Fracture Network Characteristics and Velocity Structure of a Seismic Fault Zone

[1]**S.A.F. Smith**, [2]A. Bistacchi, [3]T. Mitchell, [3]M. Rempe, [1,4]G. Di Toro, [5]R. Jones, [3]J. Renner, [6]A. Niemeijer, [7]A. Griffith, [1]S. Nielsen, [1]E. Spagnuolo & [4]S. Mittempergher
steven.smith@ingv.it
[1]Istituto Nazionale di Geofisica e Vulcanologia (INGV), Rome, Italy; [2]Dipartimento di Geologia, Università di Milano, Italy; [3]Department of Geosciences, Ruhr-University Bochum, Germany; [4]Università degli Studi di Padova, Padova, Italy; [5]Geospatial Research Limited, University of Durham, England; [6]Faculty of Geosciences, Department of Earth Sciences, Utrecht University, The Netherlands; [7]Department of Geology and Environmental Science, University of Akron, USA

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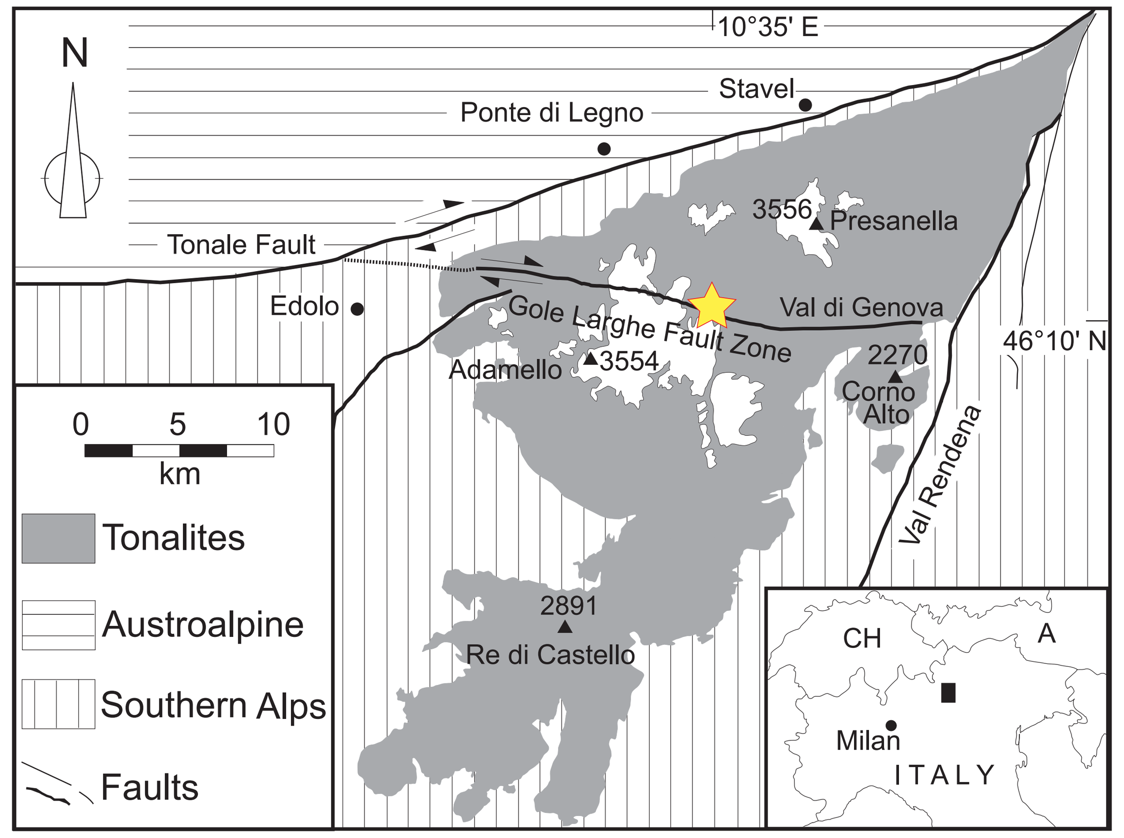
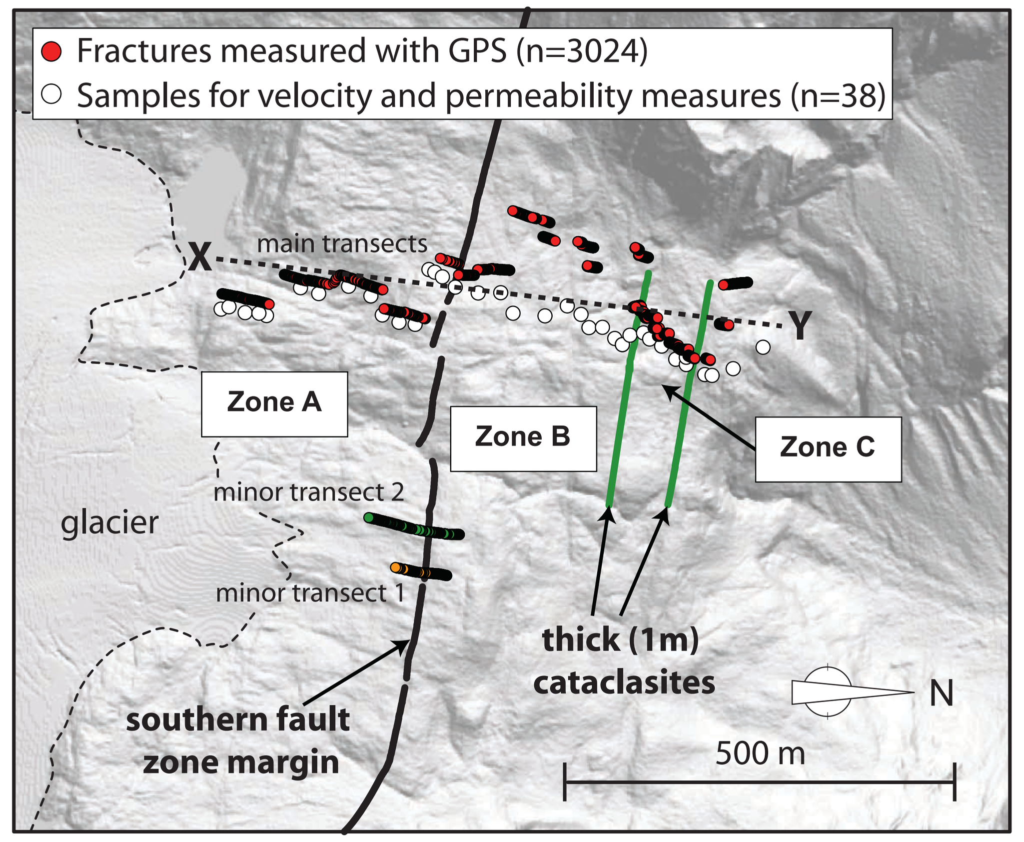
1. Introduction

