

REE study in Jurassic radiolarites from the Subbetic, Betic Cordillera, Spain.

M. Bustillo

Dpto. Petrología y Geoquímica, Fac. Ciencias Geológicas, Univ. Complutense, 28040 Madrid, Spain.

M.A. Bustillo

Dpto. de Geología, Museo Nacional de Ciencias Naturales, C.S.I.C., José Gutiérrez Abascal 2, 28006 Madrid, Spain.

Introduction

Traditionally the Betic orogene (South of Spain) has been divided into three regions according to the different paleogeographic and tectonic characteristics: Betic *sensu stricto*, Subbetic and Prebetic. The Subbetic is the thrust belt formed by allochthonous, mainly deep pelagic sediments of the Mesozoic and Cenozoic. In the Subbetic, radiolarian bearing sequences of the Middle and Late Jurassic age have been referred to as radiolarites in regional tectonic and stratigraphic papers, although, in a strict sense, radiolarites (rocks where the amount of silica being more than 90%) are very scarce. Ruiz Ortiz *et al.* (1989) carried out a general sedimentological, petrological and geochemical study, incorporating seven sections of the Radiolarite Sequence from the Middle Subbetic (fig. 1). The objective of this paper is to analyse the REE composition of these radiolarites in order to discuss the genesis of these materials.

Mineralogy and petrology

The radiolarite beds studied are mainly composed of quartz (50 and 80%) with lesser amounts of calcite (less than 30%) and hematite (less than 5%). Under thin section, the radiolarian tests, 40–70 μm in size, make up to 80% by volume of the radiolarite beds. The matrix is mainly fine-grained carbonate and/or clay minerals. The radiolarian tests are filled with microcrystalline

quartz and length-fast chalcedony. Sometimes diagenetic processes produce a redistribution of carbonate, silica and Fe-oxides and calcitized or oxidized radiolarians are observed. Occasionally, the silica released from the radiolarians is accumulated in determined places and very rich silica (quartz) zones are formed in the radiolarite beds.

Rare earth elements study

The rare earth elements have been obtained by I.C.P. at Service D'Analyses des Roches et Mineraux, C.N.R.S., France. The shale-normalized patterns have been obtained using the N.A.S.C. (North American Shale Composition - Piper, 1984-). REE and shale-normalized contents are shown in table I.

Shale-normalized AB and AG samples display significant negative Ce anomalies, indicating an open-ocean environment of sedimentation (e.g. Elderfield, 1988). The other analysed samples (JH, SE and ZG) do not exhibit this extreme depletion of Ce relative to other LREEs. These differences in Ce/Ce* record a primary variation of the initial sediment (Murray *et al.*, 1992). Therefore, JH, SE and ZG samples were formed in an environment where there was more detrital input from the continent. These results are in accordance with the fact that AB and AG samples have the richest biogenic silica contents. On the other hand, all the studied samples do not display Eu anomaly. Anomaly can be produced by: (1) variations in

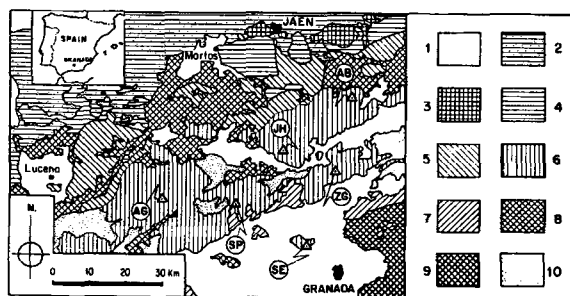


FIG 1. Geological map including the position of the studied sections. 1 - Neogene and Quaternary, 2 - Olistotromes of the Guadalquivir basin, 3 - Prebetic Zone, 4 - Intermediate Units between the Prebetic and the Subbetic Zone, 5 - External Subbetic Zone, 6 - Middle Subbetic Zone, 7 - Internal Subbetic Zone, 8 - Triassic rocks, 9 - Internal Zones and 10 - Paleogene and/or Campo de Gibraltar Units.

the detrital source -feldspar component-, and/or (2) hydrothermal input (Murray *et al.*, 1992). Therefore, all the rediolarites studied were deposited without relation to hydrothermal fluids and with detrital input of NASC type.

There is not a strong correlation between Al_2O_3 contents and ΣREE ($r=0.58$), suggesting that the final *REE* contents of the rocks are not only controlled by the proportion of detrital components, but also by other processes such as diagenetic silicification and/or *REE* fractionation during diagenesis.

