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THE ORIGIN OF THE IVREA-VERBANO BASIC FORMATION (ITALIAN WESTERN ALPS) DISTINCTION BETWEEN PYRIBOLITES AND METANORITES ***

RIASSUNTO. — Nel complesso cumulitico basico Ivrea-Verbano vi sono intercalazioni di materiale metasedimentario con metabasiti (piriboliti). Si propone l'ipotesi che tali intercalazioni siano inserite tettonicamente e rappresentino frammenti del basamento entro il quale si è intruso il complesso basico. Ciò implica una possibile differenza geochimica tra metabasiti associate ai metasedimenti e rocce basiche del complesso.

Tale ipotesi viene sottoposta a verifica attraverso l'analisi fattoriale Q-mode. I due tipi di rocce risultano ben discriminati e le piriboliti si distaccano nettamente dai trends definiti dalle rocce cumulitiche. Gli elementi che maggiormente discriminano tra i due gruppi sono nell'ordine d'importanza: K, Mg, Sr, Rb, Ca e Na.

ABSTRACT. — Layers and lenses of metasedimentary material and associated metabasites (pyribolites) occur intercalated into the ultramafic-mafic body of the Ivrea-Verbano formation. These intercalations are tentatively considered as tectonically inserted slices of the series into which the ultramafic-mafic complex was intruded. This implies a possible geochemical difference between the metabasites associated with the metasediments and the rocks of the complex.

The hypothesis is tested by Q-mode factorial analysis. The two rock types are well discriminated and the pyribolites clearly depart from the trends defined by the cumulitic rocks. The more discriminant elements, in order of decreasing importance, are: K, Mg, Sr, Rb, Ca and Na.

Introduction

Within the ultramafic-mafic Ivrea-Verbano complex, which, according to RIVALENTI et al. (1975), has been formed by gravitative differentiation of magma intruded into deep-crust, there are layers and lenses of metasedimentary rocks (stronalites and marbles) intercalated with metabasites (BERTOLANI & GARUTI, 1970). Also charnokites occur in these minor sequences. According to a working hypothesis by RIVALENTI et al. (1975) these layers and lenses may be regarded as tectonically inserted slices of the host series into which the magmatic complex was intruded.

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Their relative actual position is the result of the repeated plastic deformations which affected rocks of both units. Original unconformities are generally masked by transposition of foliation, nevertheless in places they have been well preserved. In the last case the distinction between metanorites (of cumulitic origin) and metabasites is easy in the field; on the contrary, the distinction is more difficult when structural criteria are lacking.

This paper is aimed to discover if the mafic rocks of the two units can be distinguished on geochemical basis.

Occurrence and petrography

The series of metapelites and metabasites examined is the one of Sessera Valley, (Vercelli, Italy) with few samples collected from other localities. The metabasites occur strictly associated with stronalites and various felsic lithotypes metamorphosed in the granulite facies. They appear as medium-grained blackish rocks. The normal paragenesis is given by orthopyroxene, clinopyroxene and plagioclase in variable proportions. Hornblende is generally present and sometimes abundant, while biotite, ore and apatite may be accessory phases. Garnet is locally present. Although strictly speaking the metabasites should be classified as pyrigarnites, pyriclasites and pyribolites, the last are largely predominant and therefore the metabasites will be referred to as pyribolites in the text.

Geochemistry

Table 1 reports the chemical analyses of pyribolites and of some metanorites.

Assuming that metamorphism has been isochemical, at least as far as major elements are concerned, most of the pyribolites exhibit the normative composition of olivine-tholeiites.

In Fig. 1 the various oxides of pyribolites are plotted versus $F = FeO(tot)/FeO(tot)+MgO$ ratio. Rocks of the stratiform series having comparable F ratios are also reported; they are the garnet-bearing gabbros and norites of the LLG and ULG (Lower and Upper Layered Groups; see RIVALENTI et al., 1975).

The chemical data for these rocks are taken partly from the literature (RIVALENTI et al., 1975), and partly are new analyses reported in Table 1.

The pyribolites straddle generally the field of the garnetiferous lithotypes of the LLG and ULG: therefore they cannot be unequivocally distinguished from these rocks of the complex. The only plot where some discrimination occurs is the F-K_2O.

