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Geochemistry of the Catalonian Volcanics, Spain

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SUMMARY

On the basis of twenty-nine new bulk analyses and several microprobe determinations the geochemistry and mineral composition of catalonian volcanics have been investigated. The lavas form a sequence of trachybasalts and leucite basanites. The fractionation trends may be explained by an olivine-clinopyroxene crystallization (ankaramtic type) with some significant variations in alkalies. These variations may be due to localisation within flows of residual alkalies during the initial cooling of lava flows as well as to leachining or hydrothermal processes. The K/Rb ratio is calculated to be about 290 for lavas with more than 2.5 % K_2O while those with 1.5 % K_2O have a K/Rb ratio of 490. Then mean K/Rb ratio of 350 differs considerably from that of 53 for the most altered basalts. There is a rather minor variation in Ni (10-200 ppm) and MgO (7.3-10 %) contents.

All clinopyroxenes show a relatively high Al_2O_3 (6.0-9.0 %) concentration. The composition range for plagioclase is An_{42}-An_{68}. Olivine composition varies as a function of grain size: 16.0 % FeO in phenocrysts increases to 26.0 % in the groundmass olivine. Spinel corresponds to some intermediate compositions between the two end members of the ulvospinel-magnetite series.

RESUMEN

A partir de los análisis de 29 muestras procedentes de volcanes catalanes y algunas determinaciones mediante microsonda se ha estudiado su geoquímica y su composición mineralógica.

La lava forma una secuencia de traquibasaltos y basanitas leucíticas.

La variación de composición puede explicarse por una cristalización olivino-clinopiroxeno con variaciones significativas en los álcalis, las cuales pueden atribuirse a la localización de álcalis residuales en el interior de las coladas durante el enfriamiento inicial o bien a procesos hidrotermales. La relación K/Rb calculada se aproxima a 290 para lavas cuyo contenido en K_2O es mayor de 2,5 %, mientras la relación K/Rb es de 490 para los que tienen 1,5 %. La relación media K/Rb de 350, difiere mucho del valor 53 de la mayoría de basaltos alterados.

Existe también variación en el Ni (10-200 ppm) y MgO (7,3-10 %). Los clinopiroxenos presentan valores relativamente altos para Al_2O_3 (6,0-9,0 %). Las plagioclasas están situadas entre An_{42}-An_{68}.

La composición del olivino varía en función del tamaño del cristal: FeO aumenta del 16 % en los fenocristales al 20 % de los que integran la matriz.

La espinela responde a una composición intermedia entre los dos miembros finales de la serie ulvoespinela-magnetita.

INTRODUCTION

The catalonian volcanics consist of three main eruptive centers of Pliocene and Quaternary activity which are spread over a like triangular area of more 800 km² located near the northeast spanish-french border and the Costa Brava shoreline, fig. 1. These three centres may be summarized as follows:

1) The Garrotxa and Gironés areas extend over the northwest apex of the triangle and consist of numerous volcanoes with important lava flows (fig. 1). Where the eruptive centres were on or near a stream divide, lavas have flowed down stream valleys in opposite directions so that lavas from a single centre may occur 20 km apart. Ponding of lava in valley flows above defiles is common so that locally flows may succeed 70 m in thickness. Flows mainly emanate from the base of cones which are usually superimposed on the flows. Bombs and blocks within the scoria and tuff cones are of similar type to the massive lavas. A Riss —age has been assigned to these volcanics (SOLÉ SABARÍS, 1962).

2) The La Selva area forms the southwest end of the triangle (fig. 1) and lies within a graben of the same name which represents the septrentrional extremity of the prelitoral depressed trough of catalonian chains (LLOPIS LLADÓ, 1947). The main balsatic eruptions lie around the towns of Hostalric, Massanet de la Selva and Riudarenes and are seen intruded in the crystalline basement of the trough.

SOLÉ SABARÍS (1962) stated that la Selva volcanics emanated in an early Pliocene period or an older age as compared to the Garrotxa eruptions.

3) The Empordà area extends over the northeast apex of the triangle (fig. 1). These volcanics represent the oldest ones of the catalonian eruptive group. They are probably of Miocene age (SOLÉ SABARÍS, 1962).

