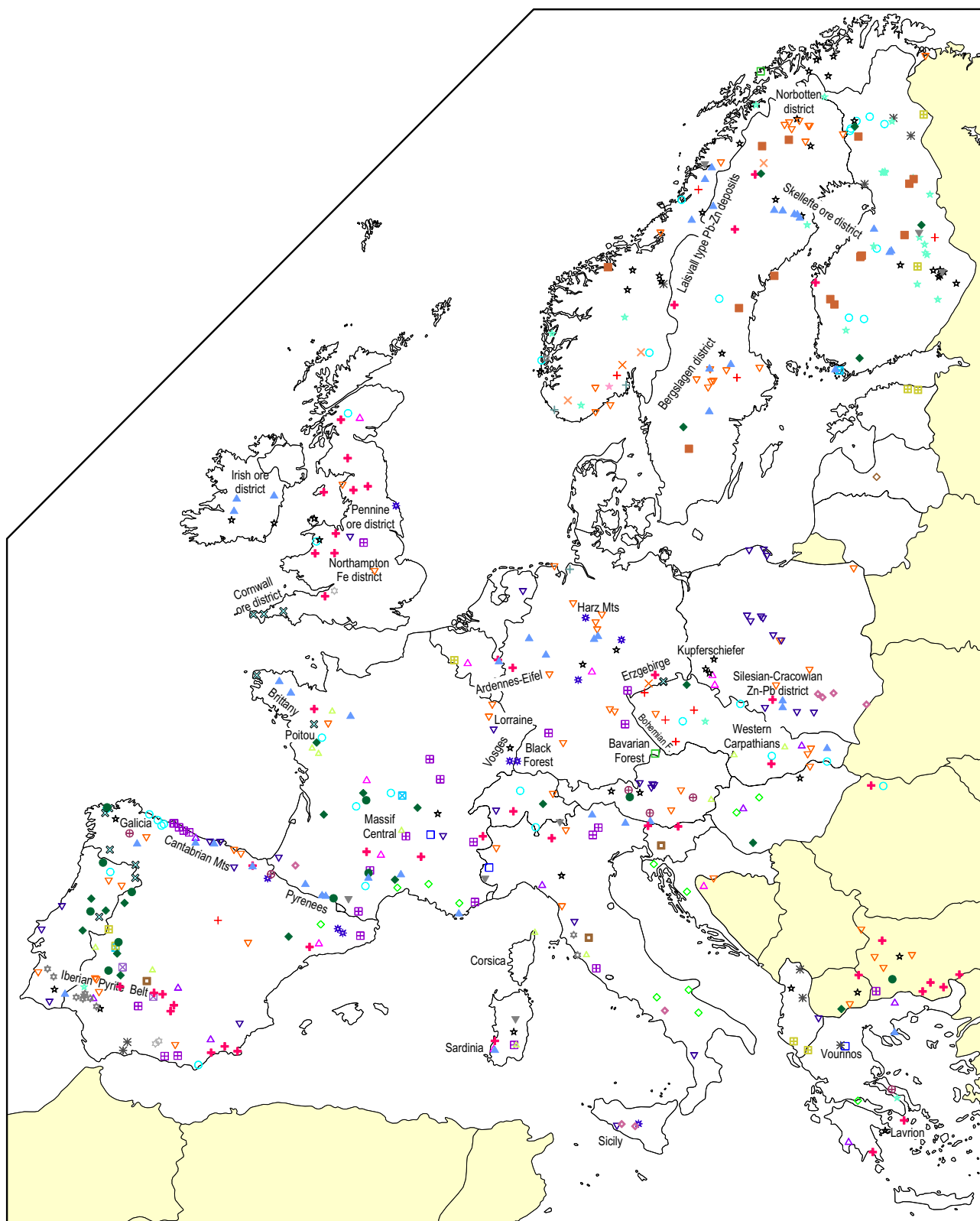


Major mineral deposits of Europe

0 500 1000 Kilometers



Deposit symbol, major and (minor) elements [number of deposits]

