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The « Valle del Cervo » plutonic body* Notes to the field trip on 1st October 1987

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ABSTRACT. — In this paper are presented some preliminary informations about the characteristics of the «Valle del Cervo» pluton, intended to serve as a guide for a field-trip.

This Oligocene magmatic body is built-up by at least three magmatic pulses and ranges in composition from monzodiorites, in the outer zone, to syenites and monzogranites in the core.

The outer zone is enriched in radiogenic Sr while the inner one is more alkaline but less radiogenic Sr enriched.

The chemical data suggest a CA, High-K_2O to «Shoshonitic» affinity.

The primary magma source could be a mantle source with substantial contribution of a crustal component, as previously suggested for the coheval dyke swarms cropping out in the same area; the changes in radiogenic Sr contents are preliminary interpreted as an effect of fluids dredged from the country rocks.

The prevailing mechanism of emplacement is a «cauldron subsidence», with a very shallow depth of emplacement, near to subvolcanic conditions.

Introduction

Late Alpine, mainly Oligocene, magmatic activity is widespread all over the internal sector of the Alpine chain. The dyke swarms and main plutonic bodies (ADAMELLO and MASINO BREGAGLIA) related to this igneous activity have recently been extensively investigated (DAL PIAZ, 1983).

The main features of this igneous activity can be summarized as follows:

— It is related to the «Periadriatic» lineament and forms a belt 20 to 50 km thick in both Southalpine and Austroalpine-Penninic domains.
— Activity is generally linked to tensional phase(s) postdating nappe piling, nappe ductile deformation and climax of meso-Alpine metamorphism (Lepontine phase 38 Ma).
— The chemistry of the magmatic products shows the low-Fe and relatively high LILE enrichments of island-arc and active continental margin types.

A comprehensive study of the dyke magmatism led the writers to suggest a sort of «zonal arrangement» of products in terms of serial classification. The magmatic activity changes in composition from low-K Tholeiites in the southeastern Alps to Shoshonites and Ultrapotassic rocks westwards (BECCALUVA et al., 1983). The depth of the mantle sources and the increasing influence of a «crustal» component are believed to be responsible for the alkalinity change in the magmatic products. Fig. 1 is redrown from a previous paper and shows the differences in chemistry of both dykes and plutonites within the above-mentioned «zonal arrangement». Volcanic-plutonic activity of Oligocene age is also seen to be widespread in the southwestern Alps. Three intrusive bodies (Miagliano, Traversella and Valle del Cervo plutons), several dyke-swarms and a preserved volcanic and volcanoclastic cover series (SCHEURING et al., 1974) occur along the Southalpine - Austroalpine boundary.

* Based on petrological, geochemical and field data related to works in progress and carried out with the co-operation of A. COLOMBO, A. DEL MORO, A. GREGNANIN, P. MACERA.

