DISTRIBUTION OF ELEMENTS IN FLOODPLAIN SEDIMENT

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The term "*floodplain sediment*" is synonymous with "*overbank sediment*", "*levee sediment*", "*vertical accretion deposit*" or "*alluvial soil*". An arbitrary distinction between overbank and floodplain sediments was made, however, by Darnley *et al.* (1995), with respect to the size of the drainage basin, *i.e.*, <100 km^2 for overbank sediment and 1000-6000 km^2 for floodplain sediment, which in practice was reduced to 500-6000 km^2. This classification was subsequently followed in the ***FOREGS Geochemical Mapping Field Manual*** (Salminen, Tarvainen *et al.* 1998). The term *'overbank sediment'* is used for alluvium (clay and silt) accumulated adjacent to low-order streams (where stream sediment and water samples were collected in this survey), and *'floodplain sediment'* to alluvium adjoining high-order drainage channels of typically larger rivers; they are both alluvial sediments, deposited, in low energy environments, from suspension on a floodplain by flood water that cannot be contained within the stream channel.

From the point of view of geochemical mapping, *overbank sediment* samples represent small drainage basins, which can be used in national geochemical mapping programmes for comparatively detailed regional surveys (Ottesen *et al.* 2000). Whereas, *floodplain sediment* samples represent much larger basins, and are a significant sampling medium for continental or global scale geochemical mapping, since they are representative of a large area (Xie and Yin 1993, Cheng *et al.* 1997, Xie and Cheng 1997, 2001, Salminen *et al.* 2005, Xueqiu 2005).

Floodplain or overbank sediments can be used in the search for new mineral resources, in monitoring environmental change, and also in the prediction of potential environmental hazards. Their effectiveness and suitability in national and continental scale geochemical mapping has already been demonstrated by studies firstly in Norway (Ottesen *et al.* 1989, 2000), and subsequently in other European countries, during the research work carried out by the Working Group on "*Regional Geochemical Mapping*" of the Western European Geological Surveys (WEGS) and subsequently FOREGS (Bølviken *et al.* 1990, 1993, 1996, Demetriades *et al.* 1990, 1993, 1994, Edén and Björklund 1996, De Vos *et al.* 1996, Hindel *et al.* 1996, Demetriades and Volden 1997, Pulkkinen and Rissanen 1997, Van der Sluys *et al.* 1997, Swennen *et al.* 2000); similar work was carried out in China (Xie and Yin 1993, Cheng *et al.* 1997, Xie and Cheng 1997, 2001, Xueqiu 2005). According to these applied research studies, floodplain or overbank sediment reflects the geochemistry of overburden in the entire upstream river basin, because fine-grained alluvium (silt and clay) is carried in suspension from eroded source materials over very long distances, and is finally deposited on the floodplain in low energy environments.

Interpretation of floodplain sediment results, presented in Part 1 of the Geochemical Atlas of Europe (Salminen *et al.* 2005), required information about the geology and mineralisation of the upstream drainage basin, as well as industrial and urban contaminating activities. For the geology, regional geological maps of Europe and information were used (Fullard and Darby 1962, Kirkaldy 1967, Bederke and Wunderlich 1968, Ager 1975, Ziegler 1990, Asch 2003, 2005), and simplified national maps in papers and geochemical atlases (Odehnal 1966, Dunham 1969, Dimitrijevic *et al*. 1971, Beck-Mannagetta and Matura 1980, Schönenberg and Neugebauer 1987, Koljonen 1992, Slowanska 1997, Reimann *et al.* 1998, 2003, Jackson 2004, Salminen *et al.* 2004, Dill *et al.* 2005), and for mineralisation the digital version of the 1:10 000 000 scale map of the International Metallogenic Map of Europe (NGU, 2003), the Metallogenetic map of Europe (Laffitte 1968-1970), the Atlas of Economic Mineral Deposits (Dixon 1979), as well as the volumes of the Mineral deposits of Europe (Bowie *et al.* 1979, Dunning *et al.* 1982, 1989, Dunning and Evans 1986), and relevant national information on mineralisation (Ribeiro 1979, 1990, Béziat and Coulomb 1990, Stolojan and Viland 1991, Faure *et al*. 2004, Béziat and Bornuat 1995, Vozar and Kacer 1996, Bouchot *et al*. 2005). Some important mineral deposits are shown on Map 15. A lithological map is being prepared and can be downloaded from website.

