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Early Permian magmatism in Briançonnais terranes: Truzzo granite and Roffna rhyolite (eastern Penninic nappes, Swiss and Italian Alps)

by Didier Marquer¹, Nathalie Challandes¹ and Urs Schaltegger²

Abstract

In the internal part of the Central Alps, heterogeneous Tertiary deformation of basement nappes led to large weakly deformed domains. This is where studies of pre-Alpine magmatism can be performed. The Truzzo granite and the Roffna rhyolite, which are part of the Penninic Tambo and Suretta nappes, respectively, are shallow-seated intrusions in old polycyclic basement rocks. Petrographical, geochemical and isotopic similarities suggest that Truzzo granite and Roffna rhyolite are part of the same post-orogenic magmatic event. Furthermore, U-Pb systematics on single zircon give a $^{206}\text{Pb}/^{238}\text{U}$ age of 268.0 ± 0.4 Ma for the Truzzo granite and a $^{206}\text{Pb}/^{238}\text{U}$ age of 268.3 ± 0.6 Ma for the Roffna rhyolite. These intrusions were derived from the mixing of crustal and mantle sources, as indicated by the isotopic results and the occurrence of different types of xenoliths.

The proximity of these intrusions becomes apparent in an Early Permian reconstruction of the Briançonnais terrane. They might have had their origin in upwelling asthenospheric mantle, related to lithospheric thinning at the site of the future Jurassic rifting and opening of the Liguro-Piemontais ocean.

Keywords: granites, U-Pb ages, zircons, Early Permian magmatism, Penninic nappes, Central Alps.

Introduction

Orogens normally comprise imbricated crystalline terranes which have to be integrated in pre-collisional paleogeographical reconstructions. The main problem for studying such strongly deformed basement is to distinguish between structures that pre-date the most recent orogenic cycle, in order to get information about pre-collisional structures, petrology and geochemistry of these rocks. Very heterogeneous deformation, in some places within the Alpine nappe pile, has allowed the preservation of metamorphic and magmatic relics (MARQUER, 1991; BIINO et al., 1997), which can be used to reconstruct the lithological composition, geochemistry and geochronology of pre-Alpine basement and intrusive rocks. In the case of intrusive rocks, it is necessary to determine primary mineralogical compositions, magmatic textures and geochemical characteristics in order to constrain their geodynamic setting in the earlier, pre-Alpine (Variscan) orogenic cycle.

The Swiss Alps are usually divided into three broad domains from north to south: (i) an external, Helvetic domain, (ii) an internal part, the Penninic zone and (iii) the South-Alpine and Austroalpine units, the latter exposed on top of the Alpine edifice (COWARD and DIETRICH, 1989). Basement rocks in the Helvetic domain and the South- and Austro-Alpine units did not undergo strong penetrative Alpine deformation, facilitating the petrological and geochemical studies of pre-Alpine structures and magmatism in these areas. On the contrary, the Penninic zone represents the strongly deformed internal parts of the Alpine mountain belt, the result of collision between the European plate in the north and the Adriatic plate in the south, with a series of microcontinents in between, one of them being the Brianconnais terrane. The Penninic domain consists of imbricate stacks of sedimentary cover and basement slices with a complex nappe geometry as the result of both thrust tectonics and post-nappe refolding (Fig. 1) (SCHMID et al., 1990; SCHREURS, 1993;

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PFIFFNER et al., 1990; MARQUER et al., 1996). Our investigations focus on the basement rocks of the upper Penninic Tambo and Suretta nappes in the eastern internal Swiss Alps, which belong to the Briançonnais paleogeographic domain (Fig. 1) (TRUMPY, 1980). The tectonic framework of the frontal part of the Suretta nappe and of the Tambo nappe has been recently described by MAR-QUER et al. (1996) and BAUDIN et al. (1993) (Fig. 2). One of the main results from these recent studies is that Tertiary deformation of the basement rocks was strongly heterogeneous, leading to the preservation of undeformed lenticular domains surrounded by mylonites at a broad range of scales. Petrological and geochronological studies of pre-Alpine intrusives can therefore be concentrated on these areas of weak Alpine deformation.

Two granitoid bodies, the mostly effusive to subvolcanic Roffna rhyolite in the northern part of the Suretta nappe (GRÜNENFELDER, 1956;

MARQUER et al., 1996) and the Truzzo granite in the southern part of the Tambo nappe (WEBER, 1966; MARQUER, 1991) were investigated (Fig. 2). Previously published Variscan ages for these granitoids show strong discrepancies: for the Truzzo granite, a 339 ± 70 Ma U-Pb age for zircon (GRÜ-NENFELDER in WEBER, 1966) and a 293 ± 14 Ma Rb-Sr whole rock age (GULSON, 1973) were measured. For the Roffna rhyolite an intrusion age around 350 Ma (U-Pb zircon) was suggested by HANSON et al. (1969). Based on new mapping, petrological and isotopic studies, we propose a close genetic link between these two intrusives. Precise intrusion ages and geochemical characteristics permit their integration in reconstructions of the Pre-Alpine setting of the Brianconnais terrane. The role and significance of this type of magmatic activity will be discussed with respect to late and post-Variscan tectonics prior to the opening of the Tethys ocean.

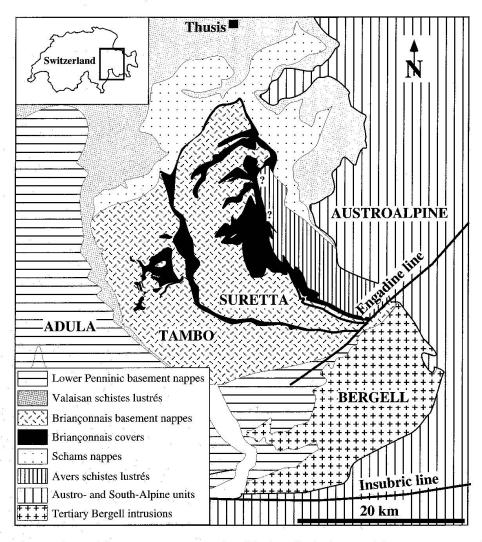


Fig. 1 Location of the Tambo and Suretta nappes on a simplified geological map of the eastern part of the Central Alps.

Geological setting

The Tambo and Suretta nappes form two ca. 3.5 km thick crystalline slivers, mainly composed of old crystalline basement (Fig. 2). The polymetamorphic basement is essentially composed of metapelites and metagreywackes including lenses of mafic rocks (amphibolites), porphyritic orthogneisses and local migmatites (STAUB, 1916: WILHELM, 1921; GANSSER, 1937; GRÜNENFELDER, 1956; Zurflüh, 1961; Strohbach, 1965; Schae-REN, 1974). The study of metamorphism and deformation in the mafic lenses has led to the recognition of two distinct metamorphic events, a pre-Alpine HP-HT and an Alpine HP-LT one (BIINO et al., 1997; Nussbaum et al., 1998). In the Suretta nappe, a late Variscan subvolcanic intrusion is located in the frontal part, the so-called Roffna rhyolite (Roffna porphyry; GRÜNEN-FELDER, 1956; STREIFF et al., 1976; MARQUER et al., 1996; Fig. 2). The Tambo basement was intruded by the Truzzo granite in the south (WEBER, 1966; Blanc, 1965; Gulson, 1973; Marquer, 1991) (Fig. 2).

The autochthonous cover of the Tambo and Suretta nappes is composed of a volcanoclastic and a reduced carbonate series. The Permo-Triassic volcanoclastic cover (BAUDIN et al., 1993), including some effusive metatuffs in the Splügen area, lies unconformably on the basement of both the Tambo and the Suretta nappes (Fig. 2). Conglomerates at the base of the stratigraphic pile show lithological similarities to the classic "Verrucano" facies and pass progressively into more and more quartzitic formations. The volcanoclastic succession is covered by a pure quartzite layer, only present in the Suretta nappe and probably Scythian in age. The Mesozoic calcareous cover above this volcanic and epiclastic series directly overlies the basement rocks in a few places (BAUDIN et al., 1995). This mesozoic cover shows sedimentary sequences typical of the Brianconnais terranes (BAUDIN et al., 1995).

Alpine deformations led to the development of a complex pattern of shear zones that isolate lenses of weakly deformed basement rocks (Weber, 1966; Marquer, 1991; Baudin et al., 1993; Marquer et al., 1994, 1996). Only the two first main deformations were responsible for large scale shear zones that show substantial petrological and geochemical modification of the initial rocks (Marquer and Peucat, 1994; Challander, 1996). Chemical mass transfer related to Alpine heterogeneous deformation have been recorded in high-strain zones but only subordinate chemical changes have occurred in weakly deformed rocks (Marquer, 1989; Marquer and

PEUCAT, 1994). To avoid textural and chemical perturbations related to Alpine deformations in high-strain zones, only samples from weakly deformed zones were collected for the following study.

