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DEUTSCHES BERGBAU-MUSEUM BOCHUM

CHARACTERIZATION OF IRON SLAG FROM NDOM (COASTAL CAMEROON, WEST CENTRAL AFRICA)

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Introduction

The presence of ancient metallurgy is attested since the 15th century in the coastal part of Cameroon by the discovery of Iron Age sites such Ngock, Massangui II, Nguimulen, and particularly Ndom (Essomba, 1986; 1992). Ndom is situated in Sanaga Maritime division of the coastal part of Cameroon. Many slag fragments, furnace remains, tuyères and metal objects have been found in Ndom. However, very little attention has been paid to the physico-chemical characterization of the metallurgical artefacts in Cameroon (Essomba, 1986, David et al., 1989). As a pilot study, archaeometallurgical investigations including chemical, mineralogical and petrographic methods have been carried out at the Deutsches Bergbau-Museum Bochum on 21 slag fragments and one iron fragment from Ndom with the aim to understand the smelting technology.

Right: Map of Cameroon showing the localization of Ndom in the coastal part of the country.
Top: Photograph of the excavated furnace in Ndom.

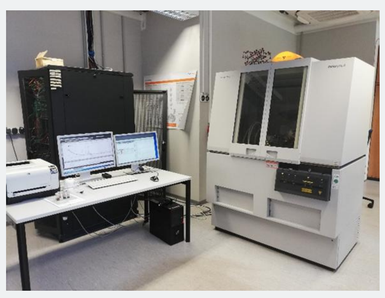
Material and methods

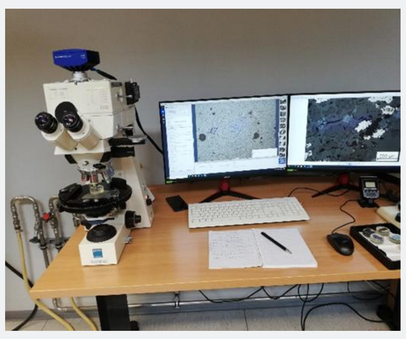
Macroscopically, all samples are dark grey and magnetic except for thereddish iron ore sample. Some samples present an oxidized surface. Their mass varies from 9 to 343 g. All samples have an irregular shape, with their size (length) varying from 2 to 10 cm. According to their structure and morphology, three types of slags have been identified after Bachmann (1982):

- ➢ Furnace slag with remains of furnace lining
- ➢ Tap slag with a flow structure
- ➢ Cake slag, characterized by their degree of porosity.

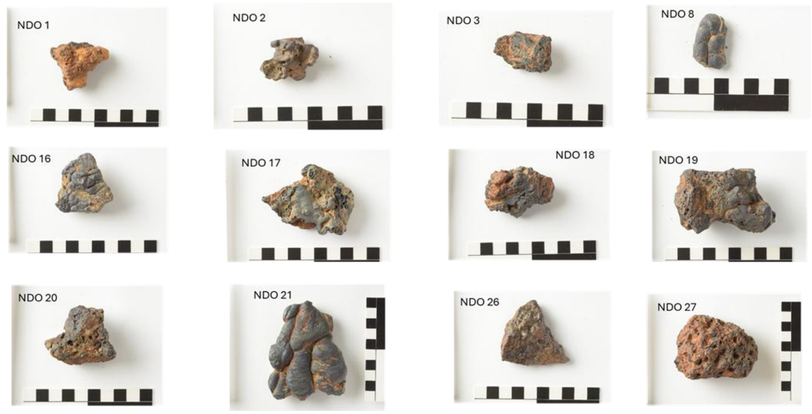
The samples were analysed by:

- ➢ Portable X-ray fluorescence analysis: Thermo Scientific Niton XL3
- ➢ X-ray diffraction: Panalytical X'pert Pro
- ➢ Optical microscopy: Polished and thin sections were observed with an Zeiss Axiophot; photomicrographs were recorded with an Axiocam 521 Color. Etching testings were carried out using Nital (2 ml HNO_3 + 10 ml Ethanol).
- ➢ Scanning electron microscopy with energy dispersive spectroscopy: Zeiss Supra 40VP with Gemini EDS system. Detailed microstructural study of the samples using backscatter electron imaging and chemical analysis of phases.

