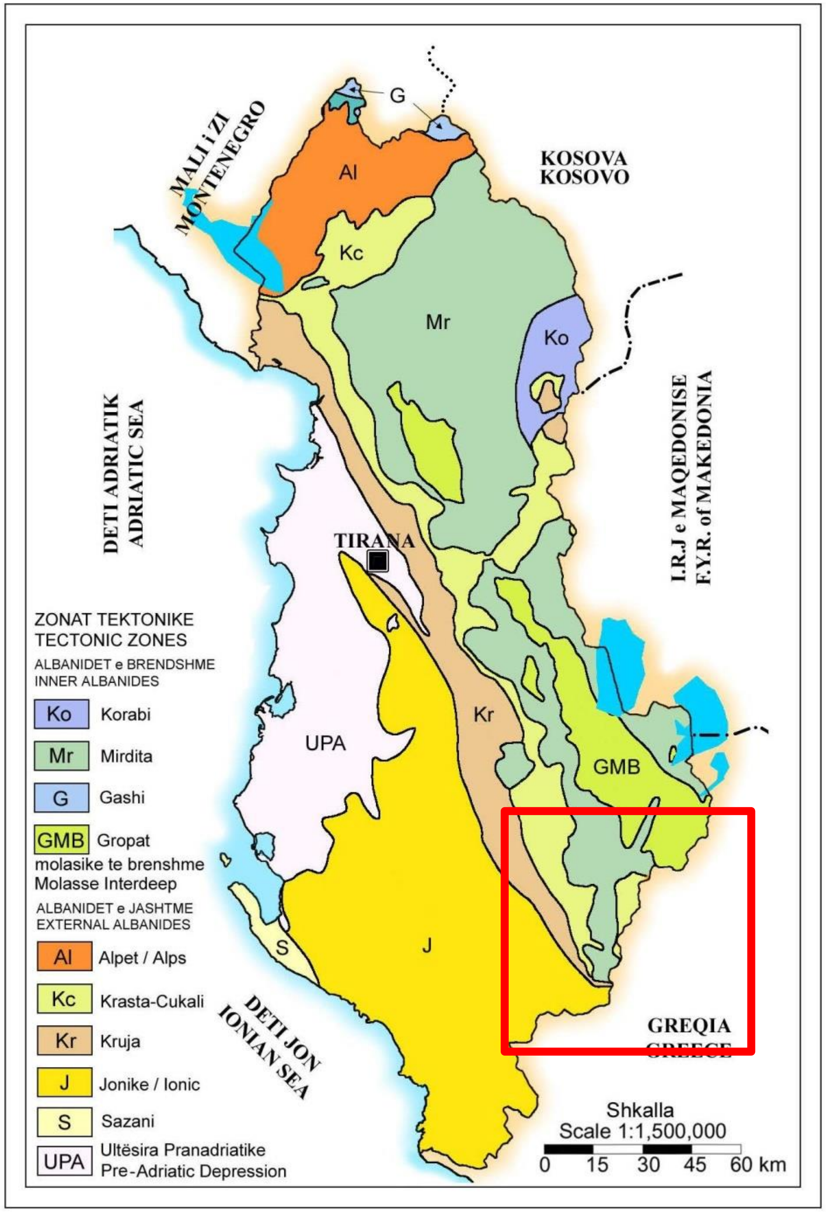
(Frasheri et al., 2002)

The Upstream Section

2. Krasta – Cukali Zone (Kc)
(Middle Triassic to Cretaceous)

composed of sandstones, marls, cherts and limestones.
Flysch (intercalations of thin layers of clayey-siliceous materials, sandstones and limestones)





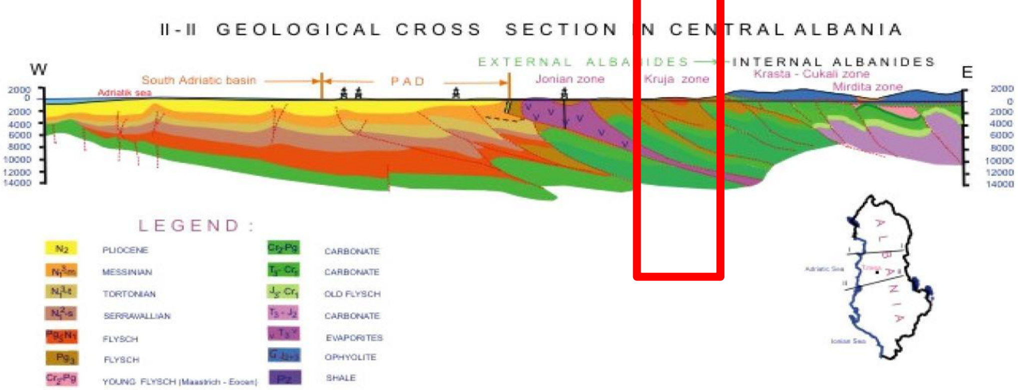
(Frasheri et al., 2002)

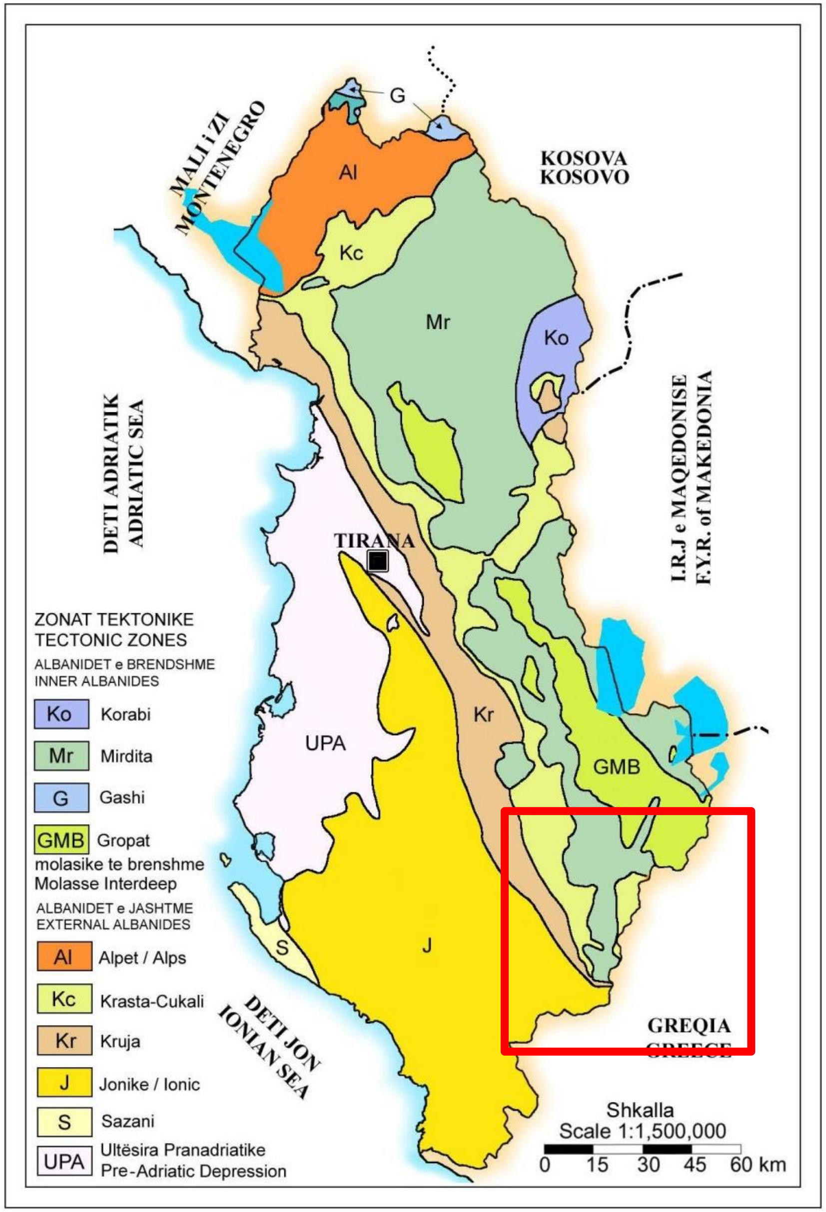
The Upstream Section

3. Kruja Zone (Kr)

(Triassic to Upper Eocene)

dolomites of Upper Triassic age and limestones of Jurassic



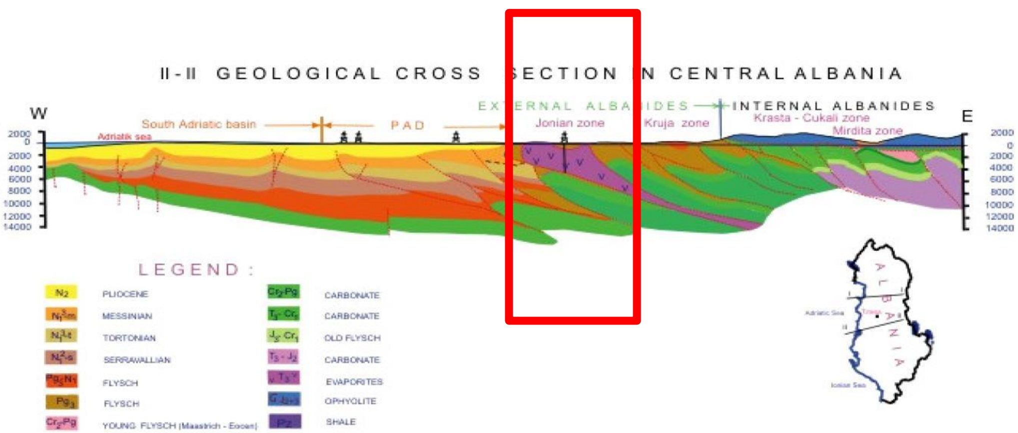


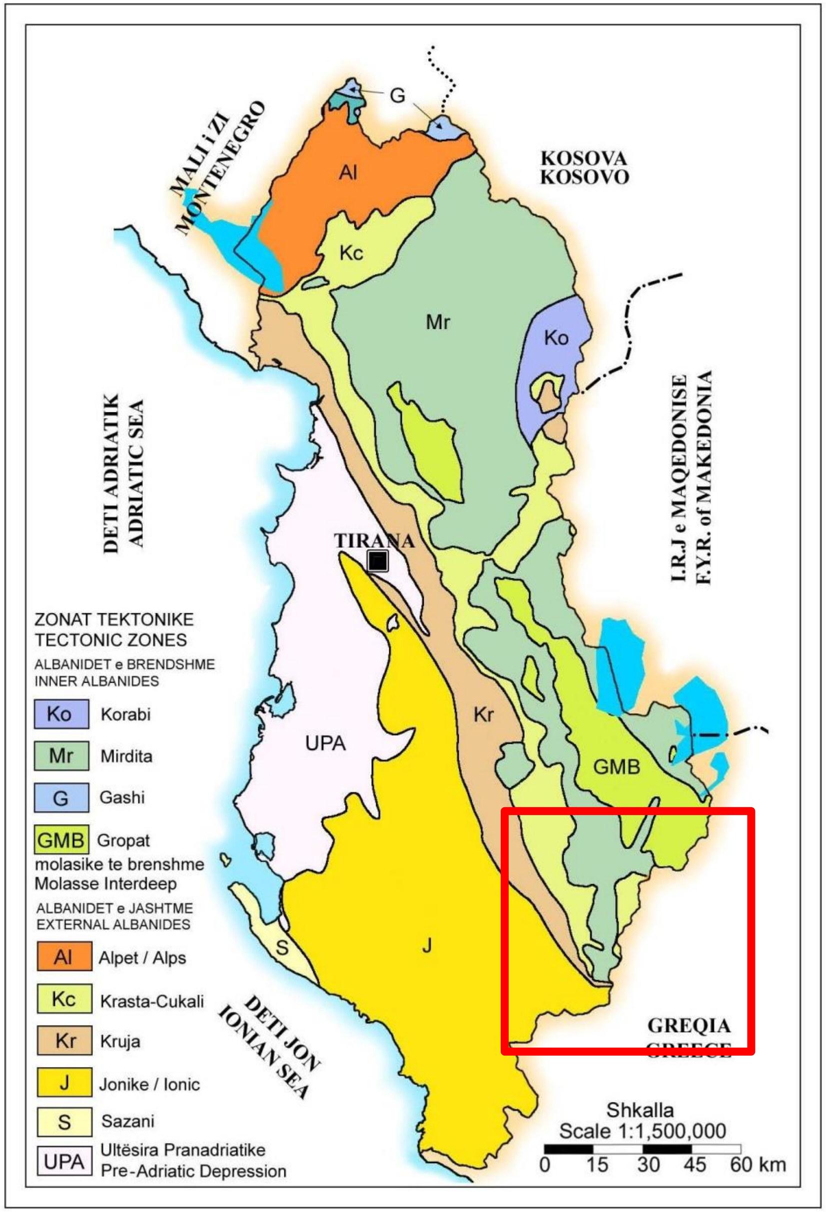
(Frasheri et al., 2002)

The Upstream Section

4. Ionian Zone (J)
(Cretaceous to Eocene / Miocene)

composed of flysch and limestones





(Frasheri et al., 2002)

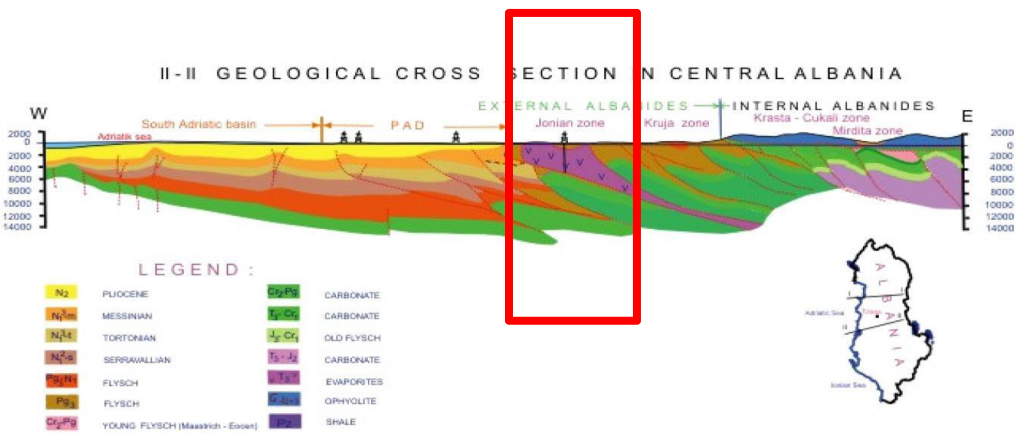
The Midstream Section

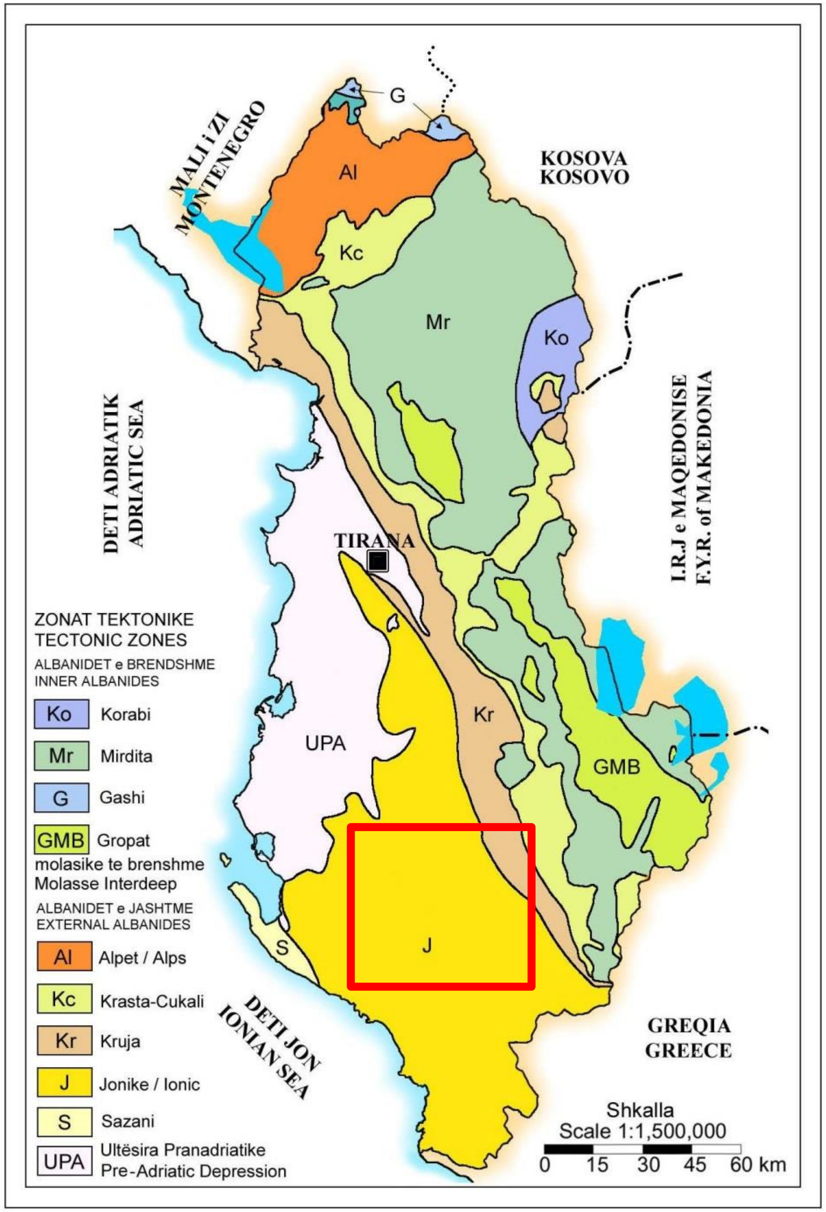
extends from the Dragot to Poçem

2. Krasta – Cukali Zone (Kc)
3. Kruja Zone (Kr)

mostly
4. Ionian Zone (J)

composed of a series of syncline and anticline structures (Permian to Quaternary)





