Environmental conditions and aquatic communities in karst waters

Case study: **Plitvice Lakes**

What is karst?

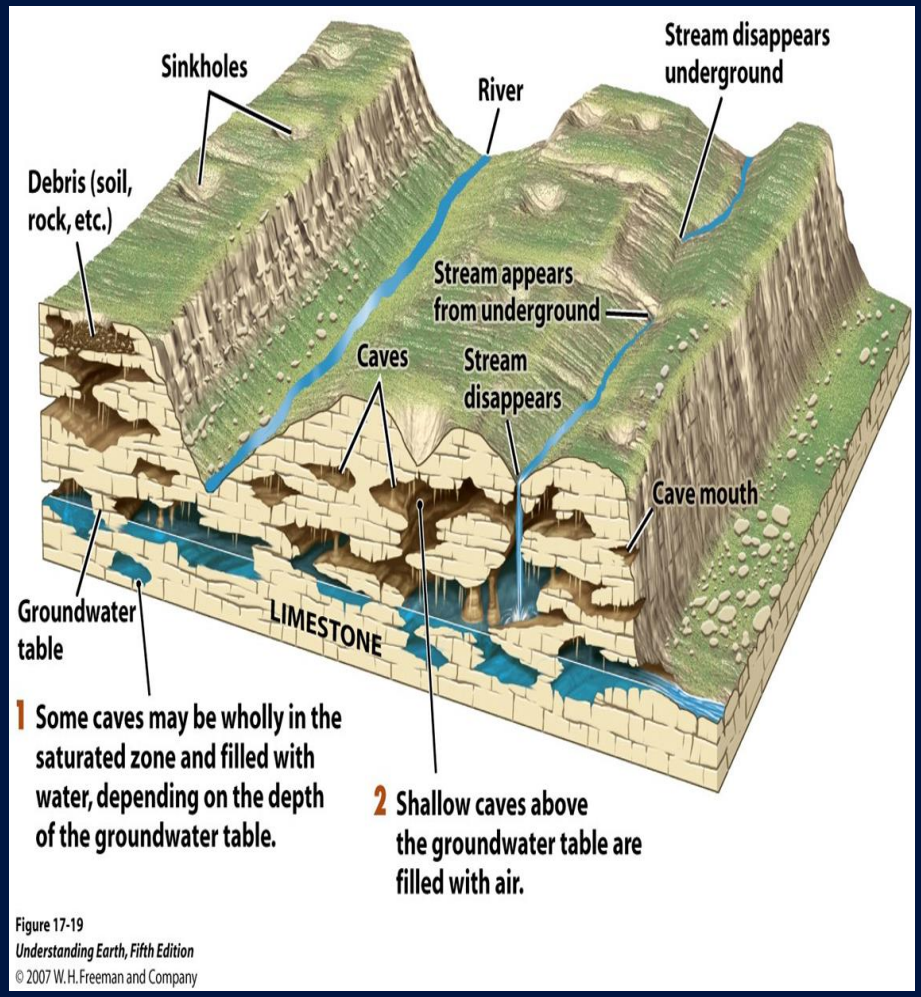
Karst – hydrogeological type of landscape on the surface and subterranean

Karst areas consist of solid but chemically soluble rock:

- **limestone $CaCO_3$**
- **dolomite $CaMg(CO_3)_2$**
- **gypsum ($CaSO_4$)**

Karst aquifers form by flowing water containing carbon-dioxide (CO_2) which **dissolves carbonate** rocks by the chemical reaction:

$$CaCO_3 + CO_2 + H_2O \Leftrightarrow Ca^{2+} + 2HCO_3^-$$



Calcite? Carbonate? Limestone?

