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Mineralogical and Chemical Study of Reinforcements Used in Quartz-Based Composite Materials

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INTRODUCTION

Quartz-based composite materials are essentially constituted by silica, mainly quartz, besides cristobalite and other products such as glasses, mirrors and granite fragments, together with pigments and orthophthalic polyester resins. These components are subjected to a compaction process by vibrocompression and to a cementation process in which resins act as a binder. The main goal of this work is to perform the mineralogical and chemical study of reinforcements used in quartz-based composite materials in order to know in detail their composition, size, morphology and distribution.

MATERIALS AND METHODS

Twenty-five samples of quartz-based composite materials were selected to perform this study, taking into account the following criteria: size, morphology and reinforcement nature, regardless of pigment colors.

The selected samples were ground using a vibratory disc mill to obtain a particle size < 40 μm and were analysed by X-ray diffraction (XRD) and by inductively coupled plasma-atomic emission spectrometry (ICP-AES).

Twenty five microslides (two of them polished) were studied by polarizing microscopy, in both transmitted and reflected light, and electron microprobe analysis (EMPA). The analyzed elements were Si, Al, Ca, Fe, K, Na, Mg and Ti.

RESULTS AND DISCUSSION

X-ray diffraction

Different crystalline phases were identified, allowing to classify the studied materials into seven types: Quartz, Quartz–Cristobalite, Quartz–Silicon, Quartz–Silicon–Cristobalite, Quartz–Albite, Quartz–Albite–Cristobalite and Quartz–Feldspar–Mica.

Polarizing microscopy

Quartz is present in all the samples, their grains are mono- and poly-crystalline of variable size and with different shapes (rounded, subrounded and angular) (Fig. 1).

fig 1. Photomicrograph in polarized transmitted light (x40) of materials with quartz reinforcements.

Cristobalite appears in many samples, forming big angular grains and, in others, as very small particles, involving the rest of the components (Fig. 2).

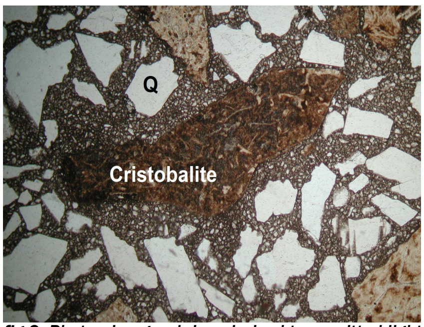

fig 2. Photomicrograph in polarized transmitted light (x40) of materials with quartz (Q) and cristobalite reinforcements.

Rock fragments constituted by quartz, feldspar, and mica are present also in several samples (Fig. 3). Likewise these minerals appear isolated. Glass and mirror fragments with different morphologies have been identified in some samples (Figs. 4, 5 and 6). Silicon grains including different metallic phases have been also detected (Fig. 7).

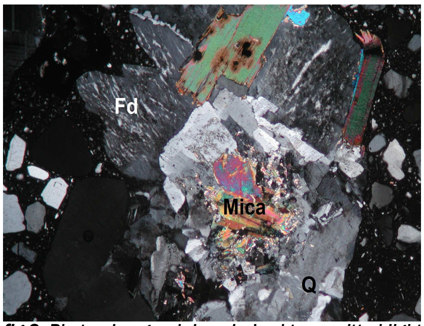

fig 3. Photomicrograph in polarized transmitted light (x40) of granite fragments with quartz (Q), feldspars with perthitic texture (Fd) and micas as reinforcements.

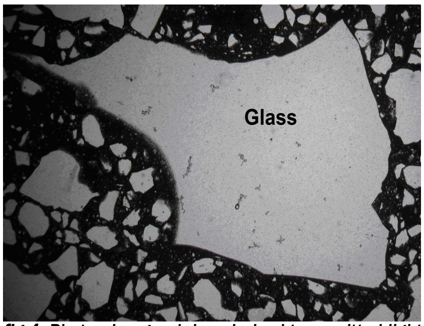

fig 4. Photomicrograph in polarized transmitted light (x40) of materials with quartz and glass reinforcements.

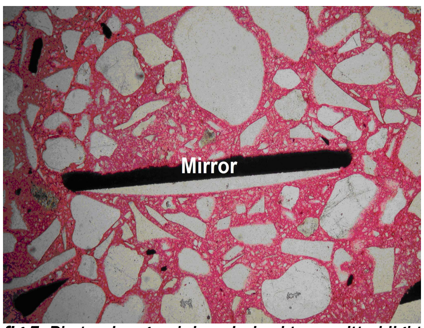

fig 5. Photomicrograph in polarized transmitted light (x40) of materials with quartz, glass and mirror reinforcements.

palabras clave: Materiales de cuarzo compacto, Refuerzos. | **key words:** Quartz-based composite materials, Reinforcements.

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fig 6. Photomicrograph in polarized transmitted light (x40) of materials with quartz and one and two face mirrors as reinforcements.

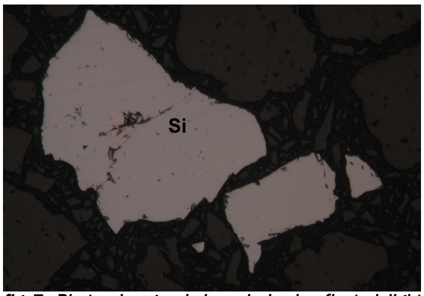

fig 7. Photomicrograph in polarized reflected light (x200) of silicon with associated metallic phases as main reinforcements.

