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

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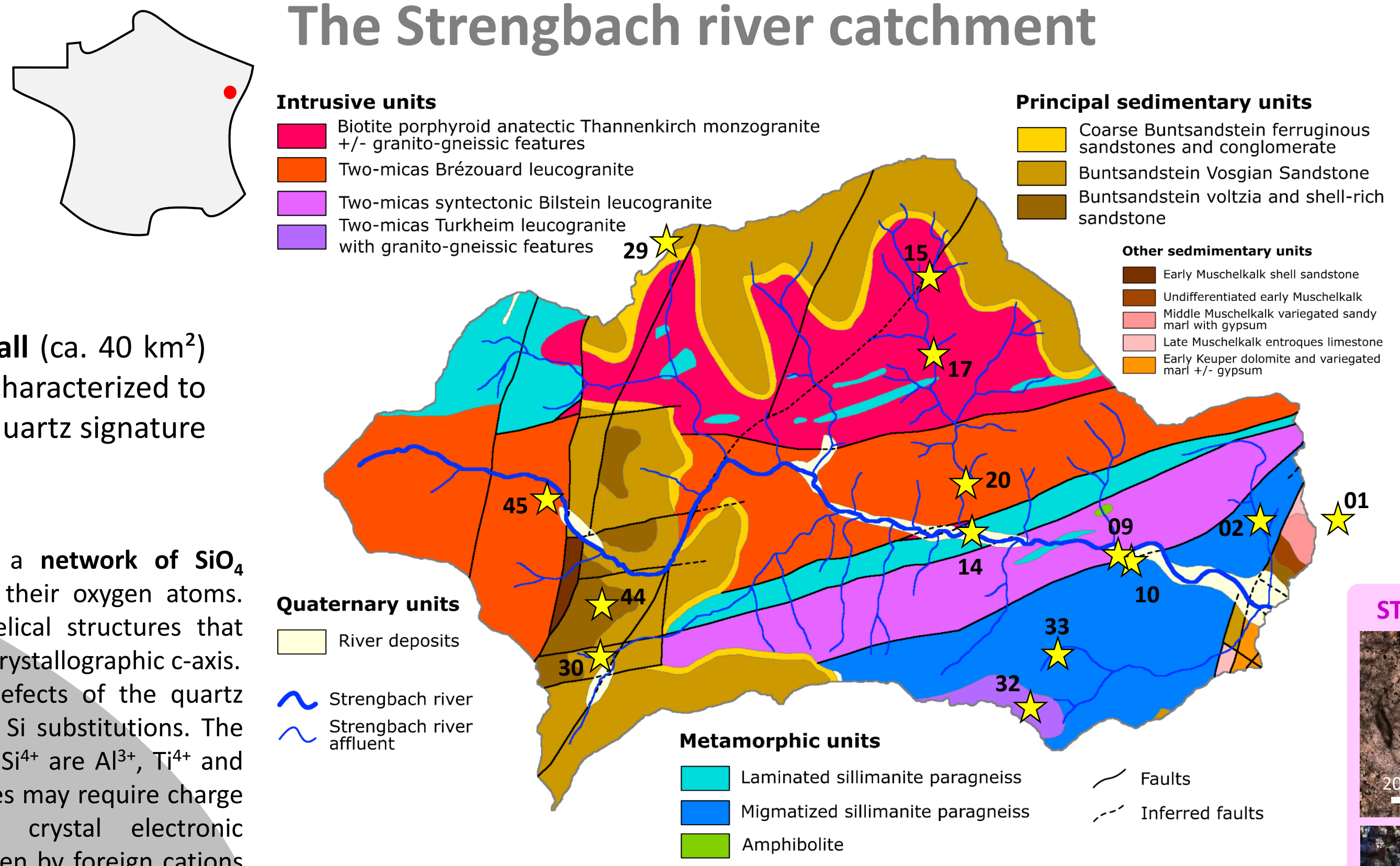
Claire AUPART¹, Catherine LEROUGE¹, Philippe LACH¹, Damien Desvisme², Florian TRICHARD², Manon BOULAY³, Magali RIZZA³, Pierre VALLA⁴, Pierre VOINCHET⁵, Gilles RIXHON⁶, and Hélène TISSOUX^{1,5}
¹ Bureau de Recherches Géologiques et Minières (BRGM), Orléans, France; ² Ablatom S.A.S, Villeurbanne, France; ³ Aix Marseille Univ, Centre Européen de Recherche et d'Enseignement en Géosciences de l'Environnement (CEREGE), Aix-en-Provence, France; ⁴ Université Grenoble Alpes, Institut des Sciences 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

Corresponding author : c.aupart@brgm.fr

Quartz is ubiquitous within continental crust and can virtually be found within all rock types (plutonic, metamorphic and sedimentary). During erosion, weathering and sedimentation processes, it has a very high preservation potential and is therefore a good candidate to **trace sediment production and transport dynamics**. One of the aims of the Quartz ANR project is to develop a multi-method protocol for quartz characterization that can be used to trace the origin of river sediments.