The present paper concerns the geochemistry of sampled volcanics collected in the Garrotxa, Gironés and La Selva areas. The twenty-nine new analyses for major and trace elements shown here represent,

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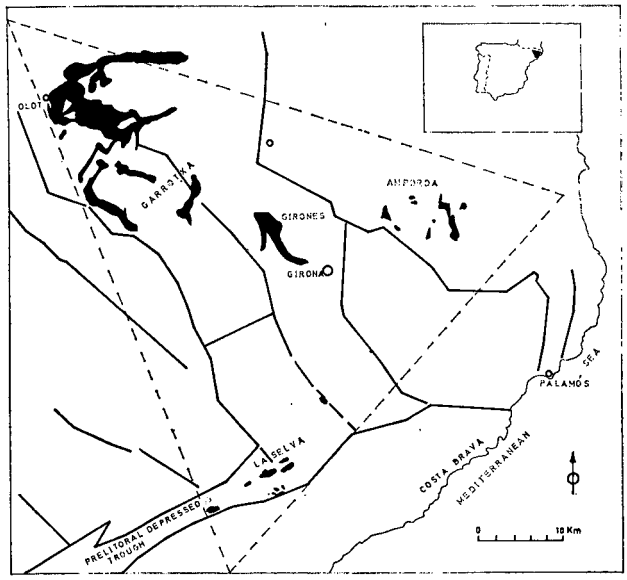

FIG. 1. — Locality map of the catalonian volcanics from a preliminary tectonic sketch by Solé-Sabarís.

as faras the author are aware, the widest geochemical contribution made to date on catalonian volcanics, tables 1, 2, 3 and 4.

Table 1.- Garrotxa volcanics (Castellfollit and Olot sectors).-

	CA09-1	CA09-2	CA10-1	CA12-1	CA12-2	CA02-1	CA04-1	CA08-1
SiO_2	47.68	47.22	49.18	49.07	49.67	44.22	44.70	45.10
Al_2O_3	15.03	14.78	15.16	15.25	15.42	14.76	15.06	14.90
TiO_2	2.30	2.30	2.12	2.11	2.07	2.72	2.50	2.50
Fe_2O_3	12.07	12.08	11.31	11.20	10.96	12.13	12.54	12.08
MnO	0.16	0.16	0.15	0.15	0.15	0.18	0.17	0.17
MgO	7.67	7.96	7.30	7.04	6.96	9.04	8.13	9.02
CaO	9.18	9.40	8.44	8.40	8.22	10.38	9.67	9.79
Na_2O	3.78	3.82	4.05	3.97	4.12	3.81	4.60	3.90
K_2O	1.63	1.61	1.83	1.86	2.00	2.11	2.27	2.26
P_2O_5	0.49	0.68	0.45	0.45	0.43	0.65	0.74	0.68
TOTAL	99.99	100.00	99.99	100.00	100.00	100.00	99.97	100.00
Ni	132	130	131	126	124	130	81	135
Rb	33	36	41	-	46	55	-	60
C.I.P.W norms.								
OR	9.62	9.50	10.82	11.00	11.83	12.45	13.43	13.32
Plag	40.76	38.73	43.66	45.58	44.43	31.86	30.10	22.32
Ne	5.67	6.51	4.56	5.41	6.40	14.81	17.66	14.24
Di	19.10	19.69	17.43	16.91	16.71	24.88	24.27	27.06
Ol	15.50	15.81	14.69	14.23	13.06	15.50	14.10	2.85
Mt	2.90	2.90	2.90	2.90	2.90	2.90	2.90	-
Il	4.37	4.37	4.02	4.02	3.94	5.17	4.92	4.78
Ap	1.07	1.48	0.99	0.97	0.94	2.42	1.62	1.49
TOTAL	98.99	98.99	99.07	99.08	99.10	98.98	98.99	99.00

