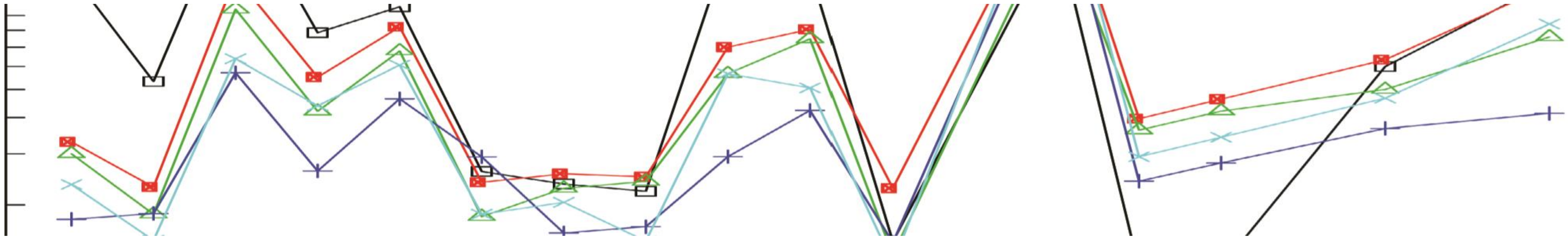
THE LAST SMELT WITH THE SINGLE RECIPE:

geochemical characterization of the bloomery iron production process at Virje - Volarski breg site



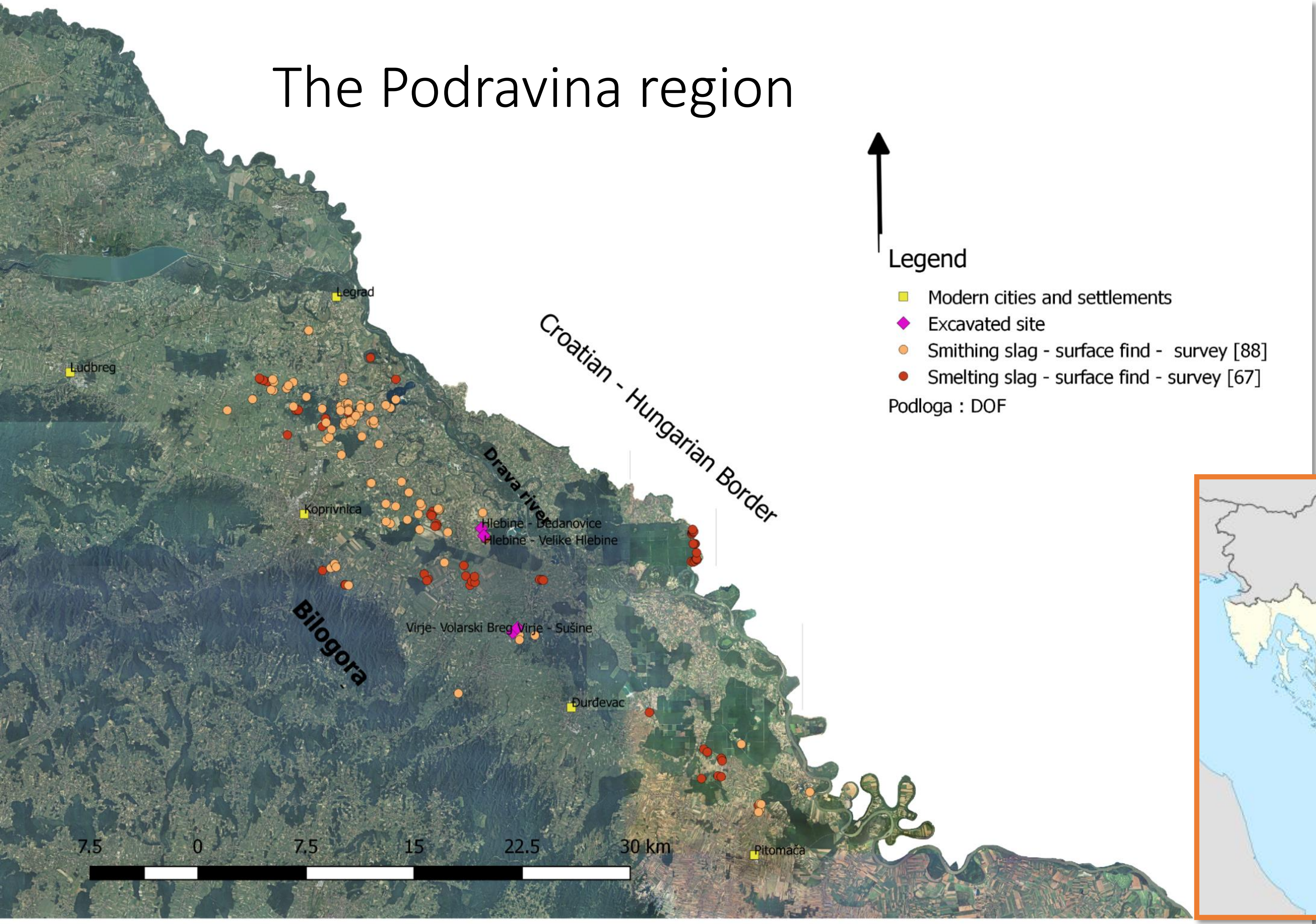
Tena Karavidović, Tajana Sekelj Ivančan, Tomislav Brenko

METARH – 7th scientific conference Methodology and Archaeometry, December 2nd and 3rd 2019, Zagreb

