Geotechnical and geomechanical characterization of the fault gouge from Alhama de Murcia fault, SE Spain.

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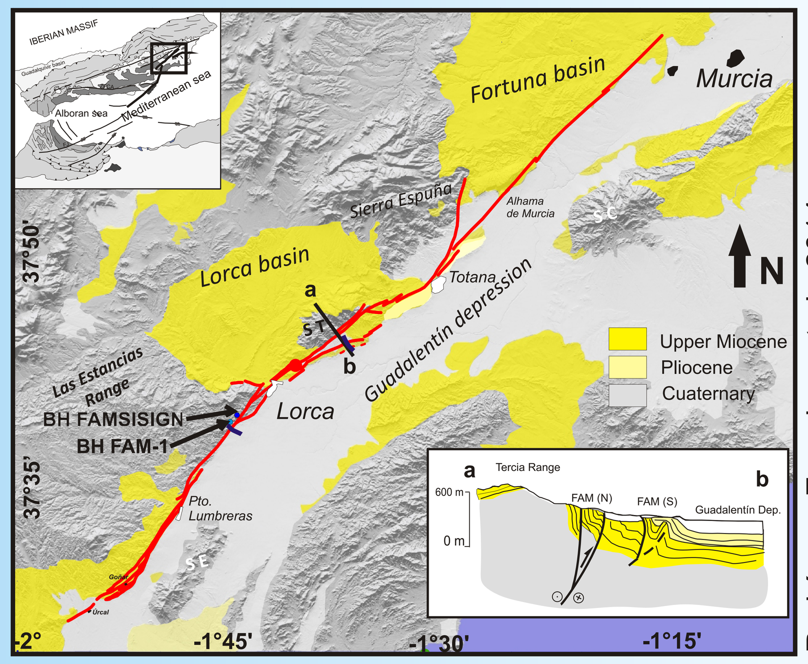
Geological and Geographic Setting

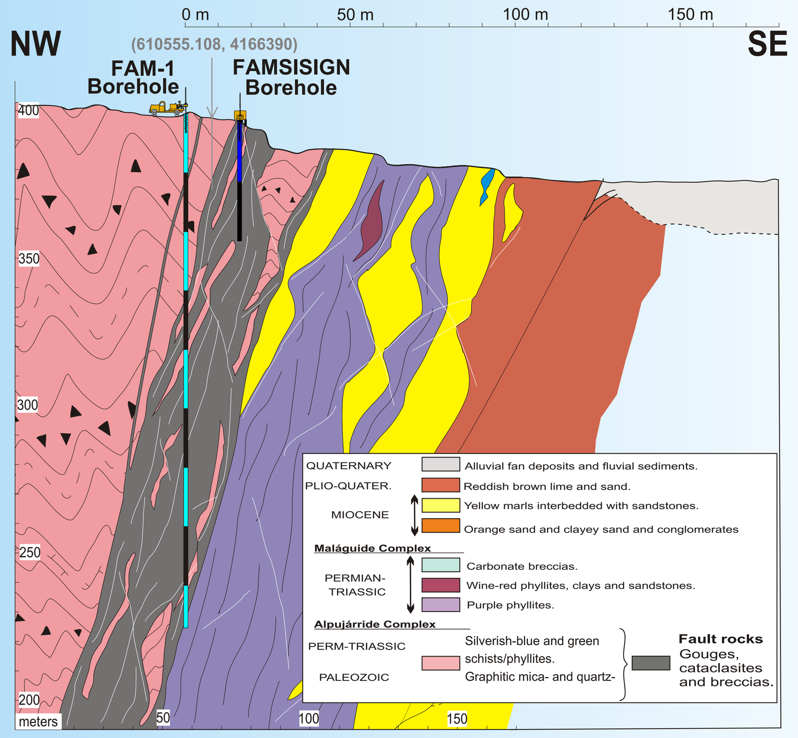
Located in the SE of Spain, the Alhama de Murcia Fault (FAM) is one of the most **active faults** in the Iberian Peninsula. It shows segments composed partially by **exhumed fine grained fault rocks** (fault gouge, FG), occasionally over **50m thick, and developed mainly in a brittle regime** (Martínez-Díaz et al., 2012).

