FOREGS, EGG and GEMAS: European Continental-scale Geochemical Projects for Environmental and Resource Management

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Introduction

In Europe, three continental-scale geochemical projects were carried out at different times to fulfil a variety of purposes and uses. The first, the FOREGS Geochemical Atlas of Europe was carried out from 1997 to 2006, with the publication of a two-volume atlas (Salminen *et al.*, 2005; De Vos, Tarvainen *et al.*, 2006), as a contribution to the Global Geochemical Baselines project of the International Union of Geological Sciences for the establishment of the European Global Geochemical Reference Network (Darnley *et al.*, 1995). It covered 26 countries and an area of 4.25 million km^2. The second, European Groundwater Geochemistry (EGG) project was carried out from 2007 to 2010, with the publication of a one-volume atlas (Reimann and Birke, 2010); this rather unique cost-effective project used as sampling medium bottled mineral water as a proxy to the geochemistry of groundwater. The third, GEMAS (GEochemical Mapping of Agricultural and grazing land Soil), was carried out from 2008 to 2014, with the publication of a two-volume atlas (Reimann *et al.*, 2014a, b); it covered 33 European countries and an area of 5.6 million km^2.

Materials and methods

In the FOREGS Geochemical Atlas of Europe project, samples of stream sediment (n=799), stream water (n=807) and residual soil (top 0-25 cm; n=845; bottom >75 cm; n=788) were collected from drainage basins of <100 km^2 in area, and floodplain sediment (top 0-25 cm; n=743) from drainage basins of 1000-6000 km^2 in area; the average density of each sampling medium was approximately 1 sample/4700 km^2. Methods of sample collection, sample preparation, laboratory analysis, quality control procedures and data processing are described in Salminen, Tarvainen *et al.* (1998) and Salminen *et al.* (2005). The EGG project bottled mineral water samples were purchased from supermarkets (n=884), and the analytical, quality control and data processing procedures are described in Reimann and Birke (2010). The field methods used in the GEMAS project for the sampling of agricultural soil (0-20 cm; n=2108), and grazing land soil (0-10 cm; n=2023), laboratory methods and quality control procedures are described in detail in EGS GEG (2008) and Reimann *et al.* (2014a).

Results and discussion

As Li is an important critical element for future sustainable technologies according to UNEP (2009), but is not yet in the list of critical materials of the European Commission (2017), it is used as an example. The geochemical maps of Li in agricultural soil from the GEMAS project (Figs. 1a), and Li in floodplain sediment from the FOREGS project (Fig. 1b) display overall similar patterns. The most striking feature on all geochemical maps is the discrete element concentration break at the maximum extent of the last glaciation, a feature that is even shown on the map of Li in bottled mineral water from the EGG project (Fig. 1c). The agricultural soil, floodplain sediment and bottled mineral water maps, display overall lower Li values to the north of this break compared to those in the south. Hence, there are at least two distinctly different Li background ranges at the continental-scale.

Comparing the geochemical maps with the Li mineralisation and mineral deposits map from the ProMine Mineral Database (Fig. 1d), the FOREGS, GEMAS and EGG project continental-scale geochemical maps exhibit overall anomalous or elevated concentrations in the vicinity of most of these occurrences. From the mineral exploration point of view, the anomalous samples shown on the bottled mineral water Li map (Fig. 1c) should be of even greater interest, as they depict the geochemistry at depth. It is stressed that in all projects the objective was to map the geochemical background element variation. However, all three geochemical maps (Fig. 1) show many areas that warrant more detailed surveys for the delineation of areas of mineral potential for Li.

In conclusion, the results of the three continental-scale geochemical surveys demonstrate the variable geochemical background across Europe. It needs to be defined for each determinand in each sample medium. For environmental impact studies a site-specific background level will need to be established. Further, all data sets can be used for area selection for more detailed mineral exploration.