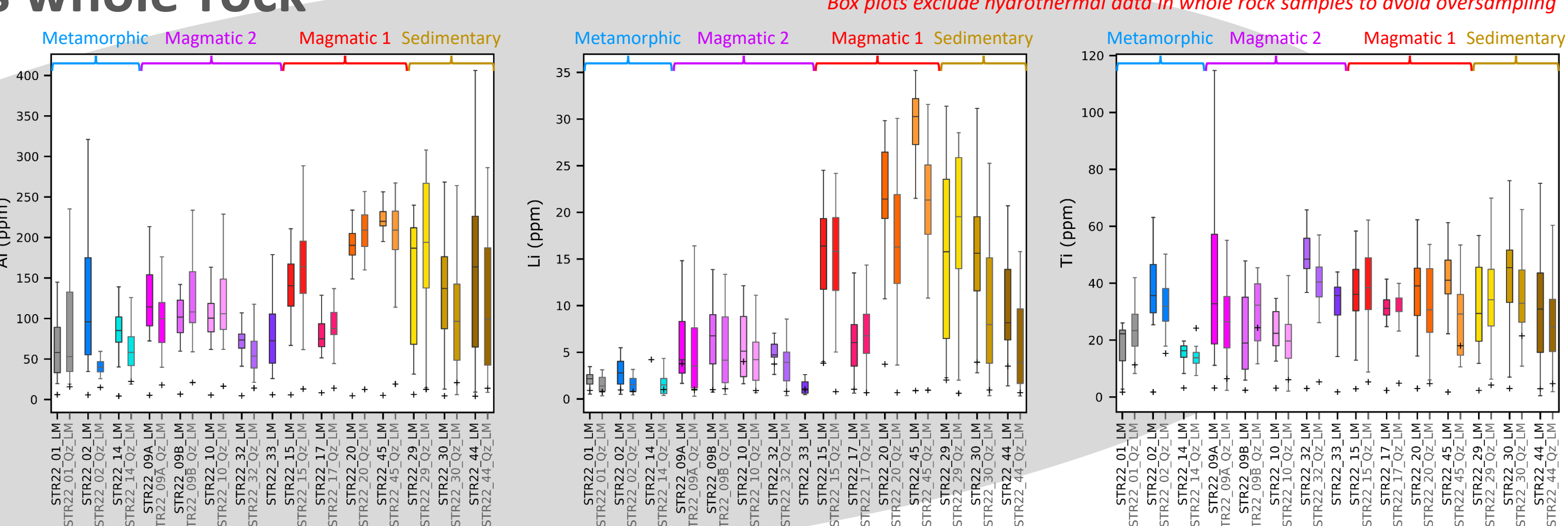
The Strengbach catchment, selected to develop the method, is relatively **small** (ca. 40 km²) with a relatively **simple lithology**. As a first step, **bedrock samples** have been characterized to establish their quartz signature that will be compared in a second step to the quartz signature within river sediments.

The Strengbach river catchment

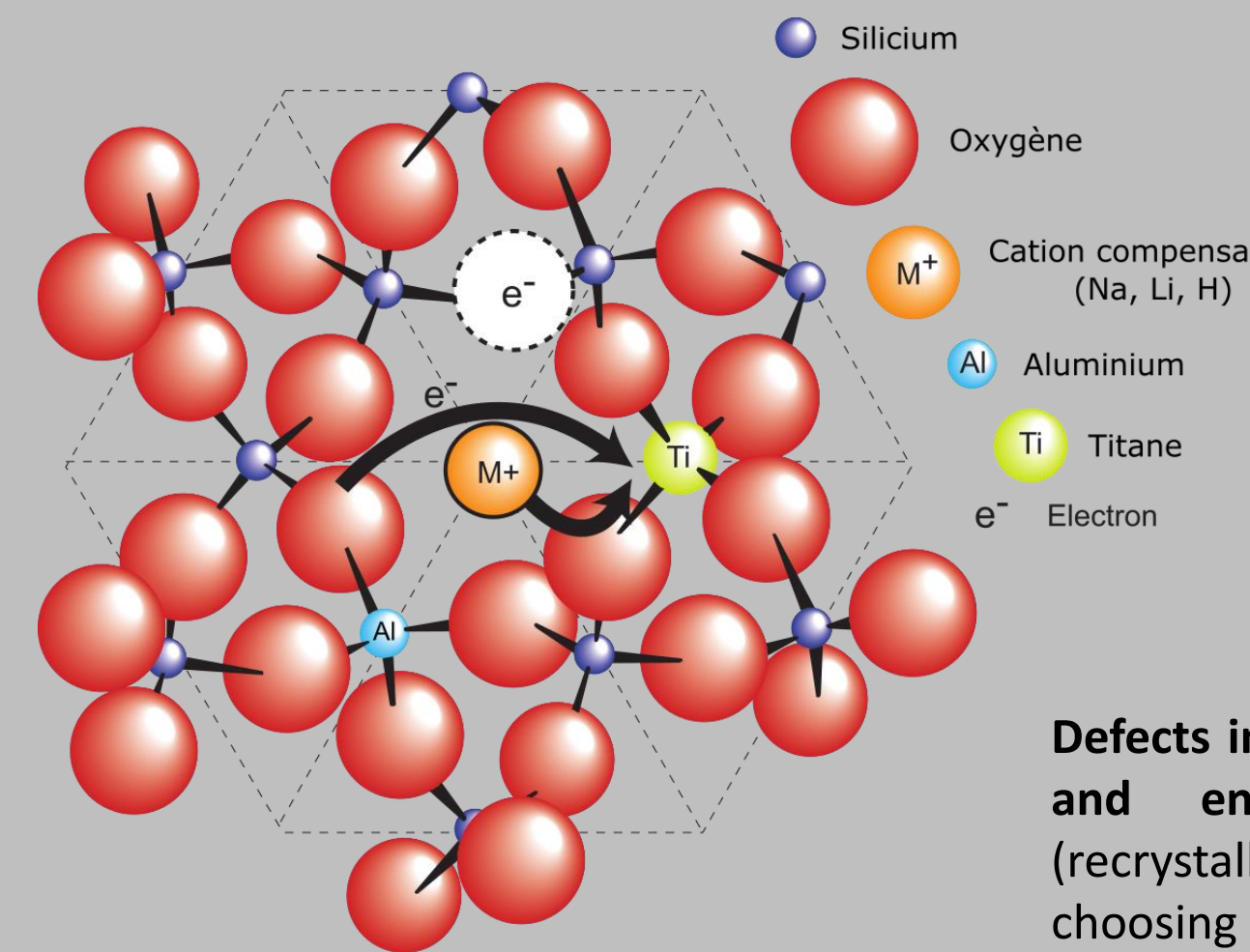


LA-ICP-MS: Grains vs whole-rock

- LA-ICP-MS analyses carried out both in whole rock samples and purified quartz grains
- Analyzed elements: Li, Be, B, Na, Mg, Al, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Ge, As, Rb, Sr, Sb, Cs, Pb, Th, U, REE
- Main elements detected: Al, Ti, Li
- No main effect of quartz purification
- Exception: STR22-02 due to selective quartz type sampling



