

Characterization of different granitic facies in the Baveno-Mottarone pluton by means of the typologic study of zircon populations

VALERIA CAIRONI

Dipartimento di Scienze della Terra, Sez. Mineralogia, Petrografia, Geochimica e
Giacimenti Minerari, Università degli Studi, Via Botticelli 23, 20133 Milano

ABSTRACT. — Zircon populations taken from samples of the Baveno-Mottarone pluton, studied with the typology method, can be clearly divided into two groups. Zircons from group 1 have the typical characters of populations from calcalkaline granites; their \bar{A} , \bar{T} points in the typologic evolution diagram are distributed along a differentiation trend starting from the granodiorite. A sample with heterogranular texture shows zircons similar to those of volcanic rocks, suggesting a high temperature crystallization due to rapid cooling. Zircons from group 2 recall the typical populations of aluminous alkaline granites in their typologic distributions, in their positions in the typologic evolution diagram, in the typologic evolutionary trend of every single sample, as well as in the typologic differentiation trend of the group and in the secondary characters. Studies on mineralogy, petrography and chemistry of these granites are still in progress; first data seem to agree with the results of the typologic study of zircon populations.

Key words: zircon, typology method, calcalkaline granodiorite, calcalkaline granite, aluminous alkaline subsolvus granite.

RIASSUNTO. — Le popolazioni di zirconi provenienti da alcuni campioni del plutone di Baveno-Mottarone, studiate con il metodo tipologico, possono essere divise in due gruppi. Gli zirconi del gruppo 1 possiedono i caratteri tipici delle popolazioni dei graniti calcoalcalini; i loro punti medi \bar{A} , \bar{T} nel diagramma di evoluzione tipologica si distribuiscono lungo un trend di differenziazione avente alla base la granodiorite. Un campione a struttura eterogranulare presenta zirconi simili a quelli di rocce vulcaniche, il che suggerisce una alta temperatura di cristallizzazione provocata da un raffreddamento rapido. Gli zirconi del gruppo 2 sono molto simili alle tipiche popolazioni dei graniti alluminosi alcalini per quanto riguarda le distribuzioni tipologiche, le posizioni entro il diagramma di evoluzione tipologica, le tendenze di evoluzione tipologica di ogni singolo campione, come pure il trend di differenziazione globale del gruppo e i

caratteri secondari. Sono in corso studi sui caratteri mineralogici, petrografici e chimici di questi graniti; i primi dati sembrano in buon accordo con i risultati ottenuti con lo studio tipologico delle popolazioni di zirconi.

Parole chiave: zircone, metodo tipologico, granodiorite calcoalcalina, granito calcoalcalino, granito alluminoso alcalino subsolvus.

1. Introduction

The Baveno-Mottarone massif, elongated from SSW to NNE, is formed by a main granitic body and a minor granodioritic intrusion (M. Mottarone). It intrudes the « Scisti dei Laghi », that is the metapelitic part of the « Serie dei Laghi » metamorphic unit, in the Southern Alps (fig. 1). This pluton, though well known for its quarries since many centuries, has been little studied in detail; the work of GALLITELLI (1937), based on chemical, optical and field observations, can be mentioned, as well as the geologic-petrographic study of GANDOLFI & PAGANELLI (1974), where a detailed description of the geological setting of the pluton can be found. These studies have shown the presence of different granitic facies: red, pink, white granite; micro- and heterogranular granite; granodiorite. The final goal of the present work is to establish the similarities and mutual relations among these facies by means of a relatively new method: the typologic study of zircon populations, first proposed by PUPIN & TURCO in 1972 and further developed (PUPIN & TURCO, 1972 a, b, c; 1975; PUPIN, 1976, 1980).

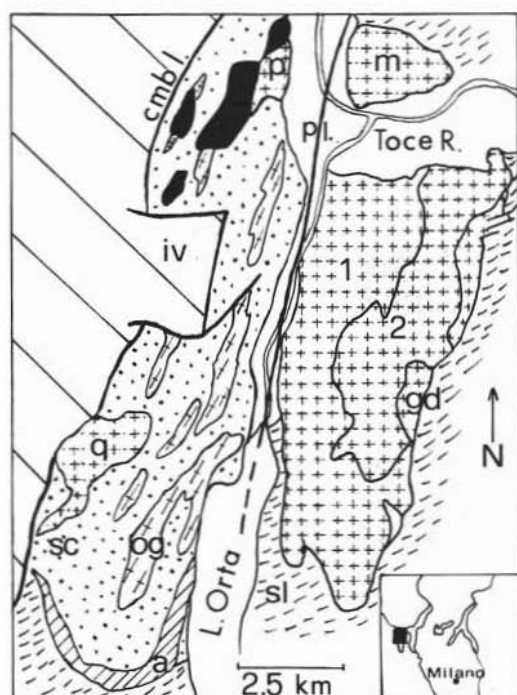


Fig. 1. — Geological sketch map of the Baveno-Mottarone pluton. Mapping after SASSI, 1985; SE-SANA, 1985; unpublished data. - *iv* = Ivrea-Verbano zone; *sc* = Strona-Ceneri zone; *sl* = Scisti dei Laghi zone; *a* = amphibolites; *og* = orthogneisses; *black* = appinitic dykes; *cmb l* = Cossato-Mergozzo-Brissago line; *pl* = Pogallo line. *Granites*: *q* = Quarna; *p* = Pedemonte; *m* = Montorfano; *1* = Baveno-Mottarone, group 1 (calcalkaline); *2* = Baveno-Mottarone, group 2 (alkaline); *gd* = Mottarone granodiorite.

2. The typology method

This method consists of a morphologic-statistic study of zircon crystals, based on a typologic classification (PUPIN & TURCO, 1972 a), which takes into account the presence and relative development of the principal crystallographic faces: pyramids {211}, {101} and {301} and prisms {100} and {110}. Two indices, *A* and *T*, reflect the relative development of pyramids and prisms respectively; every population can be represented by a point of \bar{A} , \bar{T} , coordinates on a *A* index vs. *T* index diagram (PUPIN & TURCO, 1972 b). The main factors controlling the typologic variations are now known (PUPIN, 1976; PUPIN et al., 1978): the crystallization temperature determines the relative development of prisms (high tem-

perature = {100} > {110} and vice versa for low temperature); aluminium and alkali content controls the relative development of pyramids (aluminium favours the {211} pyramid, alkalis the {101} and the {301} pyramids). On this basis information can be obtained on the physico-chemical conditions of the medium during the sometimes long crystallization period of zircon. The sequence of appearance of different crystal types in each population can be represented by a calculated «Typologic Evolutionary Trend» (T.E.T.) (PUPIN, 1976). In composite cogenetic bodies a differentiation trend in the zircon populations from the less to the more differentiated terms can be determined (PUPIN, 1976).

