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The Goli d'Aget Member: Early Permian volcanoclastic and volcanic rocks within the Briançonnais Grand St-Bernard Nappe (Valais, Switzerland)

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Key words: Penninic Alps, Grand St-Bernard nappe, Permian, rhyolite, ignimbrite, Val de Bagnes, Valais.

ABSTRACT

The well-preserved sedimentary structures of the Goli d'Aget Member (Early Permian) allow to distinguish four successive environments of deposition: 1) An alluvial plain with important channeling and evidence of volcanic activity; 2) A shallow lacustrine environment with a low water level, deposition of massive carbonates and an increasing contribution of volcanic materials; 3) A fluviatile plain with the deposition of volcanic tuffs; 4) A deltaic to lacustrine environment occasionally covered by pyroclastic flows.

An ignimbritic rhyolite from the upper part of the Goli d'Aget Member has an age of 267-282 Ma (U-Pb on zircon). Major and trace elements, as well as zircon typology point to a calc-alkaline and volcanic-arc affinity for that high-silica rhyolite.

The Goli d'Aget Member may be the best-preserved unit among the Permian units from the Swiss Penninic Western Alps. This series provides an important point of comparison with other local Permian units (Dent de Nendaz and Cleuson Members) and with similar series in the Western Alps including the Melogno porphyroids in the Ligurian Alps and the Rochachille Series near Briançon (France).

RESUME

La série volcanoclastique du Membre du Goli d'Aget présente une succession lithologique permienne dont l'excellente préservation des structures sédimentaires a permis de distinguer quatre environnements de dépôts successifs: 1) Une plaine alluviale chenalisée présentant des indices d'activité volcanique; 2) Un environnement lacustre de faible profondeur (apports volcaniques croissants et dépôt de carbonates); 3) Une plaine fluviatile, chenalisée, avec de nombreux dépôts de tufs volcaniques; 4) Un environnement deltaïque à lacustre, couvert occasionnellement de coulées pyroclastiques.

Dans la partie supérieure du Membre du Goli d'Aget, une rhyolite ignimbritique est datée à 267-282 Ma (U/Pb sur zircon). La signature géochimique de cette ignimbrite est de type «arc volcanique» (VAG) et la typologie de ses zircons d'affinité calco-alcaline.

Le Membre du Goli d'Aget est, à notre connaissance, la mieux préservée des unités permiennes du Briançonnais des Alpes valaisannes. Elle constitue donc un outil de comparaison privilégié avec les autres unités permiennes locales moins bien conservées (Dent de Nendaz, Greppon Blanc) et avec des séries similaires des Alpes ligures (porphyroïdes de Melogno) ou de la région de Briançon (Série de Rochachille).

1. Introduction

Within the Briançonnais middle Penninic units, along the northwestern Alpine arc, some Permian clastic and volcanoclastic series, lying on Carboniferous measures or other older basement units, are covered by Permo-triassic Verrucano and quartzites. Their lithostratigraphy and their volcanic deposits have been described in details for the Rochachille Series near Briançon (Fabre & Feys 1966, Fabre et al. 1982) and the Melogno porphyroids in the Ligurian Alps (Cortesogno et al. 1993). There is a lack of direct dating for these units and a Permian age is generally inferred from the under- and overlying rocks.

U-Pb isotopic ages obtained from zircons in the intrusive and effusive rocks of the Briançonnais basement in the Valais (Bussy et al. 1996b) have provided, for the first time, evidence for a Permian age of these series. A 269±2 Ma age has been obtained for the Randa orthogneisses found within the Siviez-Mischabel nappe, but the relation of this Permian peraluminous, alkali-calcic metagranite (Thélin 1987) with the Permian sedimentary series and the pre-Permian basement remains un-

