

Relationship between magnetite chemistry and magnetic susceptibility of igneous rocks: Implications for sedimentary provenance studies

Relación entre composición química de la magnetita y susceptibilidad magnética en rocas ígneas: Implicaciones en estudios de procedencia de sedimentos

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ABSTRACT

A direct relationship between magnetite chemistry and rock magnetic susceptibility has been found. Electron probe microanalysis of titanomagnetites from various igneous rocks has shown them to be enriched in either the ulvospinel phase (Fe_2TiO_4) or in the magnetite phase (Fe_3O_4). It has been found that the greater the enrichment in the magnetite phase of the titanomagnetites, the higher the magnetic susceptibility value for chemically similar rocks. Both magnetic and chemical data may be used to characterise the rocks (potential sources of sediments) which has important implications for sedimentary provenance studies.

Key words: magnetite, ulvospinel, magnetic susceptibility, sedimentary provenance.

RESUMEN

Una relación directa entre la composición química de la magnetita y la su susceptibilidad magnética de las rocas que la contienen ha sido encontrada. El análisis mediante microsonda electrónica de titanomagnetitas de varias rocas ígneas ha mostrado un enriquecimiento de dichas titanomagnetitas, bien en término ulvospinel (Fe_2TiO_4) o bien en término magnetita (Fe_3O_4). Se ha observado que rocas químicamente similares presentan valores de susceptibilidad magnética más altos cuanto mayor es el enriquecimiento en término magnetita de sus titanomagnetitas. Tanto los datos químicos como los de susceptibilidad magnética permiten una precisa caracterización de las rocas (fuentes potenciales de sedimentos), hecho éste que tiene importantes implicaciones en estudios de procedencia de sedimentos.

Geogaceta, 20 (3) (1996), 660-661
ISSN:0213683X

Introduction

In recent years, the study of Fe-Ti oxides has received increasing interest in terms of both chemistry and the magnetic properties of these minerals (Lindsley, 1991). However, hitherto these two lines of investigation have essentially followed different paths. In this paper, the importance of the relationship between magnetite chemistry and whole rock magnetic susceptibility is explored by a study of the igneous rock formations in the catchment of the River Eden, eastern Scotland. In this area three main rock types are present which exert a control on the topography (Fig. 1). The northern, upland part is characterised by andesites and volcanoclastic deposits of Lower Devonian age whereas the hills of the southern part are composed mainly of dolerite sills of Upper Carboniferous age. The intervening valley of Stratheden is underlain by relatively soft sandstones of Upper Devonian age (Armstrong, 1985).

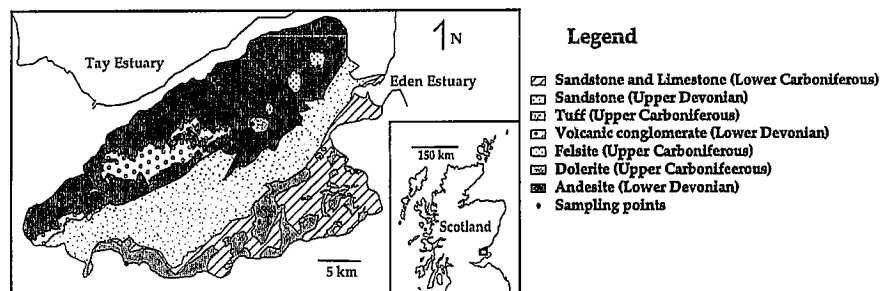


Fig.1.-Mapa geológico simplificado de la cuenca hidrográfica del río Eden mostrando los puntos de recogida de muestras.

Fig.1.-Simplified geological map of the catchment of the River Eden showing the sample locations.

Methodology

Sampling: Samples of the principal bedrock lithologies of the River Eden catchment were collected at points shown in Fig. 1. In total, 18 samples were collected in 13 locations.

Geochemical analysis: For each sample the whole rock chemistry was analysed in terms of 10 major elements (Si, Al, Ti, Fe^{3+} , Ca, Na, K,

Mg, Mn, P) as oxides and 18 trace elements by means of X-ray fluorescence (XRF) techniques. In addition, electron probe microanalysis was carried out for nine elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K) as oxides on approximately 15 grains of magnetite in a thin section of each sample. All mineral Fe was analysed as FeO and recalculated to weight percent Fe_2O_3 and FeO following the procedure of Droop (1987).

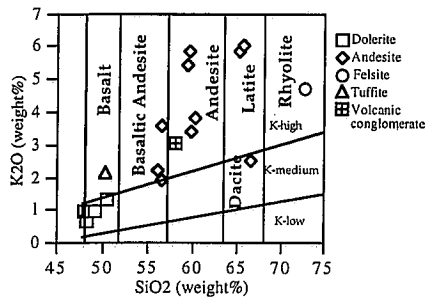


Fig. 2.-Diagrama SiO₂ frente a K₂O. Campos según Peccerillo & Taylor (1976).

Fig. 2.-K₂O versus SiO₂ diagram. Fields according to Peccerillo & Taylor (1976).

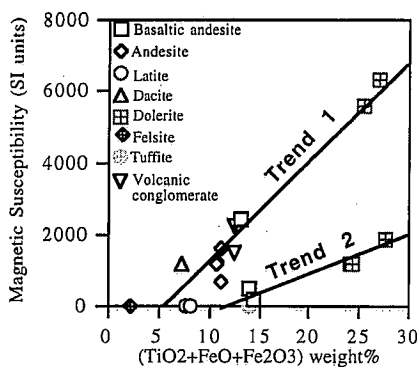


Fig. 4.-Diagrama de la susceptibilidad magnética frente al tanto por ciento en peso de (TiO₂+FeO+Fe₂O₃) de la roca (ver texto).

