

Quartz Chemico-structural characterization: a tool for sediment source tracing

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<u>Claire AUPART¹</u>, Catherine LEROUGE¹, Philippe LACH¹, Damien Desvisme², Florian TRICHARD², Magali RIZZA³, Pierre VALLA⁴, Pierre VOINCHET⁵, Gilles RIXHON⁶, and Hélène TISSOUX^{1,5} 1 Bureau de Recherches Géologiques et Minières (BRGM), Orléans, France; 2 Ablatom S.A.S, Villeurbanne, France; 3 Aix Marseille Univ, Centre Européen de Recherche et d'Enseignement en Géosciences de la Terre (ISTerre), Gières, France; 5 Histoire Naturelle de l'Homme Préhistorique (HNHP), Paris, France ; 6 Laboratoire Image Ville Environnement (LIVE), Faculté de géographie et d'aménagement, Strasbourg, France The Strengbach river catchment LA-ICP-MS: Grains vs whole-rock Quartz is ubiquitous within continental crust and can virtually be found within all rock types (plutonic, metamorphic and sedimentary). During Principal sedimentary units Intrusive units erosion, weathering and sedimentation processes, it has a very high Biotite porphyroid anatectic Thannenkirch monzogranite +/- granito-gneissic features Coarse Buntsandstein ferruginou sandstones and conglomerate • LA-ICP-MS analyses carried out both in preservation potential and is therefore a good candidate to **trace sediment** Two-micas Brézouard leucogranite whole rock samples and purified quartz Buntsandstein Vosgian Sandstone Buntsandstein voltzia and shell-rich production and transport dynamics. One of the aims of the Quartz ANR Two-micas syntectonic Bilstein leucogranite grains Two-micas Turkheim leucogranite project is to develop a multi-method protocol for quartz characterization • Analyzed elements: Li, Be, B, Na, Mg, Al, with granito-gneissic features 297 K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Ge, As, that can be use to trace the origin of river sediments. Rb, Sr, Sb, Cs, Pb, Th, U, REE liddle Muschelkalk variegated sandy marl with ovnsum Main elements detected: Al, Ti, Li The Strengbach catchment, selected to develop the method, is relatively small (ca. 40 km²) Late Muschelkalk entroques limeston with a relatively simple lithology. As a first step, bedrock samples have been characterized to • No main effect of quartz purification establish their quartz signature that will be compared in a second step to the quartz signature • Exception: STR22-02 due to selective quartz type sampling within river sediments. Quartz structure defects The ideal quartz structure is a network of SiO₄ tetrahedra linked together by their oxygen atoms. **Quaternary units** STR22 09A, 09B & 10: Syntectonic Bilstein granite CL 15kV 40 Tetrahedra are arranged in helical structures that River deposits • Magmatic and recrystallized quartz create channels parallel to the crystallographic c-axis. Extensively deformed granite • Dominant type: magmatic Some of the most common defects of the quartz Magmatic and recrystallized Strengbach river Bulging recrystallization lattice are atom vacancies and Si substitutions. The Strengbach river No distinctive chemistry differences (па, ц, п) Dominant type: recrystallized most common substitutions to Si⁴⁺ are Al³⁺, Ti⁴⁺ and between quartz types Recrystallization by subgrain Laminated sillimanite paragneiss Faults Aluminium Ge⁴⁺. Substitutions and vacancies may require charge • Chemistry close to metamorphic rotation, 10-25 μm Ø ,-- Inferred faults Migmatized sillimanite paragneiss compensation to keep the crystal electronic quartz Titane No distinctive chemistry Amphibolite neutrality. This role is often taken by foreign cations Electron differences between quartz such as H⁺, Li⁺, Na⁺ or K⁺ that can circulate within caxis channels. Slight CL colors differences of ndividual grains Quartz signatures 200 