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Ordovician and Silurian igneous rocks and orthogneisses in the Catalonian Coastal Ranges

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ABSTRACT

These rocks exhibit calc-alkaline affinities and may have originated by partial melting of the crust in a post-collision, anorogenic setting. Orthogneisses derived from biotite-bearing leucogranites occur within a probably cambrian heterogeneous series. Petrological and geochemical features suggest that they might be genetically related to the ordovician vulcanites. Basic sills and volcanoclastic rocks occur intercalated within a mainly pelitic formation in the lower part of the Silurian sequence. The silurian igneous rocks are alkali basalts and may reflect an extensional regime.

Key words: Pre-hercynian magmatism. Metavolcanites. Orthogneisses. Bulk-rock chemistry.

RESUMEN

Las rocas volcánicas ordovícicas aparecen intercaladas en una secuencia arenoso-pelítica de edad Caradoc. Se trata de materiales piroclásticos ácidos con niveles subordinados de riolitas masivas. Poseen afinidades calcoalcalinas y se podrían haber formado por fusión crustal en un contexto anorogénico post-colisional. Los ortogneises aparecen en una serie heterogénea probablemente de edad cámbrica. Corresponden a leucogranitos biotíticos y presentan afinidades geoquímicas con las vulcanitas ordovícias, pudiendo estar relacionados genéticamente. En la base del Silúrico aparecen aparecen sills con composición de basaltos alcalinos y rocas volcanoclásticas básicas intercalados en una serie esencialmente pelítica que podrían haberse originado en un régimen de distensión crustal.

Palabras clave: Magmatismo pre-hercínico. Metavulcanitas. Ortogneises. Composición química.

ORDOVICIAN METAVULCANITES

Upper Ordovician volcanic rocks, variably affected by the Hercynian regional metamorphism, form a number of outcrops of different extensions along the Catalonian coastal ranges. The main outcrops are situated in the Gavarres, Guilleries, Montseny and Pedritxes areas (Fig. 1). These rocks occur intercalated within the lower part of a mainly greywacke-shale sequence of Caradoc age (Meléndez and Chauvel, 1981; Villas *et al.*, 1987; Barnolas and García Sansegundo, *in press*; Julivert *et al.*, 1987). Discontinuous levels of metaconglomerates occurring locally at the base of this series have been interpreted in comparable sectors of the Eastern Pyrenees as a basal discordance of Upper Ordovician age (Hartevelt, 1970; Santanach, 1974; Laumonier, 1988). The Lower Paleozoic materials, probably Cambrian age (Laumonier, 1988), which crop out underlying this sequence are composed of 1) an upper portion of metapelites ('lower heterolithic series', Barnolas and García Sansegundo, *in press)* and 2) a lower member ('Guilleries series') comprising pelitic gneisses, marbles, calc-silicate rocks and amphibolites, along with orthogneissic bodies which have been genetically correlated with the ordovician metavulcanites (Durán *et al.*, 1984).

The metavulcanites as a whole form a sequence of variable thickness defined by an alternance of variably metamorphosed pyroclastic and volcanoclastic materials

