

# Early medieveal bog iron ore smelting process: a case study of Virje - Volarski Breg (NW Croatia)

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# Introduction

The Virje-Volarski breg site is located in the Podravina region of the Drava River valley (NW Croatia). Extensive field surveys were conducted and a total of 70 positions with smelting slags and 88 position with smiting slags were discovered, indicating different, interrelated metallurgical activities have been present in this region. Several sites with surface finds of smelting debris have been excavated, and these have shown that iron ore processing has been present in this region in 5th century (Virje-Sušine), 7th century (Hlebine-Velike Hlebine) and 8/9th century (Virje-Volarski breg and Sušine). At the Virje-Volarski breg remains of four bloomery furnaces had an *in situ* residue of iron slag formed during the smelting process. According to the archaeological records, these furnaces were interpreted as free – standing shaft furnaces with tapped slag.

# Objectives

- Correlation between the iron ore and slags
- Source of the used ore exploitation area work

# Samples

- Samples of bog iron ore archaeological context and geological survey
- Different types of iron smelting slag (tap slag, furnace slag) and furnace bottom slag) originating from the same archaeological context - Furnaces 1–5



# Methods

• Mineralogical composition of ores and slags – XRD

shop location

Variations in the slag composition - consisteny or change? - smelting recipe

2.5

• Geochemical analyses – major oxides and rare earth elements (REE) of ores and slags - ICP-MS

# Results

### Resources at hand - local bog iron ore

- Local bog iron ore mainly composed of Fe oxyhydroxide goethite and quartz, was found on all excavated sites
- The results of the comparison (REE correlation) indicate certain differences in elements that can be interpreted as influence of different micro environments in which the ore was formed – similar area of exploitation, different micro-location
- These differences are seen between contemporary sites exploita tion areas as prerequisite for workshop location selection, organised territory of exploitation?

Field ID	Site	Period	Sample type	Qtz	Gt	Lpc	Hem	Mag	Wue	Fay	Other minerals
SJ 107 N 113		ti 8/9th century	iron ore	+++	+++	-	-	-	-	-	P1?
SJ 111 N 122	Virje - Volarski breg		iron ore	+++	+++	-	-	-	-	-	Pl
SJ 111 N 130			iron ore	+++	+++	-	-	-	-	-	Pl
SJ 314 N 295/51	Virje - Sušine	8/9th century	iron ore	+	+++	-	-	-	-	-	Pl
NP-MB 16	Novigrad Podravski - Milakov Berek	recent	iron ore	++	++	-	-	-	-	-	Cal
NP-MB 17			iron ore	++	++	-	-	-	-	-	Msc, Prl
NP-MB 18			iron ore	+	+++	-	-	-	-	-	-





#### Ore to slag

• REE comparison of ore and slags – same

pider plot - Upper Continental Crust (Taylor and McLennan, 1995)								
	Iron ore SJ 107 N 113							
	Smelting slags							





- general trend samples of exploited ore
- Main oxide ratio low Fe<sub>2</sub>O<sub>3</sub> and high • MnO percentages – discarded ore?
- Archaeological features roasting hearth? - preparation of the ore

#### The last smelt with the single recipe?

- Similar main oxides contribution of fuel ash, furnace lining, ore, furnace temperature, fuel to ore ratio and air blowing rhythm to the slags was relatively consistent in all furnaces - single smelting recipe in all furnaces at the same location
- Different levels of oxides in different types of slag correlation to the stages of slag forming within the furnace (oxidising event (tap slag), unreduced ore? (furnace slag)) and post reduction







Pleiner, 2000; page 258, fig. 67)

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