Petrology and intrusive structures of granitoids

TRUZZO GRANITE

The Truzzo granite is a E-W-elongated intrusive body located in the southern part of the Tambo nappe (Fig. 2). The granite cross-cuts different lithologic units such as older orthogneisses, banded migmatites and amphibolites, which were previously deformed under high grade conditions (Fig. 2). Primary magmatic contacts with the surrounding gneissic rocks are sub-vertical and show characteristics of syn-intrusive deformation of the granitoid, such as preferred orientation of large K-feldspar porphyroclasts and enclaves (MAR-QUER, 1991). Mafic magmatic enclaves and basement xenoliths (orthogneisses, migmatitic gneisses) are present in the whole body of the porphyritic granite as well as in one granite sample (HTC 7) from the southern contact with migmatitic rocks, where some restitic enclaves occur. The granite underwent strong Alpine deformation in some places (Blanc, 1965; Weber, 1966). In weakly deformed domains, the granite appears as an originally isotropic and homogeneous body of porphyritic granite with large Kfeldspar porphyroclasts, oligoclase, brown biotite and primary muscovite.

The top of the granite intrusion is mainly composed of alternating layers of a K-feldspar bearing porphyritic facies and an isogranular leucocratic facies. The layering probably corresponds to intrusions of leucocratic granite sills into the porphyritic granite. The main body of leucocratic granite is of small size (1 km²) and is located in the core of the porphyritic granite (tunnel of Cimaganda oil pipeline, San Bernardino). This leucocratic granite is K-feldspar rich and contains primary muscovite and scarce pink garnet. Isolated small stocks of Truzzo granite occur within the banded migmatite gneiss and amphibolite in the southern part of the Tambo nappe (Piz Pizasc, Piz Matter, Val di Liro; Fig. 2). The granite is commonly overlain by a thin sequence of polymetamorphic basement rocks, particularly in the southeastern part of the area, close to the Permo-Triassic cover. The Truzzo granite is interpreted as an intrusion with several apophyses emplaced at shallow depth in the upper crust (WEBER, 1966).

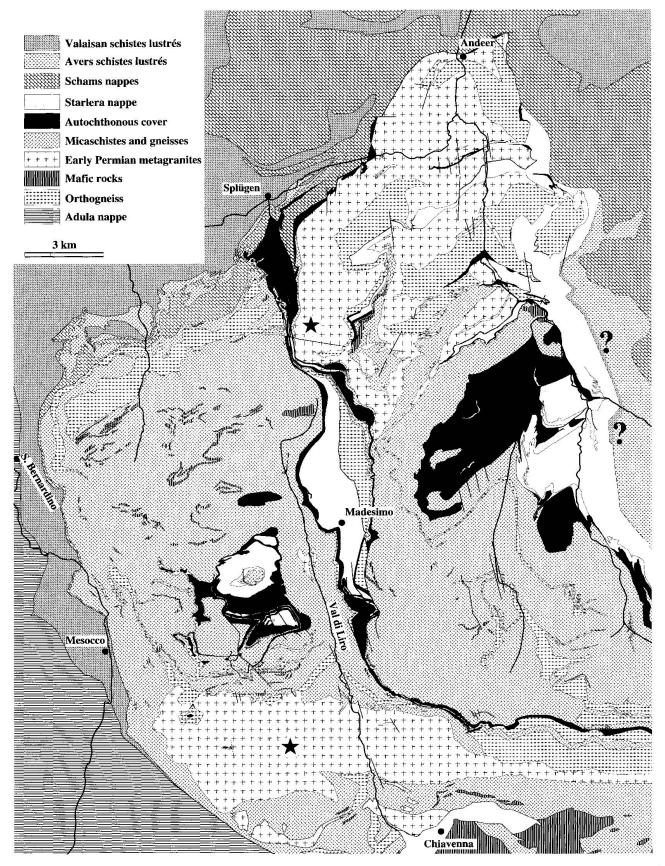
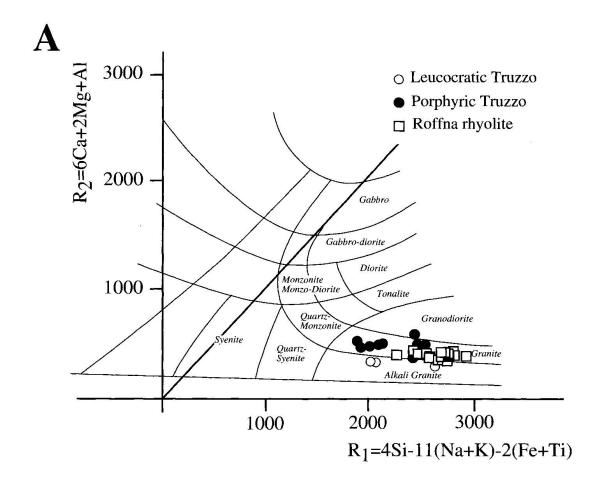


Fig. 2 Geological map of the Tambo and Suretta nappes. Geological boundaries of the Valais schistes lustrés and Schams nappes are from Schreurs (1993). The contact between Avers – autochthonous cover of Suretta is not well-defined on this map (question marks). Asterisks correspond to the location of U–Pb analysed samples in the Truzzo granite and Roffna rhyolite (Tab. 3).

ROFFNA RHYOLITE

In the frontal part of the Suretta nappe, GRÜNEN-FELDER (1956) described a large body of crystalline rocks he termed "Roffnaporphyr". Recent mapping and petrographic studies resulted in a better separation of the Roffna rhyolite from older orthogneisses in this area (Fig. 2). The Roffna rhyolite has been interpreted as a high-level intrusion of subvolcanic nature (GRÜNENFELDER, 1956; MILNES and SCHMUTZ, 1978), or alternatively, suggested to be a caldera filling at the top of the nappe (DALLA TORRE, 1991). The amphibolites, banded migmatites and old orthogneisses are



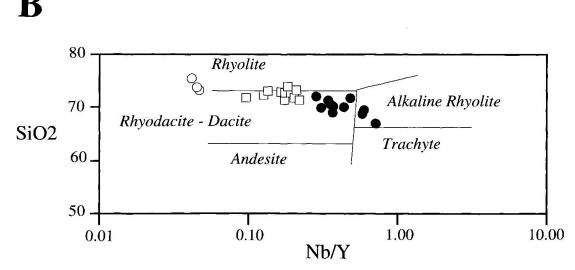


Fig. 3 Nomenclature of the Truzzo and Roffna intrusive rocks. A: R1-R2 diagram after de LA ROCHe et al. (1980). B: SiO₂/(Nb/Y) after WINCHESTER and FLOYD (1977).

clearly cross-cut by the Roffna rhyolite at several locations at the base and center of the Suretta nappe (Fig. 2). These intrusive relationships between the foliated basement and the Roffna rhyolite demonstrate that the basement rocks were strongly deformed under high grade metamorphic conditions before Lower Permian (Nuss-BAUM et al., 1998). The Roffna rhyolite hosts abundant enclaves of three main types: xenoliths of various basement gneisses, leucocratic felsic enclaves and a few small mafic microgranular enclaves. The latter contain corroded quartz grains originating from the rhyolite, which argues for magmatic mingling between acid and basic magmas during emplacement. All enclaves show a distinct preferred orientation of magmatic origin. The formation of K-feldspar phenocrysts along contacts and the partial assimilation of orthogneiss xenoliths suggest high-temperature emplacement of the rhyolite at upper crustal levels. At the base of the frontal part of the Suretta nappe (Splügen pass area), the monocyclic volcanosedimentary cover is mainly composed of metatuffs and cinerites strongly affected by Alpine deformation (autochthonous cover, Fig. 2). In weakly deformed samples, the Roffna rhyolite contains large phenocrysts of partly bi-pyramidal or corroded quartz, microcline, oligoclase, brown biotite and rare pink garnet within a homogeneous microcrystalline matrix. Normally, the fine-grained matrix had recrystallised during Alpine metamorphism. In some places, close to the contact with the old orthogneisses or around xenoliths of old orthogneisses, the Roffna rhyolite shows an enrichment of large K-feldspar phenocrysts. In that case, the old orthogneissic xenoliths show diffusive boundaries and partial assimilation which might suggest a high-temperature emplacement of the rhyolite at upper crustal levels.

Geochemistry

TRUZZO GRANITE

The samples of the porphyritic granite lie in the granite field of the R1-R2 diagram of de LA ROCHE et al. (1980; Fig. 3A, Black dots). The leucocratic garnet-muscovite-bearing granite, on the other hand, is located in the alkali granite field of the same diagram (Fig. 3A, white dots), while it plots in the rhyolite field in a SiO₂–Nb/Y diagram (WINCHESTER and FLOYD, 1977) with very low Nb/Y ratios (Fig. 3B, white dots). The alkaline tendency of this leucocratic granite is probably due to the low amounts of CaO (Fig. 3A). The low con-

centrations of CaO, Fe₂O₃, MgO, TiO₂, the minor element chemistry, and the occurrence of either acmite or normative corundum in the CIPW norm are responsible for the peralkaline or peraluminous affinity, respectively, of these granitic rocks (Fig. 4, white and black dots). This position, as well as the scatter along the peralkaline-peraluminous transition, is due to slight variations of the (Na + K)/Al ratio and is typical of low-calcium granites.