Calcite = **mineral**
calcium carbonate
chemical formula: $CaCO_3$

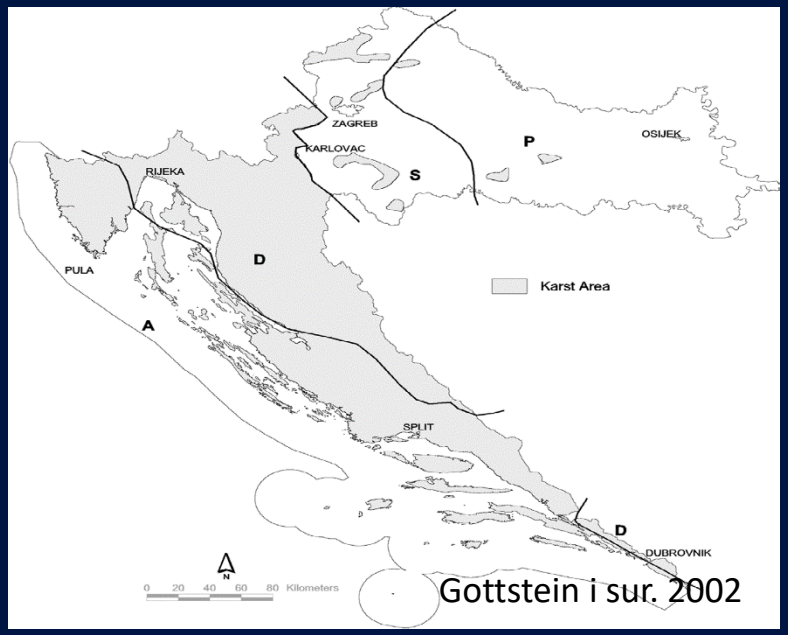
Carbonate = generic name for any **sedimentary** rock that is made of deposited carbonate (CO_3^{2-}) minerals, like limestone or dolomite

Limestone = a carbonate sedimentary **rock** made of the mineral calcite; 20% of all sedimentary rock

Limestone precipitation

$$\mathbf{Ca(HCO_3)_2 \Leftrightarrow CO_2\uparrow + H_2O + CaCO_3\downarrow}$$

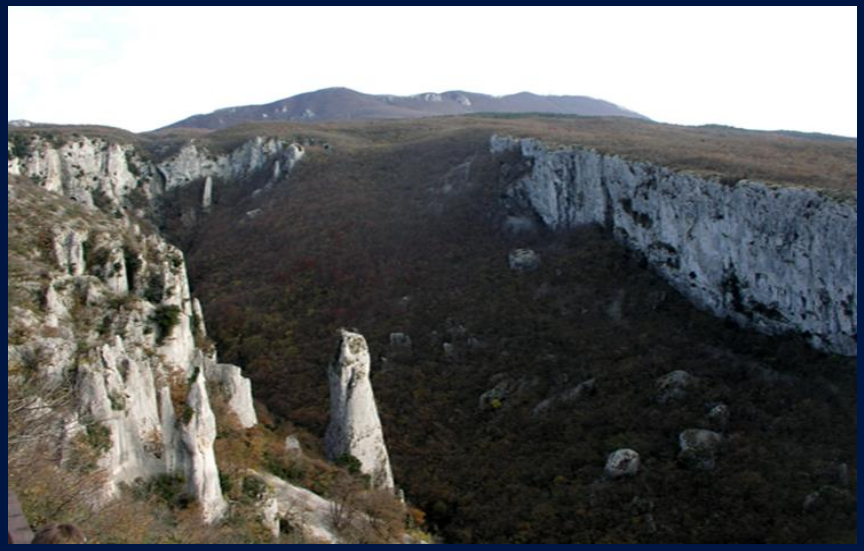
Karst region in Croatia



Gottstein i sur. 2002

- Dinarids karst massif along the Eastern Adriatic Coast
- karst covers 46 % territory of Croatia