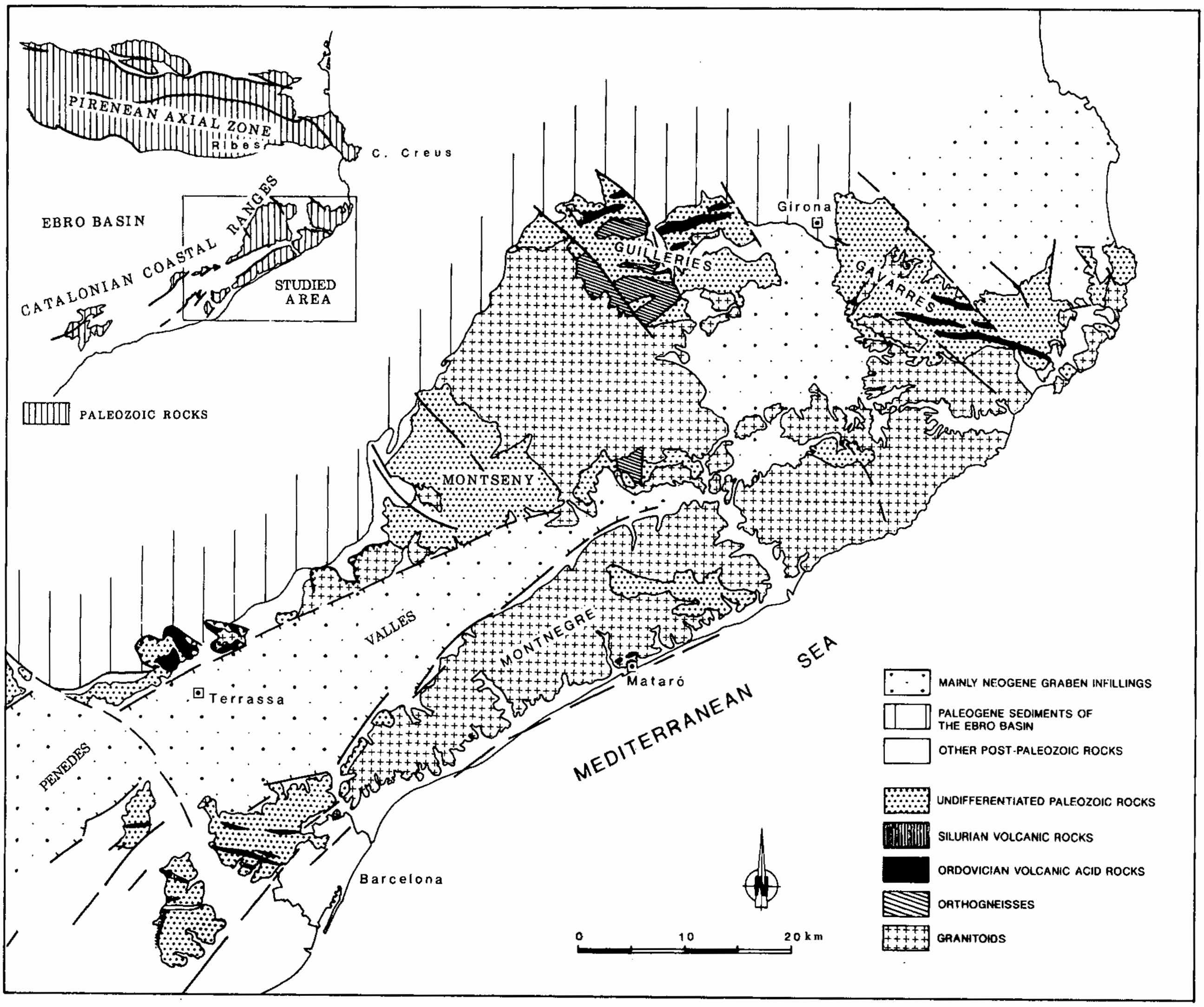

Figure 1.- Geological sketch of the Catalonian Coastal Ranges showing the location of the Ordovician and Silurian igneous rocks and orthogneisses.

with subordinated levels of massive rhyolites. These materials correspond to an explosive volcanism that gave rise to subaereal air-fall deposits and ash-flow tuffs (ignimbrites). The amount of sedimentary material is highly variable, one of the most conspicuous features being the association in some places of volcanic materials with turbidites. This suggests that the Ordovician acid volcanism was not totally subaereal, which accounts, in part, for the marked Na-enrichment in most of the samples (see below). A detailed account of the main petrographic and geochemical features of these rocks may be found in Durán *et al.* (1984) and Navidad and Barnolas *(in press)*. The most important results from these studies, with additional data from Durán (1986) and Julivert *et al.* (1987), are summarized herein.