An attempt has been made to give the fullest possible interpretation of floodplain sediment patterns, using experience from mineral exploration, and that gained from the pilot and research projects of the former WEGS and FOREGS Working Group on '*Regional Geochemical Mapping*' (Bølviken *et al.* 1990, 1993, 1996, Demetriades *et al.* 1990). The reason lies in the fact that floodplain or overbank sediment is one of the most promising sample media, which can be used in a cost-effective manner to map the geochemistry of the terrestrial surface of our planet under the auspices of the IUGS/IAGC "*Global Geochemical Baselines*" project. Also, it can be used to monitor environmental change in Europe by setting up permanent monitoring stations in selected, if not all, large drainage basins.

In the description of element distribution in floodplain sediment, as for soil and stream sediment, the following definitions were adopted with reference to the coloured maps and histograms in Part 1 of the Geochemical Atlas of Europe (Salminen *et al.* 2005):

- ***Low values*** group the three lowest shades of blue in the colour scale, corresponding to values ranging from the minimum up to the 25th percentile, defined as "*very low*" and "*low background*" concentrations in Part 1 (refer to Part 1, Tarvainen *et al.* 2005, p.97).
- ***High values*** group the three highest shades of red in the colour scale, corresponding to values from the 75th percentile up to the maximum, defined as "*high*", "*very high*" and "*highly anomalous*" concentrations in Part 1 (Tarvainen *et al.* 2005, p.97).

Correlation coefficients were calculated with Pearson's product-moment linear correlation method (Table available in electronic format on website), after elimination of outliers, and subsequent pairwise deletion of absent data. Outliers were defined as values exceeding by a factor of 1.5 other nearby results for a given element, when all analytical results are ranked. They are generally visible on the histogram accompanying each map in Part 1 of the Geochemical Atlas. Sometimes outliers differ by a factor of <1.5 among themselves, but a gap of >1.5 on the histogram may appear after a few values (when data are ranked). A decision was, therefore, taken to remove a maximum of four outliers for the calculation of linear correlation coefficients. A list of outliers for floodplain sediments is given in Table 6.

Throughout the text, the following notation is used for the correlation coefficients:

- *Very strong correlation*: >0.8
- *Strong correlation*: between 0.6 and 0.8
- *Good correlation*: between 0.4 and 0.6
- *Weak correlation*: between 0.3 and 0.4

Acknowledgements

The use of overbank or floodplain sediments in continental scale geochemical mapping would have not been possible if their potential was not foreseen by Professor Bjorn Bølviken, who was the Chairman from 1986 to 1993 of the first Working Group on Regional Geochemical Mapping of the Western European Geological Surveys (WEGS), and subsequently the Forum of European Geological Surveys (FOREGS). During the last meeting of the Working Group in Hannover, the participating members (Otmar Schermann from Austria, Erwin Decoene from Belgium, Reijo Salminen from Finland, Roland Hindel from Germany, Alecos Demetriades from Greece, Jim Bogen and Rolf Tore Ottesen from Norway) signed on the 1st of July 1993 a card, given to Professor Bølviken, with the following dedication:

"Bølviken's Regional Geochemical Mapping of Western Europe towards the Year 2000: A very important project ahead of its time. Conceived by a person with extreme foresight and supported by Europeans with different cultures, proving that European unity could be realised as long as people meet and discuss matters openly and with integrity. Thank you for bringing us together and hope that we meet again to complete the 'dream'".

This 1993 '*dream*' has now become a reality, and this section is, therefore, dedicated to Professor Bjørn Bølviken as an acknowledgement of his pioneering role.

In the far east, in China, there is another pioneer with foresight, Professor Xuejing Xie, who has proven, on the continental scale, the suitability of floodplain sediment as the most cost-effective sampling medium for global geochemical mapping. We are certain that Professor Bjørn Bølviken would not mind sharing this dedication and acknowledgement with Professor Xuejing Xie, since floodplain or overbank sediment may one day be the sampling medium that will be used for the geochemical mapping of the globe, our home planet.

Finally Dr Clemens Reimann from the Geological Survey of Norway gave valuable comments on this chapter.