Karst region in Croatia – surface landscape



Karst region in Croatia – surface landscape

Gacko Polje (Valley) and Gacka River

Crveno Lake

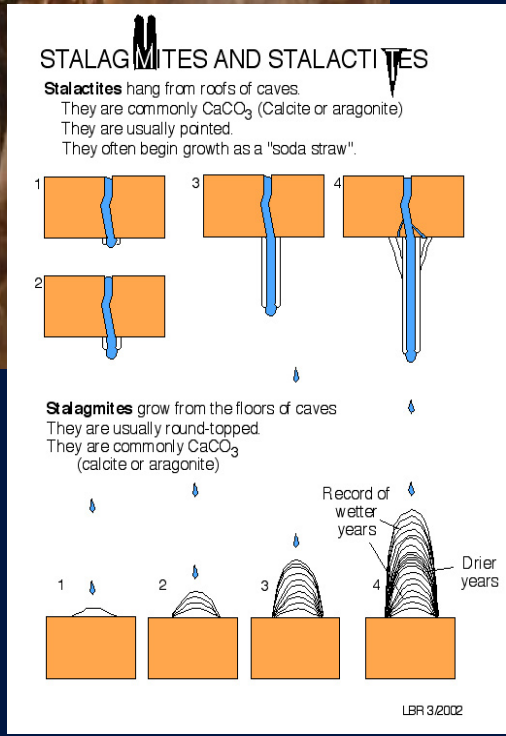
Karst region in Croatia – surface landscape

Plitvice Lakes

Krka River

Karst region in Croatia - subterranean

Cerovačke Caves



TUFA

- tufa is a type of **highly porous limestone**
- Ford and Pedley (1996) defined tufa as "the product of calcium carbonate **precipitation in cool water**, near ambient temperature, **typically contains the remains of micro- and macrophytes, invertebrates and bacteria**".
- Plitvice Lakes – the world's famous tufa barrage hydrosystem; Croatian National Park since 1949, and a World Heritage Site since 1979

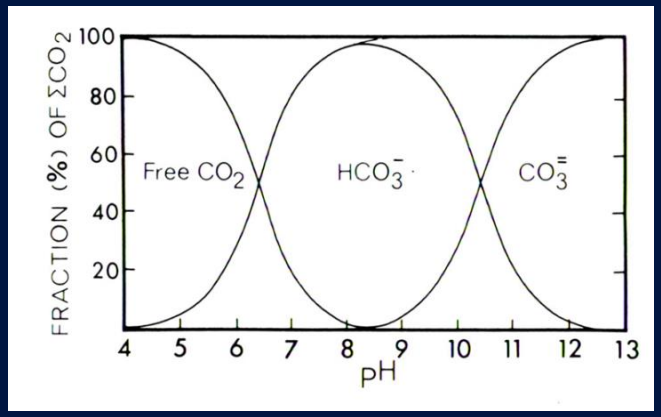
TRAVERTINE

lapis tiburtinus, meaning Tibur stone

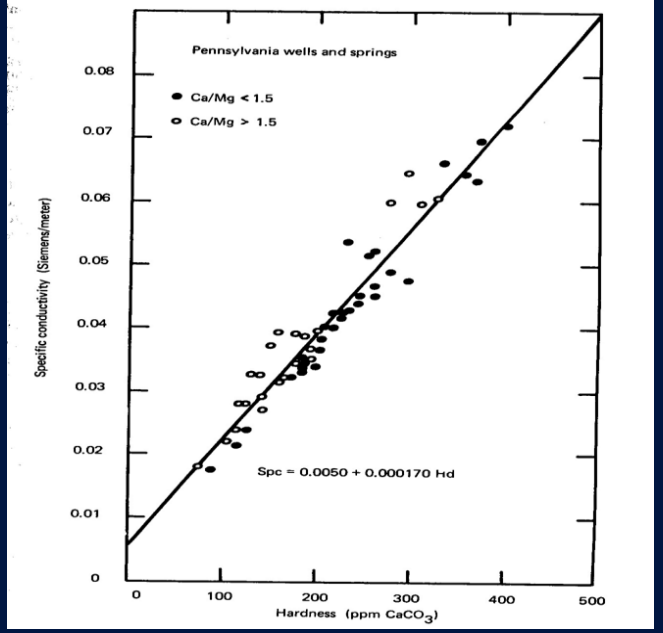
- "A **chemically-precipitated limestone** formed around seepages, springs, and along streams and rivers, of **low to moderate porosity**
- Precipitation results primarily through the transfer of carbon dioxide from or to a groundwater source leading to calcium carbonate supersaturation, with nucleation/growth occurring upon a submerged surface (Pentecost, 2005)."
- Travertines precipitate often from at hotsprings, such as those in Yellowstone (Western USA) and Pamukkale (Turkey)