Secondary characters as colour, transparency, presence of overgrowths and zoning, kind of inclusions... are also taken into account in order to give a more detailed representation of the genetic conditions of each population (PUPIN, 1976).

This method has given some interesting results on the Baveno-Mottarone pluton, too.

3. Results

The following samples have been examined:
MO 5: granodiorite

G 54: white granite with heterogranular texture

F 39: white granite

F 54: white granite

G 56: white granite

G 2: granite with red K-feldspar and pink plagioclase

F 74: granite with pink K-feldspar

G 1: granite with pink K-feldspar

F 59: granite with yellowish K-feldspar

In fig. 2 the \bar{A} , \bar{T} points of the samples in the I. *A* vs I. *T* diagram are compared with the petrogenetic classification proposed by PUPIN (1980). The samples can be clearly divided into two groups, the former falling in the calcalkaline, the second in the alkaline field; both groups show typical features in their zircon populations.

Group 1: it includes the white heterogranular granite G 54, two white granites

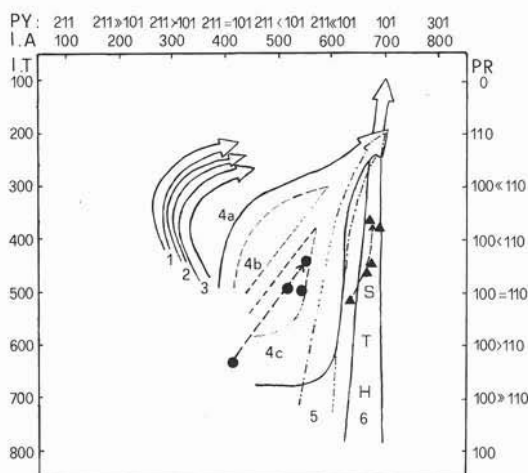


Fig. 2. — \bar{A} , \bar{T} points of the analyzed samples in the typologic evolution diagram of zircon populations, compared with typical distribution areas for different magmatic suites (after the petrogenetic classification of PUPIN, 1980). Arrows represent typologic differentiation trends. - 1 to 3 = aluminous and hyperaluminous granites and granodiorites; 4 = calcalkaline series; 5 = high K monzogranites and granites (« subalkaline serie »); 6 = alkaline and hyperalkaline granites (H = hypersolvus; T = transolvus; S = subsolvus). ● = group 1: sequence MO 5, F 39, F 54, (G 54); ▲ = group 2: sequence G 56, G 2, F 74, G 1, F 59.

with normal texture, F 39 and F 54, and the granodiorite MO 5.

The three granites have wide typologic distributions (29-30 types; fig. 3). Since the crystallization temperature of zircon determines the relative development of the two main prisms, and since this development is expressed by the T index, then the wide distribution along this index for samples F 39 and F 54 indicates a large range in the crystallization temperature.

Looking at fig. 4 it is possible to realize that the process was more intense in the range 800°C - 700°C (60-70 % of crystals with T index between 600 and 400; fig. 9, 10; temperature calibration after PUPIN & TURCO, 1972 c).

In granitic magmas the crystallization period of zircon is limited to high temperatures only if the fluid pressure is low, but it extends towards lower temperatures with increasing P_t (PUPIN et al., 1978). The frequency distribution along the temperature range in these two samples (fig. 4) shows

that P_t was not high. This is confirmed by the characters of late stage crystals: they are mostly faintly coloured and transparent and their overgrowths of hydrozircon are scarcely developed (fig. 11).

Sample G 54 has almost the same range of variation along the T index as samples F 39 and F 54, but it has a higher content of high temperature types (fig. 3 and fig. 4). Many characters of the crystals recall those of zircons from volcanic rocks (PUPIN, 1976): absence of both colour and overgrowths; transparency; typical inclusions (fig. 12, 13); they indicate therefore that high temperature crystallization is probably due to rapid cooling.

This result, together with the hetero-granular (sometimes even pseudoporphyric) texture and with the field relationships, is in accordance with the interpretation of this granite as a late stage intrusion, emplaced in a rather cooled environment. The chemical composition of this granite is very close to the two white « normal » granites, as suggested by the similar values of the \bar{A} indices of the three samples: G 54 = 536; F 54 = 550; F 39 = 522.

The typologic evolutionary trend T.E.T., describing the chemical variations of the medium during the decrease of temperature, is characteristically curved for all three samples (fig. 5), suggesting a first period during crystallization with rather constant relative amounts of aluminium and alkalis, followed by a late stage alkalinization. This is the typical T.E.T. pattern in calcalkaline rocks (see for comparison the Argentera granite A 1 in fig. 5, after PUPIN, 1976).

The typologic distribution of the granodiorite population (fig. 3) is rather typical for calcalkaline rocks containing amphibole: it shows a high frequency of types with $\{211\}$ pyramid $\geq \{101\}$ (high aluminium) and prism $\{100\} \geq \{110\}$ (high temperature) (fig. 3 and fig. 4). The T.E.T. indicates rather constant relative amounts of aluminium and alkalis during crystallization, and is similar to the T.E.T. of the Argentera amphibole monzogranite A 2 (fig. 5; A 2 after PUPIN, 1976).