Table 2 .- Garrotxa volcanics (Santa Pau sector).-

	CA06-1	CA06-2	CA07-1	CA07-3	CA07-4	CA07-5	CA05-1	CA11-1	CA11-2
SiO_2	44.53	44.58	46.72	45.82	47.85	47.50	44.95	44.65	44.77
Al_2O_3	14.43	14.76	15.44	14.72	14.90	14.71	14.67	14.71	14.60
TiO_2	2.63	2.62	2.42	2.55	2.97	2.25	2.44	2.55	2.52
Fe_2O_3	12.78	12.67	11.14	11.86	12.10	11.84	11.92	12.20	12.04
MnO	0.20	0.19	0.15	0.16	0.15	0.17	0.16	0.17	0.16
MgO	8.98	8.63	7.76	9.02	8.62	7.84	8.92	8.87	9.14
CaO	10.01	9.95	8.98	9.60	9.24	9.64	10.44	9.67	10.13
Na_2O	4.00	3.99	4.19	3.88	3.46	3.68	3.85	4.08	3.89
K_2O	1.71	1.80	2.56	2.26	1.18	1.82	1.99	2.36	2.16
P_2O_5	0.73	0.78	0.63	0.65	0.41	0.54	0.65	0.74	0.81
TOTAL	100.00	99.97	99.99	100.52	99.98	99.99	99.99	100.00	100.00
Ni	141	129	117	125	133	128	135	129	141
Rb	43	49	73	67	25	39	55	60	57
C.I.P.W. norms:									
Or	10.11	10.67	15.14	13.37	7.02	10.76	11.80	13.95	12.76
Plag	25.70	26.69	28.48	24.79	45.73	36.87	24.10	20.91	21.03
Ne	13.29	13.08	12.31	13.07	2.83	6.79	13.73	15.42	14.66
Di	23.56	22.52	20.37	22.42	17.74	21.51	25.19	23.35	24.65
Ol	16.76	16.19	13.92	16.18	15.47	14.72	15.22	16.02	15.79
Mt	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
Il	5.00	4.98	4.59	4.84	5.64	4.28	4.64	4.84	4.79
Ap	1.61	1.78	1.37	1.42	0.89	1.17	1.42	1.61	1.84
TOTAL	98.92	98.93	99.08	99.01	99.98	99.02	99.00	98.97	98.99

Table 3.- Garrotxa volcanics (Sant Feliu de Pallarols sector)and Girones volcanics (Adri sector).-

	CA01-1	CA01-4	CA02-1	CA02-2	CA14-3	CAADRI
SiO_2	44.84	44.46	44.02	44.35	44.90	44.28
Al_2O_3	13.86	14.64	14.49	14.50	13.90	4.09
TiO_2	2.66	2.71	2.63	2.48	2.67	0.15
Fe_2O_3	13.12	12.40	12.74	12.37	11.12	9.14
MnO	0.16	0.16	0.16	0.16	0.16	0.13
MgO	9.52	8.62	9.92	9.85	9.27	28.59
CaO	10.19	10.03	10.19	9.90	10.18	3.17
Na_2O	3.60	4.30	3.54	4.16	3.65	0.26
K_2O	1.46	1.95	1.72	1.72	1.42	0.03
P_2O_5	0.58	0.72	0.60	0.56	0.62	0.03
TOTAL	99.99	99.99	100.00	100.00	99.89	99.97
Ni	146	104	150	149	152	2.655
Rb	33	44	41	38	32	-
C.I.P.W. norms						
Or	8.65	11.52	10.15	10.17	8.39	0.17
Plag	28.56	22.08	25.59	22.74	29.68	12.51
Ne	10.42	15.82	12.42	15.33	10.18	-
Di	24.17	24.84	23.01	24.28	25.78	21.74
Ol	17.86	15.07	18.54	17.61	17.55	61.60
Mt	2.90	2.90	2.90	2.90	2.90	2.90
Il	5.06	5.16	4.99	4.71	5.08	0.29
Ap	1.27	1.57	1.32	1.23	1.36	0.07
TOTAL	98.89	98.96	98.92	98.97	98.89	99.28