Quantifying the structure of **seismic fault zones** over a wide range of scales requires **exceptional exposures** and **novel methods** of data aquisition and analysis. The **Gole-Larghe Fault Zone** in the Italian Alps - containing abundant pseudotachylyte attesting to its **seismic nature** - is **continuously exposed** over glacier-polished outcrops for hundreds of metres to kilometres, providing a **unique opportunity** to **quantify** the **fracture networks** and **physical properties** of a seismic fault zone. The fault zone was exhumed from depths of 8-10 km, and formed in a tonalitic pluton containing a well developed system of **cooling joints**.

We carried out a series of **transects** across the Gole Larghe Fault Zone by integrating high-precision GPS measurements, aerial photography, photogrammetry analysis, and sample collection. The data is managed in a geospatially-referenced ArcGIS project. Collectively, the transects cross around **700 metres** of **fully-exposed fault zone** and **wall rocks**, allowing us to measure **every fracture** encountered and **quantify** such parameters as the fracture density, fault rock thickness, and laboratory seismic velocities and permeabilities.

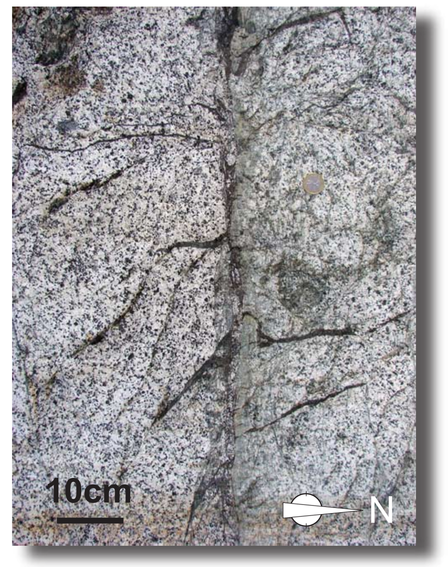




2. Field characteristics of Zones A, B, C

Well developed set of E-W trending magmatic cooling joints, infrequently reactivated as cataclasite-bearing faults.

