



First results on radiometric dating of metals by alpha spectrometry☆

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ABSTRACT

A new TSAC (Thin-Source Alpha Particle-Counting spectrometry) setup of high geometrical efficiency and low intrinsic background was built to measure the alpha particles coming from the ²³⁸U and ²³²Th decay chain radionuclides with concentration as down to five ppm level. It was designed to test the ²²⁶Ra/²³⁸U method, which is the only direct metal dating method proposed to date. Micro-PDCL, micro-RBS and SEM-EDS were used as complementary analytical techniques in order to search for heterogeneities and/or impurities that could bias the TSAC data. Ores, resulting slags and metallic profile from two recent smelting experiments that reproduced ancient techniques and two ancient ores were studied to determine how radionuclides fractionation occurs during smelting. With this TSAC setup the background signal was extremely low, but comparable to the signal from the measured metals. Preliminary results show no evidence of a preferential depletion of ²²⁶Ra in archaeological with respect to the other radionuclides.

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1. Introduction

Archaeo-metallurgical research focuses in the reconstruction of early trade routes in terms of location of metal sources (ore deposits) and in the study of metallic artifacts and metallurgical remains through various analytical and examination techniques. Important information can be derived from these studies, like ore provenance, contact between different ancient societies and their technological development.

It's not an overstatement to say that the Holy Grail of archaeo-metallurgists is to achieve a method that can directly give the date of the manufacture of a metallic artifact.

Until now, the dating of metallurgical processes is made indirectly, under favorable conditions, by [1]: a) thermoluminescence (TL) and optical stimulated luminescence (OSL) of burnt soil in kilns and crucibles, or of remaining core material in the metal artifact and slag products [2]; b) radiocarbon (¹⁴C) applied on carbon found in trapped slag inclusions (mainly from artifacts); c) an association with other archaeological artifacts found in the same archaeological context; and d) some aging or degradation specificities that may differentiate an old from a new object (e.g. intergranular corrosion is a slower corrosion process).

In 2005 [1] I. Liritzis proposed a radiometric dating method for metals that are produced from ores (native metals excluded), based on the isotopic fractionation that may occur during ore smelting. This fractionation disrupts the secular equilibrium in the ²³⁸U series. In this sense, ²²⁶Ra, a radionuclide that occurs naturally in the decay chain of ²³⁸U with a half-life of 1602 years, tends to be withdrawn by slag products away of the melted metal, as a result of its low specific gravity, 5–6 g/cm³, and its lower melting point (700 °C) when compared to some metals, as for example copper (8.9 g/cm³; 1083 °C).

As a consequence, in a metal, ²²⁶Ra would appear from the decay of its parent, ²³⁸Th (half-life, $t_{1/2} = 80000$ years). Assuming that initially in the metal ²²⁶Ra is not present, then at time t , the ratio between the activities of ²²⁶Ra and ²³⁸Th is given by Eq. (1) [1]

$$\frac{A_{226Ra}}{A_{238Th}} = \frac{\lambda_{238Th}}{\lambda_{226Ra} - \lambda_{238Th}} \left[1 - e^{-(\lambda_{226Ra} - \lambda_{238Th})t} \right], \quad (1)$$

where λ_{226Ra} and λ_{238Th} are the decay constants ($\lambda = \ln(2)/t_{1/2}$) of ²²⁶Ra and ²³⁸Th, respectively. As $\lambda_{226Ra} \gg \lambda_{238Th}$ ($4.33 \times 10^{-4} \text{ yr}^{-1} \gg 8.66 \times 10^{-6} \text{ yr}^{-1}$) the ratio of activities tend to the value $\lambda_{226Ra} / (\lambda_{226Ra} - \lambda_{238Th}) \approx 1$, and the secular equilibrium is attained after around 5000 years. This period is comparable to the elapsed time since the onset of metallurgy in some areas of the globe. Therefore, this growth of ²²⁶Ra back to secular equilibrium with its parent ²³⁸Th is the basis of this method. This model, known as the ²²⁶Ra/²³⁸Th Liritzis method,

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ML Morrison

A decorative red circular graphic with a gradient, appearing as a partial circle or a thick arc, located to the right of the author's name.

