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U–Pb zircon dating of two contrasting Late Variscan plutonic suites from the Pelvoux massif (French Western Alps)

by *Catherine Guerrot*[1] and *François Debon*[2]

Abstract

The Pelvoux massif comprises extensive Late Variscan plutons emplaced into a polymetamorphic and migmatitic basement. On the basis of their average Mg / (Fe + Mg) ratios, the plutons can be divided into a magnesian and a magnesian-ferriferous suite. Age determinations by the U–Pb conventional technique on zircon on a representative pluton of each suite gave 343 ± 11 Ma (Viséan) for the magnesian Rochail pluton and 302 ± 2 Ma (Stephanian) for the magnesian-ferriferous Turbat-Lauranoure pluton. By comparison with other External Crystalline Massifs of the Alps, these ages are interpreted to indicate that the generation of the Late Variscan plutons in the Pelvoux massif was a discontinuous process, involving two major magmatic pulses separated by a gap of some 40 Ma.

Keywords: plutonic rocks, geochemistry, geochronology, Variscan orogeny, Pelvoux massif, Western Alps.

1. Introduction

Late Variscan plutonic rocks are widely represented within the External Crystalline Massifs of the Alps or ECM (Fig. 1; DEBON and LEMMET, 1999, and references therein). But for this plutonism to be understood requires, among other things, meaningful age determinations based upon methods little sensitive to tectono-metamorphic processes (e.g. SCHALTEGGER, 1994). The U–Pb zircon datings we present here fulfil this requirement. They concern two plutons of the Pelvoux massif, viz. a domain where reliable intrusion ages were almost completely lacking. On the basis of geochemical data, two Late Variscan plutonic suites can be distinguished in this massif, namely a highly magnesian (high-*mg*-number) suite and a more iron-rich magnesian-ferriferous (low-*mg*-number) suite (DEBON and LEMMET, 1999; Figs 2 and 3). The aim of our paper is to present the data which substantiate the age of emplacement of the two suites and to situate the latter within the frame of the Late Variscan plutonic history of the ECM.

2. Dated plutonic bodies

More than twenty Late Variscan plutons occur in the Pelvoux massif, covering about one third of its area (Fig. 2). Based on data from the literature (e.g. LE FORT, 1973; BARFÉTY and PÊCHER, 1984), their main characteristics are summarized in DEBON and LEMMET (1999) who divided them into two suites of different *mg*-number. A typical representative of each suite was selected for U–Pb zircon dating, namely the magnesian Rochail pluton and the magnesian-ferriferous Turbat-Lauranoure pluton (Figs 2 and 3).

2.1. ROCHAIL PLUTON

The Rochail pluton (ca. 34 km^2) intrudes gneissic formations and comprises two granitic units (BOISSET, 1986; BARFÉTY, 1989). The main unit, making up the southern part of the pluton, is composed of a massive to weakly foliated, medium-grained monzogranite with biotite ± rare muscovite, apatite and zircon. To the north, this merges

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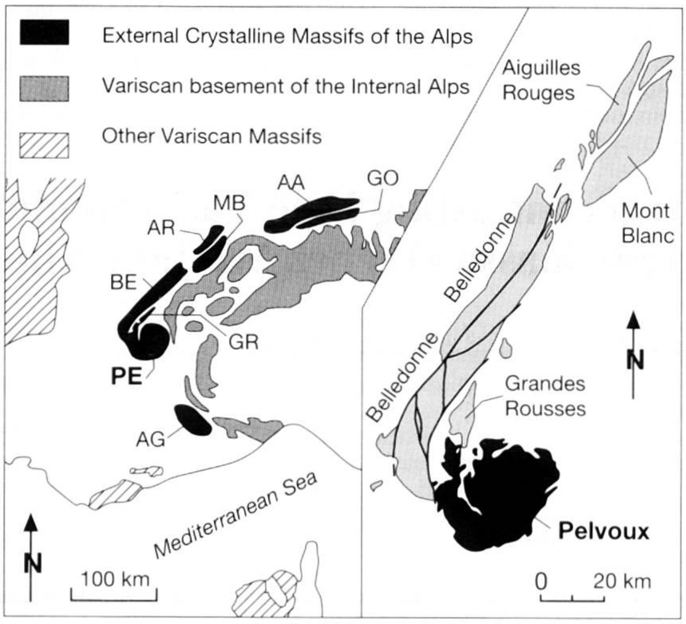

Fig. 1 External Crystalline Massifs of the Alps (modified from DEBON and LEMMET, 1999).
AA, Aar
AG, Argentera
AR, Aiguilles Rouges
BE, Belledonne
GO, Gotthard
GR, Grandes Rousses
MB, Mont Blanc
PE, Pelvoux (study area).

