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Editorial

Continental, regional and local scale geochemical mapping

1. Introduction

This special issue on "*Continental, Regional and Local Scale Geochemical Mapping*", with most of the papers directly or indirectly related to soil, is devoted to the International Year of Soils (IYS). On the 24th of April 2013 at the 146th Council meeting of the Food and Agriculture Organisation (FAO) of the United Nations, and in the framework of the Global Soil Partnership (GSP), the request from the Kingdom of Thailand to proclaim 2015 as the International Year of Soils 2015 was endorsed (http://www.fao.org/globalsoilpartnership/iys-2015/en/). Subsequently, the 68th United Nations General Assembly (20 December 2013) approved the FAO decision (A/RES/68/232; 07/02/2014; http://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/68/232). The aim of the IYS 2015 is to act as a platform for raising awareness of the importance of soil for food security and essential eco-system functions (http://www.fao.org/soils-2015/en/).

The UN Secretary, General Ban Ki-moon's message (SG/SM/16388-OBV/1414; 3/12/2014; http://www.un.org/press/en/2014/sgsm16388.doc.htm) for World Soil Day and the launch of the International Year of Soils (5 December 2014) was: "Today marks the first observance of World Soil Day and the launch of the International Year of Soils (2015). Without healthy soils, life on Earth would be unsustainable. Soils are the foundation of agriculture. They provide vital ecosystem services and the basis for food, feed, fuel, fibre and medical products important for human well-being. Soil is also the largest pool of organic carbon, which is essential for mitigating and adapting to climate change. In an era of water scarcity, soils are fundamental for its appropriate storage and distribution. However, soil degradation is a rapidly increasing problem in all parts of the world. Some 33 per cent of global soils are already degraded through urbanisation. Soil erosion, nutrient depletion, salinity, aridification and contamination are additional threats. For too long the world has taken soils for granted. But soil is a natural resource that is not easily renewed. Sustainable soil management should be a priority for all. I welcome the establishment of the Global Soil Partnership by the Food and Agriculture Organisation of the United Nations (FAO). FAO's World Soil Charter recommends a number of key measures to encourage investment in sustainable soil management as a sound and affordable alternative to restoration and rehabilitation. On World Soil Day, let us pledge to do more to protect this important yet forgotten resource. A healthy life is not possible without healthy soils."

Applied Geochemists all over the World sample soil for different purposes, i.e., the delineation of prospective areas for mineral exploration, assessment of the quality of agricultural and grazing land soil, and last but not least the quality of urban soil. Therefore, applied geochemists have a considerable amount of data on the chemical quality of soil, and they should take this opportunity, given by the IYS 2015 platform, to make their work known, and to assist the global effort in the assessment of the quality of our productive soil, and the urban soil that we are in direct contact with.

This special issue on "*Continental, Regional and Local Scale Geochemical Mapping*" includes in total nineteen papers of which seven are on Continental-, eight on Regional- and four on Local-scale geochemical mapping. The effectiveness of geochemical mapping at different scales is, therefore, well demonstrated.

2. Geochemical mapping scales

Systematic geochemical mapping is considered to be the best available method to document changes in the levels of chemical elements in materials occurring at or below the Earth's surface, such as rock, soil, floodplain or overbank sediment, stream sediment, stream water, ground water and vegetation. Geochemical maps are the principal means of presenting the spatial distribution of chemical elements and compounds in the aforementioned sample media.

Geochemical mapping is performed at different sample densities and map scales depending on the objectives of the project, and the end product is always the interpretation of the spatial variation of chemical elements and compounds. In this Special Issue of the Journal of Geochemical Exploration there are examples of Global- or Continental-, Regional- and Local-scale Geochemical Mapping projects. In Table 1 the objectives and usage of the aforementioned mapping scales are tabulated.

In global- or continental-scale geochemical mapping surveys, the interest is the delineation of large-scale patterns, and the sampling density used in different projects varies from 1 sample site/1600 km^2 in the North American Soil Geochemical Landscapes Project of the United States of America (see Woodruff et al., this issue) to 1 sample site/8300 km^2 in the Environmental Geochemical Monitoring Network of China (see Liu et al., this issue). Some continental-scale geochemical surveys are also considered as national-scale, because they cover the whole country, e.g., Australia, China and the United States of America (see Liu et al.). In national-scale geochemical mapping surveys the objective is to delineate regional-scale patterns, and the sampling density varies from 1 to 2 samples/km^2 to 1 sample/10–25 km^2. Hence, national-scale geochemical surveys are also classified as regional-scale, depending on the sampling density. In local-scale geochemical surveys the sample density increases considerably, i.e., from 5 samples/km^2 to thousands of samples/km^2. However, the sampling density in some local-scale projects does not adhere to any strict rules, as the decision depends on the objectives of the project and available funds.

The relationship between number of samples/km^2 and map scale can be estimated by using as a rule of thumb the constant of 1 data point/cm^2 on the topographical map at any scale, and to always plan the geochemical survey in a grid, even if the samples are not collected

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Table 1
Objectives and usage of global (continental), regional and local scale geochemical mapping projects for mineral exploration and environmental purposes.

