Weathering of granitic rocks in the Alps : preliminary results from orthgneiss associated with the Randa rockfall (Matter Valley, Valais, Swizerland)

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Weathering of granitic rocks in the Alps: preliminary results from orthogneiss associated with the Randa rockfall (Matter Valley, Valais, Switzerland)*

by *François Girod*[1] and *Philippe Thélin*[1]

Abstract

Preliminary data about mineralogical aspects of the alteration-weathering effects affecting the Randa orthogneiss are presented. Despite the cold-temperate climate of the Alps, phenomena as dissolution, transformation and neoformation might be documented in the matrix of the rock as well as along discontinuities.

Keywords: orthogneiss, weathering, rockfall, SEM images, smectite, Randa, Switzerland.

Introduction

Whereas most studies related to rock or mineral weathering concern pedogenesis in tropical and temperate climates, this study is focused on the weathering of a gneiss in an Alpine climate (1000 to 2000 meters above sea level). The study of the Randa orthogneiss is particularly interesting given the huge rockfall ($30 \times 10^6 m^3$, Fig. 1) which occurred in spring 1991. According to SCHINDLER et al. (1993), the causes of the unstability that led to the collapse of the cliff are: at one hand the polyhedral decomposition of the rocks during the late phase of the Alpine orogeny and, on the other hand, an opening of fractures due to stress release effective up to a depth of 200 meters. The opening of the fractures allowed groundwater to penetrate in the rock and weathering to progress.

The aim of this study is to understand the weathering processes that alter the gneiss and to build up a mineralogical weathering sequence. In order to do so, rock samples and secondary products (surface, fissure deposits) are analyzed mainly by X-ray diffraction (XRD), infrared spectroscopy (FT-IR) and scanning electron microscopy combined with an energy dispersive spectrometer (SEM/EDS). Still in progress is the study of the porosity of the rock and its permeability and it is carried out by image analyzes associated with physical measurements in accord to SARDINI et al. (1996). Engineering measurements have been carried out on two characteristic facies of the gneiss in order to find out, as shown by BAUDRACCO et al. (1982), whether the mechanical properties of the rock have been diminished by the weathering.

Geological setting

The orthogneiss or the so-called Randa augen gneiss (RA) is a subalkaline porphyritic granite, Permian in age (U/Pb zircon age: 270 Ma according to BUSSY et al., 1996) metamorphosed during the Alpine Tertiary event in the upper greenschist facies (BEARTH, 1961; BEARTH, 1964; THÉLIN, 1983; THÉLIN, 1987). Culmination ages of metamorphism and cooling history are given by STECK and HUNZIKER (1994, Fig. 2) and MARKLEY et al. (in press).

The RA outcrops in the inverted limb of the eastern part of the Siviez-Mischabel fold-nappe in the Middle Penninic domain (THÉLIN et al., 1993). The RA bedding (mainly due to a first order schis-

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tosity) generally dips 20° to 30° to the West (Fig. 3). This unit is characteristic of the sharpest reliefs on the left side of the Mattervalley, downstream the village Randa (alt. ~1400 m.). The morphology of this valley is typical of Quaternary glacier retreat; it is the deepest and longest valley lateral to the large Rhône Valley. According to the Swiss Institute of Meteorology, at the bottom of this valley the average annual rainfall is between 600 and 800 mm/year and at the top of the adjacent montains, between 2400 and 3600 mm/year. The temperature can vary between –10 to 30 °C with an average of about 4 °C. As a consequence of the large amount of precipitation, there is a strong drainage by meteoritic waters.

The Randa orthogneiss

The lithologic facies of the RA varies from place to place; most representative is an augen gneiss. The large pale crystals of this augen gneiss (phenoclasts of 1 to 10 cm in size) are mostly K and Na feldspar (originally: perthitic orthoclase/microcline transformed by metamorphism and cataclasis to chess-board albite) embedded in a coarse grained (Ø 0.3–1 cm) quartzo-micaceous matrix. The gneiss can also be homogeneously fine-grained or mylonitic; it may contain some concordant fine quartz lodes too. In certain cases cataclasis may lead to mechanical layering.