The pyroclastic rocks correspond to tuffs and cinerites of dacitic to rhyolitic composition. Relict ignimbritic features ('fiame' and residual flow banding) and structures characteristic of subaereal deposits (laminations, imbrications between tuffs and cinerites, as well as gradational structures) can be recognized in these rocks. The volcanoclastic rocks must be the result of phreatomagmatic processes and are characterized by the abundance of volcanic components with lithic fragments and subvolcanic clasts. The massive materials

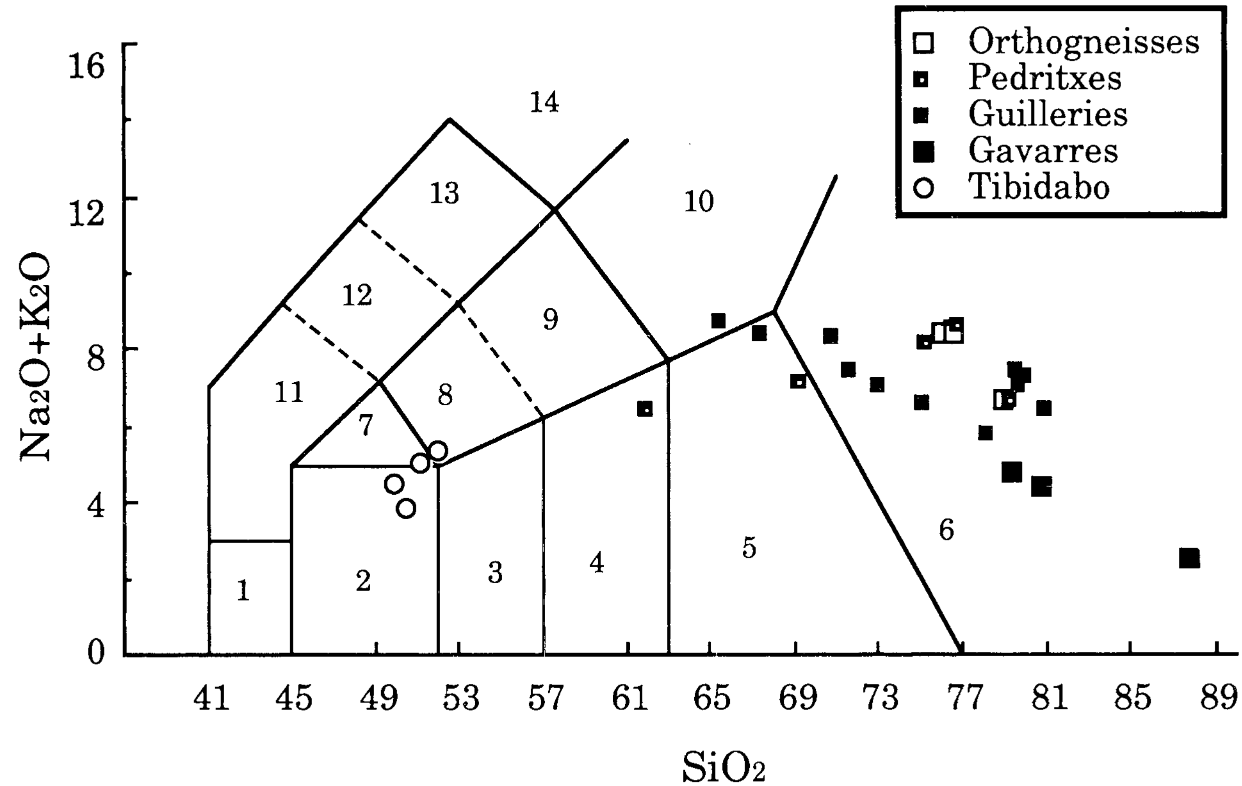

Figure 2.- Chemical composition of Ordovician (solid squares) and Silurian (open circles) igneous rocks and orthogneisses (open squares) from the Catalonian Coastal Ranges. Diagram after Zanettin (1984). Data from Durán *et al.* (1984), Durán (1986) and Gil Ibarguchi and Julivert (1988). 1: picrobasalt, 2: basalt, 3: basaltic andesite, 4: andesite, 5: dacite, 6: rhyolite (alkali rhyolite P.I.>1), 7: trachybasalt, 8,9: trachyandesite, 10: trachyite (alkali trachyte, P.I.>1), 11: basanite and tephrite, 12: phonotephrite, 13: tephriphonolite, 14: phonolite.