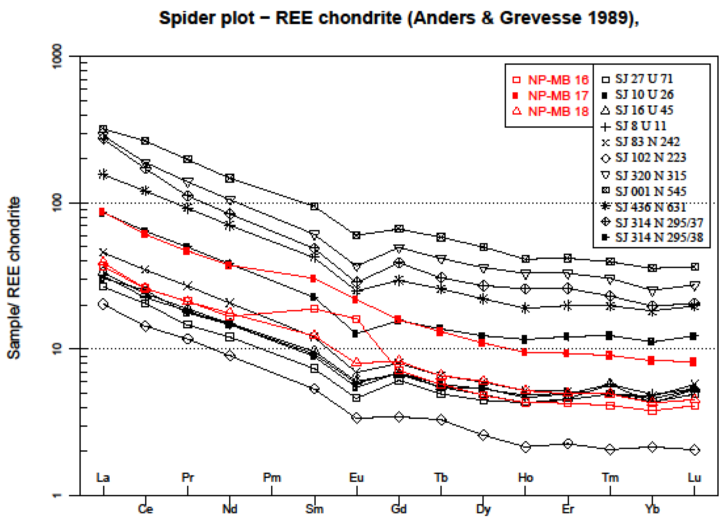
TransFER

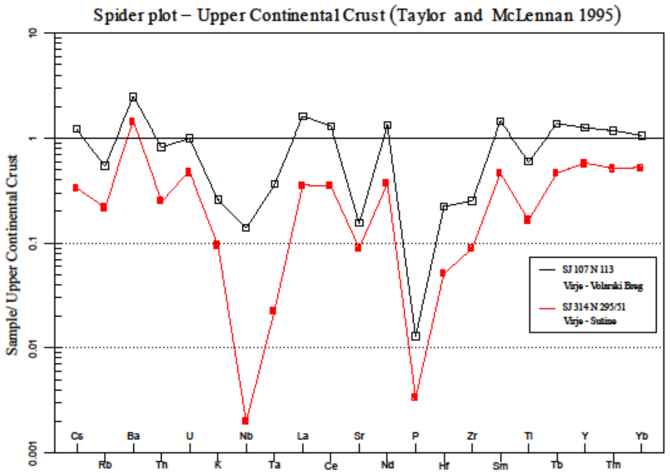
Hrzz
Hrvatska zaklada za znanost

The Podravina region

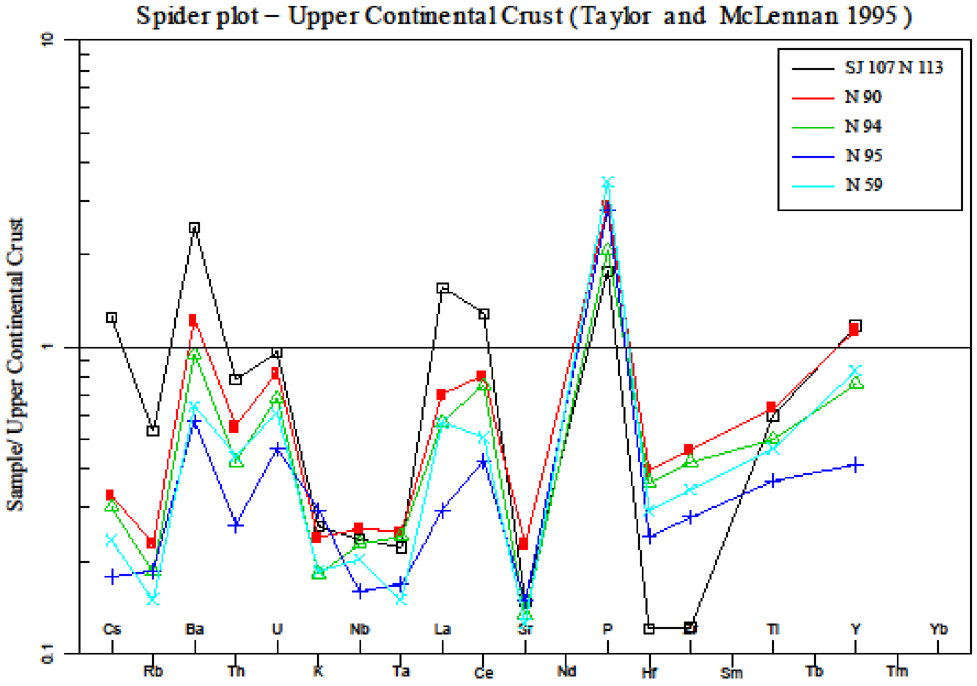


LOCAL BOG IRON ORE – RESOURCES AT HAND





- REE comparison – same general trend - minor differences in elements – different microlocation enviroment for formation / chronological and/or spatial framework
- Corellation with exsisting local ores – local origin

