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Peraluminous rocks of Bou-Azzer region (Morocco): Geology and firing transformations

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ABSTRACT

The general geology of the peraluminous rocks of the Bou-Azzer region (Central Anti-Atlas, Morocco) and their firing transformations were investigated by several techniques: optical microscopy, microprobe analysis, X-ray diffraction (XRD), X-ray fluorescence (XRF), thermal analysis, scanning electron microscope (SEM), energy dispersive spectrometry (EDS), and by measuring selected physical properties. The results of the geological study show that these rocks consist mainly of a quartz–pyrophyllite assemblage (70–74 wt.% SiO_2 and 14–17 wt.% Al_2O_3), associated with minor amounts of muscovite and nacrite. They formed from a progressive deformation and hydrothermal alteration of felsic volcanic rocks. The principal mineralogical transformations recorded from rhyodacite to peraluminuous rocks are: K-feldspar → muscovite → pyrophyllite. Regarding the firing transformations, it is found that up to about 1100 °C the rock samples are subjected to expansion associated with the destruction of the pyrophyllite hydroxyl framework. The estimated amount of energy associated with this process is 50.226 kJ/mol. Beyond 1100 °C, a marked shrinkage was observed, due to the formation of a glassy phase, and the precipitation of mullite, cristobalite and K-feldspar. The reaction pathways for these phases are proposed and the evolved heat is determined (−160.928 kJ/mol).

1. Introduction

Because of its mining importance (Cu, Co, Au, Ag...), the Bou Azzer-El Graa inlier (Anti-Atlas, Morocco) has been the subject of several studies dealing with geology, mineralogy and metallogeny (e.g. Leblanc and Billaud, 1978; Leblanc and Lancelot, 1980; Thomas et al., 2004; Gasquet et al., 2005). Though the exploration for metals has received a great interest, little attention has been paid to other minerals of this area (Caïa et al., 1968; Nataf, 1968; Leblanc, 1970). A recent geological study related to the Bou-Azzer El Graa revealed the presence of a large Neoproterozoic tectonic zone, marked by significant concentrations of peraluminous material (Berrada et al., 2006), which could be of mining interest. It is the objective of this study to describe the general geology of these peraluminous rocks and transformations that take place on heating to ⩾900 °C. For the first goal, lithological and mineralogical studies were carried out to identify the principal reactions involved in their formation.

Regarding the second aim, the microstructure of rock samples, fired at different temperatures, was investigated and some of their ceramic characteristics were determined.

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2. Geology

The study area is situated in the eastern part of the Bou-Azzer El Graa Inlier, is bordered to the North by the NW–SE major Anti-Atlas tectonic fault and belongs to the lower Neoproterozoic ophiolitic complex (Leblanc and Lancelot, 1980; Thomas et al., 2004). It outcrops as a 10–60 m wide discontinuous elevated white crest (Fig. 1a), extending over 2 km in EW direction. This crest consists of a rhythmic succession of bimodal lava flows, crystal tufs, epiclastics and carbonates layers. The acidic lavas, which represent the dominant volcanic lithology, are transected by numerous quartz veins, running parallel to the main schistosity. The latter volcano sedimentary succession is overlain by the upper Neoproterozoic Ouarzazate formation (Tekiout, 1991). The peraluminous zone and its surrounding rocks are associated with a large and continuous EW ductile shear zone, marked by an intensification of strain, with S_1 and S_2 schistosities, asymmetrical folds and deformed quartz veins.

2.1. Lithofacies

At the outcrop scale, the peraluminous rocks exhibit a clear mineralogical zonation across the crest. The white core (Fig. 1b), which is highly deformed and altered, is composed of pyrophyllite and quartz, while the outer zones also contains mottles of hematite.