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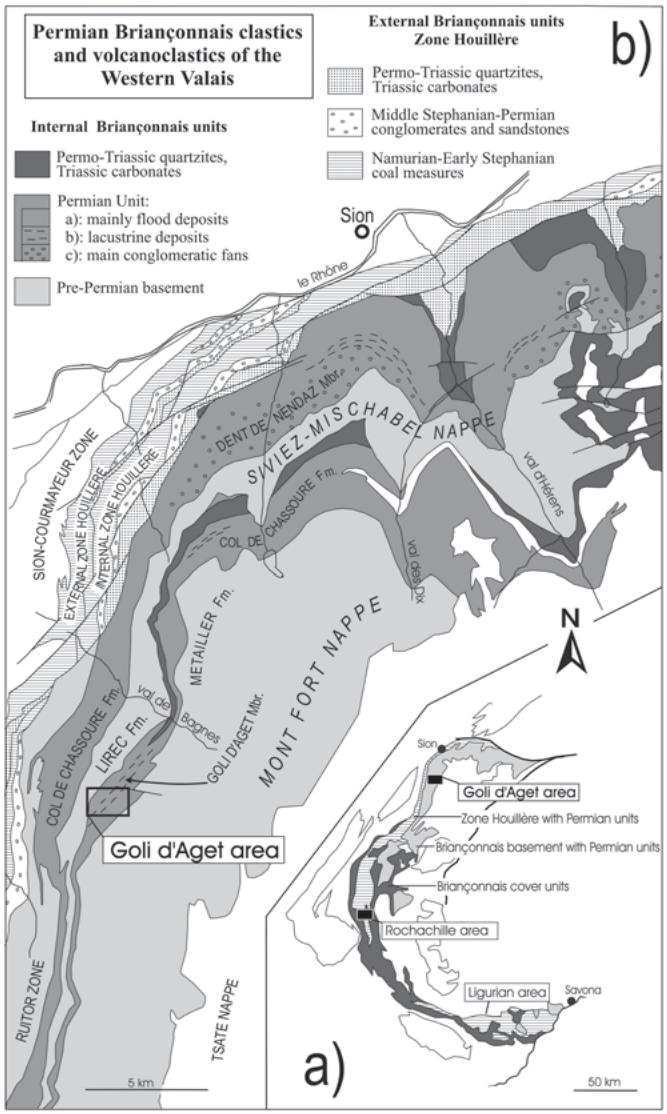

Fig. 1. a) Briançonnais units of the Western Alps from Valais to Liguria. b) Permian Briançonnais clastics and volcanoclastics of the Western Valais.

certain. The volcanoclastic Goli d'Aget Member (Bagnes Valley, Western Valais), which includes a 267-282 Ma old ignimbrite (Bussy et al. 1996b), is exceptionally well preserved and provides information on the Permian environments deposited in the Penninic realm. The aim of this paper is to describe this stratigraphic unit in order to give a comparison tool for other Briançonnais Permian units within the Western Alps.

2. Geological setting

The lithostratigraphical unit names used in this work follow the new nomenclature approved by the Swiss Comity of Stratigraphy and published in the present volume by Sartori et al.

Within the Western Valais area, the remnants of the Briançonnais continental crust form two of the main middle Penninic units that constitute the Argand's «nappe du Grand St-Bernard» (Lugeon & Argand 1905, Escher 1988).

1) The external one is the Zone Houillère (Figure 1), which contains the Briançonnais coal measures of Namurian to middle Stephanian age, the middle Stephanian to Permian conglomeratic and volcanoclastic series including crystalline basement clasts and boulders (Desmons & Mercier 1993, Jongmans 1960). The Triassic cover contains the quartzites and conglomerates of the «Verrucano briançonnais» (Trümpy 1966) and the typical Middle Triassic platform-carbonate deposits. The Zone Houillère is divided into two tectonics parts, the external and the internal zones (Escher 1988).
2) The Siviez-Mischabel and Mont Fort nappes compose the internal part of the Grand St-Bernard "super-nappe" (Escher et al. 1988). In the Goli d'Aget area, the Lirec and Métailler Formations are the pre-Permian basements of the Siviez-Mischabel and of the Mont Fort nappes respectively. The Lirec Formation is dated by the intrusion of the 500 +3/-4 Ma old Mont Rogneux metagranite, correlated with the Thyon metagranite (Bussy et al. 1996a).

