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Weathering of leucite to clay minerals in tephrites of the Vico volcano

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ABSTRACT — The weathering of leucite has been studied in tephrites of the Vico volcano. The petrography was made on undisturbed samples by optic and scanning electron microscopy with microprobe analysis. We follow a weathering sequence of leucite crystals from a core of lava to a first altered cortex and then in sandy and clayey arene of weathering. Then we compare the alteration in the B and A horizons of an overlying andosol, deriving from tephrite pyroclasts under a perhumid climate. We can observe also the leucite alteration in a «petrisco» (leucotephrite) under a xeric climate. The clay minerals composition was obtained from a powder of whole material and the less 2 μm fraction, by X Ray diffraction and TEM. The alteration of leucite to analcime in the first cortex is inherited from a former hydrothermal process. While clay minerals are forming by further weathering in relation with drainage intensity, e.g.: allophane and imogolite in andosols under perhumid climate and with high drainage; halloysite under less humid climate or with slower drainage.

Key words: Leucite, Weathering, Analcime, Allophane, Imogolite, Halloysite, Vico-volcano.

Introduction

A. Cundari and G. Graziani (1964) studied first the weathering products of leucite in the tephrites (leucotephrites and petrischi = acid leucotephrites) of the Vico volcano. They showed that leucite is generally altered into analcime, or eventually to kaolinite (probably halloysite after new investigation) and allophane. E. Azzaro and al. (1976) studied later the alteration processes of leucite in the volcanic tuffs of Bracciano. They observed the formation of analcime when the original features of tuff are remaining, whereas 10 Å halloysite appears in an incoherent and more altered tuff.

On the impulse of L. Lulli and D. Bidini we made a study of soils on the volcano of Vico (Bidini and al. 1984; Lulli and al. 1986, and 1988). P. Quantin and P. Lorenzoni (1980) made especially studies of mineralogy and micromorphology. We have namely observed the alteration of phenocrysts and volcanic glasses in various parent materials (ignimbrites, tuffs and leucotephrites), according either to their situation in a «climotoposequence» or to the either loose or cemented texture of rock.

Leucite is abundant in tephritic lava flows or ash falls in and around the caldera. The old leucotephrites are strong-