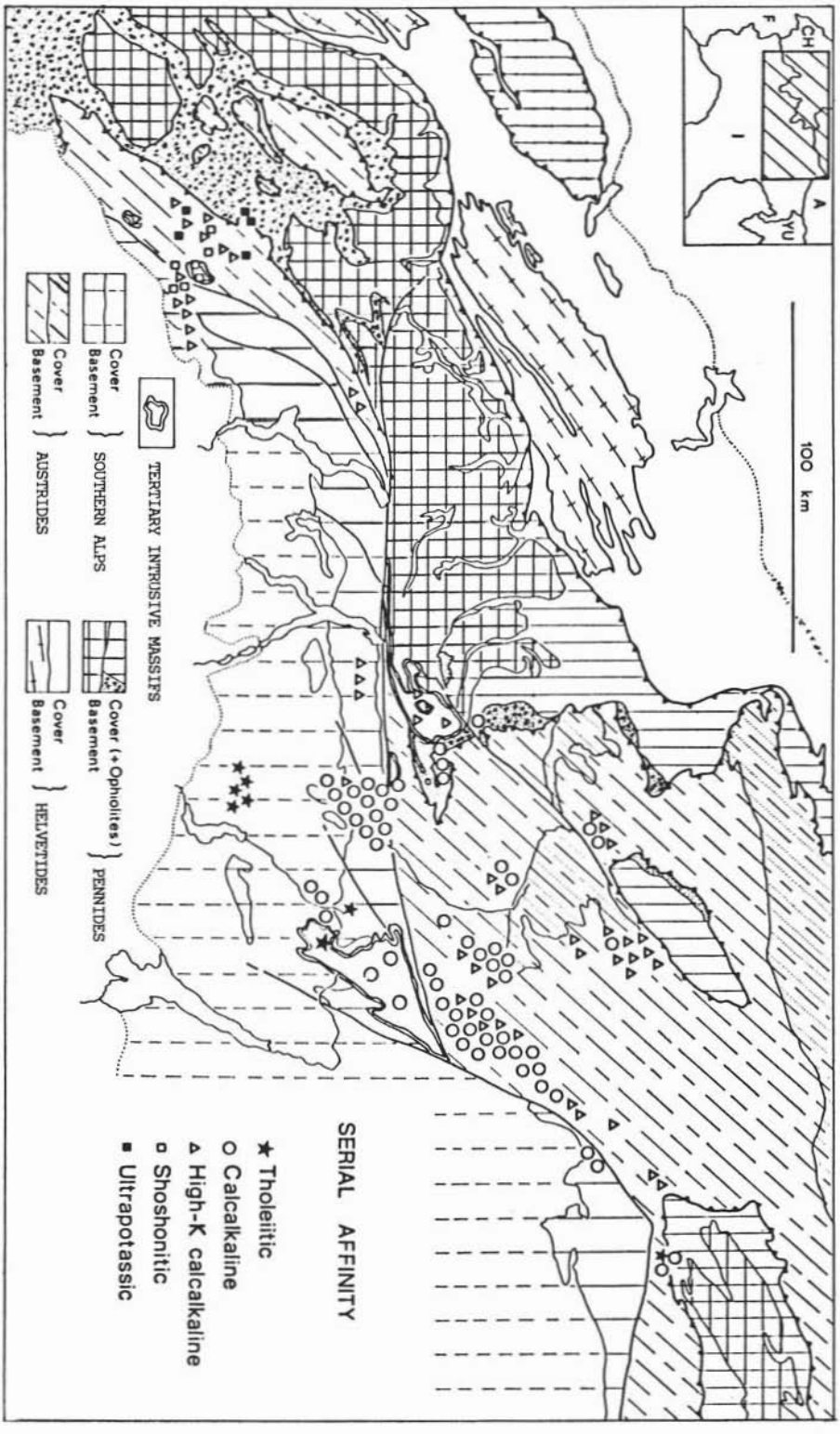

Fig. 1. — Sketch map of Alps. Distribution and serial affinity of Alpine dyke magmatism and Tertiary intrusive massifs.