Quartz structure defects

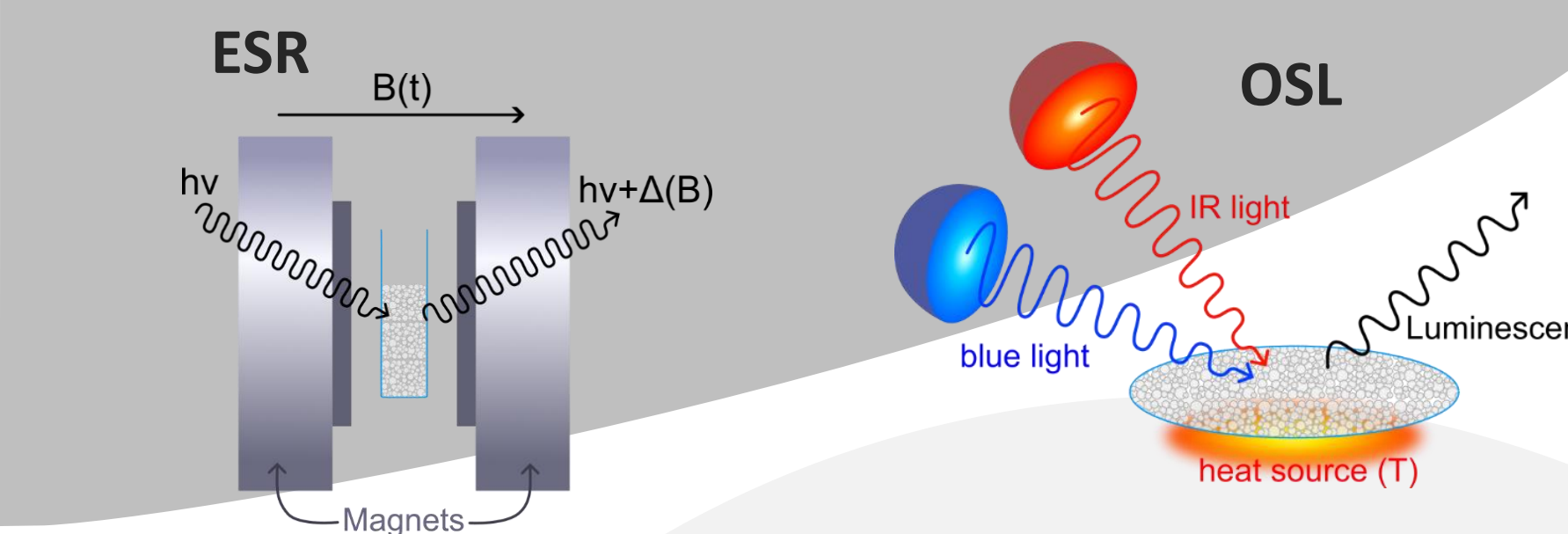
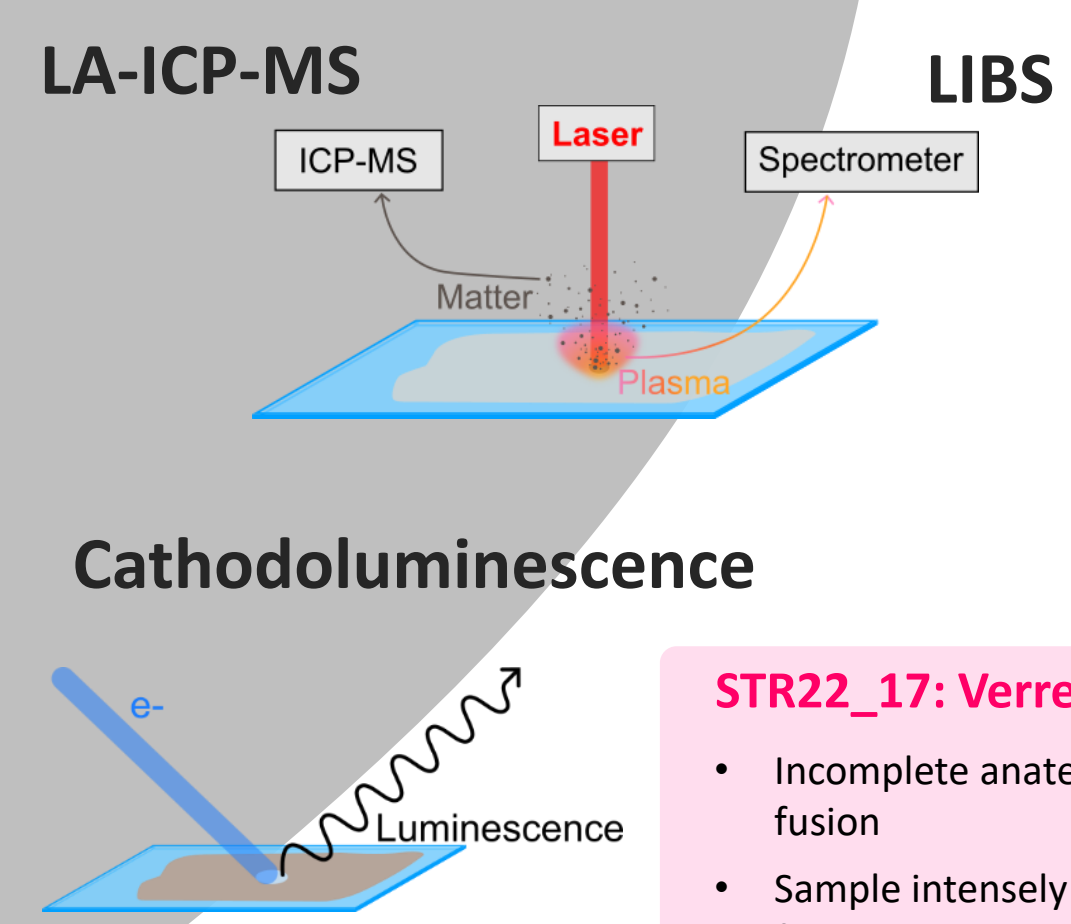


The ideal quartz structure is a network of SiO₄ tetrahedra linked together by their oxygen atoms. Tetrahedra are arranged in helical structures that create channels parallel to the crystallographic c-axis. Some of the most common defects of the quartz lattice are atom vacancies and Si substitutions. The most common substitutions to Si⁴⁺ are Al³⁺, Ti⁴⁺ and Ge⁴⁺. Substitutions and vacancies may require charge compensation to keep the crystal electronic neutrality. This role is often taken by foreign cations such as H⁺, Li⁺, Na⁺ or K⁺ that can circulate within c-axis channels.