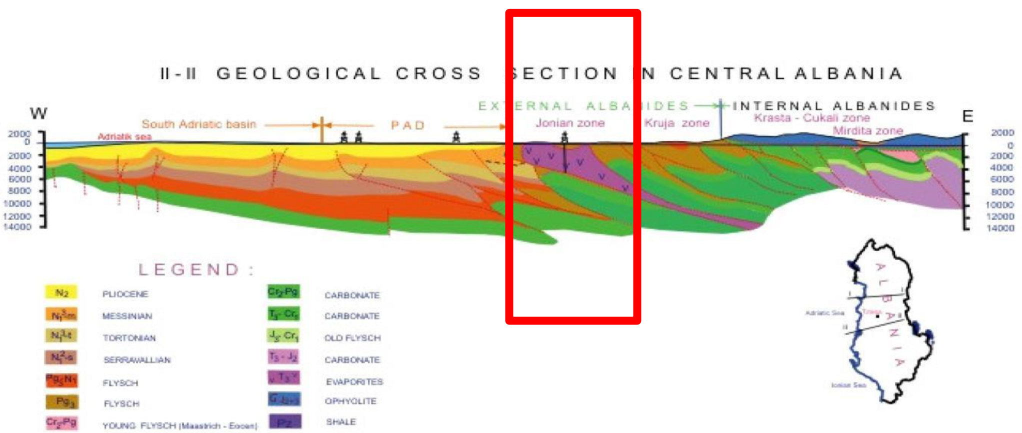
(Frasheri et al., 2002)

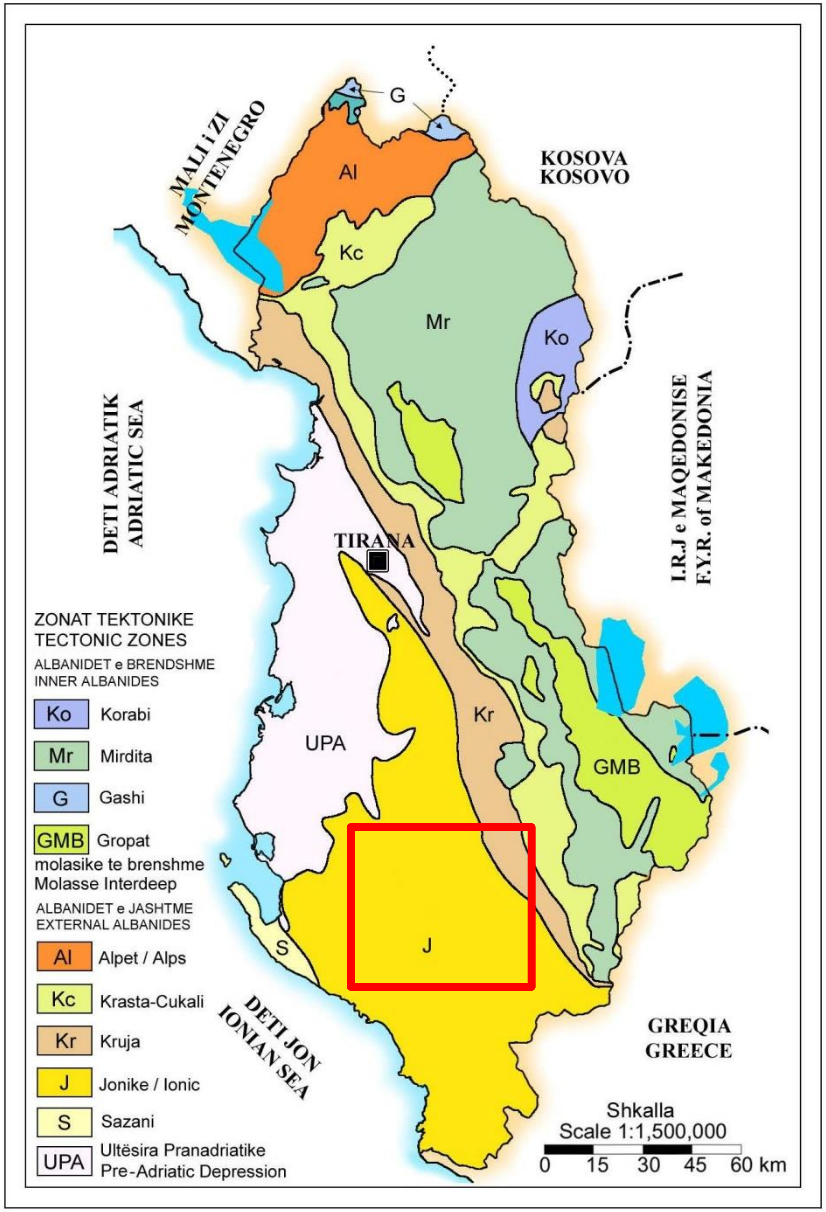
The Midstream Section

4. Ionian Zone (J)

Three subzones:

- Berati Belt
- Kurveleshi Belt
- Çika Belt





(Frasheri et al., 2002)

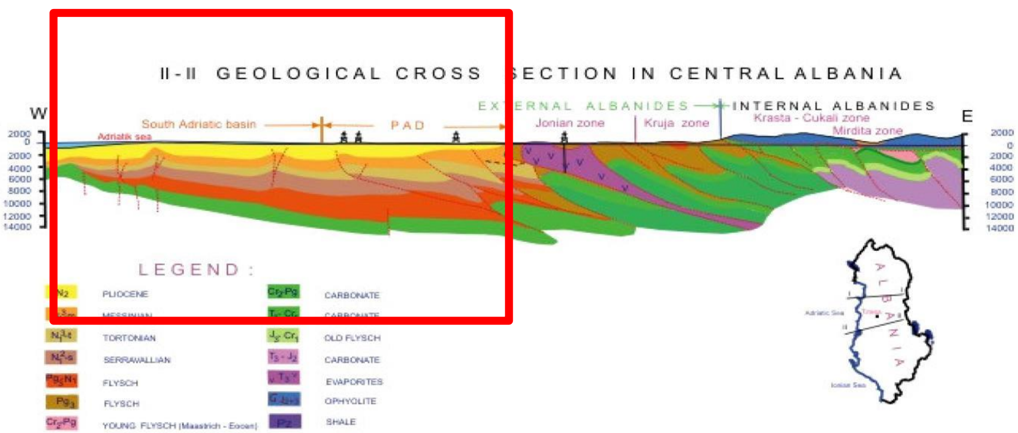
The Downstream Section

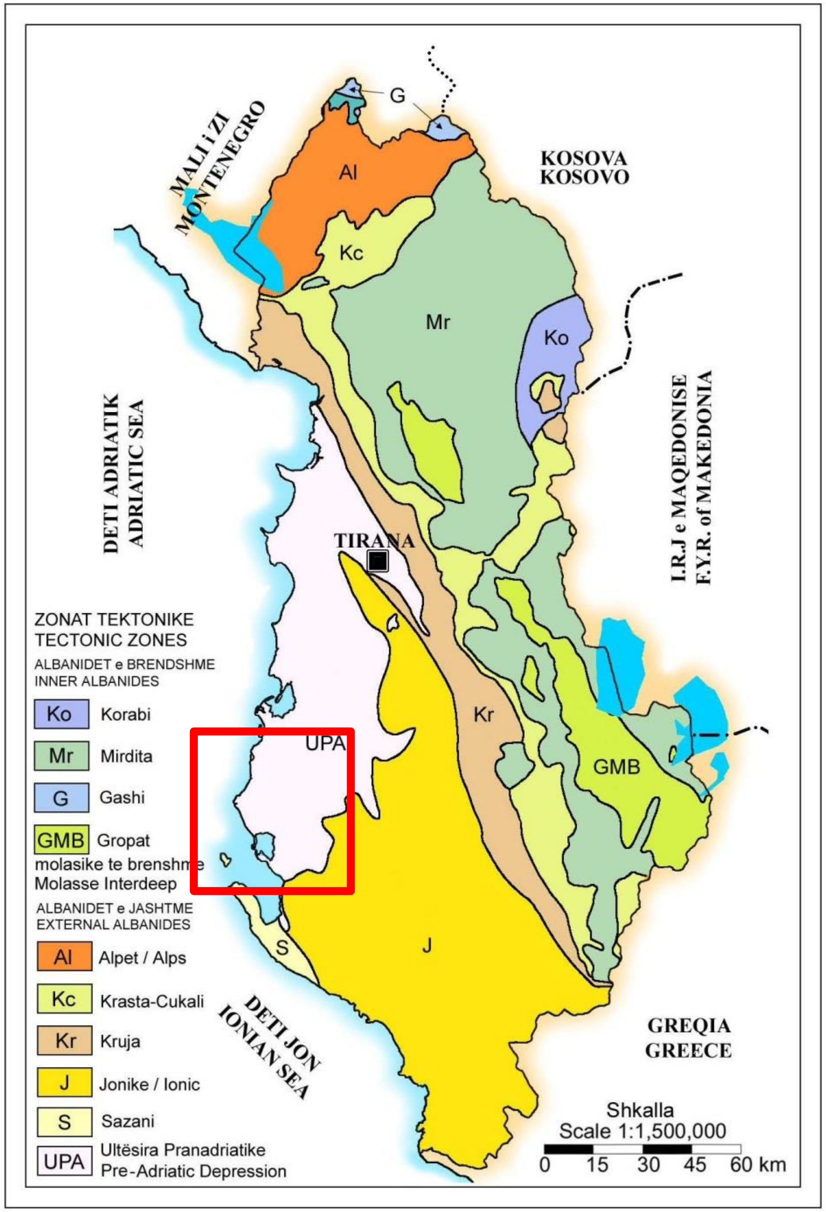
extends from the Poçem to the Adriatic Sea

4. Ionian Zone (J)

5. Pre-Adriatic Depression

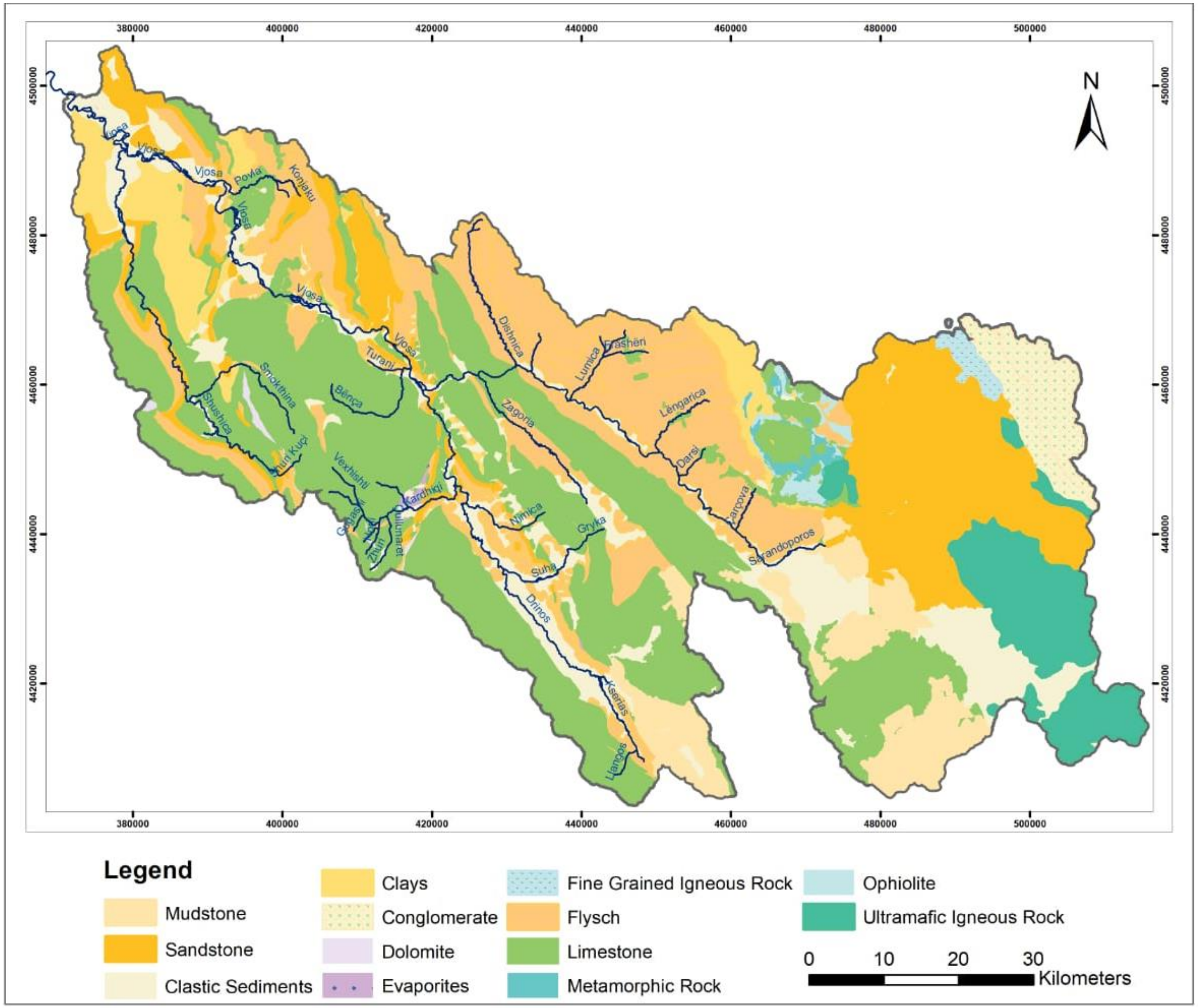
composed of Quaternary deposits (gravels, sands, silts and clays)





(Frasheri et al., 2002)

Why so high sediment deposition rates?

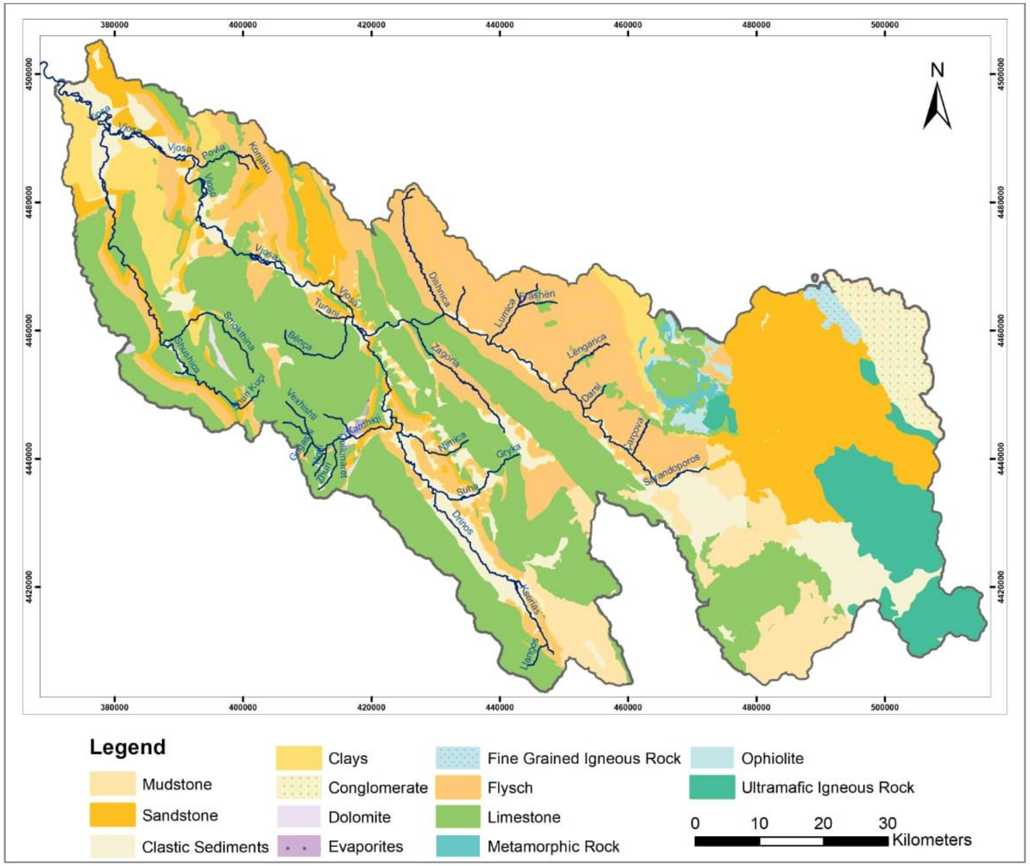


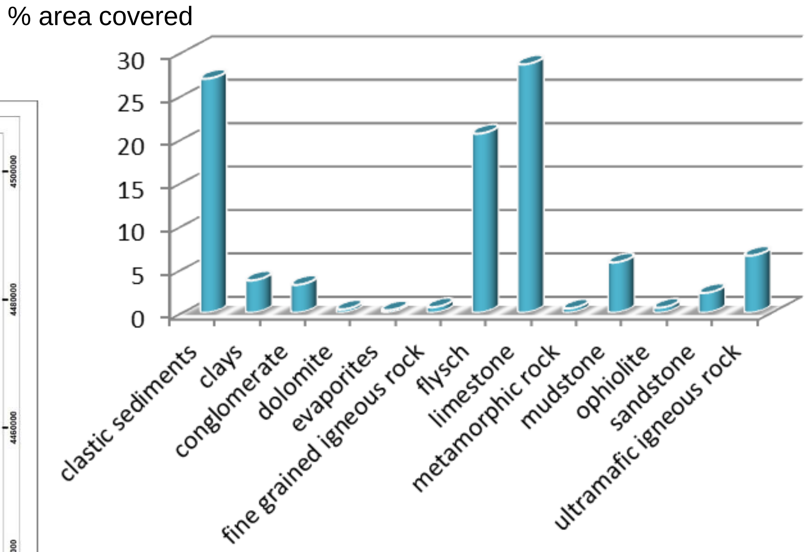
stratigraphic point of view, the geological formations represent a wide variety of rocks, formed of:

magmatic rocks,
metamorphic rocks,
carbonates,
terrigenous sediments

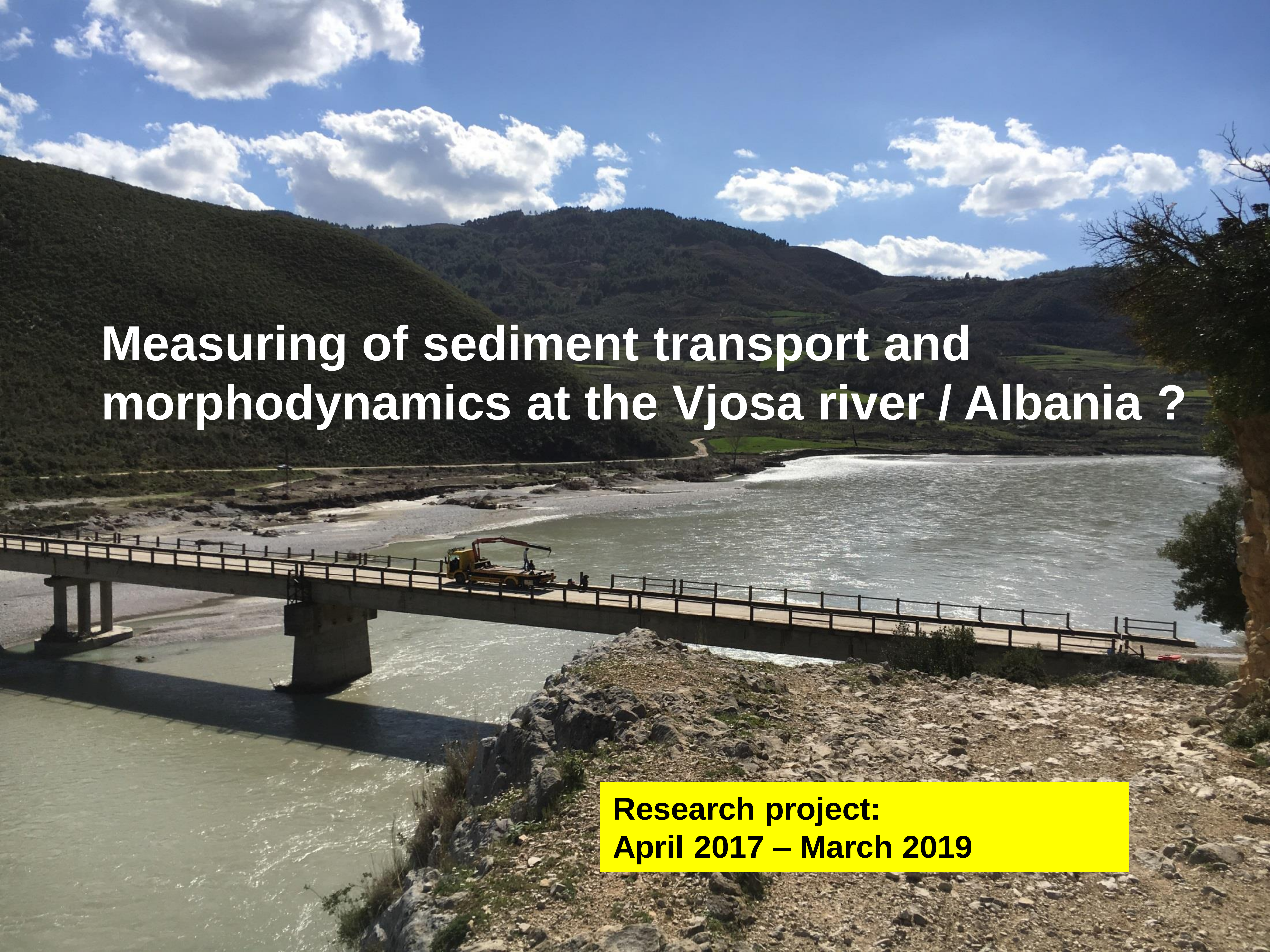
(Triassic - Quaternary Period)

The Vjosa is draining a total area of **6700 km²** in Albania and Greece





Measuring of sediment transport and morphodynamics at the Vjosa river / Albania ?



Research project:
April 2017 – March 2019

Pocem bridge

Bed load


Laboratory analysis of bed load samples

86 sediment samples obtained from the sampling stations at the bridge in Poçem

20 sediment samples were collected during 15-16 March 2018, and
66 sediment samples were collected during 27-28 March 2018.

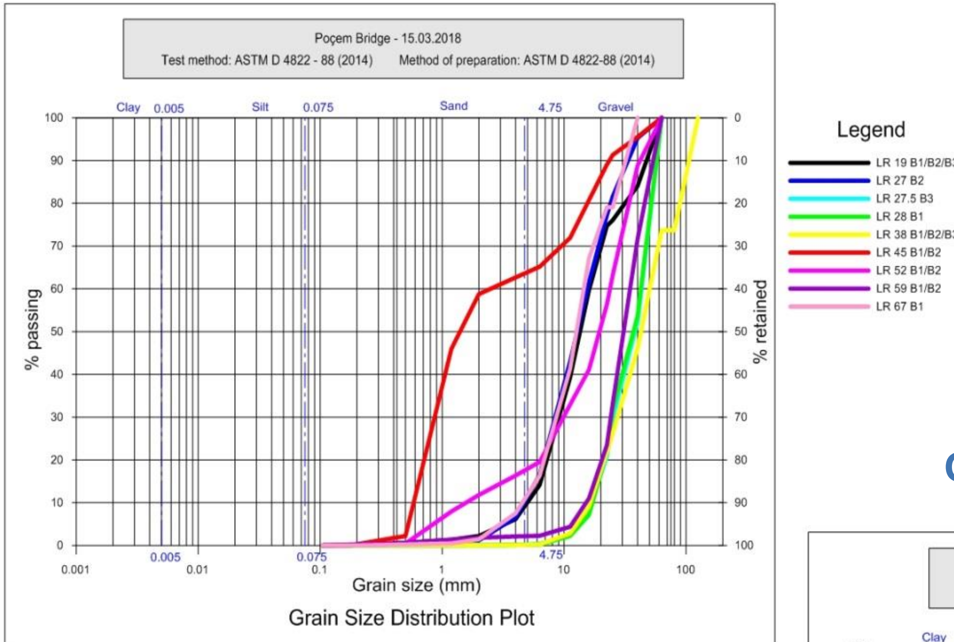
The captured samples were air-dried at room temperature or dried in the oven at 105°C for 12 h. Once dry, the samples were cooled and weighed. The samples were continued with the sieve analysis

The percentages of the sample retained and passed through the sieves were calculated using the following formulas

$$\% \, retained = \frac{w_r}{w_t} x \, 100\% \qquad \frac{\sum w_r}{w_t} x \, 100\% \, < 2\%$$

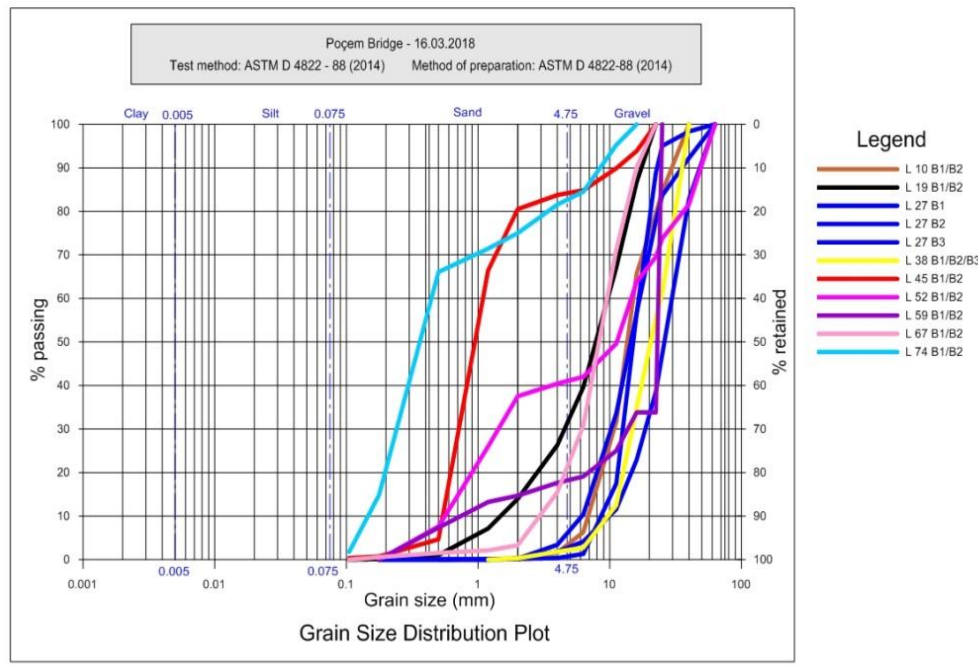
where w_r denote the weight retained in each siever and w_t is the total weight of the sample. (ASTM D4822 – 88, 2014)

Results

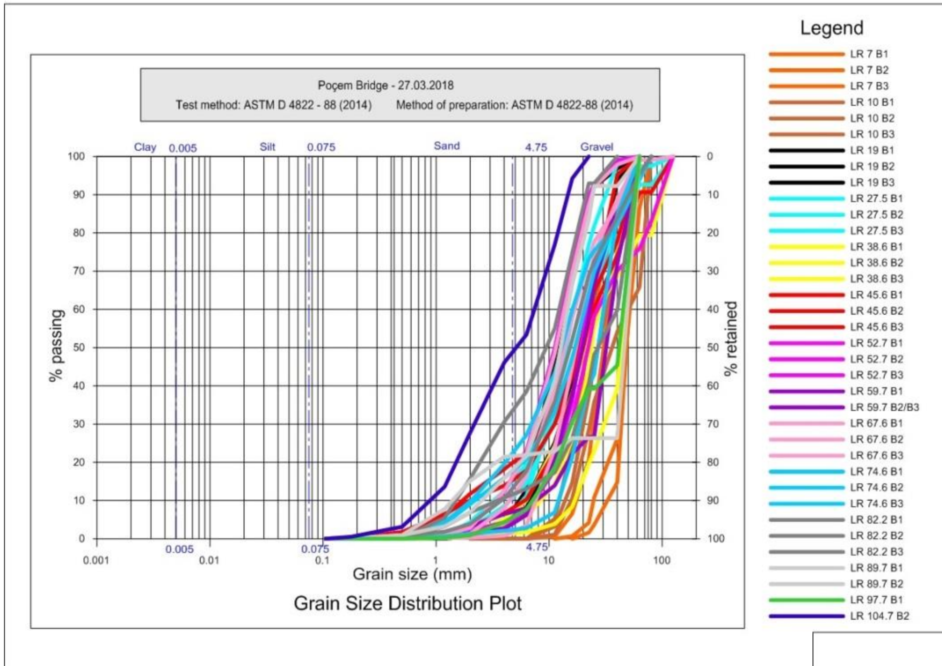


Q = 350 m^3s^{-1} (15.3.2018)

Q = 302 m^3s^{-1} (16.3.2018)

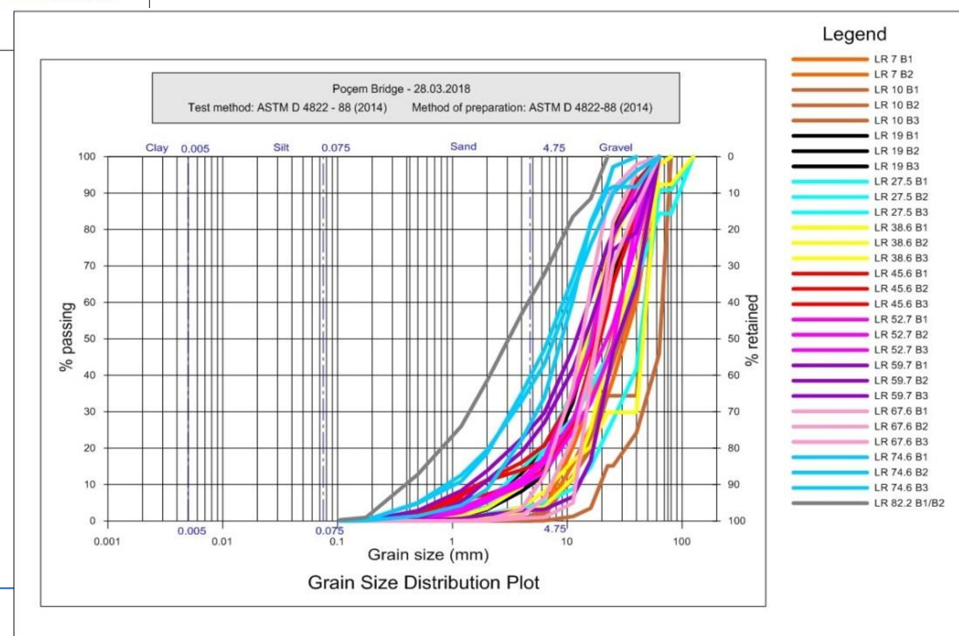


Results



Q = 870 m^{3}s^{-1} (27.3.2018)

Q = 627 m^{3}s^{-1} (28.3.2018)

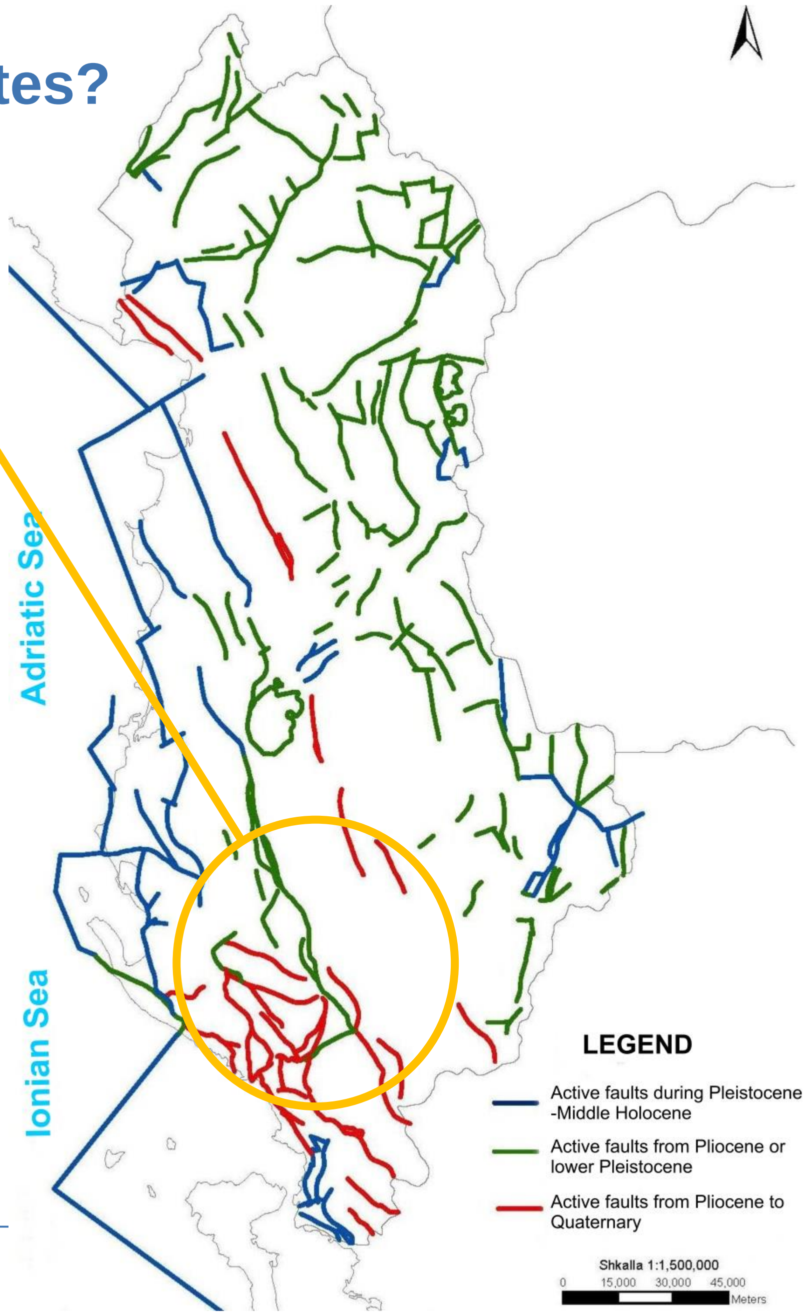


Why so high sediment deposition rates?