ROFFNA RHYOLITE

The Roffna rhyolite samples plot in the granite field of the R1-R2 diagram (Fig. 3A, white squares) and along the boundary between rhyolite and rhyodacite fields in the SiO₂-Nb/Y diagram (Fig. 3B, white squares). All samples correspond to peraluminous granite and are located in the field of continental collision granites (CCG) in figure 4. They show a homogeneous composition with SiO₂ concentrations ranging between 71 and 74% (Fig. 5). Despite the slight scattering of some mobile elements, probably related to Alpine deformation (mainly for K2O, Na2O, CaO, Ba, Rb and Sr), the Roffna samples show a similar magmatic trend for major and minor elements in Harker diagrams as those of the Truzzo samples (Fig. 5). The Roffna samples define a compositional range that seems to be part of the trend between leucocratic and porphyric granite of the Truzzo intrusion (Fig. 5). Their compositional variation in a K_2O/SiO_2 diagram emphasises the affinity with classical alkaline or high-K calc-alkaline suites (Fig. 5).

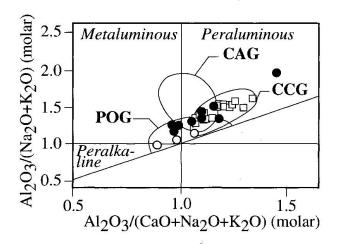


Fig. 4 Distribution of the Truzzo and Roffna samples with respect to the Shand's index modified after Maniar and Piccoli (1989). CAG: continental arc granitoids; CCG: continental collision granitoids; POG: postorogenic granitoids. Same symbols as in figure 3.

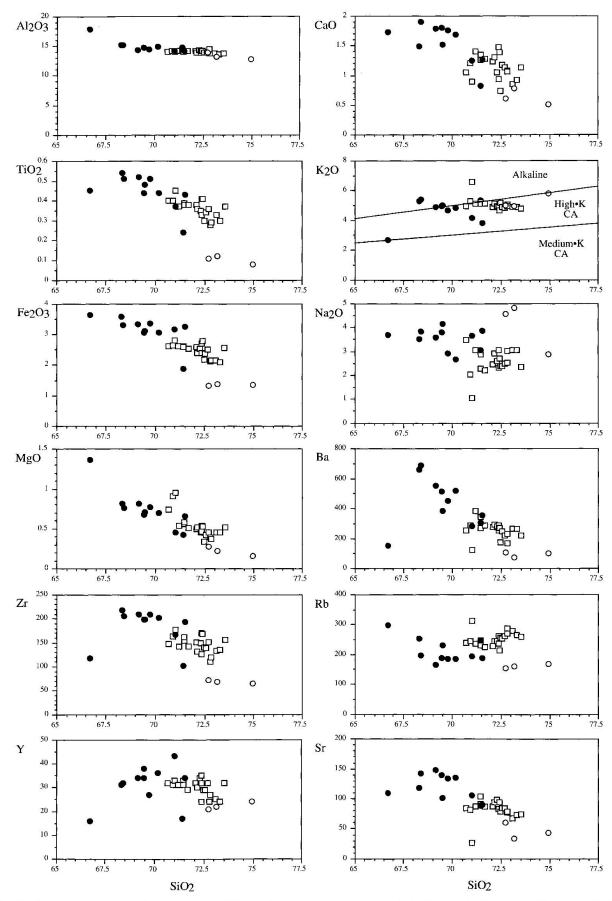


Fig. 5 Some major and minor elements illustrating the magmatic trends in Harker's diagrams. Same symbols as in figure 3. The high-K and medium-K fields are defined after Peccerillo and Taylor (1976).

Tab. 1 Chemical analyses of the Truzzo granite and the Roffna rhyolite. Same symbols as in figure 3. X and Y correspond to the Swiss topographic coordinates.

	RSZ3c	73.08 0.33 13.75		2.16	0.04	0.45	0.85	3.05	0.16	18.0	29.66	277	19	14	133	25		16	8	*	42	S	S		22	18			265			746.00
	RSZ2a	72.79 0.28 13.75	0.01	2.13	0.03	0.39	1.08	3.01	5.04 0.14	0.92	99.35	271	11	es	111	74		9	53	13	₽	0	_	4	7	18	45	70	231	23	0	746.00 152.25
	RSZ1z	73.29 0.30 13.54		2.10	0.04	0.45	0.92	3.04	0.4 0.16	0.79	99.53	264	57	13	135	24		14	31		39	4	4		14	21			267			746.00 152.25
	RSZ1a	72.36 0.33 13.90	1.06	2.41	0.03	0.47	0.94	3.04	0.4 0.40 0.44	1.14	99.53	261	83	9	127	24		10	17	15	45	0	2	37	∞	21	48	18	255	23	0	746.00 152.25
	RC46	71.44 0.39 14.14	1.28	2.61	0.03	0.56	1.26	2.89	5.5 6.13	1.19	97.66	246	35	S	154	33	ιū	П	23	14	43	0	n	78	H	22	28	23	346	30	0	748.10 158.30
	RC44	70.67 0.40 14.01	1.19	2.62	0.04	0.74	1.05	3.49	4.9 <i>/</i> 0.13	1.90	88.66	240	8	,	148	32	0	10	18	14	45	0	2	27	10	53	69	24	253	8	99	748.90 158.50
	RC39	72.14 0.36 13.84	0.90	3.40 9.40	0.04	0.52	1.30	2.90	5.09 0.14	1.02	99.65	244	94	4	131	30		10	19	14	41	0	~	35	∞	22	27	79	292	33	0	746.25 152.10
	RC38	71.18 0.37 14.11	0.85	2.63	0.04	0.54	1.40	3.06	5.13 0.13	0.97	99.38	236	%	9	142	31	\leftarrow	Ξ	31	13	41	0		33	10	56	9	24	382	31	47	746.30 151.85
	RC33	73.52 0.37 13.71	1.40	2.57	0.05	0.52	1.14	2.35	6.75 0.16	1.07	100.09	259	75	9	157	32	9	15	30	18	47	0	9	4	12	21	23	23	220	21	24	753.15 157.50
	RC32	70.90 0.40 14.18	0.85	2.64 2.64	0.03	0.91	1.20	2.02	5.2/ 0.14	1.72	99,23	243	87	7	164	31	m	15	74	17	9	0	4	35	∞	56	9	23	586	18	153	751.70 160.20
	RC31	72.39 0.41 14.10	0.28	2.79	0.04	0.53	1.39	2.70	4.6/ 0.15	1.18	100.10	214	95	7	169	35	S	16	34	18	4	0	4	43	Π	24	3	23	271	23	139	751.65
	RC30	72.07 0.38 14.11	0.92	2.59	0.04	0.50	1.24	2.44	4.88 0.14	1.27	99.49	226	87	4	151	32	en	13	28	17	45	0	es	32	6	23	25	77	274	21	61	750.40 159.10
	RC29	71.68 0.38 14.10	0.75	2.55	0.05	0.51	1.27	2.20	5.13 0.15	1.23	70.66	224	88	9	142	53	4	=	31	18	45	0	4	9	14	21	54	21	288	20	51	750.15 159.15
	RC28	72.82 0.29 14.37	0.49	2.14	0.04	0.37	1.07	2.52	6.50 0.17	1.15	99.74	286	79	9	119	27	4	10	56	18	39	0	4	36	4	16	42	14	170	14	45	749.55 159.45
	RC24	71.00 0.45 14.01	1.57	2.82	0.03	0.95	0.00	1.03	6.56 0.15	2.22	100.00	311	27	9	178	33	7	19	19	18	31	0	9	8	11	36	29	28	124	56	72	753.97 163.75
	RC20	72.36 0.41 14.09	0.59	2.70	0.04	0.54	1.47	2.31	4.95 0.14	1.27	100.07	237	83	9	170	32	9	15	31	18	46	0	S	32	13	21	29	21	290	27	61	752.75 161.50
	RC19	71.45 0.38 14.00	0.46	2.58	0.04	0.58	1.34	2.29	5.12 0.13	1.45	99.15	231	104	n	161	31	S	14	30	17	42	0	4	34	∞	22	53	16	272	23	77	752.65 161.65
	RC9	72.68 0.36 13.90	0.58	2.51	0.04	0.45	1.14	2.49	4.86 0.15	171	09.66	261	82	9	151	32	S	14	27	18	47	0	9	37	10	23	\$	22	218	19	27	753.15 157.50
	RC5	72.47 0.30 14.14	0.71	2.19	0.03	0.34	0.74	2.40	5.16 0.15	1.25	99.02	256	79	4	141	29	7	12	23	18	35	0	2	36	S	17	49	19	177	21	41	745.90 152.25
	RC4	72.28 0.35 14.28	0.67	2.55	0.04	0.46	1.05	2.59	4.9/ 0.15	1.08	19:66	244	86	7	150	34	4	15	18	18	9	0	9	36	6	25	27	25	284	53	46	745.85 152.30
	RC3	72.55 0.34 13.89	0.23	2.37	0.04	0.42	1.18	2.40	4.88 0.15	1.03	99.04	252	85	5	139	29	4	12	29	17	40	0	2	8	12	19	57	23	246	27	48	X 745.85 Y 152.35
Symboles	Samples	SiO ₂ TiO ₂ Al ₂ O ₃	Fe ₂ O ₃	FeO.*	MnO	MgO	CaO	Na ₂ O	P.O.	H ₂ O	Sum:	Rb	Sr	Np	Zr	Y	Ω	Th	Pb	g Z	Zu	<u>ನ</u>	Z_	දු	ර්	Λ	ප	PN	Ba	La	S	Coordinate X Coordinate Y

Tab. I (cont.).