correspond to levels of metarhyolites with relict igneous flow textures as well as perlitic and spherulitic structures resulting from devitrification

The rhyolitic and dacitic character of most ordovician metavulcanites in this area has been established by Durán *et al.* (1984) and Durán (1986) on the basis of the major element composition of these rocks (Figure 2). Important post-deposition hydrothermal transformation was responsible for an enrichment in Na, and to a lesser extent in Si, of most of the samples analyzed (Figure 3). The overall compositions reported by these authors suggest a calc-alkaline affinity for this volcanism; nevertheless, the scarcity of rocks with intermediate composition rather precludes the possibility of it being defined as a calc-alkaline series.

An attempt to characterize this volcanism using less mobile elements has been carried out by Navidad and Barnolas *(in press)*. According to these authors, the Zr, Ti, Nb and Y contents suggest a kind of calc-alkaline magmatism, with a considerable crustal participation, where only the more acid terms of the sequence (rhyolites-dacites) would be present. The reported Rb, Y, Nb contents and other incompatible elements of these magmas are intermediate between those of collisional and anorogenic type, which suggests a post-collisional geodynamic setting for this magmatism (cf. Fig. 4). The REE contents (Fig. 5A) are different from those of typical anorogenic acid magmas, giving a more fractionated pattern, with less significant negative Eu anomaly, although Ce/Yb ratios (2.5-4.72) are similar to those of A-type granites elsewhere (2.2-5.5, Whalen *et al.*, 1987), the origin of which could be interpreted in terms of the partial melting of recycled continental crust.

ORTHOGNEISSES

Orthogneiss bodies are found in the Montseny and Guilleries sectors (Fig. 1) in the lowermost part of the Paleozoic sequence (Durán *et al.*, 1984). The emplacement of the igneous protoliths took place during pre-Hercynian times, since these rocks exhibit the same structural