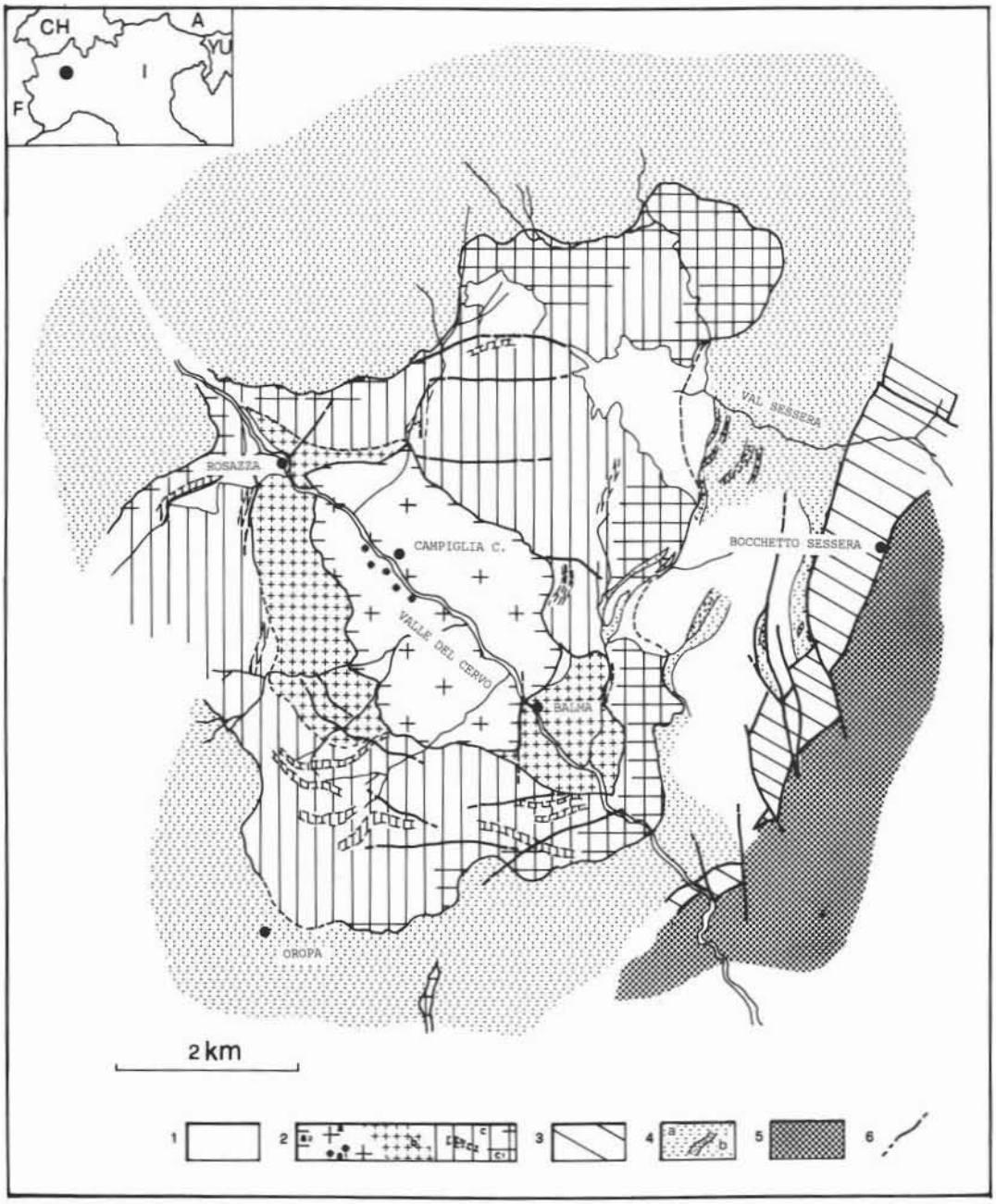

Fig. 2. — Geological sketch map of «Valle del Cervo» pluton.
1) *UNDIFFERENTIATED QUATERNARY COVER;* 2) *VALLE DEL CERVO PLUTON:* «Granitic» complex - a) Porphyritic (monzogranites) with K-feldspar megacrysts, generally pink to reddish in colour; a1) core of white «granite»; a2) outer rim of coloured «granite» with K-feldspar megacrysts grading into qz-monzonites. «Syenitic» complex - b) Light purple to grey amphibolic qz-syenites grading into monzo-syenites. «Monzonitic» complex - c) grey and light purple medium-grained qz-monzonites with large flakes of biotites, passing to (c1) grey, fine-grained facies; c2) fine-grained monzodiorites and monzonites crosscutting c and c1. 3) *CANAVESE «ANDESITES» AND PORPHYRITIC DYKES;* 4) *SESIA-LANZO ZONE:* a) Undifferentiated metamorphites (mainly metapelites) b) Eclogites; 5) *IVREA-VERBANO ZONE;* 6) *FAULTS AND FRACTURES.*

The «Valle del Cervo» pluton

Different names have been proposed for this pluton in previous works, e.g. «Sienite di Biella», or referring to small villages, sites of well-know quarries, e.g. «Sienite della Balma» and «Sienite di Oropa». Modern studies started in 1905, were carried out by G. Peyronel Pagliani and mainly by M. Potenza Fiorentini (see references), both from the former Institute of Mineralogy and Petrology of the University of Milan. Their numerous and useful petrological data and acute observations were of great help in planning and starting our program of petrologic and field investigations, now in progress, on the Oligocene magmatism in the southwestern Alps.

The «Valle del Cervo» pluton outcrops over an area of about 35 sq. km in the middle Valle del Cervo (VC). It has a characteristic ellipsoidal shape and is intruded into the pre-Alpine basement rocks of the Sesia-Lanzo Zone, very close to the contact with the Southalpine Ivrea-Verbano Zone (Fig. 2).

Lithology: Compared with previous works, our field data suggest the following lithological classification for the different facies of the pluton (Fig. 2):

— «Granitic» complex - a) Porphyritic «granites» (monzogranites with K-feldspar megacrysts, generally pink to reddish in colour; a1) core of white «granite»; a2) outer rim of coloured «granite» with K-feldspar megacrysts grading into a transitional zone of qz-monzonites.

— «Syenitic» complex - b) Light purple to grey amphibolic qz-syenites grading into monzo-syenites.

— «Monzonitic» complex - c) Grey and light purple medium-grained qz-monzonites with large biotite flakes, often grading into (c1) grey, fine-grained facies; c2) fine-grained monzodiorites and monzonites crosscutting c and c1.

Aplitic and microgranitic dykes.

No particular studies were carried out on the country rocks, so we distinguished only eclogites and metapelites of the Sesia-Lanzo Zone but left the Ivrea-Verbano Zone undifferentiated.

The word «complex» is proposed here because of the heterogeneity of the lithotypes included in the three main groups.

The main feature of the «Valle del Cervo» pluton is a roughly concentric arrangement of the different lithological complexes around a well developed «granitic» core.

The innermost part is formed of a white «granite» with randomly oriented K-feldspar phenocrysts up to 3-4 cm in lenght. Enclaves from a few centimetres up to several metres are very common and usually represented by dark grey, fine-grained fragments of mafic dykes.

The mineralogical assemblage consists of Qzt + Kfs + Pl + Bi ± Hbl. Microscopic investigations show characteristic textures for the white «granitic» core. A «groundmass», generally formed of aggregates of small grains of quartz and twinned plagioclase, occurs, and frequently exhibits near-equilibrium «granoblastic texture». Plagioclase, perthitic K-feldspar and quartz appear as coarse idiomorphic crystals. The K-feldspar megacrysts are rimmed by albite and small quartz grains form zonally arranged inclusions. Coarse flakes of brownish biotite prevail over hornblende; no clinopyroxene is present.

The white «granitic» facies gradually passes into an outer rim of porphyritic «granite» with pink to reddish coloured K-feldspar phenocrysts. Enclaves are frequent, especially in the external part of this envelope. Their diameter ranges from a few centimetres to 30-40 cm; they are composed of rounded fragments of a dense, dark, fine-grained rock interpreted as disrupted (syngranitic) basic dykes.

The «granite» with megacrysts of K-feldspar has a coarser grain-size than the white type and shows an hypidiomorphic texture. It has the same mineralogical assemblage but hornblende is more diffused. Textural features such as «groundmass», idiomorphic quartz and zonally arranged quartz grains in K-feldspar megacrysts are absent. The plagioclase (30% An) often develops myrmeckitic texture with K-feldspar. Some samples exhibit «granophyric» texture.