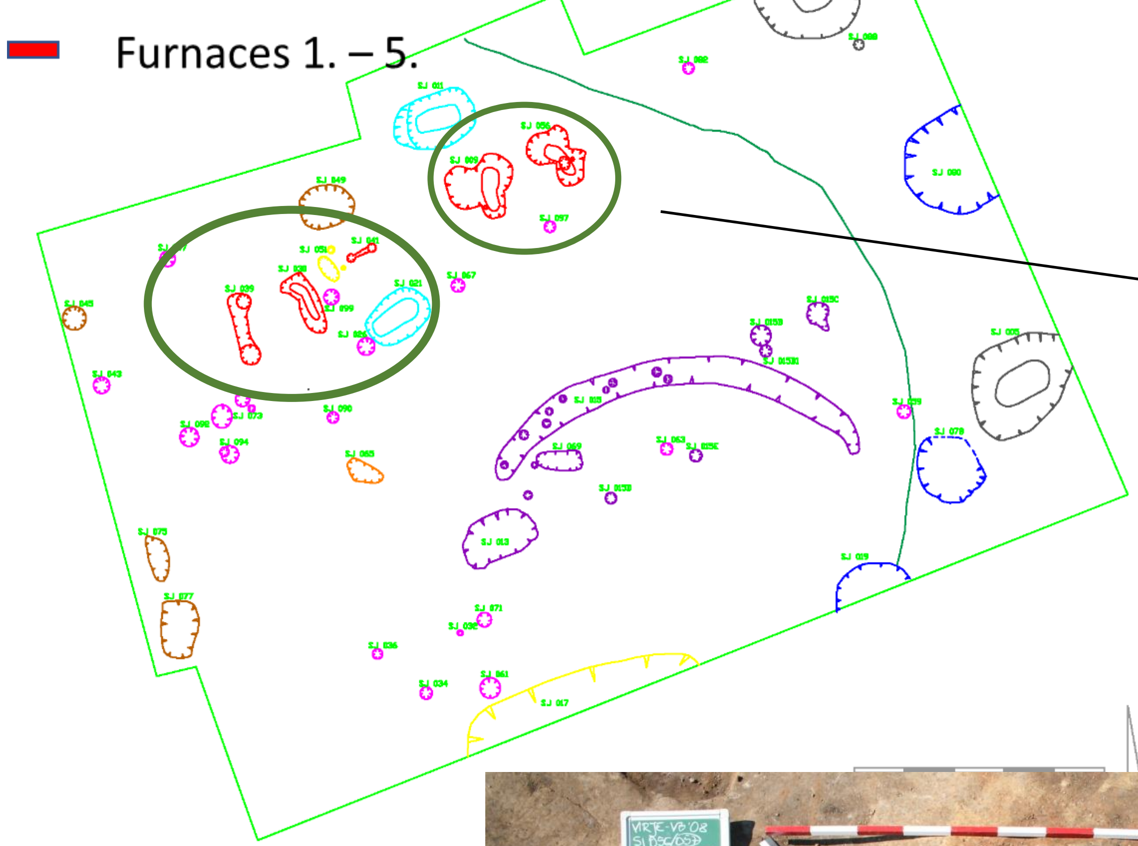


ORE TO SLAG

REE comparison – same general trend – samples of exploited ore

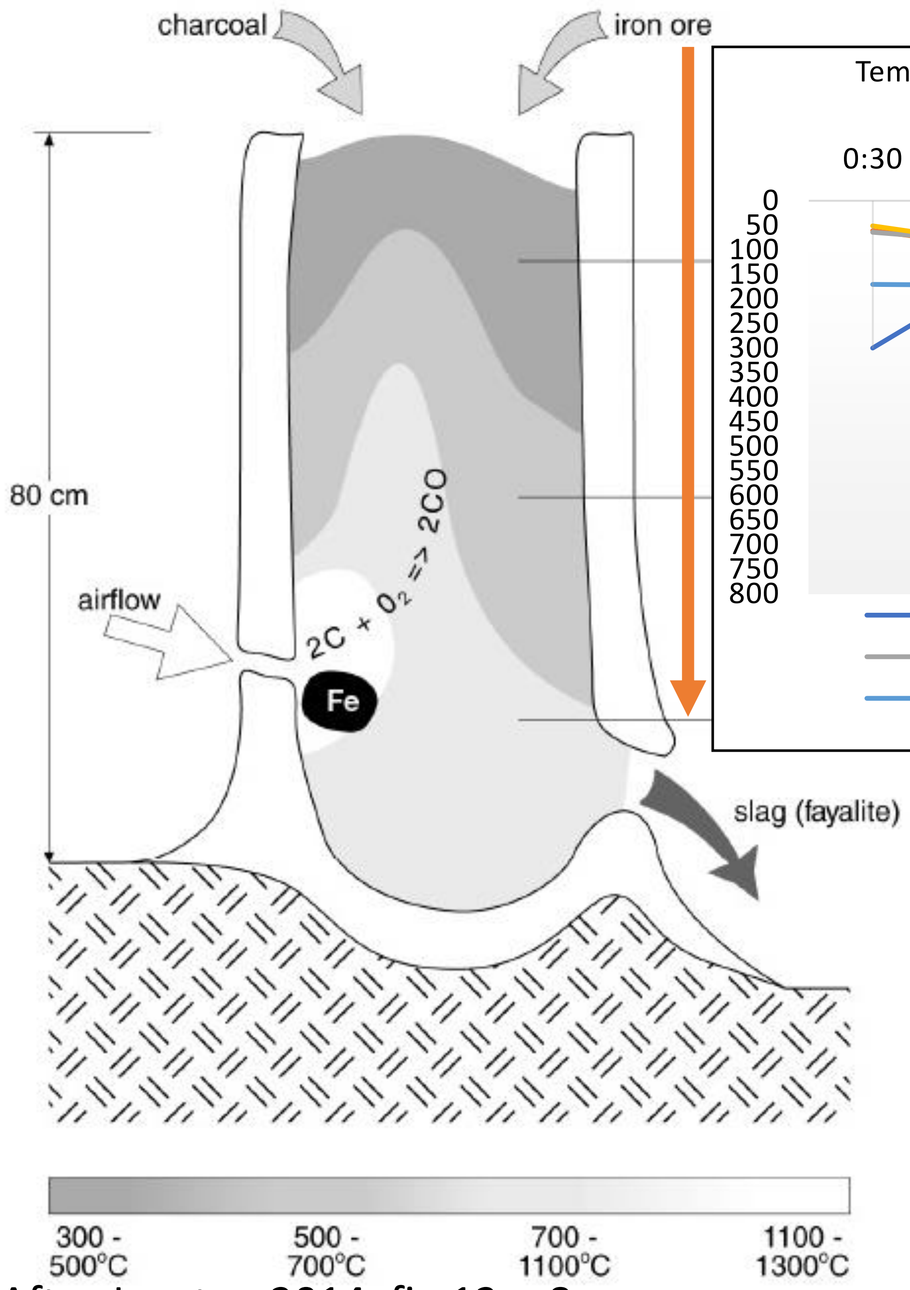
Virje - Volarski breg , bog iron ore, SJ 107, N-113