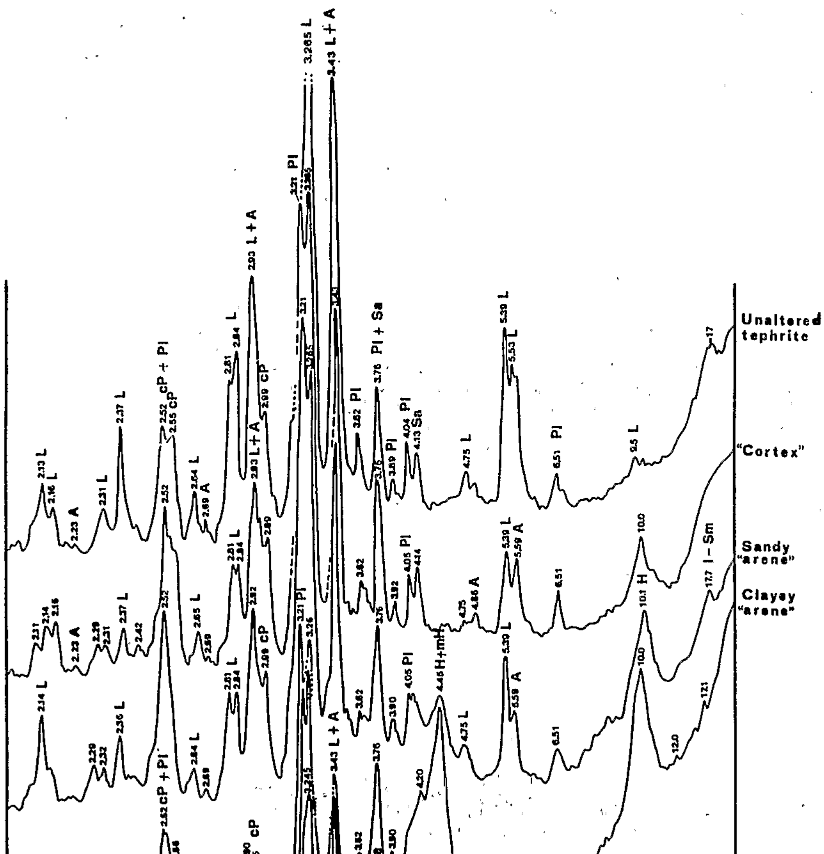

Fig. 1 - XRD on whole powder of «arene» and andisol horizons. A analcime; I-Sm interstratified; L leucite; cP augite; Sa sanidine; Pl plagioclase.

ly weathered at the soil bottom, under either the form of «petrisco» (altered acid leucotephrite) on the outer piedmont of the volcano, or the form of «arene» on the upper edge of the caldera. The aim of this paper is to show some features of leucite alteration in the «arene» or in the «petrisco» substratum and in an andisol as well.

Materials and methods

Material

The weathering of leucite has been ob-

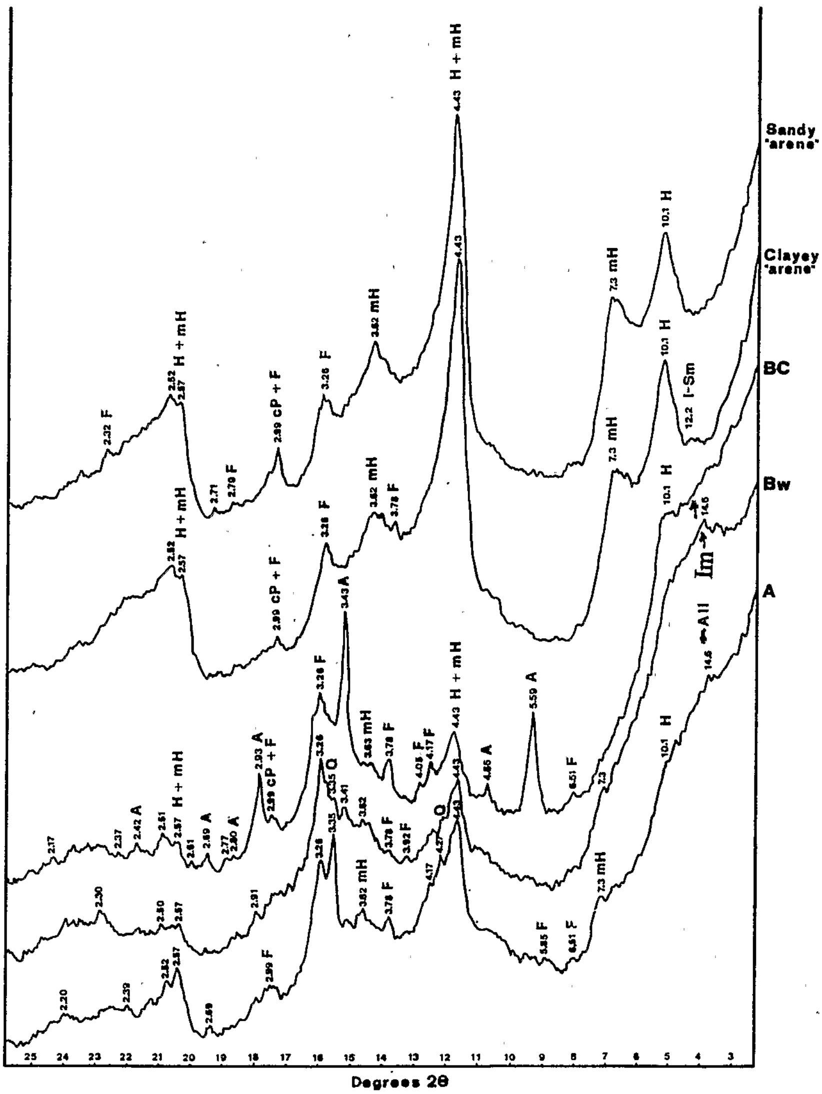

Fig. 2 - XRD on <2μm fraction of «arene» and andisol horizons. H 10 Å halloysite; mH 7 Å halloysite; F feldspar; Q quartz.