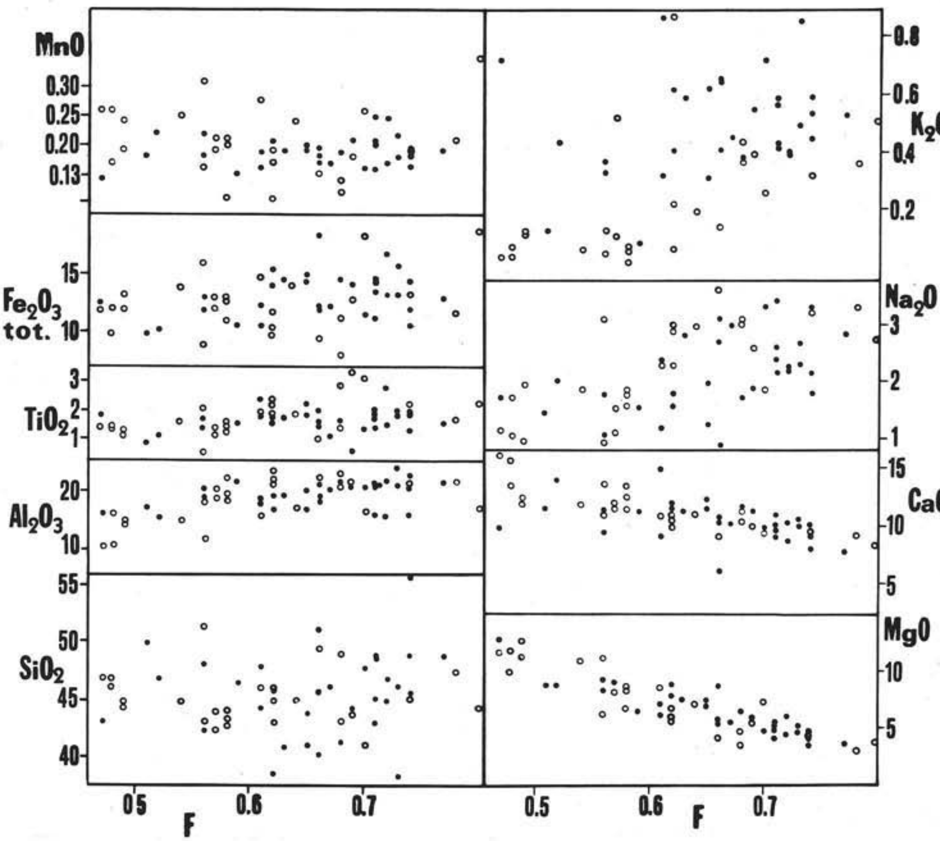

Fig. 1. — Plot of $F = \frac{FeOtot}{FeOtot + MgO}$ versus the various oxides. Pyribolites plot together with the garnet-bearing gabbros and norites of the stratiform series (LLG and ULG), except for F-K_2O plot. Simbols: Pyribolites = dots; garnet-bearing gabbros and norites of LLG and ULG = open circles.

Multivariate Q-mode analysis

As the univariate or bivariate parameters shown above do not provide any firm basis of distinction between pyribolites and garnet-bearing lithotypes of the cumulitic complex, the discrimination has been attempted by means of the Q-mode multivariate analysis. The basic principles of the method can be found in Harman (1970), Davis (1973), Shaw and Harman (1975) and others.

The elements involved in the Q-mode analysis are those of Table 1, except water. The general statistics for the untrasformed data are reported in Table 2. Table 3 sets out the weigth of the single variables over each factor, variance and relative cumulative variance. Three factors account for about 95 % of total variance which is a sufficient level for the present problem. Fig. 2 shows reciprocal plots of the three main factors F1, F2 and F3. Pyribolites are discriminated in all diagrams from

TABLE 1

Chemical analyses of Pyribolites and garnet-bearing gabbros and norites (samples marked with asterix)

