

Introduction

See section on Rare Earth Elements (REEs).
Table 54 compares the median concentrations

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

Table 54. Median concentrations of Pr in the FOREGS samples and in some reference data sets.

Praseodymium (Pr)	Origin – Source	Number of samples	Size fraction mm	Extraction	Median mg kg⁻¹
Crust ¹⁾	Upper continental	n.a.	n.a.	Total	7.1
Subsoil	FOREGS	790	<2.0	Total (ICP-MS)	6.04
Topsoil	FOREGS	843	<2.0	Total (ICP-MS)	5.60
Soil ²⁾	World	n.a.	n.a.	Total	7
Water	FOREGS	807	Filtered <0.45 µm		0.009 (µg l⁻¹)
Water ²⁾	World	n.a.	n.a.		0.0073 (µg l ⁻¹)
Stream sediment	FOREGS	848	<0.15	Total (XRF)	7.35
Floodplain sediment	FOREGS	743	<2.0	Total (XRF)	5.50

¹⁾Rudnick & Gao 2004, ²⁾Ivanov 1996.

Pr in soil

The median Pr content is 6.04 mg kg⁻¹ in subsoil and 5.60 mg kg⁻¹ in topsoil; the range is from 0.14 to 32.9 mg kg⁻¹ in subsoil and from 0.29 to 31.6 mg kg⁻¹ in topsoil. The average ratio topsoil/subsoil is 0.897.

In subsoil, low Pr values (<4 mg kg⁻¹) are located mainly throughout Finland, in the glacial drift covered area of northern mainland Europe (Netherlands to Poland), central Hungary, the Paris Basin in France, and parts of south and east Spain.

Praseodymium in subsoil has high values (>9 mg kg⁻¹) over Variscan granitic and metamorphic rocks in northern Portugal and north-western Spain, the Massif Central and Brittany in France; in the Italian alkaline province (which contains the strongest anomalies); in karst of Slovenia, Croatia and adjacent Austria; the loess/palaeoplacer area of northern France to

Germany; south-western Norway and northern Sweden (Salpeteur *et al.* 2005).

In topsoil, Pr is much lower in Scandinavia, and somewhat higher in Slovakia. A much larger area in western Spain shows high values: near Almeria (south-east Spain) over clastic rocks, schist and orthogneiss; in Variscan Extremadura; in the Central and Eastern Pyrenees; and on Gran Canaria island related to alkaline basic volcanism. There is a point anomaly near the Mourne granite in northern Ireland. Elsewhere in Europe the pattern is similar to that of the subsoil.

Praseodymium shows strong to very strong correlations with most other REEs, both in subsoil and topsoil. Correlations are strongest with the light REEs (La, Ce, Nd, Sm), which are more similar in atomic weight and ionic radius. For additional information, refer to the section on Rare Earth Elements.

Pr in stream water

Praseodymium values in stream water range over three orders of magnitude, from $<0.002 \mu\text{g l}^{-1}$ to $1.49 \mu\text{g l}^{-1}$ (excluding an outlier of $4.70 \mu\text{g l}^{-1}$), with a median of $0.009 \mu\text{g l}^{-1}$. Praseodymium data correlate most closely with the lanthanides. See section on REEs for a general discussion.

Lowest Pr values in stream water ($<0.003 \mu\text{g l}^{-1}$) are predominantly found in most of Spain, eastern and southern France, Belgium, northern and south-central Italy, western Slovenia, most of Austria and western Hungary, Albania and Greece, north-eastern Germany and south-eastern Poland and eastern Slovakia. Most of the areas of lowest values are in Alpine Orogen terrains (southern Europe), whereas other areas (especially northern Germany and Poland) are characterised

by Variscan and Precambrian terrains. Low Pr values and low REEs in general in central Sweden are related to high pH values caused by Palaeozoic rocks.

Highest Pr concentrations stream water ($>0.27 \mu\text{g l}^{-1}$) are predominantly found in southern Norway, Sweden and Finland, and Denmark. These areas of highest values are over Precambrian terrains (mostly intrusive and metamorphic rocks). Enhanced values ($>0.08 \mu\text{g l}^{-1}$) also occur in northern Fennoscandia, northern Ireland and Scotland, characterised by Caledonides, and in France (Brittany and Massif Central) by Variscan terrains. Highly anomalous Pr values in northern Germany are associated with high DOC values.