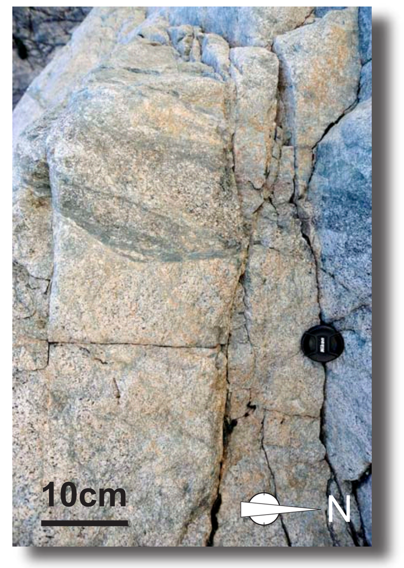
Zone A



E-W trending cataclasite- and pseudotachylyte bearing faults, nucleating on cooling joints. Displacements up to a few metres.

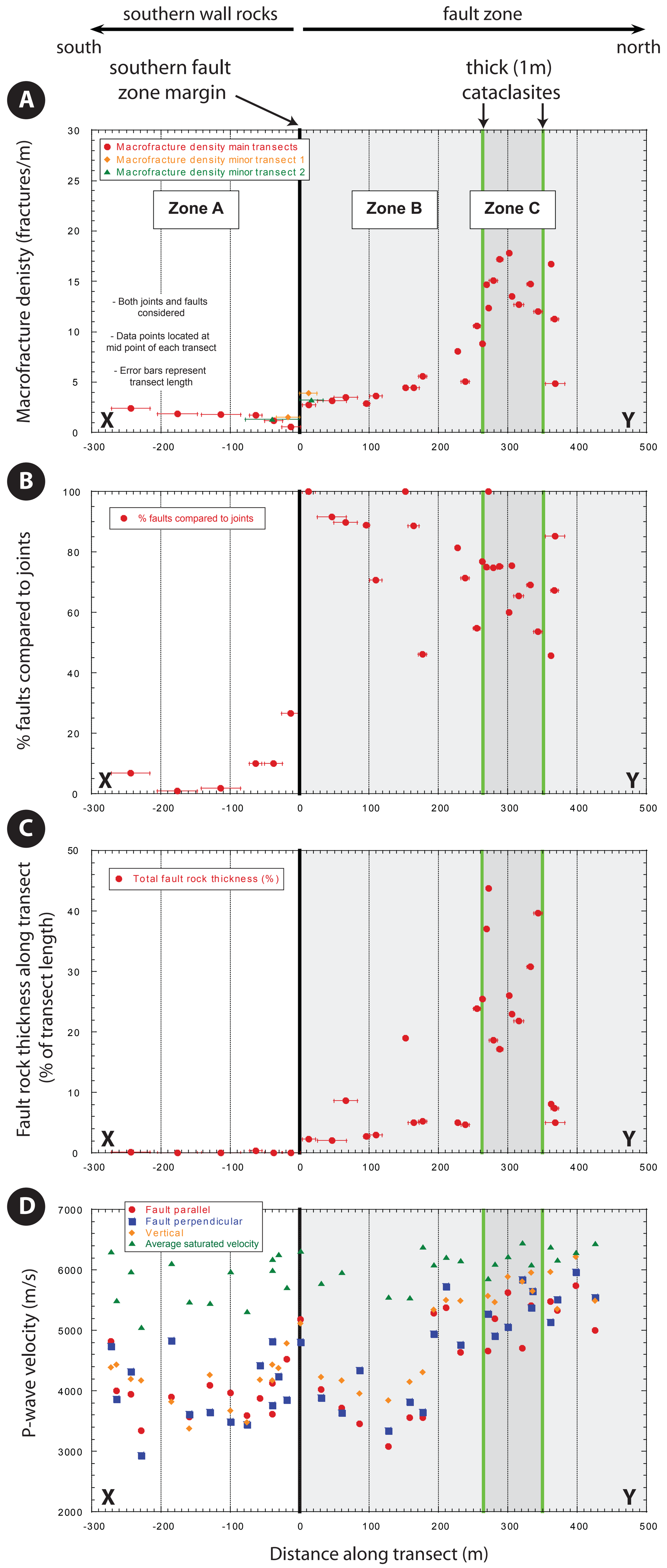
Zone B

Thick (1m) cataclasite separating zones B and C



Intensely fractured. Dominant E-W trending faults accompanied by thick zones of cataclasis and more complex secondary fracture patterns.