served in an andisol (melanudand) and the underlaying «arene» of leucotephrite (see soil profiles n° 40 and 111, in Lulli and al 1990, p. 90-93). This andisol is situated at the upper border of the caldera. We studied successively in the «arene»: the kernel of unweathered lava, the cortex of weathering, the sandy «arene» and the clayey «arene»; then in the andisol: the B and the A horizons. We have also studied the white clayey alteration of leucite in a «petrisco», at the bottom of a

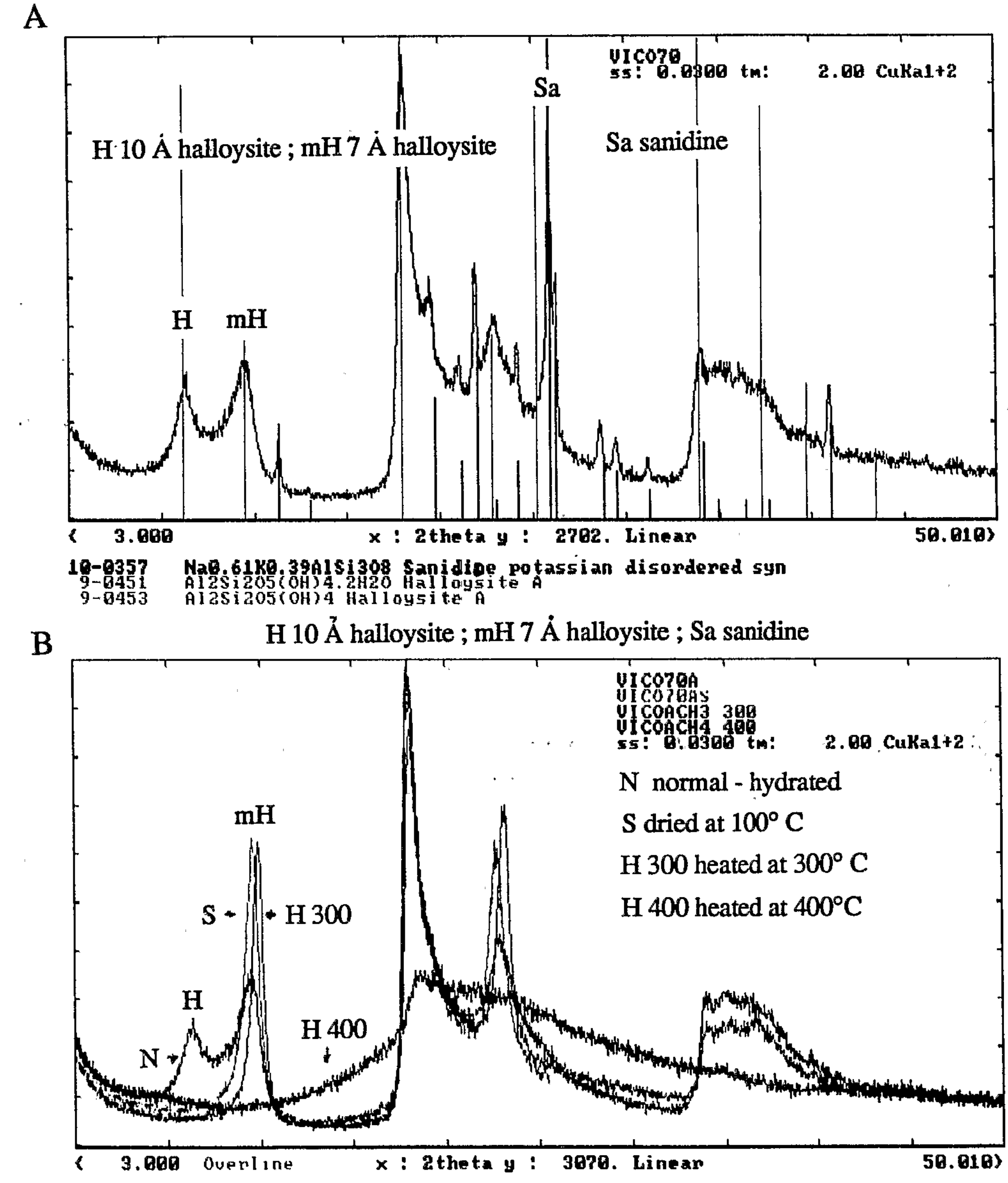

Fig. 3 - XRD on altered leucite of «petrisco»; A whole powder; B <2μm fraction. H 10 Å halloysite; mH 7 Å halloysite; Sa sanidine.

brown soil, on the outer piedmont of the volcano.

In the first site the soil has been formed under a temperate and regularly wet climate, while in the second site the soil has been formed under a climate with dry season.

Methods

For mineralogy and petrography we have used the following methods.

— X Ray diffraction: on a powder of whole material and on an oriented < 2μm fraction (normal, dried at 100°C, heated at 500°C, glycolated).

— TEM microscopy: on <2μm fraction. In the case of a petrisco, we have analysed only the white powder of weathered leucite.

— Optic microscopy: on thin sections of samples of the 4 layers of the «arene» and the A and B horizons of the andisol.

— SEM microscopy and «in situ» chemical analysis by microprobe: on the same thin sections used for O.M. of the «arene» and the andisol; and in addition on a crystal of weathered leucite from the petrisco.

Results

Mineralogy