Samples HTCS TCJa HTCS HTCS HTCS HTCS HTCS TCJa TCJa HTCS TCJa	Symboles	0	0	0	•	•	•	•	•	•	•	•	•	•	•
7494 7314 7271 7101 68.40 6915 70.18 71.42 66.71 71.25 694 6935 691 70.18 71.42 66.71 71.25 694 6934	Samples	HTC5	TC1a	TC2a	HTC1	НТС2	нтсз	HTC4	нтс6	HTC7	TC3a	TC4a	TC5a	TC6a	TC7a
0.08 0.12 0.41 0.57 0.51 0.52 0.44 0.54 0.44 0.64 1.58 1.2.80 1.315 1.347 1.450 1.45 0.39 0.82 2.15 1.49 1.48 1.58 0.44 0.54 0.64 1.58 0.69 0.90 0.90 0.90 0.82 2.15 0.40 0.83 0.89 0.82 2.15 1.40 1.48 0.89 0.82 0.15 0.90 0.82 0.15 <	SiO ₂	74.94	73.14	72.71	71.01	68.40	69.15	70.18	71.42	66.71	71.52	84.69	69.45	68.32	69.75
1280 3115 3184 14.17 15.12 14.29 14.85 14.69 14.70 14.68 15.08 1280 0.41 0.47 2.75 2.29 0.69 14.6 1.92 14.70 14.75 14.70 14.68 15.08 1280 0.41 0.47 2.75 2.29 0.69 14.6 1.94 2.15 0.10 2.34 2.00 2.54 1280 0.06 0.06 0.06 0.07 0.04 0.04 0.03 0.09 0.05 0.05 0.05 0.05 0.16 0.06 0.06 0.06 0.06 0.04 0.04 0.03 0.09 0.05 0.05 0.05 0.05 0.16 0.05 0.06 0.05 0.04 0.04 0.03 0.04 0.05 0.05 0.05 0.05 0.05 0.17 0.13 0.12 0.13 0.18 0.18 0.13 0.28 3.06 3.06 3.06 0.05 0.17 0.08 0.17 0.13 0.12 0.13 0.18 0.18 0.13 0.28 3.06 3.06 3.05 3.15 0.18 0.19 0.15 0.13 0.18 0.18 0.13 0.28 0.20 0.09 0.17 0.17 0.13 0.19 0.10 0.12 0.13 0.18 0.18 0.12 0.12 0.12 0.13 0.12 0.14 0.10 0.10 0.12 0.13 0.14 0.18 0.15 0.09 0.17 0.17 0.13 0.10 0.10 0.10 0.10 0.09 0.09 0.09 0.09 0.09 0.09 0.09 0.09 0.09 0.10 0.10 0.10 0.10 0.09 0.09 0.09 0.09 0.09 0.09 0.10 0.10 0.10 0.10 0.10 0.10 0.09 0.09 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.09 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10	TiO ₂	80.0	0.12	0.11	0.37	0.51	0.52	0.4	0.24	0.45	0.43	0.48	0.44	0.54	0.51
0.90	Al_2O_3	12.80	13.15	13.84	14.17	15.12	14.29	14.85	14.69	17.82	14.22	14.70	14.68	15.08	14.43
0,41 0,87 0,76 0,37 0,91 2,46 1,46 1,34 2,55 1,01 2,34 2,00 1,34 2,55 1,01 2,34 2,00 1,34 3,46 3,46 1,46 1,37 3,46 3,46 3,46 3,46 3,46 3,46 3,46 3,46 3,46 3,46 3,46 3,46 3,46 3,46 3,47 1,48 3,48 4,66 1,71 1,69 1,69 1,71 1,69 1,71 1,69 1,71 1,71 1,71 3,41 4,89 4,86 5,36 2,71 3,83 3,16 1,73 1,71 1,72 1,73 <th< td=""><td>Fe_2O_3</td><td>0.90</td><td>0.41</td><td>0.47</td><td>2.75</td><td>2.29</td><td>69.0</td><td>1.45</td><td>0.39</td><td>0.82</td><td>2.15</td><td>0.53</td><td>0.85</td><td>0.78</td><td>1.63</td></th<>	Fe_2O_3	0.90	0.41	0.47	2.75	2.29	69.0	1.45	0.39	0.82	2.15	0.53	0.85	0.78	1.63
1.36 1.38 1.31 3.16 3.30 3.35 3.47 1.88 3.45 3.27 3.15 3.47 3.60 0.166 0.026 0.026 0.04 0.04 0.04 0.04 0.03 0.05 0.05 0.05 0.05 0.166 0.125 0.04 0.04 0.04 0.04 0.04 0.05 0.05 0.05 0.05 0.167 0.13 0.14 0.15 0.19 0.19 0.05 1.25 1.26 1.51 1.80 1.49 0.28 4.82 4.57 3.64 3.84 3.60 2.68 3.86 3.88 3.88 4.16 3.78 3.51 0.29 0.13 0.13 0.13 0.18 0.13 0.28 0.09 0.17 0.17 0.13 0.20 0.10 0.12 0.13 0.18 0.18 0.13 0.28 0.09 0.00 0.17 0.17 0.13 0.20 0.10 0.12 0.13 0.18 0.18 0.15 0.20 0.00 0.00 0.17 0.17 0.13 0.20 0.10 0.12 0.13 0.18 0.18 0.15 0.20 0.00 0.00 0.17 0.17 0.13 0.20 0.10 0.12 0.14 0.18 0.18 0.25 0.00 0.00 0.00 0.10 0.20 0.40 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.40 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.40 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.40 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.40 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.40 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.40 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.40 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.40 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.40 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.40 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.40 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20	FeO .	0.41	0.87	0.76	0.37	0.91	2.40	1.46	1.34	2.55	1.01	2.34	2.00	2.54	1.56
0.06 0.06 0.06 0.06 0.07 0.04 0.04 0.03 0.05 0.06 0.07 0.04 0.04 0.03 0.05 0.05 0.04 0.04 0.04 0.03 0.05 0.05 0.04 0.04 0.13 0.05 0.07 0.04 0.70 0.04 1.73 0.06 0.07 0.01 1.25 0.05 0.04 1.09 0.22 1.73 0.06 0.01 1.09 1.49 4.17 5.41 4.89 4.86 5.36 2.00 0.09 0.01 0.01 0.01 0.01 0.01 0.03 0.01 0.01 0.03 0.01 0.03 0.05 0.05 0.02 0.03 <th< td=""><td>Fe,O,*</td><td>1.36</td><td>1.38</td><td>1.31</td><td>3.16</td><td>3.30</td><td>3.35</td><td>3.07</td><td>1.88</td><td>3.65</td><td>3.27</td><td>3.13</td><td>3.07</td><td>3.60</td><td>3.36</td></th<>	Fe,O,*	1.36	1.38	1.31	3.16	3.30	3.35	3.07	1.88	3.65	3.27	3.13	3.07	3.60	3.36
0.16 0.02 0.28 0.46 0.76 0.81 0.70 0.42 1.37 0.66 0.71 0.68 0.82 0.82 0.78 0.78 0.61 1.25 1.39 1.79 1.69 0.82 1.37 1.56 1.51 1.89 1.49 0.82 0.78 0.61 1.25 1.39 1.54 1.89 0.86 0.86 0.86 0.88 1.65 1.51 1.89 1.49 0.12 0.13 0.12 0.13 0.18 0.18 0.13 0.28 0.26 0.09 0.17 0.17 0.17 0.13 0.12 0.13 0.18 0.18 0.13 0.28 0.29 0.29 0.29 0.29 0.29 0.29 0.29 0.29	MnO	90.0	90:0	90:0	0.02	0.04	0.04	0.04	0.03	0.09	0.03	0.05	0.03	0.03	0.04
0.52 0.78 0.61 1.25 1.90 1.79 1.69 0.82 1.73 1.26 1.51 1.80 1.49 2.88 4.82 4.82 4.86 5.36 3.88 4.16 3.78 3.51 0.12 0.13 0.14 0.14 0.18 0.13 0.20 0.09 0.07 0.02 0.05 0.05 0.03 0.04 0.05<	MgO	0.16	0.22	0.28	0.46	0.76	0.81	0.70	0.42	1.37	99.0	0.71	99.0	0.82	0.77
2.88 4.82 4.57 3.64 3.84 3.60 2.68 3.06 3.68 3.88 4.16 3.78 3.51 5.78 4.94 4.99 4.17 5.41 4.89 1.36 0.28 2.71 3.88 5.16 4.92 5.29 0.12 0.12 0.13 0.13 0.13 0.29 1.09 0.39 1.00 0.99 0.09 0.99<	ÇaO CaO	0.52	0.78	0.61	1.25	1.90	1.79	1.69	0.82	1.73	1.26	1.51	1.80	1.49	1.76
5.78 4,94 4,99 4,17 5,41 4,89 4,86 5.36 2,71 3.83 5.03 4,92 5.17 5.41 4,89 4,86 5.36 2,71 3.83 5.03 4,92 5.41 6,18 0.13 0.12 0.13 0.18 0.13 0.18 0.19 0.09 0.17 0.17 0.13 040 1.02 1.02 0.13 0.18 0.18 0.20 0.09 0.17 0.17 0.17 0.13 0.03 169 1.61 1.62 1.85 1.96 1.85 2.94 2.97 1.98 1.94 1.96 65 6.8 7.2 1.67 2.06 2.10 2.02 1.01 1.02 1.04 1.04 1.19	Na,O	2.88	4.82	4.57	3.64	3.84	3.60	2.68	3.06	3.68	3.88	4.16	3.78	3.51	2.91