The contact with the more external lithologies is seldom well exposed. It is

generally represented by a zone of a few tens of metres where the amount of quartz decreases and the K-feldspars tend to decrease in grain size, losing their megacrystic appearance and becoming light purple in colour. The samples of this area range in composition between monzogranites and qz-monzogranites. They preserve both the hypidiomorphic texture and the mineralogical assemblage of the «granite», changing only the relative proportions of the minerals. The amount of quartz decreases towards the contact zone; biotite and hornblende with augitic cores are the femic phases.

The «granitic» complex is flanked on the southwestern and northeastern sides by two bodies of the «syenitic» complex. These «syenites» (qz-syenites) are well known because of extensive quarrying. This stone is widespread all over the world, although the «syenites» represent only a small fraction of the «Valle del Cervo» pluton. The qz-syenites are characteristically light purple or grey-purple in colour and show a medium grain-size, at times grading into a fine grain. They exhibit well developed foliation, due to the preferred orientation of the tabular feldspar crystals. A systematic study of the attitude and degree of preferred orientation has not yet been carried out, but field data show a general increase in degree of orientation along the external zones of the «syenitic» bodies. We interpret this «foliation» as a primary features due to magmatic flow during a partly forced emplacement. Enclaves still occur, but not as frequently as in the «granitic» complex; they are represented by small fragments of mafic rocks (dykes?) and minor metamorphic host rocks. The mineralogical assemblage of «syenites» is Kfs + Pl + Qtz + Hbl + Bi + Aug. Small plagioclases and biotites are more frequently included in K-feldspar. Interstitial microcline sometimes occurs. Myrmekitic texture is well developed. Plagioclase is weakly zoned (30-35% An). Hornblende is aboundant and prevails over biotite. The amount of pyroxene increases in the monzo-syenitic and fine-grained facies.

The more external zone of the pluton is composed of an association of variable lithologies, with some characteristic common features:

i) Biotite is the prevailing ferromagnesian mineral, sometimes occurring in flakes up to 5 mm in diameter.
ii) The prevailing modal composition is monzonitic.
iii) Enclaves are mainly composed of fragments of country rocks in different sizes; mafic enclaves are rare.

The prevailing lithology is a medium-grained qz-monzonite that, in the field, is not always easily distinguishable from the qz-syenites. In the northeastern area, the biotitic qz-monzonite grades into fine-grained qz-monzonites and monzodiorites forming a continuous rim towards the country rocks. These fine-grained border facies are typically rich in xenoliths of host rocks. Slabs of Sesia-Lanzo schists, appearing to be interfingered with the qz-monzonitic border facies, are well exposed in the southwestern zone.

Fine-grained qz- monzonitic to monzo-dioritic rocks also occur as dyke-shaped bodies within the «monzonitic» complex.

The mineral assemblage is: Pl + Aug + Bi ± Hbl ± Qz. In the medium-grained qz-monzonites only locally coarse feldspars occur and the grain size of plagioclase is larger than in the fine-grained qz-monzonites. Rare inclusions may be observed in the biotitic laminae: apatites and colourless pyroxenes may also be found. It should be pointed out that if large biotites occur, the small laminae are lacking or limited to a few flakes. Clinopyroxene clearly prevails over hornblende, that in some samples occurs as a small rim around the clinopyroxene crystals. Quartz and K-feldspar, if present, have allotriomorphic outlines and are interstitial. Mineral relationships seem to suggest the following growth order: Aug_1, Bi_1, Aug_2, Hbl, Bi_2, Kfs, Qz. Pyroxene is very abundant in the monzodiorites and orthopyroxene is sometimes also found.

Aplites with minor associated pegmatites occur and cut all the lithological complexes, but their distribution reaches its maximum in the southern and southeastern zones, in both the «syenitic» and «monzonitic» complexes.

Geochemistry: The following summary is

TABLE 1

Representative chemical analyses of «Valle del Cervo» pluton
All analyses are recalculated on a water-free basis
1) Andesite of Bocchetto Sessera (DE CAPITANI *et al., 1979); 2) Fine-grained qz-monzonite near host rocks; 3) Enclave in «monzonitic» complex; 4) Outer rim of «granitic» complex; 5)-6) «Granites»; 7) White «granite»; 8) La Balma «Syenite»; 9) Dyke-shaped, fine-grained qz-monzodiorite in «monzonitic» complex; 10) Aplitic dyke; 11) Sample from Miagliano pluton; 12) Porphyritic dyke in Sesia-Lanzo Zone; 13) Qz-monzonitic facies*

