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SOME CONSIDERATIONS ON PALAEOZOIC SPILITES OF CARNIA (ITALIAN EASTERN ALPS)

ALCUNE CONSIDERAZIONI SULLE SPILITI PALEOZOICHE DELLA CARNIA (ALPI ORIENTALI ITALIANE)

Abstract — Petrographic, petrochemical, geochemical and mineralogical features of a spilitic association near Paluzza town (Carnian Alps, Northeastern Italy) are presentend. The data, although not conclusive, point to a transitional versus tholeiitic parent source for the volcanis, linked to rifting processes of a continental crust.

Key words: Spilites, Basalts, Clinopyroxenes, Carnia, Eastern Alps.

Riassunto breve — *Vengono presentate considerazioni petrografiche, petrochimiche, geochimiche e mineralogiche sulle associazioni spilitiche affioranti presso Paluzza (Alpi Carniche). I dati, peraltro non definitivi, orientano verso un magma genitore transizionale tendenzialmente tholeiitico associabile a processi di rifting di crosta continentale.*

Parole chiave: *Spiliti, Basalti, Clinopirosseni, Carnia, Alpi orientali.*

Introduction and geological outlines

In the Carnian mountains (South-eastern Alps) massive spilites, pillow lavas, pillow breccias, hyaloclastites as well as keratophyres and keratophyric tuffs are widespread in the «hercynian Flysch» (GENTILI & PELLIZER, 1964; SPALLETTA et al., 1979). The volcanics are Upper Carboniferous (Namurian-Westfalian) aged and belong to Hochwipfel and Dimon formations (SELLI, 1963). They were genetically attributed to an alkali-olivin basaltic parent magma for «so-called» similarity with Karawanken high TiO_2 spilitics, and were interpreted as connected to transcurrent movements (SPALLETTA et al., 1982).

A «testing zone» was examined near Paluzza town (fig. 1) with the aim to verify

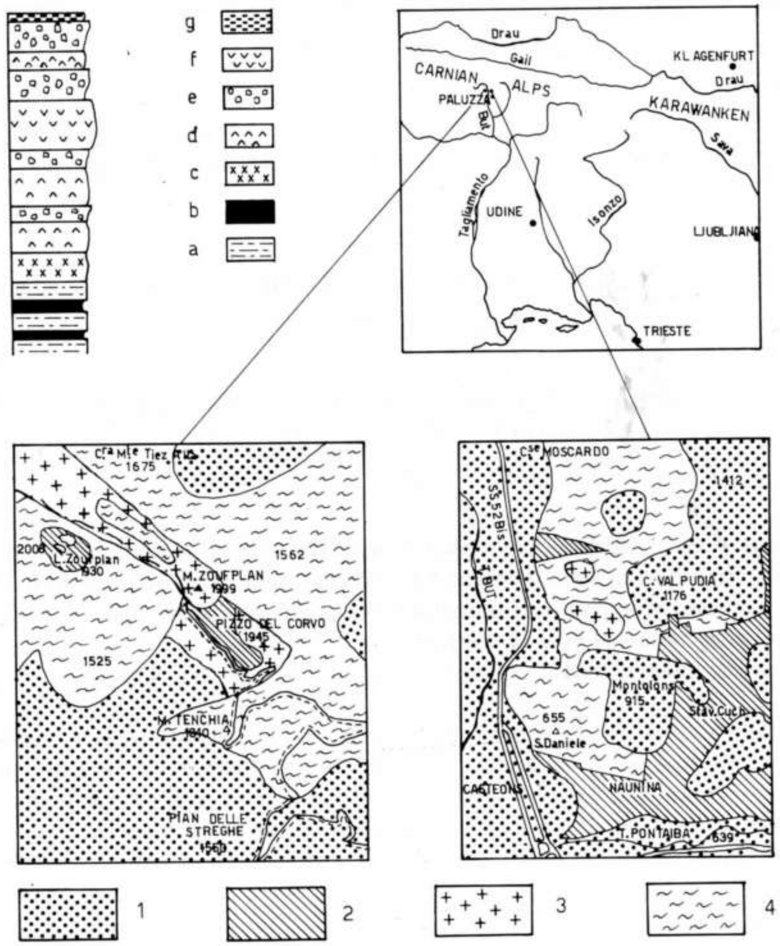


Fig. 1 - Geological sketch map showing the location of sampled areas: 1) Quaternary sediments; 2) Val Gardena Formation (Permian); 3) spilitic volcanics (Upper Carboniferous); 4) Dimon and Hochwipfel Formations (Upper Carboniferous). Stratigraphic section, after SPALLETTA et al., modified (1979): a) sandstones and siltstones; b) claystones; c) massive diabases; d) weakly porphyritic spilites; e) hyaloclastites and tuffs; f) hyaloophytic spilites and «pillow-lavas»; g) Val Gardena Formation.

- *Carta geologica schematica che evidenzia le aree di provenienza dei campioni: 1) sedimenti quaternari; 2) Arenarie di Val Gardena (Permiano); 3) vulcaniti (Carbonifero superiore); 4) flysch ercinico (formazioni del Dimon e dell'Hochwipfel: Carbonifero superiore). Colonna stratigrafica, secondo* SPALLETTA *et al., modificata (1979): a) arenarie e siltiti; b) argilliti; c) diabasi massicci; d) spiliti debolmente porfiriche; e) ialoclastiti e tufiti; f) spiliti ialoofitiche e lave a cuscino; g) Arenarie di Val Gardena.*

some petrogenetic features of the outcropping volcanics that include all the types described by GENTILI & PELLIZER (1964) in a larger area.

In the zone, the Hochwipfel and Dimon formations outcrop in stratigraphic succession, made of turbiditic units (claystones, siltstones and sandstones of the «hercynian Flysch»: s. SPALLETTA et al., 1982 and therein references) and volcanic types belonging to the Dimon formation (following SPALLETTA et al., 1982), with sequences of massive diabases, weakly porphyritic and hyaloophitic spilites, hyaloclastites and tuffs, «pillows lavas». The series is topped by Medium-Upper Permian sandstones (Val Gardena formation).