The last smelt: Virje – Volarski breg site

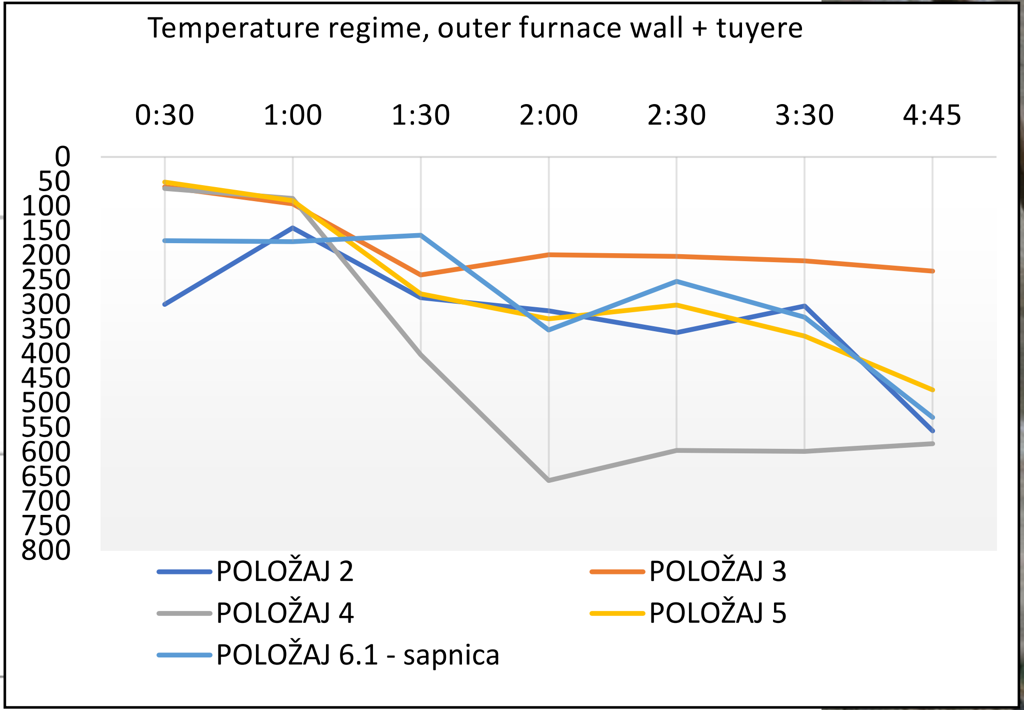


Remains of furnaces with in situ smelting slag

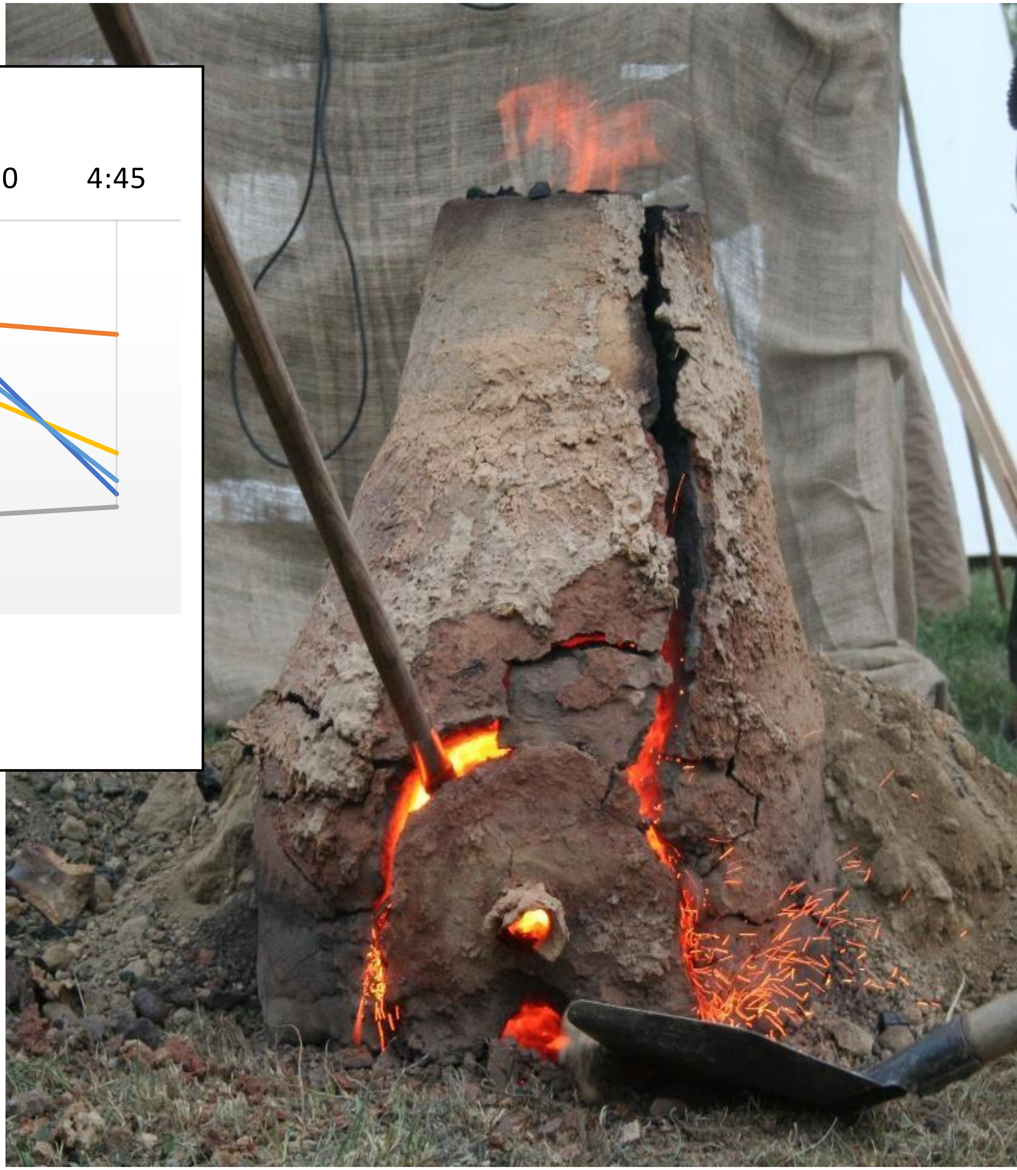
Excavation Virje Volarski breg site, 2008.