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Radiometric dating by alpha spectrometry on uranium series nuclides Albert van der Wyk,1987 **Radiometric Dating by Alpha Spectrometry on Uranium Series Nuclides** van der Wijk (Albert),1987 **Radiometric Dating by Alpha Spectrometry on Uranium Series Nuclides** Albert van der Wijk,1987 **Energy Research Abstracts** ,1992

Methods in Biogeochemistry of Wetlands Ronald D. DeLaune,K. Remesh Reddy,Curtis J. Richardson,J. Patrick Magonigal,2020-01-22 Wetlands occur at the interface of upland and aquatic ecosystems making them unique environments that are vital to ecosystem health But wetlands are also challenging to assess and understand Wetland researchers have developed specialized analytical methods and sampling techniques that are now assembled for the first time in one volume More than 100 experts provide key methods for sampling quantifying and characterizing wetlands including wetland soils plant communities and processes nutrients greenhouse gas fluxes redox active elements toxins transport processes wetland water budgets and more *Archaeological Chemistry* Mary Virginia Orna,Seth C. Rasmussen,2020-11-24 Highlighting its broad multidisciplinary nature this volume presents new research and applications in the field of archaeological chemistry which focuses on the application of chemical techniques to the study of the material remains of the cultures of historical or prehistorical peoples Consisting of 18 chapters written by a diverse collection of international authors this volume highlights new research in archaeological chemistry and shows how the field combines aspects of analytical chemistry history archaeology and materials science Current efforts to include archaeological chemistry in science education are also presented As this book utilizes current scientific advances to better understand our past it will be of broad general interest to the chemical archaeological and historical communities The Climate of Past Interglacials F. Sirocko,M. Claussen,T. Litt,M.F. Sanchez-Goni,2006-12-08 Historically climate fluctuations such as the Little Ice Age show that interglacial climate change is not entirely stable but responds to even subtle changes in radiative forcing Through research it has been made clear that even an abrupt change of climate within years is not just a theoretical possibility but has in fact happened in the prehistoric past It is therefore clear that in principle it could happen again Human civilization has exploded under the mild and relatively stable climatic conditions that have prevailed over the last 11 000 years This book focuses on revisiting the past and to study climate and environment in a suite of experiments where boundary conditions are similar but not identical to today so we can learn about the climate environment system its sensitivity thresholds and feedback The palaeoclimate community holds an important key to scientific information on climate change that provides a basis for appropriate adaptation and mitigation strategies The authors of this book have taken up this challenge and summarize their results in this special volume It presents state of the art science on new reconstructions from all spheres of the Earth System and on their synthesis on methodological advances and on the current ability of numerical models to simulate low and high frequency changes of climate environment and chemical cycling related to interglacials Summarizes important information

on climate change providing a basis for appropriate adaptation and mitigation strategies for human civilization Reports on new reconstructions on methodological advances numerical models simulating low and high frequency changes and chemical cycling related to interglacials Incorporates palaeovegetation and numerical modeling of climate and environmental and geochemical parameters to address regional feedback to global change with successful data models [Blue Carbon: Beyond the Inventory](#) William Edward News Austin, Hilary Anne Kennedy, Joanne S. Porter, William Richard Turrell, Catherine Lovelock, 2024-02-20 This Research Topic will coincide with an international Blue Carbon Conference at the Royal Society of Edinburgh in November 2021 during the UNFCCC COP26 climate negotiations we seek to showcase Blue Carbon as a Nature based Solution for Climate Change People and Biodiversity The conference theme identifies the growing climate mitigation opportunities presented by Blue Carbon yet also seeks to highlight the emergent research that points to the wider climate mitigation services of carbon in the marine environment what we are calling beyond the inventory We welcome contributions that address the science and policy dimensions of Blue Carbon particularly where these highlight opportunities and mechanisms for the protection restoration and creation of Blue Carbon habitats We also welcome case study examples that highlight successful partnerships in a wide range of international settings and would particularly encourage contributions that show case legal policy or investment opportunities **Handbook of Radioactivity Analysis** Michael F.