Table 4.- La Selva volcanics (Hostalric, Hassanet and Riudarenes sectors)-

	CA14-1	CA14-2	CA14-4	CA15-1	CA15-2	CA16-1
SiO_2	46.49	47.42	45.73	49.83	47.64	44.45
Al_2O_3	15.28	14.72	15.35	16.14	16.14	16.63
TiO_2	1.69	1.65	2.24	2.14	2.11	2.74
Fe_2O_3	10.20	10.07	11.17	10.46	9.53	11.72
MnO	0.16	0.16	0.17	0.29	0.13	0.16
MgO	8.55	8.91	8.88	6.67	7.34	8.98
CaO	11.05	11.46	11.39	11.28	11.41	11.65
Na_2O	4.04	3.87	3.11	1.26	3.98	4.30
K_2O	2.07	1.11	0.92	1.00	1.16	0.67
P_2O_5	0.45	0.62	1.03	0.62	0.54	0.69
TOTAL	99.98	99.99	99.99	99.89	99.98	101.97
Ni	147	-	181	219	191	194
Rb	82	-	29	154	60	50
C.I.P.W. norms.						
Qz	-	-	-	5.21	-	-
Or	12.27	6.54	5.45	5.92	6.84	4.00
Plag	24.87	36.05	43.12	46.65	41.38	29.76
Ne	14.49	8.79	4.54	-	8.16	13.69
Di	28.04	27.15	20.34	13.31	24.70	28.36
Hy	-	-	-	19.74	-	-
Ol	12.40	13.27	16.21	-	10.07	13.61
Mt	2.90	2.90	2.90	2.90	2.90	2.90
Il	3.23	3.14	4.25	4.06	4.01	5.21
Ap	0.98	1.35	2.26	1.35	1.19	1.51
TOTAL	99.17	99.19	99.08	99.15	99.24	99.02

METHODOLOGY

Field Collection

The specimens of at least 30 cm in length were taken from the apparent least-weathered part of each outcrop.

Garrotxa area

a) Castellfollit sector.

CA 09-1 Basalt. Top of flow in Castellfollit de la Roca village next to burnt-out church, at 16 Iglesia street.

CA 09-1 Columns at base of Castellfollit cliff fallen from upper flow.

CA 10-1 Basalt at road side 2 km back towards Olot from Castellfollit.

CA 12-1 Basalt from Pinaca quarry 1.8 km from Castellfollit.

CA 12-2 Basalt from Surroca quarry 800 m towards Castellfollit.

b) Olot sector

CA 03-1 Fairly massive scoriaceous lava from summit of Mont Olivet volcano.

CA 04-1 Fresh bomb from Montsacopa volcano.

CA 08-1 Basalt. In Olot 150 m NW upstream of Font de Sant Roc.

c) Santa Pau sector

CA 06-1 Basalt from tributary creek on outskirts of Santa Pau village.

CA 06-2 Outcrop 100 m lower in Main river probably from same flow than CA 06-1.

CA 07-1 Vesicular basalt on road East of Santa Pau.

CA 07-3 Basalt 300 m further on road East of Santa Pau at 100 m to bridge.

CA 07-4 Aphyric massive basalt on turn off to Roca Corva above river near tennis court.

CA 07-5 Basalt on path, towards end of flow, at El Torn.

CA 05-1 Vesicular bomb fragment collected inside crater of Sta. Margarida cone at ruined stable above church.

CA 11-1 Compact bomb from puzzolana pit in Mont Cruscat cone.

CA 11-1 Basalt flow at side of Hostal Canxal on main road about 1 km from Sta. Margarida cone.

d) Sant Feliu de Pallarols sector.

CA 01-1 Massive ankaramite outcrop at roadcut between Sant Feliu de Pallarols and Les Planes.

CA 01-4 Five grained vesicular lava under bridge almost 2 km SE of Sant Feliu de Pallarols in direction of Les Planes.

CA 02-1 Basalt from fresh roadcut on return from Sant Aciscle de Colltort.

CA 02-2 Basalt 300 m down road from (CA 02-1) sample.

Gironés area

a) Canet d'Adri sector.

CA 13,0 Basanite from bomb in scoria Adri cone.

CA-ADRI Olivine nodule from bomb in Adri cone.

La Selva area

a) Hostalric sector.

CA 14-1 Basalt from columnar jointed flow at Hostalric castle.

CA 14-2 Basalt from south side of hill at Hostalric.

CA 14-4 Basalt from rock pile on roadside on road up hill.

b) Massanet sector.

CA 15-1 and CA 15-2 Altered basalts from Massanet quarry.

c) Riudarenes sector.

CA 16-1 Basalt from Tort quarry near Riudarenes village.

