RENDICONTI DELLA SOCIETÀ ITALIANA DI MINERALOGIA E PETROLOGIA, 1988, Vol. 43-2, pp. 463-476

Use of zircon typology for the study of some granites from the Massif Central, France

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ABSTRACT. — The zircon morphology method is a convenient, reliable, and economical tool in granite petrology. It gives useful information on the temperature, water content, and chemistry of the magma and reasonably precise indications of the nature and origin of the material.

Use of the zircon morphology method facilitates solution of several kinds of regional problems related to the petrology of granites in the Massif Central, France. This method commonly is determinant or represents an additional constraint in comparing granites exposed in the same area or enclaves of granites in granitic hosts. Study of zircons can also provide a general outline of the magmatism in a large granitic area such as the Forez horst, or a definition of magmatic zoning in a fragment of the Hercynian chain such as the entire Massif Central.

The selected examples of regional granite problems described in this report also show that the zircon method is an excellent complement to field-geology, petrography, and geochemistry. Together with these methods, it plays a fundamental role in either relating or discriminating between granitic plutons.

Key words: Zircon typology, granites, Massif Central, France.

Introduction

A large number of granitic plutons occur in the Massif Central, France (DIDIER and LAMEYRE, 1971, 1980). These Palaeozoic granites (DUTHOU et al., 1984) can be arranged in two main groups: one is of hybrid origin, and the other of crustal origin (DIDIER and LAMEYRE, 1969; DIDIER et al., 1982). In many plutons, the largely dominant monzogranite and granodiorite types are commonly K-feldspar porphyritic and biotite-rich. When these granites are neither hornblende-bearing nor muscovite- or cordierite-bearing, petrographic and geochemical data are often insufficient to compare the closely-spaced units and to define their origin. The typologic study of zircon populations is commonly determinant in the distinction of these two groups of granites (PUPIN, 1980).

In this paper, the zircon method is performed on some selected plutons from the Massif Central (Fig. 1) to solve various types of petrologic problems such as the comparison of closely-spaced granitic units, the comparison of granitoid enclaves enclosed in granitoid hosts, the origin of the different plutons, or the definition of granitic provinces.

The zircon method

The zircon typology method (PUPIN, 1976, 1980, 1985) is based on the study of the relative development of the four main sets of crystal faces (see Fig. 1 in PUPIN, 1980, p. 208). From the variations of prism or pyramidal faces, a zircon type can be defined for each crystal. A study of a population of

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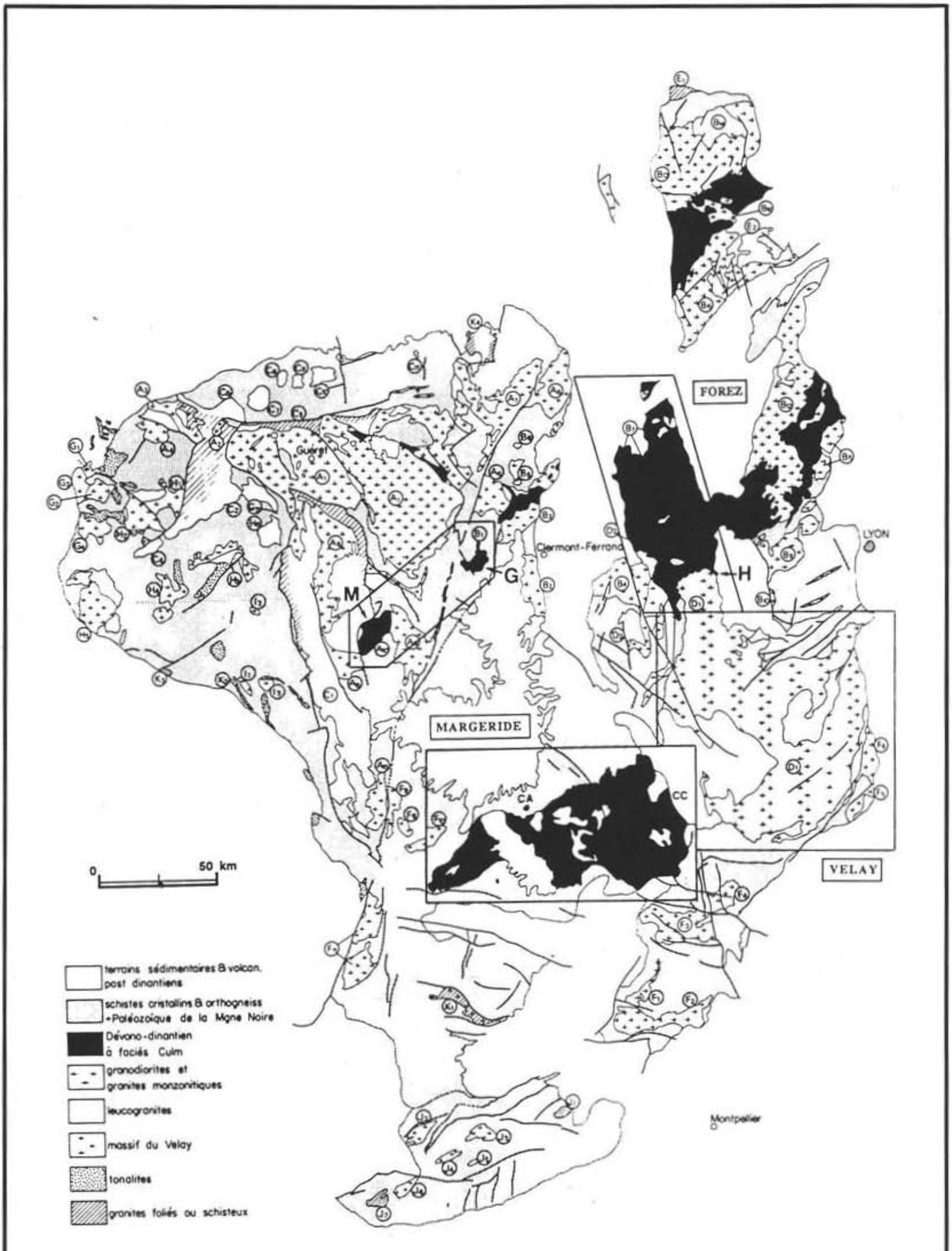


Fig. 1. — Distribution of the various types of granitoids in the Massif Central, France (from DIDIER and LAMEYRE, 1971), and location of the different, discussed areas and plutons (*C.A.: Chaudes-Aigues; C.C.: Chambon-le-Chateau; H.: Hermitage; G.: Gelles; M.: Meymac*).

more than one hundred crystals from a single sample allows definition of a zircon population, two indexes, and a list of features which characterize the studied rock. These data provide useful information on the sample petrology. Within the same fairly homogeneous geological formation (e.g. a non-complex granitic pluton), even the study of one sample gives a reasonably precise indication of the nature and origin of the material. The zircon method can also be used as a tool for the classification and interpretation of granitoids (PUPIN, 1980). Different types of granite and some of their special features can be defined by the systematic study of zircon crystal typology (see Fig. 7a in PUPIN, 1980, p. 214).