Environmental conditions for tufa deposition

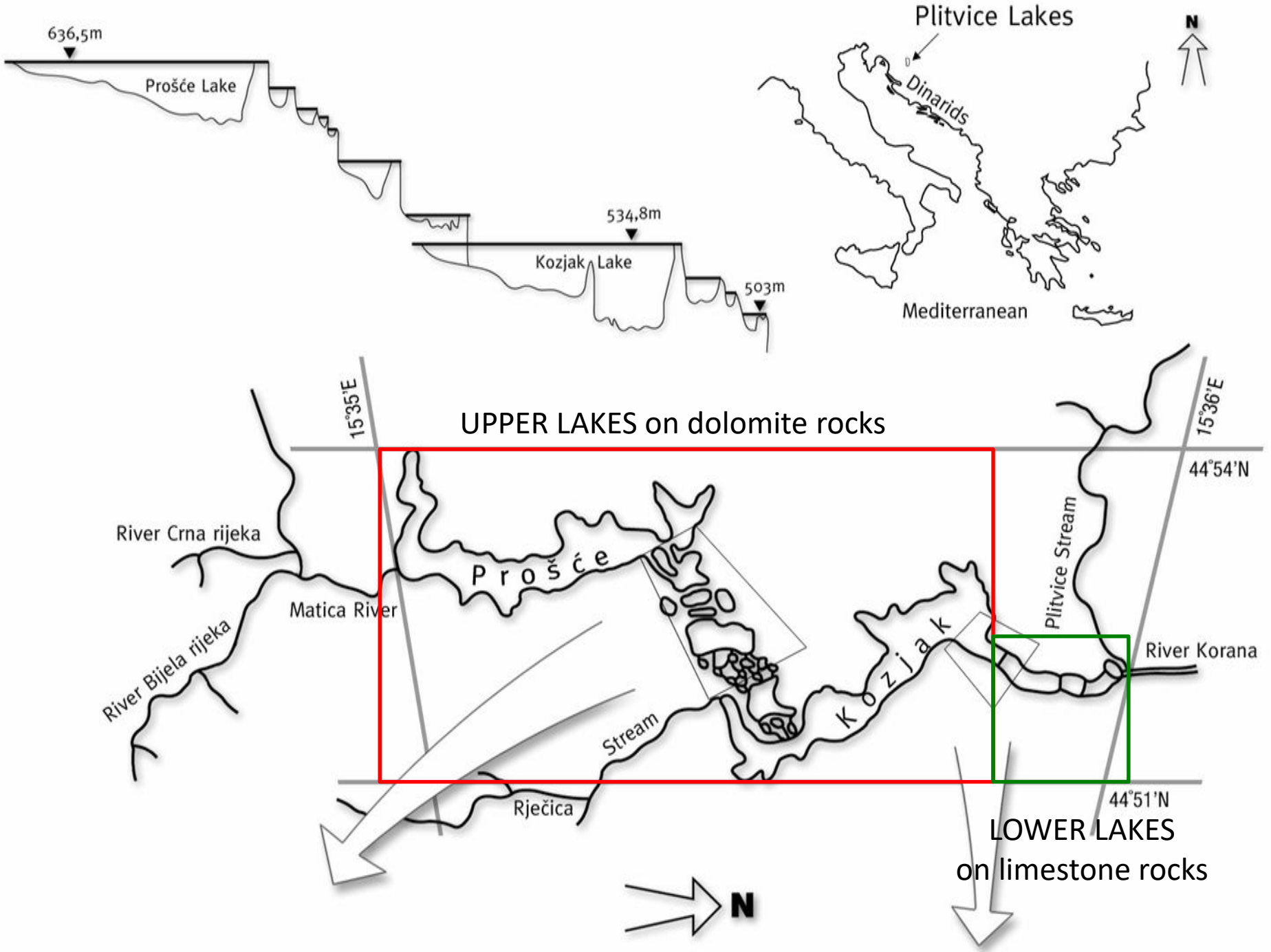
- pH > 8
- Temperature > 14 °C
- Conductivity ~ 400 µS cm^{-1}
- Alkalinity, Hardsness > 200 mg $CaCO_3$ L^{-1}
- Dissolved inorganic carbon 3-8 mmol L^{-1}