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO2	59.86	55.82	60.48	56.99	67.78	69.36	68.16	60.01	50.81	75.94	54.55	56.99	61.05
TiO2	0.73	0.80	0.62	0.54	0.38	0.31	0.36	0.65	1.00	0.04	0.96	0.96	0.65
Al2O3	19.09	15.82	15.75	14.05	15.86	15.74	15.66	15.45	17.80	14.00	17.85	14.09	16.44
FeO*	6.11	6.43	4.57	7.70	2.77	2.48	2.48	5.07	8.60	0.59	6.65	7.09	5.88
MnO	0.06	0.13	0.14	0.25	0.07	0.05	0.06	0.09	0.15	0.01	0.14	0.19	0.10
MgO	2.87	4.26	3.39	4.77	1.32	0.91	1.11	2.83	5.04	0.11	3.50	5.97	3.09
CaO	5.83	6.32	5.64	6.07	3.06	2.65	2.89	4.38	9.74	0.47	7.42	6.84	4.25
Na2O	2.62	3.77	3.29	2.32	3.80	3.84	4.23	3.50	3.94	3.54	3.42	2.12	3.11
K2O	2.80	5.72	5.55	6.65	4.72	4.50	4.86	7.45	2.28	5.28	5.29	4.71	4.95
P2O5	0.02	0.93	0.56	0.66	0.24	0.16	0.19	0.57	0.64	0.02	0.22	1.04	0.48
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Rb	0	253	313	361	262	225	271	270	89	365	78	183	236
Ba	0	2925	1183	1081	1106	1118	1048	2572	1615	189	834	2646	2512
Sr	0	1127	704	329	786	840	753	1244	683	114	467	515	957
Nb	0	32	29	27	26	21	23	29	10	19	9	27	29
Th	0	80	0	0	0	0	58	0	0	12	13	0	83
U	0	32	0	0	0	0	37	0	0	39	5	0	38
87Sr/86Sr i	0.0000	0.7098	0.0000	0.0000	0.0000	0.0000	0.7090	0.7092	0.7103	0.7113	0.7093	0.0000	0.7102

mainly based on 31 new $^{87}Sr/^{86}Sr$ isotopic determinations and about 100 new chemical analyses of samples from the «Valle del Cervo» pluton and host rocks.

The chemical data agree with the above-mentioned «orogenic» character (Fig. 1). In Fig. 3a, the main lithotypes of the «Valle del Cervo» magmatic body plot in or near the alkaline field. The K_2O/silica diagram (Fig. 3b) defines a shoshonitic (qz-monzonites and monzogranites) up to high-K character (qz-monzonites and qz-syenites). Moreover, the mildly alkaline and alkaline monzonites differ from each other in the slope of their K_2O vs SiO_2 trends, very flat in the former and very steep in the latter. A flat trend is also observed in most of the «syenitic» rocks, while a negative correlation exists in the «granites» and transitional lithologies.

The above-mentioned trends are linked to the differences in mineral fractionation and are better distinguished by trace element behaviour (e.g. Log/Log plots Ba vs Rb and Ba vs Sr, Fig. 4 a-b-). Trends 1 and 2 are related to qz-monzonites and alkali enriched qz-monzonites respectively. They may be interpreted in terms of prevailing Pl + Kfs fractionation. A Kfs + Bi separation characterizes trend 3, related to the qz-syenites. The monzogranitic rocks and transitional facies follow trend 4 and suggest an important contribution of biotite (prevailing) and Kfs fractionation.

The samples of trends 1, 2 and 3 do not show significant differences in REE behaviour while the rocks of trend 3 show lower contents in intermediate and heavy REE. Common features of the Valle del Cervo plutonites are the lack of any Eu anomaly, the high fractionation of LREE (La/Eu = 6), and the flat pattern of HREE (Eu/Yb = 2.8). The decrease in middle and heavy REE in the monzogranites cannot be related to the effect of major phase fractionation and may be best interpreted as due to the minor phase (zircon, apatite) (Fig. 5).

The chemical data do not identify a resonable scheme of fractional crystallization

showing qz-syenite and qz-monzonite derivation.

One very interesting character is the difference in $^{87}Sr/^{86}Sr$ initial isotopic ratios (Fig. 6). The «granitic» and «syenitic» complexes show homogeneous values, lower than 0.7095.

This initial isotopic ratio is similar to the values determined in the Oligocene «andesitic» dykes intruding the Sesia-Lanzo Zone in the surronding area. The small coeval Miagliano stock (CARRARO & FERRARA, 1968), occurring 10 km south of the «Valle del Cervo» pluton, exhibits the same feature