Petrography

Over a population of 45 samples, fifteen were selected as representative of the different volcanic rocks distinguished in the field. The main petrographic features of the structurally different outcrops are reported below.

1) Massive diabases (MD. Type: FB9): medium to coarse grained, subophitic texture with plagioclase (Ca-andesine to Na-labradorite) and Ca-rich pyroxenes (subordinately magnetite). Interstitial chlorite, albite, epidote, carbonates and opaques.
2) Weakly porphyritic spilites (WPS. Type: E1, E7, E15, T6, T7): fine grained, weakly porphyritic texture with olivine (chloritized), Ca-rich pyroxenes (sometimes epidotized) and albitized plagioclase phenocrysts and magnetite microphenocrysts. Groundmass made of chlorite, opaques and/or altered feldspars (intersertal texture) and epidotized Ca-rich pyroxenes. In some rocks (E1, E7, E15) chloritization processes are dominat, whereas in some types (T6, T7) albitization and epidotization are largely widespread.
3) Hyaloophitic spilites (HS. Type: V10, Z4B, Z9): albitized plagioclase phenocrysts and opaque microphenocrysts in a glassy (palagonitized and chloritized) to intersertal (partially or almost completely altered into fine-grained aggregates of sericite, epidote and clay minerals) groundmass. Vesicles can be present showing rims of palagonite or chlorite and are filled with carbonates and zeolites.
4) Hyaloclastites and tuffs (HT. Type: T5, Z6, Z4D): largely glassy (with glass sometimes replaced by quartz + chlorite + albite + sericite + epidote aggregates) with flow textures. They contain fragments, variable in size from few mm to some cm (up to «injecta» of LEHMAN, 1968) with trachytic or intersertal texture.

	FB9	E1	E7	E15	T6	T7	V10	Z4B	Z9	T5	Z6	Z4D	Z3	V16	V13
SiO_2	43.38	50.37	53.16	50.72	47.57	44.79	46.44	45.87	46.73	52.87	58.52	67.39	34.89	34.24	34.55
TiO_2	1.46	0.71	0.71	0.72	2.15	1.95	2.40	2.22	2.95	0.83	0.82	0.31	2.26	2.21	2.65
Al_2O_3	15.98	15.56	16.01	14.60	15.18	14.37	14.08	16.55	16.22	17.58	17.78	15.26	12.13	13.21	12.91
Fe_2O_3	4.24	3.35	3.31	3.78	5.68	5.74	4.67	4.28	4.04	4.40	3.15	2.75	9.28	9.48	3.80
FeO	8.17	5.21	4.81	5.83	8.15	9.23	8.67	6.48	5.77	5.37	2.45	2.00	4.08	4.73	7.31
MnO	0.18	0.14	0.39	0.22	0.14	0.14	0.29	0.26	0.26	0.11	0.12	0.05	1.40	1.54	0.21
MgO	10.41	9.93	10.00	12.74	7.13	7.02	7.71	8.39	6.57	4.35	1.88	1.54	5.11	4.79	1.90
CaO	8.34	6.26	3.15	2.99	4.23	5.70	7.37	4.44	4.16	3.92	1.97	0.16	14.82	15.08	18.58
Na_2O	2.53	2.01	3.34	3.22	5.06	4.47	2.71	2.90	2.13	1.97	9.25	8.76	2.96	2.47	2.00
K_2O	0.45	1.85	0.69	0.66	0.18	0.10	1.39	2.08	3.30	4.01	0.76	0.28	0.07	2.64	2.70
P_2O_5	0.31	0.11	0.09	0.10	0.20	0.19	0.43	0.57	0.47	0.16	0.33	0.04	0.36	0.39	0.40
L.O.I.	3.64	3.94	3.86	3.78	3.43	5.29	3.84	5.26	6.75	4.23	2.70	1.24	-	-	-
H_2O^+	-	-	-	-	-	-	-	-	-	-	-	-	4.37	0.90	0.50
CO_2	-	-	-	-	-	-	-	-	-	-	-	-	7.24	9.28	11.69
Sum	99.09	99.44	99.52	99.35	99.10	98.98	100.00	99.28	99.36	99.80	99.73	99.78	98.97	99.96	99.19
Cr	382	224	306	232	454	476	192	101	53	51	17	14	137	137	47
Ni	112	37	38	34	130	146	50	50	28	29	7	7	55	51	36
Ba	186	304	214	318	102	82	175	405	245	420	114	73	74	112	232
Ce	35	43	30	42	21	31	54	114	75	252	158	219	58	48	55
La	8	22	10	12	6	12	23	56	24	114	95	116	15	20	21
Sr	395	374	530	230	319	272	250	328	103	95	166	72	236	320	163
Zr	116	94	88	107	112	177	232	368	262	1960	766	1235	215	192	221
Rb	20	49	31	17	15	14	17	51	72	85	17	12	15	119	128
Y	21	24	18	20	23	21	31	39	36	144	48	97	32	30	33
Q	-	1.54	7.05	1.25	-	-	-	-	2.98	9.30	-	12.39	0.09	-	0.13
Or	2.67	10.93	4.03	3.92	1.06	0.56	8.22	12.29	19.50	23.71	4.49	1.62	0.39	15.62	15.96
Ab	21.40	16.98	28.24	27.22	42.82	38.81	22.90	24.55	18.05	16.67	72.22	74.16	24.99	20.85	16.87
An	30.90	27.97	15.25	14.16	18.18	18.86	22.11	18.33	17.60	18.42	4.73	0.49	19.60	13.59	15.71
Ne	-	-	-	-	-	-	-	-	-	-	3.29	-	-	-	-
C	-	-	4.19	3.39	-	-	-	2.80	2.68	3.16	-	-	-	0.30	0.94
Di	6.76	1.87	-	-	1.19	6.58	9.41	-	-	-	2.29	-	4.51	-	-
Hy	3.37	29.70	30.57	38.52	7.87	1.09	15.55	19.91	19.22	15.87	-	4.82	10.68	1.13	11.03
Ol	20.65	-	-	-	11.73	16.26	5.64	4.38	-	-	3.09	-	-	7.59	-
Mt	6.14	4.85	4.80	5.48	8.23	8.32	6.77	6.19	5.85	6.37	4.56	3.98	11.18	13.40	5.52
Il	2.76	1.34	1.34	1.36	4.07	3.70	4.56	4.21	5.60	1.58	1.54	0.58	4.29	4.19	5.03
Ap	0.73	0.25	0.22	0.23	0.46	0.46	1.02	1.34	1.10	0.38	0.77	0.10	0.84	0.91	0.94
Hm	-	-	-	-	-	-	-	-	-	-	-	-	1.56	0.24	-
Cc	-	-	-	-	-	-	-	-	-	-	-	-	16.47	21.11	26.58

