Late Variscan events in the outer Ligurian Briançonnais

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ABSTRACT

In the Ligurian Briançonnais domain a late Variscan sequence of volcanic, mainly ignimbritic, and sedimentary continental deposits filled up graben and half-graben structures, bordered by two sets of syngenetic faults (presently trending nearly E-W and N-S), during three main phases. The oldest one, of Westphalian-Stephanian age, was accompanied by calc-alkaline rhyolite; the second one, of middle (?) Stephanian age, is marked by «shoshonitic» andesites; the last, early Permian one, gave huge volumes of calc-alkaline rhyolitic to dacitic volcanics and was closed by a K-rhyolitic event. No volcanism is associated with the uncomformably overlying late Permian continental coarse deposits (Verrucano).

Key words: Ligurian Briançonnais domain, late-Variscan volcanic activity, petrogenetic processes, syn-sedimentary tectonics.

RESUMEN

En el dominio Liguro-Brianzonés (Italia), tuvo lugar el desarrollo de una secuencia tardivarisca. Esta secuencia, compuesta de depósitos volcánicos, principalmente ignimbritas y sedimentos continentales, generó el relleno, durante tres fases principales, de una serie de estructuras de tipo graben y semigraben, limitadas por

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dos grupos de fallas singenéticas (con una dirección actual aproximada E-O y N-S). La secuencia más antigua, de edad Westfaliense-Stephaniense, estuvo acompañada de riolitas calco-alcalinas; la segunda, de edad Stephaniense medio (?), viene marcada por andesitas shoshoníticas; la última, de edad Pérmico inferior, dio lugar a un importante volumen de vulcanismo dacítico y riolítico calco-alcalino, finalizando con una etapa K-riolítica. Los depósitos suprayacentes, constituidos por sedimentos de carácter continental (Verrucano) de edad Pérmico superior, no se encuentran asociados a actividad volcánica.

Palabras clave: Dominio Liguro-Brianzonés, actividad volcánica tardivarisca, procesos petrogenéticos, tectónica sinsedimentaria.

INTRODUCTION

This short paper corresponds to a kind of extended abstract of a much longer publication, written in Italian language (Cabella *et al.*, 1989); for this reason, only essential figures and references have been included here.

In particular, for more complete information about general regional geology and Permian-Carboniferous setting the reader is referred respectively to Vanossi *et al.* (1986) and to Cortesogno *et al.* (1984).

REGIONAL SETTING-DISCUSSION

Four formations, of Westphalian-lower Permian age, belonging in outer Ligurian Briançonnais domain, are present in Viozene area (fig. 1).