Global or Continental	Regional	Local
Geochemical characteristics of different sample media (bedrock, soil, sediment and water) at the global- or continental-scale	Geochemical characteristics of different sample media (bedrock, soil, sediment, water and bio-indicators), which are representative of a specific large region or a geochemical province or even a country (national scale)	Geochemical characteristics of individual metallogenic provinces or of a small area using different sample media (bedrock, soil, sediment, water, bio-indicators (vegetation); in addition, for environmental surveys house dust, road sediment/dust, PM2.5, PM10, and attic dust are used)
(a) Mineral exploration		
Geochemical data are used to evaluate the deviation of regional geochemical variables from the continental geochemical background*, and to delineate anomalous* areas with a mineral potential	Geochemical data are used to evaluate the deviation of local geochemical variables from the regional geochemical background, and to delineate anomalous areas with a mineral potential	Geochemical data uninfluenced by mineralisation processes describe the local geochemical background variation, and the anomalous results provide targets for assessment of mineral potential by drilling
(b) Environmental survey		
Geochemical data are used to evaluate the deviation of regional geochemical variables from the continental baseline* variation, and to delineate anomalous areas caused by human activities	Geochemical data are used to evaluate the deviation of local geochemical variables from the regional geochemical baseline variation, and to delineate anomalous areas caused by human activities	Geochemical data uninfluenced by human activities describe the local geochemical baseline variation, and delineate the anomalous results in areas that have been contaminated by human activities, and are targets for rehabilitation

*Definitions:–*Geochemical background*: The normal element concentration in a particular unmineralised sample type determined by a particular analytical technique; it is a fluctuating surface rather than a given value.–*Geochemical anomaly*: "An abnormally high or low content of an element or element combination, or an abnormal spatial distribution of an element or element combination in a particular sample type in a particular environment as measured by a particular analytical technique" (Govett, 1983, p.30).–*Geochemical baseline*: "A geochemical baseline is the concentration at a specific point in time of a chemical parameter (element, species or compound) in a sample of geological material", determined by a particular analytical technique. "It is a fluctuating surface rather than a given value" (Johnson and Demetriades, 2011, p.18).

at the grid nodes, but are randomly distributed within each grid cell (Table 2). For example, if the sample density is:

- 1 sample/100 km^2 (a grid of 10 × 10 km), and on the map there is 1 data/cm^2, the map scale is 1:1,000,000 (i.e., 10 km × 1000 m × 100 cm = 1,000,000 cm);
- if the sample density is 1 sample/km^2 (a grid of 1 × 1 km) and on the map there is 1 data/cm^2, the map scale is 1:100,000 (i.e., 1 km × 1000 m × 100 cm = 100,000 cm);
- 1 sample/100 m^2 (a grid of 100 × 100 m), and on the map there is 1 data/cm^2, the map scale is 1:10,000 (i.e., 100 m × 100 cm = 10,000 cm);
- 1 sample/10 m^2 (a grid of 10 × 10 m), and on the map there is 1 data/cm^2, the map scale is 1:1000 (i.e., 10 m × 100 cm = 1000 cm).

The nineteen contributions of this Special Issue are grouped according to mapping scale into (i) Continental-, (ii) Regional- and (iii) Local-scale

Table 2
Sample density related to sampling grid and map scale, and examples from different projects and papers in this Special Issue. The vertical bars show some overlap between the Regional and Local scale geochemical mapping.

Nominal sample density	Sampling grid	Map scale	Map classification/mineral exploration stage (examples)
1 sample/10,000 km^2	100 x 100 km	1:10,000,000	Continental
1 sample/6400 km^2	80 x 80 km[a]		Continental (e.g., FOREGS, EGMON; see Liu et al.; Buccianti) Continental (e.g., CGB; see Liu et al.; Wang and CGB Sampling Team; Wang et al.)
1 sample/5200 km^2	≈72 x 72 km		Continental (e.g., NGSA; see Liu et al.)
1 sample/2500 km^2	50 x 50 km	1:5,000,000	Continental (e.g., GEMAS; see Albanese et al.; Ladenberger et al.)
1 sample/1600 km^2	40 x 40 km		Continental (e.g., NASGLP; see Woodruff et al.)
1 sample/100 km^2	10 x 10 km	1:1,000,000	Regional (e.g., Birke et al.; Cicchella et al.; Lancianese et al.; Ohta et al.; Shuguang et al.; Kuzmenkova and Vorobyova; Zuo et al.); or reconnaissance phase in mineral exploration (e.g., Sadeghi et al.)
1 sample/1 km^2	1 x 1 km	1:100,000	
1 sample/250,000 m^2	500 x 500 m	1:50,000	
1 sample/62,500 m^2	250 x 250 m	1:25,000	Regional (or follow–up phase in mineral exploration)
1 sample/10,000 m^2	100 x 100 m	1:10,000	
1 sample/2500 m^2	50 x 50 m	1:5000	Local (e.g., Bavec et al.; Papadopoulou–Vrynioti et al.; Levitan et al.); or Detailed phase in mineral exploration (e.g., Yuan et al.)
1 sample/625 m^2	25 x 25 m	1:2500	Local (or Mining/Ultra detailed phase in mineral exploration)
1 sample/100 m^2	10 x 10 m	1:1000	
1 sample/25 m^2	5 x 5 m	1:500	

Notation: NGSA — National Geochemical Survey of Australia (de Caritat and Cooper, 2011a,b); FOREGS — Forum of European Geological Surveys, Geochemical Atlas of Europe (De Vos et al., 2006; Salminen et al., 2005); EGMON — Environmental Geochemical Monitoring Networks, China (Xie et al., 1997, 2012); CGB — China Geochemical Baselines; GEMAS — Geochemical Mapping of Agricultural and grazing land Soil (Reimann et al., 2014a,b). NASGLP — North American Soil Landscapes Project (Smith et al., 2013, 2014).
[a] Quadrant of the Global Geochemical Reference Network (GRN) of 160 × 160 km (Darnley et al., 1995).