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Mineralogical and Geochemical features of Upper Cretaceous Ni-laterite and Karstic-Nickel ores from Lokris (Continental Greece): implications for burial depth

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Introduction

The Ni-laterite and laterite derived sedimentary ores in Greece are a major source of nickel, which nowadays is regarded as a metal of strategic significance. The exploitable deposits with an average Ni-content in the order of 0.9-1.4%, are mainly located in Lokris area, Euboea and Kastoria, and the metallurgical facility that produces a ferronickel alloy is located at Larymna. In Continental Greece and Euboae only laterite derived sedimentary Fe-Ni ore deposits are under exploitation, whereas Ni-laterite ores are sub-economic. Lateritization took place in Cretaceous times, resulting in extensive development of Ni-lateritic profiles. Lateritization was followed in Late Cretaceous by erosion of weathering crusts, transport of the lateritic material and submarine deposition as a clastic sediment during transgression of the sea, either on ultramafic rocks (secondary deposits) or in karstic traps of limestones (Karstic Nickel deposits) (Albandakis,1980; Eliopoulos and Economou-Eliopoulos, 1999; Skarpelis, 1999; 2005).

In this study the mineralogical and geochemical characteristics of selected Ni-lateritic profiles and sedimentary Fe-Ni-deposits from the broader area of Lokris are discussed, towards a more comprehensive interpretation of the environment of deposition and the diagenetic evolution of the ores.

Geological Settings

Geologically the area of Lokris belongs to the Sub-Pelagonian geotectonic zone, which in the broader studied area consists of Triassic-Jurassic dolomites and limestones, Upper Jurassic ophiolite formations, Upper Cretaceous limestones and flysch sediments. The Ni-laterites in the area were formed during the Lower-Late Cretaceous by the intense weathering of the ultramafic-mafic sequences of these ophiolite rocks under tropical/subtropical and hence humid environment (Albandakis, 1980; Eliopoulos and Economou-Eliopoulos, 1999; Skarpelis, 2000).

Materials and Methods

Samples were taken from the Ni-laterite profile of Metochi area, where exploratory works have been carried out, as well as along four vertical profiles at the Nissi, Kopaida and Agios Ioannis (North Sector) and Villes Karstic-Nickel deposits, which represent allochthonous lateritic deposits, deposited over the karstified limestone.

Polished blocks and thin sections were prepared from a series of ore lithologies, as well as of the transgressive Cretaceous limestones. Ore petrography was carried out by combined optical microscopy, Scanning Electron Microscope and X-ray diffraction using a Bruker D8 Advance X-Ray diffractometer. The transgressive bituminous limestones were also examined under a LEICA DMRX microscope, fitted with an MPV reflectance measurement unit. Major and minor element analyses were conducted using a RIGAKU ZSX PRIMUS II spectrometer.

Results and Discussion

The general mineralogical and geochemical characteristics of each studied profile can be summarized as follows:

Metochi Ni-laterite profile: displays an *in situ* lateritic zonation above the ultramafic bedrock, the latter consisting mainly of lizardide and diopside. However, evidences of small-scale reworking of the material were also traced in the upper parts. The Ni-rich lithologies are mainly the clayey layers, consisting of mixed-layered clays and chamosite, containing Ni up to 0.64 wt.%.

Villes profile, Ag. Ioannis area: mineralization is of karstic type, overlying the Jurassic limestones. The lower parts are characterised by the predominance of silicates, in the form of quartz (silcrete fragments) and mixed-layered clays, and hematite, whereas carbonates and iron-oxides show enrichment towards the upper parts. The argillaceous layers contain less than 1 wt.% Ni, whereas the hematite-kaolinite rich layers in the upper part of the profile display up to 3.6 wt.% Ni and 1.5 wt.% Cr.