As the formation of the different crystal faces is constrained by the temperature, water-content, and chemistry (major, trace, and R.E.E.) of the magma (PUPIN, 1985), variations of these parameters during fractionation and crystallization are recorded by the zircon populations of the different facies of the plutons. For instance, in the Hermitage two-mica pluton, Forez (Fig. 1), zircons of the final aplitic facies are largely distinct from those of the early-crystallized facies (Fig. 2). Zoning in a single large crystal reveals an inner zone with a crystal type similar to the dominant type in the early-crystallized facies, and an outer zone similar to the type largely dominant in the late aplitic facies (Fig. 2). This evolution can be correlated with the variation of the main parameters during crystallization of the magma (BARBARIN, 1983).

Comparison of closely-spaced plutons

1. Gelles, Claveix and Meymac granites

In the central part of the Massif Central, the Gelles porphyritic granite is locally in contact with the Claveix granite. This later is a fine-grained, non-porphyritic monzogranite-granodiorite with the same minerals as in the Gelles monzogranite. As there is no clear contact between these two units, the Claveix granite has been considered as an aplitic facies of the Gelles porphyritic granitic pluton (FERNANDEZ and TEMPIER, 1968). However, petrography and geochemistry reveal differences between the two units (NÉGRONI, 1981).

The zircon method clearly distinguishes the Claveix granite from the Gelles granite (Fig. 3). Although the zircon populations and indices of these two granites are very similar, the morphological features of the crystals are shaply distinct. Zircon crystals from the Claveix granite are colorless, clear, and elongated; they frequently contain relic cores. Zircon crystals from the Gelles granite are colored and stubby; they never contain relic cores but commonly show overgrowths and associations of several crystals. These features suggest crystal growth in a water-rich magma (PUPIN et al., 1978). The indices and morphological features indicate that the Claveix granite belongs to the group of anatectic (par)autochtonous, aluminous granites of crustal origin, and that the Gelles granite belongs to the group of intrusive, aluminous monzogranites and granodiorites of essentially crustal origin according to the PUPIN (1980) genetic classification. The presence of scarce mafic magmatic enclaves in the Gelles pluton is in accord with the slight contribution of mantle-derived material.

In the same part of the Massif Central, the Meymac pluton occurs 40 km south-west of the Gelles pluton and on the other side of the Sillon Houiller fault (Fig. 1). Comparison of the Gelles and Meymac monzogranitic plutons underlines the similarity of their petrological, geochemical, metalogenic, structural, and gravimetric characteristics (MEZURE and NÉGRONI, 1983). These two porphyritic monzogranites also have similar populations, close indices, and similar crystal morphological features (Fig. 3). The zircon method complements the other data which suggest that these monzogranites are cogenetic, and probably belong to the same pluton divided by the Sillon Houiller shear. fault (MEZURE and NÉGRONI, 1983).

2. Forez porphyritic monzogranites-granodiorites

In the central part of the Forez horst (Fig. 1), the two-mica Hermitage pluton is intrusive