1) Parent material: The leucotephrite, at the bottom of the andisol is constituted of around 50% of alkaline basaltic glass, 30% of leucite and 20% of labradorite phenocrysts, as well as some microcrystals of apatite, Ti-magnetite and olivine. The petrisco (named acid leucotephrite by Cundari and Graziani, 1964) is a leucitic phonolite where sanidine is substituted to labradorite.

2) Powder of whole material of the «arene» and the andisol (Fig. 1): In addition to the minerals of the parent material, some products of weathering appear, like analcime and clay minerals, while the content in leucite is decreasing. In the «arene» there are two main products: analcime and 10 Å halloysite; the last one is increasing in the clayey arene. In the andisol, the analcime and the leucite are diminishing; but there are only traces of crystallized clay minerals, because the clays are para-crystalline (allophane, imogolite).

3) < 2μm fraction. (Fig. 2): In the sandy and clayey «arene», 10 Å halloysite partially dehydrated at 7 Å is the predominant mineral. In the C horizon at the bottom of soil we still observe the presence of analcime, mixed mainly with imogolite and with some traces of 10 Å halloysite. In the B horizon of andisol the fibrous imogolite is predominant, while in the A horizon we observe mostly spherical allophane and a little of halloysite. In this latter horizon we note some traces of quartz due to a probable contamination by rhyolitic ash fall, near the surface of soil.

In the »petrisco», the white product of leucite weathering is made of a pure 10 Å halloysite, partially dehydrated at 7 Å, and mixed with some relicts of sanidine (Fig. 3).

Optic microscopy

We will describe only the various forms of alteration of leucite.

