



# Compositional and microstructural characterization of Celtic silver coins from northern Italy using neutron diffraction analysis<sup>☆</sup>

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## ABSTRACT

The silver coinage of Celtic tribes settled in northern Italy (IV–I century B.C.) is a topic characterized by several issues, such as chronology, attributions and relationships between emissions produced in different periods. In order to provide numismatists with new data, several specimens, belonging to different typologies, have been analysed with neutron diffraction technique to overcome surface alteration and to provide bulky compositional and structural information of the coins. Measurements performed with the INES diffractometer at the ISIS facility provided essential data for numismatics research. A clear silver debasement occurring between the first and latter emissions has been traced, due to inflation processes which can be related with the increasing power of Roman Republic in the Cisalpine region. Moreover, compositional data enabled for the first time to identify internal evolutions inside typologies defined by numismatists. The silver loss has also been used to establish a relative chronology between different emissions. Other parameters such as texture index, residual strains and grain dimensions have been useful to understand technical aspects of minting procedures during Iron Age.

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## 1. Introduction

The importance of physico-chemical material characterization in studies on the Celtic silver coinage from northern Italy has been rarely considered. Unlike Greek and Roman coins, which have been analysed with several approaches to answer different historical issues, Celtic coins from this area still lack reliable scientific data. Indeed, the few published compositional information [1] have been carried out on untreated coins with X-ray fluorescence (XRF) technique. However, silver–copper alloy coins, especially those with a fineness < 80 wt.% of silver, have actually been demonstrated to be heavily affected by thick silver-surface-enriched layers (up to 200 μm), so data obtained on unsectioned samples by means of surface techniques, including XRF or PIXE, are not reliable [2–4].

For this reason, a wide characterization project involving the use of neutron-based techniques has been developed. The first compositional results were obtained with Prompt Gamma Activation Analysis (PGAA) and have been recently published [5]. To increase the statistical sample and to investigate also microstructural properties, a bulk and non-destructive technique such as neutron diffraction (ND) has been used in this work for the characterization of a further selection of Celtic coins. Time-of-flight neutron diffraction (TOF-ND) measurements have

been performed with the INES diffractometer at the ISIS facility on our specimens.

TOF-ND technique is a powerful tool for the analysis of metal, especially in archaeometric studies as precious archaeological artefacts can be analysed in air without any sampling or preparation [6,7]. This technique has been often applied for coin characterization in the last years [8–14], and results were very promising for numismatics studies. TOF-ND analysis is able to provide both compositional and structural information. In particular, the possibility to extract information from diffraction patterns concerning texture index, residual strain and grain dimension, has been considered very useful.

This study had therefore a twofold aim. The first was to provide ratios of precious and base metal (silver and copper respectively), to verify whether a debasement was present among coins dated to different periods and to understand their exchange ratios with foreign currency (e.g. Roman and Massalian currency). The second was to bring new data for the understanding of minting procedures during Iron Age, being documentary evidence absent.

## 2. Historical background

The pre-Roman coinage from northern Italy, commonly defined as “Celtic coinage of the Po valley”, collects different series of silver coins, produced by several tribes settled in a wide territory known in the subsequent Roman age as the Cisalpine Gaul. These tribes, either of

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