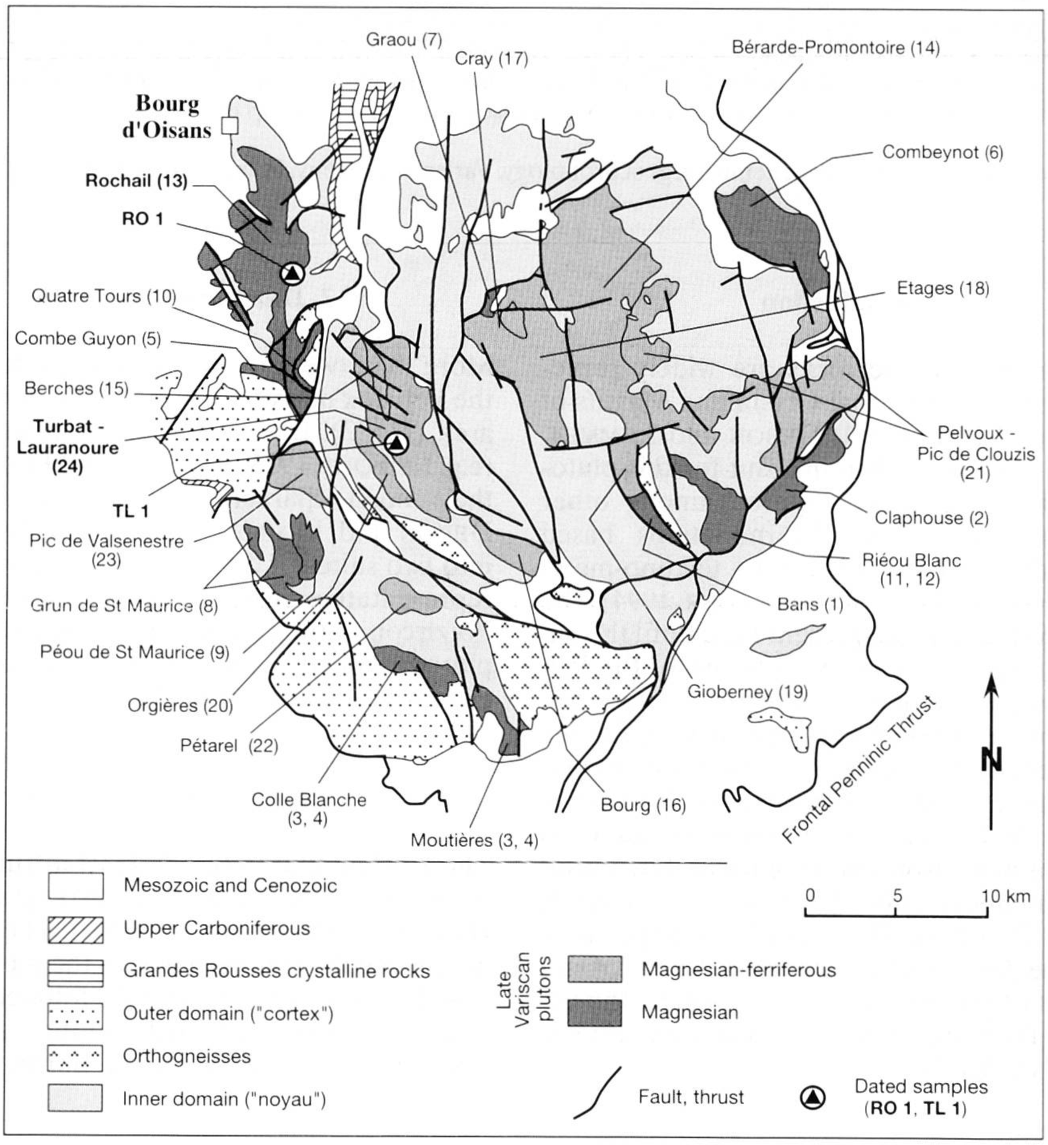

Fig. 2 Geological map of the Pelvoux massif (after DEBON and LEMMET, 1999). Typology of the Variscan plutons is based on their plots on the *mg*-number-B diagram (see figure 3).

