Available online at www.sciencedirect.com
SCIENCE DIRECT®
Journal of Geochemical Exploration 88 (2006) 325–328
JOURNAL OF GEOCHEMICAL EXPLORATION
www.elsevier.com/locate/jgeoexp

Lateritization processes of ultramafic rocks in Cretaceous times: The fossil weathering crusts of mainland Greece

N. Skarpelis *

Faculty of Geology and Geoenvironment, University of Athens, Panepistimiopoli, 157 84 Zografou, Athens, Greece

Received 1 April 2005; accepted 19 August 2005
Available online 8 November 2005

Abstract

The lateritic weathering crusts exposed in mainland Greece were developed on ophiolitic ultramafic lithologies during lower Cretaceous times. The lateritic profile consists of four zones: bedrock, saprolite clay (nontronite) and goethitic. The profiles show large variations in thickness, continuity, mineralogy and chemical characteristics. They are broadly similar to clay nickel laterite deposits. The uppermost gravelly ferruginous sector was eroded and the material reworked and redeposited partly on the lateritic crust. Silcrete layers, characteristic of groundwater silcretes, were formed into the clay and goethitic zones. Significant supergene nickel enrichments occur in the clay and saprolite zones, indicating that water moved downward to a very low water table. The structure and mineralogy of the weathering crusts indicates that environmental conditions were likely to have been dominated by alternating wet and dry periods.

Keywords: Nickel laterite; Cretaceous; Saprolite; Silcrete; Nontronite; Garnierite

1. Introduction

Nickeliferous iron-ores are exploited in mainland Greece and Euboea island for processing and production of ferronickel alloy. They are products of sedimentation under submarine conditions of laterite-derived material on karstified Triassic–Jurassic carbonates or on ultramafic ophiolitic rocks. The petrology, mineralogy and geochemistry of the remnants of lateritic weathering crusts developed at the expense of ultramafic rocks have received relatively little attention compared to their sedimentary derivatives. The study aims to contribute to the understanding of lateritization processes having taken place during the lower Cretaceous.

2. Sampling—analytical methods

Sampling of lateritic profiles was carried out in exploratory pits (Loutsi and Pavlon villages). Bulk chemical analyses of samples were obtained by combined XRF and atomic absorption spectroscopy techniques. XRD analyses of clay minerals were done on oriented mounds using Cu-ka Ni-filtered radiation. When necessary iron oxides were dissolved and Fe removed according to Mehra and Jackson (1960) and the insoluble residue was analysed by XRD. Microprobe analyses were done using a JEOL-733 microprobe.

3. Field relationships—mineralogy

The preserved lateritic profiles show large variations in thickness and continuity of individual zones. Variations are also observed in the mineralogy and chemistry

* Tel./fax: +30 210 7274210.
E-mail address: skarpelis@geol.uoa.gr.

0375-6742/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.gexplo.2005.08.066

of the zones over short distances. Post-lateritization erosion has removed the uppermost part (gravelly ferruginous or pisolitic sector) of the ferruginous zone of the lateritic crusts. Therefore only the following lateritic zones are identified (Fig. 1).

(a) Bedrock
(b) Saprolite
(c) Clay zone (nontronite) (with multiple silcrete layers locally)
(d) Goethitic (oxidic zone)

The profile is capped by a reworked granular Fe–Ni ore. The weathering crusts are transgressively covered by Upper Cretaceous limestones.