	Conductivity (µS cm^{-1})	pH
Granite	35	6.6
Gneiss	35	6.6
Volcanic Rock	50	7.2
Sandstone	60	6.8
Shale	ND	ND
Carbonate Rock	400	7.9

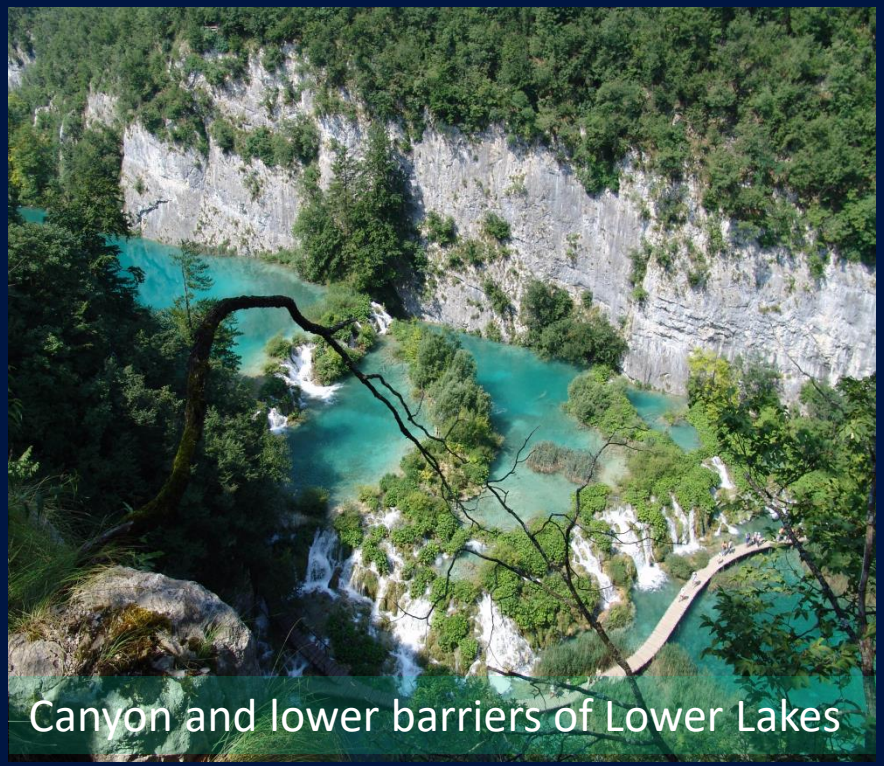


PLITVICE LAKES National Park
since 8th April, 1949
since 1979 UNESCO World Heritage Site


636,5m
Prošće Lake
534,8m
Kozjak Lake
503m
Plitvice Lakes
N
Dinarids
Mediterranean
UPPER LAKES on dolomite rocks
15°35'E
15°36'E
44°54'N
44°51'N
River Crna rijeka
Matica River
River Bijela rijeka
Prošće
Plitvice Stream
River Korana
Kozjak
Stream
Rječica
LOWER LAKES
on limestone rocks
N