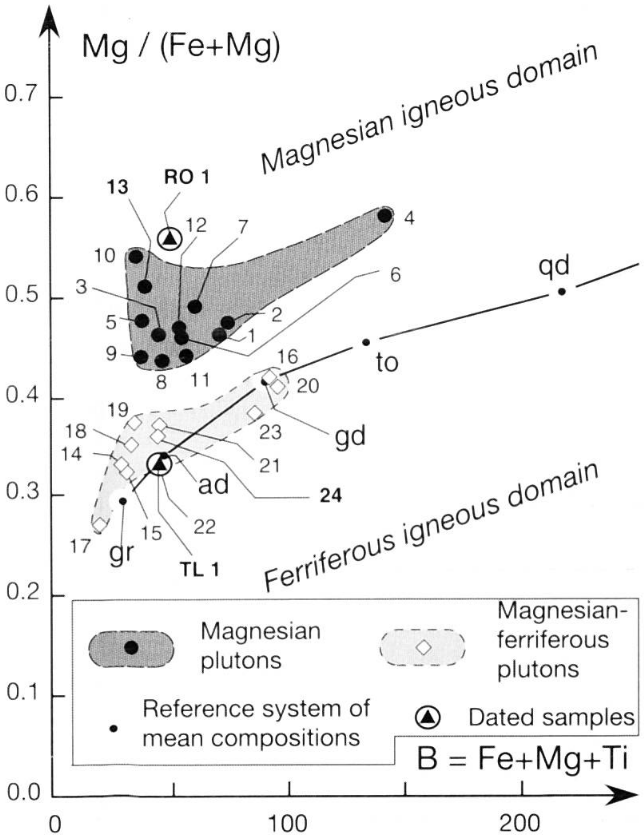

Fig. 3 Plot of the Pelvoux plutons (average compositions) on the *mg*-number-B diagram (after DEBON and LEMMET, 1999). Reference system of mean compositions: gr, granite; ad, adamellite; gd, granodiorite; to, tonalite; qd, quartz diorite. For numbering of plutons see figure 2.

into a coarser and darker foliated biotite monzogranite with a porphyritic tendency. Both monzogranites enclose conspicuous mafic igneous enclaves, especially of the vaugneritic-durbachitic type (the so-called "syénite du Lauvitel").

The emplacement age of the Rochail pluton has remained poorly constrained despite a number of radiometric studies performed both on granites and vaugneritic enclaves. Besides an age of 331 ± 32 Ma (2 σ) ascribed to the northern unit from a questionable Rb–Sr whole-rock isochron (initial $^{87}Sr/^{86}Sr$ ratio of 0.7047 ± 0.0013) (DEMEULEMEESTER, 1982), a variety of ages had been obtained through the total-lead zircon method (271, 298, 308 Ma; CHESSEX et al., 1964; KRUMMENACHER et al., 1965) and Rb–Sr or K–Ar techniques applied to both biotite (fourteen ages ranging from 267 to 339 Ma) and amphibole (five ages from 321 to 378 Ma) (BONHOMME et al., 1963; DEMEULEMEESTER, 1982; VITTOZ et al., 1987; G. BANZET, pers. commun.).

The dated sample (RO 1; Fig. 2; Tab. 1) was collected in situ on the northwestern side of Lake Lauvitel (x = 6°03'41", y = 44°58'28", z = 1595 m) from a homogeneous, light-coloured, massive, medium-grained, quartz-bearing syenite with biotite and rare muscovite, about one metre away from a vaugneritic enclave more than 5 × 2 m in size. This syenite, quite different from the so-called "syénite du Lauvitel", merges laterally into the dominant monzogranitic type, of which it represents a quartz-poor and feldspar-rich variety.