After Joosten 2014, fig.12,p.8



Results of experimental smelting temperature measurments, Somogyfajsz 2019.



Experimental iron ore smelting in a free standing furnace, Koprivnica 2019.

primary smithing

Experimental primary smithing, Adamov, 2019 (Workshop starého železářství)

SAMPLES

Smelting slag

Furnace bottom slag

Tap slag

Furnace slag

Post – reduction slag

plano convex cake

SLAG CHEMISTRY

parent material :

- ore
- fuel ash
- furnace lining

- reducing conditions

Most of the main elements – multiple sources – sampling methods – discrimination

Experimental iron smelting, Koprivnica 2019.

Operating parametres – extensive influence on smelting proces : experimental testing

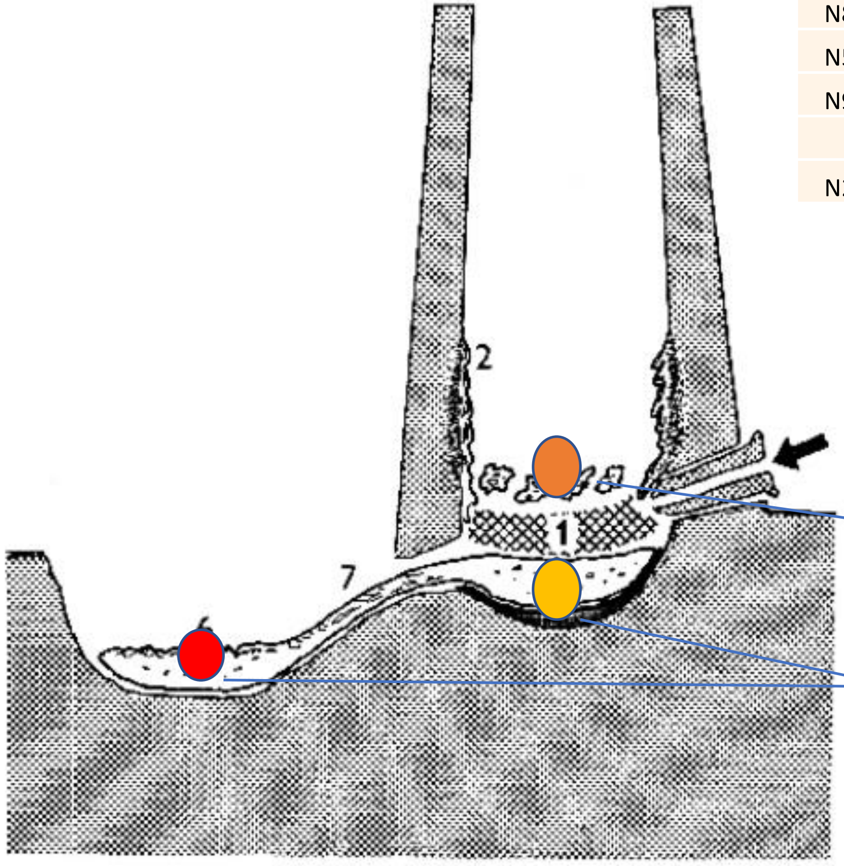
- Furnace design - depth and hight of the tuyere
- shaft shape,
- height of the furnace and width of the opening

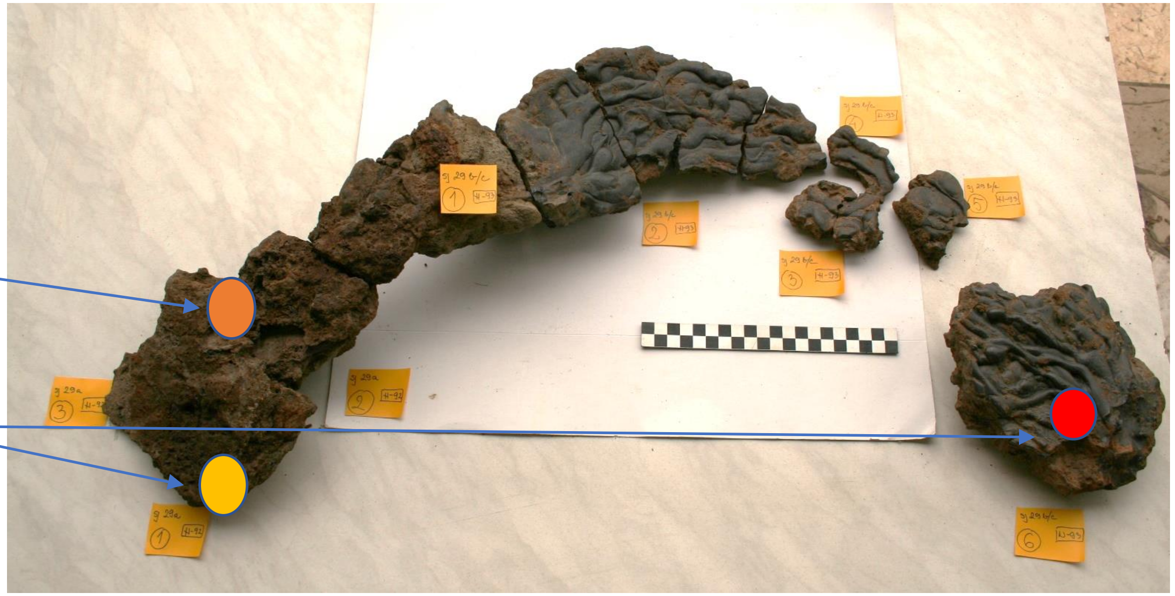
- Preparation of the ore,
- size of the ore grains
- ore to fuel ratio
- the amount of air blown into the furnace/time frame, consistency of air input blowing rhythm
- temperature achieved

HIGH LEVEL OF KNOW – HOW

Furnace 1 – 5.