Geochemical Methods

The major oxide (MgO, Al_2O_3, SiO_2, CaO, TiO_2, MnO, Fe_2O_3) concentrations were determined by X-ray fluorescence analysis using a 100 Kv semiautomatic Philips spectrometer with the exception of Na (atomic absorption) and P (colorimetry). The elements Ni and Rb were also analyzed by X-ray spectrometry using pure pressed powder samples.

Matrix corrections were made by computer. Accuracy and precision of these methods have been discussed in some detail elsewhere (Watkins, Gunn and Coy-Yll, 1970).

Correlation among the elements, ternary diagrams and C.I.P.W. norms were obtained by computer.

Mineral analyses were made using an ARL electron microprobe Further details of the method used may be seen in Coy-Yll (1972).

Petrography and Mineralogy

The Catalonian Volcanics are a remarkably homogenous group of basanitic lavas both petrographically and mineralogically. The typical basanite is a massive black vitrophyric lava with less than 10 % of elongate or isometric subheudral or euhedral magnesian olivine. These are perfectly fresh and some of them show concentric creacking. Some olivine compositions are given in table 5. Note the increase in iron content as the olivine grain size becomes smaller.

Table 5.- Microprobe analysis of olivine.-

	CA01-1	CA02-2			CA09-2		CA11-1
		Big grain	Medium grain	Small grain	Big grain	Small grain	
SiO	39.9	40.3	39.9	41.3	41.8	43.2	39.6
FeO	15.9	15.9	16.9	25.1	17.0	26.0	16.9
MgO	44.7	43.8	42.8	34.2	41.0	31.2	43.7
CaO	0.3	"	0.3	"	-	-	0.2
TOTAL	100.8	100.0	99.9	100.6	99.8	100.4	100.4

The clinopyroxene phenocrysts frequently exceed 1 cm in diameter and tend to be pale brown or colorless. Microphenocrysts of intermediate size are somewhat greenish. Oscillatory zoning is sometimes present reflecting slight chemical variations between the core and edge of phenocrysts, table 6. All clinopyroxenes show relatively high Al_2O_3 and TiO_2 contents. TOURNON (1969) recognized this same feature in a clinopyroxene from Sta. Margarida volcano in the Garrotxa area.

Table 6 .- Microprobe analysis of clinopyroxene.-

	CA01-1		CA02-2	CA09-2	CA11-1
	core	edge			
SiO_2	46.2	42.5	46.0	48.0	48.5
Al_2O_3	8.0	9.1	8.8	6.9	6.0
TiO_2	1.9	2.6	1.8	1.7	1.8
MgO	12.0	14.7	13.0	12.5	13.0
FeO	9.2	8.5	7.5	8.4	7.5
CaO	22.3	22.3	22.4	22.2	22.3
Na_2O	0.9	0.9	0.9	0.9	0.4
K_2O	0.0	0.0	0.0	0.0	0.0
TOTAL	100.5	100.6	100.4	100.6	99.5

Plagioclase forms laths in the groundmass and does not exceed 20 % of rock (CA 01-4). On rare occasions the plagioclase forms 5 mm phenocrysts (CA 07-5) (CA 12-2) of a rather corroded appearance and with glass inclusions.

The plagioclase shows frecuently fluxed orientation (CA 12-1) (CA 02-1) similar to the hawaiites. Table 7 gives some plagioclase compositions as determined by microprobe. The maximum range encountered is between An_{41} and An_{66}. Leucite occurs as interstitial in coarser grained flows (CA 07-4) (CA 02-2) (CA 06-1) (CA 14-1).

Table 7 .- Microprobe analysis of plagioclase .-

	CA01-1	CA02-2	CA06-1		CA07-4		CA09-2
			a)	b)	a)	b)	
SiO_2	55.7	51.4	53.5	57.9	51.8	60.6	53.4
Al_2O_3	28.1	31.0	29.7	26.1	30.7	24.8	29.7
CaO	10.4	13.6	13.1	8.4	12.7	7.8	12.7
Na_2O	5.2	3.7	3.6	6.0	4.5	5.8	3.9
K_2O	0.5	0.3	0.1	1.0	0.3	0.9	0.3
TOTAL	99.9	100.0	100.0	99.4	100.0	99.9	100.0
Ab	46.0	32.5	33.2	51.7	38.5	54.5	35.2
An	51.0	66.0	66.3	41.3	60.0	40.2	63.3
Or	3.0	1.5	0.5	7.0	1.5	5.3	1.5
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0

a) in phenocryst.
b) in groundmass

Spinel is found as inclusion in olivine and in the groundmass. The range of spinel composition lies within that of magnetive-ulvospinel series, table 8.