The essential minerals of this rock are 30% quartz; 10–15% microcline; 45–50% albite; 10–15% white micas (mostly phengite and primary muscovite). The main accessory minerals are chlorite, calcite, green biotite, epidote, zircon, sphene, apatite, pyrite and garnet. There is no significant chemical difference between fine grained gneiss and coarse grained gneiss (augen gneiss). For further informations on petrological aspects of RA, see the more detailed work of THÉLIN (1983, 1987).

Weathering of the gneiss

According to CARROLL (1970), YATSU (1988), SELBY (1993) or RIGHI and MEUNIER (1995), the weathering of a rock can be summarized as a sequence of physical and chemical processes. The RA body has undergone both. The primary weathering process is a physical one in which the fracturation of the rock takes place on the hectometer as well as on the micrometer scale. On the other hand post orogenic fracturation (faults, joints, cracks) is associated with Quaternary stress release phenomena (opening of fractures and appearance of new joints parallel to the topography). Bigger fractures allow meteoric waters to penetrate deep in the RA body while smaller ones (microcracks) let fluids run through the rock. The secondary chemical weathering process depends

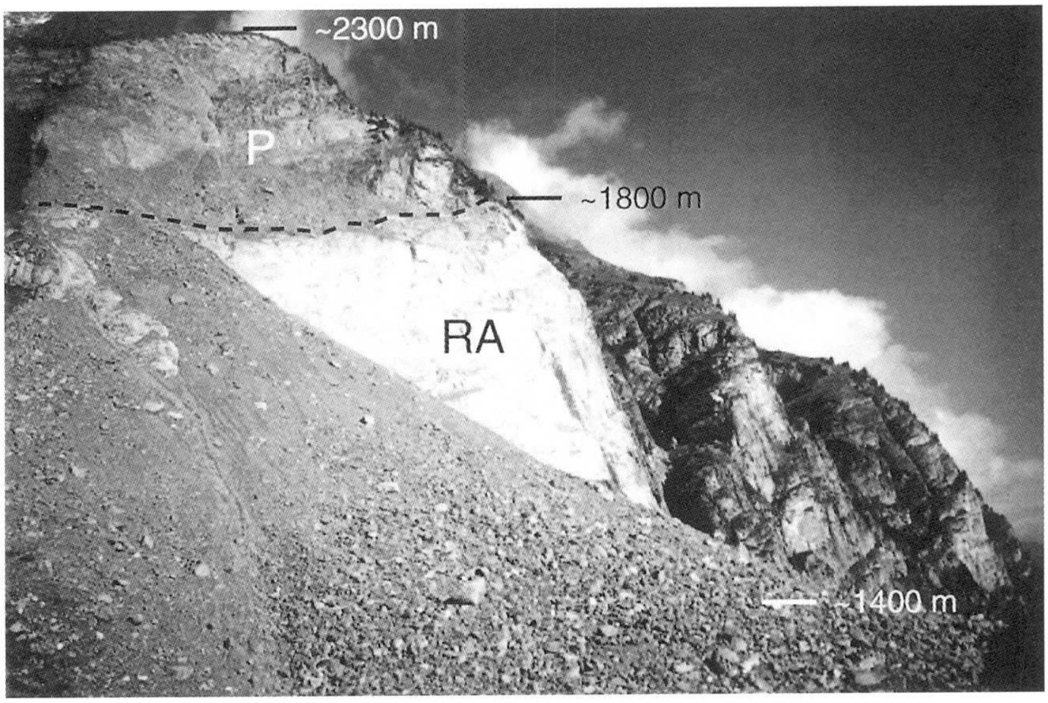

Fig. 1 The Randa rockfall: upper contact with the paragneisses (P) of the Ergischhorn polycyclic basement (Siviez-Mischabel nappe) and the Randa Augen gneiss (RA). Altitudes in meters above sea level.

on the initial porosity and permeability of the rock. During fluid percolation, mineral grains undergo pitting, etching and cracking which increases the porosity of the rock.

Observations

The site of the rockfall (Fig. 3), especially the scar and the tunnel in the RA body give a good opportunity to carry out a complete sampling of the rock and its secondary products. Sampling and observations of the superficial meteoric weathering have been carried out elsewhere in the valley as well.