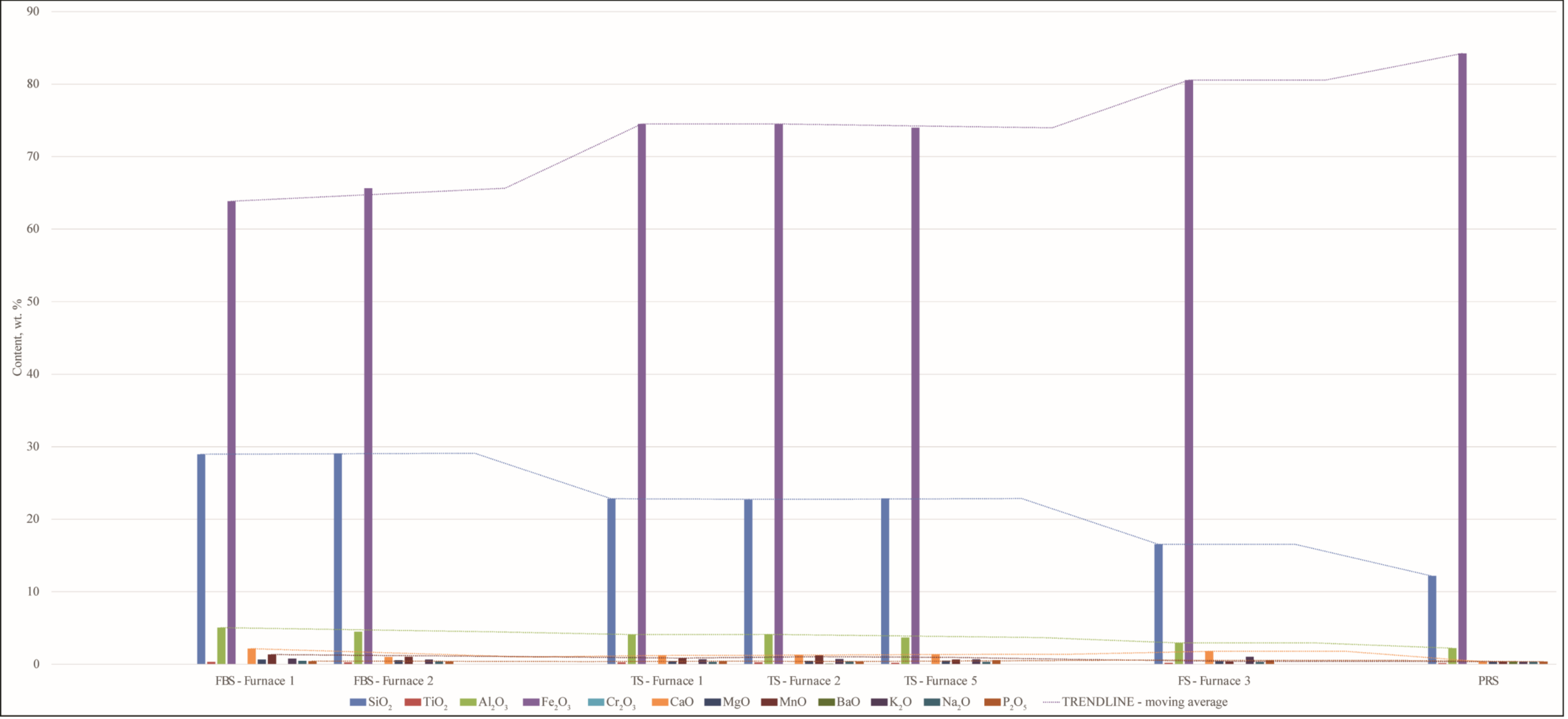
	SAMPLE type/context	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	Cr_2O_3	CaO	MgO	MnO	BaO	K_2O	Na_2O	P_2O_5
N90	FBS - Furnace 1	28.96	0.32	5.05	63.85	<0.01	2.15	0.65	1.34	0.07	0.77	0.46	0.45
N94	FBS - Furnace 2	29.1	0.25	4.47	65.64	<0.01	1.01	0.59	1.03	0.06	0.65	0.4	0.38
N67	TS - Furnace 1	22.82	0.25	4.1	74.52	<0.01	1.22	0.44	0.86	0.06	0.69	0.34	0.43
N93	TS - Furnace 2	22.7	0.25	4.13	74.49	<0.01	1.3	0.47	1.24	0.09	0.72	0.4	0.37
N83	TS - Furnace 5	22.85	0.21	3.68	73.97	<0.01	1.39	0.51	0.64	0.04	0.66	0.32	0.58
N59													
N95	FS - Furnace 3	16.54	0.18	2.94	80.56	<0.01	1.79	0.43	0.41	0.04	1.03	0.29	0.53
N22	PRS	12.16	0.16	2.22	84.23	<0.01	0.35	0.35	0.35	0.35	0.35	0.35	0.35





Results : ICP – MS (Met-Solve Analytical Services, Langley 2016)

Flat – hearth tapped furnace
(after: Pleiner 2000: 258,fig.67)