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	H_2O+	Cr	Ni	Rb	Sr	Zr	Ba
Mo642	45.91	1.82	20.62	13.28	.18	4.46	9.75	2.29	.49	.47	.73	14	4	5	390	113	48
Mo621	47.53	1.35	20.25	11.53	.16	4.39	9.73	3.32	.71	.27	.76	25	2	11	351	150	1
Mo611	45.84	1.41	19.91	12.34	.17	5.42	10.08	3.00	.51	.25	1.07	53	8	2	320	102	46
Mo629	45.28	1.83	19.98	14.44	.18	4.58	10.03	1.80	.59	.42	.86	14	5	5	340	150	41
Mo602	48.63	1.36	20.50	14.90	.16	4.03	8.81	3.48	.42	.41	1.29	36	6	2	341	156	60
Mo622	48.85	1.26	22.34	10.51	.16	3.38	8.99	3.33	.53	.10	.55	22	2	3	398	212	135
Mo400B	50.96	1.60	18.50	12.32	.22	5.66	5.94	3.13	.64	.28	.74	263	17	5	218	130	76
Mo604	41.08	1.73	20.92	14.62	.19	6.30	11.77	1.71	.38	.23	1.06	24	5	1	316	56	18
Mo634	55.36	1.85	15.23	12.01	.19	3.78	7.97	2.16	.45	.30	.70	68	17	2	193	89	54
Mo614	45.45	1.49	16.32	13.95	.21	7.71	11.40	1.83	.62	.17	.85	367	117	5	232	80	385
Mo606	39.55	1.76	18.86	15.59	.17	8.67	11.89	1.59	.41	.03	1.50	31	3	3	264	47	12
Mo608	39.94	1.97	17.57	18.42	.16	8.68	10.28	.92	.65	.02	1.38	28	30	4	186	47	26
Mo633B	46.66	2.85	15.01	16.62	.25	5.82	8.68	2.27	.39	.40	1.05	105	47	2	158	118	28
Mo626	42.73	1.94	20.17	14.67	.20	5.32	11.04	2.16	.59	.42	.76	17	3	4	340	112	20
Mo394	46.28	1.55	21.21	10.46	.15	6.49	11.33	1.56	.08	.03	.86	140	2	2	455	61	10
Mo630B	37.97	1.96	23.42	15.68	.22	5.10	10.90	2.71	.85	.40	.79	19	5	8	360	136	73
Mo617	42.96	1.87	15.64	12.52	.14	12.69	9.90	1.75	.74	.04	1.75	55	48	19	220	53	30
Mo631	48.51	2.03	15.23	14.72	.25	5.31	9.78	2.60	.42	.30	.87	117	24	3	218	83	34
Mo601	40.85	1.84	18.58	14.63	.19	7.67	11.20	2.81	.59	.31	1.32	33	4	3	268	79	26
Mo620	44.95	1.78	20.62	13.33	.21	4.89	9.91	2.42	.56	.46	.88	23	7	4	340	172	108
Mo670	47.78	1.86	17.97	12.04	.19	7.01	8.93	2.38	.32	.32	1.20	171	50	3	305	124	11
Mo650	42.21	1.67	19.51	13.01	.18	9.05	11.55	1.16	.33	.04	1.28	103	28	1	335	93	20
Mo638	47.89	1.40	17.98	11.83	.22	8.23	9.25	1.83	.37	.30	.70	493	64	8	257	89	72
Mo666	40.93	1.86	19.66	15.12	.20	7.21	11.44	1.28	.31	.29	1.70	19	3	4	300	58	10
Mo660	49.91	.93	16.72	9.90	.18	8.48	11.47	1.49	.13	.05	.75	147	14	3	330	56	18
Mo640	46.72	1.13	14.76	10.31	.22	8.47	14.14	2.08	.44	.26	1.48	392	91	8	283	87	32
Mo641	43.63	2.28	16.37	14.25	.19	6.92	12.42	2.04	.62	.46	.81	3205	194	4	400	124	34
Mo399	44.65	1.49	21.11	13.19	.17	4.54	10.43	2.26	.70	.30	1.15	26	7	11	340	118	41
Mo663	44.03	2.43	17.44	10.49	.16	6.03	15.06	1.29	.87	.58	1.63	300	125	26	501	165	173
Mo636A	48.64	1.61	20.49	13.10	.19	3.62	7.78	2.84	.53	.42	.78	19	5	5	300	130	80
Mo668	44.29	.28	20.09	14.23	.21	5.84	11.36	1.93	.55	.52	.70	19	4	4	290	107	43
Mo613	45.49	1.25	20.44	12.20	.18	5.64	10.74	2.75	.41	.24	.66	37	6	3	335	107	26
Mo342*	44.73	1.61	14.28	13.84	.25	10.74	11.88	1.92	.06	.04	.64	159	130	4	102	42	17
Mo343*	45.82	1.91	15.00	14.70	.28	8.55	10.70	2.29	.06	.03	.66	137	58	2	158	68	16
Mo289*	46.76	1.43	10.29	11.94	.26	11.82	15.71	1.11	.04	.04	.59	460	158	5	83	60	27
Mo290*	46.94	1.37	9.95	11.83	.26	11.79	15.84	1.25	.04	.03	.70	470	167	3	85	62	28
Mo292*	44.29	1.29	14.79	11.76	.19	11.14	12.37	1.99	.13	.03	2.02	279	172	3	250	56	27
Mo293*	43.13	2.13	11.64	15.96	.31	11.08	13.80	.94	.05	.03	.91	250	74	2	25	59	21
Mo344*	44.67	1.11	14.42	13.42	.24	12.58	11.85	1.02	.13	.03	.53	420	320	4	142	42	24