L'Annunziata, 2020-03-07 Handbook of Radioactivity Analysis Radiation Physics and Detectors Volume One and Radioanalytical Applications Volume Two Fourth Edition constitute an authoritative reference on the principles practical techniques and procedures for the accurate measurement of radioactivity everything from the very low levels encountered in the environment to higher levels measured in radioisotope research clinical laboratories biological sciences radionuclide standardization nuclear medicine nuclear power and fuel cycle facilities and in the implementation of nuclear forensic analysis and nuclear safeguards It includes sample preparation techniques for all types of matrices found in the environment including soil water air plant matter and animal tissue and surface swipes Users will find the latest advances in the applications of radioactivity analysis across various fields including environmental monitoring radiochemical standardization high resolution beta imaging automated radiochemical separation nuclear forensics and more Spans two volumes Radiation Physics and Detectors and Radioanalytical Applications Includes a new chapter on the analysis of environmental radionuclides Provides the latest advances in the applications of liquid and solid scintillation analysis alpha and gamma spectrometry mass spectrometric analysis Cherenkov counting flow cell radionuclide analysis radionuclide standardization aerosol analysis high resolution beta imaging techniques analytical techniques in nuclear forensics and nuclear safeguards Describes the timesaving techniques of computer controlled automatic separation and activity analysis of radionuclides Provides an extensive table of the radiation characteristics of most radionuclides of interest for the radioanalytical chemist

Energy Research Abstracts , 1988 Includes all works deriving from DOE other related government sponsored

information and foreign nonnuclear information Gamma-Ray Spectrometry of Rocks John A. S. Adams, Paolo Gasparini, 2013-10-22 *Gamma Ray Spectrometry of Rocks Methods in Geochemistry and Geophysics* provides information pertinent to the fundamental aspects of the gamma ray spectrometry of rocks This book discusses the increasing interest in using gamma spectrometry in the search for uranium ore Organized into seven chapters this book begins with an overview of the approximate frequency and wave length of electromagnetic radiations This text then examines the quantitative detection of X and gamma photons which is based upon their interactions with matter Other chapters consider the inorganic scintillation crystals as the most favorable detectors due to its requirement of a high intrinsic efficiency This book discusses as well the shape of the spectrum of a monoenergetic gamma ray beam which is dependent on the photon energy The final chapter deals with the determination of the abundances of natural radioisotopes and their stable end products in a rock or mineral This book is a valuable resource for radiological health physicists chemists geochemists and exploration geologists

Palaeolimnological Proxies as Tools of Environmental Reconstruction in Fresh Water Krisztina Buczkó, János Korponai, Judit Padisák, Scott W. Starratt, 2010-05-30 Palaeolimnology is one of the most rapidly developing fields of limnology The primary objective of this volume is to present new palaeolimnological findings from eastern and central Europe Although this area has sometimes received less attention than other areas of Europe the lakes and mires coupled with the variability in landscape and the local differences in climate provide unique opportunity for studying palaeolimnology The volume starts with a review on late Quaternary records from the Carpathian region followed by new results on the history of a crater lake Lake Saint Ana glacial lakes in the Tatra Mountains and Lake Bled in Slovenia In addition the various papers provide new insights on the development of lakes and bogs during the late glacial and Holocene using a wide range of palaeolimnological proxies including diatoms pollen macrofossils pigments cladoceran remains chironomids chaoborids stable isotopes and geochemistry The motivation for collecting recent knowledge derives from the recognition of the importance and applicability of palaeolimnological tools to help in defining reference conditions as designated within the Water Framework Directives and estimating influence of global climate change on surface waters Bibliography of Mass Spectroscopy Literature for 1971

, 1973 **Low-Level Environmental Radioactivity** Richard Tykva, Jozef Sabol, 1995-04-13 From the Introduction Low level radioactivity is related to those radioactive sources of ionizing radiation that are characterized by low activities Sometimes activity here does not represent total amount of radionuclides but rather their concentration In other cases the total activity may be quite high but we can measure only a relatively small portion of the material Low may have for different situations and circumstances not only considerably different meanings but also different absolute values as far as the activity or activity concentration is concerned For example one can refer to low activity in the case of radiocarbon dating where the concentration of ^{14}C is actually lower than its natural concentration and also in the case of radon monitoring where especially in mines or in some enclosed spaces its concentration may be several thousand times higher than the outdoor

atural concentrations Emphasis is now being placed on the analysis of naturally occurring radionuclides in the environment or on the release of radionuclides from their different man made sources because liquid and aerial discharge level controls have become more rigorous In addition the applicability of low level methodology increases the extent of different radionuclide applications considerably Since individual radionuclides differ in their decay scheme and particles emitted as well in their energies there is no universal method for the accurate measurement of all radioactive sources Moreover there is usually a mixture of radionuclides in a sample causing some difficulties in a selective evaluation of a given radionuclide Due to the random nature of radioactive disintegrations the appropriate interpretation of the experimental results would be in most cases impossible without elaborate statistical treatment and evaluation of the data obtained Thanks to the availability of computer based instrumentation the measuring data can be in most cases processed and evaluated on line which makes it possible to control and optimize the experiment in order to extract the maximum amount of information carried by the detector response The purpose of this book is to provide an introduction to low level radioactivity assessment and to clarify the nature of its sources as well as the principal methods used in its measurement Our evaluation is concentrated on the present day aspects of low level methodology The book may be useful for all who need highly sensitive analysis of natural or artificial radioactivity both within and outside the nuclear field The attempt of this book is to summarize the sources of environmental radioactivity and their possible radiological impact in terms of resulting doses to the population and to present a sound review of the measuring methods and techniques for the evaluation of low level radioactivities encountered in both the environment and in a number of applications where radioactive sources are used as a means of obtaining important information

