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Stream sediment geochemistry of the Upper Mahaweli River Basin of Sri Lanka—Geological and environmental significance

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ABSTRACT

Stream sediment geochemical maps serve as a tool for mineral exploration, identifying pollutant sources and providing information on weathering and transport processes. This paper presents geochemical maps of the upper catchment of the Mahaweli River of Sri Lanka, with interpretations based on geochemistry, geology and environmental conditions.

For the construction of these maps, stream sediment geochemical data of 1585 samples, collected from 05 main tributaries of the Mahaweli River, was used. Elemental concentrations of 19 major and trace elements were determined by X-ray fluorescence spectrometry. Geochemical maps were prepared and existing geological maps, discriminant analysis, factor analysis, and correlation coefficients were used to recognize the relationship between spatial distribution patterns and the geological and environmental factors.

These maps and statistical analysis clearly show the identical geochemical behavior of K, Rb, Ba and Sr. Even Mg and Ca show a similar distribution in different basins, the lack of correlation with metacarbonates probably being due to dissolution of Ca–Mg bearing minerals. The anomalous concentrations of these elements observed in the Anda Oya of Belihul Oya basin may indicate the existence of a Fe–Cu ore body and a Ni–Cr deposit in the upstream tributary of Badulu Oya. This however needs further detailed geological investigations. High Al levels in some streams seem to be controlled by high silt and clay contents released due to agricultural soil erosion in the upstream areas. Similarly, Pb enrichment in the vicinity of some cities may also be anthropogenic. Na, Mn, Ti, Nb, Y, Zn, Zr distribution in the stream sediment shows a relationship with the underlying lithologies of the area.

1. Introduction

Geochemical surveys based on the chemical analysis of samples of active stream sediments from the drainage courses have long been used as an exploration tool worldwide. In addition, these maps provide information on pollutant sources, weathering, and transport processes of the catchment area. The fundamental premise is that stream sediments are composite products of erosion and weathering and thus represent the source catchment area of the stream drainage network (Darnley, 1990; Cocker, 1996, 1999).

Hence many countries including Europe, North America and Japan have prepared countrywide geochemical maps (Webb et al., 1978; Kautsky and Bølviken, 1986; Thalmann et al., 1988; Reid, 1993; Atsuyuki et al., 2005).

Several stream sediment geochemical surveys have been carried out in Sri Lanka mainly for mineral exploration purposes (Dissanayake and Chandrajith, 2003; Dissanayake and Rupasinghe, 1992; Gamage et. al., 1992; Fernando, 1995; Dept. of Mineralogy, 1959). The Gem Exploration project carried out by the Institute of Fundamental Studies, Sri Lanka is the first such project and it covered several main catchment areas at close sampling intervals (IDRC, 1991; Ruapasinghe, 2000). This project covered a considerable portion of the Upper Mahaweli catchment which represents the geologically and environmentally important Central Highlands of Sri Lanka. This paper presents geochemical maps of the upper catchment of the river Mahaweli, based on the data generated from this project, and interpretations for geochemistry on geological and environmental grounds.

1.1. Physiography and geology

More than 25% of the Central Highlands of Sri Lanka lies in the upper catchment of river Mahaweli (3118 km^2), the longest river (335 km) of Sri Lanka (Fig. 1). Elevation of the area ranges from 300 m–