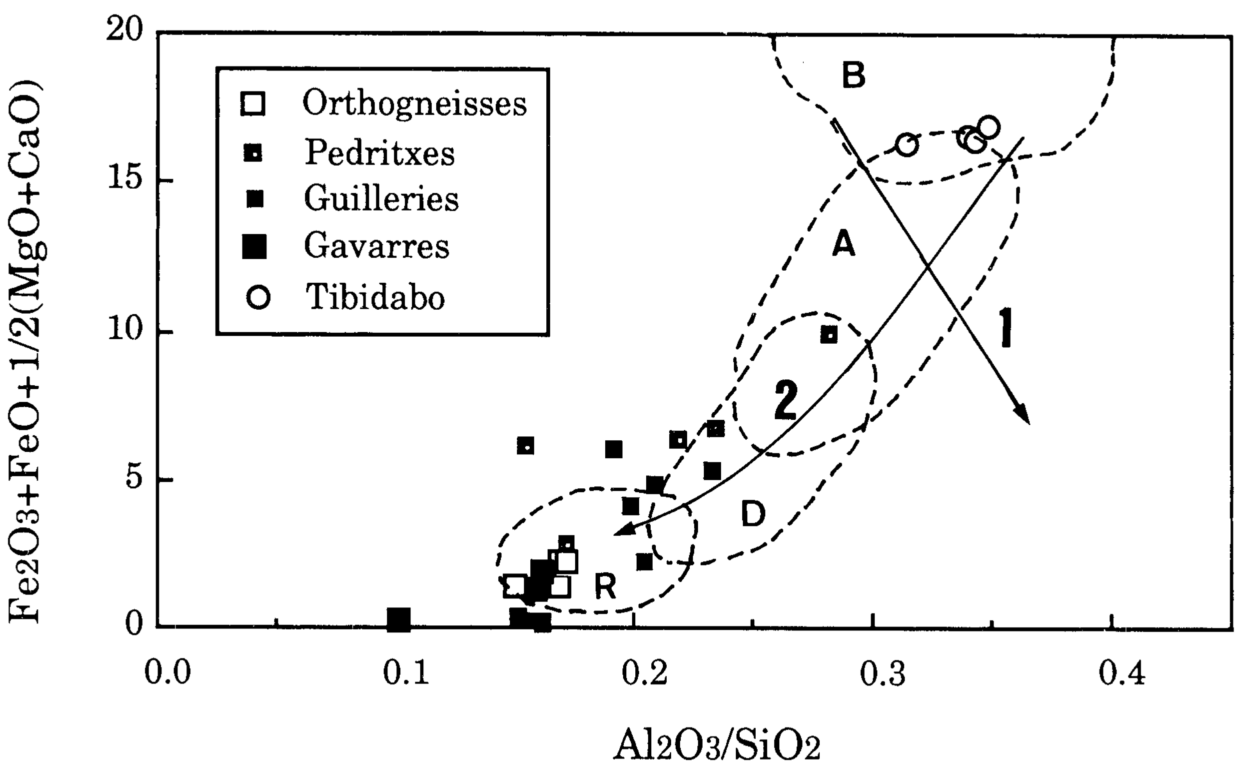

Figure 3.- Chemical composition of Ordovician (solid quares) and Silurian (open circles) igneous rocks and orthogneisses (open squares) from the Catalonian Coastal Ranges. Diagram after Church (1975), 1: Highwood lava, 2: Cascade lava, B: basalt, A: andesite, D: dacite, R: rhyolite. Data from Durán *et al.* (1984), Durán (1986) and Gil Ibarguchi and Julivert (1988)

features as the enclosing metasediments which were affected by the Hercynian events.

The orthogneisses form apparently concordant, kilometre-size, sheet-like bodies and exhibit sharp contacts with the enclosing Lower Paleozoic metasediments. Descriptions of these rocks, together with data on major element composition can be found in Durán *et al.* (1984), Durán (1986) and Navidad and Barnolas *(in press)*. Most of the orthogneisses are biotite-bearing leucogneisses and often show traces of ductile deformation.

The orthogneisses are Si- and alkali-rich, aluminous metagranites with normative corundum. From their trace element composition (cf. Navidad and Barnolas, *in press*) these rocks are characterized as non-peralkaline granitoids from anorogenic domains. The major, trace and rare earth element composition of the orthogneisses is broadly similar to that of the ordovician metavulcanites (Figs. 2, 3 and 4A). They are slightly richer in incompatible elements and have greater negative Eu anomaly than the metavulcanites; however, is the REE composition of both rock-types markedly different from that of the typical A-type granitoids (Fig. 5A).

In view of these geochemical similarities and considering their petrography and field relatioships, most authors working in this area have considered that the magmas origining the vulcanites and orthogneisses were genetically related, although, in the absence of geochronological data for the granitoids, this possibility is open to doubt (cf. Durán *et al.*, 1984, Julivert *et al.*, 1987 and Navidad and Barnolas, *in press*). Since there is no evidence of collisional events during Ordovician times in the region studied the setting was apparently anorogenic. It may have been an extensional environment, but, as mentioned above, partial melting of the pre-existent crust did not give rise to typical anorogenic magmatism; aluminous magmas with calc-alkaline affinities were produced instead. This suggests local heat influx from the mantle (uprising of mantle slices along deep fractures) in the lower part of the pre-existent crust and fusion of recycled crust (Cadomian granitoids) to

TABLE 1.- Chemical composition of Ordovician metavulcanites from the Guilleries area*

Sample	GMA11	GMA12	GMA14	GMA15	GMA16
SiO_2	69.83	67.16	62.13	64.54	68.32
TiO_2	0.2	0.11	0.19	0.18	0.12
Al_2O_3	13.85	12.87	14.49	15.15	14.21
Fe_2O_3	3.37	5.34	6.31	5.58	4.16
MnO	0.02	0.04	0.06	0.03	0.02
MgO	0.95	0.71	1.57	1.55	0.82
CaO	0.67	0.71	1.88	0.68	0.65
Na_2O	3.14	5.66	5.3	4.55	3.45
K_2O	3.63	2.3	3	3.49	3.7
I.L.	3.24	5.21	4.3	3.4	4.57
TOTAL	98.9	100.11	99.23	99.15	100.02