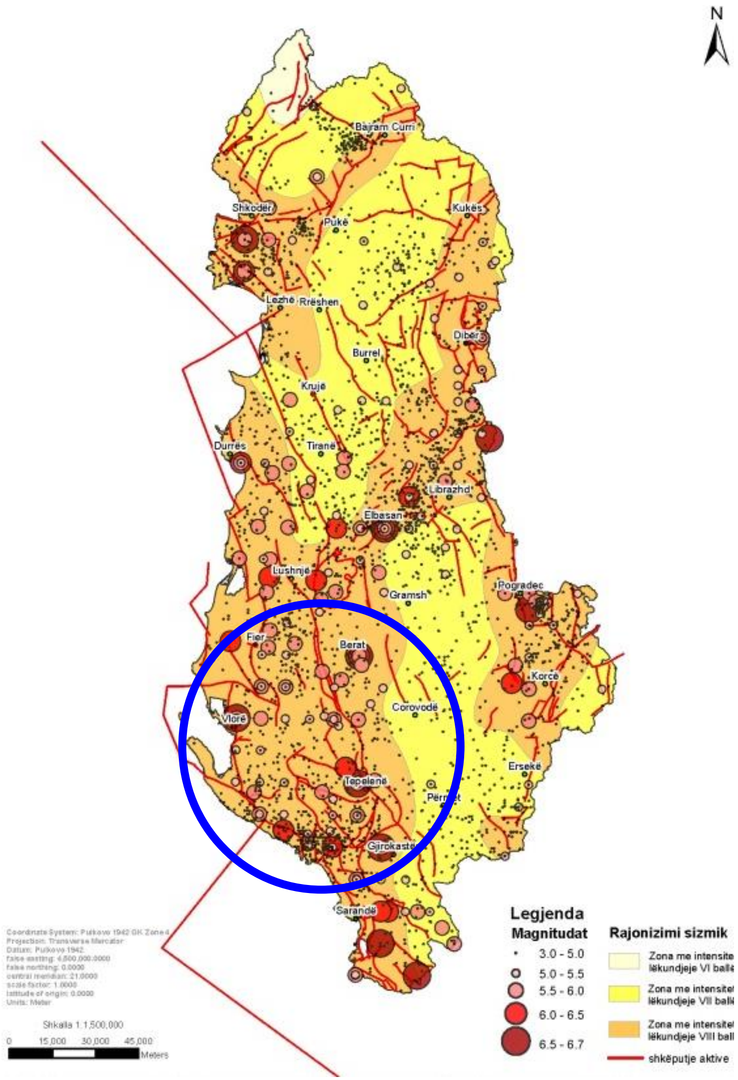
- **related to the late and neo-tectonic processes**

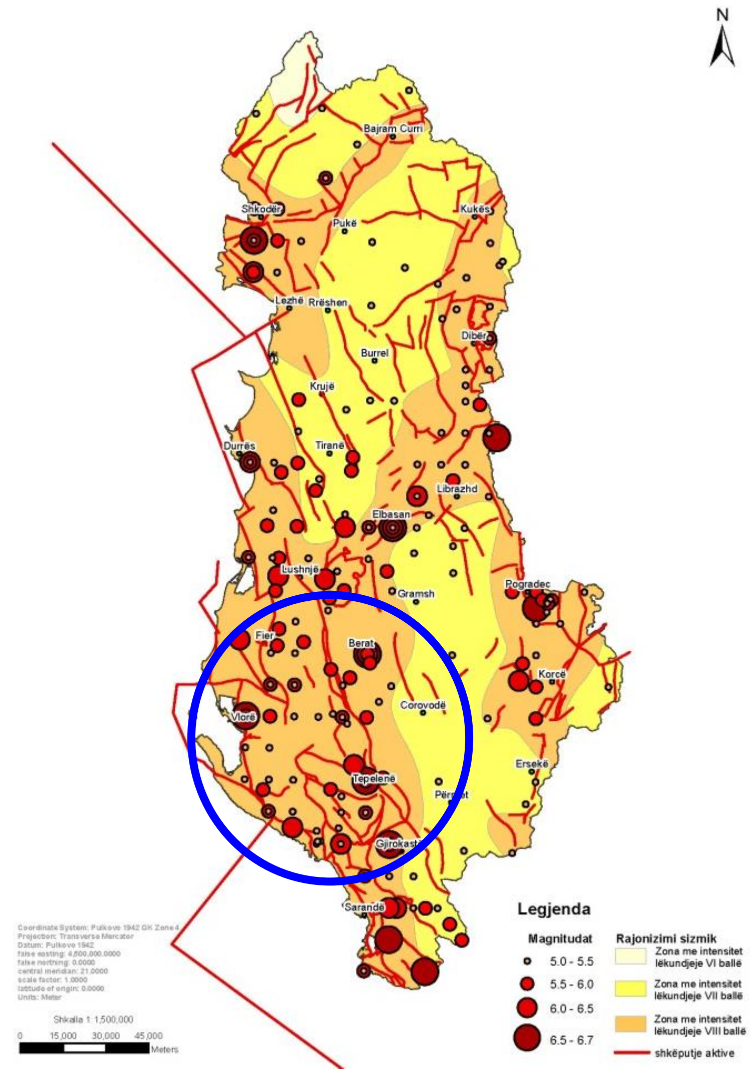
The Vjosa Watershed is characterized by pre-Pliocene compression movements, leading to the formation of anticline and syncline complexes, frequently associated to thrust faults.

Anticline belts of Berati, Kurveleshi and Çika, and syncline structures of Memaliaj and Shushica.



Seismic Activity in Albania





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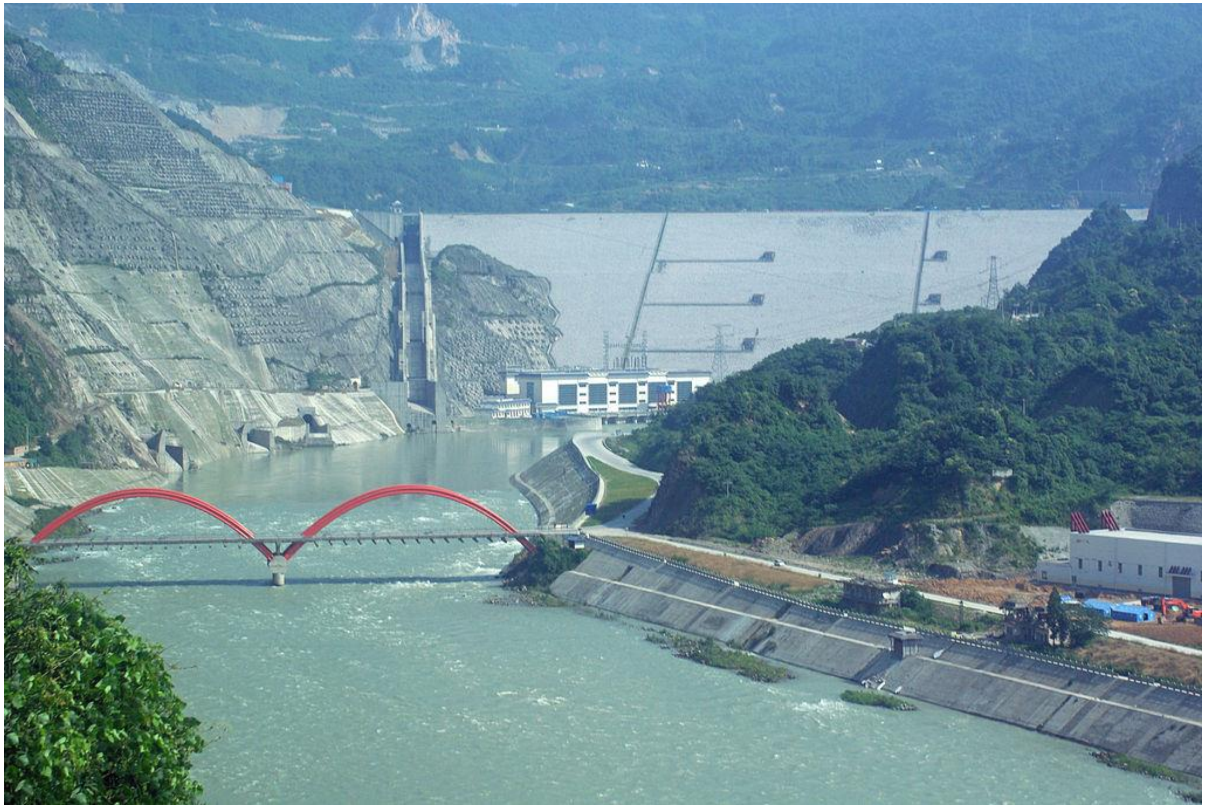
ZIPINGPU DAM FAILURES (SICHUAN PREFECTURE, CHINA) CAUSED BY THE 7.9 Mw EARTHQUAKE ON THE 12th MAY 2008



ZIPINGPU DAM FAILURES (SICHUAN PREFECTURE, CHINA) CAUSED BY THE 7.9 Mw EARTHQUAKE ON THE 12th MAY 2008.

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Why so high sediment deposition rates?

- **Vjosa is a young river (Upper Pleistocene around 150.000 years)** (Carcaillet et al., 2009)

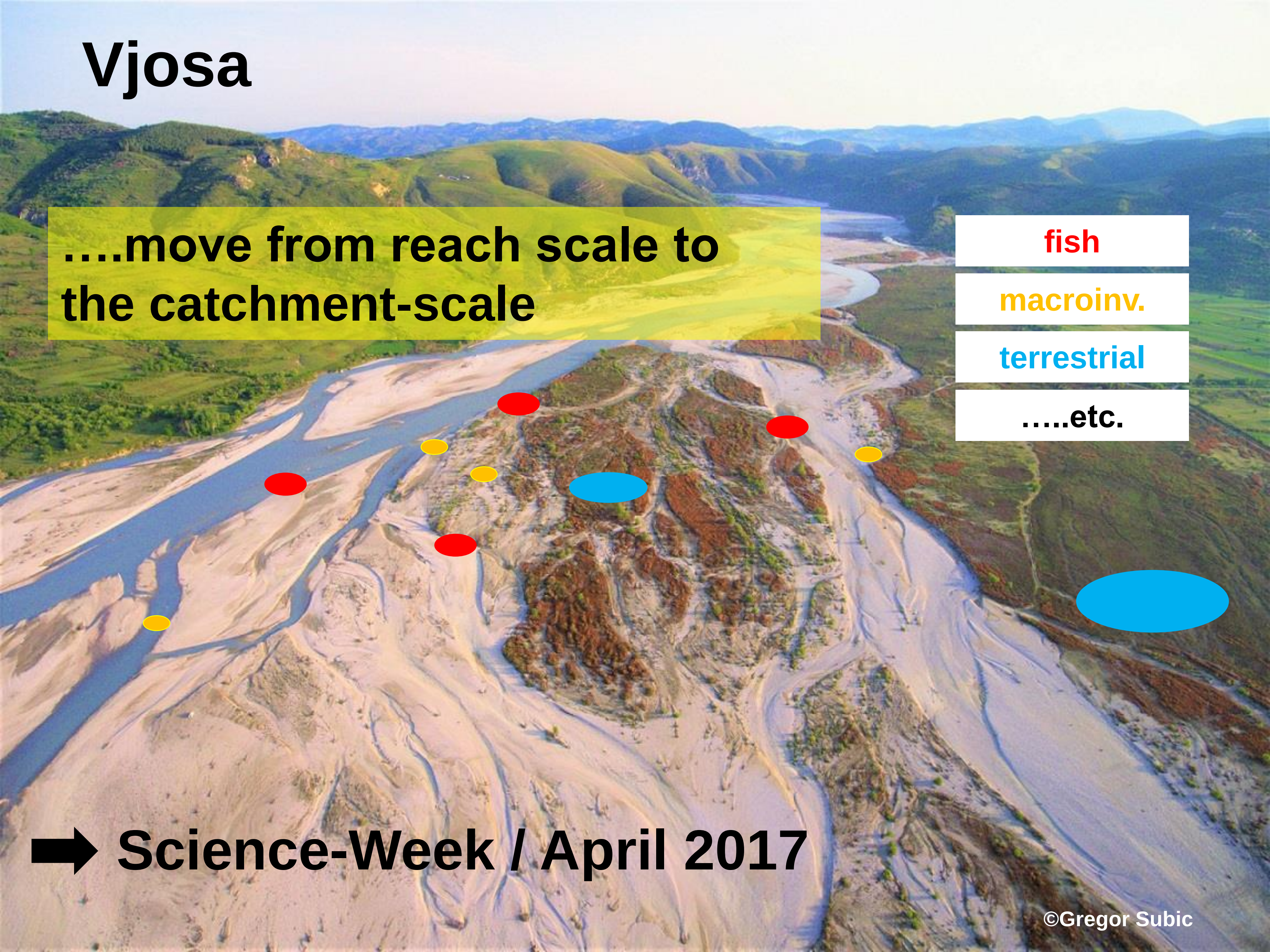
- **Land use and deforestation**

Vjosa

©Adrian Guri


Vjosa
©Adrian Guri


Vjosa
www.bettinapohlmann.de

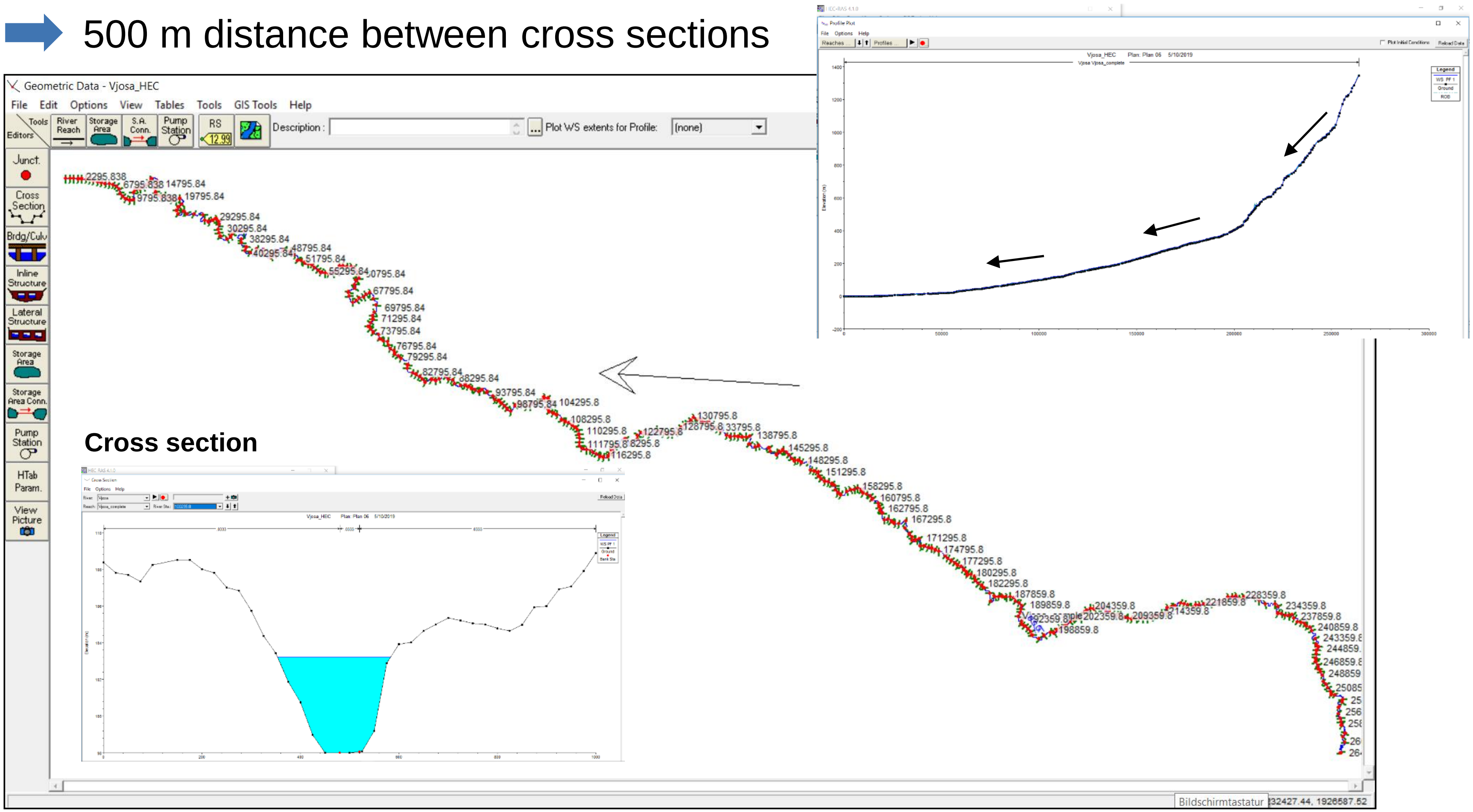

Vjosa
….move from reach scale to the catchment-scale
fish
macroinv.
terrestrial
…..etc.
➡ Science-Week / April 2017
©Gregor Subic

Hydraulics (1-D hydrodynamic–numerical model)