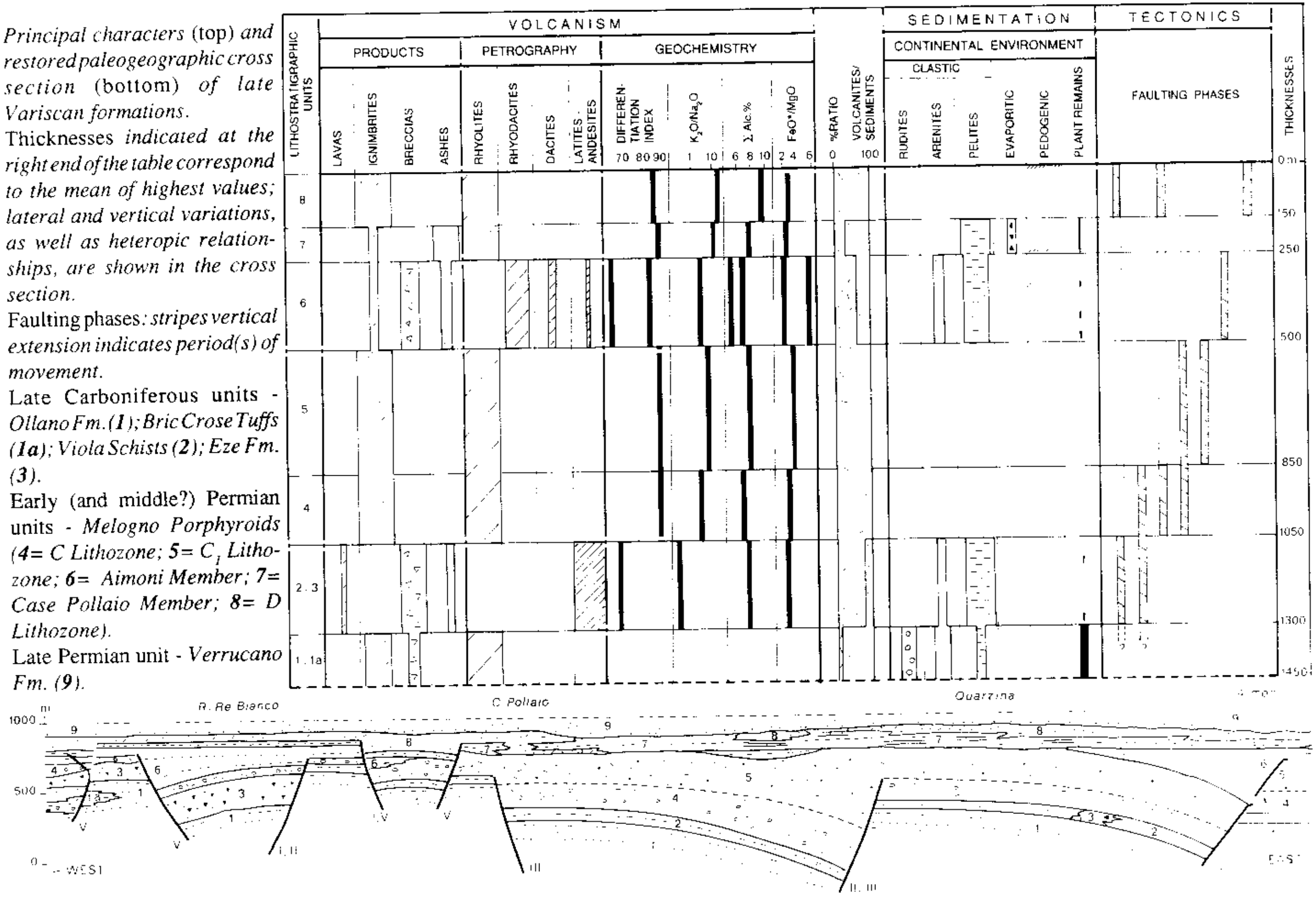
The oldest one *(Ollano Fm.*, n. *1)*, only outcropping with its 150 m upper part, consists of alternating fine (graphitic phyllades) and coarse fluvial-lacustrine metasediments, with minor interbeddings of calc-alkaline rhyolitic tuffs *(Bric Crose*

Fig. 1.—Principales caracteres *(parte superior)* y corte paleogeográfico *(parte inferior)* de las formaciones tardivariscas. El espesor indicado a la derecha de la tabla, corresponde a los valores medios más altos; en el corte inferior se expresan las variaciones laterales y verticales, así como las relaciones heterópicas. Fases de facturación: la extensión de las líneas verticales, indican los períodos de movimiento.

Unidades del Carbonífero superior: Fm. Ollano (1); Tuffs Bric Cross (1a); Esquistos Viola (2); Fm. Eze (3).

Unidades del Pérmico inferior (¿y medio?): Porfiroides Melogno (4 = Litozona C; 5 = Litozona C1; 6 = Miembro Aimoni; 7 = Miembro Case Pollaio; 8 = Litozona D).

Unidad del Pérmico superior: Fm. Verrucano (9).



Principal characters (top) *and restored paleogeographic cross section* (bottom) *of late Variscan formations.*

Thicknesses *indicated at the right end of the table correspond to the mean of highest values; lateral and vertical variations, as well as heteropic relationships, are shown in the cross section.*

Faulting phases*: stripes vertical extension indicates period(s) of movement.*

Late Carboniferous units - *Ollano Fm.* (**1**); *Bric Crose Tuffs* (**1a**); *Viola Schists* (**2**); *Eze Fm.* (**3**).

Early (and middle?) Permian units - *Melogno Porphyroids* (**4**= *C Lithozone;* **5**= C_1 *Lithozone;* **6**= *Aimoni Member;* **7**= *Case Pollaio Member;* **8**= *D Lithozone*).

Late Permian unit - *Verrucano Fm.* (**9**).

Tuffs, n. *1 a)*, representing the earliest manifestations of late Variscan volcanic activity.

The intermediate volcanic episode (middle Stephanian?) produced mainly pyroclastic fall deposits up to 250 m thick, even very coarse, together with minor lava flows, showing K-andesitic, possibly shoshonitic, affinities; they correspond to the andesitic products *(Eze Fm.*, n. *3)* well known in inner Briançonnais sectors and are contemporary with a thin series of continental, sometimes graphitic, fine detrital sediments *(Viola Schists*, n. *2)*.