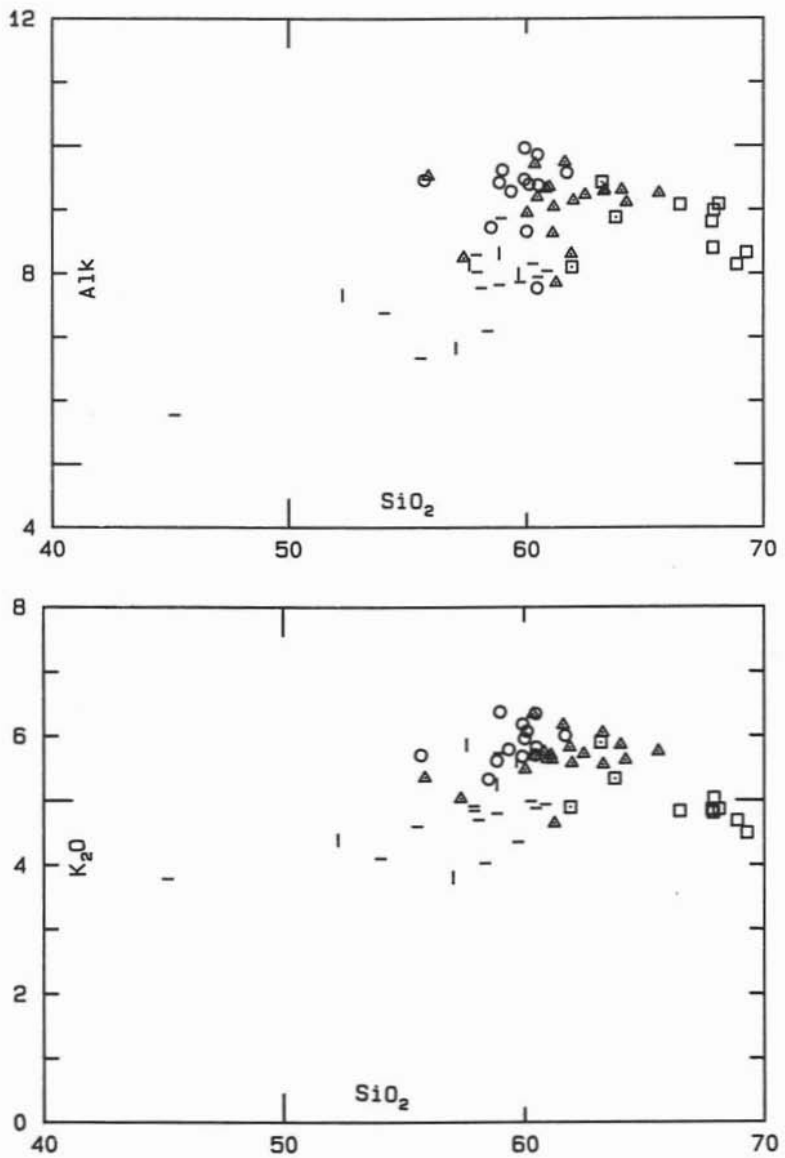

Fig. 3. — Alkali/SiO_2 (Fig. 3a) and K_2O/SiO_2 (Fig. 3b) diagrams. See text for explanation.
Symbols-Square: Monzogranite (a); Square and dot: Outer rim of «granitic» complex (a2); Triangle: Qz- syenites (b); Horizontal bar: Qz-monzonite (c); Circle: Fine-grained qz-monzonite (c1); Vertical bar: Fine-grained monzonite and monzodiorite (c2).

(0.7093). The «monzonitic» complex shows isotopic ratios which do not fit very well but which are consistently higher than those of the previous lithotypes, with a range from 0.7098 to 0.7110.
The representative chemical analyses of the different lithological groups are listed in Tab. 1.

Time relationships and some remarks on the intrusion mechanism: The isochrone data (Bi/WR Rb/Sr) for the studied rocks confirm a Tertiary age but do not show significant differences for the time of emplacement of the different complexes. The differences in the determined ages do fall within analytical uncertainity, giving a narrow range of 29-31 Ma. A slightly older age for the emplacement of the «monzonitic» complex is probably true, but cannot be proved in this way.

A «working hypotesys» for pluton emplacement is summarized here below. First, the outer continous rim of the «monzonites» was emplaced. Magmatic stoping definitely occurs, as shown by the presence of host-rock xenoliths, but it is very limited and cannot