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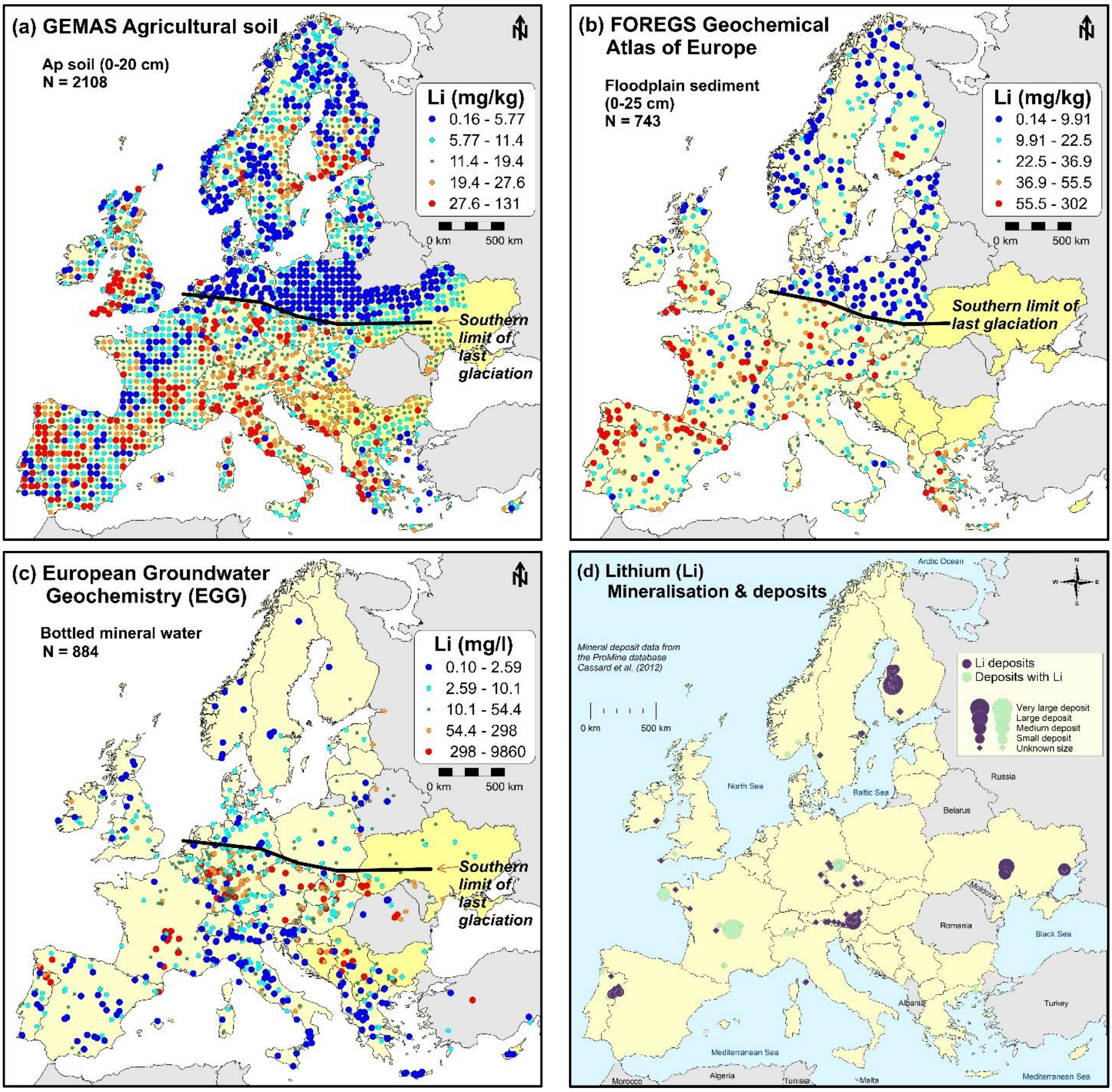

Figure 1. Geochemical maps showing the distribution of Li in (a) GEMAS agricultural soil (hot *aqua regia* extraction); (b) FOREGS floodplain sediment (total), and (c) EGG bottled mineral water; (d) Li mineral deposit map from the ProMine Mineral database (http://minerals4eu.brgm-rec.fr/); pale yellow indicates the 26 countries covered by FOREGS, and darker yellow the additional 6 countries covered by GEMAS (Albania was covered by FOREGS and EGG but not by GEMAS).

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