the garnet-bearing lithotypes of the cumulitic complex. Fig. 3 is a triangular plot of the three factors.

In this diagram the factors have been normalised and rotated so that their single contribute to the total variance is of comparable order. The new factor scores and variance are reported in Table 4.

The discrimination results improved; garnetiferous rocks of the LLG and ULG form a trend characterized by the increase of F1 value.

Interpretation

In a preceding paper (CAPEDRI et al., this volume) it has been shown that it is possible to assigne a geochemical meaning to the discrimination and trends evidenced by the Q-mode analysis. Considering the variables which weight more over the single factors (Table 3) it is evident that F1 indicates merely that the main variability of the statistical population is due to modal variation in plagioclase and mafic

TABLE 2

General statistics of untrasformed data

VARIABLE	AVERAGE	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
SiO_2	45.2024	3.1210	37.9700	55.3600
TiO_2	1.7157	.5612	.2800	3.4200
Al_2O_3	18.3560	3.0279	9.9500	23.4200
MnO	.1976	.0478	.1100	.4000
MgO	6.8422	2.4515	3.0200	12.6900
CaO	10.8850	1.8567	5.9400	15.8400
Na_2O	2.2091	.7249	.9200	3.6500
K_2O	.3760	.2362	.0200	.8700
P_2O_5	.3184	.3874	.0200	1.8000
Fe_2O_3tot	12.8478	2.2876	8.0300	18.9500
Cr	168.9655	422.2916	14.0000	3205.0000
Ni	40.9310	61.5481	2.0000	320.0000
Rb	4.3448	4.5771	1.0000	26.0000
Sr	341.2931	154.0691	25.0000	742.0000
Zr	119.9828	146.2667	32.0000	900.0000
Ba	246.8103	498.4392	1.0000	2010.0000

TABLE 3

Scaled principal factor score matrix, variance of each factor and relative cumulative variance

	F1	F2	F3	F4	F5
SiO_2	1.673	- .320	- .285	- .766	.133
TiO_2	1.006	.253	- .102	1.425	-1.109
Al_2O_3	1.604	.553	- .167	-1.430	.166
MnO	1.005	- .606	- .187	.663	-1.146
MgO	1.110	-1.971	- .030	.490	.507
CaO	1.405	-1.069	- .269	.007	.788
Na_2O	1.226	1.193	- .579	-1.192	.317
K_2O	.863	1.352	3.108	.280	.201
P_2O_5	.333	1.126	- .506	1.557	- .925
Fe_2O_3tot	1.383	- .424	.451	.449	-1.806
Cr	.101	- .318	.184	.528	.623
Ni	.252	-1.309	.084	1.237	1.530
Rb	.327	.143	1.507	.516	1.645
Sr	.918	1.274	-1.321	- .159	1.247
Zr	.251	.642	- .312	.861	- .054
Ba	.207	1.252	-1.077	1.920	1.132
VARIANCE	90.05	3.68	1.70	1.27	.85
CUM. VARIANCE		93.73	95.43	96.70	97.55