The early Permian main volcanic activity, generally represented in Ligurian Briançonnais by huge volumes of ignimbritic calc-alkaline rhyolites *(Melogno Porphyroids*, n. *4 to 8)*, displays in the Viozene area, from bottom to top, the following peculiar sequence:

— *C Lithozone (n. 4), up* to 200 m of calc-alkaline rhyolitic ignimbrites;

— *C_l Lithozone (n. 5)*, up to 350 m of analogous ignimbrites, meanly showing higher K-feldspar contents;

— *Aimoni Member (n. 6), up to* 500 m mostly of variegated fine to exceedingly coarse pyroclastic fall deposits, with minor calc-alkaline dacitic ignimbrites;

— *Case Pollaio Member (n. 7), u*p to 100 m of black ash deposits, interbedded with both rare carbonate beds, often extensively silicified, of probable evaporitic origin, and danburite - tourmaline, sometimes realgar - rich metapelitic levels;

— *D Lithozone (n. 8)*, up to 100 m of sub-alkaline potassic rhyolitic ignimbrites.

Late Permian conglomeratic continental deposits *(Verrucano Fm.*, n. *9)*, grading upwards into Scythian quartzites, rest paraconformably on the eroded top of the volcanic complex.

Most of the above listed lithologic units show abruptly or progressively decreasing thickness, both along E-W and N-S directions.

To find out the causes of such reductions, the geological mapping was integrated with the analysis of alpine deformations.

Four alpine folding phases of decreasing intensity have affected the area; they are all co-axial (E-W), except for the latest (N-S). The oldest phase produced south-verging folds, accompanied by metamorphic (T ~ 250° ÷ 350° C; P ~ 3kbar) foliation; the second phase generated north-verging folds, associated with a crenulation cleavage; the third phase was responsible for slightly south-verging flexures, sometimes with an overturned limb; lastly, the N-S phase produced open, nearly vertical folds. If compared with ductile deformations, fault tectonics is only of minor importance.

On the whole, the sudden or gradual variations in thickness of late Variscan formations cannot be accounted for by alpine orogeny, but must depend on two sets

(E-W and N-S) of syn-sedimentary faults, bordering graben and half-graben structures. The existence of pull-apart basins could not be proved.

The faults offered an easy way to rising magmas, which volcanic products, alternated and more or less reworked and mixed with minor detrital sediments, accumulated in the subsiding continental basins, transecting a poorly hilly region. Climate evolved from humid in Stephanian times to semi-arid during lower Permian times. The close relationship between tectonics and volcanism is also outlined by rejuvenation or birth of new faults at each of the three volcanic main phases: Westphalian-Stephanian (calc-alkaline rhyolites); middle (?) Stephanian ("shoshonitic" andesites); early Permian (calc-alkaline rhyolites, dacites, K-rhyolites). Only the last faulting phase (late Permian), producing suitable gradients for erosion and transport of Verrucano clastic components, was not accompanied by volcanism: in the Ligurian Alps the late-Variscan magmatism seems thus to end by the end of lower Permian.

The petrochemical characters of the volcanic products indicate that mafic and acidic rocks suffered chemical alteration mainly due to diagenetic processes and possibly in a minor extent during later metamorphism. The former show Na enrichment and Ca depletion ("spilites"), the latter present K enrichment and strong Na, Ca depletion.

