Journal of
Synchrotron
Radiation

ISSN 0909-0495

Synchrotron radiation in soil and geosciences

Roberto Terzano,[a]* Melissa A. Denecke[b] and Luca Medici[c]

[a]Dipartimento di Biologia e Chimica Agro-forestale e Ambientale, University of Bari, via Amendola 165/A, 70126 Bari, Italy, [b]Karlsruher Institut für Technologie (KIT), Institut für Nukleare Entsorgung, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany, and [c]Istituto di Metodologie per l'Analisi Ambientale, CNR-IMAA, ZI, 85050 Tito Scalo (PZ), Italy.
E-mail: r.terzano@agr.uniba.it

This special issue is the outcome of the Session SSS24 'Synchrotron radiation in soil and geosciences' that was held on 21 April 2009 in Vienna during the EGU (European Geosciences Union) General Assembly 2009, within the Soil System Sciences (SSS) program. This session was also co-listed in the scientific program of the following EGU Divisions: Biogeosciences (BG), Geosciences Instrumentation and Data Systems (GI), Geochemistry, Mineralogy, Petrology and Volcanology (GMPV). The Presidents of all these divisions are acknowledged for their support, and special thanks go to Professor Teodoro Miano, President of the SSS Division.

This was the first time that a session completely dedicated to the application of synchrotron radiation in the field of soil and geosciences was presented in the SSS Division program at EGU. The aim of this session was to present new insights and innovative opportunities offered by the use of synchrotron radiation for studying a variety of materials related to geosciences. Thirty-six contributions from 11 different countries, mostly from Europe but also a significant number from USA, Australia and Asia, were submitted to Session SSS24 and particular gratitude is expressed to all the contributors who actively participated in the session.

Synchrotron radiation is extremely bright and intense, containing a continuous electromagnetic spectrum of wavelengths extending from the infrared to the hard X-ray region. The unique properties of this radiation allow a variety of analytical techniques. The application of these techniques can provide crucial information about the nature of a large number of Earth materials, including structure, chemical composition, chemical speciation, surface and interface properties and processes. The past few decades have seen an explosion in the development and availability of synchrotron facilities. Earth scientists have recognized the power of these methods for frontier research and are taking advantage of them in increasing numbers. The research conducted at these facilities has impact on several disciplines across the Earth sciences, including geochemistry, mineralogy, soil sciences, mineral physics, molecular environmental sciences, bio-geosciences and petrology (Sutton, 2006).

The researchers attending the Session SSS24 presented data collected at synchrotron facilities located in different countries around the world: Germany (ANKA, DESY, BESSY), USA (SSRL, APS, CAMD), France (ESRF), Italy (ELETTRA), Switzerland (SLS), Korea (PAL), Brazil (LNLS), UK (Diamond), Australia (AS) and Russia (VEPP-3). Earth materials were preferentially studied by using the following synchrotron-based techniques, in order of utilization: X-ray absorption near-edge spectroscopy (XANES), extended X-ray absorption fine-structure spectroscopy (EXAFS), X-ray fluorescence (XRF), X-ray diffraction (XRD) (all four methods also as microbeam applications), X-ray computed micro-tomography (XCMT), scanning transmission X-ray microscopy (STXM), near-edge extended X-ray absorption fine structure spectroscopy (NEXAFS), X-ray scattering (XRS), full-field X-ray microscopy (FFXM) and Fourier-transform infrared spectroscopy (FT-IR). In most cases, a combination of different techniques was used to investigate the samples, often in synergy with other non-synchrotron-based methodologies. A large variety of natural objects were studied by means of these techniques, mostly soils, minerals, rocks, shells, bio-minerals, bio-films, volcanic materials, nano-particles, bio-solids, sediments, humic substances, plants, nuclear wastes and waste sludges.

In this special issue ten papers are presented, chosen after a selection among 19 written contributions that were received after the scientific Session at EGU. The submitted papers passed a peer-review process, which involved eminent scientists from all over the world working in the field either of synchrotron radiation methodologies and/or specific topics of geosciences. All the referees who collaborated in the review process are gratefully acknowledged for their time and skilled advice. The following briefly summarizes highlights of the individual contributions.