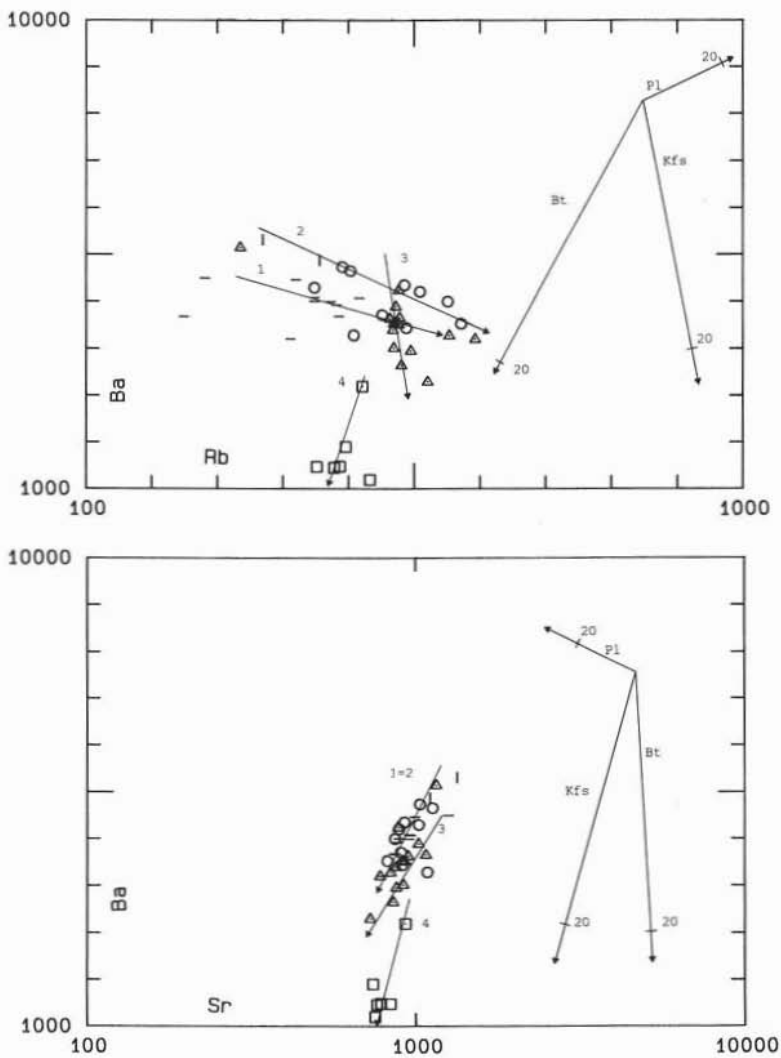

Fig. 4. — Log/log Ba vs Rb (Fig. 4a) and Ba vs Sr (Fig. 4b) diagrams. Symbols as in Fig. 3.

be considered an important factor in the emplacement mechanism. The «monzonites» often exhibit magmatic flow textures. However, the lack of plastic deformations in the host rocks also excludes the possibility of important diapiric emplacement.

The «syenitic» complex does not show clear-cut intrusion relationships with the «monzonitic» complex. No chilled margins or apophyses of syenitic rocks were observed, but enclaves that could be interpreted as fragments of rocks were found, with petrographic, chemical and isotopic data referring to the «monzonitic» complex. Taking into account the differences in chemical and isotopic features, the «syenites» may have been emplaced separately when the «monzonitic» complex was still hot enough to inhibit the formation of true chilled margins; locally, only a limited reduction in grain size was observed.

Fine-grained rocks with the petrographical, chemical and isotopic characteristics of the «monzonitic» complex form thin, elongated bodies arranged in an irregular ring; they were observed only in the «monzonitic» complex and clearly cross the flow orientation of the «monzonites». The contact zones are often «knife sharp» with no disturbance of texture or grain sizes in the «monzonites». These occurrences strongly suggest an emplacement of the fine-grained facies as dykes, following a system of ring fractures. The timing of this event, with respect to the emplacement of the «syenites», may be only hypothesized because of the lack of direct relationships. Field observations suggest that the fine-grained facies intruded the «monzonites» when they were *locally* cool enough to behave in a «brittle» way.

The emplacement of the central «granitic» complex seems to represent the last important episode. The monzogranites are in contact with both «monzonite» and «syenite» complexes. The contact between the two is not well exposed. However. dyke-shaped apophyses of porphyritic granite intrude the syenitic rocks.

The contact between the monzogranites and the «monzonitic» complex is better exposed; field relationships show a narrow but transitional contact zone, suggesting physical conditions similar to those proposed for the contact between «syenites» and

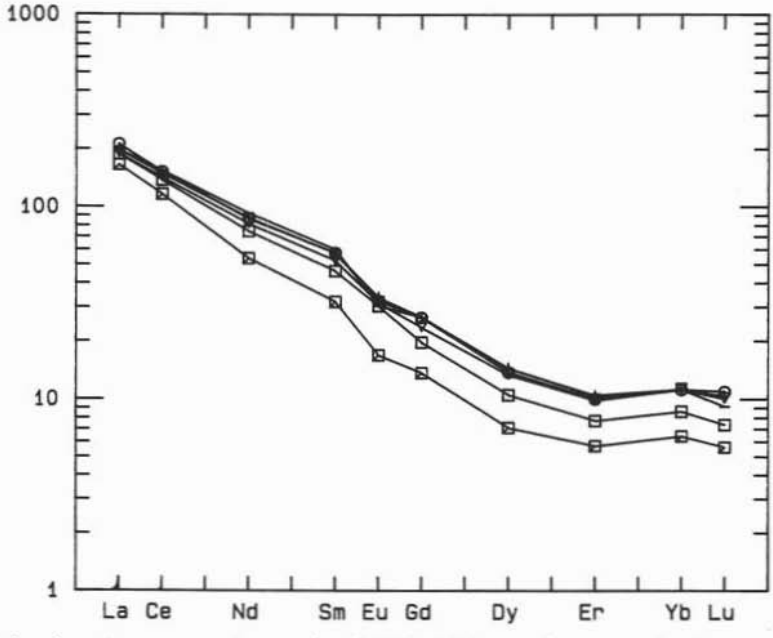

Fig. 5. — REE abundance in representative samples of «Valle del Cervo» pluton normalized to c1 condrite. Symbols as in Fig. 3.