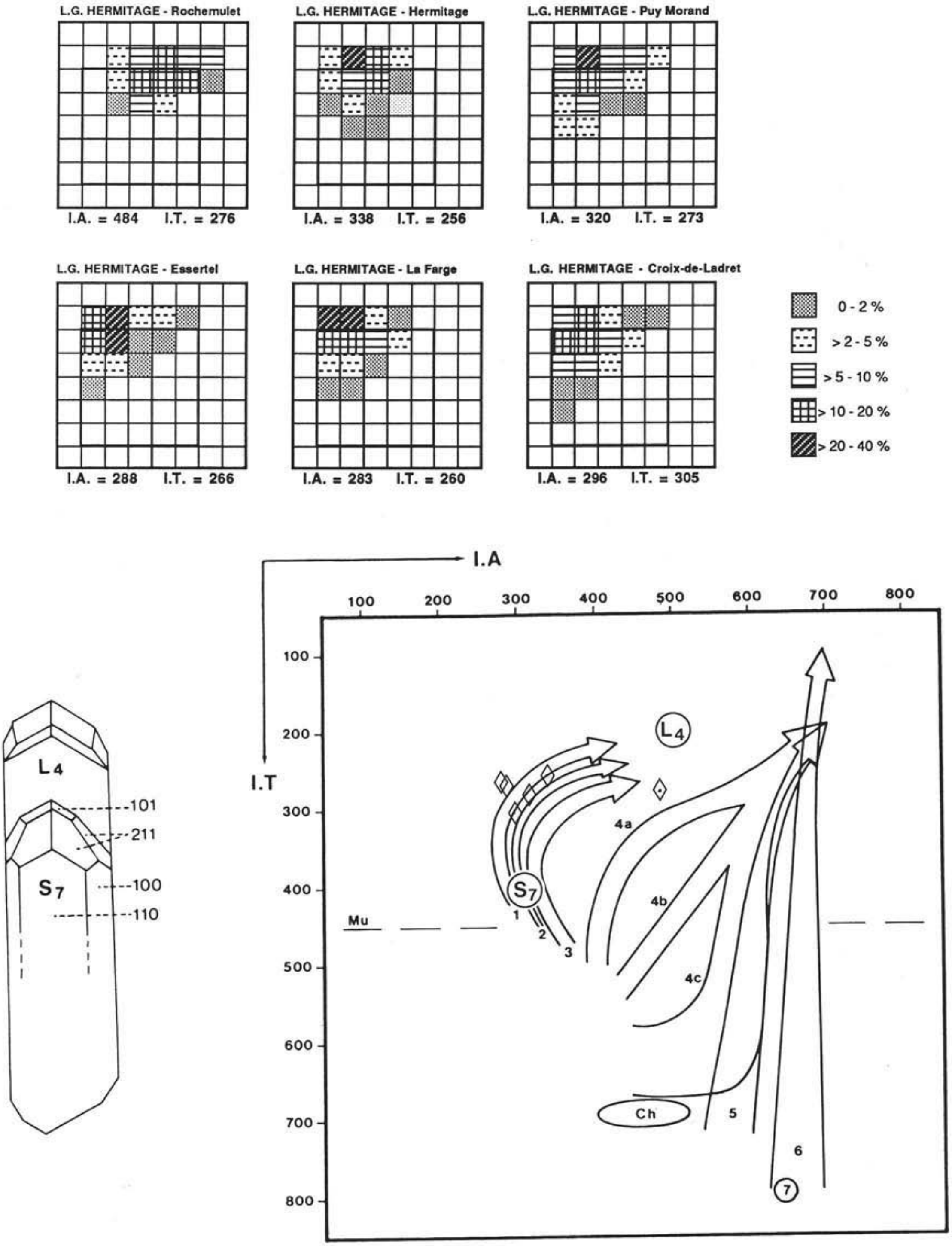


Fig. 2. — Zircon populations from the different facies of the Hermitage two-mica granite, and plots of their mean points on the IA-IT diagram (◈ : *aplitic facies*). Also reported on this diagram are the positions of the two zircon types observed in a zoned zircon crystal from the Hermitage two-mica granite.

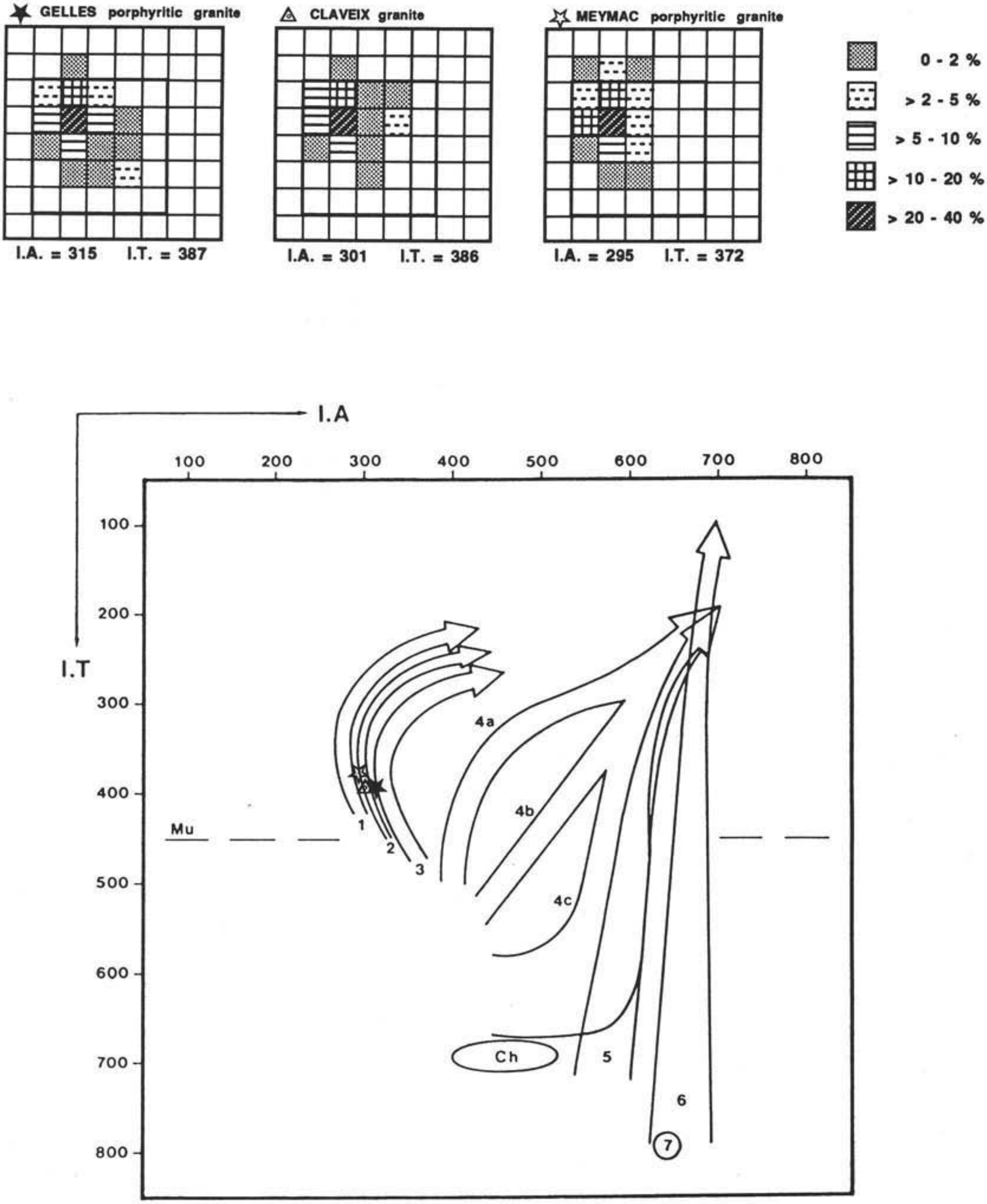


Fig. 3. — Zircon populations from the Gelles, Claveix, and Meymac porphyritic monzogranites, and plots of their mean points on the IA-IT diagram.

into porphyritic, biotite-rich monzogranites and granodiorites (Barbarin, 1983). To the north, the two-mica pluton is in contact with the darkest facies of the laterally zoned Saint Julien-la-Vêtre pluton. This facies shows many petrological and geochemical similarities with the dark-colored and biotite-rich, porphyritic granodiorite which is in contact with the two-mica pluton to the south. From these data, the porphyritic granodiorite has been considered as part of the dark facies of the Saint Julien-la-Vêtre porphyritic monzogranite separated from the main pluton by the intrusion of the Hermitage granite.