012 0.13 0.12 0.13 0.18 0.18 0.13 0.18 0.19 0.17 0.17 0.13 040 1.02 1.23 0.65 0.60 0.89 0.59 1.20 1.88 0.72 0.67 0.67 0.67 0.67 0.67 0.69 0.59 1.20 1.88 0.72 0.67	K,Ö	5.78	4.94	4.99	4.17	5.41	4.89	4.86	5.36	2.71	3.83	5.03	4.92	5.29	4.67
040 1,02 1,23 0.65 0,60 0,89 0,59 120 1,88 0,72 0,62 0,63 1,04 99,05 99,05 99,25 99,07 99,25 100,01 99,80 99,78 99,43 99,77 44 34 161 166 143 148 135 89 110 90 90,78 99,43 99,77 44 34 61 166 143 148 135 89 110 90 90,78 99,43 99,77 65 68 72 166 143 148 135 89 110 90 <t< td=""><td><u>7.</u> P,0,</td><td>0.12</td><td>0.13</td><td>0.12</td><td>0.13</td><td>0.18</td><td>0.18</td><td>0.13</td><td>0.28</td><td>0.20</td><td>0.09</td><td>0.17</td><td>0.17</td><td>0.33</td><td>0.14</td></t<>	<u>7.</u> P,0,	0.12	0.13	0.12	0.13	0.18	0.18	0.13	0.28	0.20	0.09	0.17	0.17	0.33	0.14
99.05 99.66 99.75 98.96 99.25 99.07 99.05 100.01 99.05 99.78 99.49 99.25 99.07 99.25 100.01 99.08 99.78 99.43 99.77 99.73 189 231 189 254 44 34 61 106 143 146 185 246 297 189 231 199 199 199 199 254 140 117 193 198 119 199 254 131 199 199 254 131 199 199 254 131 199 199 254 131 199 199 199 254 131 199 199 254 131 199 199 254 131 199 199 254 31 199 199 199 254 31 199 199 199 199 199 199 199 199 199 199 199 199 199	H ₂ O	0.40	1.02	1.23	0.65	09.0	0.89	0.59	1.20	1.88	0.72	0.62	0.63	1.04	99.0
169 161 153 194 196 166 185 246 297 189 231 189 254 44 34 61 106 143 148 135 89 110 90 102 140 119 65 68 72 167 206 210 202 101 117 193 198 139 131 1	Sum:	99.05	99.66	99.75	98.99	96.66	99.25	10.66	99.25	100.01	08.66	82.66	99.43	71.66	98.83
44 34 61 106 143 148 135 89 110 90 102 140 119 1 1 1 15 12 21 13 5 12 17 12 13 19 19 18 19 119 19 18 19 119 19 18 19 119 19 18 19 11 19 11 19 11 19 11 19 18 <	Rb	169	161	153	194	196	166	185	246	297	189	231	189	254	185
1 1 1 15 12 21 13 5 12 17 12 13 19 13 19 198 218 218 218 20 101 117 193 198 198 218 218 14 32 34 36 17 16 34 38 34 31	Sr	4	34	61	106	143	148	135	68	110	96	102	140	119	134
65 68 72 167 206 210 202 101 117 193 198 198 218 24 22 21 43 32 34 36 17 16 34 38 34 31 1 2 2 2 18 16 16 16 17 0 0 12 17 16 17 16 18 38 34 31 40 32 28 18 34 37 36 49 18 29 20 18 19 18 19 22 14 16 15 13 75 48 61 59 53 123 105 50 50 6 5 5 5 9 5 9 7 18 18 14 12 44 44 45 38 42 1	ŝ	_	-	-	15	12	21	13	5	12	17	12	13	19	12
24 22 21 43 32 34 36 17 16 34 38 34 31 0 2 0 4 0 1 2 0 4 2 3 34 31 40 2 18 16 16 16 17 0 12 16 17 17 17 17 <t< td=""><td>Zr</td><td>65</td><td>89</td><td>72</td><td>167</td><td>206</td><td>210</td><td>202</td><td>101</td><td>117</td><td>193</td><td>198</td><td>198</td><td>218</td><td>210</td></t<>	Zr	65	89	72	167	206	210	202	101	117	193	198	198	218	210
0 2 0 4 0 1 2 0 4 2 3 1 2 1 2 2 18 16 16 17 0 12 16 17 16 15 40 32 28 18 34 37 36 43 24 25 33 36 34 14 16 15 21 16 20 19 18 29 20 18 19 22 17 16 15 21 16 20 19 18 29 20 18 36 34 17 15 13 75 48 61 59 53 105 90 9	Y	24	22	21	43	32	34	36	17	16	34	38	35	31	27
1 2 2 2 18 16 16 17 0 12 16 16 17 16 15 19 18 19 19 18 29 20 18 19 22 18 14 16 15 21 16 20 19 18 29 20 18 19 22 18 19 22 11 16 20 19 18 29 20 18 19 22 19 18 29 20 18 19 22 19 18 29 20 18 19 22 19 19 18 29 20 18 19 22 19 19 22 19 19 18 29 20 18 19 22 19 19 22 19 19 19 22 19 19 19 22 19 19 19 19 19 19 19 19 19 19 19 19 19	n,	0	2	0	4	0		7	0	4	7	S.	_	7	-
40 32 28 18 34 37 36 43 24 25 33 36 34 34 37 36 41 41 41 41 41 41 41 41 41 41 41 41 41	Th	\vdash	2	2	18	16	16	17	0	12	16	17	16	15	17
14 16 15 21 16 20 19 18 29 20 18 19 22 17 15 13 75 48 61 59 53 123 105 50 53 62 0 0 0 0 0 0 7 18 0 <td< td=""><td>Pb</td><td>9</td><td>32</td><td>28</td><td>18</td><td>34</td><td>37</td><td>36</td><td>43</td><td>24</td><td>25</td><td>33</td><td>36</td><td>34</td><td>0</td></td<>	Pb	9	32	28	18	34	37	36	43	24	25	33	36	34	0
17 15 13 15 48 61 59 53 123 105 50 53 62 0	Ga	14	16	15	21	16	20	19	18	53	70	18	19	22	∞
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Zn	17	15	13	75	48	19	29	23	123	105	20	53	62	25
6 5 5 5 9 5 9 10 9 18 8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	Cu	0	0	0	0	0	0	0	7	18	0	0	0	0	0
31 24 37 24 29 33 37 48 44 45 38 42 31 31 31 32 31 32 32 3	Z	9	5	S	6	S	6	10	6	18	%	6	6	6	0
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2 3 1 28 41 43 34 16 49 37 37 38 44 44 65 80 177 171 13 61 81 79 83 51 61 76 80 77 77 77 81 81 82 83 84 84 85 85 84 85 85 821 807 151 356 382 84 85 85 85 821 807 151 356 382 814 658 818 818 818 818 818 818 818 818 818 8	ර්	0	0	-	Π	10	15	14	12	43	13	П	13	12	0
10 17 13 61 81 79 83 51 61 76 80 77 77 77 77 18 100 74 108 285 688 555 521 307 151 356 382 514 658 514 658 515 521 307 151 356 382 514 658 514	Λ	7	m	-	28	41	43	34	16	49	37	37	38	4	33
3 5 7 34 37 31 41 18 22 36 43 42 35 100 74 108 285 688 555 521 307 151 356 342 314 658 5 7 8 27 32 32 20 32 33 36 34 31 745.00 747.30 745.00	ප	0	17	13	19	8	7	83	51	19	92	9 8	11	11	98
100 74 108 285 688 555 521 307 151 356 382 514 658 5 7 8 27 32 33 32 20 32 33 36 34 31 745.00 747.30 747.30 745.00	PZ	· co	ĸ	7	34	37	31	41	18	22	36	43	42	35	37
5 7 8 27 32 33 32 20 32 33 36 34 31 745.00 747.30 747.30 745.00	Ba	100	74	108	285	889	555	521	307	151	356	382	514	658	453
0 0	La	S	r-	∞	27	32	33	32	20	32	33	98	34	31	32
745.00 747.30 747.30 745.00 745.00 745.00 745.00 745.00 742.75 742.75 743.85 748.95 744.95 744.80 136.00 136.80 136.80 136.00 13	S	0	0	0	∞	0	0	0	0	0	0	0	0	0	0
136.00 136.80 136.80 136.00 136.00 136.00 136.00 138.00 133.25 136.40 133.00 136.10 136.20	Coordinate X	745.00	747.30	747.30	745.00	745.00	745.00	745.00	742.75	742.75	743.85	748.95	744.95	744.80	744.80
	Coordinate Y	136.00	136.80	136.80	136.00	136.00	136.00	136.00	133.25	133.25	136.40	133.00	136.10	136.20	136.20