Nissi profile, Ag. Ioannis area: mineralization is of karstic type, with a fine-grained sedimentary mixture of calcite, magnetite, boehmite, and garnierite, occupying the lower parts displaying 1.4 wt.% Ni and 415 mg/kg Co. The overlain layer shows a coarser and more brecciated character, with significant occurrence of angular chromite and quartz grains. Towards the middle and upper parts of the profile silicates in form of mixed-layered clays and Fe-oxides, mainly as pelloids, are predominant. Nickel concentration ranges between 0.5-1 wt.% and this of Co between 415-459 mg/kg. The overlying carbonate rock represents a marly bituminous limestone, with frequent occurrence of hematite, chromite and pyrite grains. Within this layer, apart from bituminite-like material, well preserved macerals of the vitrinite group were traced, providing evidences for their indigenous nature. The random reflectance values of the indigenous vitrinite population ranges between 0.75-0.82% (Fig. 1), with these values corresponding to the middle catagenesis maturation stage, providing indications for the burial depth of the studied profiles.

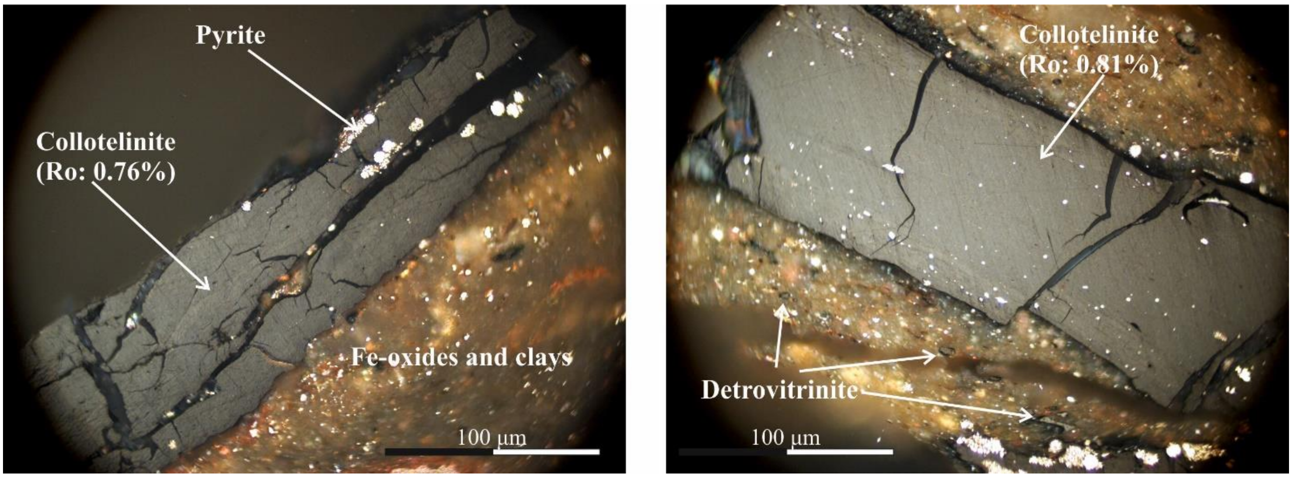

Figure 1. Photomicrographs of the Cretaceous bituminous limestone, overlying the Nickeliferrous karstic ore in Nissi deposit, showing telovitrinite particles and the respective reflectance values; white light, using oil immersion.

Kopaida profile: karstic type mineralization with an argillaceous prevailing sedimentary facies. The main mineralogical assembly of the clay-rich strata consists of hematite, goethite, chlorite, kaolinite, quartz, chamosite and boehmite. Within the more massive Fe-rich strata, magnetite, chromite and asbolane are more evident. Nickel values range from 0.95-1.3 wt.% and those of Co between 411-566 mg/kg.

North Section profile: the mineralogical assembly consists mainly of hematite, goethite, chromite, chlorite, magnetite, kaolinite, chamosite and boehmite. The lower part is a coarse brecciated facies, whereas towards the upper parts finer sedimentary facies prevail. Nickel values range from 0.3 to 0.5 wt.% and those of Co between 302-483 mg/kg.

Conclusions

The sedimentological and mineralogical features of the studied profiles confirm the prevailing allochthonous nature of the Ni-rich horizons and are in accordance with the previous studies. The comparative study of the different deposits demonstrates also that the formation of Karstic Nickel ore-types took place in variable depositional environments with fluctuations in the hydrological regimes and the transportation and/or the depositional modes of the clastic material. The presented data reveal that in most cases coarser material was deposited at the base getting finer towards the top. In some places, evidences of terrestrial plant input suggest shallow, relatively anoxic environment at least during the initial deposition stage of the overlying carbonates.

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