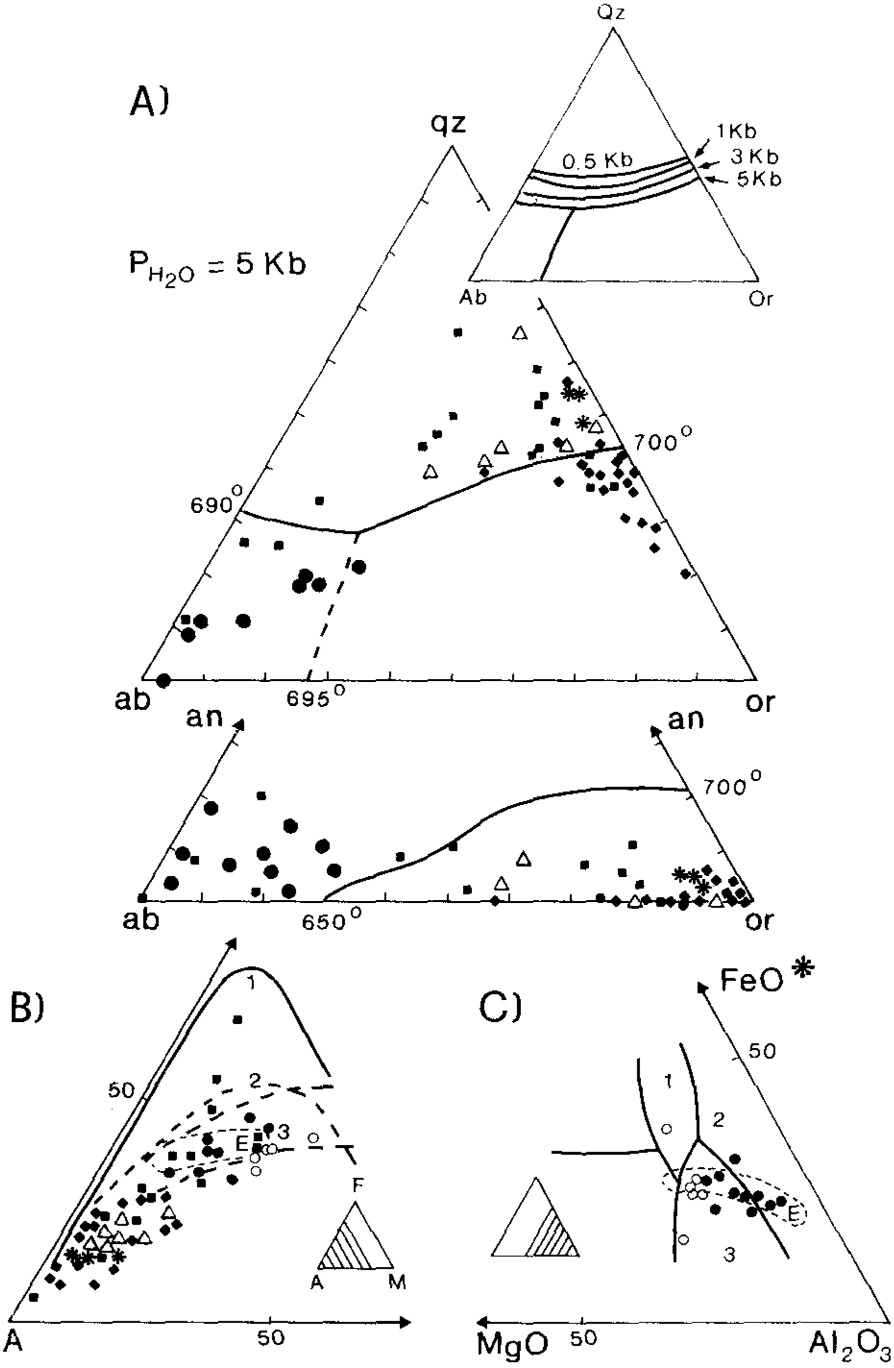
In spite of the observed alterations, the petrochemical data (fig. 2) allow to define two main different series:

— a calc-alkaline one represented by volcanic products of C, C_1 Lithozones and Aimoni Member; dacites and rhyodacites from this latter show petrographic evidence of crustal contamination (resorbed quartz xenoliths, xenoliths from upper and lower basement), magmatic differentiation (crystal aggregates with cumulate texture) and high $FeO_{tot.}/MgO$ ratios in the most mafic terms;

— a sub-alkaline potassic series of shoshonitic affinity, which the volcanics of Eze Formation and D Lithozone belong in. The andesites of Eze Formation show evidence of amphibole fractionation under high PH_2O conditions, driving the residual liquids towards alkali-rich oversaturated compositions. The resulting trend is characterized by high K_2O, Al_2O_3 amounts, no iron enrichment and low $FeO_{tot.}/MgO$ ratios.

The primary high K contents of D Lithozone rhyolites, showing abundant K-feldspar megacrysts and large K-feldspar/quartz ratios, are greatly increased by deuteresis during late-post-magmatic stages under high fluid activity.

The above outlined sedimentary, tectonic and volcanic picture has a very good fit in the overall palaeogeography of the Variscan southern Europe, namely of the


A)
qz
P_{H_2O} = 5 Kb
Qz
0.5 Kb
1Kb
3 Kb
5Kb
Ab
Or
700°
690°
ab
695°
or
an
an
700°
ab
650°
or
B)
1
2
3
E
F
50
A
M
A
50
C)
FeO*
50
1
2
3
E
MgO
50
Al_2O_3

Catalanian-Alpine sector, extending from Pyrénées through southern France, Corso-Sardinian block and Tuscany to Alps.

