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Effect of geo-pedological conditions on the distribution and chemical speciation of selected trace elements in forest soils of western Alborz, Iran

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ABSTRACT

Geologic and pedologic controls have an important influence on the abundance, distribution and behavior of elements in natural soil environments. In order to assess the role of these factors on distribution and chemical speciation of selected trace elements in soil, soils on six parent materials including phyllite, tonalite, peridotite, dolerite, shale and limestone were sampled in western Alborz in Iran. Soil genesis and development of representative residual pedons were studied for each parent material and the total content of Si, Al, Fe, Ca, Mg, Co, Cr, Cu, Mn, Ni, Pb, V and Zn were compared. Enrichment/depletion patterns of trace elements were assessed using Ti as the reference element and lowest horizon as the reference layer. A modified BCR (European Community Bureau of Reference) sequential extraction procedure was used to fractionate the elements into four operationally defined species. The total contents of Co, Cr, Ni and V are highest in soils derived from peridotite (53, 984, 285, and 204 mg kg^{-1}, respectively) and dolerite (39, 1023, 176, and 185 mg kg^{-1}, respectively). Lead and Zn contents are highest in soils derived from shale (27 and 106 mg kg^{-1}, respectively), which is probably due to the high sorption capacity of clay. Different elements exhibited very different enrichment/depletion patterns in a given pedon. Moreover, depth distribution patterns differed also for a given element among soils with different parent material and even showed considerable variation among soils with similar lithology. Lead, Zn, Cu and Mn have been generally enriched in most pedons, except in some acidic and strongly leached soils, whereas Co, Cr, Fe, Ni and V have been leached, especially from Dystrudepts and Eutrudepts. The latter elements, however, showed enrichment trend in Hapludalfs and Argiudolls parallel to the development of illuvial B horizons. Iron, Cr, Cu, Ni, V and Zn are present primarily in the residual fraction, independent of soil and parent material type, whereas Mn, Pb and Co were mainly present in the non-residual fractions of most pedons. Trace element concentrations in the soils of the study area are related primarily to the parent material type while pedogenic processes appear to have played a minor role.

1. Introduction

The concentrations of trace elements in residual soils depend mainly upon the bedrock type, from which the soil parent material is derived, and pedogenic processes acting upon it (Mitchell, 1964). The influence of the parent material on trace elements tends to decrease with soil development (Zhang et al., 2002). The most important aspects of pedogenesis relating to the behavior of trace elements are those affecting (i) the release of metals from the parent material by weathering and (ii) the translocation and accumulation of sorbents such as clay minerals, oxides and organic matter, which are controlled by leaching, eluviation, salinization, calcification, podzolization, ferralitization, gleying and organic matter accumulation (Alloway, 1995). These geo-pedological factors not only determine the total content but also the chemical speciation and bioavailability of elements.

Pedons developed from sedimentary parent materials are distinguished clearly in their metal concentrations from soils on volcanic parent materials in Sicily, Italy (Palumbo et al., 2000). The only exception, carbonate-free Alfisols and Mollisols were markedly enriched in heavy metals compared to the underlying limestones and calcarenites, due to the formation of Fe–Mn oxides and clay accumulation. Total element content is primarily dependent on landscape position and landform, whereas pedogenic processes govern their depth distribution, and the organic carbon content is closely correlated with the DTPA-extractable concentrations (Sharma et al., 2005). The total contents of Zn, Mn and Fe are highest in piedmont profiles (Typic Haplustalfs), moderate in profiles on concave hillslopes (Typic Hapludalfs) and lowest in profiles on plains (Udic Haplustalfs) in Punjab, India.

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The enrichment factor assesses the effects of pedological and other non-lithogenic factors on soil element abundances. An enrichment factor expresses the ratio between the abundance of the element of interest and a conservative lithogenic element with no significant anthropogenic source, relative to the corresponding ratio between the two elements in the parent material (Bowen, 1979). Blaser et al. (2000) determined the enrichment factors for various trace elements in Swiss forest soils using Zr as a reference. Trace elements showed completely different depth patterns, possibly due to the different patterns of natural processes and anthropogenic inputs. Tijani et al. (2006) found various degrees of enrichment of Pb, Rb, Sr and Ba in moderately weathered granite-gneiss and weathered schist-quartzite settings, in contrast to a depletion of the same elements in soils on weakly weathered pegmatite bedrocks.