Pr in stream sediment

The median Pr content in stream sediment is 7.0 mg kg^{-1} , with a range from 0.30 to 125 mg kg^{-1} .

The praseodymium distribution map shows low stream sediment values ($<4.6 \text{ mg kg}^{-1}$) in most of eastern Finland, the northern European plain including Denmark, western Ireland, southern and eastern Spain, the western Pyrenees, the western Alps and northern Appenines, north-easternmost Italy, the Jura Mountains, Slovenia, coastal Croatia, and western and southern Greece.

High Pr contents in stream sediment ($>9.85 \text{ mg kg}^{-1}$) are well represented in Variscan Spain and Portugal, where they outline the granitic basement of the Iberian Massif; the highest Pr anomalies are found over the granitic-metamorphic rocks of the eastern Cordillera Central in Spain; moderate values fit with metamorphic areas of the Iberian Massif in a similar way as they do in the French Massif Central. Here the area with high values extends into the Poitou region and southern Brittany. In

the southern part of the Massif Central, the highest Pr values are associated with Ce, U, Sn and Ta, indicating hydrothermal alteration related to the late Variscan granitic phases.

High Pr in stream sediment also occurs in southern Norway (including the Sovi deposit), northern coastal Norway and adjacent Sweden, parts of central and south-eastern Sweden, north-east and south-western Finland, a point anomaly in northern Estonia (phosphate deposits), Scotland and north-east England, the Bohemian Massif (including a point anomaly in Variscan granite near the border of Austria, Czech Republic and northern Bavaria), the Roman Alkaline Province, and point anomalies in south-eastern Austria, westernmost Austria (probably Variscan granite), and the Canary Islands.

Praseodymium in stream sediment has a strong to very strong correlation with Y, with the other REEs, and with Th and U, and a good correlation with Nb, Ta, Ti, Zr, Hf and Rb. For a comparison with the other rare earth elements, see the section on REEs.

Pr in floodplain sediment

Total Pr values in floodplain sediment, determined by ICP-MS, vary from 0.5 to 27.9

mg kg^{-1} , with a median of 5.5 mg kg^{-1} .

Low Pr values in floodplain sediment (<3.8

mg kg⁻¹) occur over the glacial drift covered plain extending from north-east Germany to Poland, Lithuania and Latvia; the greenstone, schist, paragneiss, metagreywacke and granulite areas of northern and eastern Finland; north-eastern Ireland with mostly basaltic rocks; the alluvial parts of the lower Garonne and Rhône rivers in France, the Ebro Basin, La Mancha and Murcia areas in Spain with calcareous and clastic rocks, the molasse basin in central Austria and the calcareous Dalmatian coast in Croatia; the ophiolite, flysch and calcareous rocks of Albania and Greece.

High Pr values in floodplain sediment (>7.4 mg kg⁻¹) occur overall in areas with felsic intrusives and mineralisation as in south-west Finland; southernmost, south-eastern, central and northern Sweden; southern, central and northern Norway, Wales, and Massif Central extending to the Pyrenees in France; northern Portugal and adjacent parts of north-western Spain, south-central Spain (Sierra Morena); central Swiss-Italian Alps; the Roman Alkaline Province in Italy; an extensive zone from the Ardennes to the Harz Mountains, Erzgebirge, Bohemian Massif, northern Bavaria, the Austrian-Czech border area, southern Austria, eastern Slovenia and central Croatia, and eastern Hungary (sediments derived from the volcanic rocks and mineralisation of the Apuseni Mountains in Romania). The high Pr

values in Estonia are on glacial outwash cover, and there may also be an association with phosphorite mineralisation.

There are three Pr point anomalies in floodplain sediment; the first and highest (27.0 mg kg⁻¹), is in the Skellefte mineralised region of northern Sweden; the second (17.3 mg kg⁻¹) in the floodplain sediment of the Navia River in north-west Spain is related to felsic intrusives and mineralisation, and the third on Gran Canaria in the Canary Islands (16.2 mg kg⁻¹) is unusual since it is associated with intermediate to mafic igneous rocks.

In conclusion, granite, granodiorite, shale, sandstone and schist lithologies show the highest Pr concentrations in floodplain sediment, and the glacial drift covered terrain (north-east Germany and Poland) the lowest; low Pr 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 Pr 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 Pr is similar to that of other light rare earth elements (Ce, Nd, Sm).