-  Ag +/- (As, Au, Ba, Co, Sb, Pb, U, Zn) [9]
-  Al [12]
-  Asbestos [3]
-  Au +/- (Ag, As, Ba, Bi, Co, Cu, Pb, Sb, Te, U, Zn) [33]
-  Ba +/- (Cu, F, Pb, Zn) [10]
-  Bi +/- (W) [2]
-  Co +/- (As, Cu, Ni) [2]
-  Cr +/- (Ni, PGE, V) [9]
-  Cu +/- (Ag, As, Au, Ba, Co, Fe, Hg, Mo, Ni, Pb, pyrite, Se, Sn, Zn) [49]
-  F +/- (Ba, Cu, Pb, U, Zn) [25]
-  Fe +/- (Ba, Cu, Hg, Mn, Ni, P, Pb, pyrite, V, Ti, Zn) [66]
-  Graphite [2]
-  Gypsum [1]
-  Hg [3]
-  K [10]
-  Li +/- (Sn, Be, Ta) [3]
-  Magnesite [6]
-  Mn [9] - The Tartana deposit at Drama in Greece contains also Cu, Pb, Zn
-  Mo [3]
-  Na, Cl [33] - The Klodaws deposit in Poland contains also K
-  Nb, REEs, Th [1] - Sove deposit in Norway
-  Ni +/- (Co, Cu, Fe, PGE, Zn) [24]
-  P [9] - The Sokli deposit in Finland contains also Nb, U
-  Pb +/- (Ag, Au, Ba, Cd, Cu, F, Pb, REEs, Sb, U, Zn) [46]
-  Pyrite +/- (Ag, Au, Cu, Fe, Pb, Zn) [11]
-  S [8]
-  Sb +/- (Au, W) [12]
-  Sn +/- (Bi, Cu, Pb, Ta, U, W, Zn) [13]
-  Sr [3]
-  Talc [7] - The Lahnaslampi & Horsmanaho deposits in Finland contain also Ni
-  Ti +/- (Fe, Ni, P, Zr) [3]
-  U [21] - The Ranstad deposit in Sweden contains also Mo and oil
-  V +/- (Fe, Ti) [15]
-  W +/- (Cu, Mo, Sn) [11]
-  Zn +/- (Ag, Au, Ba, Cu, Hg, Ge, Pb, pyrite) [46]

Compiled by A. Demetriades¹ by abstraction of relative mineral deposit data from the digital version of the Mineral Atlas of the World - Europe Map (NGU 2003) with additional national data and information provided by P. Klein², W. De Vos³, P. Eilu⁴, M. Birke⁵, M.J. Batista⁶, L. Martins⁶, J. Locutura⁷ and K. Lax⁸

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For details on the mineral deposits consult the Website
<http://www.gtk.fi/publ/foregsatlas/>