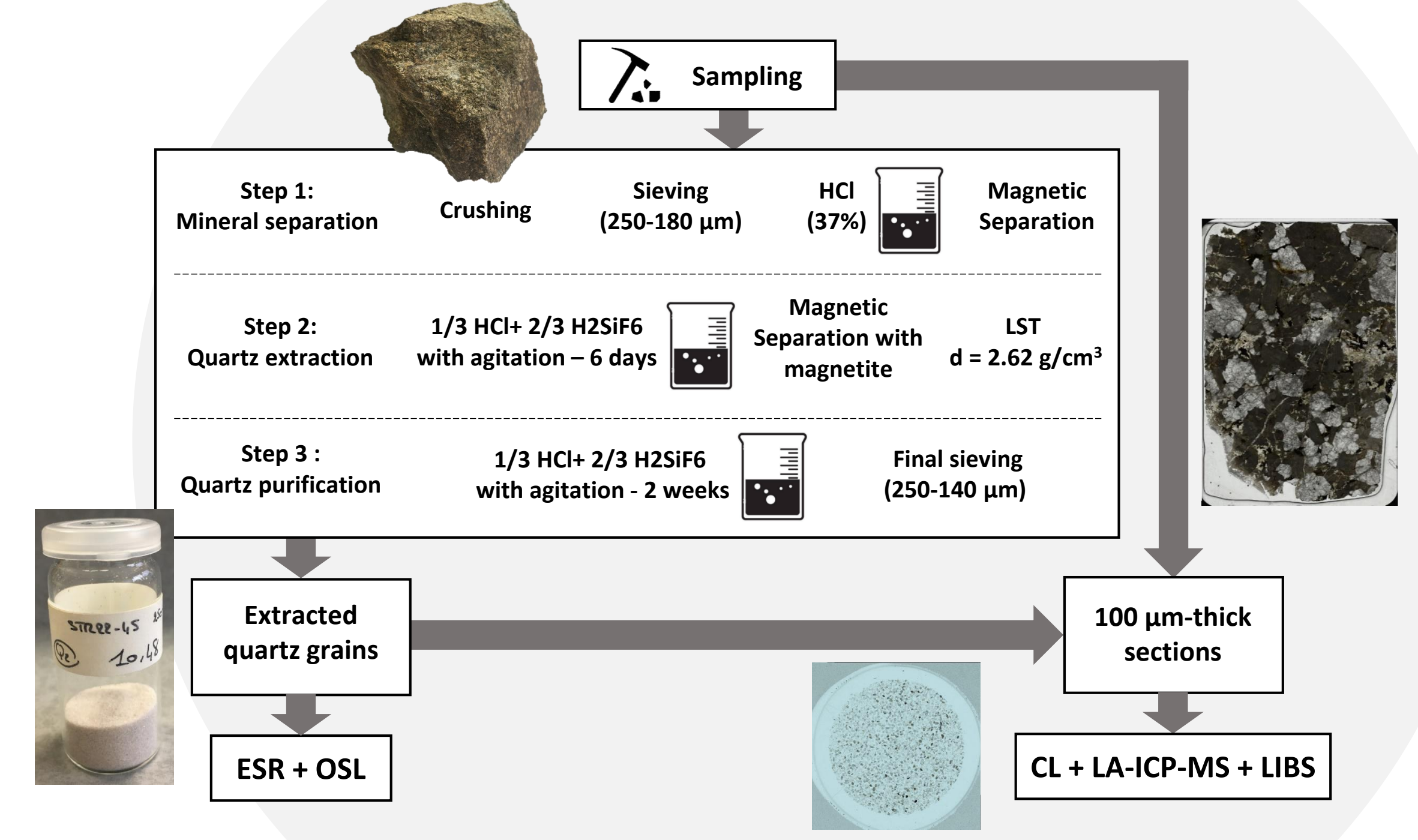
Defects in the quartz structure are intricately linked to quartz conditions and environment of crystallization and consecutive history (recrystallization, metamorphism, alteration, etc.). It implies that, by choosing complementary analytic methods, it is possible to establish a signature common to quartz with a similar history.

LA-ICP-MS (Laser Ablation coupled to Inductively Coupled Plasma Mass Spectrometry) and **LIBS** (Laser Induced Breakdown Spectroscopy) are complementary methods for **trace elements** quantification. LA-ICP-MS tends to have the best sensitivity for heavy elements while LIBS has best results for light elements.