Due to strong assimilation of basement xenoliths, sample HTC 7 (66.71% SiO₂, Tab. 1; black dot on Fig. 4; weight: 5 kg), containing 10–20% xenoliths, is not representative. Nevertheless, it is important to consider this sample because it represents the most contaminated geochemical endmember. It gives an idea on the magnitude of crustal contamination effects in shifting points in figures 3 and 4 with respect to the other samples free of xenoliths.

Geochronology

Rb-Sr

The age of intrusion of the Truzzo granite has so far been controversial: 339 \pm 70 Ma (207 Pb/ 206 Pb age, Grünenfelder in Weber 1966), 305 Ma (Rb-Sr whole rock age; JÄGER et al., 1969) or 293 ± 14 Ma (Rb-Sr whole rock age; Gulson, 1973). The previoussy published Rb-Sr analyses of the Truzzo granite by Gulson (1973) and Marquer et al. (1994) are given in table 2, for comparison with our new isotopic data of the Roffna rhyolite. The combined isotopic data yield a Rb-Sr reference line of 285 ± 22 Ma (Fig. 6) with a large MSWD value of 82, indicating post-crystallization disturbance of the Rb-Sr whole-rock system (Fig. 6, black dots). The age of the Roffna rhyolite, on the other hand, has previously been considered to be around 350 Ma (207Pb/206Pb age of zircons; HANSON et al., 1969). Eleven samples of weakly deformed rhyolite were selected and yielded a reference line with an age approximate of 275 \pm 100 Ma (MSWD = 197; Fig. 6, squares).

The Rb-Sr reference lines for weakly deformed samples from both lithologies give elevated errors much in excess of analytical scatter. The high MSWD values reflect effects of the Alpine metamorphism and deformation recorded by these granites (STEINITZ and JÄGER, 1981). It has

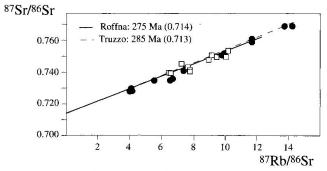


Fig. 6 Rb–Sr diagram for the Truzzo and Roffna granitoids. Same symbols as in figure 3. See text for explanations.

Tab. 2 Rb-Sr isotopic analyses of the Truzzo granite and the Roffna rhyolite. Analyses labelled G.xx were taken from Gulson (1973).

		<u> </u>		
	Rb ppm	Sr ppm 8	7Rb/86Sr	⁸⁷ Sr/ ⁸⁶ Sr
Truzzo gran	ite			
HTC2	196	143	3.97	0.73070
HTC4	185	135	3.90	0.72928
TC2a	152	60.2	7.32	0.74256
TC4a	226	99.8	6.57	0.73775
TC5a	192	139	4.02	0.72940
TC6a	254	114	6.46	0.73625
G.73.791	255	131	5.46	0.73650
G.73.105/4	305	89.5	9.72	0.75200
G.73.105/7	315	91.1	9.86	0.75340
G.73.789	207	51.8	11.51	0.76270
G.73.789/1	208	51.2	11.59	0.75970
G.73.790	266	56.6	13.98	0.77060
G.73.790/1	266	56.4	14.19	0.77070
Roffna rhyo	lite			
RC3	257	83.5	8.92	0.74752
RC4	236	96.7	7.09	0.74597
RC5	255	80.2	9.26	0.74900
RC19	236	104.7	6.53	0.74125
RC31	218	94.2	6.73	0.73925
RC33	259	75.6	9.95	0.74971
RC38	241	87.6	8.00	0.74161
RC39	249	92.2	7.84	0.74390
RC46	245	91.1	7.81	0.74144
RSZ1a	260	81.5	9.28	0.75107
RSZ2a	270	75.3	10.41	0.75489

to be pointed out, however, that these deviations are minor when compared to those from more intensely deformed rock portions, shifting Rb/Sr ratios to lower values in amphibolite-facies examples and to higher values in greenschist-facies examples (MARQUER and PEUCAT, 1994). The initial isotopic ratio for the Truzzo granite and the Roffna rhyolite are relatively high, 0.713 and 0.714 respectively, implying a significant continental component in the granitic rocks. It should be noted that all the samples underwent a similar degree of Alpine metamorphic overprint and deformation and show identical initial Sr isotopic ratios for both Roffna rhyolite and Truzzo granite (Fig. 6).

U-Pb

To better constrain the emplacement age of both types, zircon populations were separated from representative samples of the Truzzo granite (TC5a) and the Roffna rhyolite (RC38) and analyzed for their Pb and U isotopic composition (Fig. 7 a and b; Tab. 3). These samples were chosen because they are located far from the intrusion boundaries and their chemical analyses are close

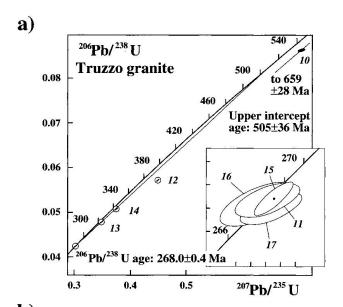
Tab. 3 U-Pb analyses for the Truzzo granite and the Roffna rhyolite.

Number Description	Weight	n _o	රි	Concentration	us				A	Atomic ratios	S			Ap	Apparent ages		Error
(a	[gm]	of	'n	Pb	Pb	Th/U	206/204	206/238	Error	207/235	Error	207/206	Error	206/238	207/235	207/206	corr.
		grains		rad.	nonrad.				2σ [%]	87	2σ [%]		2σ [%]				×.
			[mdd]	[mdd]	[bg]	p)	(c)	(p		(p		(p					
Roffna rhyolite (RC38)								12/6			1						
1 spr, cuh	0.0103	9	672	34.5	7.2	0.13	3253	0.05423	0.34	0.4221	0.40	0.05645	0.17	340.4	357.5	470.3	0.91
2 spr, euh	0.0128	4	534.4	25.3	6.5	0.18	3248	0.04938	0.34	0.3704	0.41	0.05441	0.18	310.7	320.0	388.0	0.00
3 lpr, clrls	0.0093	∞	675	30.4	14.7	0.16	1264	0.04736	0.34	0.3466	0.48	0.05308	0.30	298.3	302.2	332.2	0.78
4 eq, brownish	0.0070	5	512	36.9	6.3	0.17	2681	0.07535	0.34	0.6084	0.41	0.05856	0.20	468.3	482.6	550.9	0.87
5 transp, pr, incl	0.0123	7	765	32.4	2.8	0.15	9154	0.04469	0.35	0.3232	0.40	0.05245	0.15	281.8	284.4	305.3	0.93
6 flat-equant, euh	0.0060	n	683	27.5	2.1	0.16	5233	0.04246	0.34	0.3026	0.41	0.05168	0.19	268.1	268.4	271.4	0.89
7 lpr, clrls	0.0018	Н	563	24.4	2.9	0.41	696	0.04255	0.37	0.3038	0.73	0.05179	0.60	268.6	269.4	276.1	0.57
8 eq brownish	0.0035	\vdash	416.5	26.3	1.4	0.64	3622	0.05784	0.39	0.4447	0.48	0.05576	0.28	362.5	373.5	442.8	0.81
9 pink spr, tips	0.0029	2	268	47.3	1.4	0.15	5718	0.07860	0.33	0.9549	0.38	0.08811	0.16	487.8	680.7	1385.0	0.91
Truzzo granite (TC5a)																	
10 brown frags	0.0073	1	349	29.2	32.8	0.22	430	0.08601	0.35	0.7106	0.80	0.05992	0.71	531.9	545.1	8.009	0.46
11 lpr, clrls	0.0036	ю	1080	43.3	18.1	0.15	590	0.04240	0.34	0.3024	69.0	0.05172	0.56	267.7	268.2	273.1	0.59
12 clear frags	0.0076	7	595	32.6	9.1	0.17	1766	0.05707	0.34	0.4503	0.44	0.05724	0.24	357.8	377.5	9.005	0.85
13 frags pr	0.0075	7	759	34.5	2.0	0.17	8292	0.04778	0.36	0.3488	0.41	0.05294	0.19	300.9	303.8	326.2	0.89
14 pr, clrls	0.0063	2	561.7	26.6	15.1	0.11	751	0.05068	0.34	0.3750	09:0	0.05367	0.46	318.7	323.4	357.2	0.65
15 lpr, clrls, incl	0.0034	m	1294	51.0	6.1	0.09	1930	0.04248	0.33	0.3026	0.44	0.05166	0.24	268.2	268.4	270.5	0.84
16 roundish frag	0.0019	Т	486	19.1	3.0	0.08	839	0.04242	0.41	0.3013	0.76	0.05151	0.63	267.8	267.4	263.9	0.56
17 lpr, clrls	0.0013	_	753.7	29.7	2.8	80.0	926	0.04246	0.34	0.3022	0.72	0.05161	0.59	268.1	268.1	268.0	0.58

