Preface for thematic issue on “Supergene ore deposits”

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Supergene ore deposits such as Ni-laterite, Al-bauxite, or Pb-Zn oxide deposits are typically mined by open pit methods. Open pit mining has a considerable impact on the environment, such as dust generation of partly toxic materials, changes in water table elevation, and impact on fauna and flora and urbanization. Furthermore, lower ore grades and multiple metal carriers in supergene ores (silicates, carbonates, oxyhydroxides) create beneficiation and metallurgical processing challenges. Both environmental impact, mining, and processing costs can be reduced through a better and early understanding of the complex evolution of these supergene deposits and applying high-resolution analytical techniques.

This thematic issue contains six original contributions on Ni-laterite deposits from two major mining regions, the Caribbean islands (Cuba and Dominican Republic) and New Caledonia (Koniambo), which were presented at the 13th SGA Biennial Meeting (2015) in Nancy, France. One paper discusses karstic bauxite, an important source for aluminum, which has new uses in the cement industry. Two papers document supergene (Cu) Pb-Zn deposits. It is shown that in many laterite profiles and Pb-Zn carbonate-oxide deposits, ascending hydrothermal fluids at the base of the alteration

profile and descending or laterally infiltrating meteoric water, can lead to a complex metal distribution even at the mineral scale. This has implications for tracing high-tech elements such as Ge and V (Pb-Zn deposits) and platinum-group elements (PGEs) (Ni-laterite deposits).

About 70% of the current global Ni production is from laterite deposits. Nickel laterites were extensively studied in the 1980s and 1990s. Research restarted about 15 years ago, as typical Ni-laterite grades decreased from 2 to 4% down to 0.8% (cut-off), and ore processing became more complex. Ni laterites were classically mined for garnierite in veins, or disseminated in the saprolite zone, or at the interface between serpentinite and saprolite. Currently, several Ni laterite ores are characterized by multiple Ni-carrier minerals finely dispersed in the soil matrix. Advanced analytical techniques (micro-Raman spectroscopy, infrared spectroscopy) coupled with EMPA and XRD instruments and thermodynamic and numerical modeling yield new insights in the complex processes and mechanisms of laterite evolution.

So far, the Caribbean deposits were little studied, and this volume presents remarkable contributions on laterite from the Dominican Republic and Cuba by the Caribbean Lithosphere Study group (<http://caribbeanlithos.com/>), covering the mineralogy and geochemistry of Ni, but also of PGE/PGM along laterite profiles. Serpentine, usually considered having formed through hydrothermal processes, occurs in saprolite as Ni- and Fe-rich varieties. These varieties are, in fact, a combination of lizardite-nepouite and Fe³⁺-lizardite, a mineral association resulting from weathering and Ni leaching from goethite (Villanova-de-Benavent et al. this issue). Domènech and coworkers (this issue) study limonite-dominated Ni laterite with a thin saprolite zone at the base (Punta Gorda, Cuba; 1.0–1.6% Ni), similar to 60% of Ni-laterite deposits worldwide. They show, on the basis of mineralogical analyses and 1D

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reactive modeling, that Ni is partly dissolved/desorbed from goethite and reconcentrated in Ni-Fe (III)-rich serpentine. This finding leads to a new type of deposit, a transition of hydrous Mg silicate- to clay silicate-type deposits (Tauler et al. this issue). These deposits are characterized by Ni-rich, tri-octahedral smectite, in contrast to mixed di- and tri-octahedral smectite more typical of Ni laterite worldwide. This is the first detailed study of Ni laterite using micro-XRD, SEM, and EPMA, combined with bulk-rock geochemistry (XRF, ICP-MS).

Although not economic, the Carribean Ni-laterite deposits (Dominican Republic) also host chromite with different platinum-group minerals (PGM). A systematic study on the evolution of the chromite grains and PGMs along a laterite profile reflects the serpentinization and supergene history including biomediation of in-situ formation of isometric PGM (Aigelsberger et al. this issue).

The New Caledonia deposits were extensively studied in the past. This volume presents new data, new concepts, and modeling approaches for the Koniambo deposits. The complexity of laterite formation is well demonstrated by Cathelineau et al. (this issue). Upward fluid flow led to the emplacement of hydrothermally (50–95 °C) deposited Ni-Mg kerolite and micro-quartz as crack-seal fractures and breccia cements, without a clear genetic relationship with laterite formation. The latter are considered as the first Ni pre-concentration, along serpentine fractures formed during obduction. In the same deposits, Quesnel

et al. (this issue) present a 3D model on the Ni-laterite surface. The authors found Ni enrichment in saprolite below the thinnest laterite layers on slopes, whereas saprolite below thick laterite is Ni poor. They propose lateral Ni leaching from the thick laterite layers and downward flow along the slopes and precipitation in the surrounding saprolite. This finding represents a new exploration tool.

Karstic bauxite, the most important bauxite type in southern and western China, hosting over 0.5 Gt of late Permian bauxite, was studied in the Maokou Formation (Pingguo, western Guangxi province; Liu et al. this issue). The combination of mineralogy and geochemistry including Sr–Nd–Pb isotopes and S isotopes on pyrite allows to decipher the role of microbial activity during early diagenesis and subsequent weathering of a basaltic protolith.

Finally, the (Pb)-Zn deposits of the High-Atlas Mountains, Morocco (Choulet et al. this issue), show the mixed signatures of hydrothermal (< 130 °C) and meteoric water contributions. Interestingly, willemite has heterogeneous contents of Ge, which seems to be crystallographically controlled. In the same region, two sulfide deposits hosted by Jurassic dolostones (Cu at Jbel Klakh and Pb-Zn at Jbel Haouanit) recorded the weathering of the Pb-Zn-Cu-V mineral assemblage. Weathering resulted in vertical zoning from the laterite to the protolith depending on pH and Eh conditions (Verhaert et al. this issue).