- 419 Cross sections
- 500 m distance between cross sections

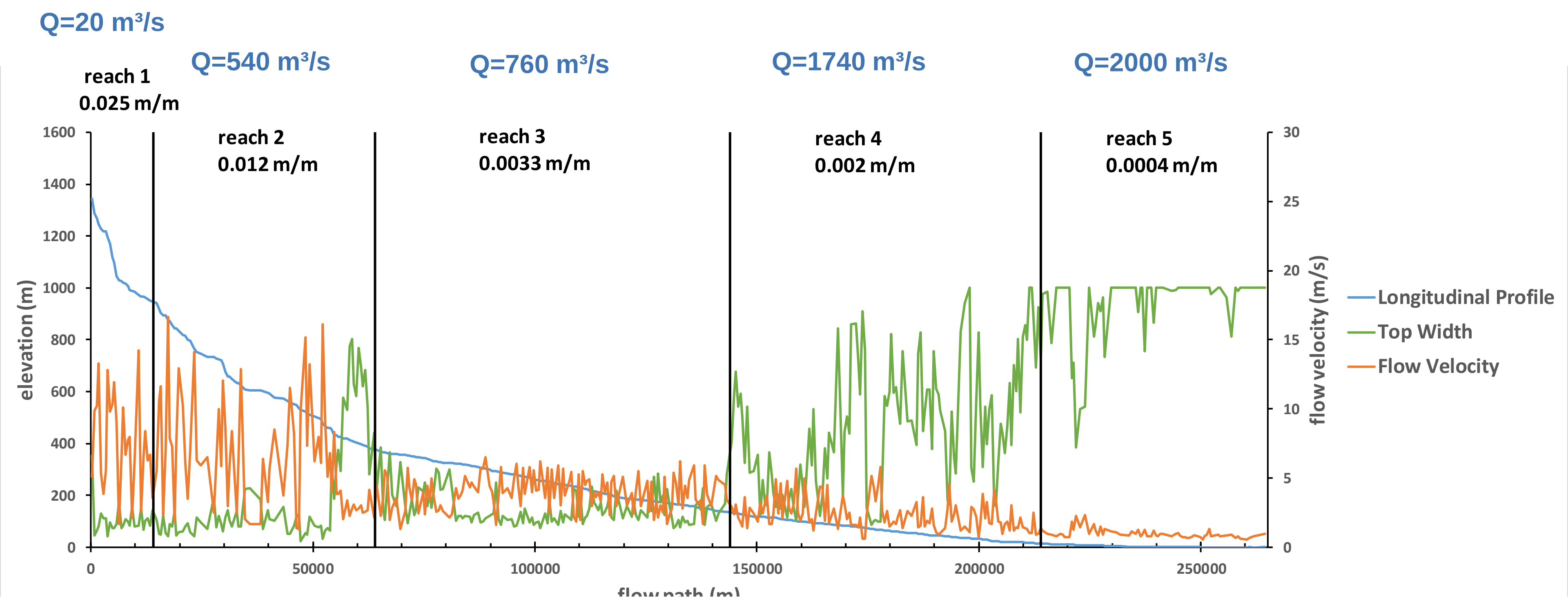
Longitudinal profile

Cross section



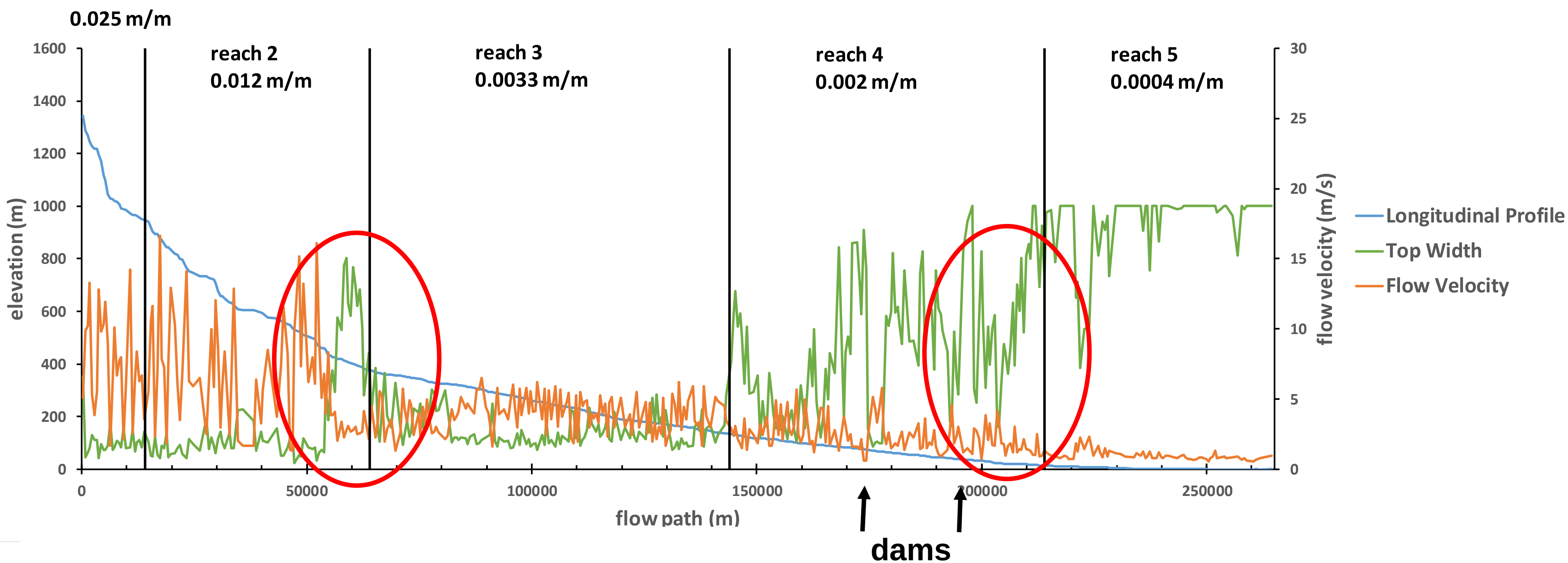
Results Hydraulics

Longitudinal profile, *erosional energy* and *active floodplain*



Link to river morphological types is requested!

Results Hydraulics – river morphological types



Link to morphological parameters is requested !

River morphological parameters

……for the entire longitudinal profile!

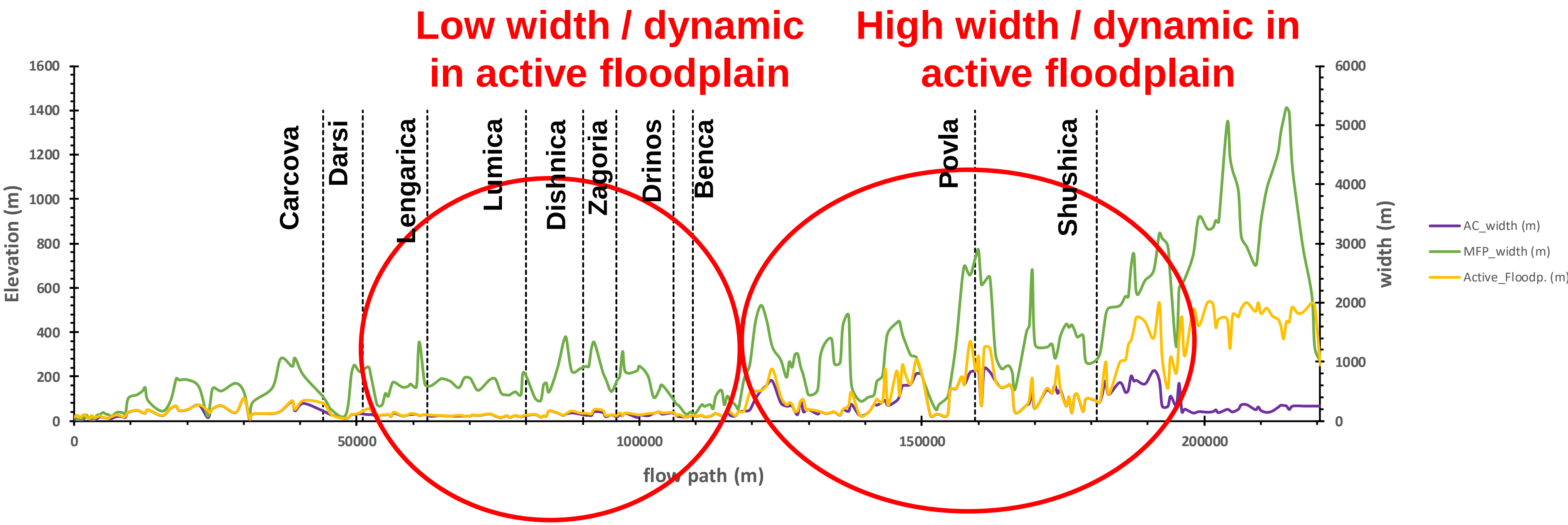
©Gregor Subic

Longitudinal profile Vjosa

- Comparison of morphological parameters

+

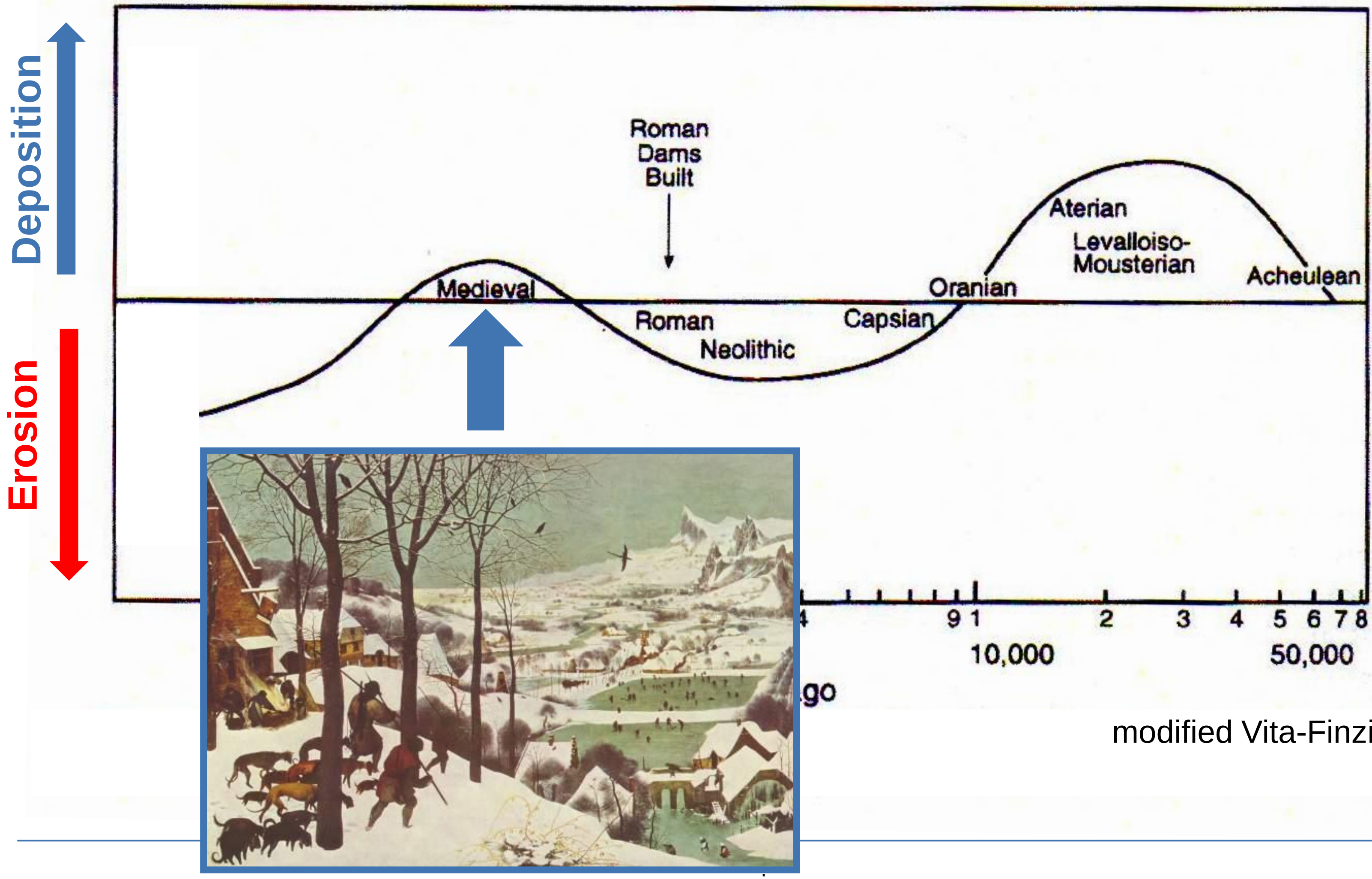
- results - Hydraulic



- Two different reaches concerning river morphodynamics
- Reasons for these differences?

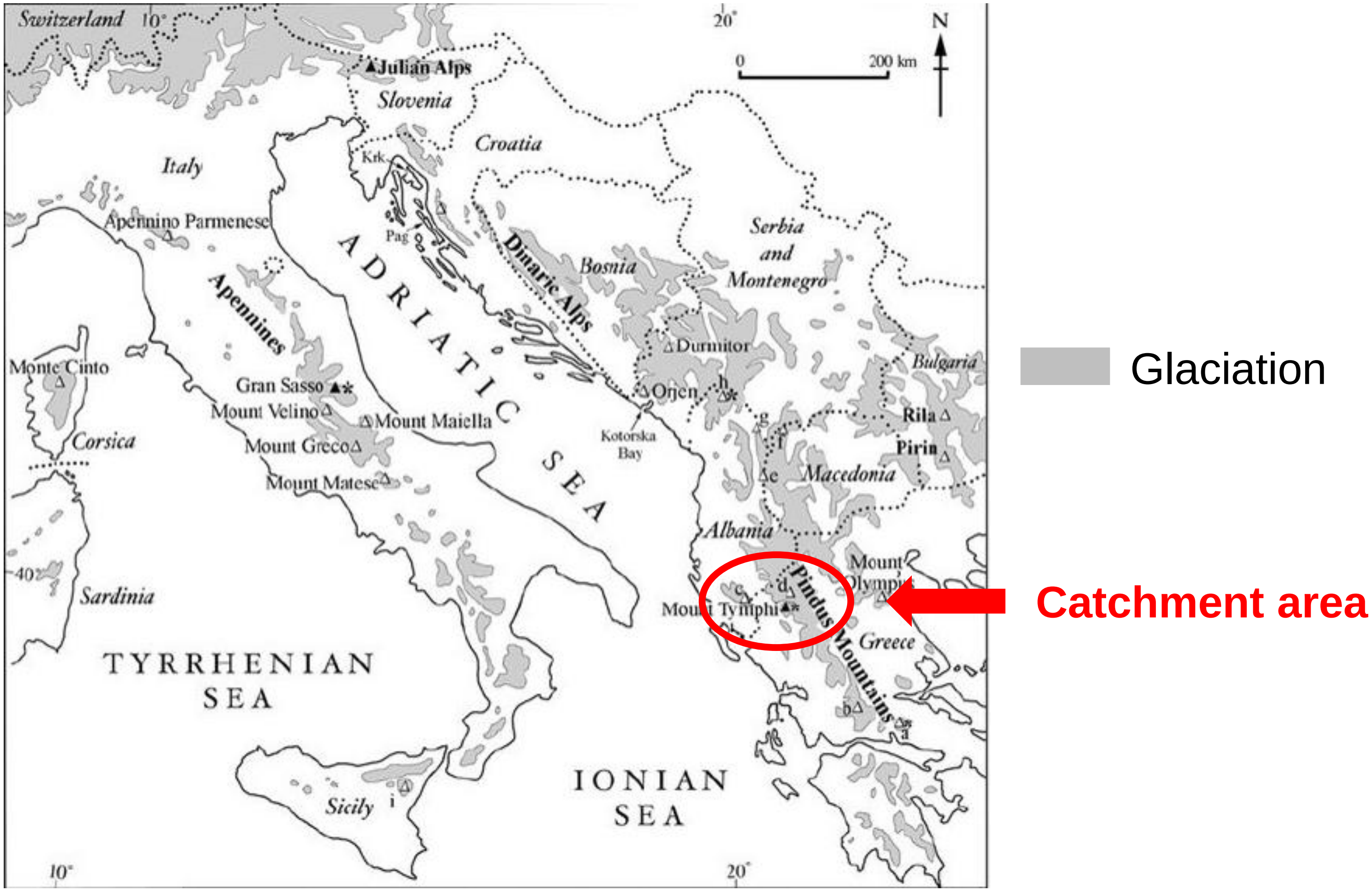
Changes in the sediment regime

- History of erosion and deposition in the mediterean area



modified Vita-Finzi (1969)

Glaciation in the Mediterranean area



Hughes et al., 2006


Charavgi
Llovinë e Poshtme
Selo
Llovinë e Sipërme
Krioner
Llongo
Kastaniani
Koshovicë
Sotirë
Image © 2019 DigitalGlobe
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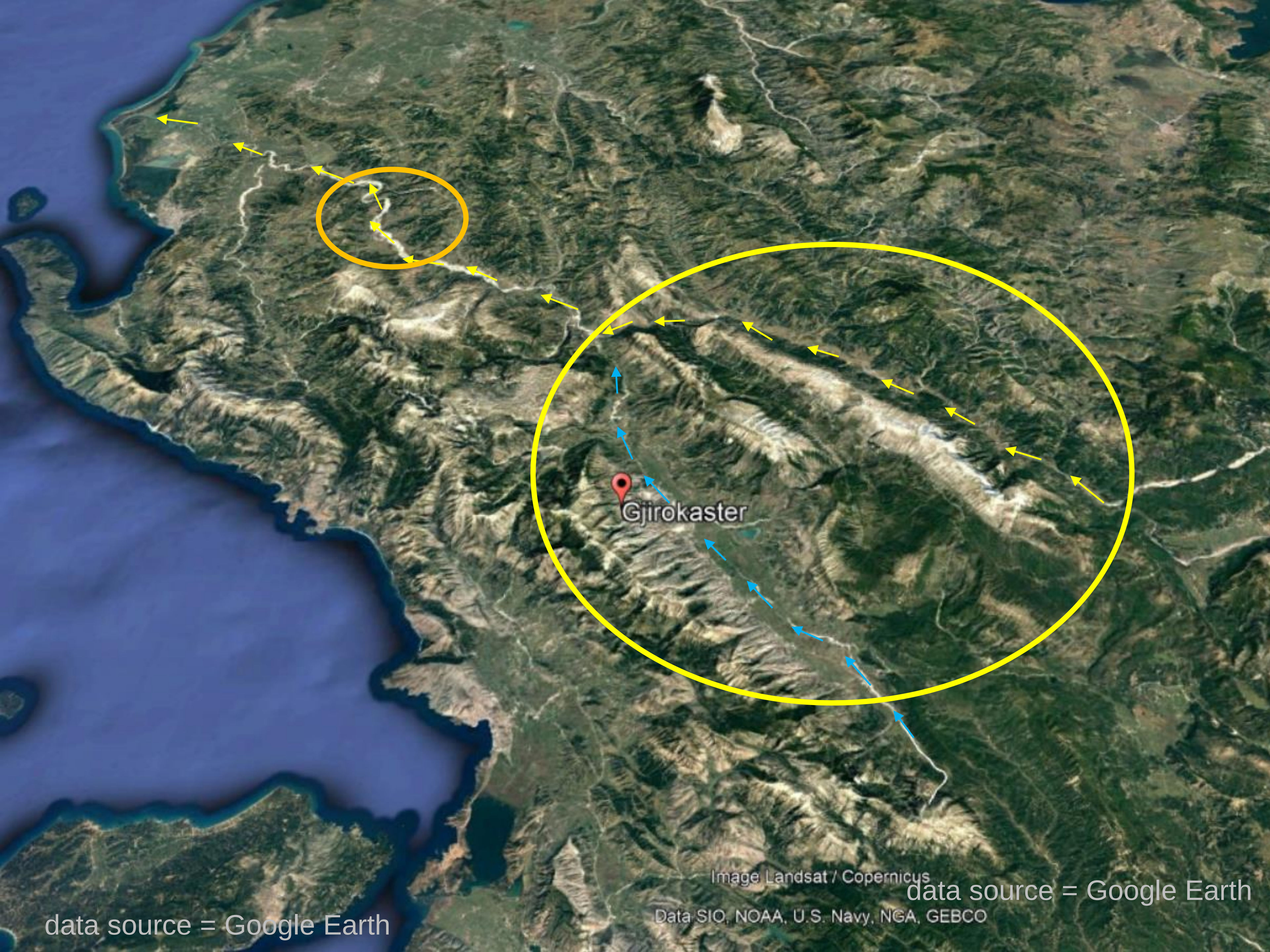
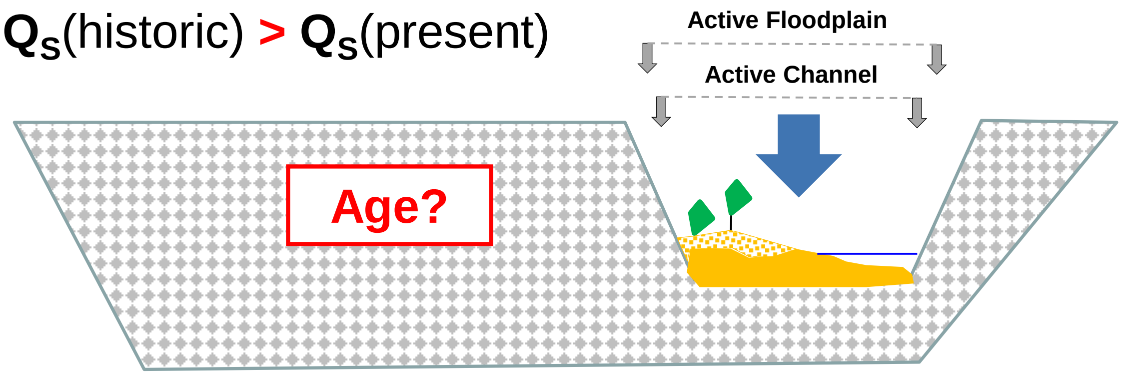