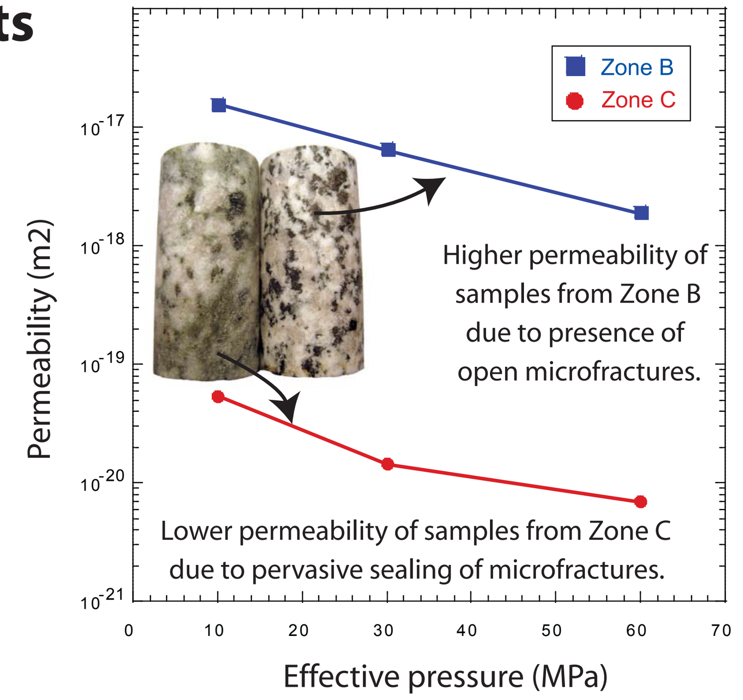
Zone C



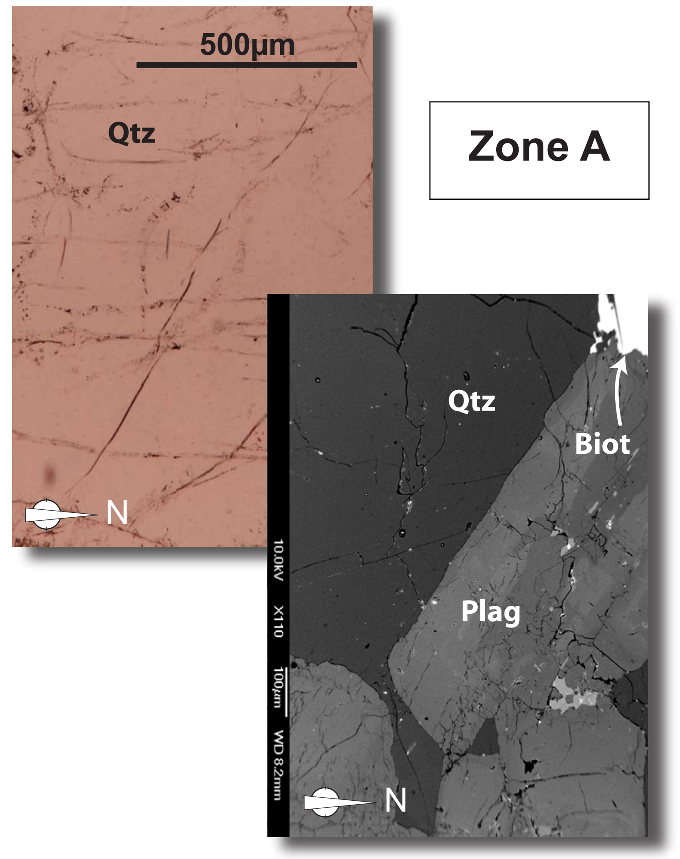
3. Macrofracturing in Zones A, B, C and laboratory measurements of P-wave velocity and permeability

Macrofracture density (joints + faults) shows a **small but abrupt increase** at the southern margin of the fault zone, and then **increases gradually** towards the centre of **Zone C** (Figure **A**, left). The southern margin is better defined by a **large and abrupt increase** in the percentage of faults as compared to joints (Figure **B**). The **total thickness of fault rocks** as a percentage of transect length is much higher **in Zone C** than elsewhere (Figure **C**).