Fig. 4.-Magnetic susceptibility versus whole rock weight percentage of (TiO₂+FeO+Fe₂O₃) diagram (see text).

Magnetic measurements: Whole rock magnetic susceptibility was measured for a core of 10 cubic centimeter from each sample using a Bartington MS2B single sample, dual frequency sensor which creates a weak magnetic field from an alternating current and detects the magnetization of the material lying within it which is roughly proportional to the concentration of ferrimagnetic minerals within the sample. The measurements were made at low frequency and displayed in SI units.

Results

Whole rock chemistry: The Upper Carboniferous dolerites are very similar in chemical composition within the River Eden catchment. The Lower Devonian andesites, however, show differences in their chemistry regionally and can be classified as basaltic andesites, andesites, latites, and dacites, on the basis of a K₂O versus SiO₂ diagram (Fig. 2).

Magnetite chemistry: The electron microprobe data are presented in the form of a TiO₂-FeO-Fe₂O₃ ternary diagram (Fig. 3). By

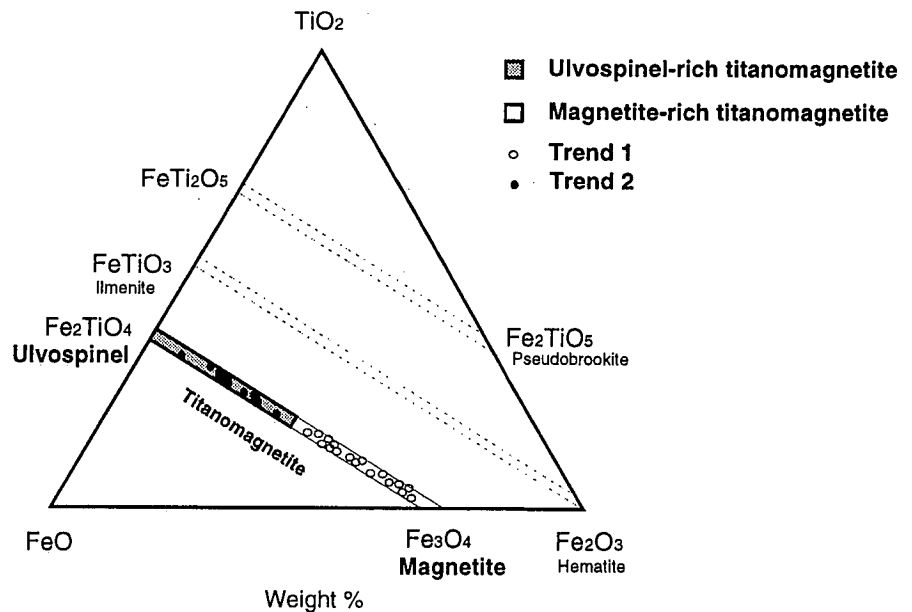


Fig. 3.- 30 análisis representativos de los 270 análisis de magnetita realizados, representados en el sistema FeO-Fe₂O₃-TiO₂ mostrando las principales soluciones sólidas magnetita-ulvospinel, hematita-ilmenita y pseudobroquita-FeTi₂O₅ (ver texto)

Fig. 3.- 30 Representative magnetite analysis from a dataset of 270 analysis plotted in the system FeO-Fe₂O₃-TiO₂ showing the major solid solution series magnetite-ulvospinel, hematite-ilmenite, and pseudobrookite-FeTi₂O₅ (see text).

this means, all of the magnetites analysed are classified as titanomagnetites. Within each individual sample the magnetite grains analysed are chemically very similar (approximately the same weight percentage of TiO₂, FeO, and Fe₂O₃). However, the magnetite grains show differences in their chemistries between samples. In 6 samples the titanomagnetites are enriched in the ulvospinel phase (Fe₂TiO₄) while in the other 12 samples they are enriched in the magnetite phase (Fe₃O₄).

Discussion and conclusions

When magnetic susceptibility is plotted versus whole rock weight percentage of (TiO₂+FeO+Fe₂O₃) (Fig. 4) two different trends can be distinguished. Each shows a direct relationship between magnetic susceptibility values and whole rock chemistry: the higher the weight percentage of (TiO₂+FeO+Fe₂O₃) in the rock, the higher the magnetic susceptibility value. However, the two trends are differentiated on the basis of magnetite chemistry. The titanomagnetites of all the rocks in trend 1 are those enriched in the magnetite phase, whereas those in trend 2 are all enriched in the ulvospinel phase (Fig. 3).

This study has shown that there is a clear, direct relationship between magnetite chemistry and whole rock magnetic susceptibility. It has enabled the characterisation of igneous rocks so that chemically and magnetically similar materials can be differentiated on the basis of their magnetite chemistry. The implications for sedimentary provenance studies are important.

Since the above analytical methods applied to the study of rocks, which are potential sources of sediments can also be applied to sediments, the comparison of «source» and «sediment» dataset should allow a precise determination of sediment provenance and permit quantification of the relative contribution of source lithologies. Further work on these aspects is in progress.

Acknowledgements

Special thanks go to Dr. W.E. Stephens and Dr. R.W. Duck for their continuous support. Thanks are extended to Angus Calder, Donald Herd and Andy Mackie for their technical assistance. This research was supported by a grant from the program 'Programa de Formación de Investigadores del Departamento de Educación, Universidades e Investigación' from the Basque Government, which is gratefully acknowledged.

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