Gjirokaster
Image Landsat / Copernicus
data source = Google Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
data source = Google Earth

Reach Permet

Q_S(historic) > Q_S(present)

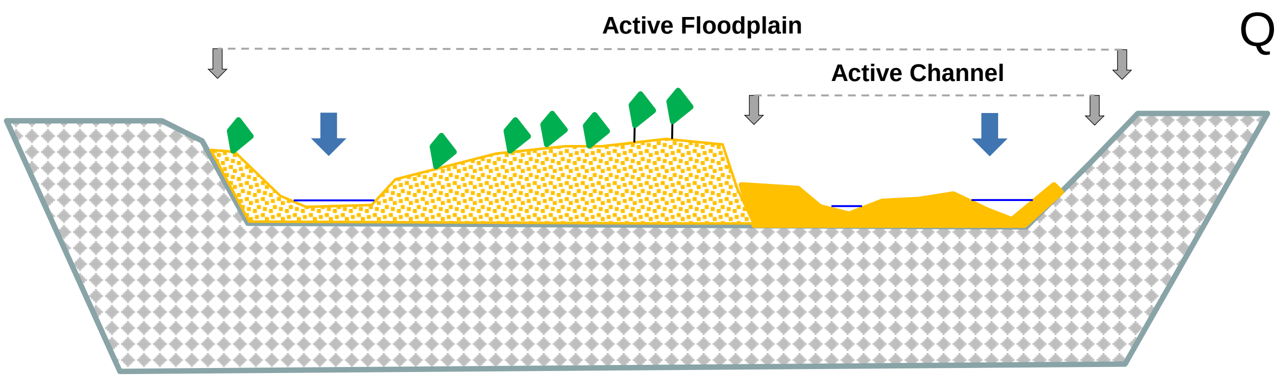


Alluvion

Q_S = Sediment transport

Reach Pocemi

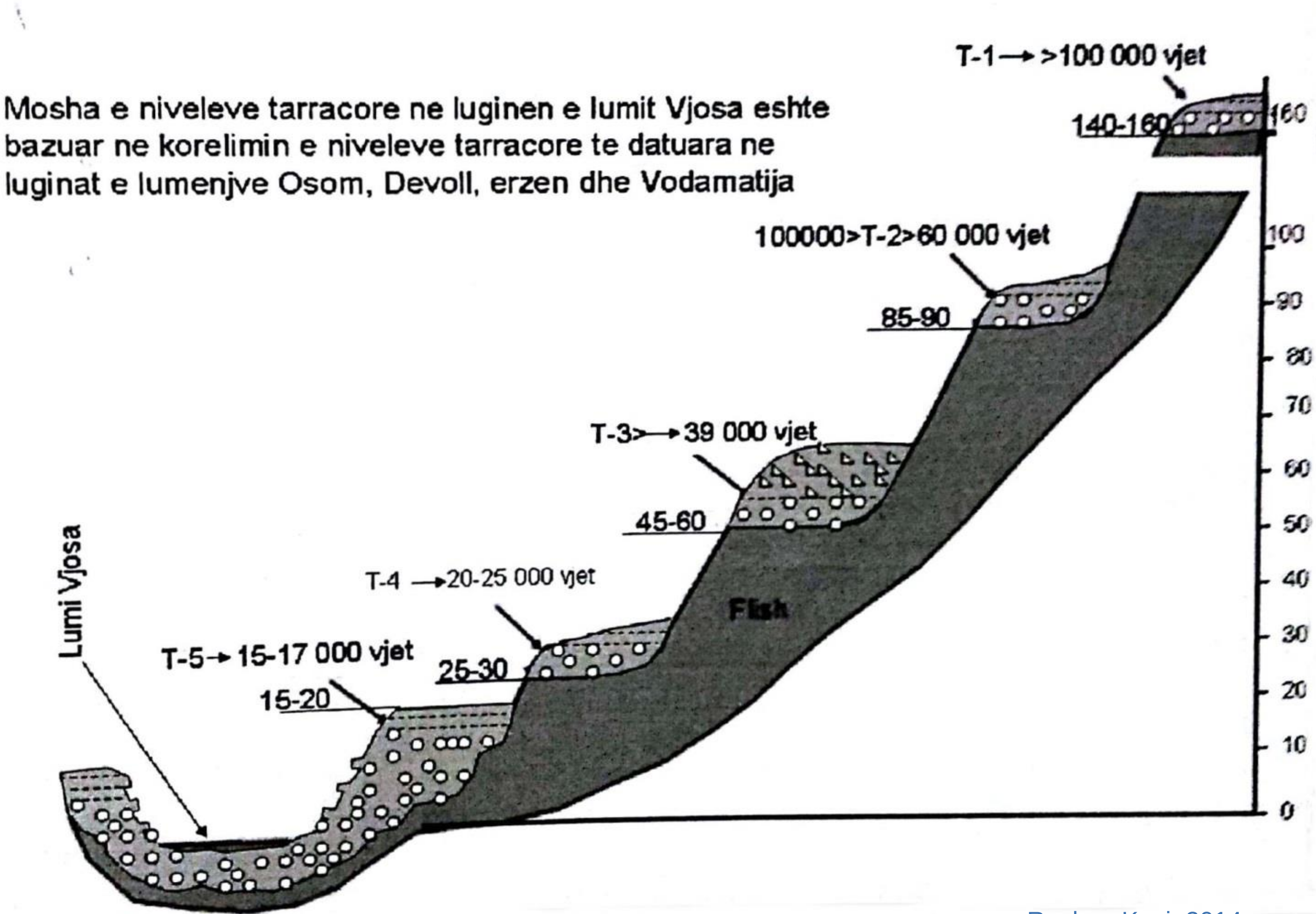
Q_S(historic) ~ Q_S(present)



Alluvion

Q_S = Sediment transport

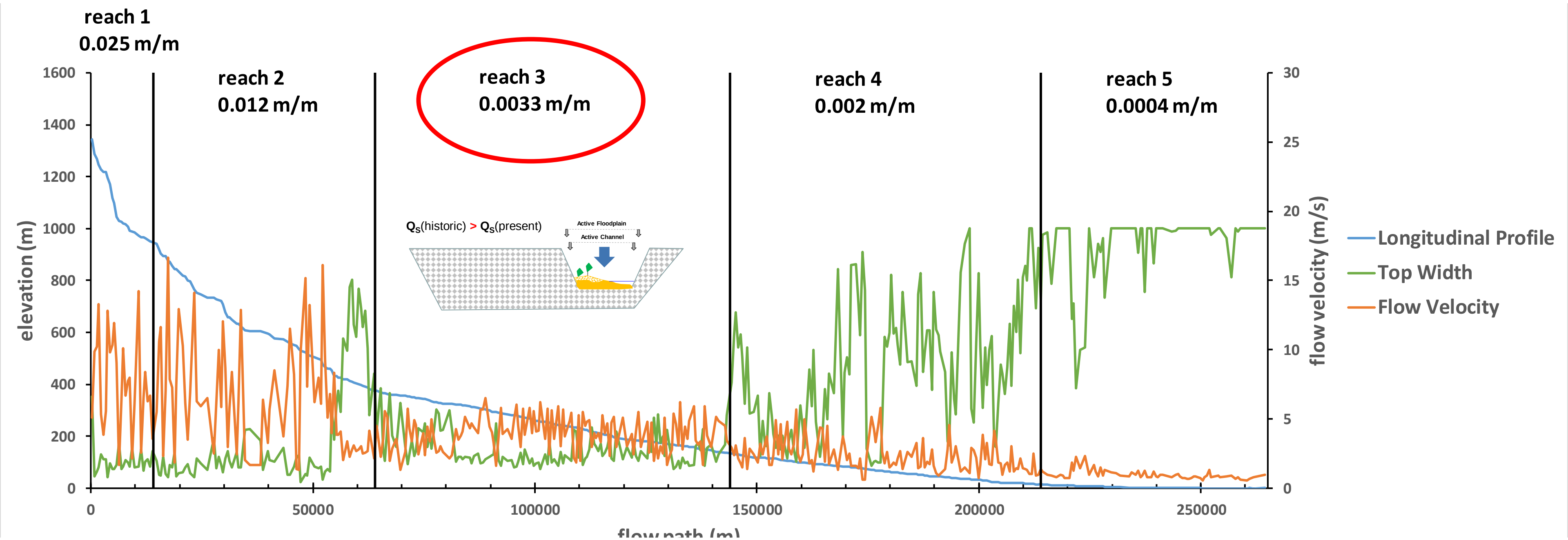
Schematic model of the Vjosa river terraces



Rexhep Koçi, 2014

Results - Hydraulics (1-D HN-model; 419 cross sections)

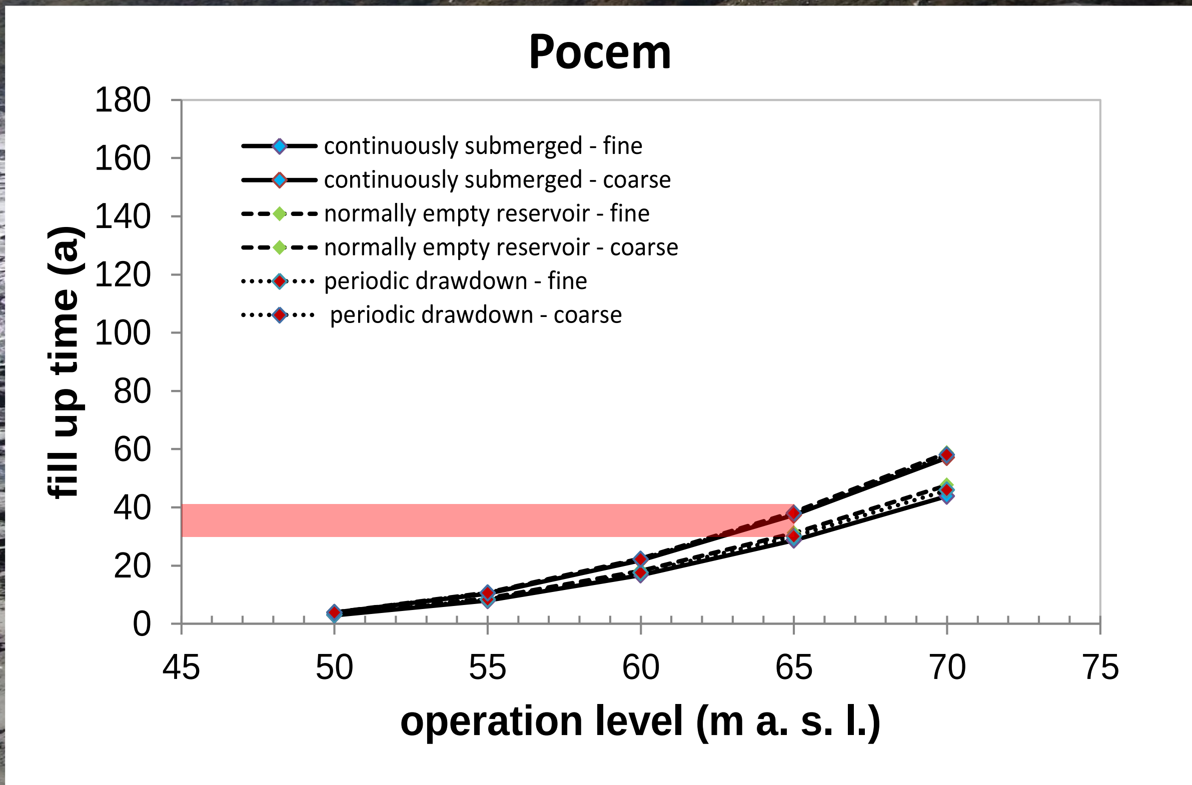
➡ ***Longitudinal profile***, ***erosional energy*** and ***active floodplain***



➡ **Slope**: Indicator for ***fluvial sediments*** and **no** ***(fluvio)-lacustrinen sediments***

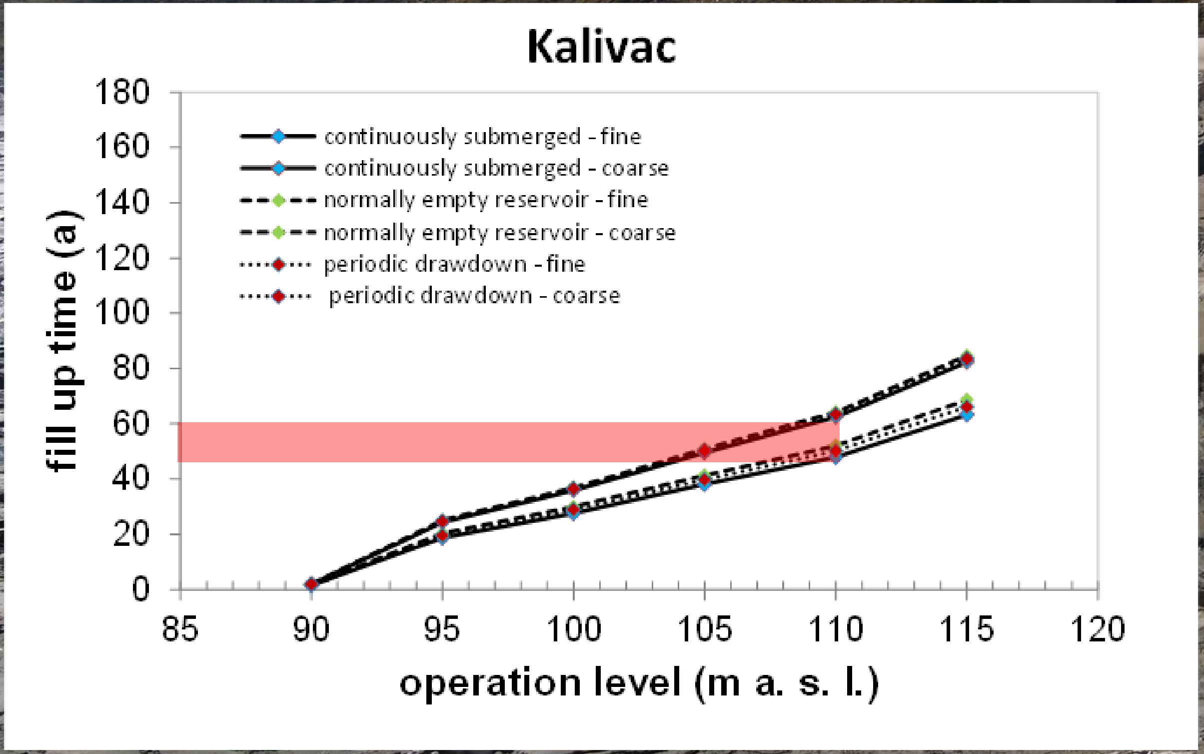
How fast will the reservoirs will be filled up with sediments at the Vjosa?

How fast will the reservoirs will be filled up with sediments at the Vjosa?



Pocem = 30 – 40 years

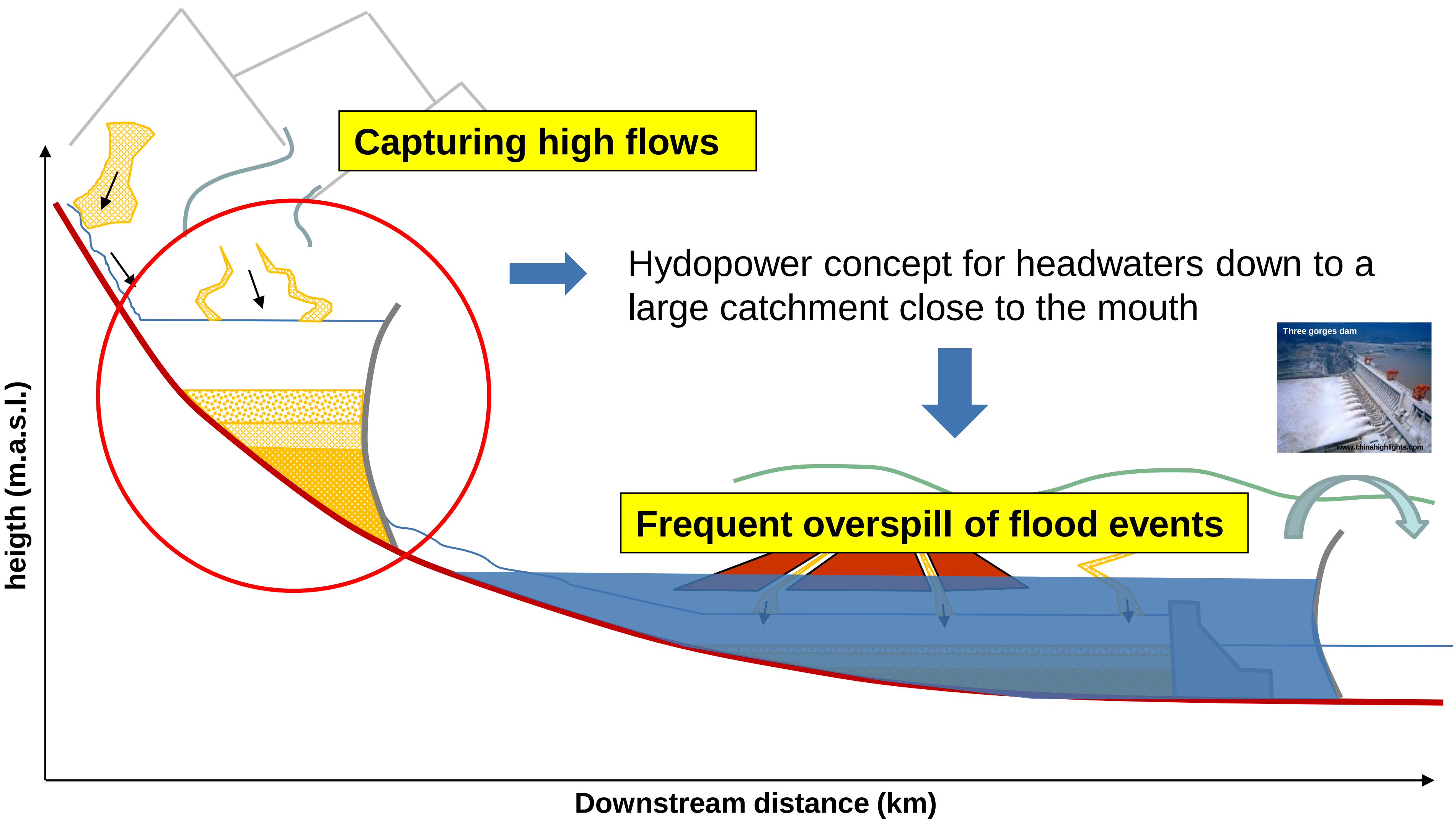
How fast will the reservoirs will be filled up with sediments at the Vjosa?