In relation to *LREE/HREE* contents, the samples record La_n/Yb_n values (assessed through the ratio of shale-normalized La and Yb values) in general between 0.9 and 1.95. These values indicate deposition in an environment with a strong terrigenous source. Some of them, are even higher than values proposed for terrigenous particulate input to oceans (p.e. 1.3, Sholkovitz, 1990), which may indicate the influence of the adsorbed and preferentially *LREE*-enriched component (Byrne and Kim, 1990). The La_n/Yb_n lowest value of the samples ($ZG-2=0.67$) is probably due to diagenetic *LREE* mobility.

Finally, the Eu anomaly combined with the La/Y ratio can be a useful tool to suggest some

considerations about the physicochemical environment of formation (Drake and Weill, 1975; Crnicki and Jurkovic, 1989). In this sense, the analysed samples indicate an oxidizing and basic environment of formation.

References

- Byrne, R. H. and Kim, K. H. (1990) *Geochim. Cosmochim. Acta*, **54**, 2645–56.
 Crnicki, J. and Jurkovic, I. (1989) *Travaux*, **19**, 239–48.
 Drake, M. J. and Weill, D. F. (1975) *Geochim. Cosmochim. Acta*, **39**, 669–712.
 Elderfield, H. (1988) *Phil. Trans. Roy. Soc. Lond.*, **325A**, 105–26.
 Murray, R., Buchholtz, M., Gerlach, D., Price, G. and Jones, D. L. (1992) *Geochim. Cosmochim. Acta*, **56**, 2657–71.
 Piper, D. Z. (1974) *Chem. Geol.*, **14**, 285–304.
 Ruiz-Ortiz, P. A., Bustillo, M. A. and Molina, J. M. (1989) in *Siliceous Deposits of the Thetys and Pacific Regions* (Hein, J. R. and Obradovic, J., eds.) Springer-Verlag, 107–27.
 Sholkovitz, E. R. (1990) *Chem. Geol.*, **88**, 333–47.

TABLE 1. Rare Earth element composition in analysed samples (*) = shale-normalized samples

	AB-6	AG-8	AG-11	JH-12	JH-9	SE-21	SE-3	SE-56	SP-3	ZG-2	ZG-3
La	31.83	26.85	20.69	15.00	24.09	14.96	6.71	12.63	16.35	17.35	21.08
Ce	24.01	44.85	29.09	31.55	44.70	33.85	18.65	27.45	41.33	44.83	47.07
Nd	33.28	29.14	20.41	13.85	20.84	12.99	7.39	11.31	16.27	14.67	17.75
Sm	6.56	6.61	4.55	3.05	4.76	2.90	1.91	2.87	3.53	3.37	4.17
Eu	1.47	1.50	0.99	0.68	1.05	0.62	0.42	0.65	0.79	0.76	0.94
Gd	5.14	5.87	4.20	2.50	4.25	2.53	1.58	2.62	3.31	3.00	3.71
Dy	3.78	4.93	3.43	2.23	3.49	2.31	1.54	2.34	2.51	3.39	3.21
Er	1.76	2.28	1.80	1.21	1.80	1.34	0.83	1.30	1.27	1.98	1.83
Yb	1.40	1.69	1.48	1.08	1.47	1.24	0.71	1.16	1.11	2.21	1.63
Lu	0.26	0.29	0.22	0.17	0.23	0.20	0.17	0.32	0.16	0.44	0.33

(*)	AB-6	AG-8	AG-11	JH-12	JH-9	SE-21	SE-3	SE-56	SP-3	ZG-2	ZG-3
La	0.78	0.65	0.50	0.37	0.59	0.36	0.16	0.31	0.40	0.42	0.51
Ce	0.29	0.54	0.35	0.38	0.54	0.41	0.22	0.33	0.50	0.54	0.57
Nd	0.88	0.77	0.54	0.36	0.55	0.34	0.19	0.30	0.43	0.39	0.47
Sm	0.87	0.88	0.61	0.41	0.63	0.39	0.25	0.38	0.47	0.45	0.56
Eu	0.91	0.93	0.61	0.42	0.65	0.39	0.26	0.40	0.49	0.47	0.58
Gd	0.82	0.92	0.66	0.39	0.67	0.40	0.25	0.41	0.52	0.47	0.58
Dy	0.69	0.90	0.62	0.41	0.63	0.42	0.28	0.43	0.46	0.62	0.58
Er	0.47	0.61	0.48	0.32	0.48	0.36	0.22	0.35	0.34	0.53	0.49
Yb	0.40	0.48	0.42	0.31	0.42	0.35	0.20	0.33	0.31	0.63	0.46
Lu	0.43	0.48	0.36	0.28	0.38	0.33	0.28	0.52	0.26	0.72	0.54