The Permian clastics and volcanoclastics series of the internal Briançonnais nappes differ from those of the Zone Houillère. In the external part of the Siviez-Mischabel nappe, the Col de Chassoure Formation (Sartori et al. 2006) is overturned and tectonically overlain by the basement (Lirec Formation; Figs. 1 and 2a).

Between the Lirec and Métailler Formations, a surprisingly well-preserved Early Permian stratigraphic series, the Goli d'Aget Member, occupies the hinge of a second phase syncline (Burri 1983) in the Mont Rogneux – Grand Laget area (Bagnes Valley). The best outcrops of this series are on the eastern side of the syncline where the series is overturned (Figure 2). This section, which also yielded samples of rhyolite for U-Pb analyses on zircons (Bussy et al. 1996b), is described below. This Permian series grades upward, in apparent continuity, into the "Verrucano Briançonnais" and into the Early Triassic quartzites and evaporites. The Goli d'Aget Member is part of the Permian Col de Chassoure Formation defined in Sartori et al. (2006).

3. The Goli d'Aget Member

3.1 Introduction

The 200 meters thick Goli d'Aget Member lays between the Mont Rogneux and the Grand Laget summits, on the western edge of the "Val de Bagnes" (Swiss topographic coordinates: 585.200/095.300). The Goli d'Aget Member is in tectonic contact along two post-nappe shear zones with the Métailler Formation in its internal part and with the Lirec Formation in its external part (Figure 2a). Previous geological and petrographic descriptions of the area have been provided by Schaer (1959), Burri (1983), Gouffon & Burri (1997).

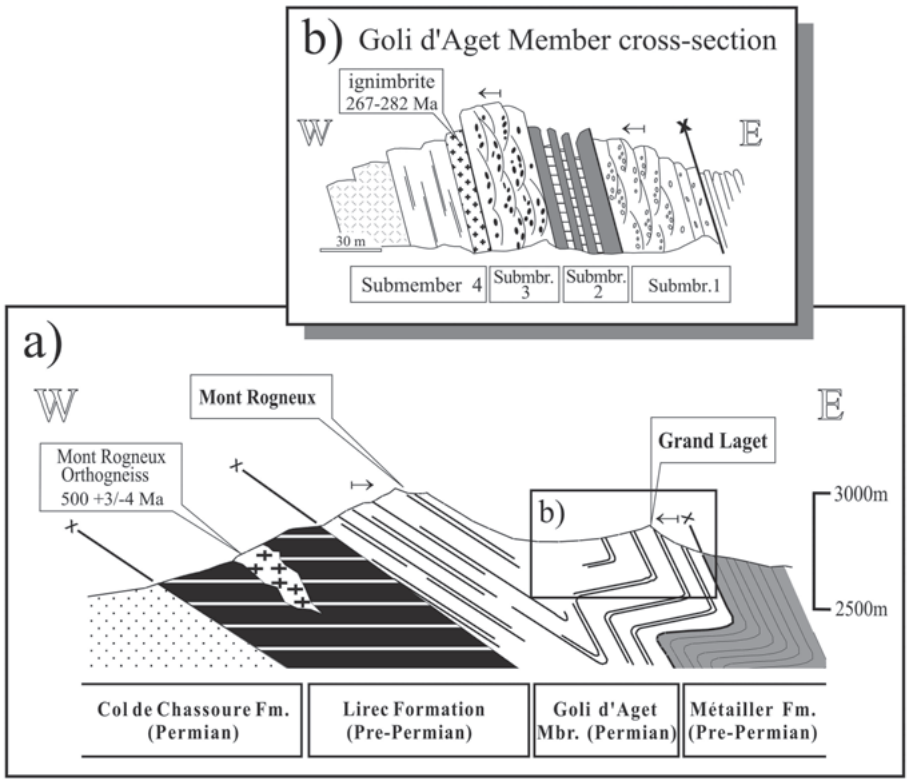

Fig. 2. a) Tectonic units of the "Grand Saint-Bernard nappe" (Briançonnais) in the area of Grand Laget and Mont Rogneux mountains. b) Schematic cross section of the Goli d'Aget Member. Four submembers are distinguished.