Study of zircon populations from many samples of the Saint Julien-la-Vêtre porphyritic monzogranite and from the southern, porphyritic granodiorite is determinant in the distinction of these independent granitic units (Fig. 4). The [100] prismatic and [101] pyramidal faces are largely dominant in zircon crystals from the northern monzogranite, whereas the [110] prismatic and [211] pyramidal faces are largely dominant in zircon crystals from the southern granodiorite. Indices of zircon populations from the two units are totally distinct. In this central part of the Forez horst, the zircon method permits discrimination of two granitic plutons with similar petrographic and geochemical features. Data from this method also indicate that the Saint Julien-la-Vêtre porphyritic monzogranite belongs to the group of intrusive, calc-alkaline granites of hybrid origin, whereas the southern Péri-Forez porphyritic granodiorite belongs to the group of intrusive, aluminous monzogranites and granodiorites of essentially crustal origin according to the PUPIN (1980) genetic classification.

3. Margeride and surrounding porphyritic monzogranites

In the southeastern part of the Massif Central, the Margeride porphyritic monzogranite forms a vast laccolith about 100 km long and 50 km wide. In this body, three main facies and a local biotite cumulate have been distinguished (COUTURIÉ, 1977). Zircon populations of various facies from localities scattered all over the laccolith are decidedly similar considering the extent of the unit and the variety of the facies (PUPIN, 1976).

To the west, the Margeride porphyritic monzogranite presents a fault contact with the Chambon-le-Chateau porphyritic monzogranite. This latter is finer-grained and contains K-feldspar megacrysts smaller than those in the Margeride granite. The zircon populations, indices, and crystal morphological features of the two porphyritic monzogranites are very similar (Fig. 5). As the Margeride granite, the Chambon-le-Chateau granite belongs to the group of intrusive, aluminous monzogranites and granodiorites of essentially crustal origin according to the PUPIN (1980) genetic classification. In this case, the zircon method is compatible with the hypothesis that the Chambon-le-Chateau granite represents a fine-grained margin facies of the Margeride granite (LEMOINE, 1967), though it is still possible that it is an independent unit (COUTURIÉ, 1977).

At about 1 km from the northern contact of the Margeride laccolith with the country metamorphic rocks, the Chaudes-Aigues porphyritic monzogranites forms a 1 km^2 unit (RESTITUTO, 1971). This fine-grained granite contains small K-feldspar megacrysts but becomes microgranular and non-porphyritic close to the contact with the surrounding metamorphic rocks. The Chaudes-Aigues granite has been described as either part of the dike swarms or the fine-grained margin of the Margeride granite (COLIN, 1966). The zircon populations and indices of the Chaudes-Aigues porphyritic monzogranite and the Margeride porphyritic monzogranite are clearly distinct (Fig. 5). Developments of the [100] and [110] prismatic faces and of the [101] and [211] pyramidal faces are relatively similar in zircon crystals from the Chaudes-Aigues granite, whereas the [110] prismatic and [210] pyramidal faces are largely dominant in zircon crystals from the Margeride granite. The zircon method thus confirms the hypothesis that the Chaudes-Aigues granite forms an independent, small granitic unit, intrusive into the metamorphic rocks (RESTITUTO, 1971; COUTURIÉ, 1977; LABOUE, 1982).