Field observations:

• in the tear off area: large trails of dark red to black deposits (iron oxydes probably produced by pyrite oxydation) (Fig. 4a)

• large elongated pores (several mm to several cm in length) containing a significant amount of calcite associated with iron oxi-hydroxides (Fig. 4b)

• in the tunnel, intense fracturation of the RA: some fractures are filled either with fine material and may contain little water

• downstream of the village Randa (e.g. near St. Niklaus): most of the open fractures parallel to the steep flank side of the valley (mainly stress release joints) may contain very little material (powder containing mostly mica, chlorite, quartz and feldspar grains)

Microscopic observations and SEM/EDX analyses :

• heterogeneous micro to macro-porosity (pore Ø ranges from several cm to several µm) (Fig. 5a)

• the porosity is intragranular in feldspars (phenoclasts) and intergranular between feldspar, quartz and mica (phengite)

• feldspar and quartz surfaces are often covered with etch pits (Figs 5 b, c, d)

• Mn and Fe rich thin fibers (< 1 µm) or small pellets (1–10 µm) are to be found on feldspar or pitted quartz surfaces (Fig. 5b)

• dioctahedral smectite is located in the pore of some feldspar grains (Fig. 5e)

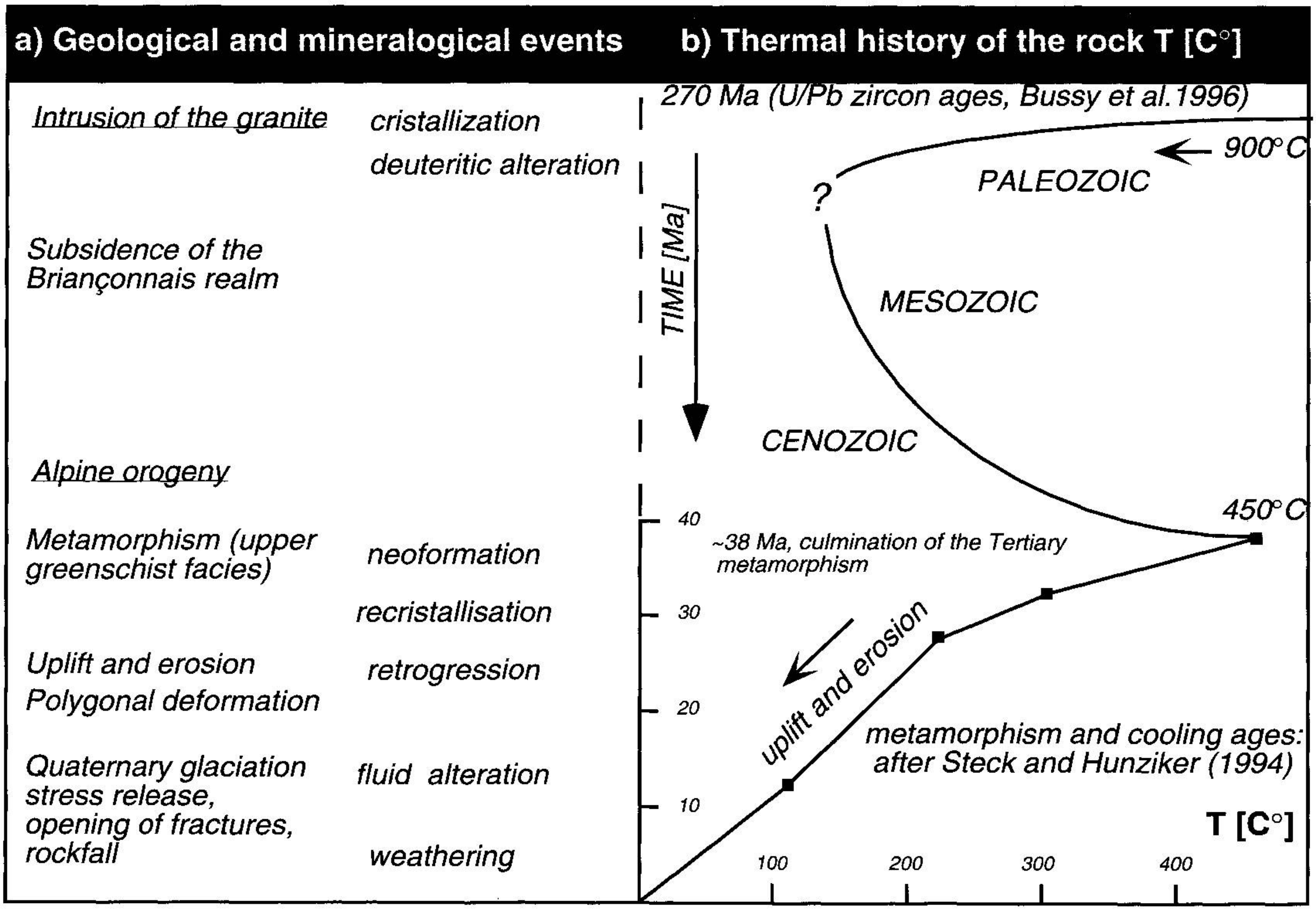

Fig. 2 Synoptic scheme of the main postulated geological and mineralogical events related to the RA, ages according to STECK and HUNZIKER (1994) and BUSSY et al. (1996).

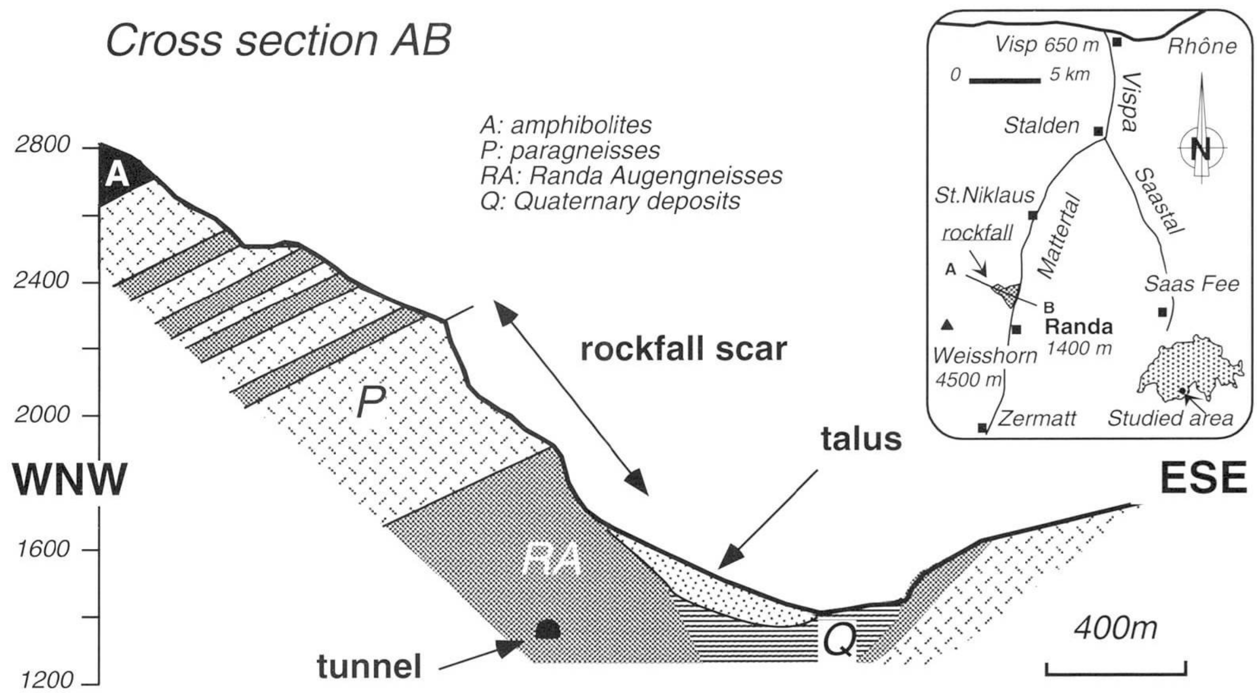

Fig. 3 Cross section at the Randa rockfall and location of the studied area. For more details about cross sections of the rockfall, see figure 3 from SCHINDLER et al. (1993).