a) euh = euhedral, clrls = colourless, incl = inclusions, pr = prisms; transp = transparent, frags = fragments; lpr = long prismatic, spr = short prismatic b) Calculated on the basis of radiogenic ²⁰⁸Pb/²⁰⁶Pb ratios, assuming concordancy c) Corrected for fractionation and spike d) Corrected for fractionation, spike, blank and common lead (STACEY and KRAMERS, 1975)

to the average of the porphyric Truzzo granite and the Roffna rhyolite sets.

Truzzo granite: The zircon population is heterogeneous and typical for a crust-derived granite: Round to short-prismatic zircons of > 100 μm size have brown colour and often show resorption (pitted surface, rounded edges); inherited cores are visible through inclusions around them. Small short-prismatic pink zircons as well as long-prismatic colourless zircons are sharply faceted, with {211} faces dominating clearly over {110}. The zircons of this sample show a relatively large variation in measured U contents in zircon, up to a maximum of 1300 ppm U for long prismatic zircons representing inheritance-free, new growth in the melt. A discordia line defined by analyses 11,



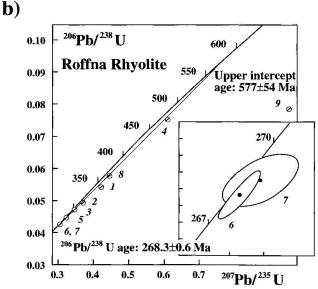


Fig. 7 U-Pb diagrams for Truzzo granite (a) and Roffna rhyolite (b). Mean ²⁰⁶Pb/²³⁸U ages are at 95% confidence level.

12, 13, 14, 15, 16 and 17 points to an upper intercept age of 505 ± 36 Ma, interpreted as an inherited age from a source rock. Analyses 10, pointing to an upper intercept age of 659 Ma, and 12 suggest that a second older component is present, too. The four analytically concordant points (11, 15, 16 and 17) cluster at a $^{206}\text{Pb}/^{238}\text{U}$ age of 268.0 ± 0.4 Ma, which agrees with the lower intercept age of 266.5 ± 4.5 Ma of a best-fit line calculated above.

Roffna rhyolite: The zircons of this sample show a similar morphology as those of the Truzzo granite. Short-prismatic zircons are brown to pink in colour and display visible cores through inclusions and turbidity. Prismatic to long-prismatic zircons show {211} as well as {110} faces, beside some very flat grains with {110} only. All zircons are nicely faceted and show no signs of resorption. The analyses show only a limited range of U concentration, despite a large variation in zircon morphology. Most of the analyzed grains or microfractions (2 to 8 grains) contain inherited lead from at least two sources. A best-fit line calculated with analyses 3, 5, 6 and 7 yield an upper intercept age of 577 ± 54 Ma, whereas analysis 9 (pointing to 2.0 Ga) suggests the presence of an additional component of Proterozoic age (Fig. 7b). The first age could possibly be a mixture between the two components of 505 and 659 Ma, respectively, found in the Truzzo granite. Only two analytical points plot near the concordia curve, at a mean 206 Pb/ 238 U age of 268.3 ± 0.6 Ma, with a slight offset towards higher ²⁰⁷Pb/²³⁵U values. Comparing these two points with the better constrained and more concordant points of the Truzzo granite (see above), we consider these two points as being concordant and their 206Pb/238U age therefore presents the best estimate for the age of zircon crystallization. A lower intercept age of 264.4 ± 3.4 Ma of a best fit line is calculated using analyses 3, 5, 6 and 7. It ranges within errors limits close to the above estimate ²⁰⁶Pb/²³⁸U age.

Significance of Early Permian magmatism

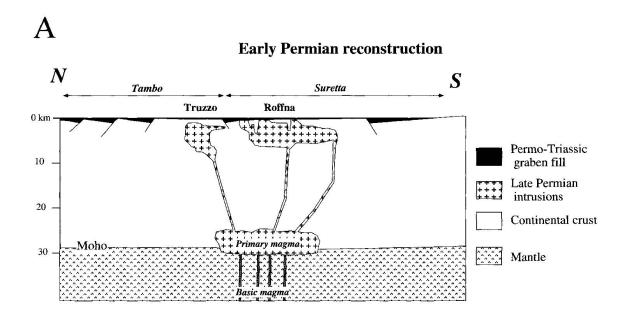
Petrographical, geochemical and isotopic similarities suggest that the Truzzo granite and Roffna rhyolite are part of the same magmatic event. The analyzed Truzzo granite and Roffna rhyolite samples are representative of a number of small local intrusions in the Briançonnais basement and do not correspond closely in their geochemical compositions to magmas typical of the classical subduction cycle and related continental arc volcanism. The leucocratic granite samples and some samples of the porphyritic granite show charac-

teristics more typical of post-orogenic granites (Fig. 4, POG). The scattering of some of the Truzzo analyses, and the position of the Roffna rhyolite samples in the "Continental Collision Granitoids" field (Fig. 4, CCG) could be partly due to increased continental crust contamination and/or infracrustal melting, as is emphasised by the composition of the most contaminated sample HTC 7 located on the right part of the diagram (Fig. 4). The tectonic setting of these intrusions could be related to a post-orogenic event with the participation of crustal sources, as indicated by the occurrence of different types of xenoliths (BAR-BARIN and DIDIER, 1992). This strong crustal contamination is also emphasised by the results of the isotopic systems studies.

Both lithologies were derived from the same type of source and underwent similar magmatic processes. Knowing the geometry and the kine-

B

matics of the main Alpine deformations (BAUDIN et al., 1993; MARQUER et al., 1994, 1996) and the sedimentary records (STAMPFLI et al., 1998), it is possible to reconstruct the initial position of the Tambo and Suretta nappes before Alpine tectonics (Fig. 8A). The Truzzo granite and the Roffna rhyolite are closely located in the continental margin of the Brianconnais terrane in the Early Permian time, corresponding to two shallow but deep-rooted intrusions in the Brianconnais basement (Fig. 8). These intrusions appear as small plutons isolated in the old Brianconnais basement, as it was also described for other intrusions in the western Central Alps (e.g. Randa intrusion, Siviez-Michabel, ThéLIN et al., 1993), and differ from the large Variscan batholiths occurring in the External Crystalline Massifs. The acid magmatism was possibly triggered by mafic magmatism at the base of the crust (Fig. 8A: only one primary mag-



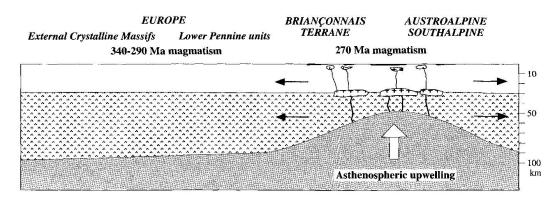


Fig. 8 A Early Permian reconstruction of the Briançonnais continental crust with location of the Truzzo and Roffna granitoids. B: Schematic sketch of the tectonic setting of the Briançonnais domain during Early Permian time.

matic chamber is drawn), which led to partial melting of lower crustal sources, indicated by high initial Sr isotopic ratios and abundant inherited lead components in the dated zircons. The melts subsequently intruded into higher crustal levels and are currently found as cross-cutting Permian volcano-sedimentary sequences that were deposited in small sedimentary basins unconformably overlying the basement rocks (Fig. 8A).