Levels and moving average of the main oxides in slag composition

Mesurable ratios

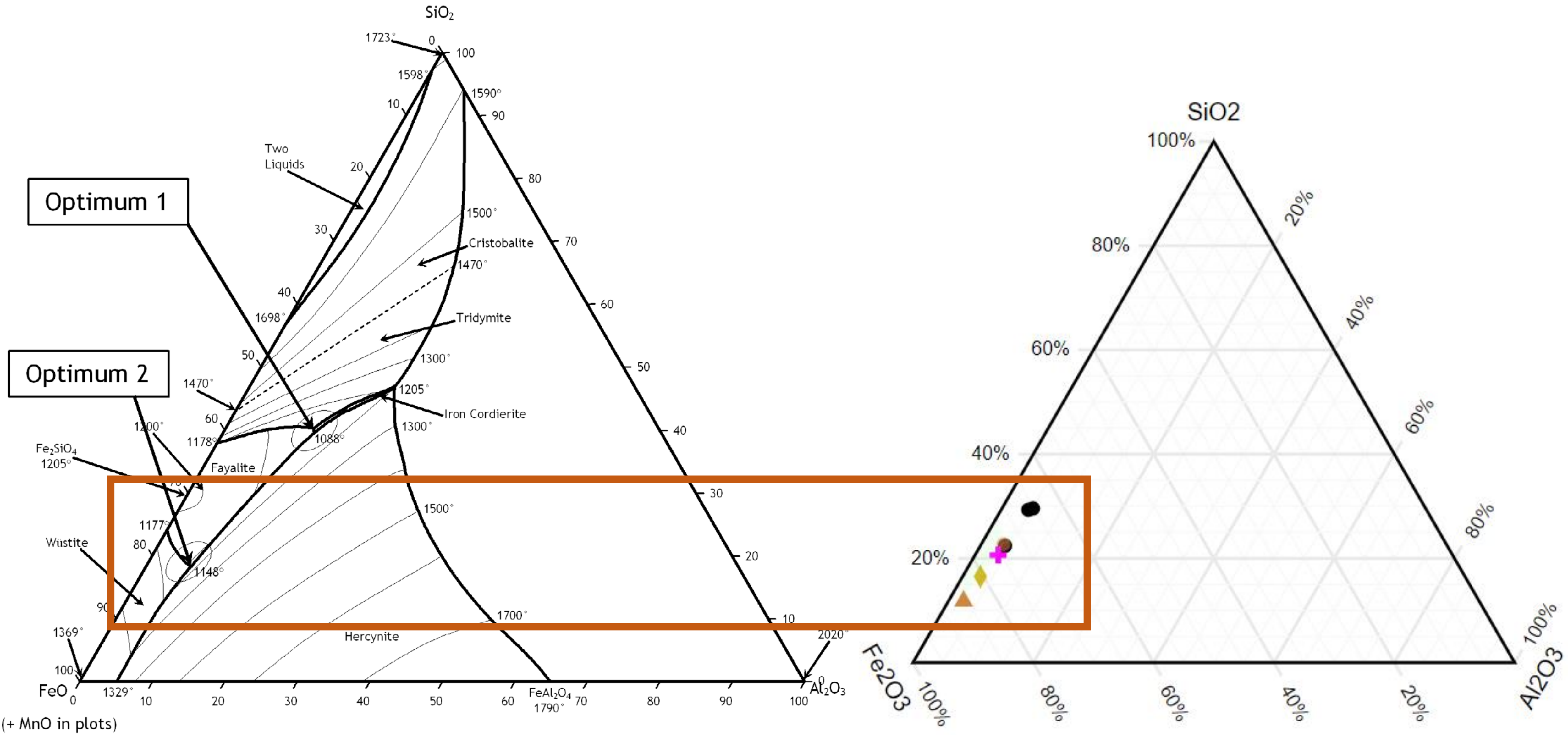
comparative study of technological solution and and smelting recipes/working parameters intra – site and on other sites from the same geological region which used similar resources (ore, fuel, furnace clay)

Same levels of main oxide and trace element ratio in same type of slags from different furnaces

same operating parameters in all furnaces and similar resources

Different levels of main oxides in different types of slag

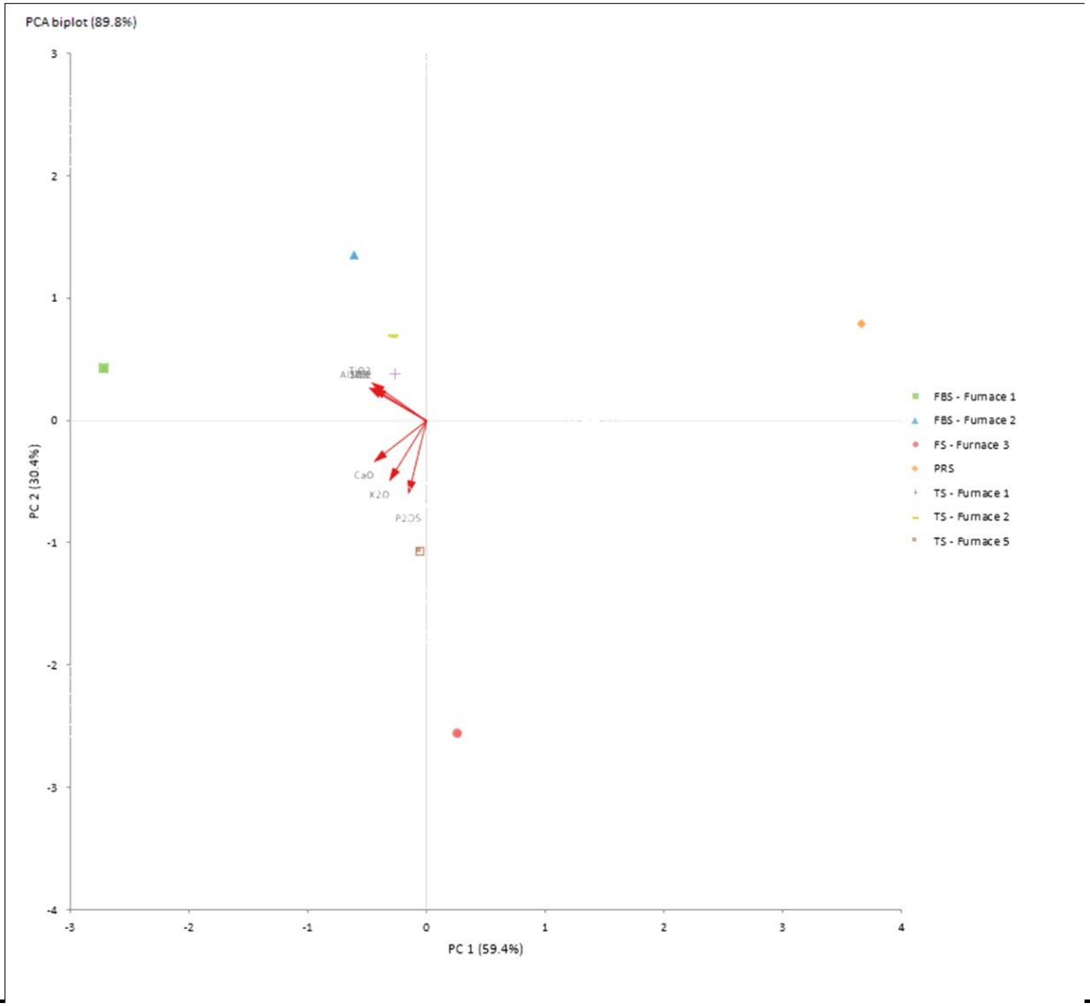
Stages of production= stages of slag forming within the furnace and post reduction