• residue of calcite grains are often found within some pores or microfractures (Fig. 5f) thin

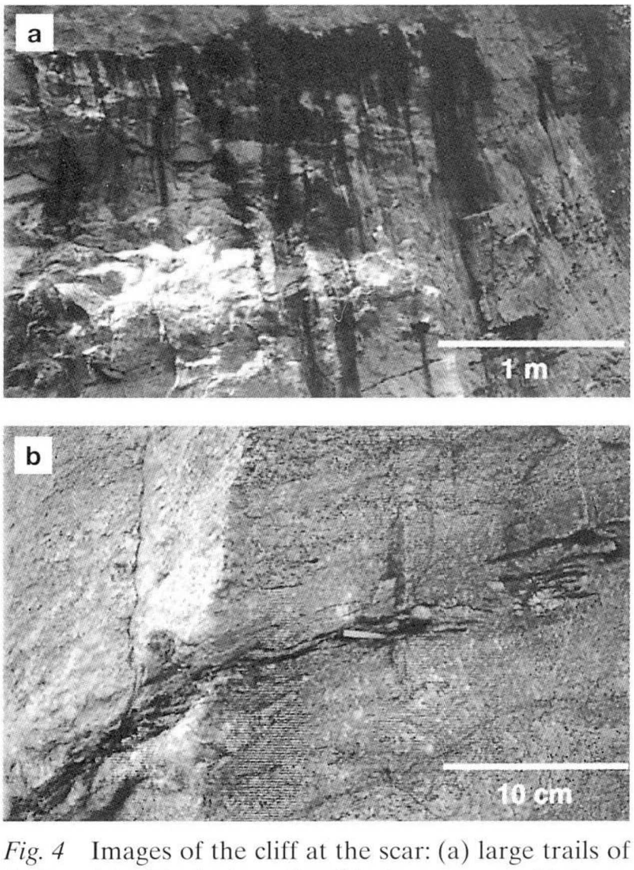

Fig. 4 Images of the cliff at the scar: (a) large trails of dark red to black deposits: (b) shear zone with large elongated pores.

echelon veins (millimetric to centimetric) are filled with Fe-hydroxides such as goethite, sometimes associated with calcite and chlorite

XRD analyses:

• complex intergrade clay minerals such as chlorite/smectite and smectite associated with pure chlorite and micas are to be found at the interface between rock and immature soils

• chlorite, mica, quartz and albite constitue most of the clay fraction ($< 2\ \mu$) of the powder located on the surface of the rock

• pure smectite associated with chlorite and mica is to be found in material of several fissures in the tunnel

Rock mechanic measurements:

• uniaxial unconfined compressive strength of the coarse grained gneiss ranges between 80 to 180 Mpa

• uniaxial unconfined compressive strength of the fine grained gneiss ranges between 70 to 100 Mpa.

Preliminary interpretation

The results clearly show that physical and chemical weathering is continuously altering the RA. It is nevertheless probable that hydrothermal fluids of post to late metamorphic origin have also contributed to the alteration of the RA lithology and of the country rock. According to SELBY (1993),