Table I - Major (wt%), trace (ppm) element contents and CIPW norms of MD (FB9), WPS (E1, E7, E15, T6, T7), HS (V10, Z4B, Z9), HT (T5, Z6, Z4D) and PL (Z3, V16, V13) petrographic types of the «spilitic suite» near Paluzza town (Carnian Alps).
- *Composizione chimica dei tipi petrografici delle rocce spilitiche dei dintorni di Paluzza. Elementi Maggiori (peso%), elementi in tracce (ppm). Norma CIPW di: MD (FB9), WPS (E1, E7, E15, T6, T7), HS (V10, Z4B, Z9), HT (T5, Z6, Z4D) e PL (Z3, V16, V13).*

5) «Pillow-lavas» (PL. Type: Z3, V16, V13): vesicular and intensively altered with intersertal and variolitic textures (albite + chlorite + opaques) and abundant carbonate amygdules.

Petrochemical notes

The chemical nature of the analyzed samples is illustrated from the data of table I and the subsequent diagrams.

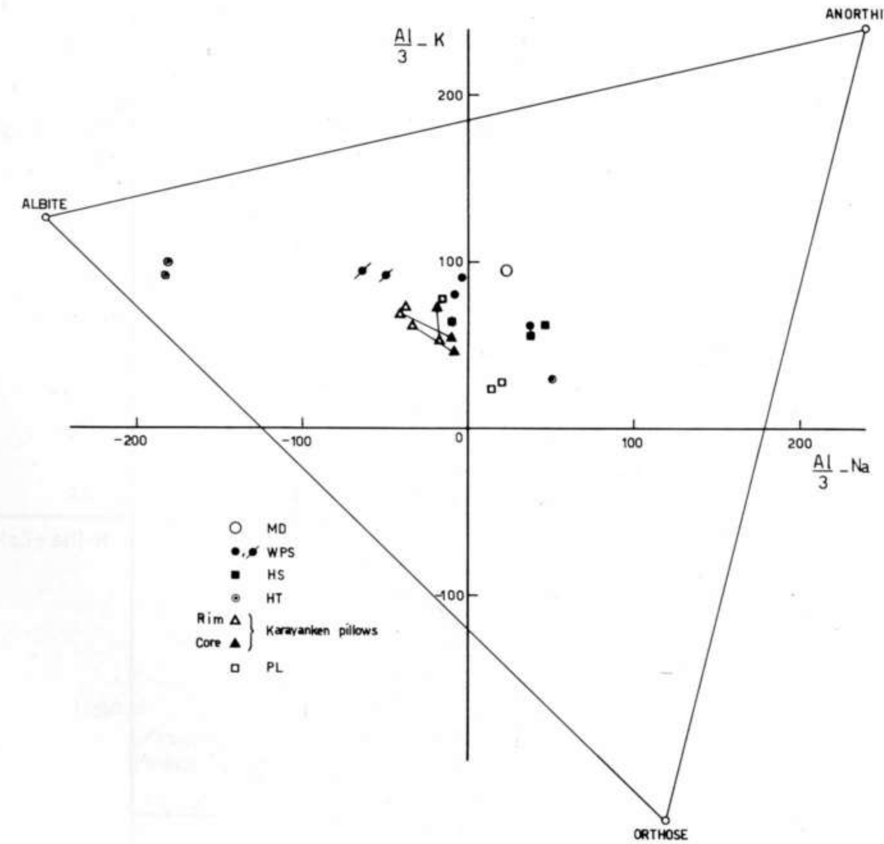


Fig. 2 - Diagram Al, Na, K, after DE LA ROCHE (1968). The samples of Karawanken pillows (LOESCHKE, 1973) with L.O.I. < 3%.
- *Diagramma Al, Na, K, secondo* DE LA ROCHE *(1968). I campioni dei pillows delle Caravanche (*LOESCHKE*, 1973) con L.O.I. < 3%.*

It should be emphasized that the large variability of the chemical compositions, linked to «spilitic» alteration, makes obscure the original affinity. As a matter of fact, some high Mg contents in MD, WPS, and Hs types point to chloritization processes, Na enrichment reflects albitization and so on, as well as the very high Ca and CO_2 values of PL are referable to intensive carbonatation. Moreover the «pillows» present also very high Mn and relatively high ferric iron contents that can be indicative