Location



Rodríguez-Escudero et al., 2014

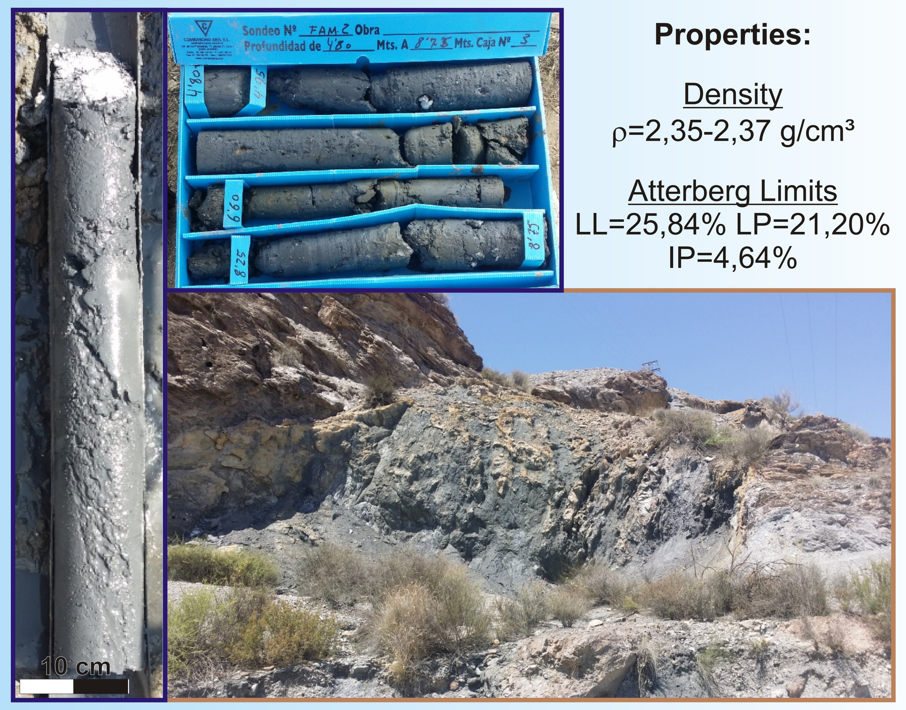
Boreholes



FAM-1 is a **175 m deep** survey using wire-line continuous sampling (PQ-3, 83 mm) until 119,55 m, where the core diameter becomes HQ-3 (61 mm).

FAMSISIGN is a **38 m deep** survey using wire-line continuous sampling (PQ-3, 83 mm).

Fault gouge



Properties:

Density
ρ=2,35-2,37 g/cm³

Atterberg Limits
LL=25,84% LP=21,20%
IP=4,64%

Rodriguez-Soto, 2016

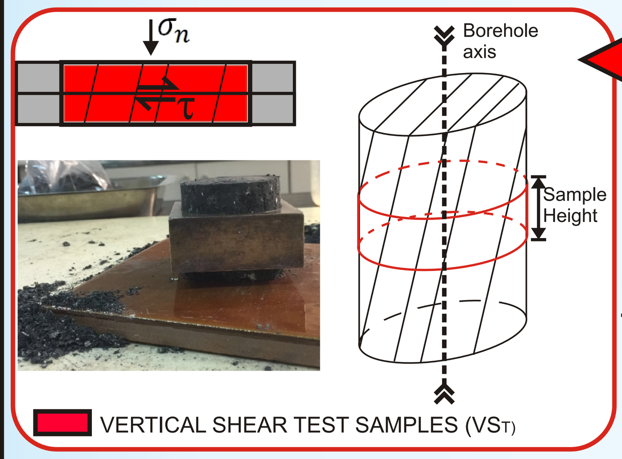
Tests

Mineralogy and Microfabric

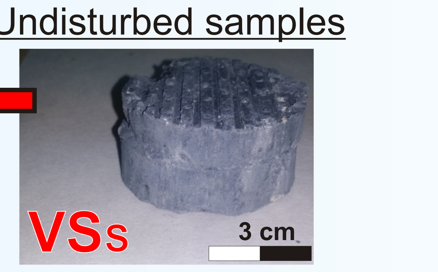
X-ray diffraction test, **optic microscopy** and **Scanning Electron Microscopy**