The alpine metamorphism grades into the greenschists facies and affects all the rock types. Numerous observations of thin sections and X-ray diffraction (XRD) analyses indicate that albite, chlorite, illite and quartz are the usual components of the rocks from the Goli d'Aget Member.

In this chapter, the characteristics of the sedimentary rocks are described first; descriptions of the mineralogy and the geochemistry of the ignimbritic rhyolite are given in the following section.

3.2 Lithostratigraphy

From field evidence, the Goli d'Aget Member can be divided into four submembers (Figure 2b). A description of the lithology and the environment of deposition are given below for each submember. The Figure 3 summarizes the observations and the interpretations.

a) Submember 1: conglomerates with pink quartz pebbles.

Millimetric and centimetric pebbles of white and pink quartz are incorporated into an arkosic-micaceous matrix. Numerous interlacing channels with graded beds are well preserved. The size of the grains and the thickness of the beds increase towards the top of the submember. Some beds are characterized by a high concentration of pebbles in their upper two third parts. They are interpreted as mudflow deposits. Less massive beds are fine-grained layers without pebbles. A darker arkosic bed in the middle of the submember is interpreted as volcanodetritic deposits.

The predominant channeling indicates a deposition in an alluvial plain, occasionally covered by mudflows, and a source of materials from crystalline rocks. The arkose layer indicates a volcanic activity.

b) Submember 2: massive carbonates, arkoses and shales.

Rusty carbonated beds (dolomite and ankerite), centimetric to decimetric, alternate with grey shales (white mica and albite). Mud-cracks and bioturbation traces are preserved on the surface of the grey shales, but no bioclasts were observed in these recrystallized rocks. Arkosic layers are frequent in the upper part of the submember. An important part of this detritic material is of volcanic origin and consists of tuff levels with porphyric quartz and plagioclases with a doleritic texture. Most layers have tens meters of lateral continuity and channeling has not been observed. A green centimetric phyllitic level marks the upper boundary of the submember and indicates the transition to another sedimentary environment.

The sediments of this submember are interpreted as deposits in a lacustrine environment with a shallow water depth (occasionally emergent) and an increasing contribution of volcanic material.