The \bar{A} , \bar{T} points of the samples of this group describe a differentiation trend moving from the granodiorite to the granites, parallel to the 4b line of calcalkaline series in the

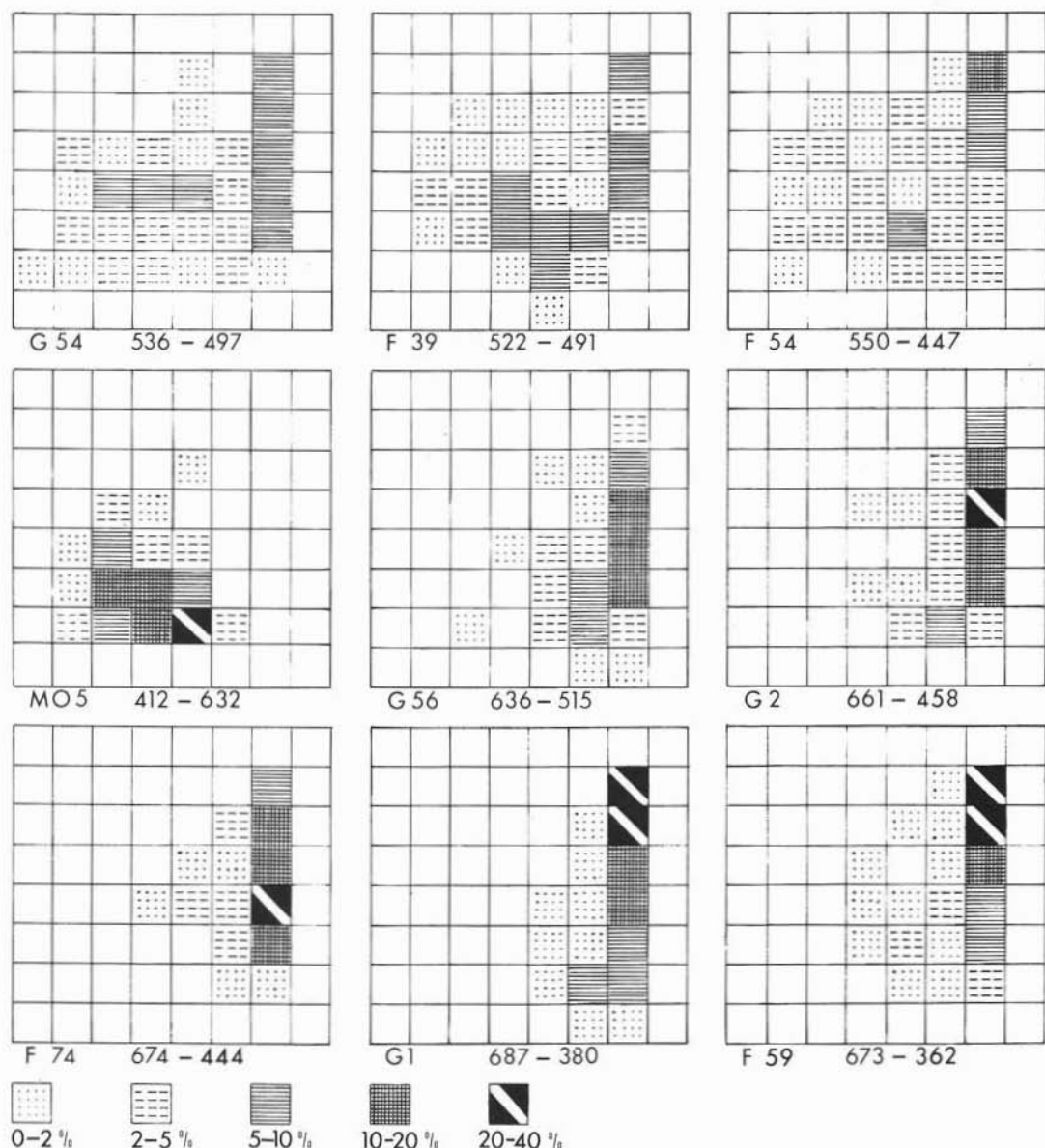


Fig. 3. — Typologic distribution diagrams for the analyzed samples.

petrogenetic classification of PUPIN (1980) (fig. 2). A typical example of this line is given by the Argentera massif, very similar, as already seen, to the samples analyzed in this paper.

Group 2: it includes all the granites with coloured feldspars and one white granite (G 56). For all samples the typologic distribution is considerably reduced (14-19

types; fig. 3). The crystallization temperature ranges from about 850° C to about 600° C, but the percentage of late stage crystals clearly increases following the order: G 56, G 2, F 74, G 1, F 59 (fig. 4). In the last two samples the high frequency of late stage types and the great development of some typical secondary characters (dark colours, turbidity, zoned overgrowths of hydrozircon, metamictization; fig. 14, 15, 16) indicate a

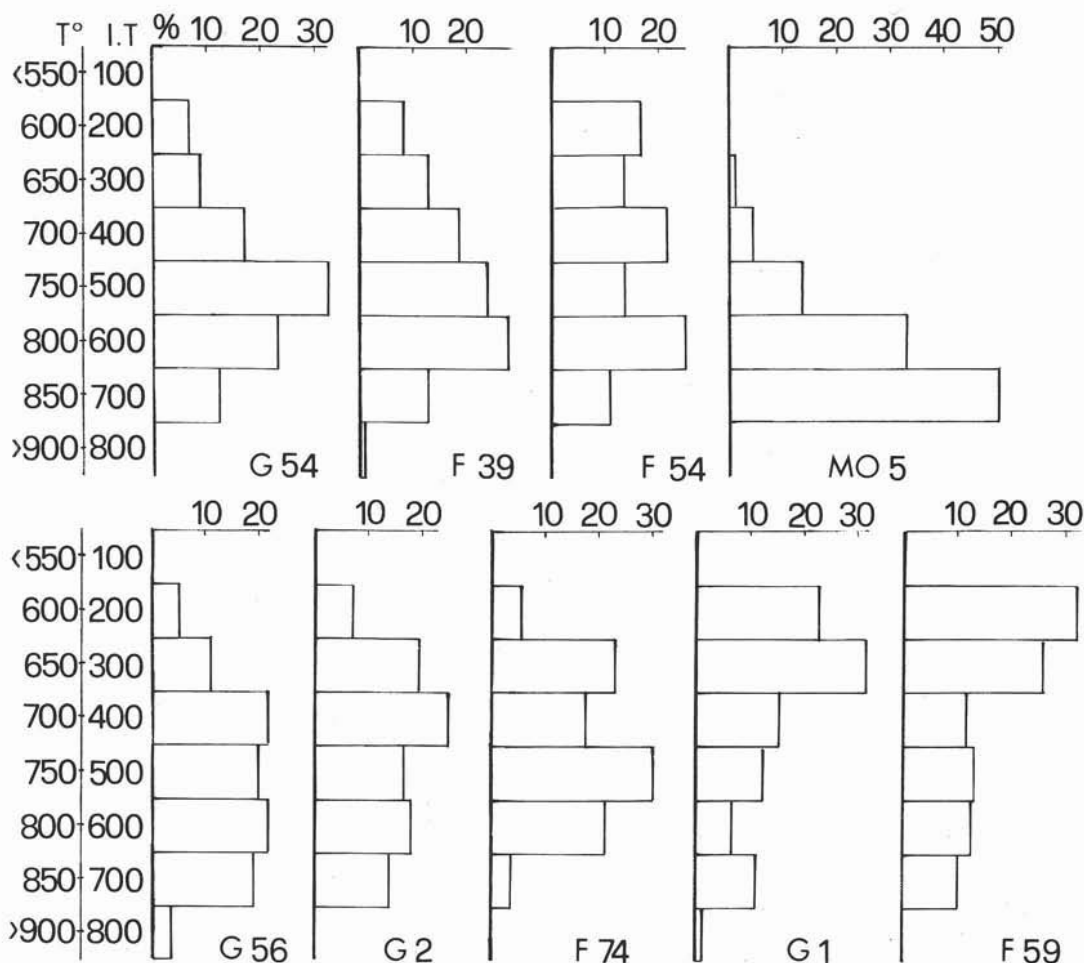


Fig. 4. — Histograms of frequency of zircon types related to their T index in the analyzed samples. Temperature calibration after PUPIN & TURCO (1972 c).