Table 8.- Microprobe analyses of magnetite-ulvöspinel series.-

	CA01-1	CA02-2	CA06-1				CA11-1	CA14-1
Al_2O_3	2.5	1.4	3.5	3.1	7.9	2.9	5.0	5.9
TiO_2	21.3	22.8	6.2	8.5	10.0	17.0	10.4	14.0
FeO	44.4	48.5	33.9	33.8	37.9	40.0	25.6	38.4
$Fe_2O_3^*$	26.3	24.6	54.8	50.2	41.6	34.1	47.9	37.0
MgO	4.2	2.5	2.5	3.5	2.4	4.5	10.2	4.6
TOTAL	98.7	99.8	100.9	99.1	99.8	98.5	99.1	99.2
$MgAl_2O_4$	7.6	4.6	8.3	7.5	7.8	8.2	11.8	15.2
$FeAl_2O_4$	41.3	45.8	-	-	5.2	-	-	-
Fe_2TiO_4	41.3	45.8	9.4	13.5	16.8	30.6	15.6	23.3
$Fe^{II}Fe_2^{III}O_4$	51.0	49.5	82.2	79.0	70.1	61.2	72.5	61.4
TOTAL	99.9	99.9	99.9	100.0	99.9	100.0	99.9	99.9

* Fe_2O_3 concentration inferred from stoicheometry.

Perhaps the least expected mineral is the presence of abundant 3-4 mm quartz xenocrysts in the Hostalrich samples (CA 14-2) (CA 14-4). These occur in parallel flow oriented stringe. Cracks in the quartz are filled with carbonate.

Zeolite is rare but does occur in vesicles in somewhat altered lavas from Hostalric (CA 14-4).

The Adri olivine nodules consist of agregates of olivine, magnesian clinopyroxene, enstatite and brown spinel.

GEOCHEMISTRY

Twenty-nine new analyses for major and trace elements are presented, table 1, 2, 3 and 4. MONTOTO and ESBERT (1967) have presented 12 analyses made by various workers dating back to 1932. Cood agreement is found with the older analyses in SiO_2, CaO, MgO, P_2O_5 and in some instances alkalies. However TiO_2 appears overestimated in the older analyses.

In figs. 2 and 3 the alkalies ($Na_2O + K_2O$) and

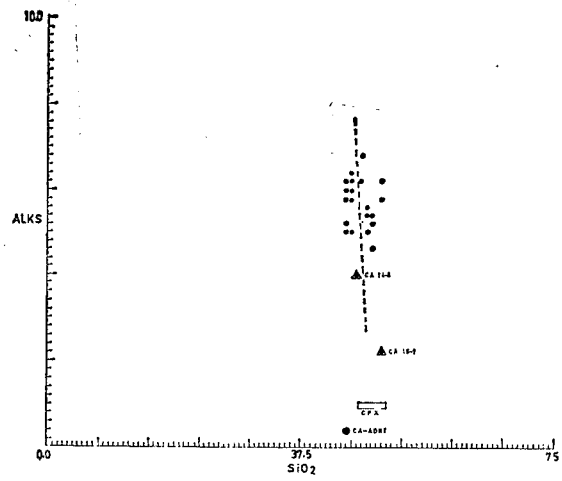

FIG. 2. — Variance of alkalies ($Na_2O + K_2O$) with SiO_2. Least mean-square regression line added. Open rectangle: composition of clinopyroxene as determined by microprobe.