Photos of the analytical devices used in the study. In clockwise direction: pXRF, XRD, SEM-EDS, Optical microscope.



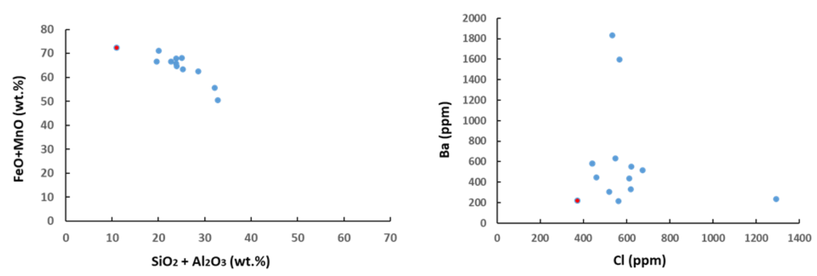
Photos of some samples of slag and ore sample NDO 26.

Portable X-Ray Fluorescence

Slag samples have a content of SiO_2 between 10 to 21 wt.%. Al_2O_3 content varies from 9 to 13 wt.% and FeO content varies from 50 to 71 wt.%. The content of alkali oxides is very low in all the samples (<5 wt.%). Concerning the trace elements, the Cl content varies from 250 to 680 ppm except for one sample with 1300 ppm. The Ba content is ranging from 200 to 650 ppm except for two samples with more than 1500 ppm. Copper content in most samples varies from 100 to 200 ppm with two samples having 300 ppm Cu and three samples with less than 100 ppm Cu.

The iron ore sample has a SiO_2 content of 4 wt.%, an Al_2O_3 content of 7 wt.% and a FeO content of 72 wt.%.

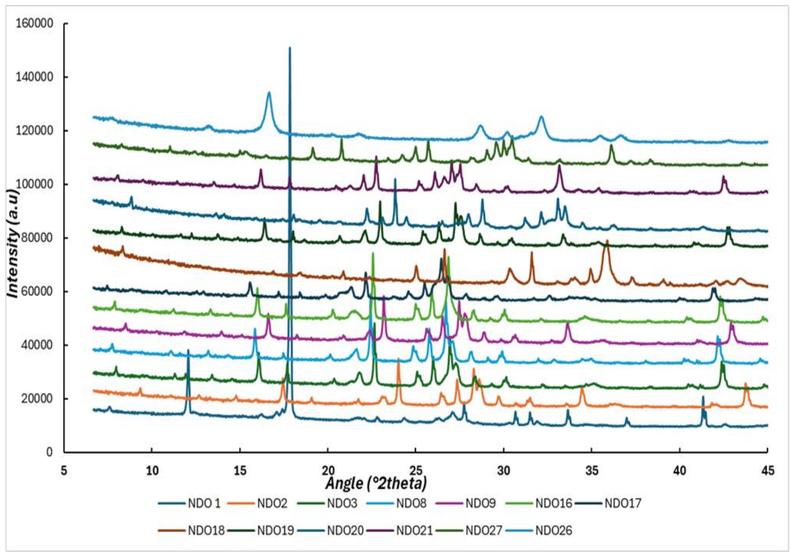
The correlation binary diagrams SiO_2+Al_2O_3/FeO+MnO and Cl/Ba show a homogeneous group of slags in a good correspondence with the iron ore sample collected in the locality.



Chemical binary correlation diagrams (left) SiO_2+Al_2O_3/FeO+MnO and (right) Cl/Ba of the samples. The red point represents the iron ore sample NDO26.

X-Ray Diffraction

The ore sample shows mullite as main phase, associated with goethite. All slag samples contain quartz, fayalite, and hercynite. In addition, wüstite, cristobalite, leucite, and magnetite are present in some samples. In addition, the presence of mullite in NDO 1 confirms the presence of furnace wall in this sample.



X-ray diffractograms of the samples with indicated main peak positions.