high fluid pressure in the magma and a long crystallization period for zircon. These secondary characters connected with the high fluid content were already observed in the pink Baveno granite by PIGORINI et al. (1964) in their study on zircon with the method of dimensional statistics and «reduced major axis». This method was proposed by POLDERVAART (1950, 1956) and later criticized by PUPIN (1976, on pages 314-317). By the way, it is worth noting that the pink Baveno granite is famous for its richness in miarolitic cavities, containing more than 40 different mineral species (GALLITELLI, 1937).

The typologic distributions of all the samples in this group are narrow along the A index (fig. 3) remarking only very little chemical variations in the magma. In particular, the {101} pyramid, that is always more developed than the {211}, suggests an alkaline composition (fig. 15). This is confirmed by the subvertical T.E.T. of all these samples, very typical for alkaline granites, where the alkaline character is present from the very beginning of crystallization (fig. 5; for comparison: K = Kagenfels alkaline subsolvus granite, Vosges; I = Ile Rousse alkaline subsolvus granite, Corsica; data after RÊVE, 1985 and PUPIN, personal communication, respectively).

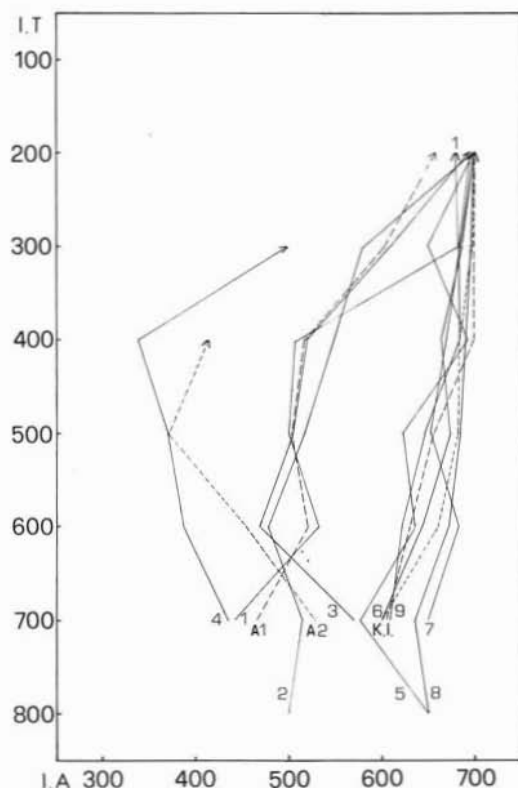


Fig. 5. — Typologic evolutionary trends (T.E.T.) of each analyzed population. - 1 = G 54; 2 = F 39; 3 = F 54; 4 = MO 5; 5 = G 56; 6 = G 2; 7 = F 74; 8 = G 1; 9 = F 59. For comparison: A1 = Argentera granite; A2 = Argentera amphibole monzogranite (PUPIN, 1976). I = Ile Rousse (Corsica) alkaline subsolvus granite (PUPIN, personal communication). K = Kagenfels (Vosges) alkaline subsolvus granite (RÊVE, 1985).

The \bar{A} , \bar{T} points of these samples are distributed along a subvertical differentiation trend (fig. 2); such a slope indicates that the different levels of differentiation are due to an increase of fluid content, while the alkalinization is weak (since the magma is alkaline already in its less differentiated product G 56). The differentiation trend of this group falls in the distribution field of alkaline subsolvus granites (fig. 2); this is in good agreement with the observed mineralogical composition: presence of albite and orthoclase-perthite.

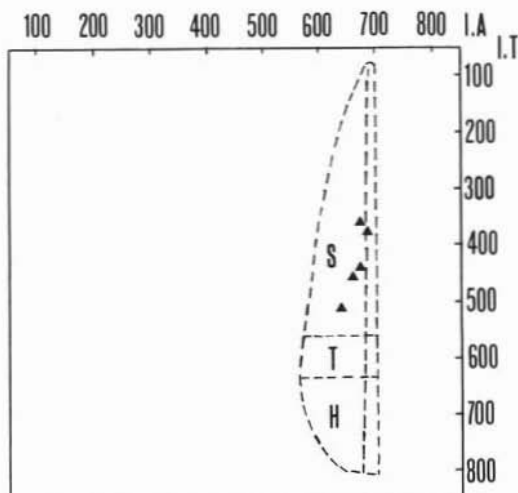


Fig. 6. — Position of the analyzed samples of group 2 in the distribution area of zircon populations from alkaline granites (TESSIER, 1979). Left = aluminous alkaline granites; right = hypoaluminous hyperalkaline granites.

4. Discussion

The different granite facies of the Baveno-Mottarone pluton were considered in previous works (GALLITELLI, 1937; GANDOLFI & PAGANELLI, 1974) as different aspects of a single granite type, the colour of feldspars being considered essentially a postmagmatic feature. On the contrary, the typologic study of zircon populations in samples from this pluton has revealed the presence of two different granite types, respectively with a calcalkaline character and with a distinct alkaline composition. Whereas the first group includes only white granites, the second one comprises all samples with coloured feldspars as well as one sample of white granite (G 56).

This fact proves that the colour of feldspars is not a valid criterion to distinguish the two groups, as it could be thought at first.

Since only the old chemical analysis of GALLITELLI (1937) were available, new analysis have been performed (SASSI, 1985; SESANA, 1985) on 27 samples.