The *bedrock* is mostly serpentinized harzburgite and grades into the saprolite zone. Lizardite is the predominant polymorph of serpentine in most samples. The contact between the two zones is irregular. In several cases lizardite and Cr-spinel are the only mineral constituents. A greenish to greenish-yellow serpentinite appears locally to underlie the clay zone. It comprises Ni-bearing lizardite and Cr-spinel and contains up to 2.2% Ni. The *saprolite* comprises serpentine (mainly lizardite), talc, chlorite, goethite and minor quartz. The saprolite is locally transected by dense stockworks of calcite. Joints of saprolite are coated by thin films of asbolane, indicating downward movement of manganese and associated elements. Filling of voids and fissures by garnierite (nepouite) results in a strong increase of nickel concentration. Formation of garnierite veinlets by downward migration of nickel leads to a strong enrichment of parts of the saprolite zone. The transition to the clay zone is marked by the gradual disappearance of serpentine and the appearance of nontronite. The *clay zone* consists of nontronite with minor goethite. Locally it grades downward to lizardite serpentinite. The thickness of the nontronitic layer ranges between 1 and 10 m. The primary mineralogy and texture of the rock is destroyed. Spheroidal to ellipsoidal ferruginous concretions (peloids), ranging in size between 0.3 and 2 cm, are usually found dispersed within the clay zone. They consist of magnetite, partly altered to martite, and chlorite. Chlorite forms radial aggregates filling voids within the ferruginous matrix. Microscopic examination of several peloids indicates various stages of ferrugination of primary silicate minerals in the saprolite. The development of peloids by complete replacement of silicates and the concretionary growth over a nucleus is possibly due to continuous input of iron as a result of decomposition of the bedrock. The *goethitic* ore is soft and friable consisting of goethite, minor hematite and residual Cr-rich spinel. Relics of serpentine and talc were detected by XRD. The contact with the saprolite zone is an intertonguing one. The modal proportion of hematite increases upwards. The transition from the lower goethitic zone to the upper hematitic is gradual. Aluminium substitution in goethite–detected by XRD on the basis of (111) reflection–is estimated to be around 13 mol%. A *zone of reworked Fe–Ni ore* overlies the lateritic profile and is capped by the transgressive Upper Cretaceous limestones. It comprises ferruginous spheroidal particles and angular fragments of silcrete set in a clayey matrix. Peloids, pisoids and ooids, as well as composite granules are recognised. They consist of hematite, chlorite, kaolinite and minor goethite. A goethite cortex is observed around peloids, a textural feature characterising spheroidal particles (nodules) of dismantled ferricretes (Ambrosi and Nahon, 1986). A nuclear grain (residual chromite or fragments of saprolitic material) usually serves as an initial site for the accretion of laminae. The petrology of the silcrete fragments indicates they are identical to the silcretes of the lateritic profile.

Silcretes are usually developed within the clay and the goethitic zones. They appear as large, flat-lying masses,

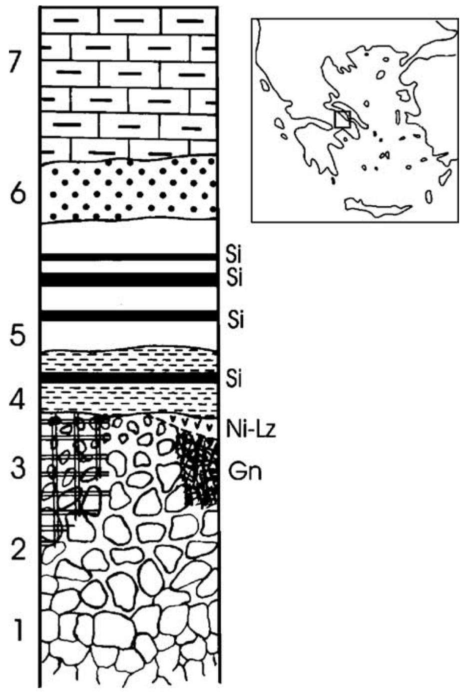

Fig. 1. Location map and schematic section through the lateritic profiles of mainland Greece: (1) bedrock, (2) saprolite, (3) calcite stockwork, (4) clay zone, (5) goethitic zone, (6) reworked Fe–Ni ore, (7) Upper Cretaceous limestones. Gn: garnierite veinlets, Si: silcretes, Ni-Lz: nickel enriched serpentinite.