TABLE 4

Scaled varimax factor scores, variance of each factor and relative cumulative variance

	F1	F2	F3
SiO_2	.966	-1.321	.553
TiO_2	.808	- .438	.492
Al_2O_3	1.379	- .585	.814
MnO	.343	-1.115	.226
MgO	- .490	-2.206	.100
CaO	.352	-1.732	.259
Na_2O	1.754	.072	.424
K_2O	- .347	1.043	3.321
P_2O_5	1.140	.579	.009
Fe_2O_3tot	.335	-1.098	.989
Cr	- .227	- .276	.132
Ni	- .671	-1.150	- .097
Rb	- .528	.167	1.446
Sr	2.016	.196	- .331
Zr	.699	.289	.017
Ba	1.446	.656	- .500
VARIANCE	34.134	36.045	25.250
CUM. VARIANCE		70.179	95.429

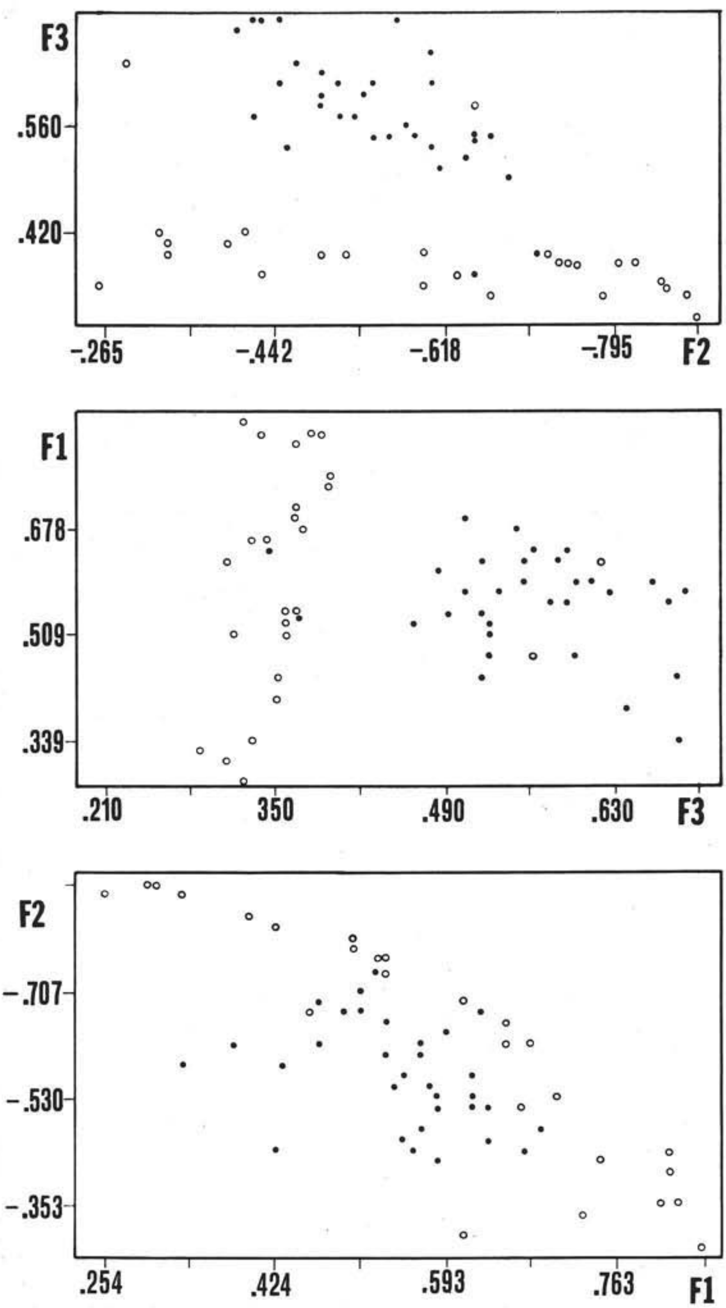

Fig. 2. — Reciprocal plots of the three main factors F1, F2 and F3. Pyribolites are discriminated in all diagrams and the garnet-bearing gabbros and norites gives a trend. Symbols as in Fig. 1.

minerals; variation in F2 is due to increase of plagioclase and contemporaneous decrease of mafic minerals; F3 shows that the population can be discriminated also on the basis of K_2O (and Rb).

