

## Introduction

See section on Rare Earth Elements (REEs).  
Table 70 compares the median concentrations

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

Table 70. Median concentrations of Tm in the FOREGS samples and in some reference data sets

<b>Thulium (Tm)</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	0.30
<b>Subsoil</b>	<b>FOREGS</b>	<b>790</b>	<b>&lt;2.0</b>	<b>Total (ICP-MS)</b>	<b>0.31</b>
<b>Topsoil</b>	<b>FOREGS</b>	<b>843</b>	<b>&lt;2.0</b>	<b>Total (ICP-MS)</b>	<b>0.30</b>
Soil <sup>2)</sup>	World	n.a.	n.a.	Total	0.6
<b>Water</b>	<b>FOREGS</b>	<b>807</b>	<b>Filtered &lt;0.45 µm</b>		<b>&lt;0.002 (µg l<sup>-1</sup>)</b>
Water <sup>2)</sup>	World	n.a.	n.a.		0.0051 (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>0.400</b>
<b>Floodplain sediment</b>	<b>FOREGS</b>	<b>743</b>	<b>&lt;2.0</b>	<b>Total (XRF)</b>	<b>0.290</b>

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

## Tm in soil

The median Tm content is 0.31 mg kg<sup>-1</sup> in subsoil and 0.30 mg kg<sup>-1</sup> in topsoil; the range varies from <0.02 to 1.08 mg kg<sup>-1</sup> in subsoil and from <0.02 to 4.03 mg kg<sup>-1</sup> in topsoil. The average ratio topsoil/subsoil is 0.935.

Thulium in subsoil shows low values (<0.22 mg kg<sup>-1</sup>) throughout Finland and northern Norway, the glacial drift area from Poland to the Netherlands, west Ireland, the Paris Basin in France, the western Alps and Rhône valley, central Hungary, central Portugal, southern Spain, parts of east and north Spain, and parts of east and south Greece.

High Tm values in subsoil (>0.43 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 alkaline magmatic

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

In topsoil, the Tm pattern is very similar to that of subsoil.

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

## Tm in stream water

Thulium values in stream water range over two orders of magnitude, from <0.002 µg l<sup>-1</sup> to 0.068 µg l<sup>-1</sup> (excluding an outlier of 0.28 µg l<sup>-1</sup>), with a median value of <0.002 µg l<sup>-1</sup>. Almost 60% of the

data are less than the analytical limit of quantification. Thulium data correlate closely with the rare earth elements in general for the highest values in Fennoscandia, but not for the lowest values distribution in the remaining

Europe; the Tm distribution is most similar to that of Tb. See section on REEs for a general discussion.

Lowest Tm values in stream water ( $<0.002 \mu\text{g l}^{-1}$ ) are uniformly found in all of southern and central Europe, in western Ireland, in most of Britain, in south-west, central and northern Norway, in central and northern Sweden, northern Finland and the Baltic states. Highest Tm concentrations ( $>0.02 \mu\text{g l}^{-1}$ ) are found in southern Norway and mostly in southern Sweden, characterised by Precambrian terrains (mostly

intrusive and metamorphic rocks).

Enhanced values in stream water ( $>0.01 \mu\text{g l}^{-1}$ ) also occur in central and northern Sweden and in southern Finland, characterised by Precambrian terrains, in southern Ireland and in northern Scotland over the Caledonides. In northern Ireland, the isolated Tm anomaly is associated with the Mourne granite. The isolated value in southern Italy around Naples is related to alkaline volcanism. The highly anomalous Tm values in northern Germany are associated with high DOC values.

### **Tm in stream sediment**

The median Tm content in stream sediment is  $0.39 \text{ mg kg}^{-1}$ , and the range varies from  $0.02$  to  $6.43 \text{ mg kg}^{-1}$ .

The Tm stream sediment distribution map shows low values ( $<0.27 \text{ mg kg}^{-1}$ ) in central and east Finland, in the northern European plain from Poland to the Netherlands on glacial drift, in western Ireland, in parts of south, east and north Spain on mostly calcareous sediments, in the French-Swiss Jura Mountains, in the western Alps and the northern Apennines, part of the southern Apennines, in north-easternmost Italy, coastal Croatia, north-west Greece and Crete.

High Tm values in stream sediment ( $>0.53$

$\text{mg kg}^{-1}$ ) occur in the Variscan part of the Iberian Peninsula on felsic rocks in north Portugal, Galicia and most of the Spanish part of the Iberian Massif; 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, Albania, and a point anomaly near the Mourne granite in northern Ireland.

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

### **Tm in floodplain sediment**

Total Tm values in floodplain sediment, determined by ICP-MS, vary from  $0.02$  to  $1.89 \text{ mg kg}^{-1}$ , with a median of  $0.29 \text{ mg kg}^{-1}$ .

Low Tm values in floodplain sediment ( $<0.2 \text{ mg kg}^{-1}$ ) 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 River basin, Cantabria, Pyrenees, Galicia, La Mancha and Valencia in Spain on chiefly clastic and partly calcareous rocks; the alluvial sediments of the lower Garonne River in France; north-central Austria mostly on molasse deposits; in central Greece on calcareous and clastic rocks.

High Tm values in floodplain sediment ( $>0.4 \text{ mg kg}^{-1}$ ) occur over the metamorphic and felsic igneous rocks and mineralised areas of the Precambrian Shield in northern, central and

southernmost Sweden, parts of 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. In Wales, the high Tm levels in floodplain sediment are ascribed to felsic intrusives and mineralisation. High Tm values in floodplain sediment occur in France over the Massif Central on felsic crystalline rocks, and north part of the Paris Basin on mostly carbonate rocks; the Roman Alkaline Province, and Corsica over granite and schist; an extensive area with felsic rocks and mineralisation begins from the Harz Mountains to the Erzgebirge and Bohemian Massif; the Brno area (Li deposits) in the Czech Republic; there is an area with high Tm values in floodplain sediment in the border area of Austria, Hungary and Slovenia, and into Croatia, which is

covered by Tertiary and Quaternary sediments; in Slovenia and Croatia, except Dalmatia, they are explained by possible concentration in karstic soil; whereas in eastern Hungary the Tm anomalous values are probably due to the mineralisation in the Apuseni Mountains in neighbouring Romania. The two point Tm anomalies in the floodplain sediment of north-eastern and northern Poland are ascribed to sediments derived possibly from phosphorite mineralisation in the Soviet Union, and to halite deposits respectively.

In conclusion, granite, granodiorite, shale, sandstone and schist lithologies show the highest Tm concentrations in floodplain sediment, and the

glacial drift covered terrain (north-east Germany and Poland) the lowest; low Tb 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 Tm 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 Tm is similar to that of the other HREEs (Dy, Er, Gd, Ho, Lu, Tb, Yb).