Comparison of granitoid enclaves and granitoid hosts

1. Porphyritic granite enclaves enclosed in the Margeride granite

Near its northern contact, the Margeride

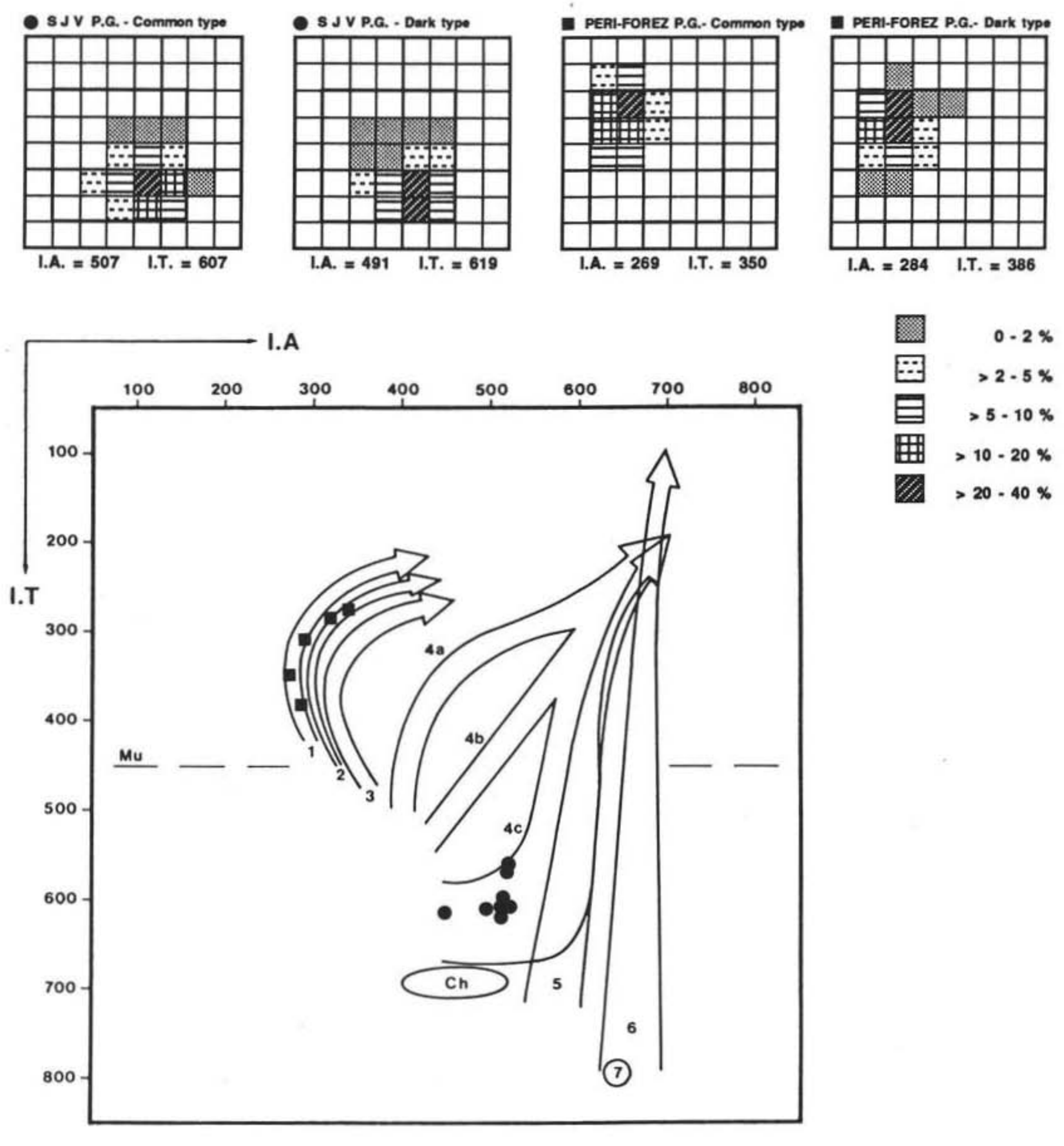


Fig. 4. — Selected zircon populations from the Saint Julien-la-Vêtre (*SJV*) porphyritic monzogranite and from the Péri-Forez porphyritic granodiorite, and plots of their mean points on the IA-IT diagram. (*P.G.: porphyritic granite*).

porphyritic monzogranite contains scarce ovoid enclaves of porphyritic granite (LABOUE, 1982). These enclaves range in size from some tens of centimeters to one meter in diameter. They have sharp contacts with their host, from which they can be distinguished by their different color. Zircon typology on one of these enclaves gives population, indices, and crystal morphological features identical to those of the different facies of the enclosing Margeride granite (Fig. 5). These porphyritic enclaves may thus represent a variety of the light-colored microgranular enclaves of DIDIER (1964, 1973) and correspond to fragments of marginal or early-crystallized parts of the Margeride pluton.

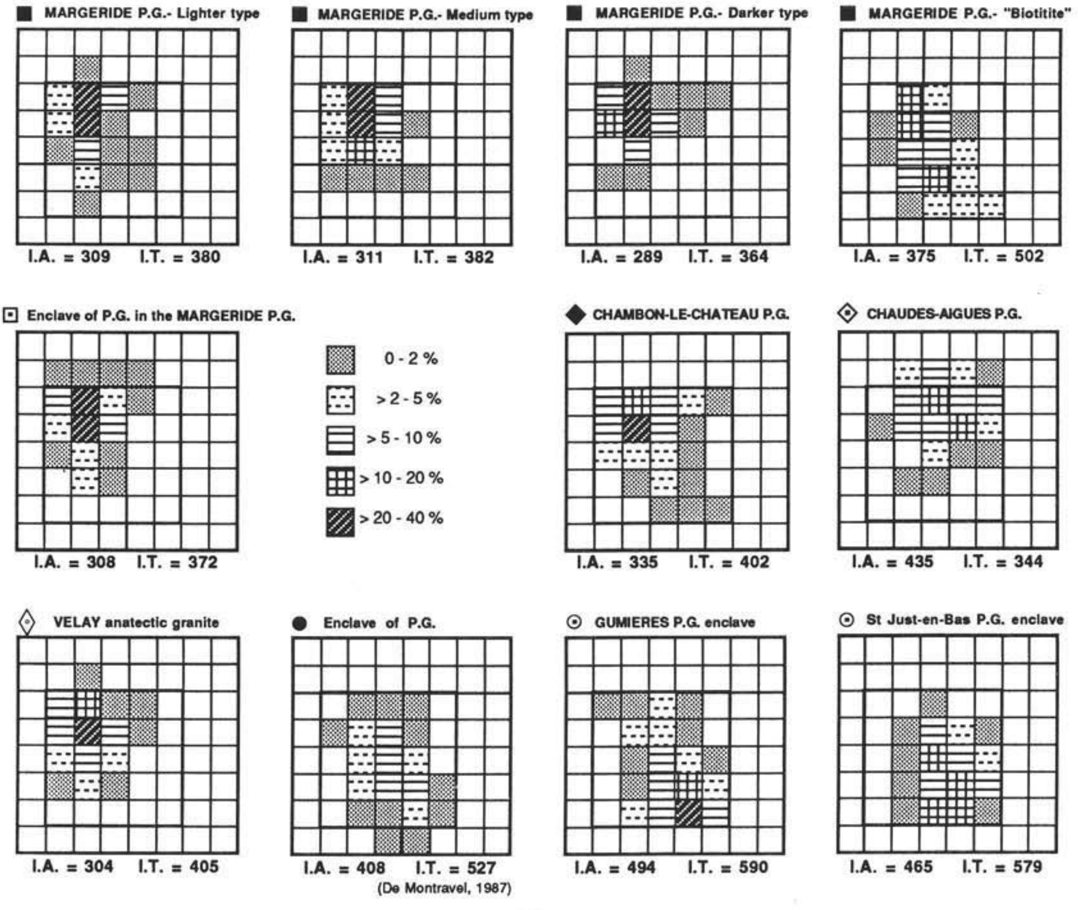
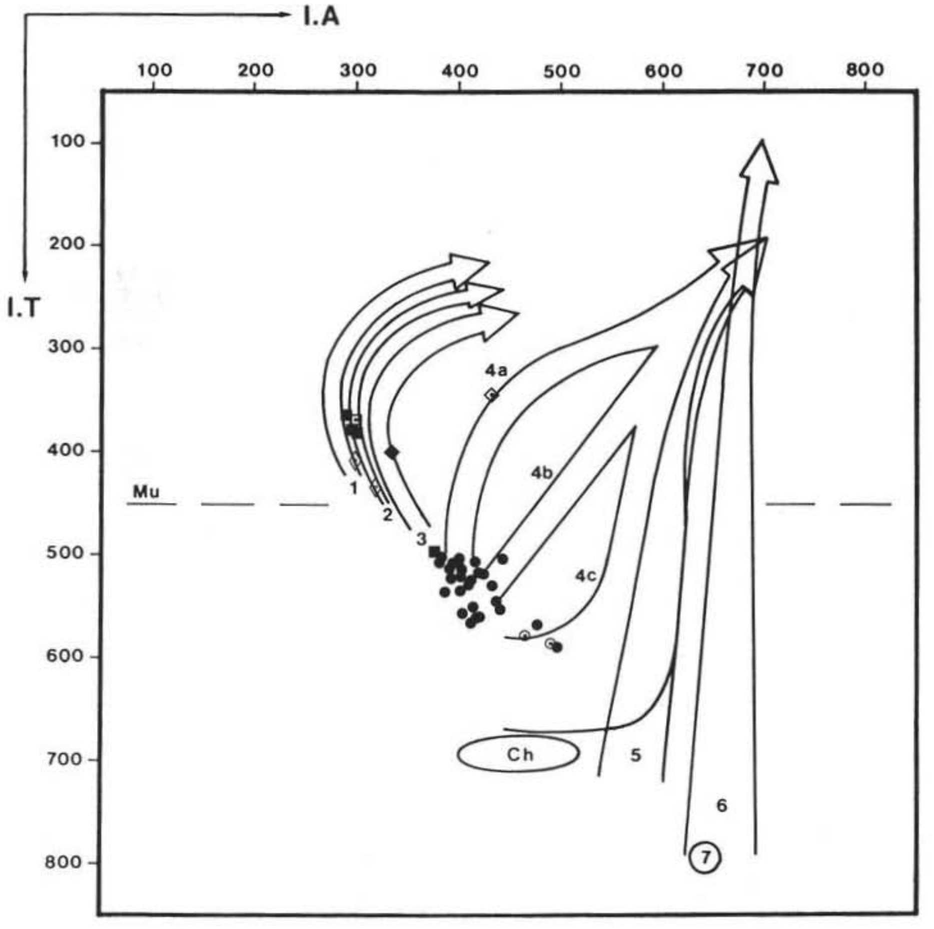