In some of the samples the amount of feldspar, glass, mirrors and/or silicon is close to that of crystalline silica.

Chemical analysis

The range of contents of the different elements analyzed on the studied materials is shown in Table 1.

SiO_2	67.4 - 98.9
Al_2O_3	0.06 - 7.9
Na_2O	0.9 - 6.0
K_2O	0.18 - 2.0
CaO	0.5 - 3.7
MgO	0.05 - 0.67
Fe_2O_3	0.18 - 0.99
TiO_2	0.01 – 1.2

Tabla 1. Range of contents of the different elements analyzed (wt%).

In most of the samples, the highest CaO contents are related to the important occurrence of glasses and mirrors in them. Most samples with high Na_2O contents present albite as one of their main components, except for some samples in which cristobalite and sodic-calcic glasses and mirrors are abundant. Feldspars and micas are responsible for the relatively high K_2O contents shown by some samples. The SiO_2 contents vary within a wide range, from 67.4% (albite > SiO_2) to 98.9% (quartz, cristobalite and silicon). The highest Al_2O_3 contents correspond to aluminosilicate-rich samples, such as feldspars (mainly albite), and phyllosilicates (micas and chlorites) in minor quantity. The occurrence of biotite, chlorite and opaque minerals contributes to increase the Fe_2O_3 contents. The highest MgO contents belong to glass- and mirror-rich samples. There is a good correlation between different pairs of elements. Thus, an important negative correlation between SiO_2 and Al_2O_3 has been found (IRI = 0.8259), showing the substitution of Si by Al in feldspar, mainly, and micas. This correlation becomes slightly higher when considering also K_2O and Na_2O together with Al_2O_3 (IRI = 0.8759), as it could be expected. On another hand, there is a positive correlation between Na_2O and Al_2O_3 (IRI = 0.7108). When only feldspars-rich samples are considered, this last correlation is greatly improved (IRI = 0.9568). The very high positive correlation found between K_2O+Na_2O and Al_2O_3 (IRI = 0.9971) reveals that these elements are present in feldspars.

Electron microprobe analysis

Electron backscattered images of silicon present in two of the studied samples have revealed the occurrence of five metallic phases inside silicon grains. The chemical analyses indicate that these phases are composed of Fe-Si-Ti, Si-Fe, Si-Fe-Al-Ca, Al-Si-Fe and Si-Al-Ca (Fig. 8).

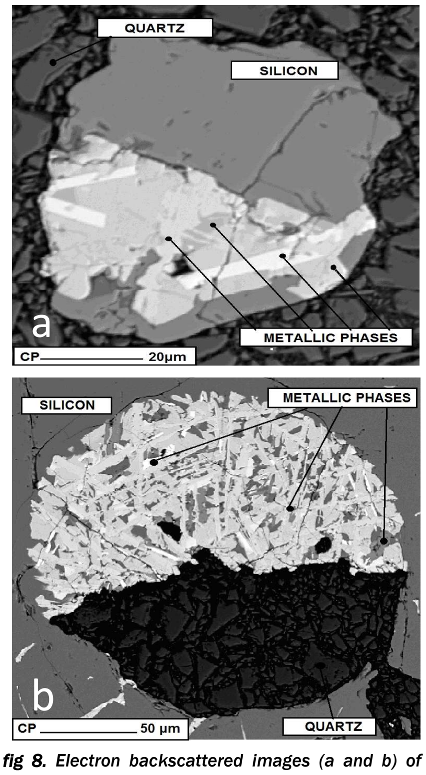

fig 8. Electron backscattered images (a and b) of silicon and associated metallic phases.

Relating chemical analysis to microscopic study

According to the chemical analysis and the microscopic study performed on the quartz-based composite materials considered in this work, four typologies can be established:

- Materials with high SiO_2 and minor Na_2O, CaO and Fe_2O_3 contents, whose main reinforcements identified are quartz+/-cristobalite and, exceptionally, quartz+silica-rich mirrors.
- Materials with relatively high contents of Na_2O, CaO and MgO, together with SiO_2, whose reinforcements are constituted by quartz+/-cristobalite and sodic-calcic glasses and mirrors.
- Materials with the highest SiO_2 contents, composed of quartz and silicon+/- cristobalite as main components.
- Materials with the lowest SiO_2 contents and the highest Al_2O_3 contents, and important values of Na_2O, K_2O and CaO, with quartz, feldspars (albite and potassium feldspar with perthitic texture) +/- cristobalite and micas as main reinforcements, and several silicates and opaques as accessory minerals. The highest Fe_2O_3. contents are due to the occurrence of such opaques.

CONCLUSIONS

The mineralogical and chemical study performed on reinforcements used in twenty-five representative samples of quartz-based composite materials reveals the chemical-mineralogical variety of samples commercialized under the same designation. Likewise, the results derived from this study show that most samples do not contain the amount of crystalline silica (93-95%) indicated by the different companies which commercialized these products. Moreover, in some samples feldspars are altered, decreasing the material quality. On the other hand, it is worth mentioning the presence of metallic silicon and associated phases as reinforcement in these materials.

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