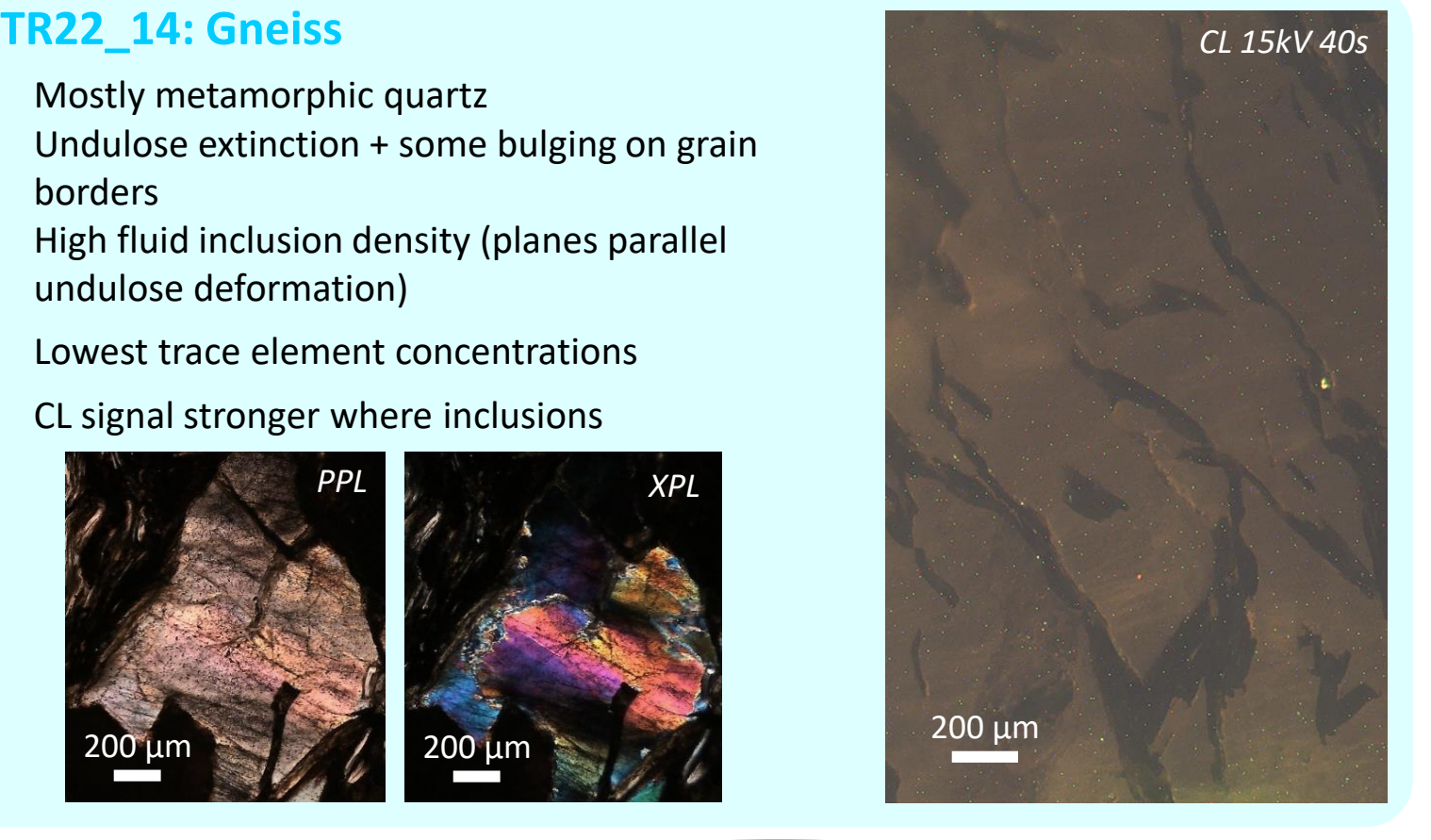
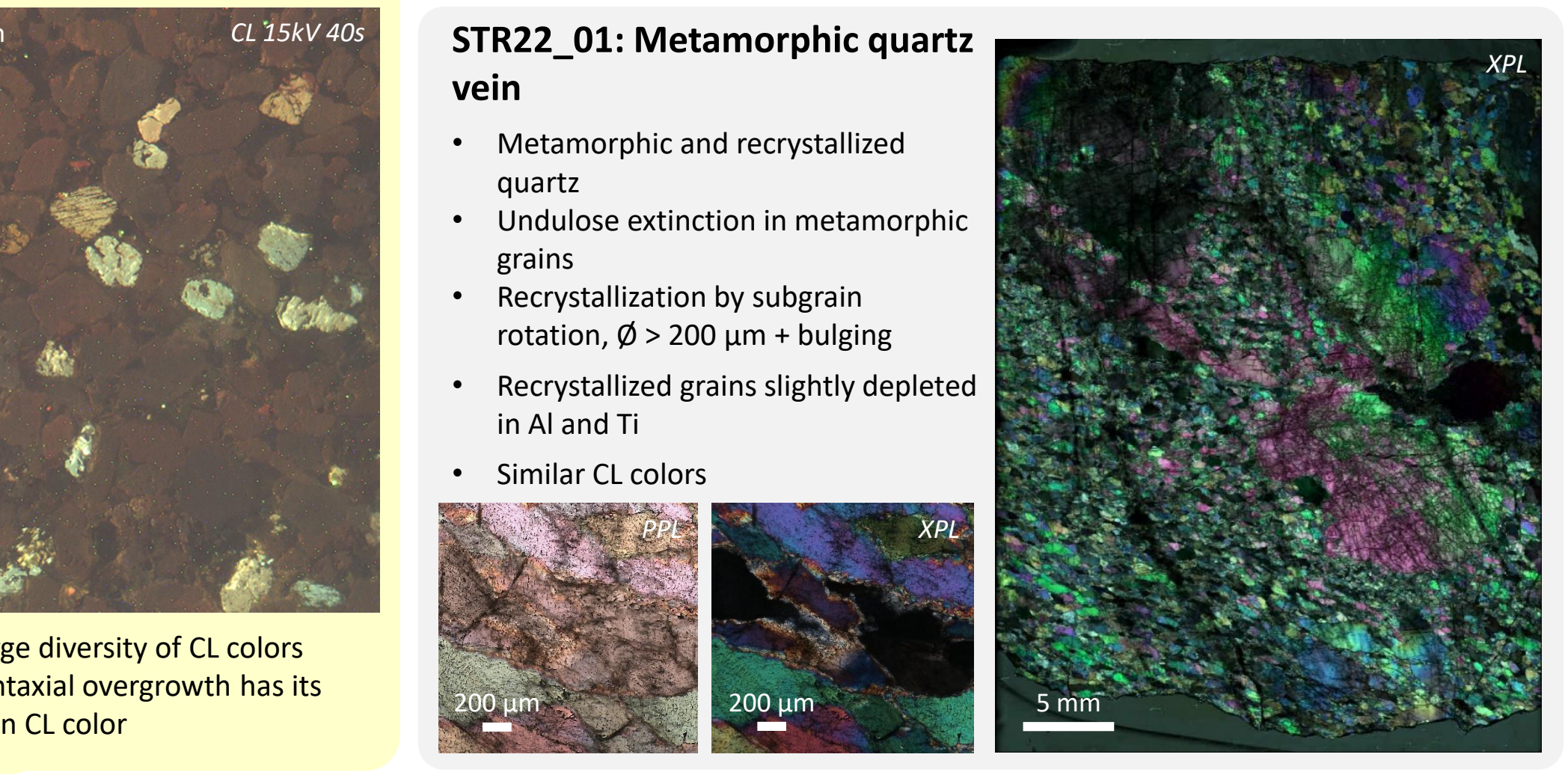
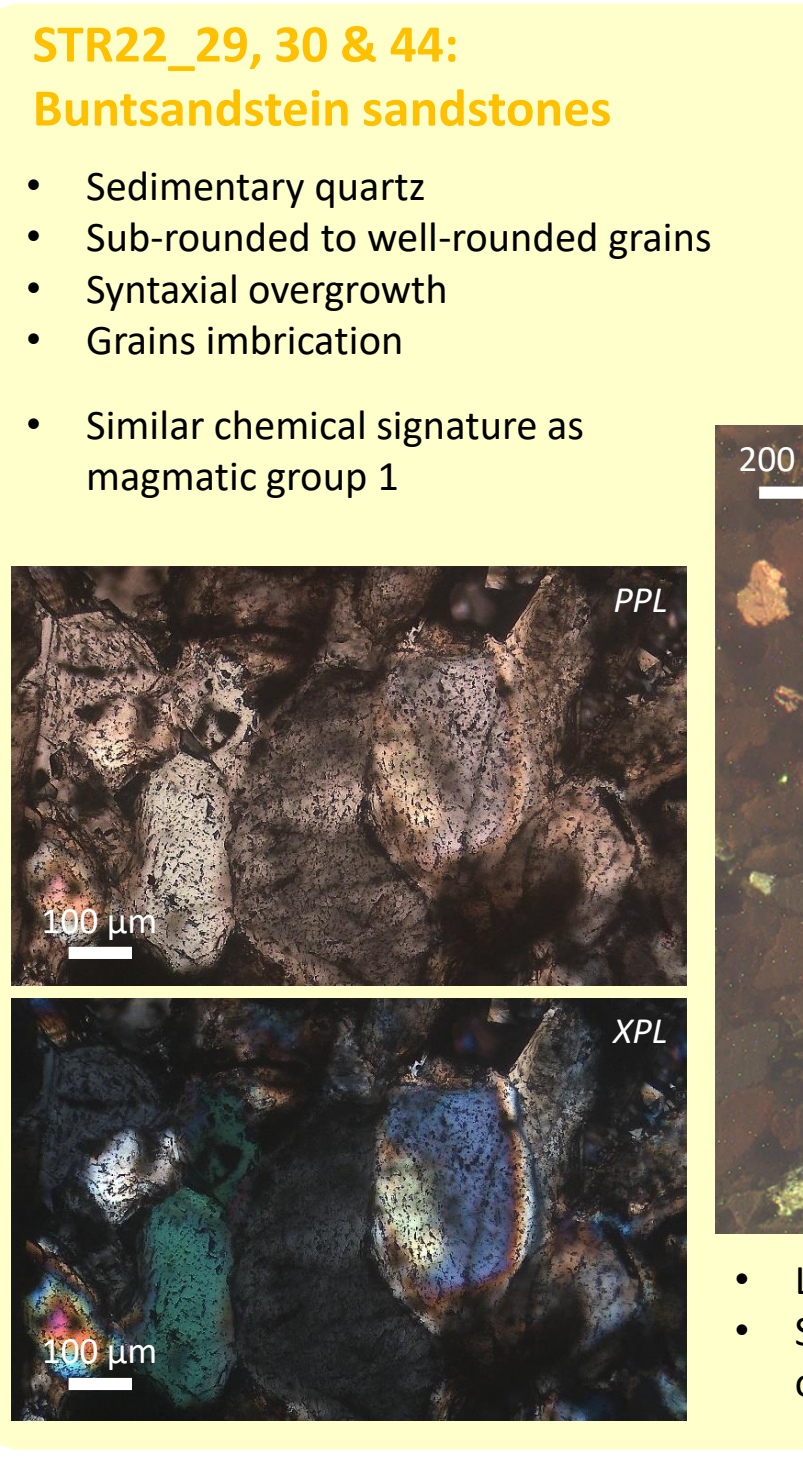
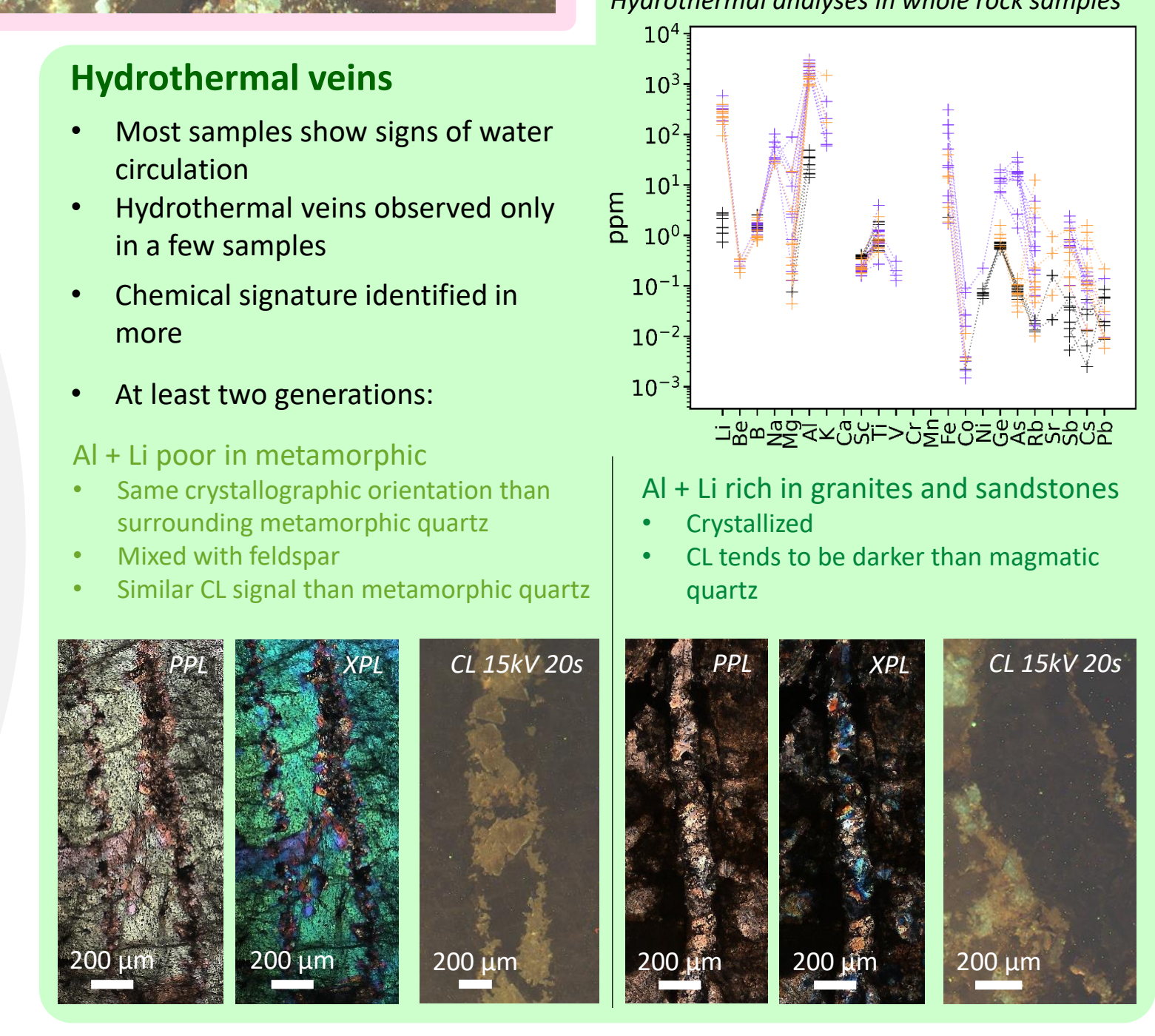
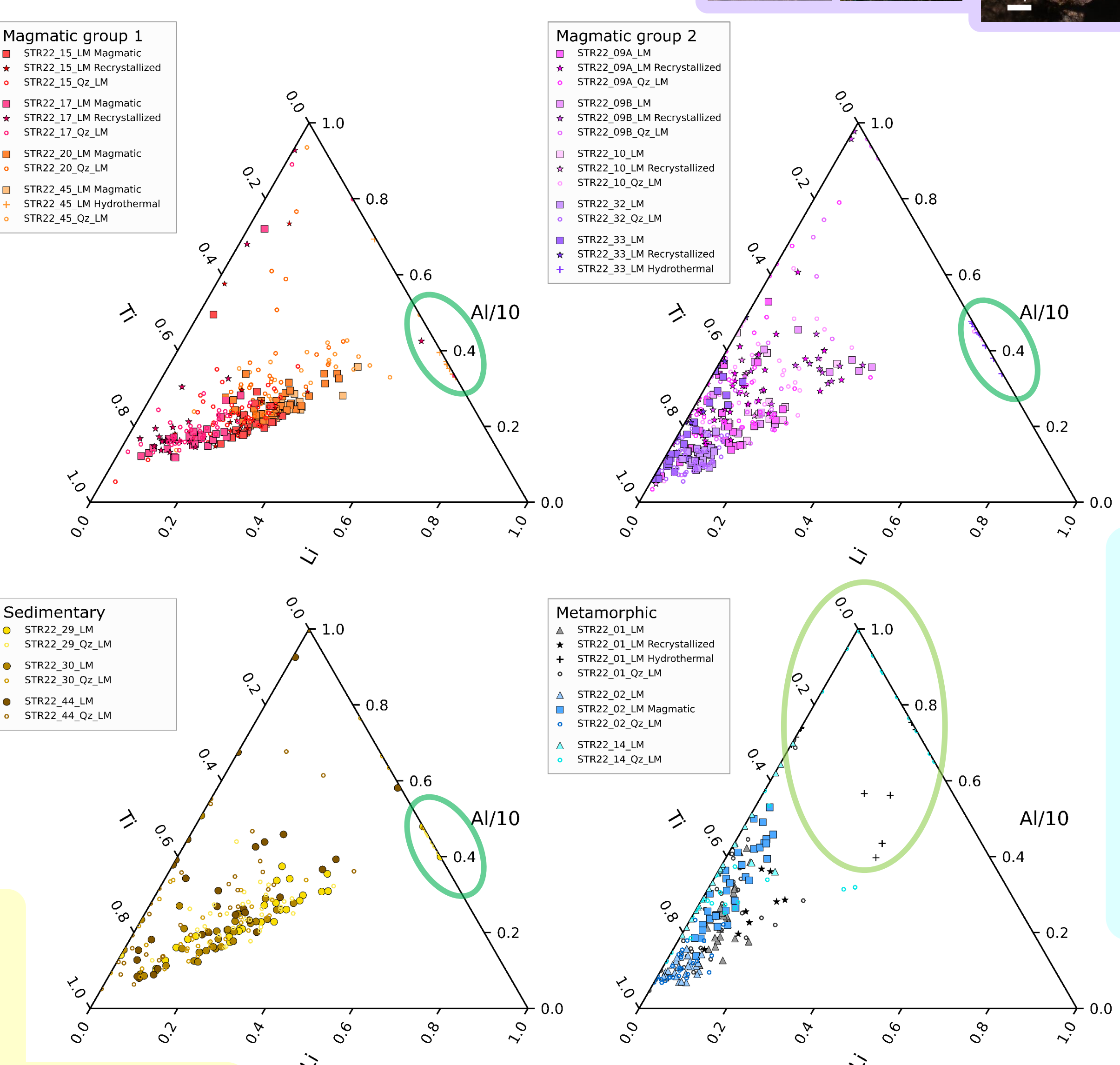
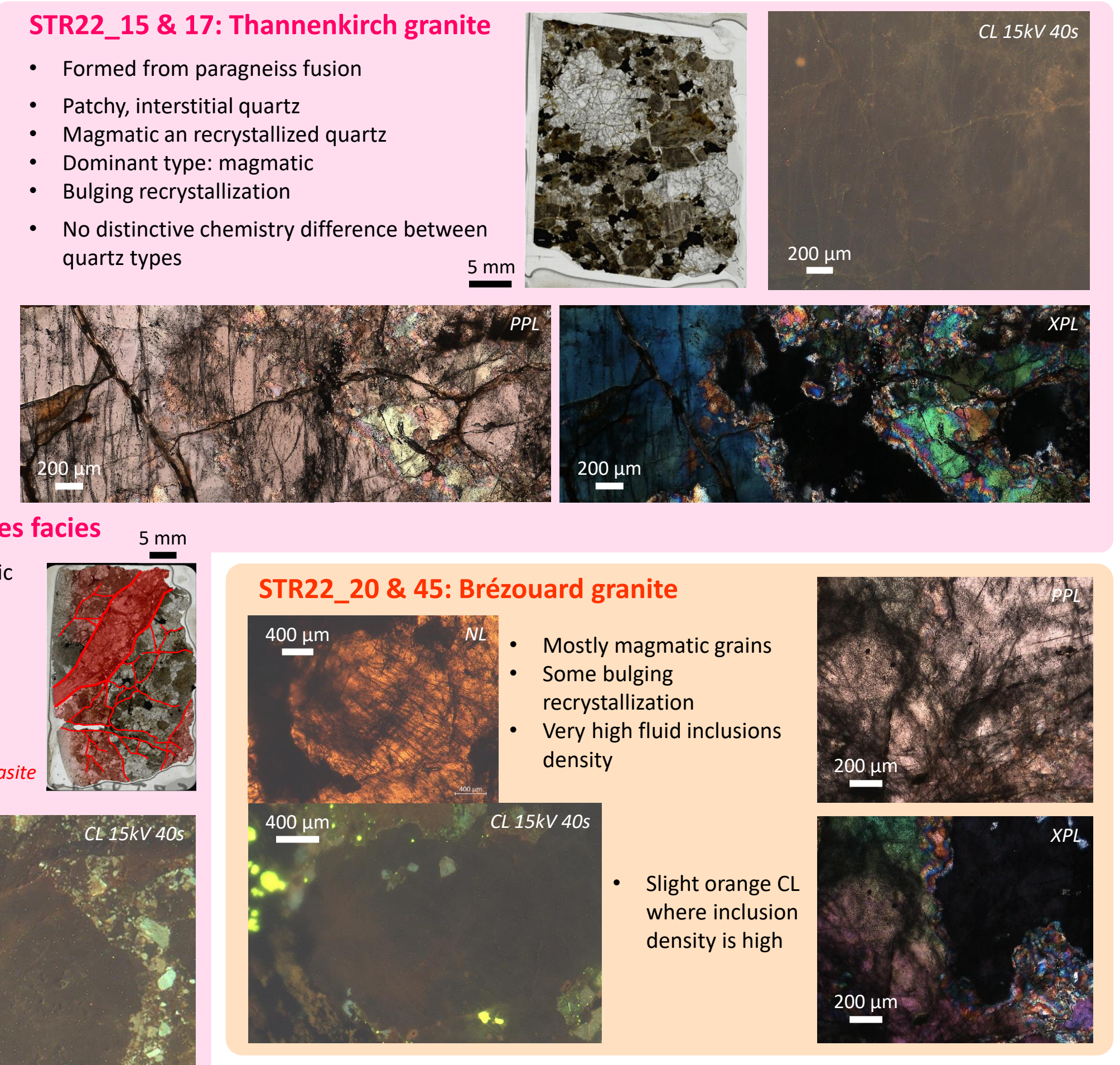
Cathodoluminescence, **OSL** (Optically Stimulated Luminescence) and **ESR** (Electron Spin Resonance) are techniques relying on electronic traps that are a direct consequence of the **mineral structure and its defects**. Not only chemistry affects the analyses, but also purely structural defects (vacancies, extra O or Si, dislocations, etc.). Cathodoluminescence is mostly used to image mineral structure variations in minerals or for mineral identification. OSL and ESR are more commonly used as dosimetric methods for dating. These two methods require pure quartz grain samples. Analyses thus return bulk results in opposition with other techniques punctual analyses. **All these techniques have shown their interest for source tracing.**