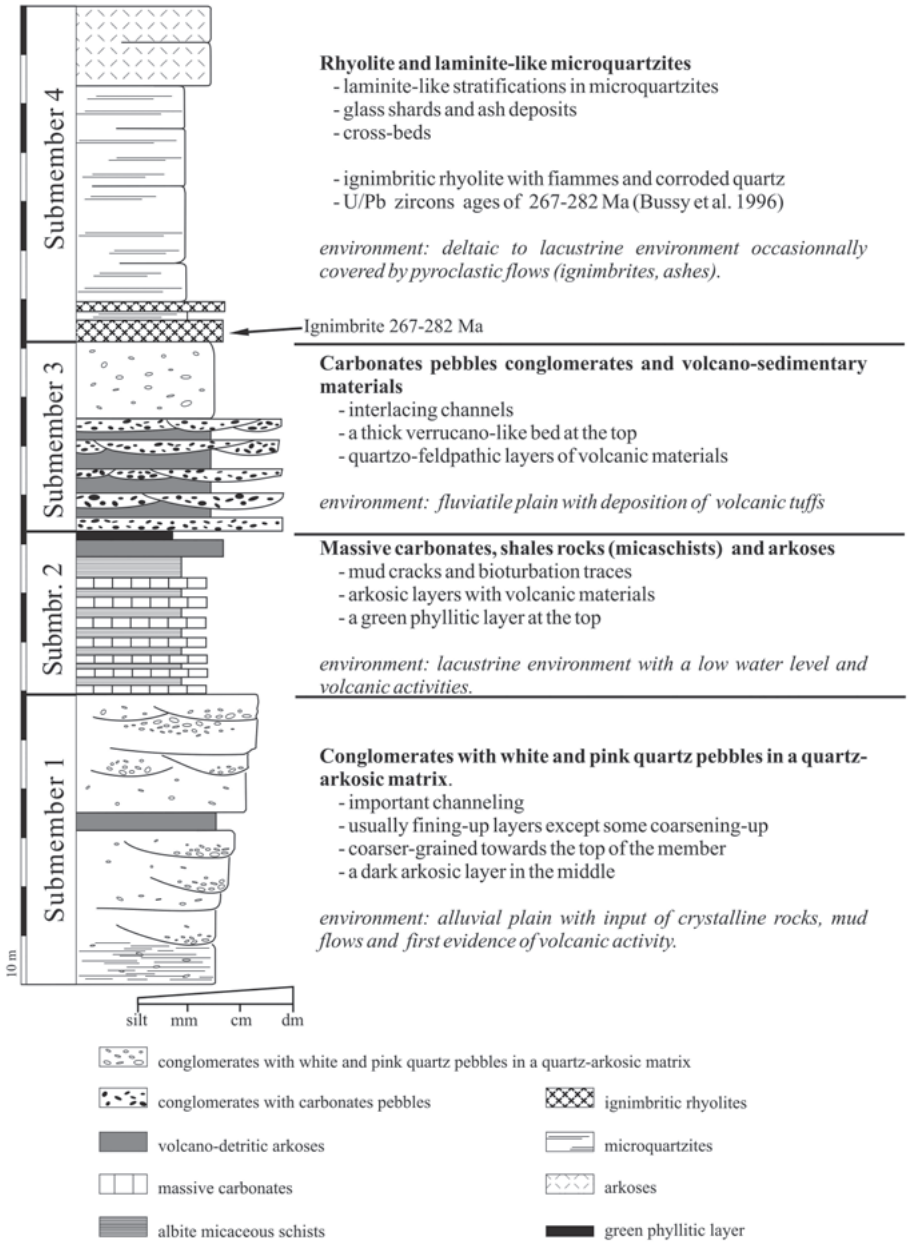

Fig. 3. Detailed stratigraphic log of the Goli d'Aget Member and interpretation of the environments of deposition. More accurate description of the lithology is in the text. The ignimbritic rhyolite lies at the bottom of the submember 4.

c) Submember 3: conglomerates with calcareous pebbles and volcano-sedimentary deposits (volcanic tuffs).

Channeling is important and the massive carbonates of the submember 2 are remobilized to form the pebbles (centimetric to decimetric) of a conglomerate with a silica rich matrix. A 30 m thick bed of greenish conglomerate lies at the top of the submember. Its abundant silica matrix contains pink quartz, white quartz and quartzo-feldspathic elements (Verrucano-like facies). Volcanic blocks (dacitic to rhyolitic), cross-stratifications and gulling figures are visible too.

In this fluviatile plain, the input of volcanic materials continues to increase towards the top of the submember with volcanic tuffs and Verrucano-like beds.

d) Submember 4: rhyolite and colored microquartzites.

The rhyolite is a white massive metric bed at the base of this submember. Its small lateral extension (about 20 m) is due to channel erosion. Rhyolitic pebbles are present in the microquartzites above. Corroded quartz and centimetric fiamme structures filled with mica point to an effusive mode of deposition (ignimbrite). A U-Pb dating from zircons indicates a Permian age of 267-282 Ma (Bussy et al. 1996b). One meter above

Table 1. Whole-rock major and trace elements of the Goli d'Aget rhyolite. Analyses done by X-Ray fluorescence at the Centre d'Analyse Minérale – University of Lausanne. FeO concentration has been measured by colorimetry and CO_2 by coulometry. H_2O concentration was determined from loss on ignition analyses (enclosed S, F, Cl in part). ld = limit of detection.