µm Defects in the quartz structure are intricately linked to quartz conditions and environment of crystallization and consecutive history (recrystallization, metamorphism, alteration, etc.). It implies that, by STR22_15 & 17: Thannenkirch granite CL 15kV 40 Magmatic group 2 Magmatic group 1 choosing complementary analytic methods, it is possible to establish a • Formed from paragneiss fusion STR22_15_LM Magmatic STR22 09A LM ★ STR22_09A_LM Recrystallized ★ STR22 15 LM Recrystallized signature common to quartz with a similar history. STR22_15_Qz_LM STR22_09A_Qz_LM • Patchy, interstitial quartz STR22_17_LM Magmatic STR22 09B LM Magmatic an recrystallized quartz **LA-ICP-MS** (Laser Ablation coupled to Inductively Coupled Plasma Mass ★ STR22_17_LM Recrystallized sTR22_09B_LM Recrystallized STR22_09B_Qz_LM • Dominant type: magmatic STR22_17_Qz_LM spectrometry) and LIBS (Laser Induced Breakdown Spectroscopy) are LA-ICP-MS LIBS STR22_10_LM STR22_20_LM Magmatic Bulging recrystallization STR22_20_Qz_LM STR22_10_LM Recrystallized complementary methods for trace elements quantification. LA-ICP-MS tends STR22_10_Qz_LM No distinctive chemistry difference between ICP-MS STR22_45_LM Magmatic Spectrometer STR22_45_LM Hydrothermal STR22_32_LM to have the best sensitivity for heavy elements while LIBS has best results for quartz types STR22_32_Qz_LM STR22_45_Qz_LM light elements STR22_33_LM ✤ STR22_33_LM Recrystallized Cathodoluminescence, OSL (Optically stimulated Luminescence) and ESR STR22_33_LM Hydrothermal (Electron Spin Resonance) are techniques relying on electronic traps that are a direct consequence of the mineral structure and its defects. Not only chemistry affects the analyses, but also purely structural defects (vacancies, Cathodoluminescence extra O or Si, dislocations, etc.). Cathodoluminescence is mostly used to image mineral structure variations in minerals or for mineral identification. STR22_17: Verreries facies OSL and ESR are more commonly used as dosimetric methods for dating. 5 mm These two methods require pure quartz grain samples. Analyses thus return • Incomplete anatectic STR22_20 & 45: Brézouard granite fusion bulk results in opposition with other techniques punctual analyses. Sample intensely All these techniques have shown their interest for source tracing. Mostly magmatic grains fractured Some bulging **ESR** • Chemistry closer to recrystallization OSL Very high fluid inclusions magmatic group 2 Metamorphic Sedimentary ▲ STR22_01_LM STR22_29_LM Fractures and a STR22 29 Qz LM ★ STR22_01_LM_Recrystallized + STR22_01_LM Hydrothermal STR22_30_LM STR22_01_Qz_LM STR22_30_Qz_LM CL 15kV 40s ▲ STR22_02_LM STR22_44_LM STR22_02_LM Magmatic STR22_44_Qz_LM o STR22_02_Qz_LM Slight orange CL







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Hydrothermal veins Most samples show signs of water

- circulation Hydrothermal veins observed only in a few samples
- Chemical signature identified in more

At least two generations:

- Al + Li poor in metamorphic • Same crystallographic orientation than surrounding metamorphic quartz • Mixed with feldspar
- Similar CL signal than metamorphic quartz





drothermal analyses in whole rock samples

- Al + Li rich in granites and sandstone Crvstallized
- CL tends to be darker than magmati quartz



CL 15kV 20

STR22_29, 30 & 44: Buntsandstein sandstones

- Sedimentary quartz
- Sub-rounded to well-rounded grains
- Syntaxial overgrowth Grains imbrication

where inclusion

density is high

Similar chemical signature as magmatic group 1



own CL color





References: Ackerson et al., 2015; Augustsson & Reker, 2012; Baele et al., 2016; Boggs et al., 2002; Duttine et al., 2002; Götze et al., 2021; Minelli et al., 2021; Shimada et al., 2013; Tissoux et al. 2015