Fig. 5.— (1) Zircon populations from the different facies of the Margeride porphyritic monzogranite, from the Chambon-le-Chateau and Chaudes-Aigues porphyritic monzogranites, from the Velay anatectic granite, and from some enclaves of porphyritic granites enclosed in the Velay anatectic granite and in the Péri-Forez porphyritic granodiorite, and (2) plots of their mean points on the IA-IT diagram (*P.G.: porphyritic granite*).

2. *Porphyritic granodiorite enclaves enclosed in the Velay anatectic granite*

In the central-eastern part of the Massif Central, the huge Velay anatectic complex is mainly composed of cordierite-bearing granite, biotite-bearing granite near the margins, and kilometer-sized screens of metamorphic rocks (DIDIER, 1964; DUPRAZ, 1983, 1986). Many of the abundant enclaves scattered in the various anatectic granites all over the pluton are made of dark-colored and commonly highly deformed porphyritic granodiorites (DIDIER, 1964). These granodiorite enclaves range in size from some centimeters to more than one kilometer. They are located everywhere in the complex, where they are either isolated or form swarms (DE MONTRAVEL, 1986) (Fig. 6). These enclaves have been considered as fragments of the older, surrounding Margeride or Tournon porphyritic monzogranite plutons, enclosed by the Velay granite during emplacement (COUTURIÉ 1969; CHENEVOY et al., 1974). Zircon typology of the porphyritic granodiorite enclaves clearly indicates that they are invariably distinct from the Margeride porphyritic monzogranite (PUPIN and TURCO, 1975; DE MONTRAVEL, 1986) (Fig. 5). Zircon features of the porphyritic granodiorite enclaves are decidedly



(2)

homogeneous throughout the Velay complex. The dominant [100] prismatic and [101] pyramidal faces in zircons from these enclaves give them high A and T indices, whereas the dominant [110] prismatic and [211] pyramidal faces in zircons from either the Velay anatectic granites or the Margeride porphyritic monzogranite give them low A and T indices (Fig. 5). Therefore, the porphyritic granodiorite enclaves are not fragments of the essentially crustal aluminous porphyritic monzogranites (e.g. Margeride or Tournon monzogranites) which surround the Velay complex (PUPIN and TURCO, 1975; DE MONTRAVEL, 1986). They are best interpreted as restitic fragments (DIDIER, pers. comm.) of metaluminous, porphyritic granitic plutons involved in the high-grade metamorphic event that generated the Velay anatectic complex. These metaluminous granites come from a lower structural level, where they were enclosed in the Velay anatectic complex and carried up during the doming intrusion in the aluminous porphyritic monzogranite plutons to a higher structural level. Plutons of metaluminous, porphyritic granites of the same type as the porphyritic granodiorites enclosed in the Velay complex only occur further north in the Montagne Bourbonnaise area or further south in the Cévennes region.

In the Forez area, besides the common, small, porphyritic granodiorite enclaves, there are two kilometer-sized bodies. They are enclosed, respectively, in the northern end of the anatectic complex at Gumières, and in the Péri-Forez aluminous porphyritic