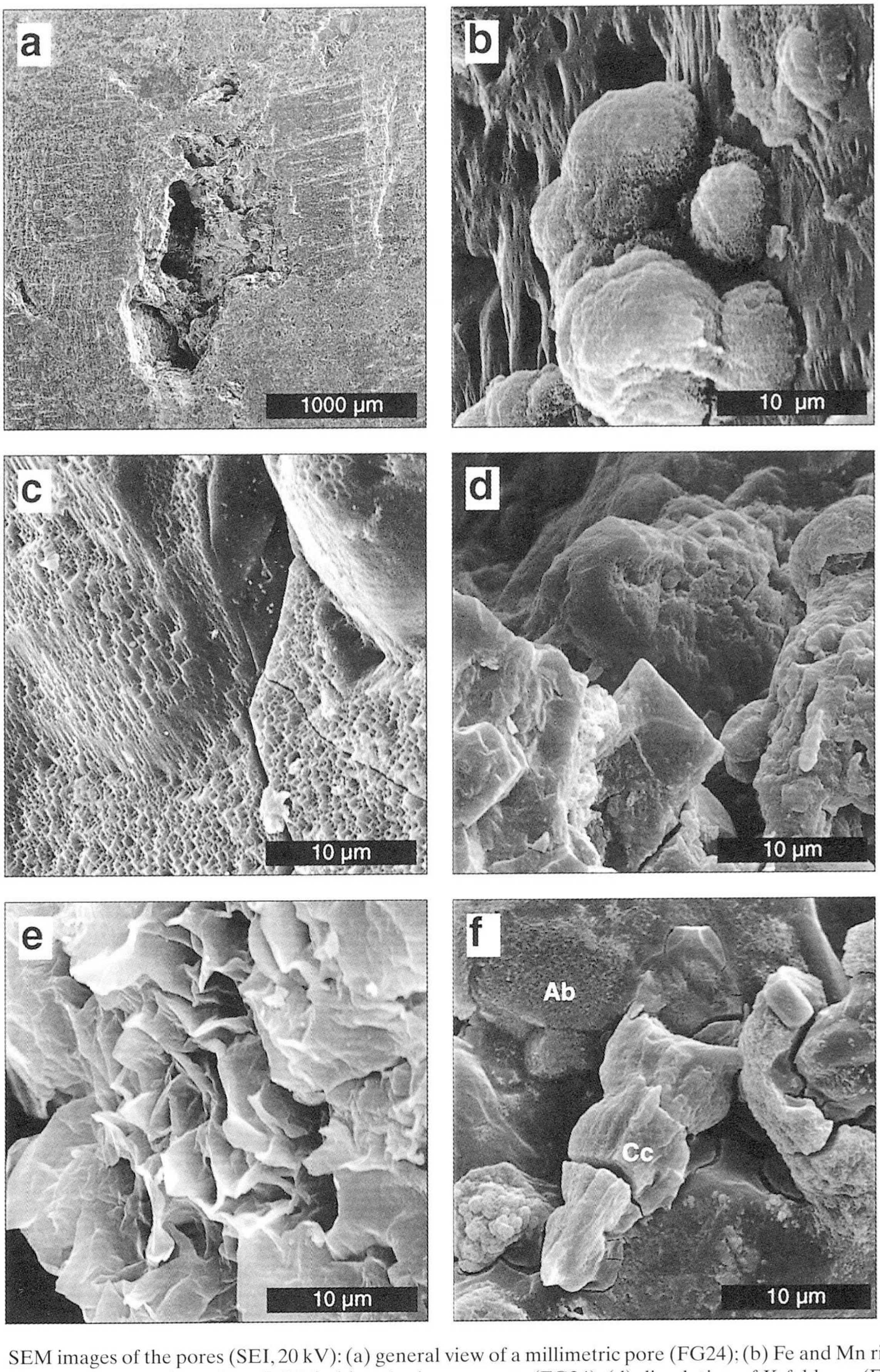

Fig. 5 SEM images of the pores (SEI, 20 kV): (a) general view of a millimetric pore (FG24); (b) Fe and Mn rich pellets on a pitted quartz grain surface (FG24); (c) etch pits on quartz (FG24); (d) dissolution of K-feldspar (FG130); (e) smectite in K-feldspar (FG19); (f) residue of calcite grains on a feldspar surface (Cc: calcite; Ab: albite; FG130).

the end-products of meteoric weathering and hydrothermal alteration may be similar. It is therefore difficult to find out from what kind of fluid originate secondary Fe and Mn rich pellets, smectite and the partial dissolution of quartz, feldspar (albite and K-feldspar) and calcite grains (cf. Fig. 5). It is still possible that both types of fluids have altered the gneiss. If any hydrothermal fluid alteration should have occured (possibly after the retrogression of regional metamorphism, cf. Fig. 2), porosity may actually be increased by meteoric fluid percolation. The complex multiscale fracturation of the RA body seems to control main fluid flow paths through the rock but, as shown by MEUNIER and VELDE (1979), fluids also flow through the rock along intergranular joints, intragranular microcracks and microfissures thus developing several types of weathering microsystems which depend on the dimensions and the interconnection of voids.

Although the macroporosity can locally be very important, the average porosity of the RA does not seem to have been increased enough so as to decrease significantly the mechanical properties of the rock: the data of the mechanical measurements on the most representative facies reveal that it remains in the high strength field of gneiss (BELL, 1993).