The intrusion age of both Roffna and Truzzo protoliths can be dated around 268 Ma. The U-Pb system of zircon is thus less susceptible to effects of Alpine deformation and metamorphism than the Rb-Sr whole-rock systems. The age is similar to the U-Pb zircon date of 270 +6/-4 Ma from the nearby Braccia/Fedoz gabbro located at the boundary between Penninic and Austroalpine nappes (Margna nappe; Hansmann et al., 1996) and to rhyolites and granites in Austroalpine, Penninic and Southalpine units, all scattering around 270–275 Ma (Del Moro and Notarpietro, 1987; STILLE and BULETTI, 1987; BARTH et al., 1994; Bussy and Cadoppi, 1996; Bussy et al., 1996). Large mafic complexes in the lower crust of the future southern margin of the Liguro-Piemontais ocean, such as the Braccia/Fedoz gabbro (Austroalpine-Malenco units, HERMANN et al., 1997) or in the Ivrea zone (Southalpine unit; HANDY and ZINGG, 1991; QUICK et al., 1994) demonstrate maf-

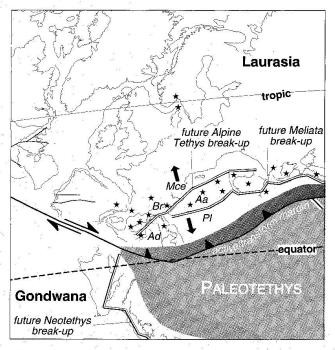


Fig. 9 Early Permian framework of peri-Tethysian domains, modified after STAMPFLI et al. (1998). Aa: Austroalpine; Ad: Adria; Br: Briançonnais; Mce: External Crystalline Massifs; Pl: Pelagonia. Stars: Early Permian plutonism.

ic underplating of this part of the crust. It is suggested that the upwelling of asthenospheric mantle below the Brianconnais and Austroalpine-Southalpine domains is responsible for the formation and emplacement of mafic intrusions during the Early Permian; the mantle melts in turn caused partial melting and granulitic metamorphism in the lower continental crust (DAL PIAZ, 1993; HERMANN, 1997). The strongly crust-contaminated melts rose into the upper crust and formed the Permian acid volcanism recorded in the Brianconnais and adjacent Austroalpine domains (Fig. 8B). Shallow-seated but possibly deep-rooted Early Permian intrusions are also described from more westerly areas of the Briançonnais terrane (e.g. Randa, Siviez-Michabel; Thélin et al., 1993).

The Permian upwelling of the asthenosphere is thought to be caused by extensional plate tectonic forces leading to mega-shearzones concurrent with lithospheric thinning. The Early Permian extension is recorded by the volcano-sedimentary deposits in shallow basins at the top of the continental crust, mainly in the southern Penninic, Austroalpine and Southalpine domains (ZIEG-LER, 1993). The type of Early Permian plutonism described here is found in a belt running from Catalonia (Spain), Corsica-Sardinia, Provence, Brianconnais, Southern Alps and Eastern Alps (see Fig. 9) and is different from the Visean to Stephanien magmatism widely exposed in the southern part of the Variscan orogen in Europe (BONIN et al., 1993; STAMPFLI, 1996). This latter, dominantly calk-alkaline magmatism is interpreted as related to subduction processes (FINGER and STEYRER, 1990; STAMPFLI, 1996) or as late- to postorogenic magmatism related to post-convergence extension processes (Bonin et al., 1993; SCHALT-EGGER and CORFU, 1995), for example in a basinand-range-type setting (WERNICKE, 1992; GANS et al., 1989). The Brianconnais domain, however, seems to be lacking this Lower to Upper Carboniferous magmatism (Fig. 8B).

Conclusions

Our new petrological investigations in the Truzzo granite and Roffna rhyolite of the central Alpine Briançonnais terrane show evidence for a magmatic event at 268 ± 1 Ma. An Early Permian reconstruction of the position of Truzzo granite and Roffna rhyolite in the Briançonnais terrane, based on the restoration of the Tertiary tectonics, emphasises the proximity of these intrusions. Both intrusions were shallow-seated and, as demonstrated here, are related to the same mag-

matic event. They might have their origin in upwelling asthenospheric mantle in Early Permian times, related to lithospheric thinning at the site of the future Jurassic rifting and opening of the Liguro-Piemontais ocean (DAL PIAZ, 1993; HER-MANN, 1997).

Even if the upper intercept ages are poorly constrained in this study, the ages calculated from inheritance-bearing zircons of both lithologic units suggest the presence of different age components in the source or the contaminating host rocks (values around 2.0 Ga, 650 and 500 Ma). These values are typical of basement sequences in the Austroalpine, Penninic and Helvetic domains and in fact suggest that the composition of the basement in the Central Alpine segment is not significantly different from other basement parts of the Variscan orogen with respect to its pre-Carboniferous evolutionary history (SCHALTEGGER and GEBAUER, 1999). On the other hand, Early Permian magmatic activity is mainly restricted to the Brianconnais terranes and the Austroalpine-Southalpine units. It reflects a different setting than the late Variscan/Upper Carboniferous tectonic setting and related magmatism.

As a possible geodynamic scenario for this period we propose large shear zones running through the consolidated Variscan orogen, reaching deep into the lithosphere and causing lithospheric thinning, upwelling of asthenosphere and emplacement of mantle melts in the lower crust in Early Permian time.

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APPENDIX

ANALYTICAL TECHNIQUES

Rb-Sr: Rb and Sr contents were determined by XRF in the laboratory of Géosciences Rennes. Isotope analyses were also performed in Rennes using Cameca THN 206 and Finnigan Mat 262 mass spectrometers. The NBS 987 standard was measured at a value of 0.71020 ± 5 (internal error, 2σ). Total error on the 87Sr/86Sr used in calculation is 0.025% (external error, 2 σ), although analytical errors were better (3–8 \times 10⁻⁵ for THN206 measurements and $1-2 \times 10^{-5}$ for MAT262 measurements), for 87Rb/86Sr it is 1%. Isochrons were calculated according to the method of Ludwig (1994). The probable errors of the isochrons are quoted as $2\sigma \times \sqrt{\text{MSWD}}$, where MSWD > 1.

U-Pb: Conventional U-Pb analyses were carried out on microfractions or single zircons from

a non-magnetic zircon fraction of a Frantz separator. Zircons were air-abraded to remove zones of marginal lead loss, washed in warm 4N nitric acid and rinsed several times with distilled water and acetone in an ultrasonic bath. Dissolution and chemical extraction of U and Pb were performed following Krogh (1973), using bombs and anion exchange columns that are scaled down to 1/10 of their original size. Total procedural blanks were 2 pg Pb and 0.1 pg U. A mixed 205Pb-235U tracer solution was used for all analyses. Both Pb and U were loaded with Si-Gel and phosphoric acid on single Re filaments and measured on a Finnigan MAT 262 mass spectrometer using an ion counting system. The performance of the ion counter was controlled by repeated measurements of a NBS 982 standard solution.

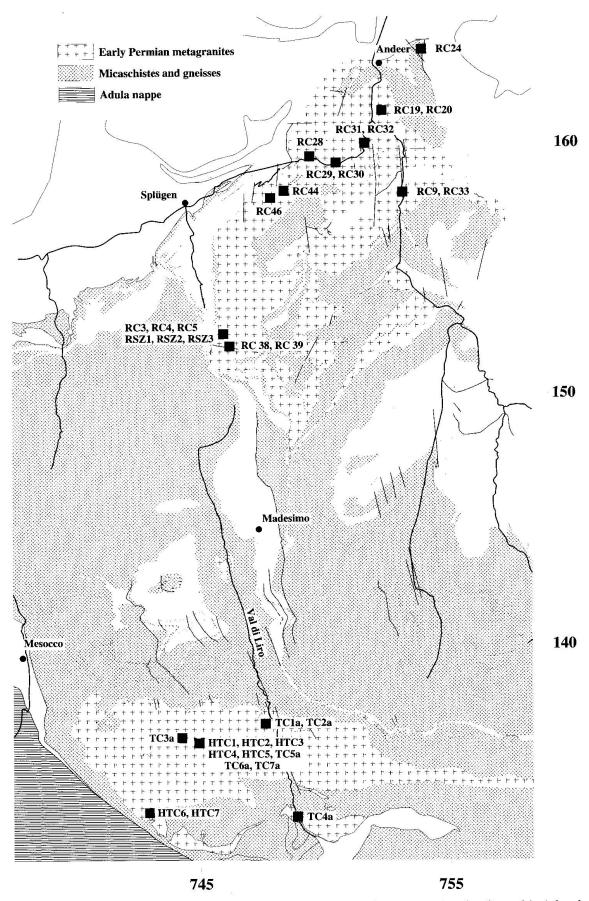


Fig. 10 Locations of the samples analysed in the Truzzo granite and the Roffna rhyolite. See table 1 for detailed X-Y Swiss topographic coordinates.