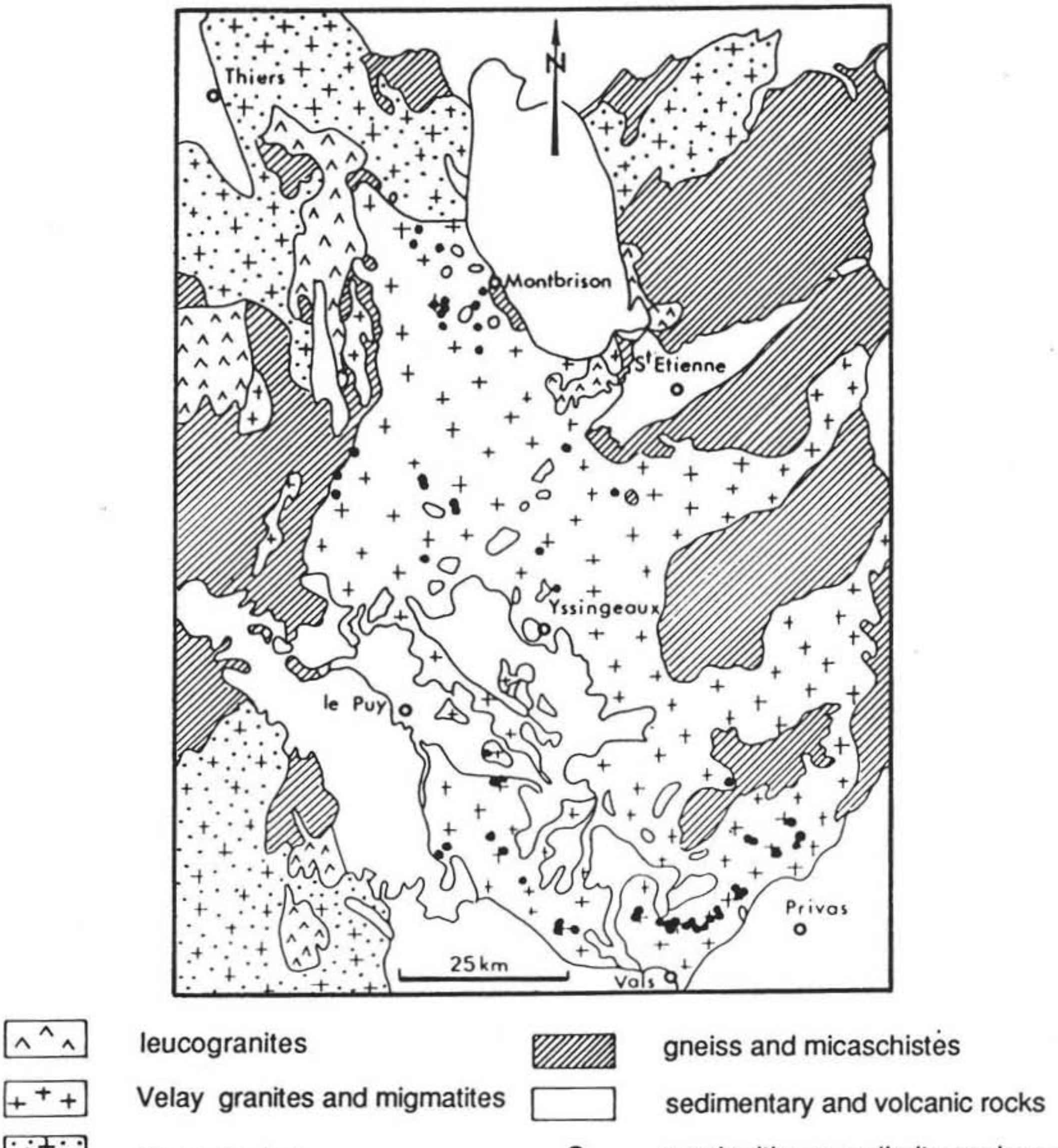


Fig. 6. — Locations of the enclaves of porphyritic granodiorites in the Velay anatectic complex (De Montravel, 1987).

monzogranite which forms a belt around the northern end of the anatectic complex, at Saint Just-en-Bas (Barbarin, 1983). As with the smaller enclaves, these dark-colored, porphyritic granodiorite units are strongly sheared. The occurrence of this type of enclave, even in the surrounding aluminous, porphyritic monzogranites confirms the distinction between porphyritic granites enclosed in the Velay complex and those surrounding this complex (Fig. 5). Furthermore, it suggests that, in the Monts-du-Forez area, there are three main successive plutonic events: 1. intrusion of metaluminous,