major elements (wt%)		trace elements (ppm)	
SiO_2	79.94	Nb	<ld
TiO_2	0.14	Zr	144
Al_2O_3	10.74	Y	37
Fe_2O_3	0.94	Sr	104
FeO	0.23	U	<ld
MnO	0.01	Rb	9
MgO	<ld	Th	6
CaO	0.84	Pb	<ld
Na_2O	6.27	Ga	9
K_2O	0.26	Zn	4
P_2O_5	0.03	Cu	<ld
H_2O	0.02	Ni	<ld
CO_2	0.73	Co	28
Cr_2O_3	<ld	Cr	<ld
NiO	<ld	V	<ld
		Ce	51
Total:	100.15	Nd	28
		Ba	<ld
		La	32
		S	<ld
		Hf	6

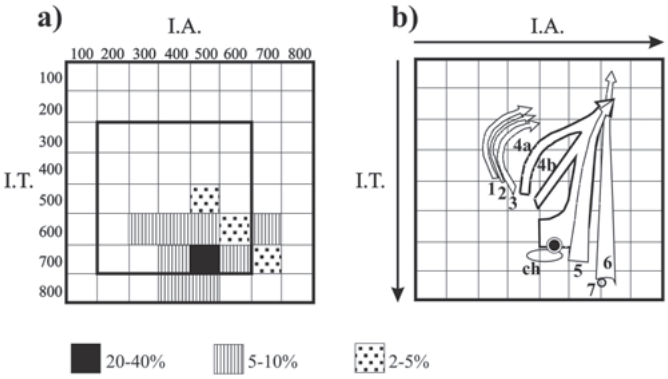

Fig. 4. Zircon typological diagram after Pupin (1980). a) Typological distribution of the Goli d'Aget rhyolite zircons in percent of zircons in each case, n=33. b) The white-rimmed black circle is the mean point (IA=494, IT=679) of the Goli d'Aget rhyolite zircons population. The different fields correspond to zircons from: (1) aluminous leucogranite, (2) (par)autochthonous monzogranites and granodiorites, (3) intrusive aluminous monzogranites and granodiorites, (4 a, b, c) calc-alkaline series granites, (5) sub-alkaline series granites, (6) alkaline series granites, (7) tholeiitic series granites, (ch) magmatic charnockites area.

the rhyolite lies a 30 cm thick tuff level including porphyric quartz, but without any observable fiamme structure. These volcanic layers are followed by about 40 m of microquartzites of various colors: usually white-green, sometimes grey, black or purple. These rocks are very fine grained except for some poorly rounded rhyolitic pebbles. The beds are continuous on tens of meters and have a laminite aspect. The part of volcanic materials is always very important and some glass shards are preserved. At the top of the submember, a coarser-grained arkose shows numerous cross-bedding figures.

The laminite-like succession of dark and clear levels is dominant in this submember. This millimetric to centimetric alternation could be due to the volcanic contributions (ash layers with preserved glass shards). These very fine-grained deposits and the continuity of the beds point to a low energy context of deposition: a deltaic to lacustrine environment occasionally covered by pyroclastic flows (ignimbrite, ashes).

3.3 The rhyolite of the Goli d'Aget Member

a) Mineralogy

Despite the metamorphic overprint, the rhyolite still shows a well-preserved microgranular porphyroidal texture and fiamme structures typical of an effusive mode of deposition (ignimbrite). The main components are millimetric phenocrysts of corroded quartz and albite in a microgranular matrix of quartz and albite (identified by XRD). Millimetric to centimetric fiammes are filled with white mica. Various accessory minerals are present: epidote, rutile, zircon, apatite and some gold spangles.

b) Geochemistry

Major and trace concentrations were determined using X-Ray Fluorescence (Table 1). The major elements show high silica content (about 80 wt% of SiO_2) for this rhyolite. Pearce et al. (1984) use Rb, Nb, Y and SiO_2 to discriminate the geodynamic context of granitoid settings: within-plate, ocean-ridge, syn-collisional, and volcanic-arc granites. Despite the high silica content and the low content in Nb, the rhyolite appears to be of a volcanic-arc granites origin (VAG).