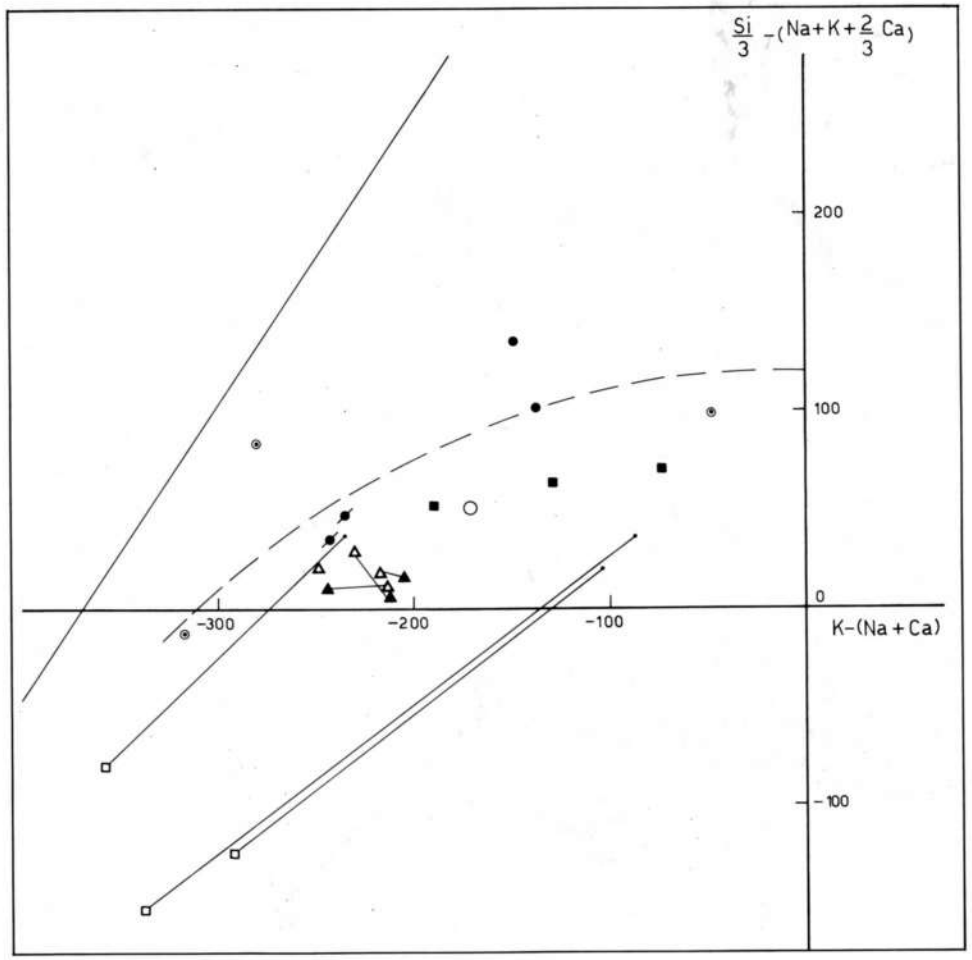
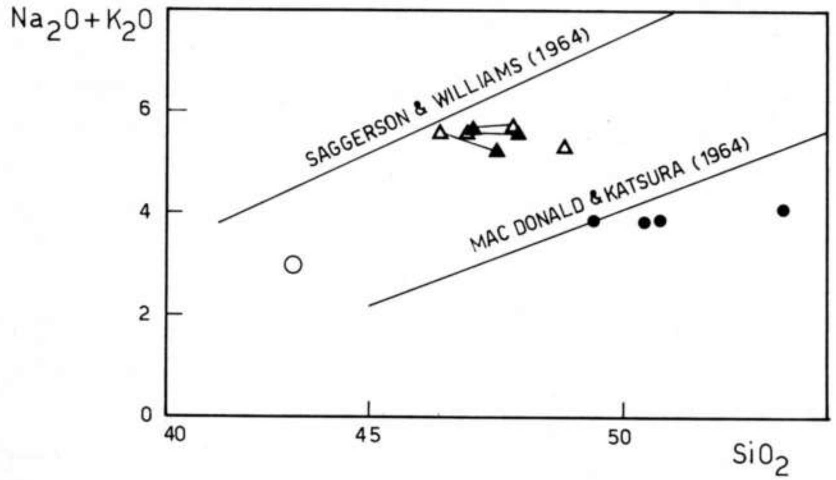


Fig. 3 - Diagram Si, K, Na, Ca, after De La Roche (1974). Symbols as in fig. 2. Points: carbonate free composition of the pillows.
- *Diagramma Si, K, Na, Ca, secondo* De La Roche *(1974). Simboli come in fig. 2. Punti: composizione dei pillows su base priva di carbonati.*



ig. 4 - Alkali-silica diagram for more «fresh» samples. Symbols as in fig. 2.
- *Diagramma alcali-silice per i campioni meno alterati. Simboli come in fig. 2.*

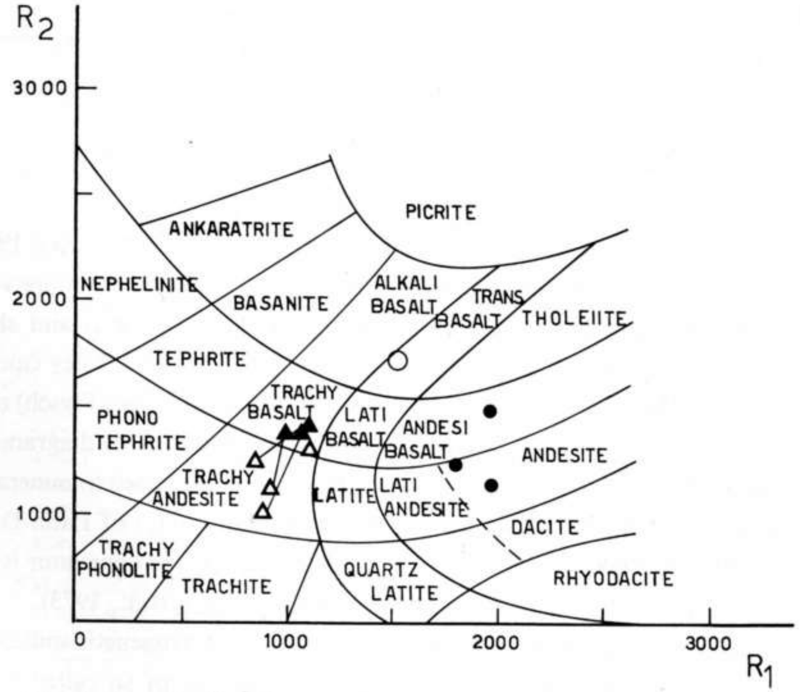


Fig. 5 - Distribution of spilits (the more fresh samples only) in the classificative diagram of De La Roche et al. (1980).
- *Distribuzione delle spiliti (solamente i campioni meno alterati) nel diagramma di classificazione secondo* De La Roche *et al. (1980).*