MAIN PLITVICE LAKES		Area (ha)	Depth (m)	Elevation (m a.s.l.)
UPPER LAKES				
1	**Prošće**	**68,2**	**37,4**	**636,6**
2	Ciginovac	7,5	11,1	625,6
3	Okrugljak	4,1	15,3	613,6
4	Batinovac	1,5	5,5	610,1
5	Veliko jezero	2,0	8,1	607,5
6	Malo jezero	2,0	9,0	605,6
7	Vir	0,6	5,0	598,7
8	Galovac	12,5	24,4	584,6
9	Milino jezero	-	-	-
10	Gradinsko jezero	8,1	10,0	553,0
11	Veliki burget	-	-	-
12	**Kozjak**	**82,0**	**46,4**	**535,0**
LOWER LAKES				
13	Milanovac	3,2	18,4	523,3
14	Gavanovac	0,7	10,0	519,0
15	Kaluđerovac	2,1	13,4	505,2
16	Novakovića Brod	0,4	4,5	503,0

Higher barriers of Upper Lakes



Canyon and lower barriers of Lower Lakes

- The phenomenon of karst hydrography: 16 cascade lakes divided by tufa barriers originated in a biodynamic process
- Solution lakes, formed during the postglacial period ~15000 years ago

Biogenic tufa deposition:

briophytes + epiphyton: cyanobacteria & diatoms & mucopolysaccharides + calcite

Cyanobacteria

Phormidium crustatum

Cratoneurum commutatum
Bryum ventricosum
Didymodon tophaceus.

Diatomeae

Bryophytes

Epiphyton

⇨ Tufa

Biogenic tufa deposition: *in situ* experiment

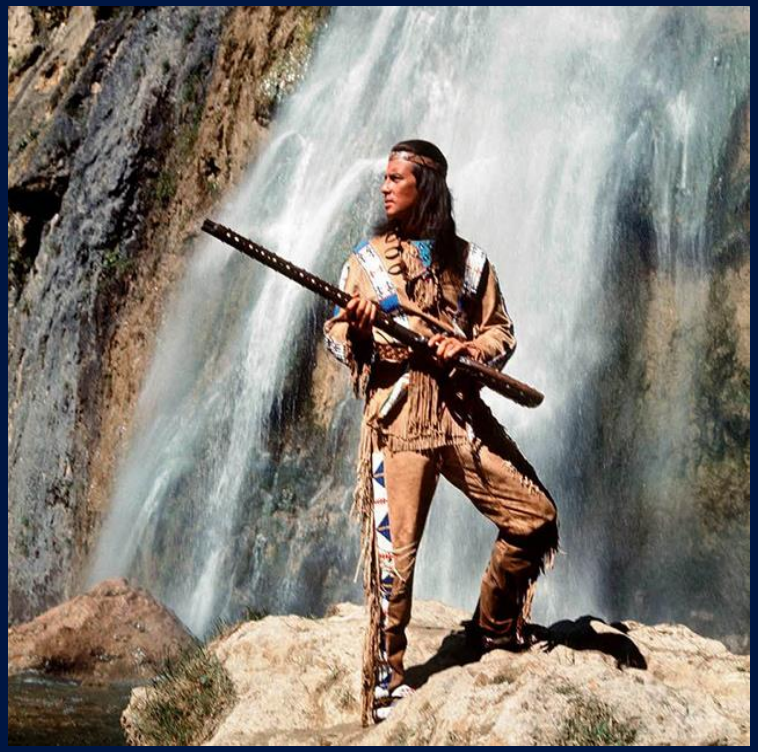
Organic supstrate

Tufa deposition

Inorganic supstrate

No tufa deposition

Fun fact



- Ten films about Winnetou, the Indian chief in the novels of the German writer Karl May, were shot from 1962 to 1968, in the karst region of Croatia, particularly on Plitvice Lakes

Local delights

Plitvice strudel

Basa – cheese & cream


Waterfall
Veliki slap 76 m high
Last waterfalls
Sastavci