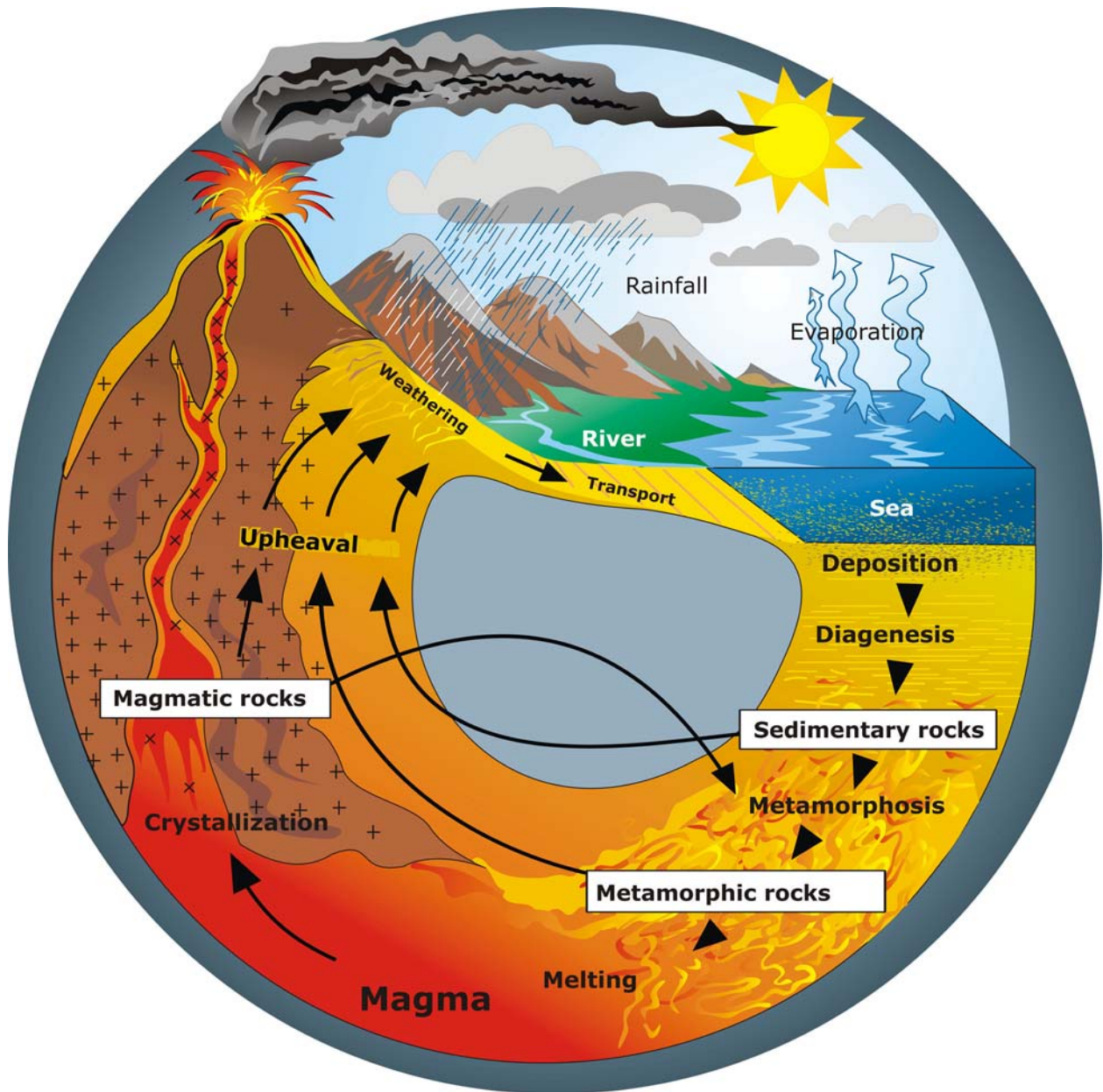


Figure 56. Great geochemical cycle. Drawing: Tapani Tervo, Geological Survey of Finland.

DISCUSSION AND CONCLUSIONS

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The FOREGS – EuroGeoSurveys geochemical baseline mapping programme provides European decision makers, scientists and all interested parties, with real continent-wide information on the distribution of elements in the near-surface environment at the end of the twentieth century. It is the baseline against which the next generations will quantify changes, whether natural or human-made. The programme started with agreements on standardised methods for sample site selection, sampling procedures, sample preparation, analytical techniques, quality assurance and database management, which is the best way to achieve a harmonised and high quality digital data set covering 26 European countries (Salminen, Tarvainen *et al.* 1998, Tarvainen *et al.* 2005). The same level of harmonisation could not have been achieved by simply merging previously existing national data sets (Darnley *et al.* 1995, Bölviken *et al.* 1990, 1996, Plant *et al.* 1990, 1996, 1997, Salminen *et al.* 2005). The analytical work was assigned to a number of Geological Survey laboratories. Each laboratory was in charge of carrying out a range of analyses with a particular agreed methodology or analytical equipment, on a certain sample type (soil, humus, stream sediment, stream water or floodplain sediment), and of applying internationally accepted quality control procedures on all samples analysed (Sandström *et al.* 2005).