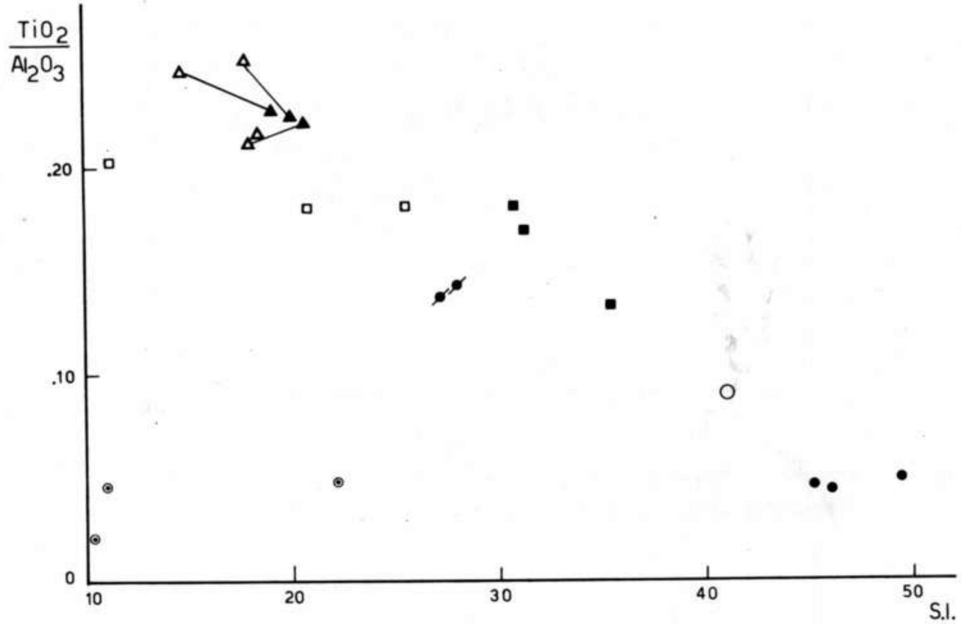


Fig. 6 - Diagram TiO_2/Al_2O_3 versus S.I. Symbols as in fig. 2.
- *Diagramma TiO_2/Al_2O_3 verso S.I. Simboli come in fig. 2.*

of laterization processes in subaerial environment (MELFI & CARVALHO, 1983). A petrochemical puzzle is constituted by HT types for the spanning the more variable compositions (up to Keratophyres of GENTILI & PELLIZER, 1964) and showing «anomalous» Zr and other incompatible elements concentrations. They can testify an explosive activity which experienced a «sedimentary» (Hercynian Flysch) mixing.

From DE LA ROCHE (1968) and DE LA ROCHE et al. (1974) diagrams (figs. 2 and 3) the samples fit the «spilitic» field with behaviours connected to mineralogical changes and with a generalized trend falling into alkaline suites of Lahn-Dill type (JUTEAU & ROCCI, 1974, DE LA ROCHE et al., 1974). The same behaviour is shown by palaeozoic spilites of the Karawanken mountains (LOESCHKE, 1973).

But the use of major, minor and trace elements as petrogenetic indicators of altered rocks is seemingly limited to the probable mobility of so called immoble elements in the alteration processes. However, considering the more «fresh» samples (as FB9, E1, E7, E15), they belong to transitional and subalkaline fields (figs. 4 and 5), that contrasts with alkaline behaviour of Karawanken volcanics.

Moreover, it is remarkable also the lower TiO_2 content of the Carnian spilites (< 2.7%) versus the higher TiO_2 value (3.5 as average: s. LOESCHKE, 1973) of the Karawanken (fig. 6).

In these cases, the pyroxenes as indicators of the pristine character can have wide relevance (s. VALLANCE, 1973; NESBIT & PEARCE, 1977; DAL NEGRO et al., 1982; LETERRIER et al., 1982; COMIN-CHIARAMONTI et al., 1983; BELLIENI et al., 1983).

Chemical data for Ca-rich pyroxenes of some analyzed rocks (when containing not altered calcic clinopyroxene crystals) are presented in table II, from which a transitional versus tholeiitic trend clearly can be inferred in fig. 7.

	1C	1R	2C	2R	3C	3R	4C	4R	5C	5R	6	7
SiO_2	50.82	51.33	51.57	51.47	51.87	51.37	51.32	51.76	52.44	52.67	50.31	50.73
TiO_2	1.15	0.73	0.78	1.08	0.85	0.68	0.94	0.74	0.87	0.76	1.76	1.31
Al_2O_3	3.21	2.87	3.04	3.29	2.98	2.32	3.24	2.94	1.31	0.90	4.18	2.82
FeO_t	7.57	6.56	5.83	6.02	6.61	9.30	7.06	6.26	8.79	10.39	11.30	12.65
MnO	0.36	0.24	0.14	0.31	0.07	0.01	0.07	0.13	0.18	0.32	0.25	0.28
MgO	15.27	15.84	15.94	15.61	15.55	14.32	15.21	16.02	14.97	14.89	13.67	15.57
CaO	20.85	21.41	21.75	21.56	21.83	21.37	21.32	21.60	21.24	20.04	18.68	16.22
Na_2O	0.47	0.01	0.01	0.01	0.01	0.60	0.01	0.01	0.11	0.01	0.39	0.38
Cr_2O_3	0.28	1.00	0.86	0.57	0.21	0.01	0.51	0.55	0.07	0.01	0.17	0.05
Total	99.98	99.99	99.92	99.92	99.98	99.99	99.68	100.01	99.98	99.99	100.71	100.01
Si	1.876	1.896	1.901	1.898	1.913	1.905	1.902	1.907	1.951	1.966	1.871	1.892
Al^{IV}	0.124	0.104	0.099	0.102	0.087	0.095	0.098	0.093	0.049	0.034	0.129	0.108
Sum	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
Al^{IV}	0.016	0.021	0.033	0.041	0.042	0.007	0.044	0.034	0.008	0.006	0.054	0.016
Fe^{2+}	0.164	0.188	0.180	0.186	0.204	0.195	0.219	0.190	0.273	0.324	0.350	0.363
$*Fe^{3+}$	0.070	0.015	0.000	0.000	0.000	0.093	0.000	0.003	0.000	0.000	0.000	0.030
Cr^{3+}	0.008	0.029	0.025	0.017	0.006	0.000	0.015	0.015	0.002	0.000	0.005	0.001
Mg	0.840	0.872	0.876	0.858	0.855	0.792	0.840	0.879	0.830	0.828	0.763	0.871
Mn	0.011	0.008	0.004	0.010	0.002	0.001	0.002	0.004	0.006	0.010	0.008	0.009
Ti	0.032	0.020	0.022	0.030	0.023	0.019	0.026	0.020	0.024	0.021	0.049	0.037
Ca	0.825	0.847	0.859	0.852	0.863	0.849	0.847	0.852	0.847	0.802	0.744	0.648
Na	0.034	0.001	0.001	0.001	0.001	0.044	0.001	0.001	0.008	0.001	0.028	0.027
Sum	2.000	2.001	2.000	1.993	1.996	2.000	1.994	1.999	1.998	1.992	2.001	2.002
Ca	43.19	43.89	44.76	45.02	44.85	43.99	44.40	44.19	43.30	40.84	39.89	35.73
Mg	43.98	45.18	45.65	44.70	44.44	41.04	44.02	45.59	42.43	42.16	40.91	45.34
Fe^{**}	12.83	10.93	9.59	10.28	10.71	14.97	11.58	10.22	14.27	17.00	19.20	20.93