As to petrogenetic process, a double source may be envisaged: an anatectic crustal magma gave the calc-alkaline rhyolites both of the earlier and of the main episodes; a different magma, deriving from partial melting of mantle (and lower crust ?) rocks, followed by multiple fractionations under high PH_2O conditions, produced the sub-alkaline potassic andesites of the intermediate episode and, possibly, the latest K-rhyolites. The mixing of crust and mantle derived melts might offer satisfactory explanations for the genesis of volcanic rocks (dacites-rhyodacites) of the calc-alkaline series.

The causes of melting and of volcanics distribution in time and space can be examined in the light of various geodynamic models which have been proposed to explain Variscan orogeny and late-Variscan events.

Fig. 2.—Compositional and petrochemical data of the Viozene area volcanic rocks.

A) Qz-Ab-Or-An+H_2O diagram (projections from Qz and An apexes; PH_2O = 5 kbar). The ternary system Qz-Ab-Or+H_2O for 0.5 and 5 kbar PH_2O conditions is also drawn. Eze Formation in the Aimoni area (*solid circles*); «Porfiroidi del Melogno» volcanic rocks: C and C_1 Lithozones (*open triangles*); Aimoni Member (*solid squares*); Case Pollaio Member (*asterisks*); D Lithozone (*solid diamonds*).

B) *AFM diagram. Tholeiitic (1) and calc-alkaline (3) trends are from* RINGWOOD (1974). *The line* 2 dividing the tholeiitic from the calc-alkaline rock series is also drawn. The field *E* shows the Eze *Formation andesitic rocks from the intermediate-inner Briançonnais sectors. Open circles represent* basalts and basalt-andesites from Casotto Valley. Other symbols as in A.

C) MgO*-Al_2O_3 *diagram from* PEARCE *et al.* (1977) *for the most primitive mafic volcanic rocks* of Eze Formation. FeO* represents total iron as FeO. The geotectonic environments are: *1*=continental; *2=spreading center island; 3=orogenic (island arcs and continental active margins). The key for the* field *E* and for symbols is in A and in B.

Fig. 2.—Datos composicionales y petroquímicos de las rocas volcánicas del área de Viozene.

A) Diagrama Qz-Ab-Or-An+H_2O (proyecciones desde los ápices Qz y An; P H_2O = Kbar). Se representa también en el sistema ternario Qz-Ab-Or+H_2O en condiciones de 0,5 y 5 Kbar de P H_2O. Formación Eze en el área Aimoni *(círculos negros);* P rocas volcánicas «Porfiroidi del Melogno»: Litozona C y C1 *(triángulos);* Miembro Aimoni *(cuadrados)*; Miembro Case Pollaio *(asteriscos);* Litozona D *(diamantes).*

B) Diagrama AFM. Tendencias toleíticas (1) y calcoalcalinas (3) según Ringwood (1974). La línea 2 marca la división entre las series de las rocas toleíticas con respecto a las calcoalcalinas. El campo E *muestra las rocas andesíticas de la formación Eze del sector intermedio-interno brianzonés.* Los círculos vacíos representan los basaltos y las andesitas basálticas de Casotto Valley. Los demás símbolos son como en A.

C) Diagrama MgO*-Al_2O_3 según Pearce *et. al.* (1977) para las rocas volcánicas máficas más antiguas de la formación Eze. *FeO* representa el hierro total en forma de FeO. Los ambientes* geotectónicos son: 1 = continental; 2 = isla en centro de expansión; 3 = orogénico (arco isla y margen *continental activo). El resto de los símbolos están en A y B.*

Most of the models, involving A- or B-subductions, seem at first adequate to justify both the chemical (calc-alkaline and potassic sub- alkaline) composition of melts and the very large volumes of acidic rocks which have been produced. Nevertheless, the models suggesting that magmas generation followed tectonic-metamorphic events appear to match chronological and dynamic constraints better than others considering melting to preceed tectogenesis. In any case, even the first one cannot solve the problem of the long time span separating melt generation from the beginning of volcanic activity.

Thus, the question arises if melting could not have been enhanced, long after the main tectonic phases had come to an end, possibly by mantle diapirism, genetically linked to, or indipendent of, orogenetic events.

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