Scientific Dating Methods H.Y. Göksu, M. Oberhofer, D. Regulla, 1991-10-31 Begins a series publishing courses and educational seminars organized by the Commission of European Communities Joint Research Centre at Ispra Italy Perhaps as the series matures responsible parties will see the wisdom of not trusting authors to present readable typescripts of mentioning where

Handbook of Water Purity and Quality Satinder Ahuja, 2021-04-21 Handbook of Water Purity and Quality Second Edition provides those involved in water purification research and administration with a comprehensive resource of methods for analyzing water to assure its safety from contaminants both natural and human caused The book includes an overview of the subject and discusses major water related issues in developing and developed countries Issues covered include sampling for water analysis regulatory considerations and forensics in water quality and purity investigations Microbial as well as chemical contaminations from inorganic compounds radionuclides disinfectants pesticides and pharmaceuticals including endocrine disruptors are discussed at length In addition the luxury of municipal water purified for human consumption is unavailable for a very large number of people To help solve this problem some economical water purification techniques including a million dollar Grainger prizewinner that can save millions of lives have been included This fully updated second edition includes four new chapters on topics such as the GenX Water Contamination

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Encyclopedia of Quaternary Science, 2006-11-24 The quaternary sciences constitute a dynamic multidisciplinary field of research that has been growing in scientific and societal importance in recent years This branch of the Earth sciences links ancient prehistory to modern environments Quaternary terrestrial sediments contain the fossil remains of existing species of flora and fauna and their immediate predecessors Quaternary science plays an integral part in such important issues for modern society as groundwater resources and contamination sea level change geologic hazards earthquakes volcanic eruptions tsunamis and soil erosion With over 360 articles and 2 600 pages many in full color the Encyclopedia of Quaternary Science provides broad ranging up to date articles on all of the major topics in the field Written by a team of leading experts and under the guidance of an international editorial board the articles are at a level that allows undergraduate students to understand the material while providing active researchers with the latest information in the field Also available online via ScienceDirect 2006 featuring extensive browsing searching and internal cross referencing between articles in the work plus dynamic linking to journal articles and abstract databases making navigation flexible and easy For more information pricing options and availability visit www.info.sciencedirect.com 360 individual articles written by prominent international authorities encompassing all important aspects of quaternary science Each entry provides comprehensive in depth treatment of an overview topic and presented in a functional clear and uniform layout Reference section provides guidance for further research on the topic Article text supported by full color photos drawings tables and other visual material Writing level is suited to both the expert and non expert *Man-Made and Natural Radioactivity in Environmental Pollution and Radiochronology* Richard Tykva, Dieter Berg, 2013-03-14 Radioactivity can be detected at different levels in almost all objects all over the world including the human body This omnipresence of naturally occurring radioactivity is of immediate and crucial concern to people who work in the nuclear industry to state and local authorities responsible for environmental protection and control of nuclear weapons and to researchers as physics e g interaction in scientific and technological disciplines such of radiation with matter chemistry e g management of radioactive wastes biology Ce g radiation bioeffects and risks ecology e g remediation of environmental pollution electronics e g measurement instruments etc Unlike other environmental pollutants such as heavy metals and pesticides some other scientific disciplines for example archaeology hydrology and geology profit by the environmental radionuclides using methods based on their application in radiochronology The basic goal of this book is to examine the complex state of radioactivity in the environment

including its sources and applications In principle there are two sources of environmental radioactivity namely man made and natural The authors of this book set out to analyze mainly empiric al aspects of the activities of both groups On one hand a detailed analysis of the sources releasing radionuclides into the environment by human activities should while describing environmental pollution and its dangers contribute to its decrease in the future Nuclear Science Abstracts ,1975

Whispering the Secrets of Language: An Mental Journey through **Radiometric Dating By Alpha Spectrometry**

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