Table II - Representative microprobe analyses of clinopiroxenes of MD (1 to 4: FB9) and WPS (5 to 7; 5: E7; 6, 7: T6) types. C: core; R: rim.
- *Analisi rappresentative dei clinopirosseni di MD (1 a 4: FB9) e WPS (5 a 7; 5: E7; 6, 7: T6). C: nucleo; R: periferia.*

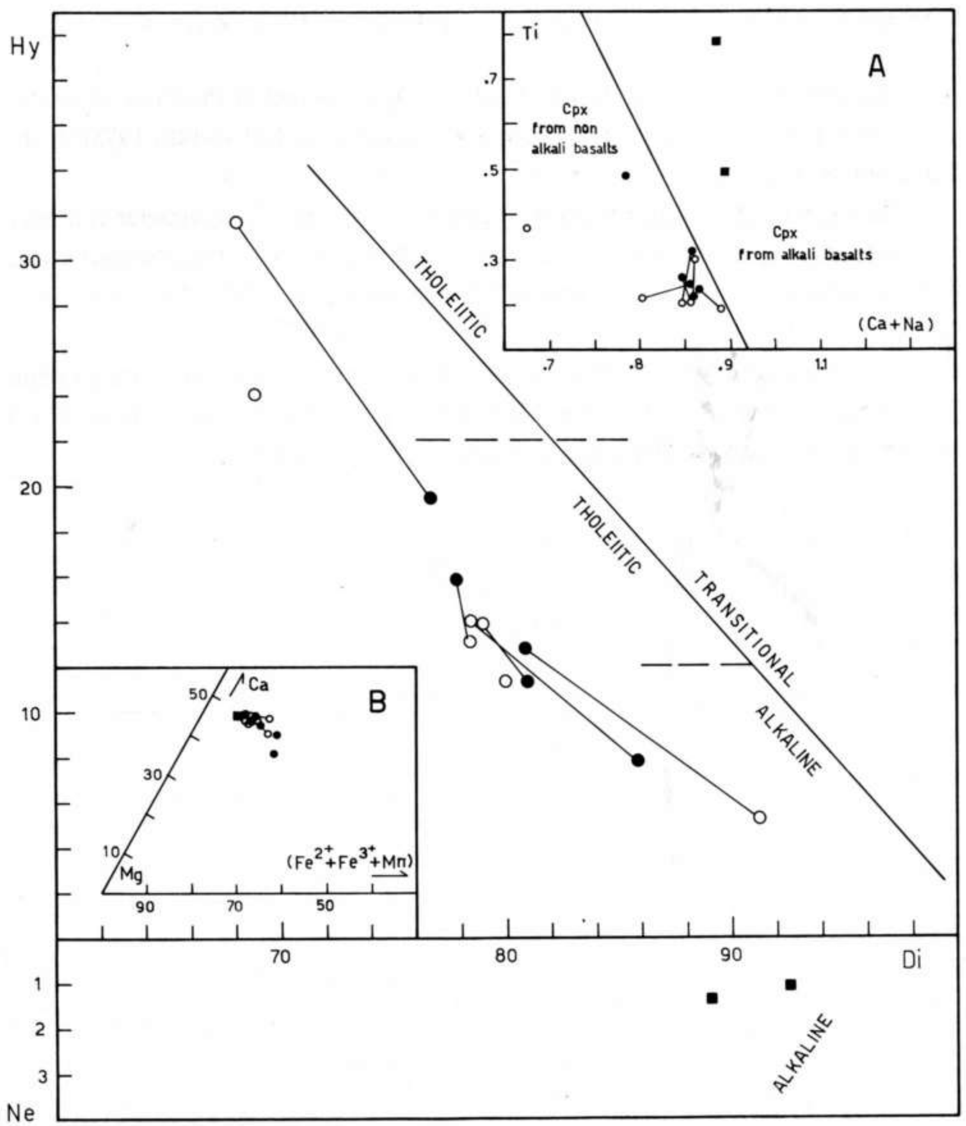


Fig. 7 - Normative (CIPW) Di vs Hy-Ne for Ca-rich pyroxenes. Full cyrcles, core; open cyrcles, rim of Carnian samples; squares: Karawanken Ca-rich pyroxenes. Inset A: analyses plotted onto discriminative diagram proposed by LETERRIER et al. (1982). Inset B: pyroxene quadrilateral showing plot of clinopyroxenes.

- *Norme CIPW per pirosseni ricchi in Ca delle spiliti carniche: circoli pieni, nucleo; circoli vuoti, periferia; quadrati: pirosseni calcici delle vulcaniti delle Karawanke. Inserto A: analisi proiettate entro il diagramma discriminativo proposto da* LETERRIER *et al. (1982). Inserto B: quadrilatero dei pirosseni che mostra il campo di variazione degli stessi.*

It is noteworthy that TiO_2 content of Ca-rich clinopyroxenes reflects the TiO_2 contents of the whole rock compositions. This means that clinopyroxenes reflects the primary character of the magmas (DAL NEGRO et al., 1982).

A notable feature is that the two Ca-rich clinopyroxenes analyzed by LOESCHKE (1973) have a distinct alkaline character.