— In the kernel of almost unaltered leucotephrite, leucite looks almost intact, polygonal, with polysynthetic twinning; it shows some inclusions of labradorite microlites.
— In the cortex, the leucite is altered around its margin and along some radial fissures, leaving some islets of unaltered mineral.
— In the sandy «arene» as well as in the clayey one, the leucite is almost completely altered, in a light yellowish product, which is isotropic in cross-light. It remains only few islets of unaltered mineral. Sometimes we observe some recrystallization of zeolites at the margin of the crystal. We note also in the clayey «arene», some palagonitized glasses, which could indicate a product of phreato-magmatic outburst.
— In the B horizon of the andisol, the leucite again is almost completely altered to a light brown and isotropic product, with some dull yellowish verge at the margin.
— In the A horizon, the small crystals of leucite which are isolated in the soil matrix are completely altered to a dull or light brownish and isotropic product; while the phenocrysts of leucite which remain included in the pyroclasts of tephritic lava are not completely altered, leaving some unaltered islets of the primary mineral. (That means a latter eruption of tephritic pyroclasts).

Scanning Electron Microscopy (SEM) and microprobe analysis

We have summarized some relevant results of microprobe analysis, after normalisation in percentage of the main elements, on the anhydrous oxides basis (Tab. 1). The «in situ» microprobe analysis allows us to specify the chemical composition of leucite and of its different forms of alteration we have observed by optic microscopy and further by SEM. The SiO_2/Al_2O_3 molar ratio (Ki) provides a good estimate of the corresponding mineral, either leucite for a value of 4.5 and high contents in K_2O, or analcime for 4.0 and high contents in Na_2O, or halloysite for 2.0, and finally imogolite for 1.1 or allophane for 1.8, according to the previous data of mineralogy.

The pure leucite in lava kernel «e» has a low content in Na. But in the cortex «d», the leucite center is altered to a

TAB. 1
Microprobe analysis of leucite and its alteration products

		SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	Ki
e	kemel	58	22	0.4	0.0	0.1	0,9	19	4.5
d	cortex	61	26	0.5	0.2	0.1	11	0.9	4.0
b	sand-arene	51	43	1.5	0.3	0.3	1-2	1-2	2.0
a	clay-arene	52	44	1,7	0,2	0,3	O.O	1.1	2.0
B	horizon	39	59	0,7	0,1	0.8	0.0	0,1	1.1
A	horizon	49	46	1,7	0.5	0.1	0,4	0,7	1.8
P	petrisco	53	44	0,7	0.2	0.7	0,9	0.0	2.0
V	glass	52	19	10	1.7	5.8	4.1	4.3	4.6

composition corresponding to analcime (K replaced by Na). In sandy «arene b» a major part of leucite is weathered to a composition of halloysite, mixed with a little of zeolites. In clayey «arene a» and petrisco, leucite is almost completely weathered to halloysite composition ($K_i=2.0$). In the B horizon of andisol, leucite is fully weathered to isotropic plasma of imogolite composition ($K_i=1.1$); but in the A horizon, leucite is less weathered to a more siliceous product of allophane ($K_i=1.8$) composition. Around the leucite the volcanic glass «V» is of Na and K rich trachybasaltic composition, which is the source of Na to form analcime.

Interpretation

1) In the «cortex», the diffusion of Na from the glass to the leucite center can explain the formation of analcime. That is the result of a hydrothermal and alkaline process of alteration (Azzaro and all. 1976), during a hydromagmatic eruption.

2) In the «arene» and the «petrisco», the formation of halloysite, by evacuation of Na, K and a part of Si, is a weathering process under humid climate and with rather slow drainage (Quantin 1991). However, some relicts of zeolites can remain. That confirms the observations of Cundari and Graziano (1964), about the presence of analcime, allophane and «kaolinite» in the altered leucite of a petrisco.

3. In the B horizon of andisol, the leucite transformation to a fibrous imogolite, by a strong evacuation of Na, K and Si, is due to a weathering process under perhumid climate and high drainage (Quantin 1991). However in the A horizon, the more siliceous allophane formation means a less advanced stage of weathering, in the presence of relicts of volcanic glass and of a high humus content.

Conclusion

The alteration of leucite to analcime is inherited from a former hydrothermal process. Clay minerals are formed by further weathering, in relation with the rainfall drainage intensity: allophane and imogolite under perhumid climate and with high drainage; halloysite under humid climate, or with slower drainage.

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