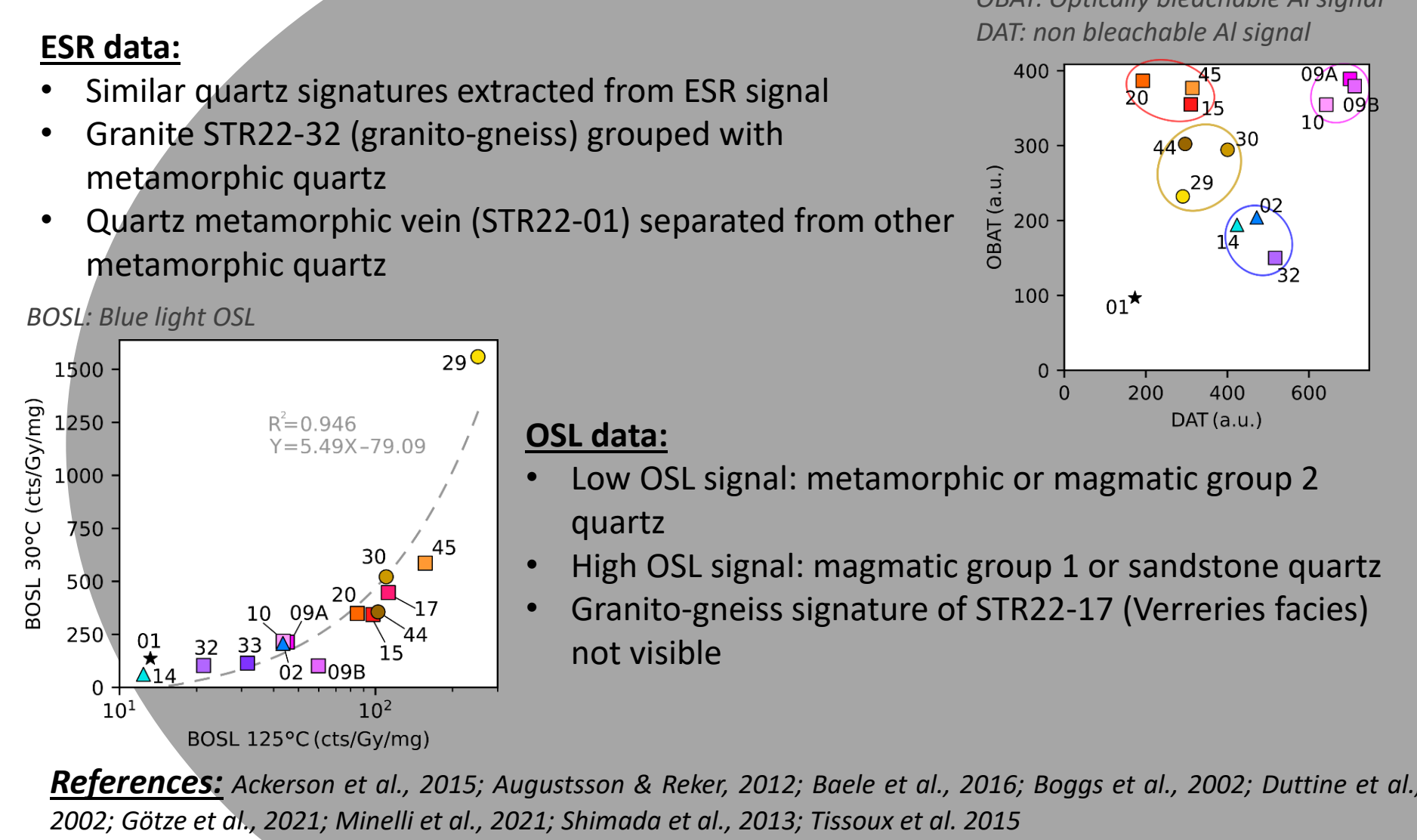
Sample preparation



Quartz signatures



Comparison to ESR and OSL



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