At this point the petrotectonic definition of Carnian spilites by means of geochemical criteria is highly speculative. However, as an attempt, we can use of

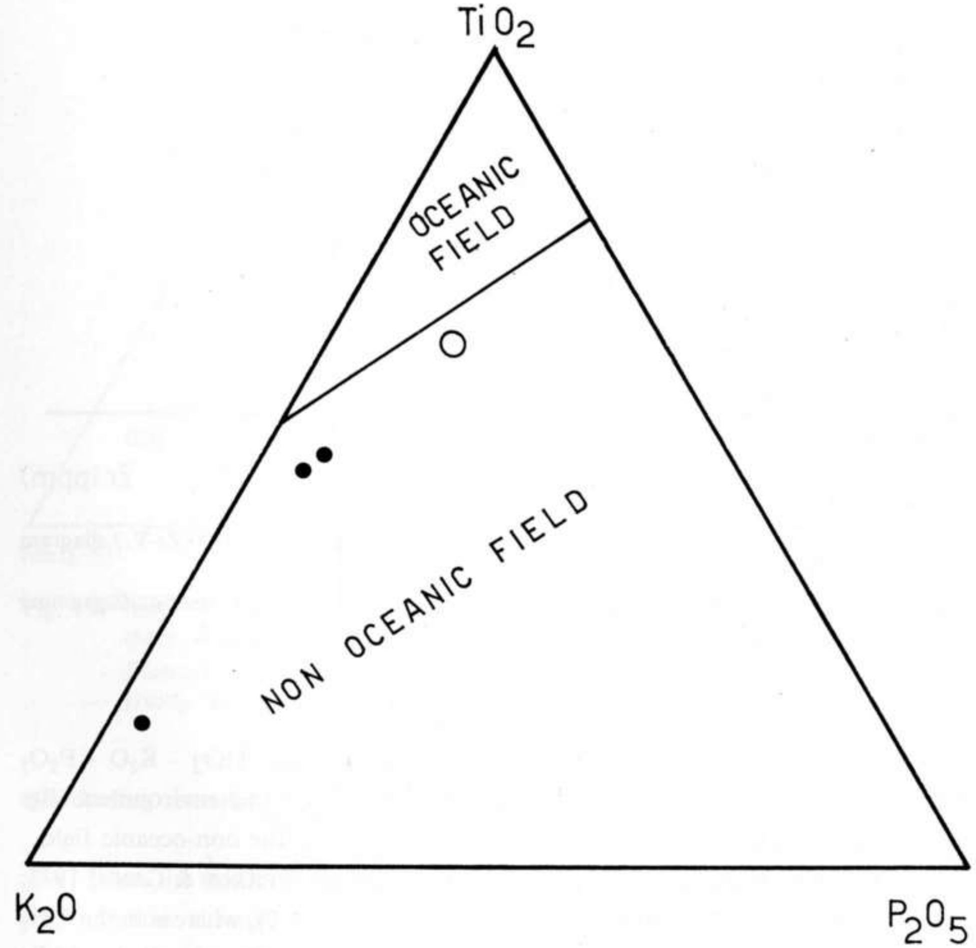


Fig. 8 - TiO_2 - K_2O - P_2O_5 diagram (PEARCE et al. 1975). Symbols as in fig. 2.

- *Diagramma TiO_2 - K_2O - P_2O_5 secondo* PEARCE *et al. (1975). Simboli come in fig. 2.*

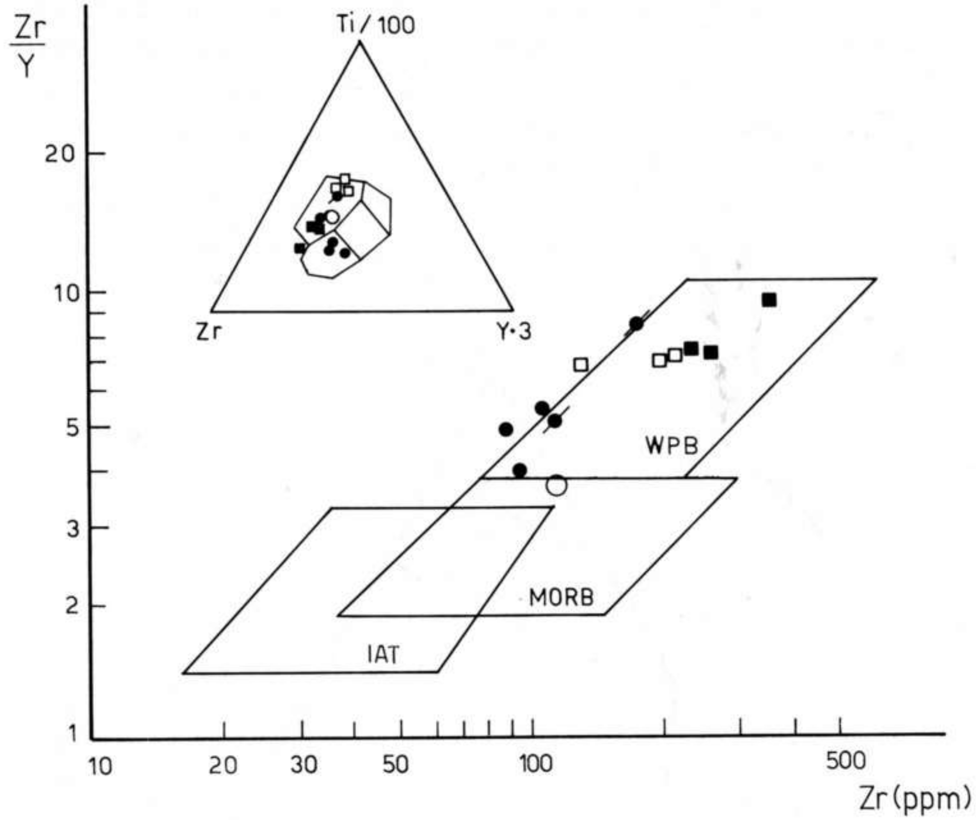


Fig. 9 - Zr/Y vs Zr diagram (PEARCE & NORRY, 1979). The inset: Ti/100-Zr-Y.3 diagram (PEARCE & CANN, 1973). Simbols as in fig. 2.
- *Diagramma Zr/Y vs Zr secondo* PEARCE & NORRY, *1979. Nell'inserto: diagramma Ti/100-Zr-Y.3 (*PEARCE & CANN, *1973). Simboli come in fig. 2.*

discriminant diagrams for plate tectonic environments. The TiO_2 - K_2O - P_2O_5 diagram (PEARCE et al., 1975) appears to indicate a non-oceanic environment (fig. 8), although alteration tends to move oceanic basalts into the non-oceanic field.