At first sight, these data do not show great differences between the two groups, which could be considered a single group with rather large range of variations. But

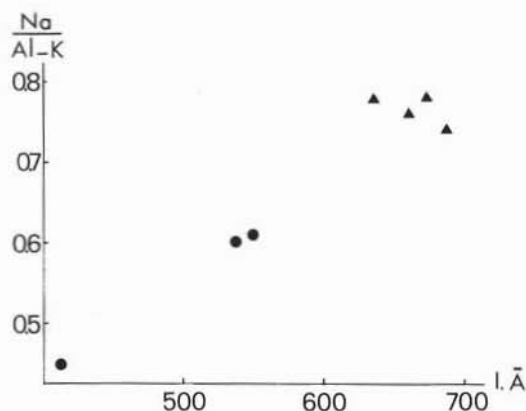


Fig. 7. — $Na/(Al-K)$ vs. \bar{A} index correlation diagram for some of the analyzed samples.

a more careful inspection of the same data shows that in almost all oxides vs. SiO_2 diagrams the samples can be divided into two groups, which correspond very well to the indications given by the typologic

Tab. 1
Main chemical differences between group 1 and group 2 granites

	$Na_2O + K_2O$	$Al/(Na+K+Ca/2)$	$Na/(Al-K)$
GROUP 1			
range	7.50 - 8.22	1.25 - 1.31	0.60 - 0.64
average	7.95	1.28	0.62
GROUP 2			
a) white granites			
range	8.22 - 8.62	1.12 - 1.17	0.73 - 0.78
b) granites with coloured feldspars			
range	7.90 - 8.43	1.12 - 1.19	0.70 - 0.73
average a + b	8.23	1.16	0.73

study of zircon populations (diagrams in SASSI, 1985; SESANA, 1985). The main differences concern alkali content, $Al/(Na+K+Ca/2)$ index and alpaite coefficient $Na/(Al-K)$ (ZLOBIN, 1959) (tab. 1).

However, these differences are not as great as could be expected from the zircon typologies. In particular, the granites of

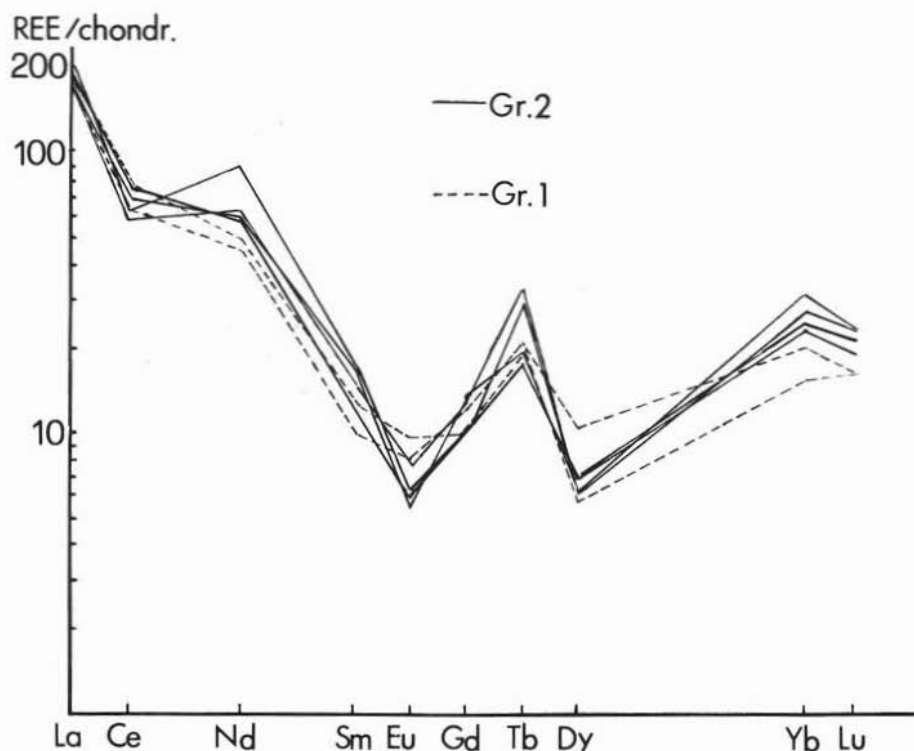


Fig. 8. — REE distribution pattern for some samples of the Baveno-Mottarone pluton.

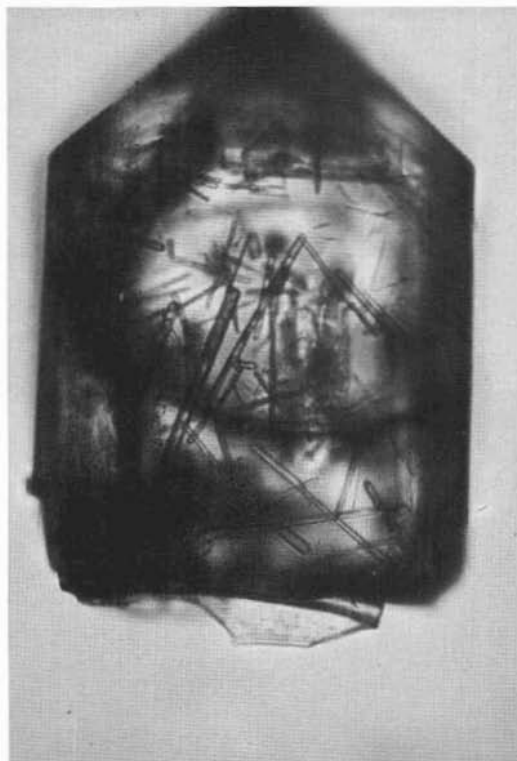


Fig. 9. — Group 1. Type P₁: $py \{101\}$; $pr \{100\} \gg \{110\}$. High temperature crystal with typical inclusions of needle-shaped apatite.

group 2, though definitely more alkaline than those of group 1, do not show the classical values for alkaline granites. Since « postmagmatic geochemical variations induced locally by deuteric processes are without any effect on zircon populations » (PUPIN, 1980), it must be deduced that the character of this magma at the time of zircon crystallization was much more alkaline than it now appears from the chemical analysis. This is probably an effect of relative loss of alkalis and gain of aluminium through intense late-postmagmatic alteration, which is largely widespread in the analyzed samples.