Kalivac = 45 – 60 years

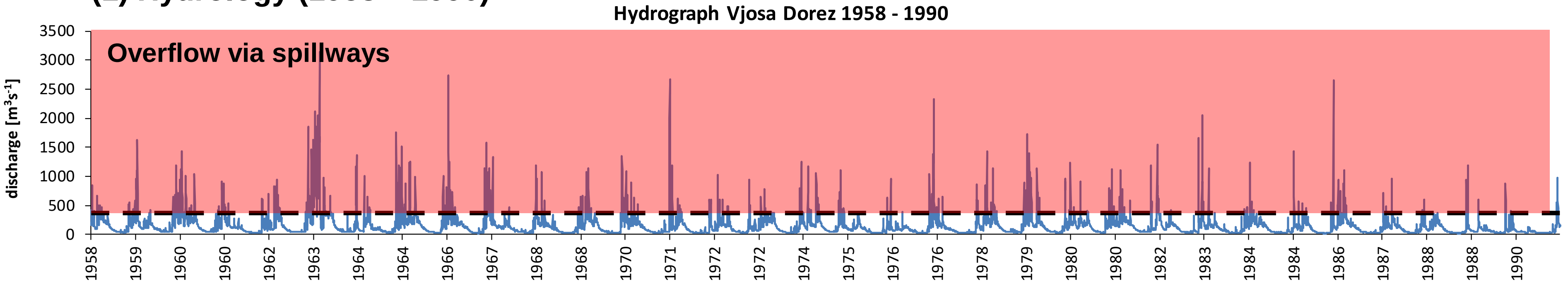
©Göckler

Unusal concept of Vjosa dams!



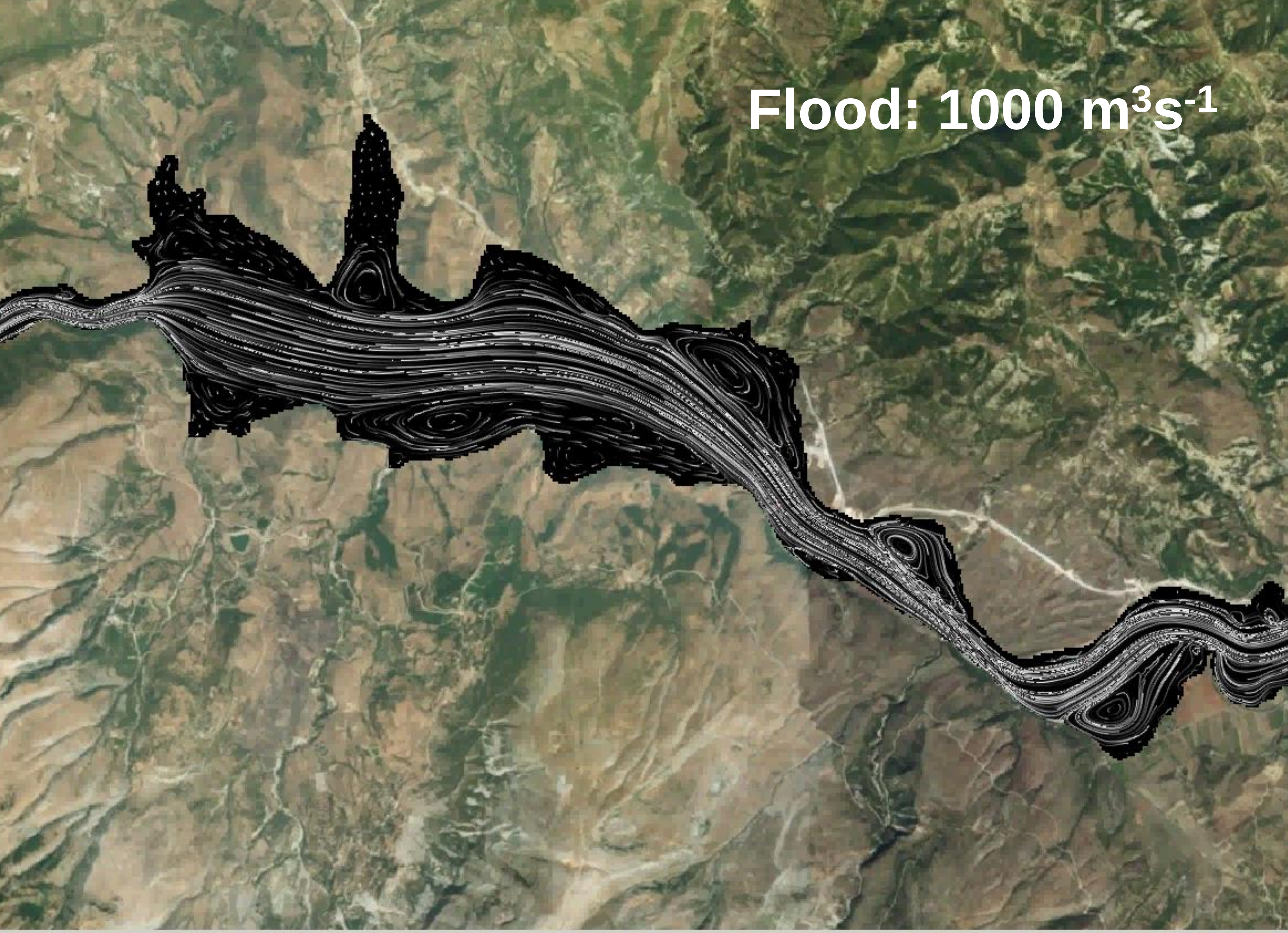
What problems?

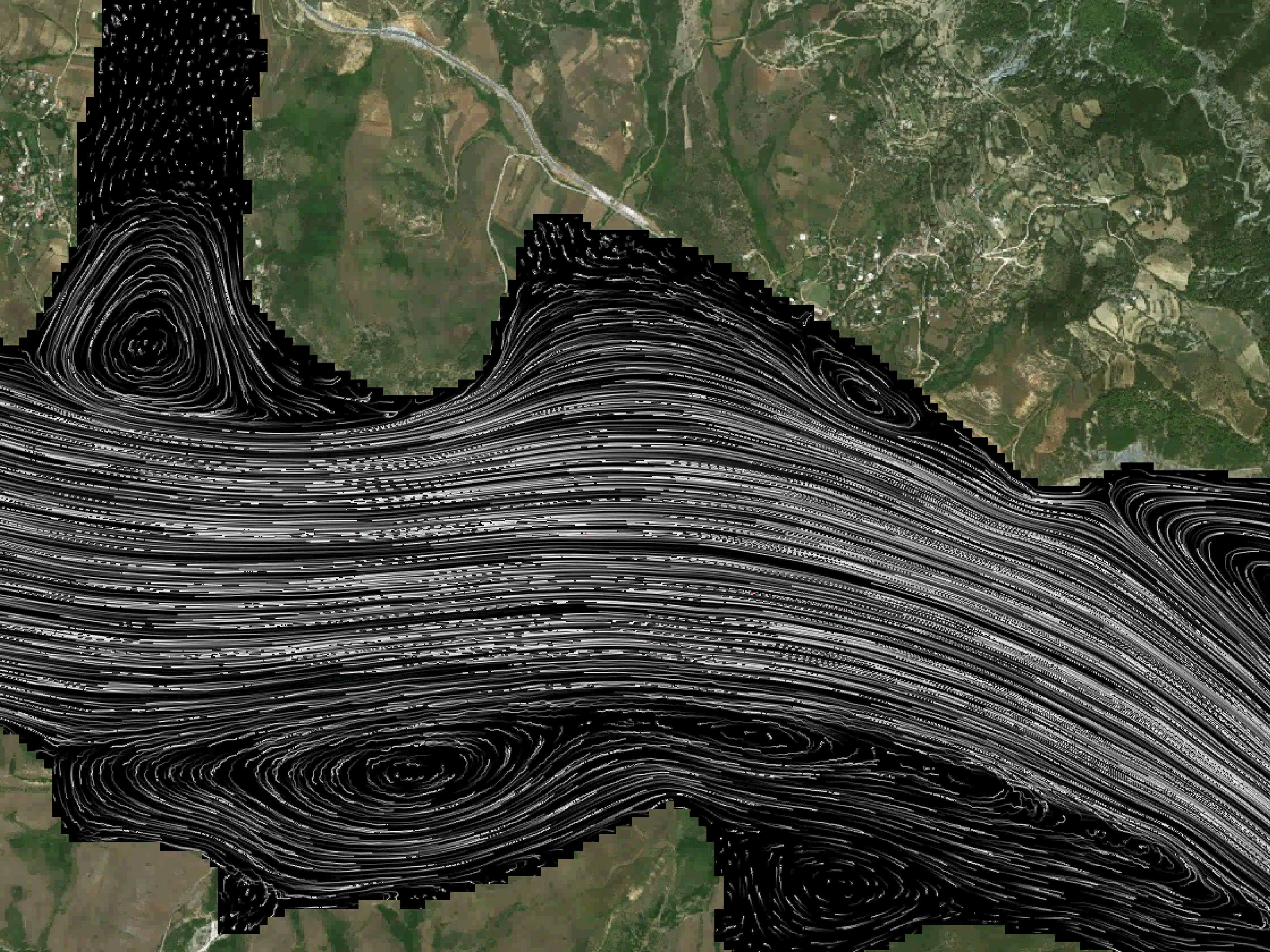
(1) Hydrology (1958 – 1990)



Turbines operate to a maximum discharge level!

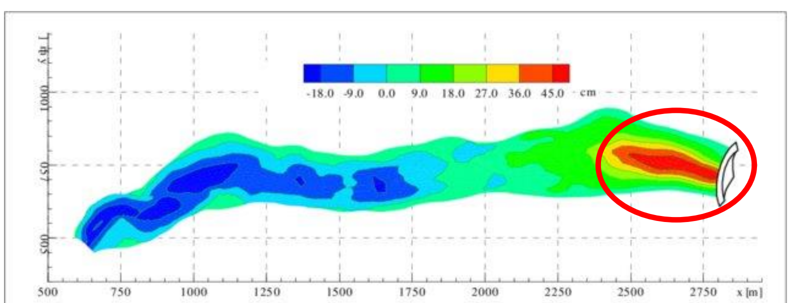
Impact on flow dynamics and sedimentation in the reservoir!


Flood: 1000 m³s⁻¹



Bottom outlet as critical point

Annual check required if its operating!



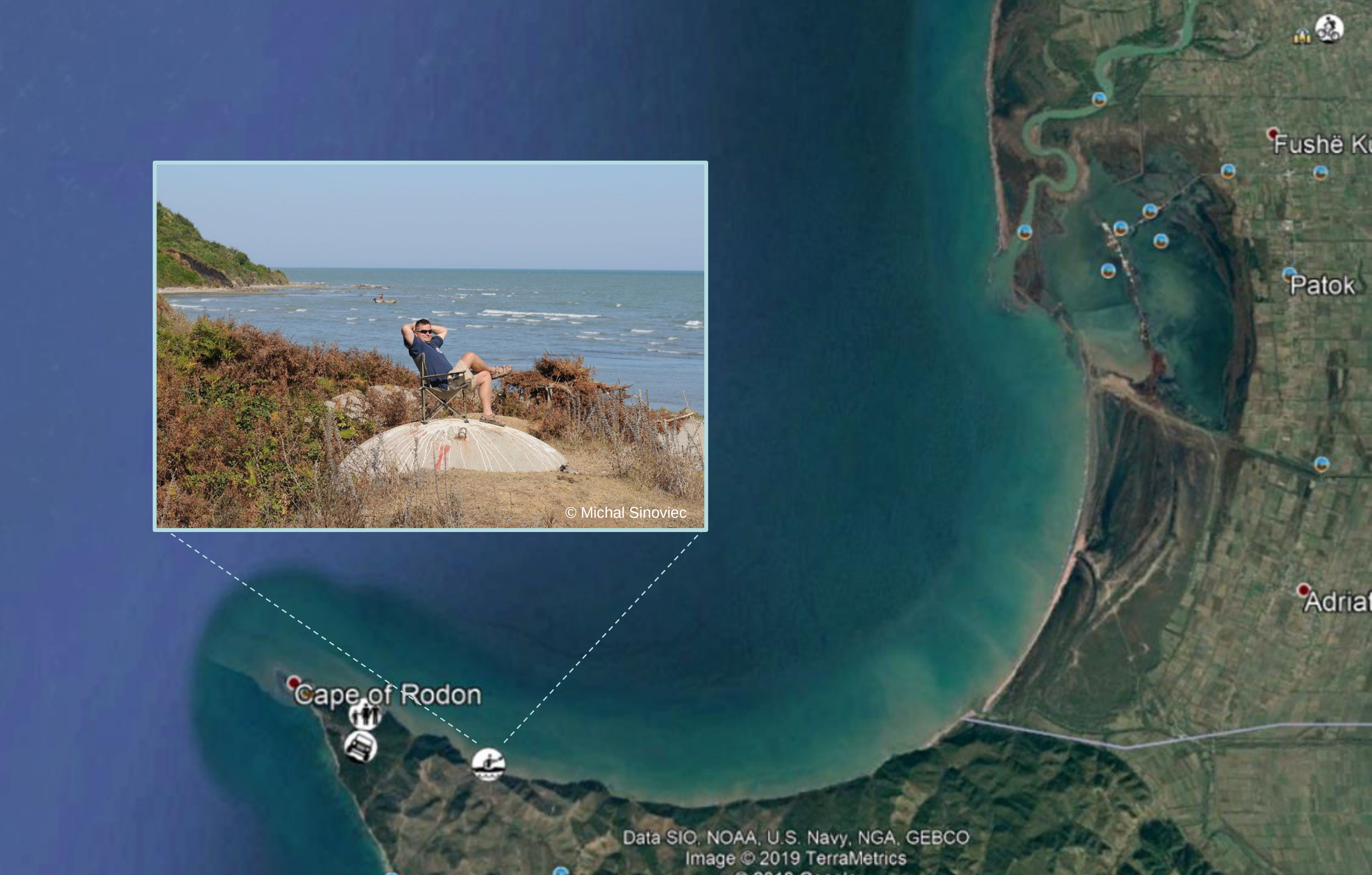
Deposition at Swiss-hydropower plant after a flood event

Althaus *et al.* (2009)

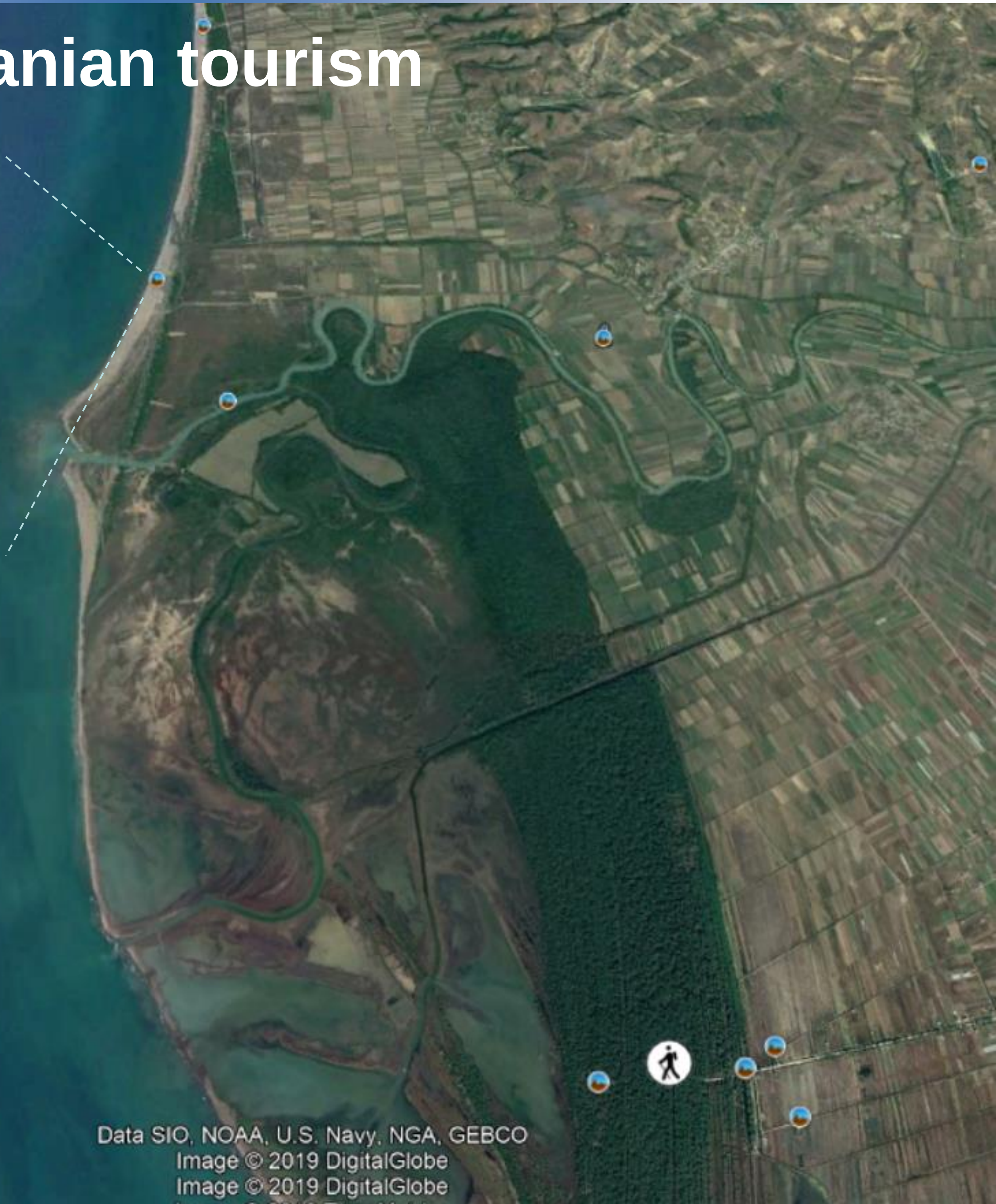
How important are river sediments for Albanian tourism?