Strength tests

Shear tests

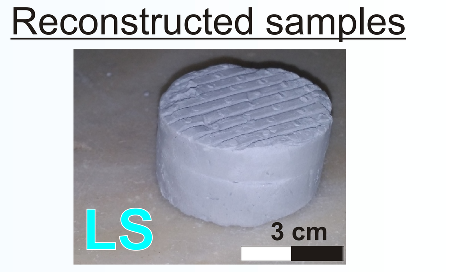


Undisturbed samples



For direct shear tests, slip surface is **unfavorably oriented to the tectonic fabric** in undisturbed samples. (VSs).

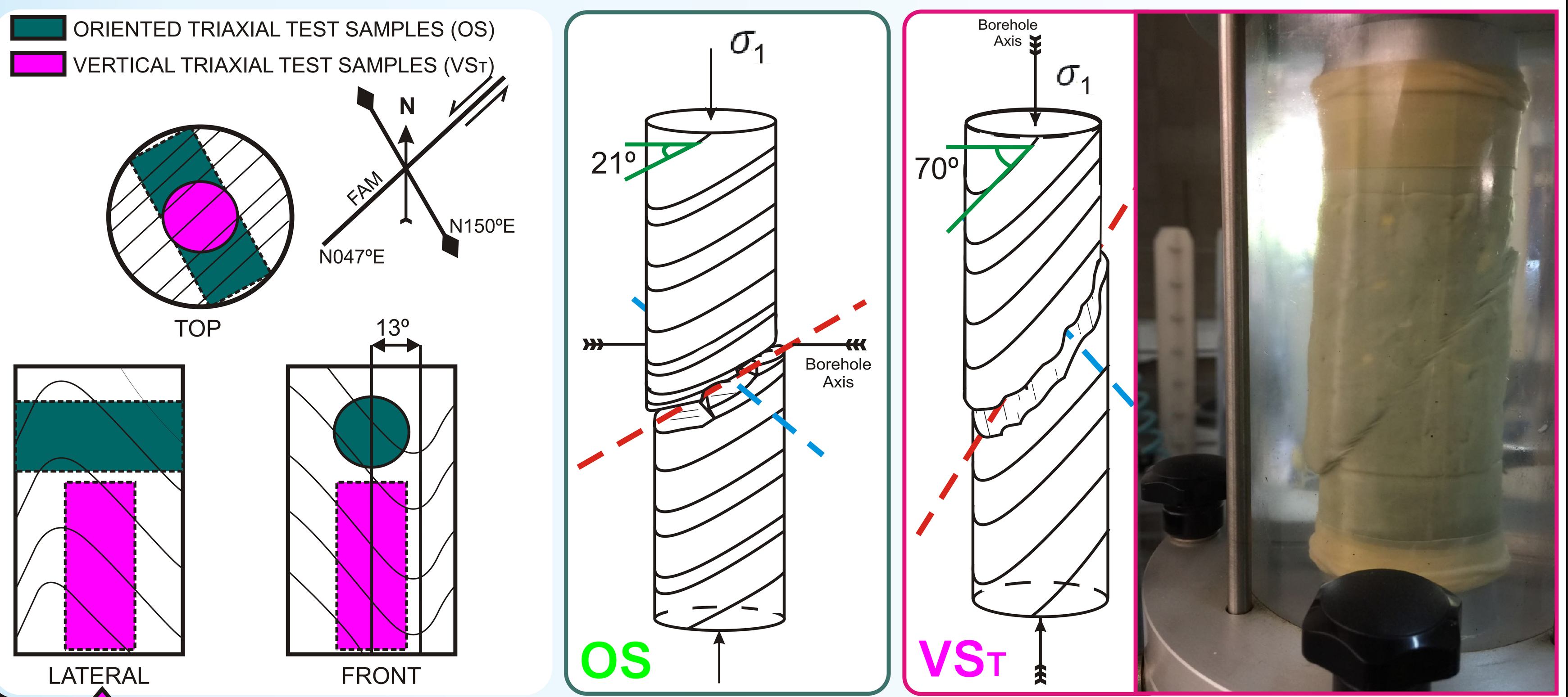
Reconstructed samples



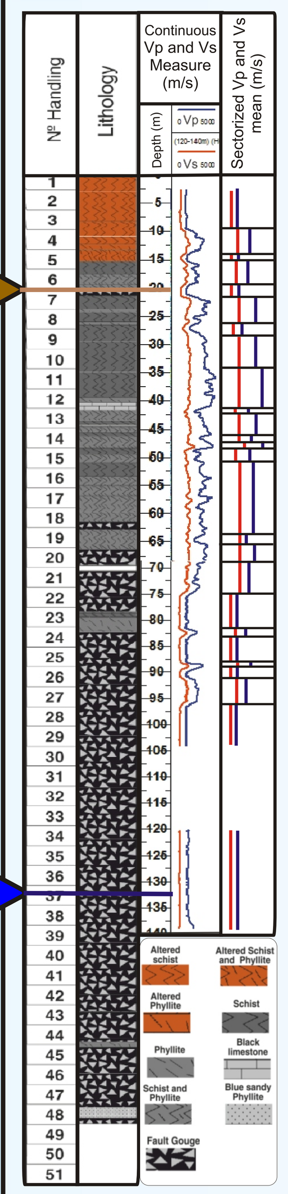
Sieved (0,064mm) and **reconstructed** FG samples (LS) and **pulverized** FG **quartz** samples (QS) analyzed by direct shear tests.