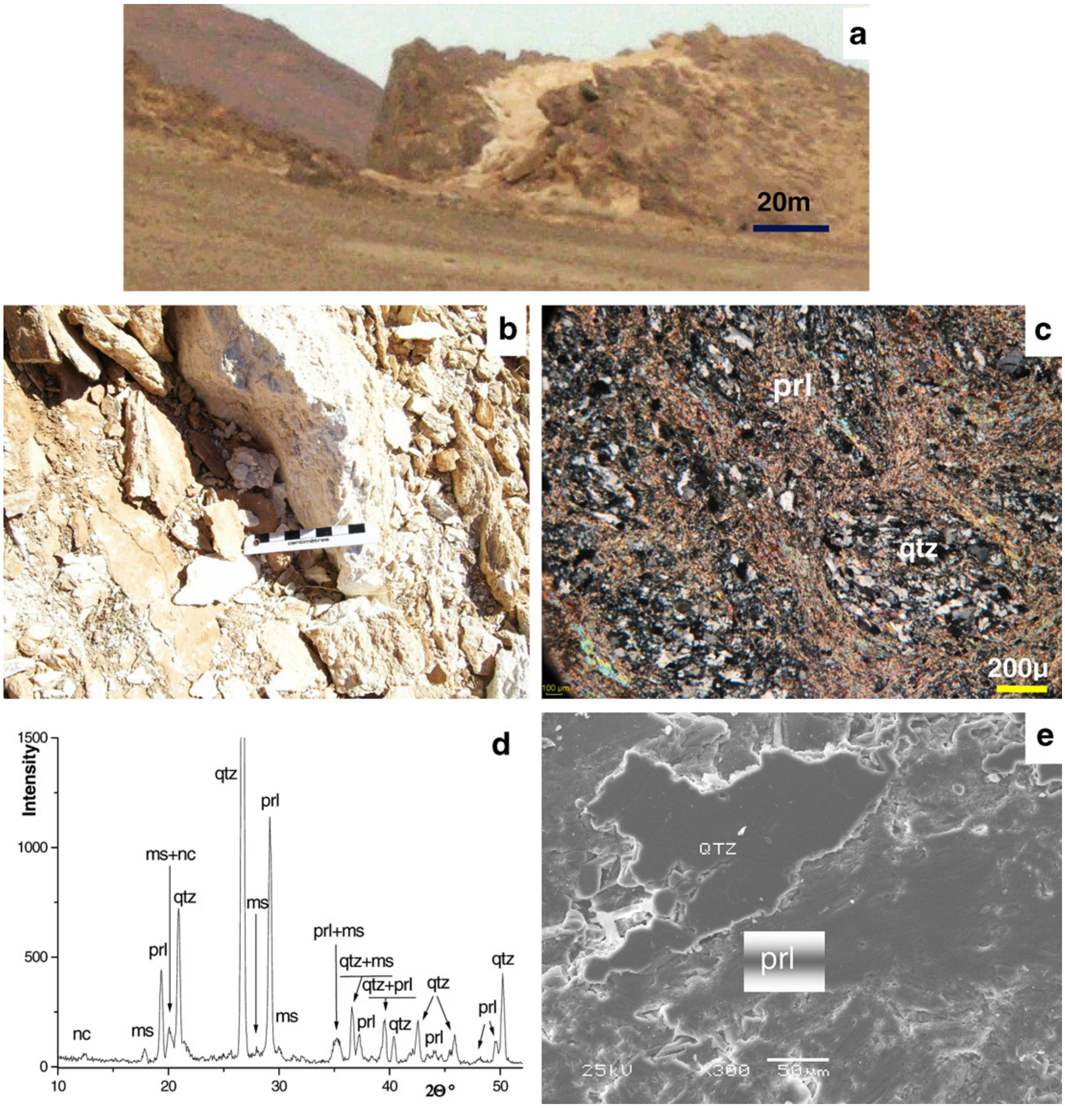

Fig. 1. (a) Photograph showing the peraluminous rocks crop out as a clustered and elongated white crest. (b) Macroscopic white and soft feature of the peraluminous core. (c) Microphotograph of the peraluminous rocks presenting an anastomosed quartz–pyrophyllite assemblage (symbols: prl = pyrophyllite; qtz = quartz). (d) XRD pattern of the pyrophyllitic rock (nc = nacrite; ms = muscovite; prl = pyrophyllite; qtz = quartz). (e) SEM image of peraluminous sample showing texture of the principal phases.

The adjacent host rocks are least deformed and consists of altered rhyodacite (lava and volcanoclastics) intercalated with small mafic volcanic sills. The observed gradual changes suggest that the peraluminous rocks originated from intense hydrothermal alteration and deformation of the rhyodacite.

2.2. Mineralogy

2.2.1. Host rocks

The weakly deformed, light-colored felsic volcanic host rocks have a rhyodacitic composition (66–71% of SiO_2; Table 1). In thin sections, the rocks exhibit a microlitic porphyritic texture, with fractured quartz and plagioclase phenocrysts. The matrix is composed by stretched microcrystalline quartz within the S_1 plans, muscovite, plagioclase laths, minor chlorites and iron oxides.

2.2.2. Peraluminous rocks

These rocks considered as the ore zone (40–60% of pyrophyllite), appear as 5–15 m wide lenses (Fig. 1b), along shear strike. They grade into the least altered rhyodacite by a lateral lithofacies, which contains less pyrophyllite.

Table 1
Chemical analyses of the least altered rhyodacite (LaRD) and peraluminous equivalent rocks (PrRock)

Sample	SiO_2	Na_2O	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	MnO	TiO_2	P_2O_5	LOI	S	Total	Nb	Y	Zn	Zr
	wt.%													ppm			
LaRD	66.73	3.85	12.58	3.09	3.34	2.56	0.86	0.14	0.45	0.15	3.43	0.03	97.21	21	16	89	171
PrRock	78.14	0.10	13.76	0.21	0.41	<0.1	<0.1	<0.01	0.4	0.07	2.61	0.04	95.94	21	17	38	179

Fe_2O_3 expresses total iron.