Trace elements in soils occur in different chemical forms or species. The trace elements that occur as relatively immobile species in silicates, aluminosilicates and other primary minerals become available to plants by weathering. Therefore, the analysis of chemical species in soils provides more useful information on element mobility and availability than the determination of total contents only (Sahuquillo et al., 2002). Sequential extraction procedures that are used to predict long-term release potential of contaminants in sediments, may also be used to investigate the influence of pedogenic controls on trace element distribution and fractionation (Palumbo et al., 2000). The fractions obtained by sequential extraction schemes are exchangeable species, metals bound to carbonates, metal released in reducing conditions such as those bound to hydrous oxides of Fe and Mn, metals bound to oxidizable components such as organic matter and sulfides, and a residual fraction (Sahuquillo et al., 2002). Heavy metals are mainly in the residual fraction of arid soils in central Iran; however, the carbonate-bound metal fraction was substantial in pedons with strong calcification, especially Co, Ni and Pb (Goodarzi, 2008).

The western Alborz is one of the least polluted areas in Iran and diverse in terms of lithology, providing an excellent opportunity to study the background concentrations of soil trace elements, and their relationship to parent materials and soil-forming processes. Trace

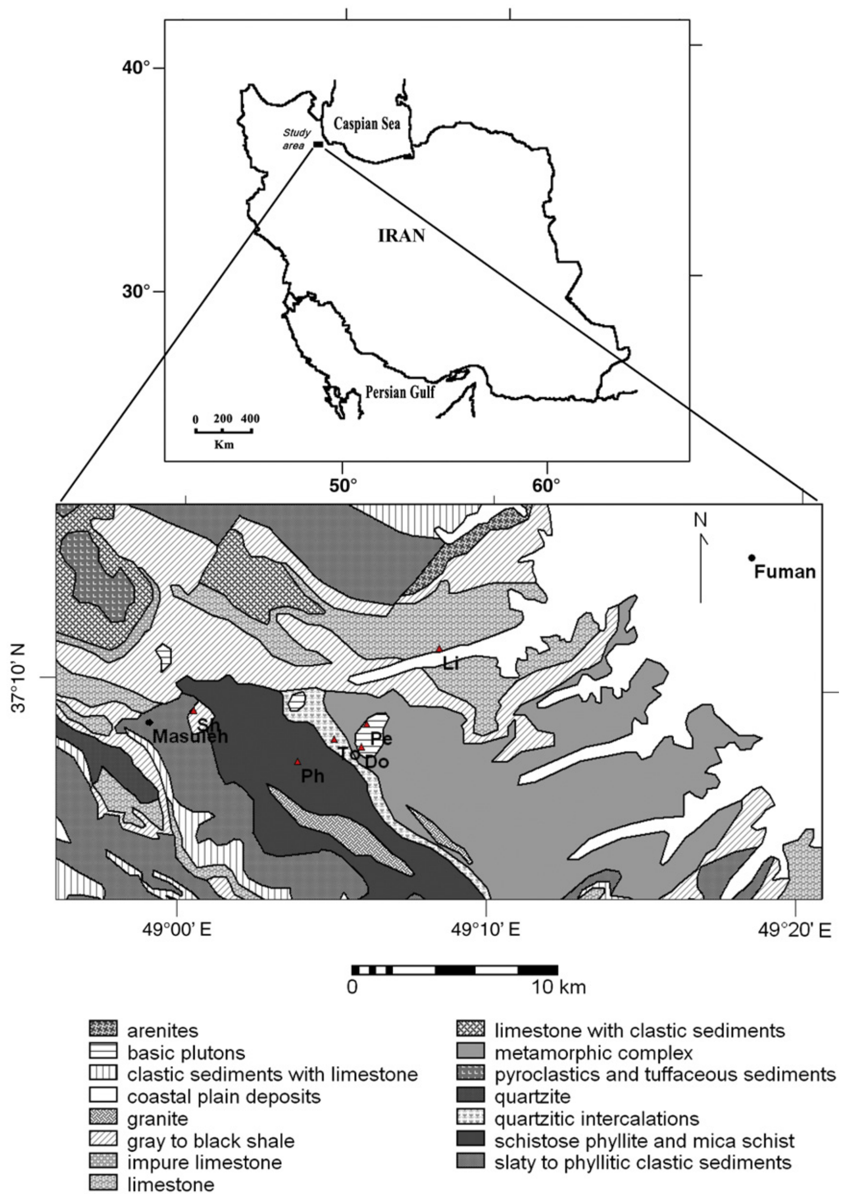

Fig. 1. Geological map of the study area and location of selected parent materials.