*Analyses from Durán (1986) included in Figs. 3 and 4 of Julivert *et al.* (1987)

TABLE 2.- Rare earth element composition of Silurian metabasites from the Tibidabo area

Sample	431C	431A	430A	431B
La	31.48	19.69	24.17	16.69
Ce	66.99	42.37	48.42	37.43
Nd	26.74	18.8	21.1	20.15
Sm	6.88	4.44	5.2	4.66
Eu	2.11	1.53	1.71	1.4
Gd	6.23	4.23	4.52	3.41
Dy	4.9	3.63	4.15	3.92
Er	2.5	1.76	2.03	1.57
Yb	2.27	1.49	1.77	1.72
Lu	0.59	0.23	0.27	0.43

produce a large quantity of acid magmas in a short period of time.

SILURIAN IGNEOUS ROCKS

Basaltic igneous rocks occur at the base of the Silurian sequence in various places in the Sierra de Collcerola area. Silurian metabasites occur in two forms: 1) as sills or interlayered bodies, metric to decamentric in thickness, often microgabroic in appearance; 2) as centimetric to milimetric beds within an essentially metapelitic matrix; the microtextures and field relatioships of the latter suggesting an origin as basic tuffs or volcano-sedimentary materials. These rocks were affected by Hercynian regional metamorphism under greenschist facies conditions, and, locally, by the thermal effects of late-kinematic Hercynian granite

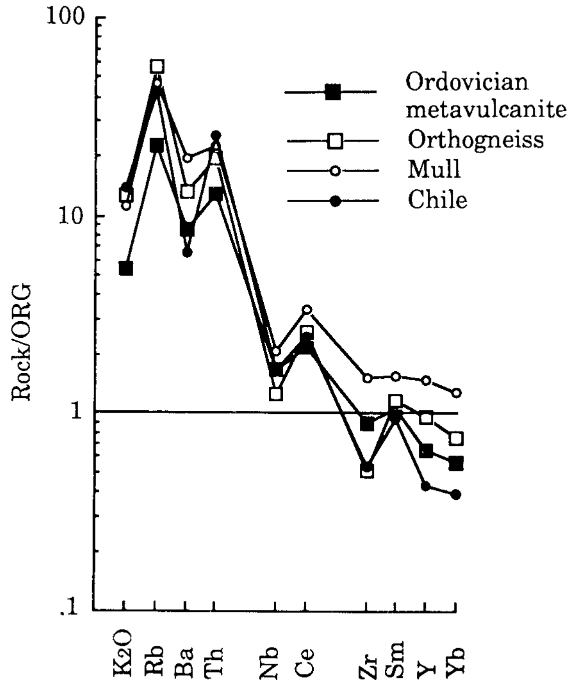

Figure 4.- Spidergram (rock vs. ORG) for Ordovician metavulcanites and orthogneisses from the Catalonia Coastal Ranges. Diagram and data for anorogenic (Mull) and orogenic (Chile) granites after Pearce *et al.* (1984). Data from Navidad and Barnolas *(in press)*.

intrusions, giving rise to hornblende- to pyroxene-hornfels associations. Some data on the petrography and major element chemistry of these rocks may be found in Julivert *et al.* (1987) and Gil Ibarguchi and Julivert (1988). New data obtained by ICP methods (cf. Govindaraju and Mevelle, 1987, for analytical technique details) on their REE composition are presented in this study. Samples analyzed are the same as those reported by Gil Ibarguchi and Julivert (1988) for major elements and correspond to the massive, sill-like varieties.