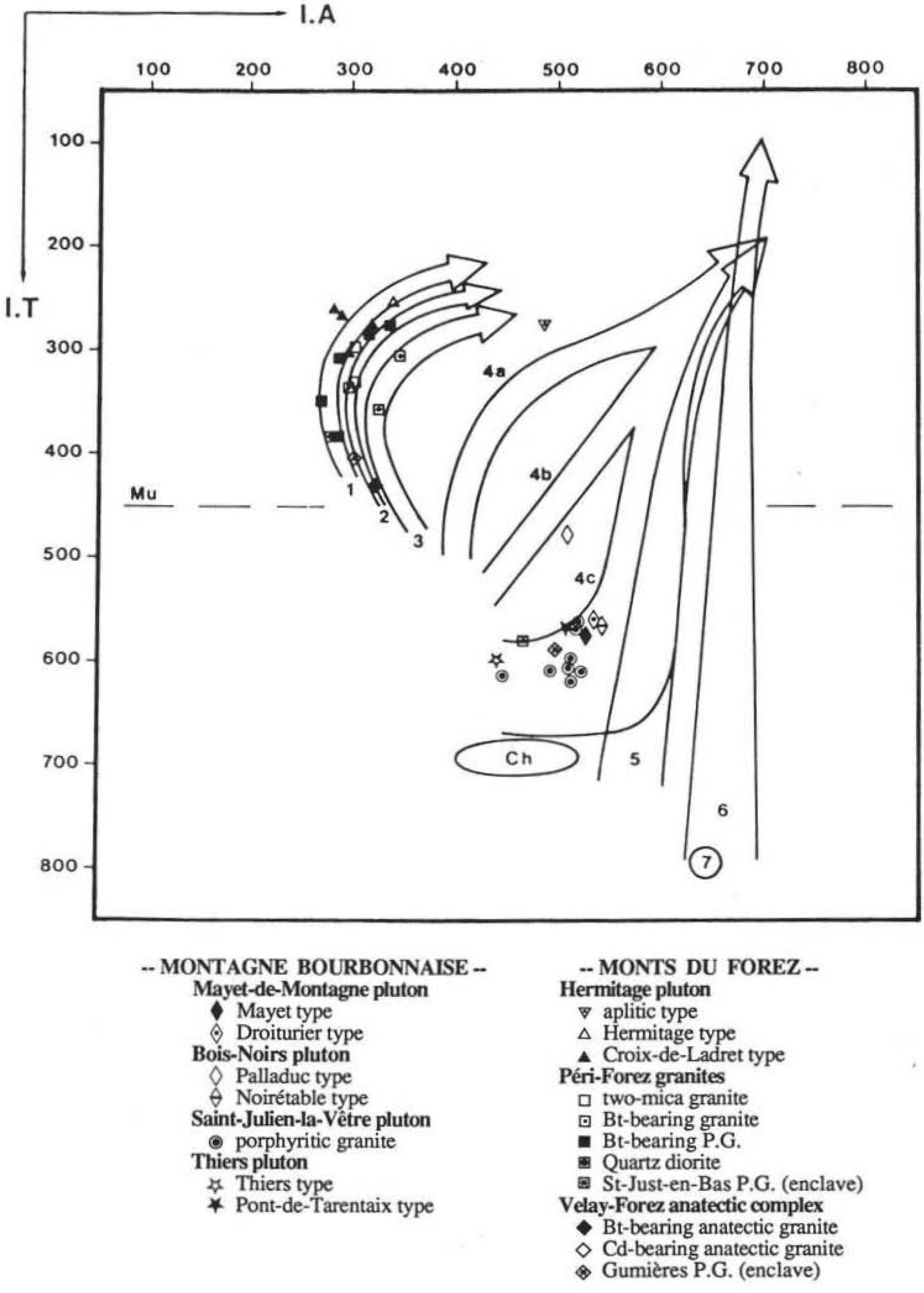


Fig. 7. — Distribution on the IA-IT diagram of the mean points of zircon populations from the various granites of the Forez horst.

porphyritic granite plutons probably in the metamorphic series; 2. intrusion of the aluminous, porphyritic monzogranite plutons; and 3. doming of the Velay anatectic complex.

3. *Sheared granite enclaves enclosed in the Bois-Noirs granite*

In the northern part of the Forez horst (Fig.

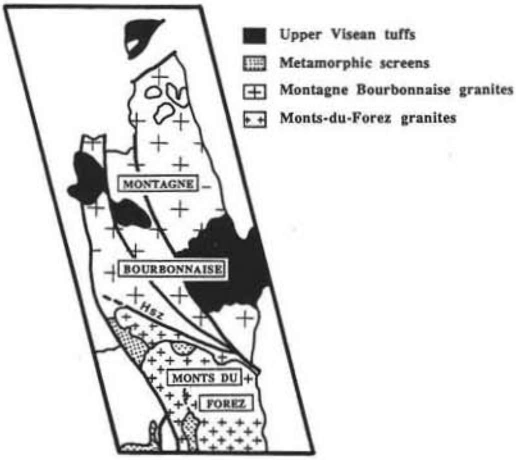


Fig. 8. — Sketched map of the Forez horst, showing the Montagne Bourbonnaise and the Monts-du-Forez granitic provinces divided by the Hermitage shear zone (Hsz).

1), local east-west shear zones cut across the normally-zoned Bois-Noirs pluton. These deformed zones frequently contain meter-sized, lenticular enclaves of strongly sheared granites. Lack of exposure makes the structural data ambiguous. Petrographic and geochemical studies of these highly deformed enclaves have not determined whether they represent pieces of the Bois-Noirs granite locally involved in the shear zones, or older sheared granites enclosed in the Bois-Noirs granite. However, zircon typology on one of these enclaves at Lavoine (Pupin, pers. comm.) clearly favors the second hypothesis. The sheared granite enclaves contain zircons with [110] prismatic and [211] pyramidal faces dominant. They belong to the group of intrusive, aluminous granites of essentially crustal origin. In contrast, the enclosing Bois-Noirs monzogranite has zircons with dominant [100] prismatic and [101] pyramidal faces and belongs to the group of intrusive, metaluminous granites of hybrid origin according to the Pupin (1980) genetic classification. The zircon method should be applied to the other enclaves and also to the Le Donjon sheared granite to the north in order to determine whether the Montagne Bourbonnaise metaluminous granitic plutons were emplaced in an area occupied by older aluminous granitic plutons.

Definition of granitic provinces

Use of the zircon method in the study and comparison of the different granitic plutons of the Forez horst (Fig. 1) also permits distinction between two groups of granitoids (Barbarin, 1983, 1984). In the group located in the northern part of the host called Montagne Bourbonnaise (Fig. 8), the metaluminous monzogranites are characterized by zircons with dominant [100] prismatic and [101] pyramidal faces indicating a hybrid origin (Fig. 7). In the other group, located in the southern part of the horst called Monts-du-Forez (Fig. 8), the aluminous monzogranites or granodiorites are characterized by zircons with dominant [110] prismatic and [211] pyramidal faces indicating a crustal origin (Fig. 7). In this case, the zircon method not only complements the other data but is determinant in the distinction between the Montagne Bourbonnaise and Monts-du-Forez granitic provinces.

These two granitic provinces are divided by the Hermitage ductile shear zone (Fig. 8) which is part of a major Variscan crustal suture in the eastern part of the Massif Central (Barbarin and Belin, 1982). This fracture separates the north-eastern part of the Massif Central where the granites are of the same types as in the Montagne Bourbonnaise granitic province, from the central-eastern part where the granites are of the same type as in the Monts-du-Forez granitic province, the latter being a northern extension of the huge Velay anatectic complex.

On the scale of the whole Massif Central, the zircon method leads to the definition of magmatic zonation in the Variscan orogeny (Pupin, 1981, 1985). From the study of hundreds of zircon populations, it is possible to quantify the abundance, in each area of the Massif Central, of various granitic types defined in the genetic classification (Pupin, 1980). The same type of study was carried out in other Hercynian segments such as Brittany or Corsica (Pupin, 1985).

Conclusions

The solution of various types of granite problems in the Massif Central using the zircon method emphasizes the quality and reliability of this petrological tool. However, this method has its limits and should be used together with field-geology, petrography, geochemistry, and isotopic work, if possible. From the various examples, it is clear that this method is determinant in the distinction between granites of different types in the Pupin genetic classification. However, it cannot specify whether or not two granites of the same type are cogenetic. Zircon typology is an excellent complement to the classical methods. Considering the quantity of information provided compared to its efficiency and cost, the zircon method is profitable and should be systematically used in granite studies.

Acknowledgments. — I am very grateful to Dr Jean-Pierre Pupin, University of Nice (France), who kindly taught me his method for studying zircon morphology, and maintained his interest throughout the progress of my research. Many colleagues from the Department of Geology in Clermont-Ferrand, were at the origin of this report. I thank John Clemens for his assistance on early version of the manuscript. Helpful comments were also received from Profs. Jean Didier and Jean Lameyre, and an anonymous reviewer.

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