Mineralogical analyses of the fault gouge reveal that the smectite is to be found alongside with chlorite, quartz, feldspar, and mica grains (mostly phengite). As shown by SCHINDLER et al. (1993), the fine material content of the fractures associated with the high water-table level may influence drastically the stability of the cliff, especially if some swelling clay minerals are present. Our SEM observations show that smectite was formed within the RA body.

The clay minerals of the soil-rock interface are either be part of the weathering sequence of the minerals of the gneiss or they are associated with weathering of allochthonous minerals. The steep topography of this region does not let any continous weathering sequence to be formed and therefore no relation can be established between the bottom rock and the associated soils or deposits.

Acknowledgement

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References

BAUDRACCO, J., BELL, M. and PERAMI, R. (1982): Effets de l'altération sur quelques propriétés mécaniques du granite du Sidobre (France). Bull. Int. Assoc. Engin. Geol. 25, 33–38.

BEARTH, P. (1961): Contribution à la subdivision tectonique et stratigraphique de la nappe du Grand-Saint-Bernard. In: A la mémoire de P. Fallot (ed. S. G. d. France) Vol. 2, 407–418.

BEARTH, P. (1964): Randa, Blatt 43. Schweiz. Geol. Komm.

BELL, F.G. (1993): Engineering Geology. Blackwell Scientific Publications, 359 pp.

BUSSY, F., SARTORI, M. and THÉLIN, P. (1996): U–Pb zircon dating in the middle Penninic basement of the Western Alps (Valais, Switzerland). Schweiz. Mineral. Petrogr. Mitt. 76, 81–84.

CARROLL, D. (1970): Rock Weathering. Plenum Press, 203 pp.

MARKLEY, M.J., TESSIER, C., COSCA, M.A., CABY, R., HUNZIKER, J.C. and SARTORI, M. (in press): Alpine deformation and $^{40}Ar/^{39}Ar$ geochronology of synkinematic white micas in the Siviez-Mischabel Nappe, western Penninic Alps, Switzerland. Tectonics.

MEUNIER, A. and VELDE, B. (1979): Weathering mineral facies in altered granite: the importance of local small scale equilibria. Min. Mag. 43, 261–268.

RIGHI, D. and MEUNIER, A. (1995): Origin of Clays by Rock Weathering and Soil Formation. In: VELDE, B. (ed.): Origin and Mineralogy of Clays (Springer Verlag, 43–161.

SARDINI, P., LEDÉSERT, B. and TOUCHARD, G. (1996): Quantification of microscopic networks by image analysis and measurement of the permeability of Soultz-sous-Forêts granite (Alsace, France). In Fluid Flow and Transport in Rocks (Conference Volume of the 9th Krongsberg Seminar, 3–5 mai 1995), CHAPMAN et al., 171–189.

SCHINDLER, C., CUENOD, Y., EISENLOHR, T. and JORIS, C.L. (1993): Die Ereignisse vom 18. April und 9. Mai 1991 bei Randa (VS); ein atypischer Bergsturz in Raten. Eclogae geol. Helv. 86 (3), 643–665.

SELBY, M.J. (1993): Hillslope Materials and Processes. Oxford University Press, 451 pp.

STECK, A. and HUNZIKER, J. (1994): The Tertiary structural and thermal evolution of the Central Alps – compressional and extensional structures in an orogenic belt. Tectonophysics 238, 1–26.

THÉLIN, PH. (1983): Les gneiss œillés de la nappe du Grand Saint-Bernard: essai d'évaluation des critères susceptibles d'en préciser l'hérédité pré-métamorphique (Alpes valaisannes, Valais, Suisse), Thèse Uni. Lausanne (unpublished), 485 pp.

THÉLIN, P. (1987): Nature originelle des gneiss œillés de Randa (Nappe de Siviez-Mischabel, Valais). Bull. Géol. Lausanne 290, 75.

THÉLIN, PH., SARTORI, M., BURRI, M., GOUFFON, Y. and CHESSEX, R. (1993): The Pre-Alpine Basement of the Briançonnais (Wallis, Switzerland). In: VON RAUMER, J.F. and NEUBAUER, F. (eds): The pre-Mesozoic Geology in the Alps, 297–315. Springer-Verlag.

YATSU, E. (1988): The nature of weathering. Sozosha. 624 pp.

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