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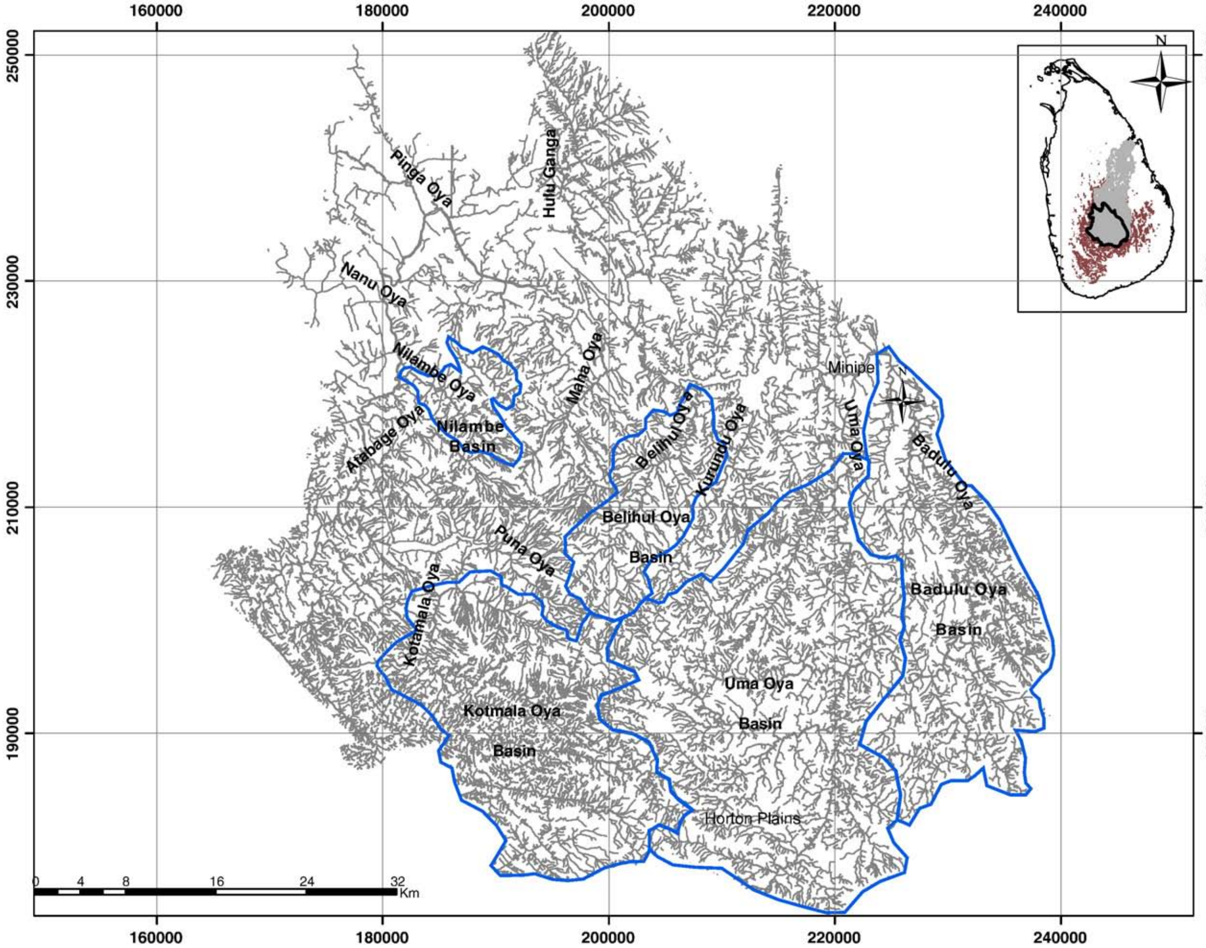

Fig. 1. Location map of the Upper Mahaweli Basin.

2500 m and it comprises of a highly dissected terrain consisting of a unique arrangement of plateaus, ridges, escarpments, intermontane basins, and valleys (Fig. 2). The southern and western parts of the Central Highlands receive an annual rainfall of 2500 mm–5000 mm from the southwestern monsoon and inter monsoon while the northern and eastern parts receive an annual rainfall of 750 mm–> 2000 mm from the northeastern monsoon and inter monsoon (Survey Department, 1988).

Geologically, the Upper Mahaweli catchment area lying in the Highland Complex of Sri Lanka mainly consists of granulite grade metasedimentary and meta-igneous rocks, belonging to the early Proterozoic (Cooray, 1994). Quartzite, quartzofeldspathic gneisses, marble, calc silicate gneisses, pelitic and semi-pelitic gneisses, charnockite and chranockitic gneisses are the major lithologies of the Upper Mahaweli catchment area (Geological Survey & Mines Bureau, 1996, 1997) (Fig. 3). Natural erosion rates, calculated from the low cosmogenic nuclides, of the Upper Mahaweli catchment are 10–30 mm/ky (Hewawasam et al., 2003). However, the average erosion rate of the area has been calculated presently as 100–500 mm/ky. Improper soil management practices in this area and the presence of easily weathered feldspar-rich rocks and high annual rainfall are responsible for these high rates of erosion.

1.2. Drainage and land use

The area extending from the western edge of the Horton Plains, where Agra Oya begins, to Minipe is considered as the upper regime of the Mahaweli river. Kotmala Oya, Puna Oya, Hulu Ganga, Maha Oya, Badulu Oya, Uma Oya, Kurundu Oya, Belihul Oya are some of the main tributaries of the river Mahaweli that join the main river along this upper regime (Fig. 1). The upper catchments of the tributaries are covered with Tropical Montane Forests, tea cultivation and vegetable plots with paddy fields and human settlements found in between.

2. Methodology

For the Gem Exploration project, stream sediment samples were collected from the 2nd order or higher streams of the Badulu Oya (BO), Belihul Oya (BH), Uma Oya (UM), Kotmala Oya (KO) and Nilambe Oya (NL) tributaries of the Mahaweli river. The sediment deposition, flow rate, slope of the river and human impact on natural sedimentation process of the river were considered while selecting sampling locations, taking care to avoid disturbed locations within areas of gemming and sand mining.

Samples were taken at about 0.3 m–0.6 m depth on banks or river bed and in order to minimize the effect of seasonal climatic changes, core samples which represent different random climatic phases, were taken. Collapsed and washed bank materials were not sampled and in river beds with boulders, samples were collected using the hand pit method. The slope of the channel at sampling locations which is critical in determining the amount of heavy and light fraction of the sample was estimated (Fig. 2). A total of 4–5 kg of raw samples (without sieving) were taken from each location.

All stream sediment samples were air dried and divided into two duplicates using the cone and quarter method and one duplicate was selected for chemical analysis. Samples were separated using a