…..very, very important!

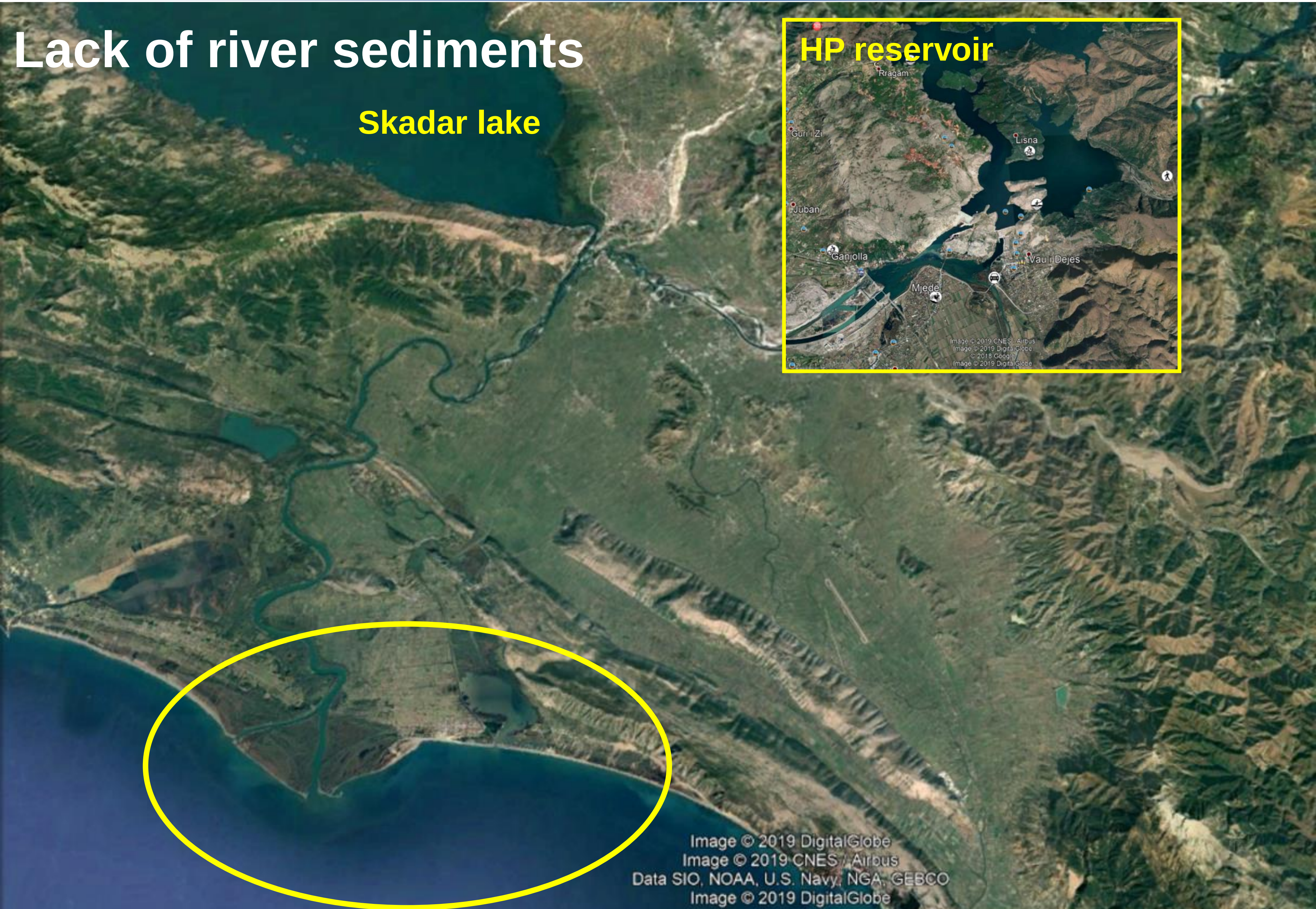
River sediments = Albanian tourism



River sediments = Albanian tourism



Lack of river sediments



Thank you for your attention!

measures / costs

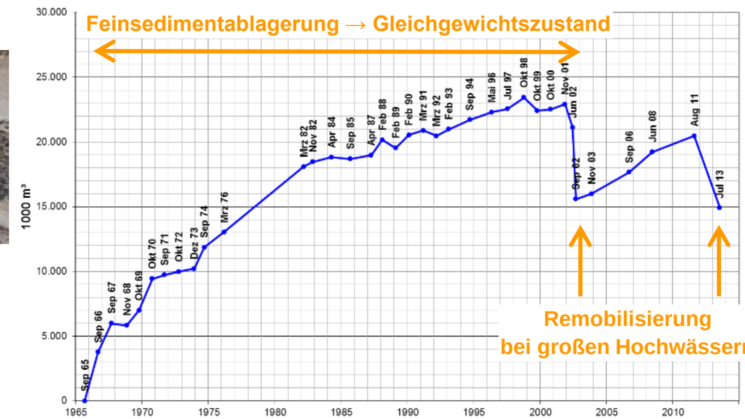
economic importance

At the moment **costs** for **depositing** of dredged material in Austria **10 – 20 €** per m³.

dredging

flushing

Flood impacts

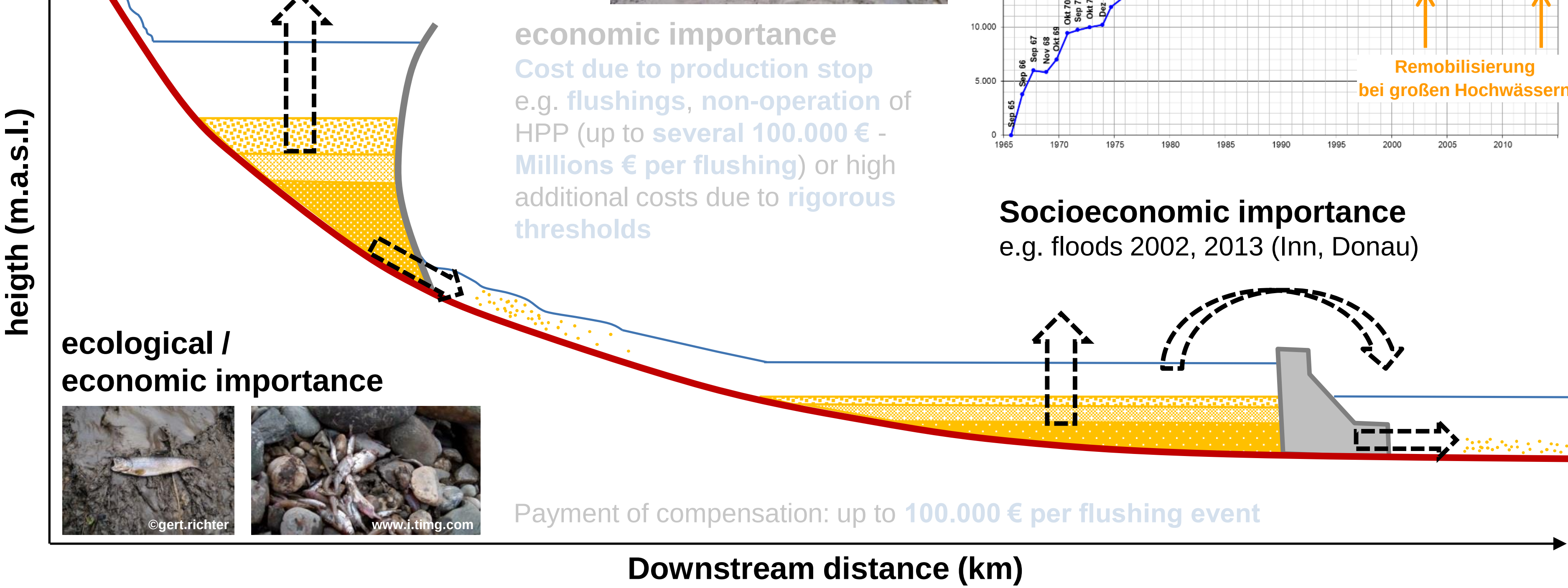


economic importance

Cost due to production stop
e.g. **flushings**, **non-operation** of HPP (up to **several 100.000 €** - **Millions € per flushing**) or high additional costs due to **rigorous thresholds**

Socioeconomic importance

e.g. floods 2002, 2013 (Inn, Donau)



ecological / economic importance

Payment of compensation: up to **100.000 € per flushing event**

Head of CD-Laboratory „Sediment research and -management“

Module 1 (Verein für Ökologie und Umweltforschung)

VEREIN FÜR ÖKOLOGIE UND UMWELTFORSCHUNG

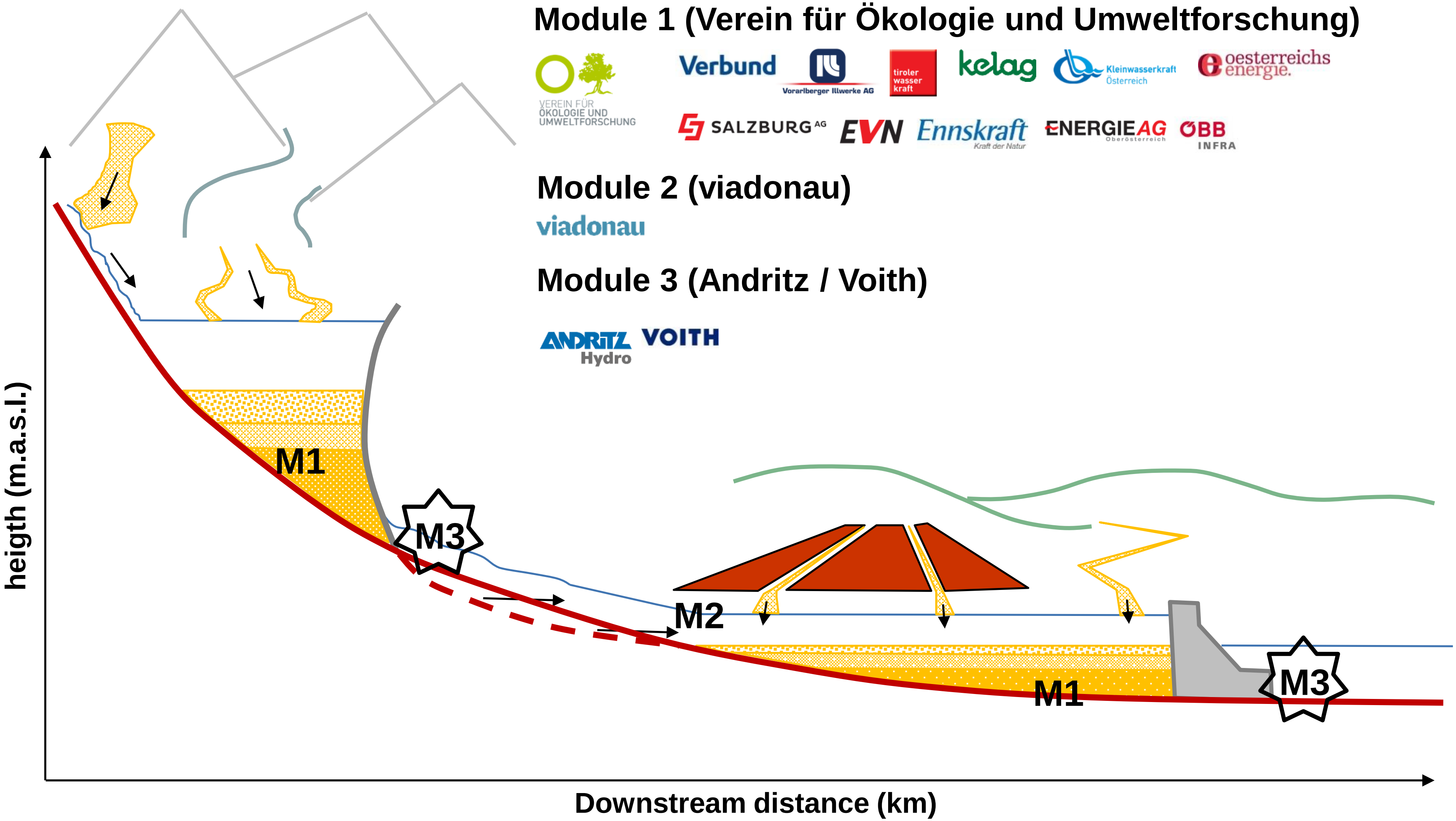
Verbund, Vorarlberger Illwerke AG, tiroler wasser kraft, kelag, Kleinwasserkraft Österreich, oesterreichs energie., SALZBURG AG, EVN, Ennskraft, ENERGIE AG Oberösterreich, ÖBB INFRA

Module 2 (viadonau)

viadonau

Module 3 (Andritz / Voith)

ANDRITZ Hydro, VOITH



Sedimentation (Storage power plant)

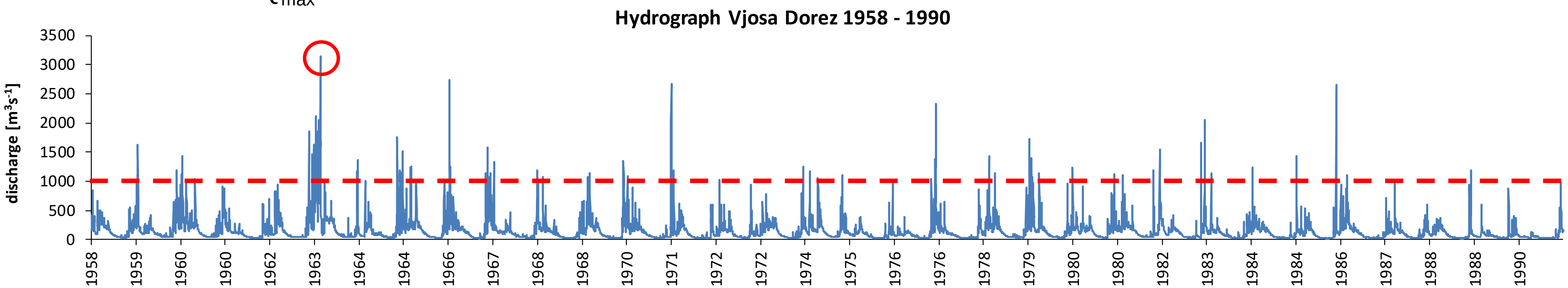
„Whereas the last century was concerned with reservoir development, the 21st century will need to focus on sediment management; the objective will be convert today´s inventory of non-sustainable infrastructure for future generations.“

Third World Water Forum, Kyoto 2003

Hydrologie

➡ Langzeitaufzeichnungen notwendig

Q_{max}= 3140 m^3s^{-1}



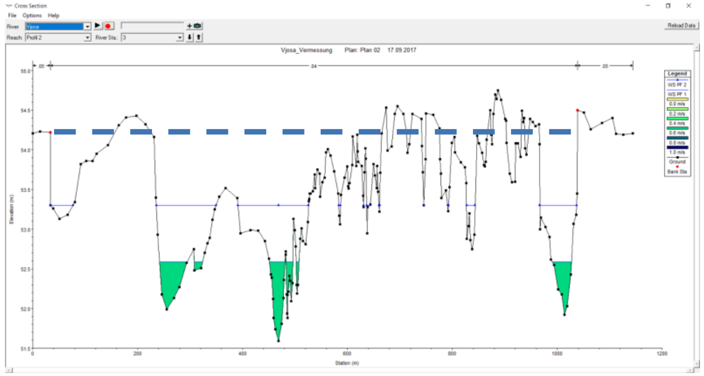
<u>Charakteristische Abflüsse:</u>

Q_L = 15 m^3s^{-1}

Q_M = 148 m^3s^{-1}

HQ_1 ~ 1000 m^3s^{-1}

Transect 2



Q_{bf} ~ 1000 m^3s^{-1}

.

Summary / Conclusions

➡ The ***fill up*** of ***Vjosa reservoirs*** is estimated within ***30 – 60 years***

➡ ***High economic cost*** for ***sediment management*** and ***treatment***

➡ ***Coastal (Lagune) erosion*** will ***increase*** due to lack of sediment transport (3 – 5 tons per year)

➡ ***Degradation*** of ***ecology*** and ***European tourism*** in the ***Vjosa catchment***

Risk of:

Lose – Lose – Lose Situation

(Sedimentation) **(Ecological degradation)** **(Coastal erosion)**

Sedimentation in reservoirs (global view)

Region	Storage capacity for hydropower use: 80% of the reservoir is filled up with sediment
Africa	2100
Asia	2035
Australia & Oceania	2070
Central America	2060
Europe	2080
Middle East	2060
North America	2060
South America	2080

Basson (2009)