The typologic characters of zircon populations in the samples of group 2 are quite close to the characters of populations of alkaline aluminous granites. In fact, as defined by BONIN (1982), alkaline suites can be divided into two « lines »: hypoaluminous hyperalkaline and aluminous alkaline. It has been observed by several authors (TESSIER,

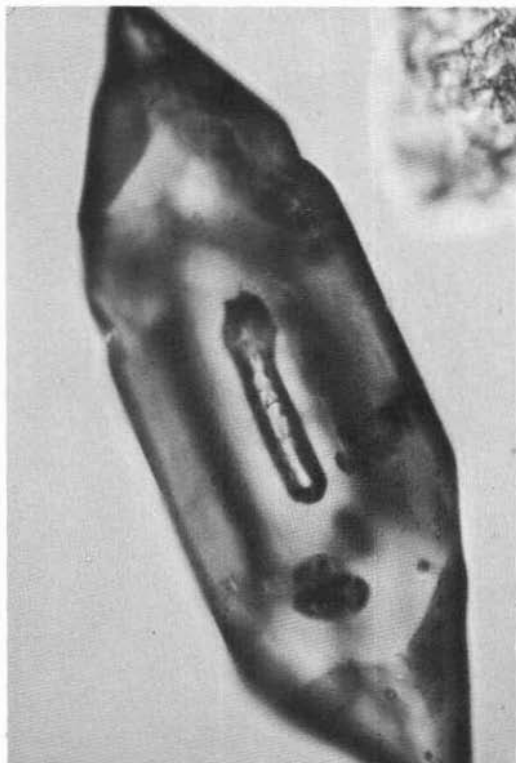


Fig. 10. — Group 1. Type S₁₁ (average of S₆ and S₁₀): $py \{211\} \gg \{101\}$; $pr \{100\} = \{110\}$. Medium temperature type indicating high aluminium content (great development of $\{211\}$). High relief longprismatic or rounded inclusions.

1979; BONIN, 1982) that the distribution field of \bar{A} , \bar{T} points of zircon populations from alkaline suites on the I. \bar{A} vs. I. \bar{T} diagram can be divided into two main areas (fig. 6): the well defined zone on the right of the field is typical for hypoaluminous alkaline-hyperalkaline suites, whereas the area on the left is typical for aluminous alkaline suites. As shown in fig. 6, the differentiation trend for the samples of alkaline granite of the Baveno-Mottarone pluton falls almost entirely in the characteristic zone of aluminous alkaline granites.

The \bar{A} index of zircon populations generally increases with the alkali content and decreases with the aluminium content of the magma; this causes the previously described distribution. The influence of relative amounts of aluminium and alkalis on the development of pyramids is clearly shown by

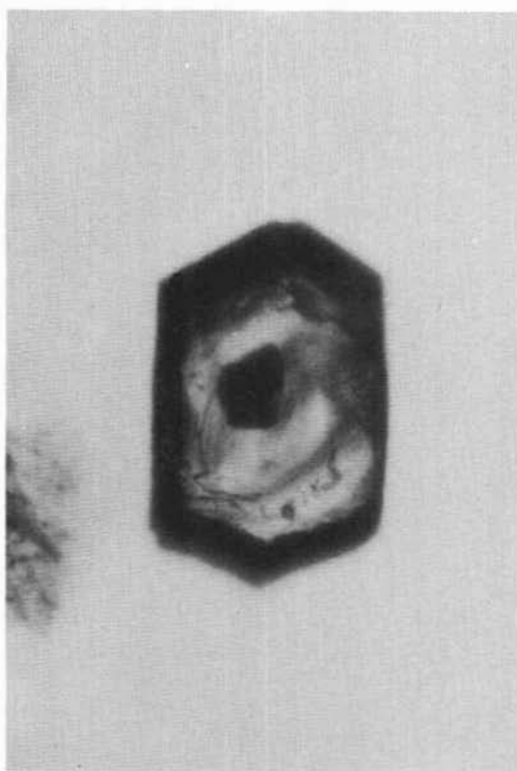


Fig. 11. — Group 1. Type G_1 : $py \{101\}$; $pr \{110\}$. Low temperature type indicating low P_T in the magma even in the late stages: the crystal is clear and colourless and shows no overgrowths of hydro-zircon.

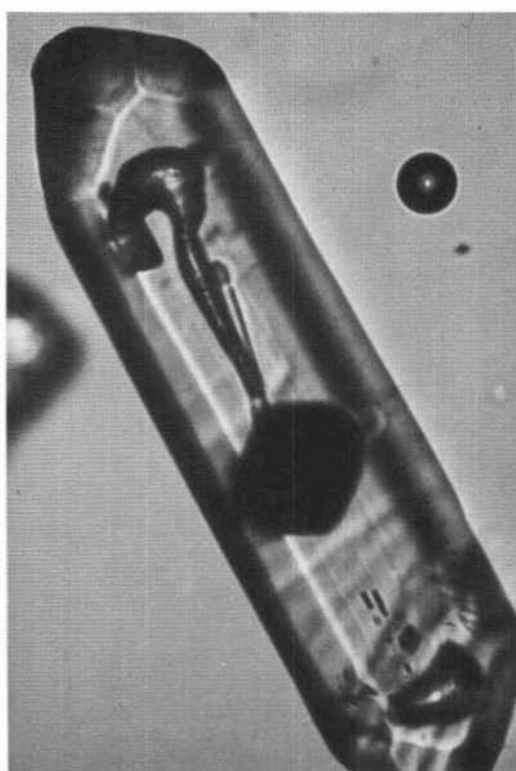


Fig. 12. — Group 1 (sample G 54). Type U_{18} : $py \{211\} = \{101\}$ and $\{301\}$; $pr \{100\} > \{110\}$. High temperature crystal showing the typical dark rounded (glass?) or irregular inclusions of zircons from volcanic rocks.

the general correlation between the \bar{A} index of zircon populations and the agpaite coefficient $Na/(Al-K)$ of ZLOBIN (1959) (PUPIN, 1976). This condition is well realized for the analyzed samples of the Baveno-Mottarone pluton, even if for the alkaline granite samples the agpaite coefficient, reflecting the present day chemical composition, is not so high as their zircon typologies would indicate (fig. 7).

Another character of zircon populations found in the granites of group 2 is the high frequency of xenotime outgrowths (fig. 16) on zircon crystals (already observed by FIGORINI et al., 1964); after PUPIN (1980) « xenotime is more likely to be found as outgrowths on zircons in rocks with an alkaline trend ».