Rb are considerably scattered especially in samples from the Hostalric sector. In the K_2O vs. Rb diagram (fig. 3) it will be seen that the Hostalric samples appear to have lost K and Na (see fig. 2), but gained more than 100 % ppm Rb as well as some Ca and

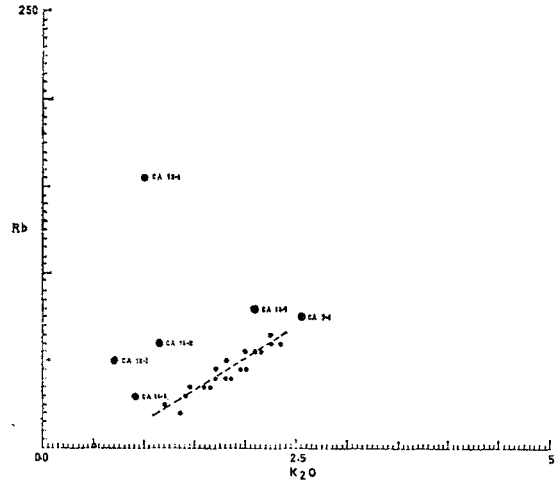

FIG. 3. — Variation of Rb as a function of K_2O. Rb in ppm; K_2O in percent; open circle: plagioclase composition as determined by microprobe.

The remaining chemical variations can be ascribed to fractionation due to olivine-clinopyroxene crystallization. The trend of Fe vs. MgO (fig. 4) does not extrapolate towards the composition of the Adri olivine nodule but towards the composition of an average

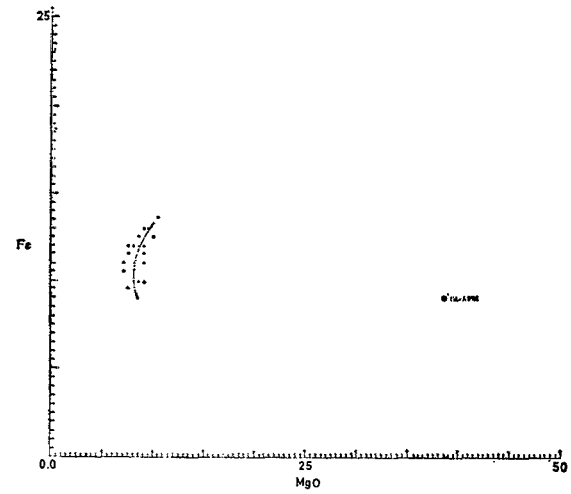

FIG. 4. — Plot of Fe vs. MgO. The trend do not extrapolate towards the composition of the Adri olivine nodule but towards the composition of an average olivine-clinopyroxene mixture.

Al (see tables 1, 2, 3 and 4). This large gain in Rb which is completed with apparent loss in $K_2O + Na_2O$ suggests modification by groundwater rather than contamination. As even flows of 15 m in thickness or more are partially altered, it is possible that the La Selva volcanics have been altered hydrothermally. This seems to be probable since in the La Selva area there exists a very important hydrothermal activity associated to some late stage of the pliocenic tectonics.

It has been demonstrated elsewhere that residual alkalies may become localised in the upper part of lava flows at a late stage in crystallization (WATKINS, GUNN and COY-YLL 1970) (HART, GUNN and WATKINS, 1971). In the deepest part of the flow a significant amount of the K is retained in plagioclase feldspar while in the enriched zone the alkalies are in a k-feldspar or orthoclase-albite intergrowth. This may result in significant fractionation of K from Rb as Rb is strongly discriminated against by plagioclase.

According to K/Rb ratio the catalonian lavas show fractionation patterns similar to the tholeiitic icelandic lavas: the lava samples with more than 2.5 % K_2O have a K/Rb ratio of 290 while those with 1.5 % K_2O have a K/Rb ratio of 490. In fig. 3 a K_2O of 0.5 % is inferred for the plagioclase in close agreement with that determined by microprobe, table 7. The mean K/Rb ratio of 350 may be compared with a ratio of 53 for the most altered Hostalric basalts.

olivine-clinopyroxene mixture. In fig. 5 the extrapolation of regression line does not intercept the Al_2O_3 axis at a 30 % Al_2O_3 as might be the case if the fractionation process depended only on the plagioclase crystallization. The intercept at 18.0 % Al_2O_3 can be explained by the rather high Ti and Al contents of the clinopyroxene, table 6.

This olivine-clinopyroxene fractionation appears, however, to be very minor because little variation in Ni (10-200 ppm) and MgO (7.3-10 %) contents is observed, tables 1, 2, 3 and 4.