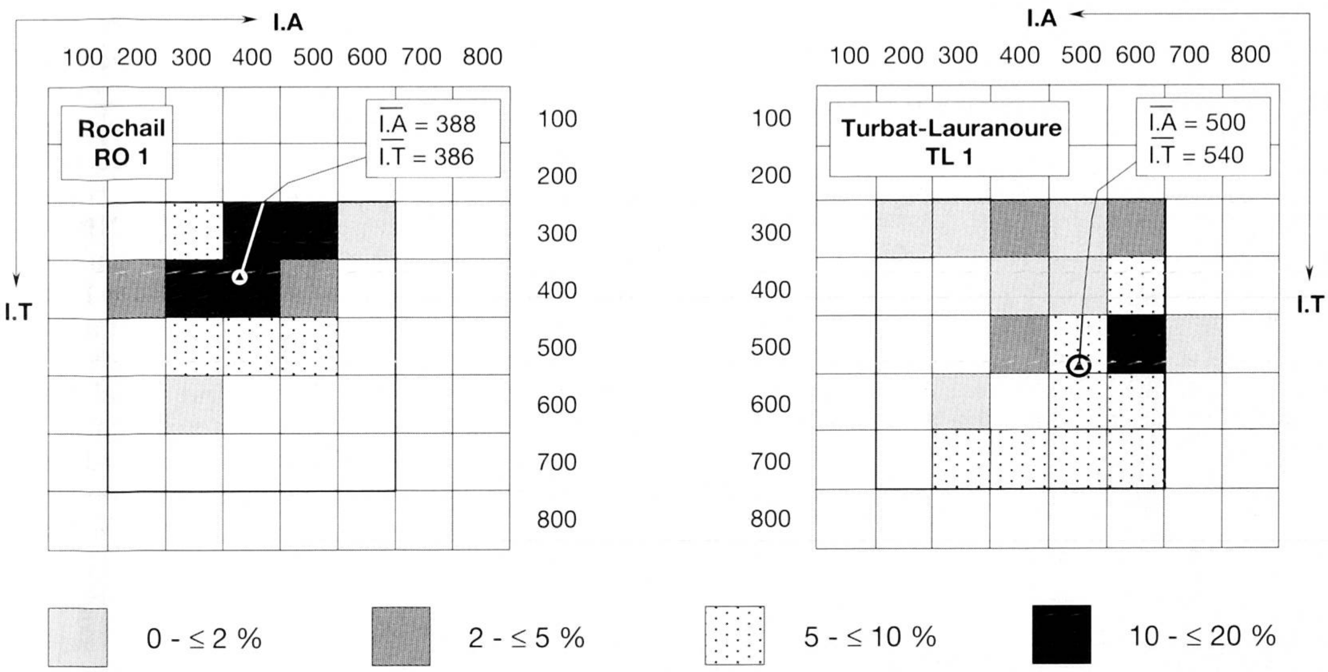

Fig. 4 Distribution of zircons from the dated samples (RO 1, TL 1) in the typological diagram of PUPIN (1980).

Tab. 1 Chemical composition of the dated samples (RO 1, TL 1).

Pluton Dated sample	Rochail RO 1	Turbat-Lauranoure TL 1
SiO_2	63.49	71.85
TiO_2	0.32	0.26
Al_2O_3	19.40	14.35
Fe_2O_3*	1.60	2.30
MnO	tr	0.03
MgO	1.03	0.56
CaO	0.92	1.61
Na_2O	5.48	3.17
K_2O	6.18	4.74
P_2O_5	0.13	0.13
LOI	1.09	0.78
Total	99.65	99.78
B = Fe + Mg + Ti	50	46
Mg/(Fe + Mg)	0.56	0.33
Ba	1498	563
Cr	25.7	6.7
Hf	6.8	4.8
Nb	6.9	10.8
Ni	12.9	3.1
Rb	244	213
Sr	814	137
Ta	1.8	1.6
Th	61.6	16.0
U	12.3	3.0
V	26.3	20.2
W	0.6	0.6
Y	5.7	22.9
Zr	219	158
La	10.14	32.35
Ce	19.64	67.07
Pr	2.21	7.58
Nd	8.58	28.87
Sm	1.61	6.14
Eu	0.81	0.80
Gd	1.22	4.78
Tb	0.16	0.75
Dy	0.90	4.15
Ho	0.21	0.91
Er	0.57	2.10
Tm	0.10	0.35
Yb	0.65	2.25
Lu	0.12	0.37

Major elements in oxide-%; trace elements in ppm; Fe_2O_3*, total iron as ferric oxide; LOI, loss on ignition; tr, traces. Analyses performed at the CRPG-CNRS (Nancy), by ICP-Emission (major elements) and ICP-MS (trace elements).