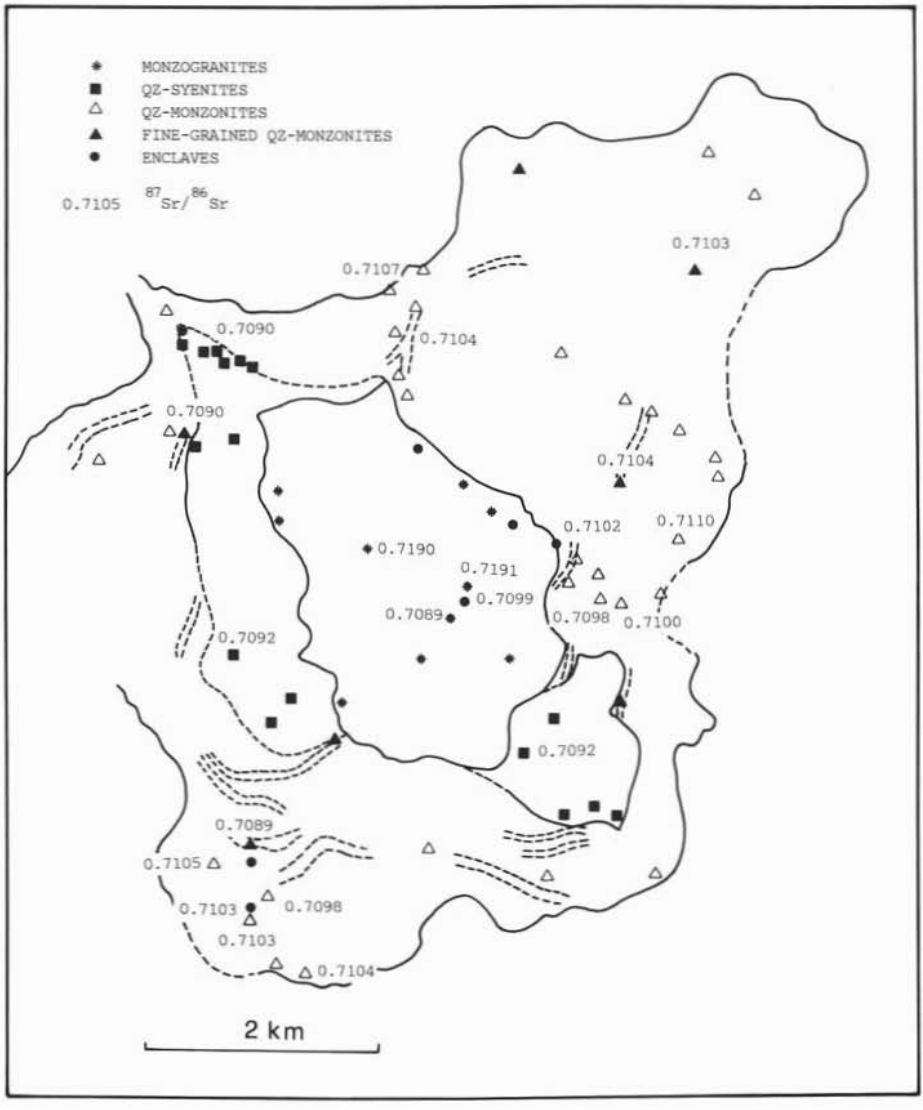

Fig. 6. — Represetative $^{87}Sr/^{86}Sr$ initial isotopic ratios of «Valle del Cervo» pluton.

«monzonites».

As a final phase, acidic dyke swarms, mainly aplites, cut all the complexes; their emplacement is related to fracture systems showing a brittle behaviour.

A summary of the hypotesys for the emplacement of the Valle del Cervo pluton could be as follows:

1) Emplacement of the «monzonitic» complex, mainly by means of a «cauldron subsidence» mechanism coupled with a very limited magmatic stoping in the marginal zones.
2) Cooling of the upper portion of the first intrusive body. Limited subsidence and formation of ring-shaped fractures in the cool upper part. Intrusion of fine-grained qz-monzonites.
3) Intrusion of the «syenitic» bodies. (A connection with the above-mentioned subsidence and a sort of tectonic control for the «syenite» emplacement may be suggested, but is not adequately supported by our data in this phase of the work).

4) Last subsidence and intrusion of the monzogranitic core.
5) Fracture-controlled intrusion of the last-stage aplitic dykes.

Conclusive remarks

The «Valle del Cervo» pluton expresses the widespread magmatic episode that affected the Alps after the nappe emplacement and metamorphic climax of the Alpine orogenesis.

The overall chemical and isotopic similarities among the rocks of the pluton and the coeval igneous activity of its surroungings indicate that the magma sources were essentially the same and located in a mantle anomalized during subduction by the interaction with a crustal component. Different melting episodes led to the generation of distinct magma bodies, characterized by similar Sr isotopic ratios but with different alkalinity. The lack of systematic correlation between Sr isotopic ratio and alkalinity suggest that the process of alkali enrichment was different from that responsible for isotopic diversification. The highest Sr isotopic ratios were found in the outer portions, rich in xenoliths, and the lowest in the inner parts, which «intrude» the formed. Two magmatic series are recognizable in the inner zone: «syenites» and «granites»; their isotopic ratios are similar to those shown by other coeval magmatic activities occurring in the neighbourhood (Miagliano, Sesia-Lanzo and Southalpine dykes).

Taking into account the above-mentioned features, the following picture is proposed: the sources had a uniform isotopic ratio, similar to the lowest found in the «Valle del Cervo» pluton (0.7088). After some evolution, the first melt underwent limited contamination, mainly dredging radiogenic Sr from host rocks, but without appreciably modifying their chemical composition. More or less evolved subsequent melts, both very alkaline (syenites) and mildly alkaline (granites), were emplaced in the inner part of the pluton, but did not react with the pre-existing rocks and preserved their original isotopic ratios.

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