

## Introduction

See section on Rare Earth Elements (REEs).  
Table 36 compares the median concentrations

of Ho in the FOREGS samples and in some reference datasets.

Table 36. Median concentrations of Ho in the FOREGS samples and in some reference data sets.

<b>Holmium (Ho)</b>	<b>Origin – Source</b>	<b>Number of samples</b>	<b>Size fraction mm</b>	<b>Extraction</b>	<b>Median mg kg<sup>-1</sup></b>
Crust <sup>1)</sup>	Upper continental	n.a.	n.a.	Total	0.83
<b>Subsoil</b>	<b>FOREGS</b>	<b>790</b>	<b>&lt;2.0</b>	<b>Total (ICP-MS)</b>	<b>0.74</b>
<b>Topsoil</b>	<b>FOREGS</b>	<b>843</b>	<b>&lt;2.0</b>	<b>Total (ICP-MS)</b>	<b>0.68</b>
Soil <sup>2)</sup>	World	n.a.	n.a.	Total	0.7
<b>Water</b>	<b>FOREGS</b>	<b>807</b>	<b>Filtered &lt;0.45 µm</b>		<b>0.002 (µg l<sup>-1</sup>)</b>
Water <sup>2)</sup>	World	n.a.	n.a.		0.0014 (µg l <sup>-1</sup> )
<b>Stream sediment</b>	<b>FOREGS</b>	<b>848</b>	<b>&lt;0.15</b>	<b>Total (XRF)</b>	<b>0.92</b>
<b>Floodplain sediment</b>	<b>FOREGS</b>	<b>743</b>	<b>&lt;2.0</b>	<b>Total (XRF)</b>	<b>0.68</b>

<sup>1)</sup>Rudnick & Gao 2004, <sup>2)</sup>Ivanov 1996.

## Ho in soil

The median Ho content is 0.74 mg kg<sup>-1</sup> in subsoil and 0.68 mg kg<sup>-1</sup> in topsoil; the range varies from <0.02 to 2.58 mg kg<sup>-1</sup> in subsoil and from 0.03 to 9.16 mg kg<sup>-1</sup> in topsoil. The average ratio topsoil/subsoil is 0.923.

Holmium in subsoil shows low values (<0.500 mg kg<sup>-1</sup>) throughout central and northern Finland, the glacial drift covered area from Poland to the Netherlands, the Paris Basin in France, the western Alps and Rhône valley, central Hungary, central Portugal, southern Spain, part of east Spain, and part of eastern Greece.

High Ho values in subsoil (>1.00 mg kg<sup>-1</sup>) are located mainly in the crystalline basement of the Iberian Massif in northern Portugal and north-west Spain, in the Italian and north Greece alkaline magmatic provinces (Plant *et al.* 2005), in

soil on karst of Slovenia and Croatia, in southern Hungary and Austria, in Brittany and the loess/palaeoplacer area of northern France to Germany, south-western Norway, and northern Sweden (Salpeteur *et al.* 2005). Point anomalies of Ho appear in western Greece, associated with terra rossa soil and phosphorite mineralisation, and in northern Ireland near the Mourne granite.

In topsoil, the Ho pattern is very similar to that of the subsoil. There is a point anomaly in Gran Canaria in alkali basalt.

Holmium in soil has a strong to very strong correlation with the other REEs. The geochemical behaviour of Ho is most similar to that of the other heavy REEs (Gd, Tb, Dy, Er, Tm, Lu and Yb). For more information, see the section on REEs.

## Holmium in stream water

Holmium values in stream water range over two orders of magnitude from <0.002 to 0.17 µg l<sup>-1</sup> (excluding an outlier of 0.71 µg l<sup>-1</sup>), with a median value of 0.002 µg l<sup>-1</sup>. About 50% of the

data are less than the analytical limit of quantification (0.002 µg l<sup>-1</sup>). Holmium data correlate very well with terbium. See section on REE for a general discussion.

Lowest Ho values in stream water ( $<0.003 \mu\text{g l}^{-1}$ ) are uniformly found in all of southern and central Europe, in Estonia, in north-western and south-eastern England, in south-western Norway, in central Norway and Sweden and in northern Finland. Highest Ho concentrations ( $>0.03 \mu\text{g l}^{-1}$ ) are found in southern Norway, southern Sweden and southern Finland, over Precambrian terrains (mostly intrusive and metamorphic rocks).