Table 6. Outliers of the floodplain sediment data. Criterion: an outlier has a value exceeding by factor of 1.5 other nearby results, when all analytical results are ranked. A maximum of four outliers were removed for the calculation of linear correlation coefficients.

Sample	Country	Element	Unit	Value	Next value	Factor
N26E14F4	Greece	As	mg kg^{-1}	390	197	1.98
N28W05F1	Portugal	Be	mg kg^{-1}	47.5		
N29W05F2	Spain	Be	mg kg^{-1}	21.81		
N29W05F3	Spain	Be	mg kg^{-1}	15.3	10.1	1.51
N26E14F4	Greece	Cd	mg kg^{-1}	23.6	15.2	1.55
N26W03F3	Spain	Cu	mg kg^{-1}	495		
N33E11F2	Slovakia	Cu	mg kg^{-1}	495		
N26W05F1	Portugal	Cu	mg kg^{-1}	435	267	1.63
N44E07F5	Sweden	Dy	mg kg^{-1}	19.6	12.9	1.52
N44E07F5	Sweden	Er	mg kg^{-1}	12.2	7.29	1.67
N36E04F2	Germany	Fe_2O_3	%	35.8		
N44E07F5	Sweden	Fe_2O_3	%	32.9	10.4	3.17
N34W03F2	UK	Ga	mg kg^{-1}	52.0	29.0	1.79
N44E07F5	Sweden	Gd	mg kg^{-1}	22.6	14.8	1.53
N29E07F5	Italy	Hg	mg kg^{-1}	4.39		
N33E09F4	Slovakia	Hg	mg kg^{-1}	3.56	2.19	1.63
N44E07F5	Sweden	Ho	mg kg^{-1}	4.47	2.74	1.63
N44E07F5	Sweden	Lu	mg kg^{-1}	2.21	1.15	1.92
N44E07F5	Sweden	MnO	mg kg^{-1}	6.61	0.99	6.68
N40E03F4	Norway	Mo	mg kg^{-1}	191		
N44E07F5	Sweden	Mo	mg kg^{-1}	53.2	6.59	8.08
N19W10F1	Spain	Nb	mg kg^{-1}	125	43.0	2.91
N26E14F2	Greece	Ni	mg kg^{-1}	1 080		
N28E11F1	Albania	Ni	mg kg^{-1}	947	555	1.71
N36E04F2	Germany	P_2O_5	%	2.61		
N36E07F2	Germany	P_2O_5	%	1.63	1.06	1.54
N26E14F4	Greece	Pb	mg kg^{-1}	7 084		
N34E03F1	Belgium	Pb	mg kg^{-1}	3 614		
N37W01F1	UK	Pb	mg kg^{-1}	2 075	1 190	1.74
N33E11F3	Slovakia	Sb	mg kg^{-1}	99.4	54.5	1.82
N34W02F3	UK	Sn	mg kg^{-1}	649		
N28W04F2	Portugal	Sn	mg kg^{-1}	260		
N28W05F1	Portugal	Sn	mg kg^{-1}	238		
N28W05F4	Portugal	Sn	mg kg^{-1}	181	118	1.53
N27W02F2	Spain	Sr	mg kg^{-1}	1 661	1 063	1.56
N28W05F1	Portugal	Ta	mg kg^{-1}	38.1		
N34W03F2	UK	Ta	mg kg^{-1}	15.1	5.78	2.62
N44E07F5	Sweden	Tm	mg kg^{-1}	1.89	1.08	1.75
N44E07F5	Sweden	U	mg kg^{-1}	89.0	18.0	4.94
N28W05F4	Portugal	W	mg kg^{-1}	123		
N29W05F3	Spain	W	mg kg^{-1}	103.8		
N28W04F2	Portugal	W	mg kg^{-1}	84.2		
N35W01F2	UK	W	mg kg^{-1}	82.2	42.3	1.94
N44E07F5	Sweden	Y	mg kg^{-1}	130.5	56.4	2.31
N44E07F5	Sweden	Yb	mg kg^{-1}	13.0	7.92	1.64
N26E14F4	Greece	Zn	mg kg^{-1}	4 91		
N34E03F1	Belgium	Zn	mg kg^{-1}	3 643	1 764	2.07