2.2. TURBAT-LAURANOURE PLUTON

The Turbat-Lauranoure pluton (ca. 33 km^2) intrudes gneissic and migmatitic formations (LE FORT, 1973; BARFÉTY and PÊCHER, 1984). It is a homogeneous body of variably porphyritic and foliated, coarse-grained biotite ± muscovite syenogranite enclosing rare microgranular enclaves. No previous radiometric age is available for this pluton, apart from a questionable whole-rock Rb–Sr age of ca. 300 Ma (310 Ma with new constants) given by three samples collected from three magnesian-ferriferous plutons (*i.e.* Etages, Orgières, Turbat-Lauranoure; J. SONET, in LE FORT, 1973).

The dated sample (TL 1) was collected in situ on the northern side of the Bonne river (x = 6°08'46", y = 44°52'57", z = 1590 m) from a massive syenogranite; it is representative of the main rock type (Fig. 2; Tab. 1).

3. U–Pb zircon geochronology

3.1. ANALYTICAL PROCEDURE

After crushing the sample and concentrating the heavy minerals with heavy liquids, the zircons were separated into fractions of different magnetic susceptibility, non-magnetic zircons being generally more concordant (KROGH, 1982a). Zircons from the least magnetic fraction were examined under a binocular microscope, and some 30 to 50 grains selected according to optical and morphological criteria. These were then air-abraded in order to remove their outer surfaces so as to minimize effects due to lead loss (KROGH 1982b). Techniques of zircon dissolution and chemical separation of Pb and U were adapted from KROGH (1973) and PARRISH (1987). All samples were spiked using a mixed ^{205}Pb–^{233}U–^{235}U isotope tracer added before dissolution. Pb and U were loaded on the same single Re filament with silica-gel and H_3PO_4 and analyses were performed on a Finnigan MAT 261 mass spectrometer in single collector operation, using a secondary electron multiplier. Mass discrimination, controlled by regular measurements of the NBS-981 common Pb standards, was 0.28% / a.m.u. Total procedure blanks were less than 15 pg for Pb and 1 pg for U. Pb analyses were corrected for a blank isotopic composition of $^{206}Pb/^{204}Pb$ = 18.0, $^{207}Pb/^{206}Pb$ = 0.85, $^{208}Pb/^{206}Pb$ = 2.06. Individual errors are given at 2σ. Regressions were calculated according to DAVIS (1982), and also according to LUDWIG (1999) for lower intercept and concordia age. Quoted errors are given at the 95% confidence level.

3.2. ROCHAIL PLUTON

The analysed sample from the Rochail pluton (RO 1) contains abundant pale-pink euhedral zir-

Tab. 2 U–Pb analytical results for zircons from the dated samples (RO 1, TL 1).