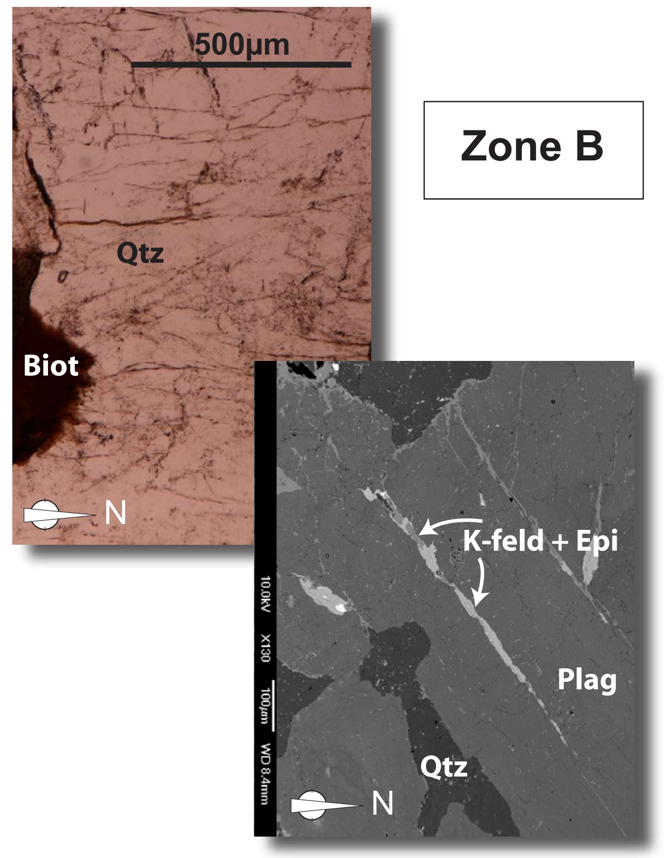
P-wave velocities were measured on samples collected away from main faults or joints. **Zones A and B** have relatively **low P-wave velocities** (Figure **D**) due to the presence of **open microfractures** (see below). In contrast, the area close to and within **Zone C** has **uniformly higher P-wave velocities** (Figure **D**) even although it has **higher microfracture densities**, because microfractures are **pervasively sealed** (below). **Saturated P-wave velocities** show much less difference between the 3 zones, reflecting the saturation of open microfractures in Zones A and B (Figure **D**).



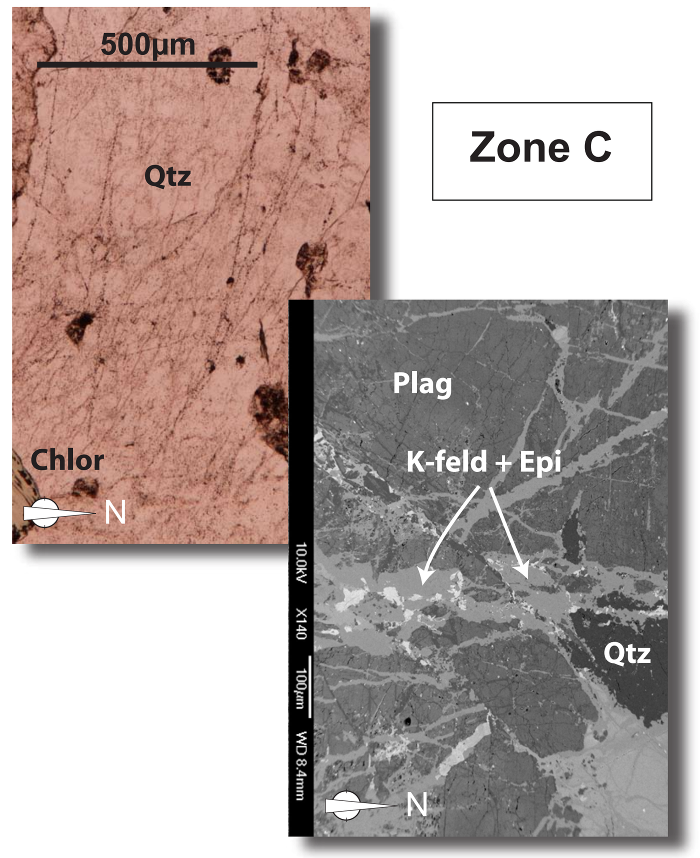
4. Microfracturing in Zones A, B, C



- Low density of open microfractures
- Microfractures are both inter- and intra-granular
- North-South trending, conjugate set dominates



- Intermediate density of microfractures
- Fracture sealing increases towards Zone C
- North-South set dominates, but increasing importance of East-West trending



- High density of sealed microfractures
- Sealing minerals are K-feldspar, epidote, chlorite
- North-South and East-West trending sets dominate

5. Conclusions

1) The investigated area contains **3 distinct zones**. Zone A is the jointed wall rock, Zones B and C are within the Gole Larghe fault zone.

2) Zones B and C are differentiated because **Zone C has**: i) **higher macrofracture** and **microfracture** densities, and; ii) proportionally **thicker fault rocks**, than Zone B.

3) **P-wave velocities** and **permeabilites** of samples collected from all three zones are **controlled by microfracture populations**. An unexpected result is that **P-wave velocities are high in Zone C** even although **microfracture densities are high.** This is because **microfractures in Zone C** are **pervasively sealed**.