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Geochemical mapping using a geomorphologic approach based on catchments

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Abstract

The Extended Sample Catchment Basin (ESCB) mapping technique, discussed in this paper, can be used to display the spatial distribution of geochemical variables measured in stream sediments taking into consideration the geomorphologic settings and the hydrographic patterns of surveyed areas. This approach is based on the association of an area of statistical representativeness with each sample, and on the assumption that the concentrations measured in the stream sediments can be considered as average reference values for this area.

ESCBs can be easily identified considering the position of the sampling points within the hydrographic network and using the confluences between the streams of highest rank as break points for representing changes of the geochemical background. This approach, different from the traditional geostatistical and deterministic ones, does not consider the Euclidean distance among the sampling points as a measure of geochemical similarity but only refers to their functional relationship along the streams (following the water and the sediment flow) to measure their proximity.

ESCBs can be seen as a specific development of previous techniques based on catchments and proves to be especially useful for supporting land planning in a preliminary survey phase while it is not specifically suitable for the identification of point sources of geochemical anomalies.

Due to the fractal nature of the hydrographic network, all the procedures can be driven in a GIS environment by using digital terrain models apart from their spatial resolution.

Keywords: Geochemical mapping; Stream sediments; Catchments

1. Introduction

Stream sediments are commonly used in environmental and exploration geochemistry to measure the average concentration of chemical elements in soils and rocks over wide areas and to identify possible sources of anomalies. A number of mapping techniques, such as point symbol maps, areal maps, worm diagrams and contour maps, have been developed to display the geochemical characteristics of stream sediments and their spatial representativeness (Govett, 1983).

The spatial behavior of geochemical variables has been also investigated by means of geostatistical techniques based on autocorrelation principles (Matheron, 1965; Wackernagel, 1995; Webster and Oliver, 2001). Geographically weighted regression techniques have also been developed to meet the necessity to partition the study area into more homogeneous sectors

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(e.g. Fotheringham et al., 2000). The efficiency of the above-mentioned techniques is closely dependent on the selection criteria of the *loadings* to be used for weighting the contributions of the points where the variables have been measured. Some relatively recent approaches, based on the conversion of spatial distribution of variables into the frequency domain, rely on multifractal models to separate anomalies from background values (Cheng et al., 1994, 1996, 2000; Cheng, 1999). Fractal geometry has also been used to characterize geochemical landscapes by means of stochastic simulation techniques in the case of low spatial resolution of the geochemical data sets available on stream sediments (Rantitsch, 2001).

Even if these mapping techniques prove to be helpful to build mathematical models of the spatial distributions of the variables and to identify subtended processes at different scales, they only partially or indirectly face the problem of the geographic origin of stream sediments and of the close dependence of their composition from the local geomorphologic processes. Catchments have been used in a number of scientific papers to take into account the provenance area of sediments for developing models of geochemical dispersion (Moon, 1999), mapping anomalous concentrations (Rantitsch, 2004) but also for simply representing geochemical baselines of selected areas (e.g. Bonham-Carter et al., 1987; Ódor et al., 1997; Spadoni et al., 2003). In a previous work Spadoni et al. (2004) emphasized the usefulness to adopt "sample catchment basins" (SCB) as map units. This geographically based approach produces choropleth maps where catchments areas are assumed to be represented, on average, by the same concentrations of the nearest sample downstream. The resulting maps prove to be useful in defining the source areas of geochemical concentrations and, in case, of localized geochemical anomalies. This technique also avoids "mathematical interference" between neighbouring samples. This is a very important aspect especially when neighbouring samples are representative of different catchment systems. However, the SCB approach is not able to produce statistical inference and also shows some remarkable inconsistencies at the closing points of sub-catchments. According to this technique, the concentration value at the sampling point is considered representative only of the catchment upstream. As a consequence, sampling points act as break points in the maps and as conceptual breaks in illustrating the spatial distribution of the variables. It means that the concentration values estimated on the two sides of sampling points (upstream and downstream) are different. This incongruence is of primary importance when facing the problem of a more realistic spatial representation of the geochemical processes especially when considering that the selection of sampling points placement along the hydrographic network is generally due only to practical considerations (e.g. site accessibility) and the need to follow predefined rules of stochastic sampling.

2. Stream sediments and hydrographic network

2.1. Stream sediments

In exploration and environmental geochemistry, one of the most commonly used method of prospecting is based on the study of active stream sediments. According to the definition given by the Forum of the European Geological Surveys (FOREGS), these are represented by the fine and medium size fraction of sediments (<0.150 µm) carried and settled by second order streams (Salminen et al., 1998). Stream sediments can be considered as averagely representative of the outcropping rocks in the drainage basin, upstream of the sampling point (IGS, 1978; Webb et al., 1978; Meyer et al., 1979; Bölviken et al., 1986; Lahermo et al., 1996), and their nature is closely linked to a number of local processes, of natural and anthropogenic origin, that can significantly affect their composition (Fig. 1). These input sources have an inhomogeneous distribution within catchments and can be localized in circumscribed areas (point sources). Conversely, inputs rising from erosion/deposition processes are widespread in the catchments but act with different intensities according to the local geomorphologic and hydrological features.

Most of times, during the "strategic" phase of a survey, when the reconnaissance aspects are prevalent, but often during the subsequent phases too, an accurate modelling of the erosion/deposition processes is missing. The same lack of information affects the distribution of many sources of possible anomaly. In these situations, from a statistical point of view, stream sediments collected at each sampling point have to be necessarily assumed as if they were homogeneously originated from the whole surface of the SCB upstream.

2.2. Hydrographic network

In 1983, Mandelbrot introduced the principles of fractal geometry to provide an appropriate tool to describe the structure and character of spatial objects (Mandelbrot, 1983). In particular, when dealing with geographical objects, jagged irregularity is observed across a range of scales (in a coastline, in a mountainscape,