The Zr/Y versus Zr and Ti/100 - Zr - Y.3 diagrams (PEARCE & CANN, 1973; PEARCE & NORRY, 1979) indicate «within-plate» basalts (fig. 9), whereas in the TiO_2 - MnO.10 - P_2O_5.10 diagram (MULLEN, 1983) the samples scatter in all the fields, the scatter itself being (following MULLEN, 1983) a significant signature of continental tholeiitic series (fig. 10).

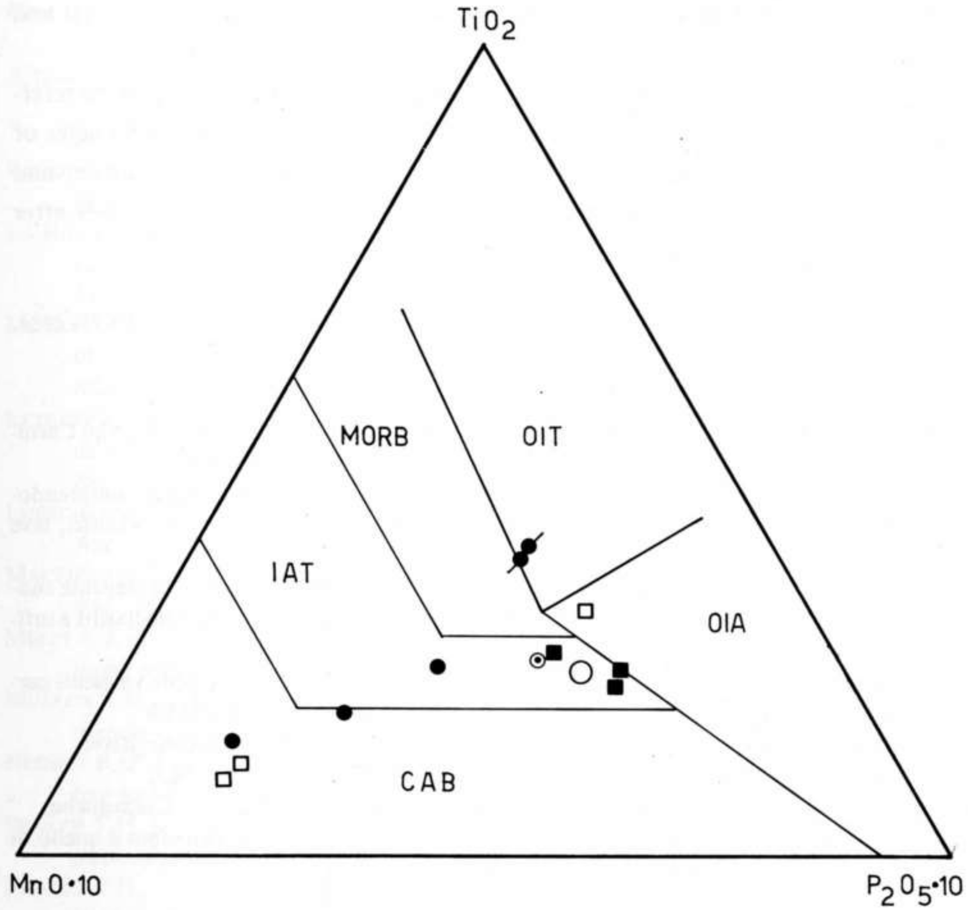


Fig. 10- MnO.10-TiO_2-P_2O_5 discriminant diagram for basalts and basaltic andesites (MULLEN, 1982). Symbols as in fig. 2.
- *Diagramma MnO.10-TiO_2- P_2O_5 per basalti ed andesiti basaltiche secondo* MULLEN *(1982). Simboli come in fig. 2.*

Concluding remarks

From the available data on the palaeozoic Carnian spilites some considerations can be made, although not conclusive:

1) The parent magma (s) probably has (have) a transitional versus tholeiitic character.
2) The Carnian spilites do not appear genetically linked to Karawanken spilites which experienced a more alkaline source.

3) The most probable tectonic environment is connected to a continental crust and the volcanism may be linked to rifting processes.

In any case, in our opinion, a more detailed and systematic study must be referred to mineral phases, as Ca-rich clinopyroxenes, in which the pristine character of the original source is preserved. Any approach to petrography, petrochemistry and geochemistry can result significative only for the spilitic alteration processes after the knowledge of a «possible» parent magma.

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RIASSUNTO — Sono state studiate alcune associazioni spilitiche affioranti nelle Alpi Carniche con un'età compresa tra Namuriano e Westfaliano (Carbonifero sup.).

I campioni esaminati, provenienti da due zone situate nei pressi di Paluzza, comprendono diabasi massicci, ialoclastiti, spiliti porfiriche, tufiti talora con elementi piroclastici, lave a cuscino.

Lo studio petrografico ha consentito di raggruppare i vari tipi secondo la seguente suddivisione: diabasi massicci, spiliti debolmente porfiriche, spiliti ialoofitiche, ialoclastiti e tufiti, lave a cuscino.

Lo studio petrochimico, necessario per una caratterizzazione seriale delle vulcaniti carniche, è stato eseguito sia su campione di roccia che su pirosseni ricchi di Ca.

I dati ottenuti consentono le seguenti considerazioni, peraltro non conclusive:

1) Il magma originario ha carattere transizionale tendenzialmente tholeiitico;
2) le spiliti carniche non si possono geneticamente collegare a quelle delle Caravanche;
3) la più probabile situazione tettonica associabile a questo tipo di vulcanesimo è quello di processi di «rifting» in crosta continentale.

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