The Session SSS24 at EGU started with a keynote lecture by Juergen Thieme, whose contribution 'X-ray spectromicroscopy in soil and environmental sciences' is the opening article of this special issue. In this feature article, Thieme *et al.* illustrate the capabilities of synchrotron X-ray microscopy and spectromicroscopy in studying nanometer-sized particles in soils and sediments.

STXM is also used by Plaschke *et al.* to investigate humic-acids–metal interactions. Beside this technique, Plaschke *et al.* also employed C 1*s*-NEXAFS and laser scanning luminescence microscopy to identify zones in the humic acids where binding of metals at different strength occur. Quantum chemical calculations performed at the *ab initio* level for model complexes confirmed the distinction in the observed complexation effect for different metals (especially lanthanides and actinides).

Micro-XANES spectromicroscopy is used by Prietzel *et al.* to find relationships between the speciation of S and Fe in soil aggregates. Sulfur and iron are key elements in regulating the availability of micro-nutrients and toxic metals in soil, therefore their speciation is relevant in studying physico-chemical processes in soil.

Chromium (VI) in polluted soils can be made less dangerous by treating the soil at temperatures lower than 378 K (*e.g.* achievable by using the heat from industrial flue gas), exploiting the natural reducing power of soil organic matter (SOM). Wei *et al.* used XANES to demonstrate that in this process $\sim$90% of Cr(VI) can be transformed into less hazardous $Cr(OH)_3$ and that this action is performed exclusively by SOM without the contribution of other soil constituents (*i.e.* iron minerals).

Another potentially dangerous pollutant has been studied by Esbrí *et al.* They assessed mercury speciation using XANES in a large number of ores, calcines, dump materials, soils, sediments and suspended particles from three important mining districts in Europe (Almadén and Asturias in Spain, and Idria in Slovenia). The information obtained allowed the authors to find relationships between Hg speciation, mobility and dependence on metallurgy treatment at the site.

Hg speciation was also determined by Santoro *et al.* by XANES in different size fractions of a soil sample collected in a site polluted by the activities of a former chlor-alkali plant. The authors observed a higher Hg concentration in the submicrometric fractions, as well as an enrichment in relatively more soluble and dangerous Hg species. A special procedure was developed to study the soil colloidal fraction, both for sample preparation and for XANES data collection.

XANES at a submillimeter resolution is used by Soldati *et al.* to investigate Mn speciation in the shell of the freshwater bivalve *Diplodon chilensis patagonicus*, used as a natural proxy archive of the environment and ecosystem history. They found that Mn speciation does not depend on sample provenance, ontogenetic age, Mn concentration or seasonal depositions.

Industrial sludge rich in copper can be electrokinetically treated to reduce the amount of metal before the disposal of the sludge in the environment and to recover part of this valuable material. Liu *et al.* have studied the variation in Cu speciation during the electrokinetic treatment of the sludge by using *in situ* XANES and EXAFS. With such an approach they, among other things, found that at the end of the process 85% of the copper is dissolved in the aqueous phase and 13% can be recovered on the cathode.

Pyromorphite and mimetite are minerals of the apatite group largely used as sequestration agents in water treatment and soil remediation. High-resolution synchrotron XRD data, which cannot be obtained with conventional XRD instruments, allowed Flis *et al.* to provide new structural information about the pyromorphite–mimetite solid solution series, of high interest for Earth scientists.

The last paper of this issue by Polacci *et al.* describes the advantages of using XCMT to accurately image the internal structure of volcanic rocks from various active hazardous volcanoes around the world. Using the detailed information attainable with this technique, the authors could obtain novel insights into modes of gas exsolution, transport and loss in magmas that were not recognized in previous studies using solely conventional two-dimensional imaging techniques. Combining these data with those from other geosciences disciplines can be extremely useful to better understand the behavior of volcanoes and forecast their future activity.

In conclusion, the papers published in the special issue show that synchrotron radiation applied to the field of soil and geosciences is an extremely powerful research instrument and that the range of applications of this tool is continuously increasing.

References

Sutton, S. R. (2006). *Elements*, **2**, 7–8.