c) Typology of zircons

The method of zircon typology (Pupin 1980, 1988) was applied to a population of 33 zircon crystals extracted from the rhyolite, using a SEM. The zircon crystals are colorless or pale pink, show a pronounced elongation, inclusions of opaque minerals and frequent tube-like "bubbles". In the Figure 4, the index of "agpaicity" (IA) describes the relative development of the {211} (low IA) and the {101} (high IA) pyramidal faces. The T index (IT), or index of temperature, describes the relative development of the {110} (low IT) and the {100} (high IT) prismatic faces. The distribution of the zircons from the rhyolite, of medium spreading type, is presented in the Figure 4a. Agpaicity and Temperature Indexes, after Pupin (1980), are respectively: IA=494 and IT=679. According to Pupin (1980), such morphology of zircons indicates a calc-alkaline magmatic series (Figure 4b). A U-Pb dating of these zircons provides a Permian age between 267 and 282 Ma (Bussy et al. 1996b).

4. Discussion

The Goli d'Aget Member can be followed towards the east in the same structural position, but underwent there stronger deformations. Its lithostratigraphic contents seem to be gradually dominated by volcanic tuffs.

The Col de Chassoure Formation situated in a more external position (Figure 1b) contains a facies succession very similar to that of the Goli d'Aget Member, however with a strong difference in thickness. Rusty carbonated beds alternating with grey to greenisch shales can be observed localy near the stratigraphic top of this external Col de Chassoure Formation, and are reworked in overlying polygenic conglomerates. Sedimentary structures are not well preserved in this structural position. Although both map units are folded by the alpine deformations and cut by post-nappe shear zones, they are clearly associated with the pre-Permian Briançonnais basement and not with the Zone Houillère, which bears its own Stephano-Permian and Verrucano series. The Randa granite (269±2 Ma) seems to intrude the eastward equivalent of the Col de Chassoure Formation (Mossalp Series of Thélin 1987), but this relationship is still equivocal.

The Goli d'Aget Member also shows a striking similarity with the Roche-Château and Rochachille Series lying tectonically on the Zone Houillère north of Briançon (Fabre et al. 1982, Figure 1a). Coarse conglomerates predominate in the basal Roche-Château Series. The following one, the Rochachille Series, is an alternation of red or green cineritic shales, sandstones, dolomites and ignimbrites. Unconformities are widespread within the series and emphasized by dolomitic pebbles conglomerates. The last conglomeratic sequence, the Poussenot Series, is overlain by the Verrucano green shales and conglomerates. Except for the missing variegated microquartzites, these rock types are very similar to those of the Goli d'Aget Member and form a succession of comparable thickness. The ignimbrites in the middle of the Rochachille Series are of andesitic composition but have not yet been dated. An Early Permian age is considered to be very likely for these detritic and volcanic deposits (Fabre et al. 1982). The Goli d'Aget and the Rochachille Series have been probably deposited in similar Permian basins, but, contrary to the Goli d'Aget Member, the pre-Namurian basement of the Zone Houillère is still unknown.

Comparisons with the Briançonnais Ligurian units are more difficult because of the tectonic imbrications observed in this region and because of the predominance of volcanic units within the presumed Permian units. Similarities between the Goli d'Aget Member and the Melogno porphyroids have been noted: a thick accumulation of rhyolitic-dacitic ignimbrites and some associated rock types such as variegated pyroclastic deposits, black ashes and carbonates beds (Cortesogno et al. 1993). This series is assumed to be of Early Permian age and lays either on Late Carboniferous detritics and volcanics similar to the Zone Houillère or directly on a pre-Namurian basement.

5. Conclusions

The Briançonnais Goli d'Aget Member consists of Early Permian (to Late Permian?) continental detritic and volcanic deposits. Numerous sedimentary structures are particularly well preserved and provide important information on the environments of deposition: 1) an alluvial plain, 2) a shallow lake, 3) a fluviatile plain, 4) a lacustrine delta. In this series, an ignimbritic rhyolite, with a volcanic-arc (VAG) and a calc-alkaline affinity, is late Early Permian (267-280 Ma). The Goli d'Aget Member appears to be an excellent reference to investigate the other Permian units in the Penninic Western Alps.

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