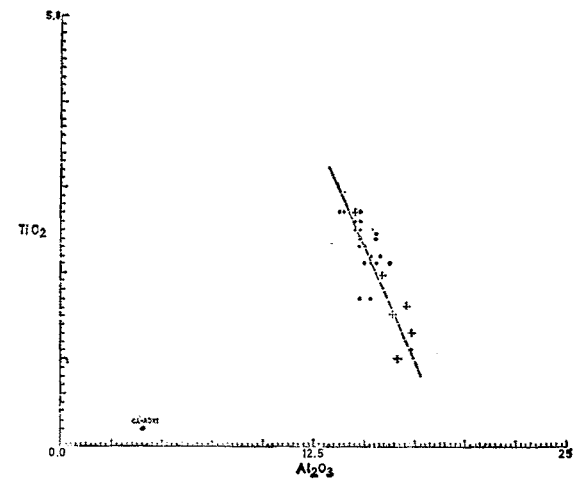

FIG. 5. — Negative correlation of Al_2O_3 vs. TiO_2. Black dots: analyses here reported; crosses: analyses as given by Tournon (1969).

Fig. 6 shows the normative mineral composition as given in tables 1, 2, 3 and 4 according to the method of STRECKEISEN (1967) in which feldspathoids (F), feldspars (A), and mafic minerals (M) are calculated to 100 per cent and plotted in a ternary dia-

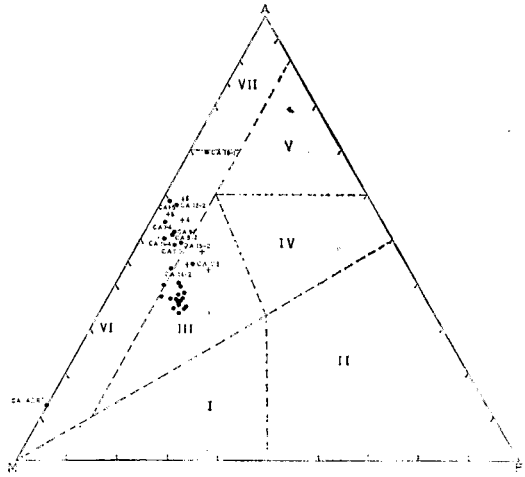

FIG. 6. — Ternary diagram FAM for catalonian volcanics. Black dots: analyses here reported; croses: analyses as given by Tournon (1969); A-normative feldspars; F-normative feldspathoids; M-normative mafic minerals; I-katungites, mafurites, ugandites, mela-leucites; II-leucitites, leucite nephelinites; III-leucite basanites; IV-phonolites; V-phonolites poor in nepheline; VI-trachybasalts; VII-trachytes, latites.

gram. All analyses here reported with those given by TOURNON (1969) lie within two main varieties of rocks: trachybasalt and leucite basanite. Moreover the localisation of points suggests a continous trend between both types of rock. Note for instance the trend given by (CA 07-4) (CA 07-5) and (CA 07-1) samples corresponding to a single lava flow between Santa Pau and El Torn localities.

SUMMARY

The catalonian volcanics include two main varieties of rocks: trachybasalt and leucite basanite. Their petrochemical variations are as follows:

a) Variations due to an ankaramitic type fractionation.

b) Variation in alkalies due to localisation within flows of residual alkalies (K, Na and Rb).

c) Leaching or hydrothermal processes in the La Selva area has resulted in a strong relative concentration of Rb with loss of K and Na contents.

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FE DE ERRATAS EN LOS TOTALES DE LAS TABLAS QUE SE INDICAN

Tabla	*Columna*	*Dice*	*Debe decir*
1	CA09-2	100.00	100.01
1	CA12-1	99.08	99.07
1	CA12-2	99.10	99.11
1	CA03-1	98.98	98.99
1	CA04-1	98.99	99.00
1	CA08-1	99.00	99.01
2	CA06-1	98.92	98.93
2	CA06-2	98.93	99.01
2	CA07-3	99.01	98.99
2	CA07-5	99.02	99.00
2	CA11-1	98.97	98.98
2	CA11-2	98.99	99.00
4	CA14-1	99.17	99.18
4	CA14-4	99.08	99.07
4	CA15-1	99.15	99.16
4	CA15-2	99.24	99.25
4	CA16-1	99.02	99.04
8	CA14-1	99.2	99,9