Beside the zircon characters, the granites of group 2 can be distinguished from those

of group 1 by other features, visible in thin sections (SESANA, 1985). The most evident one is the presence of a deep green, strongly pleochroic biotite (deep green/greenish black), sometimes zoned with a greenish brown core and a deep green rim; this kind of biotite has been referred to as « siderophyllite » by GALLITELLI (1937). It appears to be formed as a gradual transformation of « normal » brown biotite. This type of biotite is considered by BONIN (1982) as typical for aluminous alkaline granites. After this author, biotite in alkaline and hyperalkaline granites crystallizes first with a composition near the annite end member, then evolving either towards the lepidomelane composition, in presence of Al-poor, Fe-bearing fluids (in hypoaluminous hyperalkaline granites), or towards the siderophyllite composition, in presence of Al-rich,

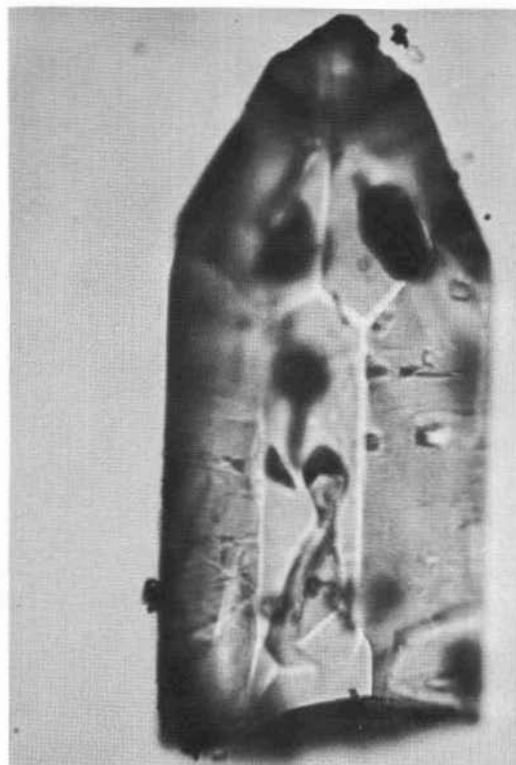


Fig. 13. — Group 1 (sample G 54). Type S_{12} : $py \{211\} > \{101\}$; $pr \{100\} = \{110\}$. Medium-high temperature crystal showing almost symmetric rounded inclusions and an irregular cavity filled with little crystals and glass; all these characters are typical of zircons from volcanic rocks.

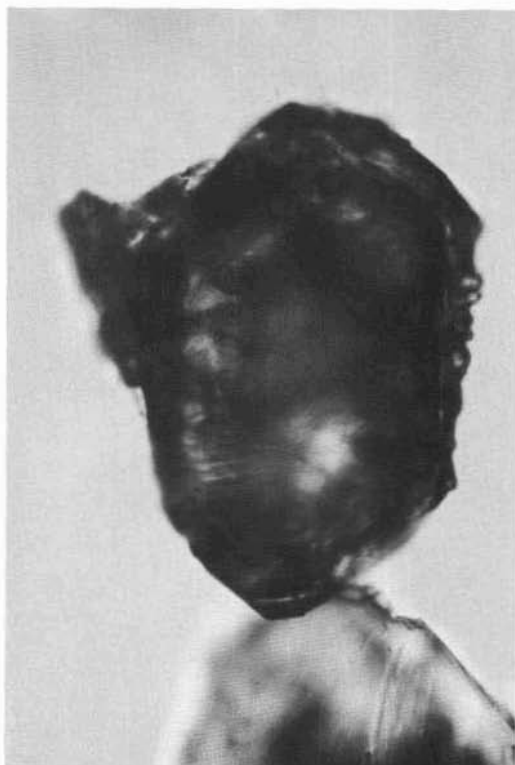


Fig. 14. — Group 2. Type S_{10} : $py \{211\} < \{101\}$; $pr \{100\} > \{110\}$. High temperature type. Dark colour, turbidity and zoned overgrowth of hydro-zircon indicate high P_r in the magma.

F-bearing fluids (in aluminous alkaline granites). During late stage hydrothermal processes these siderophyllites can further react with F-Li bearing fluids, giving terms of the siderophyllite-polilithionite serie. In the samples of group 2, Li-bearing micas are widespread in miarolitic cavities, (zinnwaldite and protolithionite, GALLITELLI, 1937), but a mica whose optical characters seem to correspond to those of zinnwaldite has been seen also in thin sections (SESANA, 1985).

Another very typical character of the samples of group 2 is the widespread occurrence of fluorite, interstitial or associated with chloritized biotite.

Studies on minor elements and REE contents are still in progress; first results on REE (fig. 8) show different distribution patterns between the two granite types: the granites of group 2 have a more

pronounced negative Eu-anomaly and are relatively enriched in medium to heavy REE, as indicated by the presence of minerals such as xenotime, orthite and gadolinite too (GALLITELLI, 1937).

These characters are considered by several authors as related to an alkaline composition (BUMA et al., 1971; BOWDEN & WHITLEY, 1974), but more detailed studies and a greater number of analysis are still necessary to get reliable information on the REE distribution pattern in the Baveno-Mottarone pluton.

5. Conclusions

The typologic study of zircon populations in some samples of the Baveno-Mottarone pluton has revealed the existence of two distinct granite types. The well defined zircon typologies of the two types suggest their



Fig. 15. — Group 2. Type L₂: *py* {211} \ll {101}; *pr* {110}. Low temperature type, with internal zoning showing a great development of the {101} pyramid from the very beginning of zircon crystallization (high alkali content).

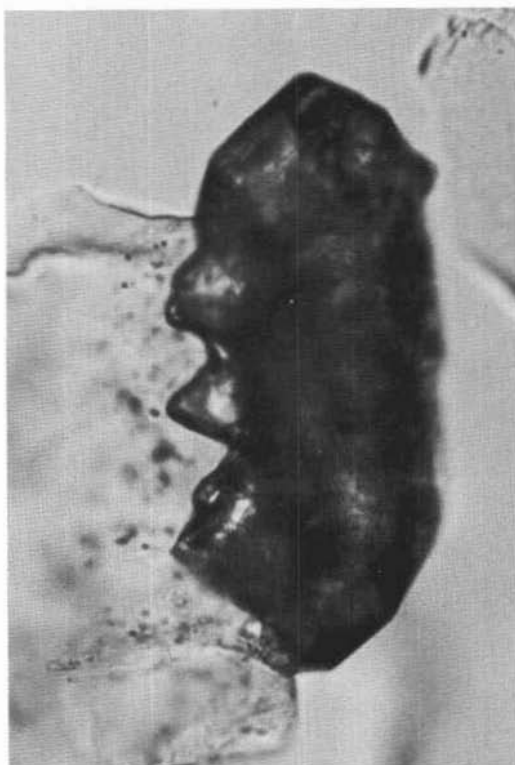


Fig. 16. — Group 2. Type G₁: *py* {101}; *pr* {110}. Low temperature type with characteristic xenotime outgrowths; partially included in K-feldspar. Secondary characters indicate high P_T in the magma.

attribution, respectively, to calcalkaline and aluminous alkaline granites. Several chemical and petrographic characters seem to agree with this interpretation.