Geochemically the Silurian rocks are very different from the Ordovician metavulcanites and orthogneisses. Both major elements and rare earths of the Silurian rocks are alkaline. According to their major element composition these rocks may be classified as alkali basalts (TAS classification, Fig. 3), while the REE spectra are also very similar to those of alkali basalts from continental areas elsewhere, showing continously fractionated patterns from LREE to HREE and minor negative or slightly positive Eu anomalies (Eu/Eu* = 0.99-1.08, Fig. 5B).

The geodynamics involved in the origin of this type of magmatism is normally related with distensive/anorogenic environments. In the present case this could be related with the previous Upper Ordovician episode of apparently static partial melting of the pre-existent continental crust. Hence the same process of localized decompression might be responsible for the heating of the lower crust and, subsequently, the ascent of deep, mantle-derived magmas and their emplacement into or near surface levels during the Lower Silurian.

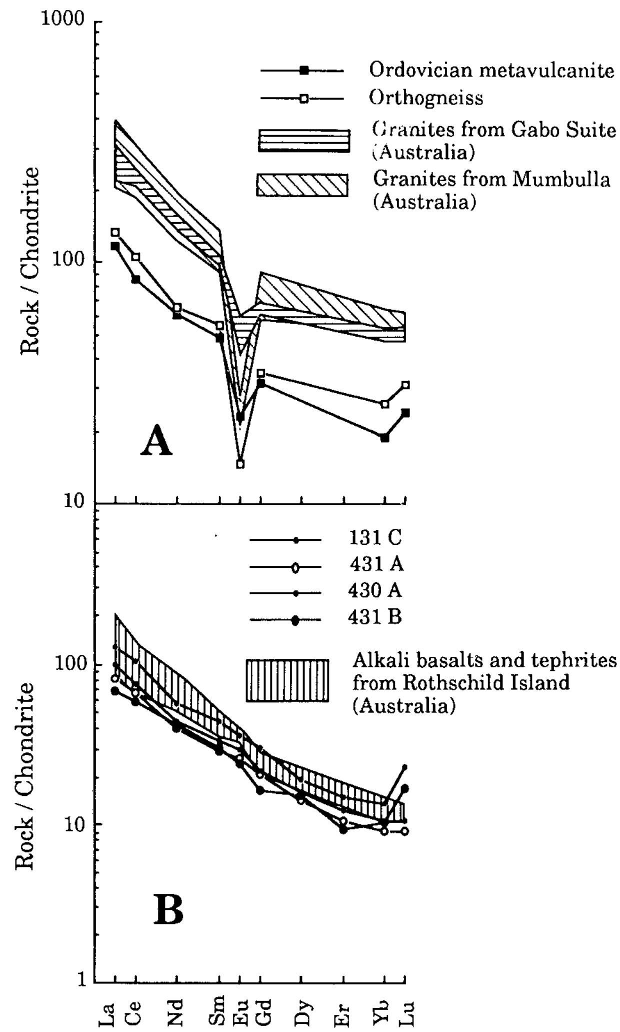

Figure 5.- Chondrite normalized REE distribution for the Ordovician metavulcanites and orthogneisses (part A), and for the Silurian metabasites (part B) from the Catalonia Coastal Ranges. Data in A from Navidad and Barnolas *(in press)*, in B from this study. Compositional range of akali basalts and tephrites from Rotschild Island in A after Hole (1988), and of anorogenic granites from Gabo and Mumbulla in B after Collins *et al.* (1982). Normalization values after Evensen *et al.* (1978).

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REFERENCES

BARNOLAS, A.and GARCÍA SANSEGUNDO, J., *in press*: *Caracterización estratigráfica y estructural del Paleozoico de Les Gavarres*. Libro Homenaje a Faura i Sans. Serv. Geolog. Generalitat de Catalunya.

CHURCH, B. N., 1975: Quantitative classification and chemical comparison of common volcanic rocks. *Geol. Soc. Amer. Bull.*, 86: 257-263.

COLLINS, W. J., BEAMS, S. D., WHITE, A. J. R and CHAPPELL, B. W., 1982: Nature and origin of A-type granites with particular reference to Southeastern Australia. *Contrib. Mineral. Petrol.*,80: 189-200.