Enhanced values in stream water (between  $0.01$  and  $0.03 \mu\text{g l}^{-1}$ ) also occur in southern Norway, in central and northern Sweden, and southern Finland over Precambrian terrains and

the Fennoscandian Caledonides (mostly intrusive and metamorphic rocks), in Denmark on glacial drift, in southern Ireland and in northern Scotland, characterised by Caledonides, and in France (Brittany). In northern Ireland, the anomalously high Ho data are associated with the Mourne granite and thick drift peat cover giving rise to acid water resulting in the dissolution of trace metals into solution. Highly anomalous Ho values in northern Germany are associated with high DOC values.

### Ho in stream sediment

The median Ho content in stream sediment is  $0.89 \text{ mg kg}^{-1}$ , and the range varies from  $0.04$  to  $16.7 \text{ mg kg}^{-1}$ .

The Ho distribution map shows low stream sediment values ( $<0.64 \text{ mg kg}^{-1}$ ) in eastern and northern Finland, in the North European plain from Poland to the Netherlands on glacial drift, in western Ireland, in parts of south, east and north Spain, in the French-Swiss Jura Mountains, in the western Alps and the northern Apennines, part of the south Apennines, in north-easternmost Italy, coastal Croatia, and north-west Greece.

High Ho values in stream sediment ( $>1.22$

$\text{mg kg}^{-1}$ ) occur in the Variscan part of the Iberian Peninsula on felsic rocks in north Portugal, Galicia and the Sierra de Gredos in Old Castilia (Spain); in the Massif Central in France (Variscan granite) extending into the Poitou region to the north-west; in most of Norway, north Sweden, parts of south and east Sweden, a point anomaly in northern Estonia (phosphate deposits), eastern Scotland, the Bohemian Massif, the eastern Alps and Albania.

Holmium in stream sediment has a strong to very strong correlation with Th, U and the REEs. For more information, see the section on REEs.

### Ho in floodplain sediment

Total Ho values in floodplain sediment, determined by ICP-MS, vary from  $0.5$  to  $4.47 \text{ mg kg}^{-1}$ , with a median of  $0.68 \text{ mg kg}^{-1}$ .

Low Ho values in floodplain sediment ( $<0.47 \text{ mg kg}^{-1}$ ) occur in northern and eastern Finland on gneiss and greenstone of the Fennoscandian Shield, the glacial drift covered plain from north Germany to Poland; the Ebro basin, Cantabria, Pyrenees, Galicia, La Mancha and Valencia in Spain on chiefly clastic and partly calcareous rocks; the alluvial sediments of the lower Garonne and Rhône rivers in France; north-central Austria mostly on molasse deposits, and in central Greece on calcareous and clastic rocks.

High Ho values in floodplain sediment ( $>0.95 \text{ mg kg}^{-1}$ ) occur over the metamorphic and felsic igneous rocks and mineralised areas of the Precambrian Shield in northern, central and

southernmost Sweden, south-west Finland, and almost the whole of Norway; on glacial outwash cover in Estonia, where there may also be an association with phosphorite mineralisation. High Ho values in floodplain sediment occur in France over the Massif Central on crystalline rocks, and north part of the Paris Basin on mostly carbonate rocks; in central Swiss-Italian Alps with felsic intrusives and mineralisation, the Roman Alkaline Province, and Corsica over granite and schist; an extensive area with felsic rocks and mineralisation begins from the Harz Mountains, Erzgebirge, Bohemian Massif to Brno (Li deposits) in the Czech Republic and ends in north-eastern Austria on Tertiary and Quaternary sediments; southern Austria with felsic intrusives; high Ho values in floodplain sediment of Slovenia and Croatia, except Dalmatia, are explained by possible

concentration in karstic soil; in eastern Hungary the Ho anomalous values are probably due to the mineralisation in the Apuseni Mountains in neighbouring Romania.

In conclusion, granite, granodiorite, shale, sandstone and schist lithologies show the highest Ho concentrations in floodplain sediment, and the glacial drift covered terrain (north-east Germany and Poland) the lowest; low Ho contents are also generally found in calcareous areas (*e.g.*, eastern Spain, Greece and Dalmatian coast), except where

there is intense development of residual soil in karst terrain (*e.g.*, Slovenia and Croatia). The distribution map of total Ho in floodplain sediment shows, therefore, the geochemical differences of the geological substratum and mineralised areas quite well, and no distinguishable influences from anthropogenic activities are recognised. It is noted that the spatial distribution of Ho is similar to that of other HREEs (Dy, Er, Gd, Lu, Tb, Tm, Yb).