Ternary diagram presenting liquidus temperatures for the system FeO-SiO2-Al2O3
Rehren et.al. 2007

63 – 80 wt% Fe2o3,
20 – 29 wt% SiO2
3-5 wt% of Al2O3

1100 – 1250 °C

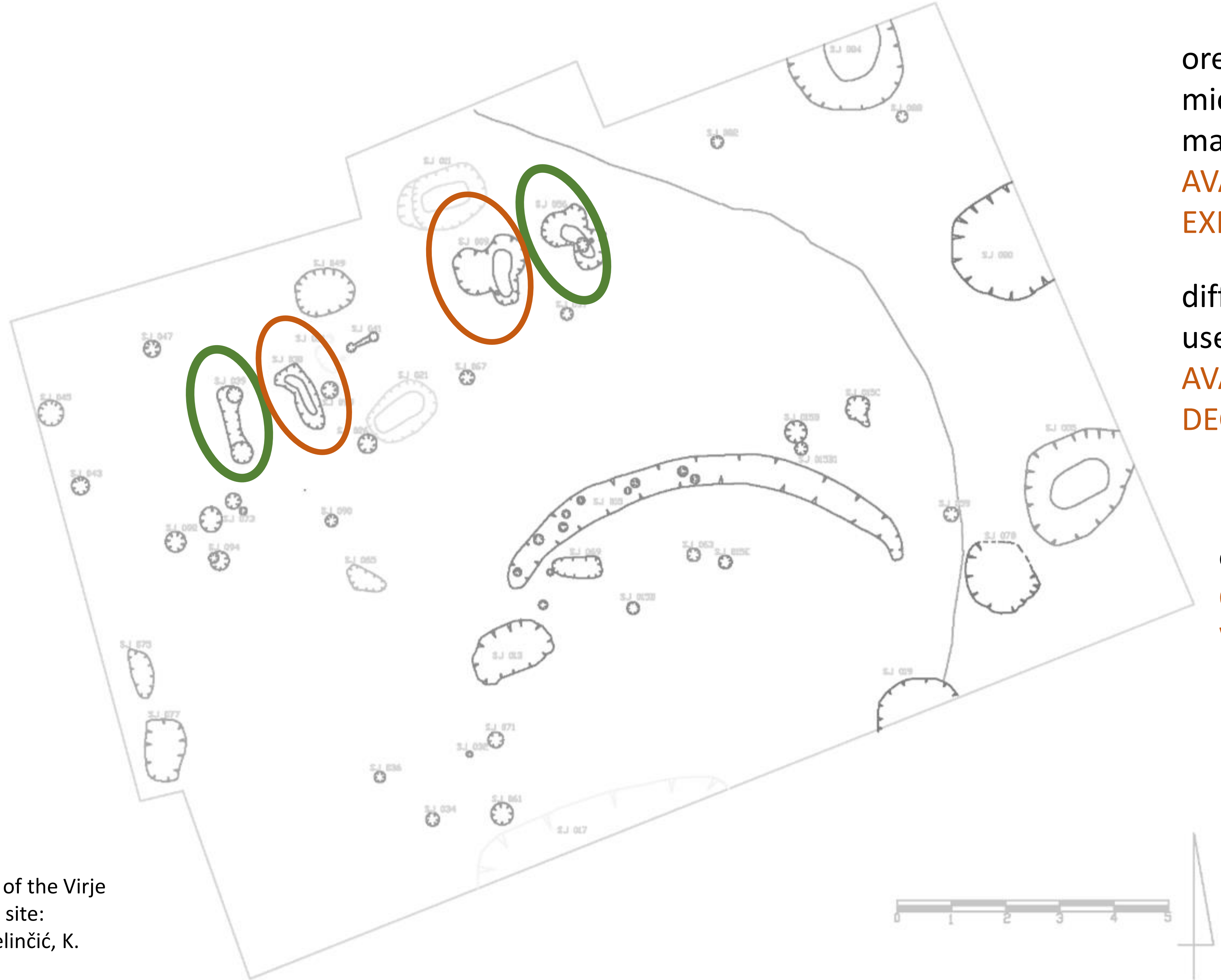


Positive correlation – furnace 1 and 2
Furnace 3 and 5

Negative correlation
Furnace 1/2 to 3/5

	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	FeO	SrO	BaO
ore	☒	☒	☒	☒			☒	☒	☒	☒	☒	☒
clay		☒	☒			☒		☒				☒
fuel ash	☒			☒	☒	☒	☒				☒	

Parent material contribution in slag chemistry (Charlton et.al. 2013)



ores were collected in different micro location (the variation in main components) – AVAILABILITY AND EXPLOATATION STRATEGY

different fuel ash was used occasionally - AVAILABILITY OR DECISION

Indication for the sequence of operations in the workshop – ORGANISATION OF THE WORKFLOW /WORKSHOP

Ground plan of the Virje volarski breg site: drawing K. Jelinčić, K. Turkalj, IARH

The potential of structured sampling methods and chemical analyses of different types of slag as well as combination of multiple group identification methods can have a potential to answer questions such as organization of the workshop, exploitation strategy. Presence of multiple compositional groups in a slag samples derived from multiple phases, sites or regions may indicate the use of different mineral resources and fuels furnace design and operating parameters/smelting recipes, change or consistency over time.

Thank you for your attention!