References

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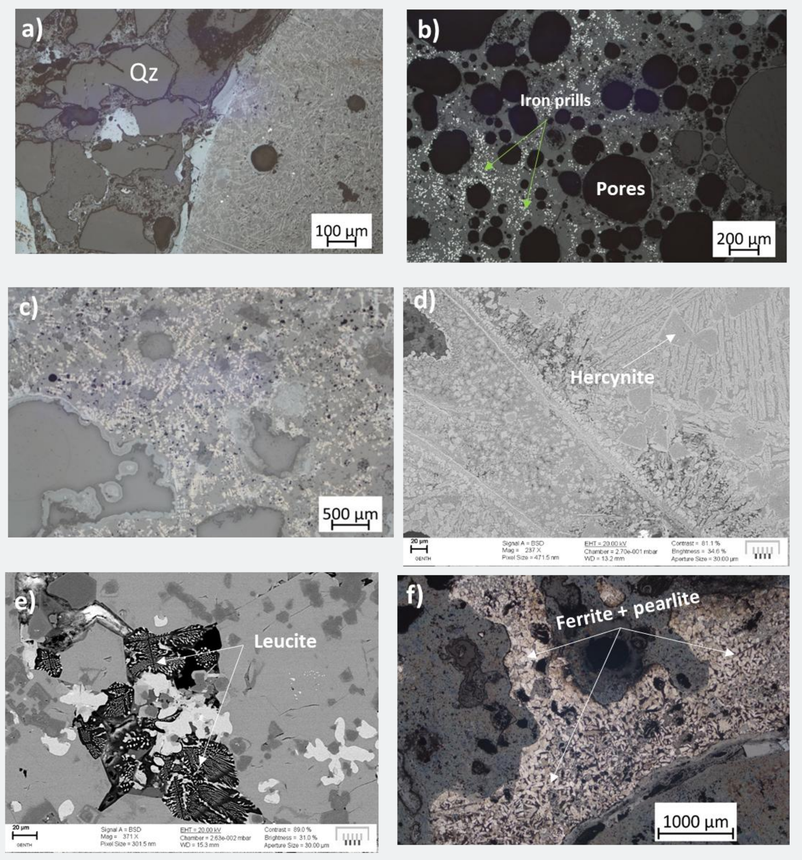
Optical Microscopy and Scanning Electron Microscopy

The mineralogical compositions identified by optical microscope and SEM on polished sections confirm the results of the X-ray diffraction analysis: quartz, wustite, fayalite, and hercynite are present in all samples, whereas leucite, magnetite, and cristobalite are only present in some samples and mullite only in NDO 1 and the ore fragment NDO 26.

The presence of mullite and cristobalite indicates a furnace temperature above 1000°C. Slag microstructures of some samples contain many magnetite crystals and pores. Etching of some sections shows the presence of ferrite with low amount of pearlite, indicating a steel with a low amount of carbon (Serneels 1993).



Microstructures of the slag samples:
Optical microscopy: a) furnace slag microstructure showing a quartz-rich ceramic on the left and slag on the right consisting of finely crystallized wustite, fayalite, and pores; b) porous slag with iron prills (white points); c) slag showing melting of some grains; Backscatter electron image: samples showing crystals of d) hercynite and e) leucite; Optical microscopy of etched sections: f) ferrite with a low amount of pearlite.

Conclusion

The macroscopic, chemical, and mineralogical characterization of the slag samples from Ndom indicates that these samples are constituted of cake, furnace and tap slag. The chemical analysis shows a widely homogeneous groups of slags in agreement with an iron ore sample as a part of lateritic soils, suggesting that they were probably produced with raw materials collected in the same area. The mineralogical analysis shows in all samples the presence of quartz, fayalite, wustite, and hercynite, suggesting that the same technology was employed for their production. The presence of pores and prills of iron in the microstructure of some samples indicate a smelting temperature higher than 1100 °C, which is in agreement with the observed phases mullite and cristobalite. The results of etching tests of some samples suggest a presence of steel with a low amount of carbon.

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