The standardised protocol guaranteed homogenous baseline data for soil and sediment samples throughout Europe in accordance to the conditions set-up by the international ‘*Global Geochemical Baselines*’ project, carried under the auspices of the International Union of Geological Sciences (IUGS) and International Association of GeoChemistry (IAGC) (Darnley *et al.* 1995). It can still be argued that the extended sampling period from 1998 to 2001, with its inherent seasonal variation, may have affected the element concentrations, especially in stream water samples, which are normally considered to be

more susceptible to change. However, the geochemical maps show that the continent-wide patterns can be explained satisfactorily without the strong seasonal variations playing a significant part.

The geochemical distribution maps illustrate the influence of the internal geological part and the external environmental part of the great geochemical cycle (Mason 1952, Fortescue 1980), and also the human impact (O’Connor 2005).

The geological part of the geochemical cycle (Figure 56) includes the plate tectonic development of our continent and the formation of various rock types (Plant *et al.* 2005, Salpeteur *et al.* 2005). The internal energy of our planet is the driving force behind tectonic plate movements, rifting and collisions of (micro)continents. Internal heat is responsible for melting of rock masses and subsequent extrusion of magma as volcanic rocks or intrusion as plutonic rocks. Crystallisation of a magma is a powerful agent of geochemical differentiation. Continental collisions give rise to mountain chains with great geological complexity, including fold belts, metamorphic massifs and large intrusions. With geological time, these continental rocks are weathered and eroded, their constituents are transported and some of them are deposited in sedimentary basins, and may in turn take part in a next continental collision. These processes occur in cycles through geological time. At every stage in the cycle, there are mechanical, chemical and physical forces at work that separate or recombine the chemical elements. The result is a highly differentiated geological and geochemical landscape, with some elements showing affinity with each other in specific geological settings (*e.g.*, Ni, Co, Cr – see relevant maps), and some elements avoiding each other (*e.g.*, Si and Ca – see relevant maps).

Enough time has passed for geochemical differentiation to take place during the geological development of our European continent: the

oldest rocks in the current mapping area are 3500 million years old, in Fennoscandia. Certain rock units, such as ophiolite masses in Greece, alkali volcanics in Italy or greenstone belts in Lapland, are shown as anomalies in several soil and sediment geochemical maps. *For example*, most of Greece and Albania are shown as a major anomaly in the subsoil and topsoil nickel maps. The same nickel anomaly is seen in the stream sediment and even in the floodplain sediment. Floodplain sediment was collected from different alluvial soil types hundreds of kilometres downstream from the soil sampling sites. Residual soil reflects the composition of the local underlying bedrock, while floodplain sediment is a natural composite sample of a greater drainage basin. At the continental scale, the large geochemical anomalies are the same for these different sample types: extensive anomaly patterns, reflecting the geological history of our continent, may override any differentiation caused by weathering, transportation, soil development or human influence in the surface environment (see maps of HREEs: Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu in Norway).

The environmental part of the great geochemical cycle includes surficial processes that ultimately depend on the energy of the sun. After upheaval to the surface environment the rocks are weathered, and the weathered material is transported by water, wind and ice. Rock particles are deposited as sediments, and the small cycle ends-up with formation of sedimentary rocks. In addition to the transportation in particulate form, elements are also transported in water (for example, complexed with organic material), in air and by glaciation. These processes are also affected by biological activity, climate and topography. Various conditions in the surface environment affect the development of the different soil types. Soil forming processes can naturally change the distribution of elements between subsoil and topsoil. The soil geochemical maps of the FOREGS-EuroGeoSurveys atlas represent the geochemistry of residual soil, which generally reflects the chemical composition of the underlying bedrock. On crystalline bedrock, there is also a systematic difference between the glacial till area encompassing Fennoscandia and Scotland, and the rest of Europe. The dilution of many element concentrations in the marginal area of the last glaciation is another geological process.