Sample		Concentrations				Isotopic Ratios					Apparent Ages		
#	Grain [1]	weight (µg)	U (ppm)	Pb rad (ppm)	Pb com (pg) [2]	Pb 206/204 [3]	Pb 208/206 [4]	Pb/U 206/238 [4]	Pb/U 207/235 [4]	Pb 207/206 [4]	Pb/U 206/238 (Ma)	Pb/U 207/235 (Ma)	Pb 207/206 (Ma)
ROCHAIL PLUTON RO 1													
A	3,c,sp,eu,m1	12	431.1	21.8	7	2317	0.21	0.0518 ± 4	0.4788 ± 34	0.06701 ± 18	325.7	397.2	838.0
B	1,p,lp,eu,m1	9	241.6	12.5	18	370	0.52	0.0484 ± 2	0.3559 ± 31	0.05332 ± 40	304.8	309.2	342.6
C	5,p,lp,eu,m1	27	1251.3	75.4	293	440	0.38	0.0597 ± 3	0.5975 ± 33	0.07263 ± 22	373.6	475.6	1003.6
D	1,p,sp,sb,m1	23	1142.7	58.6	122	682	0.38	0.0500 ± 2	0.3679 ± 20	0.05332 ± 26	314.7	318.1	342.6
F	1,c,t,m1	5	1075.1	53.6	62	295	0.16	0.0525 ± 2	0.3859 ± 24	0.05332 ± 24	329.8	331.4	342.6
G	1,p,lp,eu,m1	2	825.9	168.0	16	1227	0.83	0.1979 ± 10	3.3283 ± 180	0.12199 ± 32	1163.9	1487.7	1985.5
TURBAT-LAURANOURE PLUTON TL 1													
A	3,p,sp,eu,m0	13	753.4	69.6	24	2373	0.06	0.0935 ± 8	1.1468 ± 120	0.08901 ± 60	575.9	775.7	1404.3
C	5,p,lp,eu,m0	52	442.4	25.7	82	1048	0.08	0.0594 ± 3	0.4573 ± 26	0.05580 ± 26	372.2	382.4	444.4
D	4,c,sp,eu,m0	35	456.2	21.5	99	491	0.09	0.0480 ± 3	0.3465 ± 32	0.05240 ± 40	302.0	302.1	303.0
E	1,p,lp,sb,m1	4	846.7	43.4	280	57	0.10	0.0514 ± 12	0.4184 ± 243	0.05903 ± 346	323.2	354.9	568.2
F	1,c,lp,eu,m1	4	808.5	40.6	27	388	0.09	0.0507 ± 3	0.3958 ± 58	0.05658 ± 78	319.1	338.6	475.0
G	1,v,sp,eu,m1	4	1443.0	74.1	29	681	0.04	0.0548 ± 5	0.4118 ± 60	0.05445 ± 70	344.2	350.2	389.9

[1] = number of grains, c colourless, p pink, v violet, lp long prism, sp short prism, eu euhedral, sb subhedral, t tip, m0 magnetic at 0° tilt, m1 magnetic at 1° tilt.
[2] = Total common Pb (spike, contamination and mineral)
[3] = corrected for mass fractionation
[4] = corrected for mass fractionation, blank (Pb=15 pg, U=1 pg), spike, and initial common Pb according to STACEY and KRAMERS (1975).
Uncertainties are given at ± 2σ and refer to the last decimals.

cons, commonly asymmetric or displaying internal zoning. Most of the crystals show small black inclusions. One hundred crystals were indexed; this population, scattered near the centre of the classification diagram of PUPIN (1980), has I.A, I.T mean values of 388 and 386 respectively (Fig. 4).

Six zircon fractions (each of 1 to 5 individual grains) were analysed from this sample. Three fractions (B, D and F, Tab. 2) are collinear and show a degree of discordance from 3 to 10%, reflecting lead loss. Despite rather low $^{206}Pb/^{204}Pb$ ratios probably related to the presence of small inclusions, they define a discordia intersecting the concordia at 343 +11/−10 Ma (92% probability of fit) (Fig. 5), the lower unforced intercept being at the origin of the diagram. The other three fractions (especially fraction G) reveal the presence of an old inherited component, probably of Early Proterozoic age. No alignment is seen from these three fractions, probably due to some combination of inheritance and lead loss.

The age of 343 +11/−10 Ma, i.e. Early Viséan (ODIN, 1994), is interpreted as the intrusion age of the Rochail pluton. Because of their field relationships, it is most likely that this age can be ascribed also to the vaugneritic-durbachitic enclaves.

3.3. TURBAT-LAURANOURE PLUTON

The sample from the Turbat-Lauranoure pluton (TL 1) contains rather abundant transparent pink zircon crystals. One hundred crystals were indexed; this population, widely scattered in the centre of PUPIN's (1980) classification diagram, has I.A, I.T mean values of 500 and 540 respectively (Fig. 4), comparable with those of 575 and 429 previously obtained by COSTARELLA (1987).

Of the six fractions analysed, only fraction D is concordant at 302 ± 2 Ma. The other fractions show