In the triangular plot of Fig. 3 the groups are discriminated on the basis of the same variables, but now plagioclase is accounted for in F1, while F2 accounts for mafic minerals and in F3 K_2O and Rb have again a strong weight.

The trend shown by metanorites in the diagram F1-F2 (Fig. 2) indicates an increase of plagioclase at expenses of mafics, while the plot F2-F3 reveals that plagioclase enrichment is also accompained by increase of K_2O and Rb. In the triangular plot of factors metanorites define a trend which again is the consequence of plagioclase enrichment accompanied in the late stages by slight K enrichment.

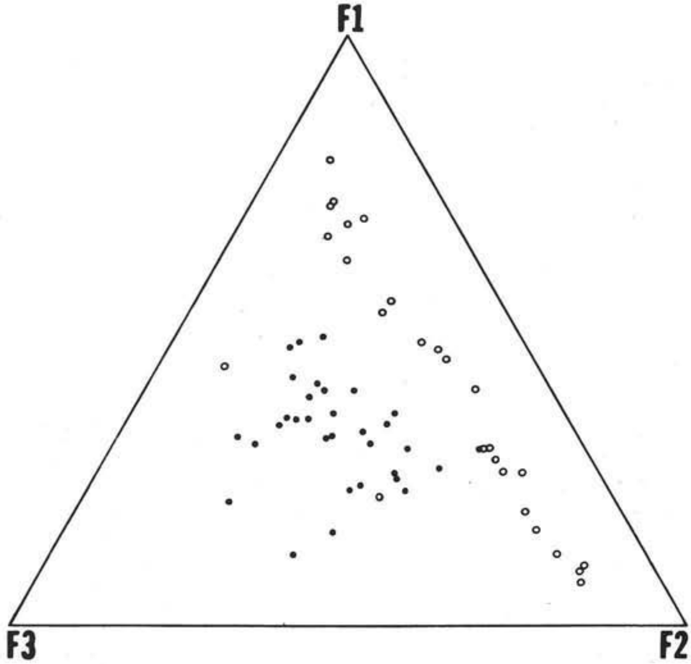

Fig. 3. — Triagular plot of the three main factors F1, F2 and F3, after rotation from the original orthogonality and normalization. Note the discrimination and trend given by garnet-bearing gabbros and norites of the stratiform series. Symbols as in Fig. 1.

These trends are conform with the differentiation scheme proposed by RIVALENTI et al. (1975) for these rocks, i.e. a late plagioclase crystallization accompained by increase of H_2O activity, and hence of incompatible elements such as K.

Pyribolites do not give any trend; they cluster always out from the trends defined by the cumulitic rocks. Therefore they behave as rocks geochemically unkindred to the rocks of the cumulitic complex.

Conclusions

The Q-mode factor analysis has proved to be a successful method for discriminating pyribolites and metanorites of the stratiform complex of the Ivrea-Verbano formation.

As pyribolites never follow the variation trends (dependent on the mechanism of igneous fractionation) of the metanorites, they may have been formed by some other mechanism and/or in another geotectonic environment.

This result supports the hypothesis that pyribolites and the associated metasediments may represent the crustal series into which the magmatic complex was intruded.

The data of present paper are not sufficient for assessing the original nature and the geotectonic meaning of the pyribolites. As a working hypothesis supported by the composition of the rocks examined, it might be put forward that they represent the basaltic layers of an oceanic sequence.

This hypothesis will be tested by future work.

Appendix

— Chemical analyses have been carried out by XRF, according to FRANZINI and LEONI (1972); H_2O^+ has been determined gravimetrically, and Na_2O by AA.

— The Q-mode Fortran program used in this paper is a modified version of the Klovan and Imbrie program (KLOVAN & IMBRIE, 1971).

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