At the regional scale, pedogenetic or soil-forming processes can be the critical driving force for the element distribution. *For example*, the FOREGS-EuroGeoSurveys Geochemical Baseline Mapping Programme, and the Baltic Soil Survey pedogeochemical mapping programme, show very different anomalies for Ni in the topsoil of Northern Europe. In the Baltic Soil Survey (Reimann *et al.* 2003), agricultural soil was collected from a regular 50 km x 50 km grid. The grid sampling included various soil types. In the FOREGS-EuroGeoSurveys programme, only one type of soil (residual soil) was selected for sampling. The FOREGS-EuroGeoSurveys soil samples reflect, therefore, the variation of elements in bedrock or soil parent material, whereas the Baltic Soil Survey shows that agriculture is carried out on diverse soil types in different parts of northern Europe.

The geological cycle is the major driving force for the distribution of most elements in the atlas. However, the climatic and other surficial factors, including human influence, are extremely important to understand the chemical characteristics of elements in stream water. As shown by Ander *et al.* (2006, this volume), in addition to total chemical composition, pH and Eh values, as well as the amount of dissolved organic carbon, are key issues in the interpretation of solute saturation and aqueous speciation of stream water samples. The environmental part of the geochemical cycle controls also the amount of organic carbon in soil and sediment. Soil layers rich in organic carbon can form barriers to limit the transportation of trace elements in the soil profile.

The human impact on Europe has been profound and pervasive. Europe, with its diverse landscapes and climatic conditions, its abundance of metal ores and energy minerals such as coal, oil and gas, have shaped our cultural and technological development over a very long time (O'Connor 2005). The oldest document settlement was at Isernia in central Italy and dated at 730,000 years old. Ever since that time the European landscape is subject to a continuous change with the 18th Century Industrial Revolution changing drastically the land, and polluting the near-surface environment to a variable degree from the agricultural, industrial and urban activities.

Among the sample media of the FOREGS-EuroGeoSurveys programme, humus is mostly

affected by anthropogenic input (airborne). However, the results are difficult to interpret, because of the heterogeneous material. Especially, if the humus layer is thin, varying amounts of mineral detritus are easily intermixed with the humus sample. Hence, humus is not the best material for continent-wide comparison. In some cases, the humus samples revealed the same anthropogenic input that has been recorded in the moss geochemical sampling (Siewers et al. 2000). However, humus samples represent anthropogenic input over a long time scale, thus there may be old anomalies, which are not seen in the latest moss samples, but are observed in humus.

In addition to humus samples, topsoil and stream water samples, and in some cases stream and floodplain sediments, can be affected by anthropogenic input. Elements and compounds, with a clear human induced contribution in one or more sample media, are Cd, Hg, Pb, Cu, Zn and NO₃.

The FOREGS-EuroGeoSurveys mapping programme was designed to reveal large continental scale geochemical anomalies or patterns. Some small geological units of local significance cannot be seen in such a low density sampling survey. On the other hand, some single anomalies can be over-expressed in the randomised sample design used. The presentation technique, combining colour surface and dots, shows the scale of the anomalies. Each single anomaly can be identified as a big dot on the map, but red colours reveal only those geochemical anomalies that are based on several samples.

The FOREGS-EuroGeoSurveys programme gives data for elements infrequently investigated at a large scale, *e.g.*, Tl, In, Be, Li, Bi, REE, U, Th, *etc.* Their interpretation is only tentative, and based mainly on our knowledge of the geology and mineralisation of the continent. It can only be hoped that future studies will contribute to the understanding of the patterns found in the present geochemical mapping project.

The geochemical distribution maps and analytical data are now available for comparison with other environmental and health related data sets, and they may contribute to identifying or even solving some problems in these domains.

In conclusion, the FOREGS-EuroGeoSurveys '*Geochemical Atlas of Europe*' provides invaluable information about the natural and anthropogenic induced concentrations of chemical elements in materials of the near-surface environment, where we live on, grow our crops, raise our livestock, and from which we extract our drinking water, and other raw materials, including mineral wealth. The geochemical distribution maps show distinct geographical differences in the levels of potential harmful elements from natural sources, including lithology and mineralisation. This geochemical variation shows how difficult it is to define *a single guideline value* for soil and sediment to be applied all over Europe. Finally, the geochemical maps could be used to identify potential geohazard and geohealth risks for more detailed investigations.