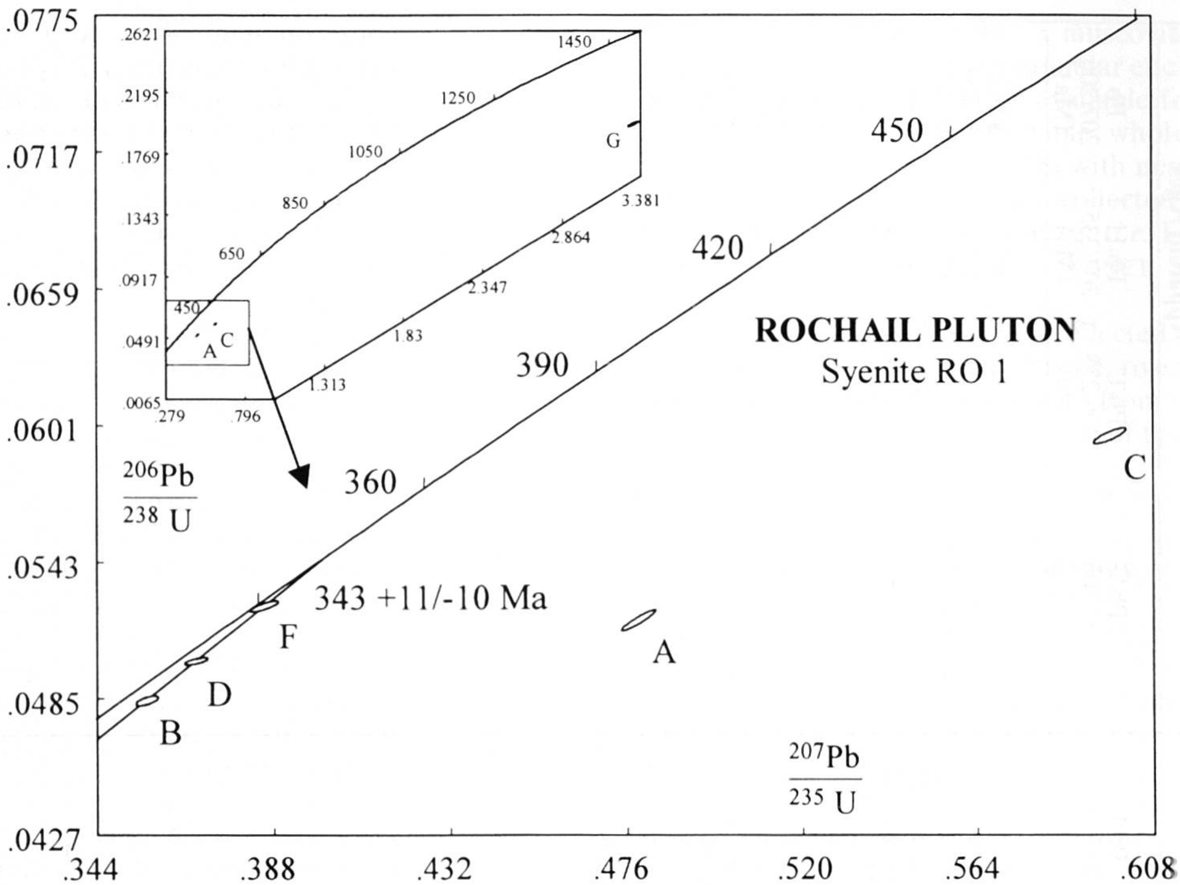

Fig. 5 U–Pb concordia diagram for zircons from the Rochail pluton (sample RO 1).