DURÁN, H., 1986: *El Paleozoico de Les Guilleries*, Abst. Ph. D. Thesis, Univ. Autónoma Barcelona, pp. 1-34.

DURÁN, H., GIL IBARGUCHI, J. I., JULIVERT, M. and UBACH, J., 1984: Early Paleozoic acid volcanism in the Catalonian Coastal Ranges , Northwestern Mediterranean:. In: Sassi, F. P., Julivert, M., Eds., *IGCP No. 5, Newsletter*, 6: 33-43.

EVENSEN, M. M., HAMILTON, P. J. and O'NIONS, R. K., 1978: Rare-earth abundances in chondritic meteorites. *Geochim. Cosmochim. Acta*,42: 1199-1212.

GIL IBARGUCHI, J. I. and JULIVERT, M., 1988: Petrología de la aureola metamórfica de la granodiorita de Barcelona en la Sierra de Collcerola, Tibidabo:. *Estudios Geol.*, 44: 353-374.

GOVINDARAJU, K. and MEVELLE, G.,, 1987: Fully automated dissolution and separation methods for inductively coupled plasma atomic emission spectrometry rock analysis. Application to the determination of rare earth elements. *Jour. Anal. Atom. Spectrom.*, 2: 615-621.

HARTEVELT, J. J. A., 1970: Geology of the Upper Segre and Valira valleys, Central Pyrenees, Andorra/Spain. *Leidse Geol. Meded.*, 45: 167-236.

HOLE, M. J., 1988: Post-subduction alkaline volcanism along the Antarctic Peninsula. *Journal of the Geol. Society, London*, 145: 985-998.

JULIVERT, M., DURÁN, H., GARCÍA LÓPEZ, S. ,GIL IBARGUCHI, J. I., TRUYOLS MASSONI, M. and VILLAS, E., 1987: Pre-Carboniferous rocks in the Catalonian coastal ranges: volcanism, stratigraphic sequence and fossil content. In : Flügel, H.W., Sassi, F. P., Grecula, P., Eds.:, *Pre-Variscan and Variscan events in the Alpine-Mediterranean mountain belts*, Mineralia Slovaca, Monography, Alfa Bratislava, pp. 313-322.

LAUMONIER, B., 1988: Les groupes de Canaveilles et Jujols, «Paléozoïque Inférieur»: des Pyrinées orientales. Arguments en faveur de l'age essentiellement Cambrien des series. *Hercynica*, 4 (1): 25-38.

MELENDEZ, B. and CHAUVEL, J., 1981: Sur quelques Cystoidées cités par les Drs. J. Almera et M. Faura dans l'Ordovicien de Barcelona. *Acta Geol. Hisp.*, 14: 318-321.

NAVIDAD, M. and BARNOLAS, A., *in press*: El mgmatismo del Paleozoico Superior de Los Catalanides, Gerona: *Bol. Geol. Min.*

PEARCE, J. A., HARRIS, N. B. W. and TINDLE, A. G., 1984: Trace element discrimination for the tectonic interpretation of granitic rocks. *Jour. Petrol.*,25 (4): 956-983.

SANTANACH, P., 1974: *Estudi tectónic del Paleozoic inferior del Pirineu entre la Cerdanya i el riu Ter*. Tesis, Univ. Barcelona, Publ. Fund. S. Vives Casajuana, pp. 1-131.

VILLAS, E., DURAN, H. and JULIVERT, M., 1987: The Upper Ordovician clastic sequenceof the Catalonian Coastal Ranges and its brachiopod fauna. *Neues Jhb. Geol. Paläont. Abh.; Mh.;* 174: 55-74

WHALEN, J. B., CURRIE, K. L. and CHAPPELL, B. W., 1987: A-type granites: geochemical characteristics, discrimination and petrogenesis. *Contrib. Mineral. Petrol.*, 95: 407-419.

ZANETTIN, B., 1984: Proposed new chemical classification of volcanic rocks. *Episodes*, 7, (4): 19-20.