The main problem arising from these data concerns the relationships between these two granites, which represent different geological environments.

Considering that the whole complex has clearly intruded in a post-uplift period, a possible solution would be an earlier origin of the calcalkaline magma with respect to the alkaline one. The calcalkaline magma could be the last magma originated in the late orogenic phases, while the alkaline one could be the first formed in the post-uplift period; it would have enriched in fluids during its rise through the wet postorogenic crust.

However, the emplacement of the two magmas is probably very close in time:

no clear limits can be seen on the field between the two granites and no time relations can be obtained on the basis of field observations; it is only possible to establish that the pink alkaline facies is younger than the granodiorite (SASSI, 1985; SESANA, 1985).

The age determination of 276 ± 5 m.y. (Rb/Sr whole rock isochron) given by HUNZIKER & ZINGG (1980) for these granites cannot help in their interpretation, because the different facies have not been considered separately.

Another hypothesis on the genesis of these magmas cannot be excluded: it is possible that they have formed by separation from a single magma at deeper levels and have then intruded as independent pulses. However it must be considered that the typologic characters of zircon populations

of the analyzed samples can be better explained by the first hypothesis. In fact, zircon typologies like those of group 2 have always been found in granites belonging to alkaline suites and not in granites derived from calcalkaline parents, even if with an alkaline composition (PUPIN, 1976, 1980; TESSIER, 1979).

Studies on the Baveno-Mottarone pluton will be continued, since much more work

is still necessary for a better understanding of this multiple intrusion.

Acknowledgements. — Many thanks are due to Prof. J.P. PUPIN, who taught me the typology method and controlled the results of my study, and to Prof. A. BORIANI for useful suggestions and critical discussion of the paper.

Thanks also to Dr. M. ODDONE (Istituto di Chimica Generale, Università di Pavia), who carried out the determination of minor elements and REE contents.

REFERENCES

- BONIN B. (1982) - *Les granites des complexes an-nulaires*. BRGM, n. 4.
- BOWDEN P., WHITLEY J.E. (1974) - *Rare earth patterns in peralkaline and associated granites*. Lithos, 7, 15-21.
- BUMA G., FREY F.A., WONES D.R. (1971) - *New England granites: trace elements evidence regarding their origin and differentiation*. Contrib. Mineral. Petr., 31, 300-320.
- GALLITELLI P. (1937) - *Ricerche petrografiche sul granito di Baveno*. Atti Soc. Tosc. Sc. Nat., 46, 150-226.
- GANDOLFI G., PAGANELLI L. (1974) - *Ricerche geologico-petrografiche sulle plutoniti erciniche della zona del Lago Maggiore*. Mem. Soc. Geol. It. Suppl. vol. XIII, 29-54.
- HUNZIKER J., ZINGG A. (1980) - *Lower Palaeozoic amphibolite to granulite facies metamorphism in the Ivrea Zone (Southern Alps, Northern Italy)*. SMPM, 60, 181-213.
- PIGORINI B., SOGGETTI F., VENIALE F. (1964) - *Studio morfologico-statistico dello zircone accessorio nei graniti di Alzo, Baveno e Montorfano*. Atti Soc. It. Sc. Nat., CIII, I, 18-47.
- POLDERVAART A. (1950) - *Statistical studies on zircon as a criterion in granitization*. Nature, 165, 574-575.
- POLDERVAART A. (1956) - *Zircon in rocks. 2. Igneous rocks*. Am. J. Sci., 254, 521-554.
- PUPIN J.P., TURCO G. (1972 a) - *Une typologie originale du zircon accessoire*. Bull. Soc. Fr. Mineral. Cristallogr., 95, 348-359.
- PUPIN J.P., TURCO G. (1972 b) - *Applications des données morphologiques du zircon accessoire en pétrologie endogène*. C.R. Acad. Sci. Paris, 275, D, 799-802.
- PUPIN J.P., TURCO G. (1972 c) - *Le zircon acces-soire en géothermométrie*. C.R. Acad. Sci. Paris, 274, D, 2121-2124.
- PUPIN J.P., TURCO G. (1975) - *Typologie de zircon accessoire dans les roches plutoniques dioritiques, granitiques et syénitiques. Facteurs essentiels déterminant les variations typologiques*. Pétrologie, I, 2, 139-156.
- PUPIN J.P. (1976) - *Signification des caractères morphologiques du zircon commun des roches en pétrologie. Base de la méthode typologique. Applications*. Thèse Doct. Etat, Univ. Nice, France, 394 pp.
- PUPIN J.P., BONIN B., TESSIER M., TURCO G. (1978) - *Rôle de l'eau sur les caractères morphologiques et la cristallisation du zircon dans les granites*. Bull. Soc. Géol. Fr., 20, 5, 721-725.
- PUPIN J.P. (1980) - *Zircon and granite petrology*. Contrib. Mineral. Petrol., 73, 207-220.
- RÊVE J.M. (1985) - *Repartition de l'Uranium et du Thorium dans les roches alcalines des Vosges du Nord*. Thèse Doct. 3ème cycle, Univ. Paris-Sud-Orsay (France).
- SASSI A. (1985) - *I graniti di Baveno-Mottarone e Montorfano: parte settentrionale*. Tesi di laurea, Univ. Milano (Italia).
- SESANA E. (1985) - *I graniti di Baveno-Mottarone e Montorfano: parte meridionale*. Tesi di laurea, Univ. Milano (Italia).
- TESSIER M. (1979) - *Caractères morphologiques du zircon des roches magmatiques alcalines et calcoalcalines de Corse. Implications petrogenetiques*. Thèse Doct. 3ème cycle, Univ. Nice (France), 112 pp.
- ZLOBIN B.I. (1959) - *Paragénèse des minéraux sombres des roches alcalines en liaison avec un nouveau type du coefficient agpaitique*. Geokhimiya, SSSR, 5, 410-422. Trad. S.I.G. n. 3431.