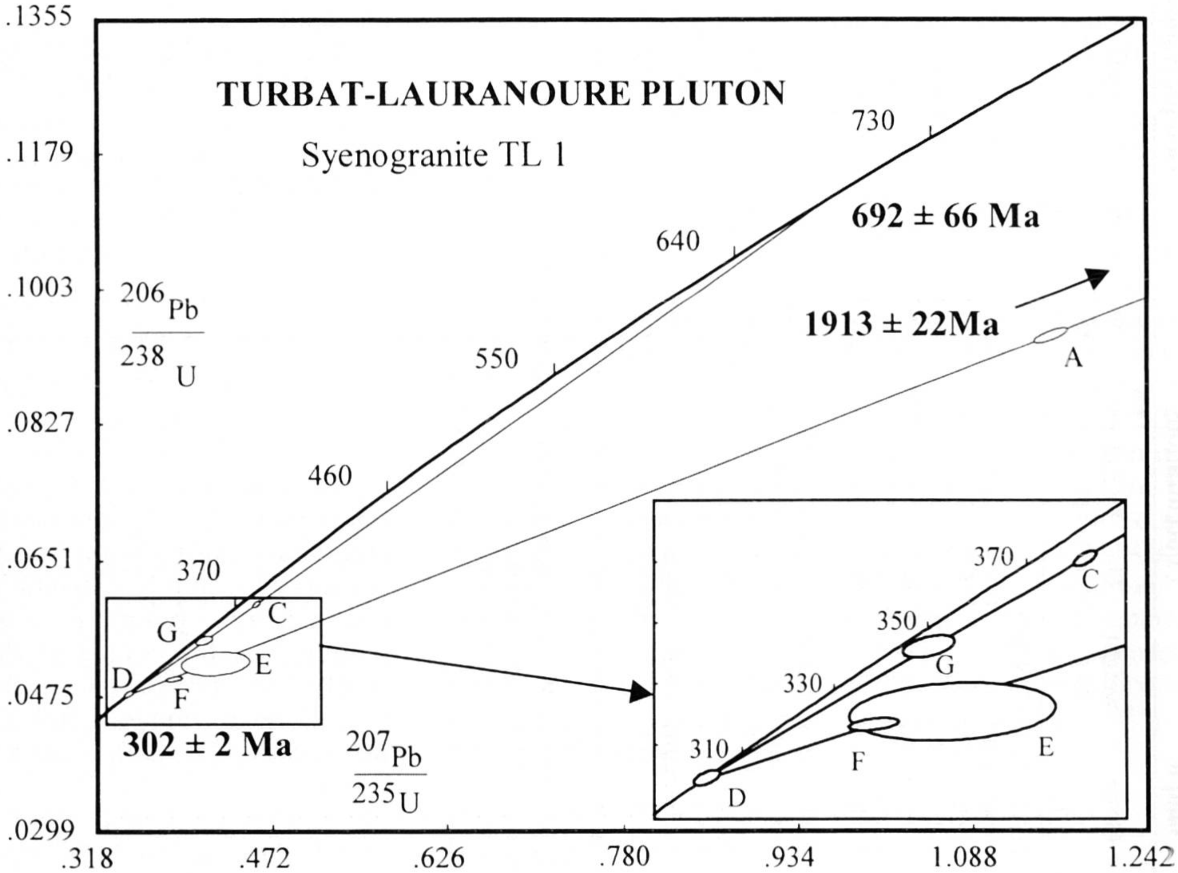

Fig. 6 U–Pb concordia diagram for zircons from the Turbat-Lauranoure pluton (sample TL 1).

evidence of inherited lead (Tab. 2). Fraction E, with a high common lead content, was not considered for further calculation. Two alignments are observed in the Concordia diagram (Fig. 6). The first, with fractions D, C and G, defines a regression with an upper intercept at 692 ± 66 Ma and a lower intercept at 302 ±11 Ma (68% probability of fit). The second alignment (D, F, A) gives an upper intercept at 1913 ± 22 Ma and a lower intercept at 302 ± 2 Ma (95% probability of fit). Fraction E falls on this regression line. This sample thus shows evidence of Cadomian and Lower Proterozoic inheritance. In relation with the concordant position of fraction D, and with the two linear alignments obtained, a weighted average mean age of 302 ± 2 Ma, i.e. Stephanian (ODIN, 1994), can be assigned to the crystallization of the Turbat-Lauranoure pluton.

4. Conclusion

Apart from an unpublished age of 312 ± 7 Ma ascribed to the magnesian Combeynot granite (Fig. 2) by CANNIC et al. (1998; see also DEBON and LEMMET, 1999), this study provides the first reliable and reasonably precise U–Pb zircon ages on plutonic rocks from the Pelvoux massif, which is of major interest for the reconstitution of the magmatic evolution of the Variscan belt in the External Crystalline Massifs of the Alps.

The Late Variscan plutonic bodies, in the ECM as a whole, can be divided into an early (Viséan; ca. 330–340 Ma) high-*mg*-number suite, and a later (mainly Stephanian; ca. 295–305 Ma) low-*mg*-number suite (DEBON and LEMMET, 1999). This two-fold partition is, in all respects (typology, age), quite comparable with that defined in the Pelvoux massif. It is likely that the Late Variscan plutonic activity in the latter was comparable to that evidenced elsewhere in the ECM, viz. a discontinuous process comprising two major events separated by a gap of up to some 40 Ma. The first event would include most of the magnesian plutons, followed by a second event with more iron-rich, magnesian-ferriferous plutons.

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