Uniaxial and Triaxial compression tests

Uniaxial tests performed in vertical samples (VST). **Consolidated Undrained Triaxial tests** performed in vertical samples (VST) and in **oriented in the current tectonic stress direction** samples (OS).

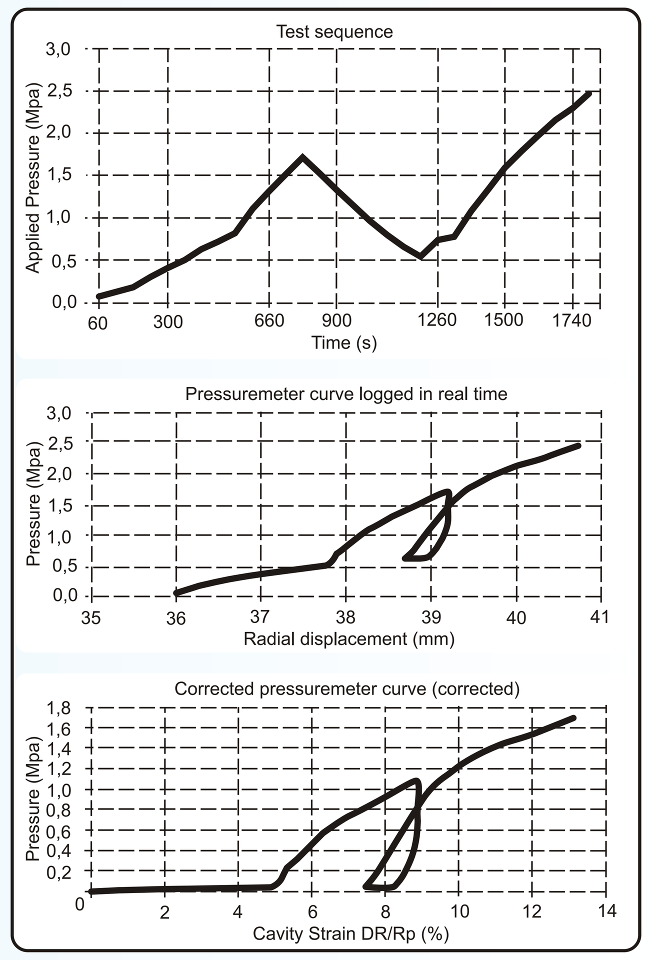


In situ tests



Full waveform acoustic logs obtained in FAM-1 borehole.

8m deep **OYO pressuremeter** performed in FAMSISIGN borehole.

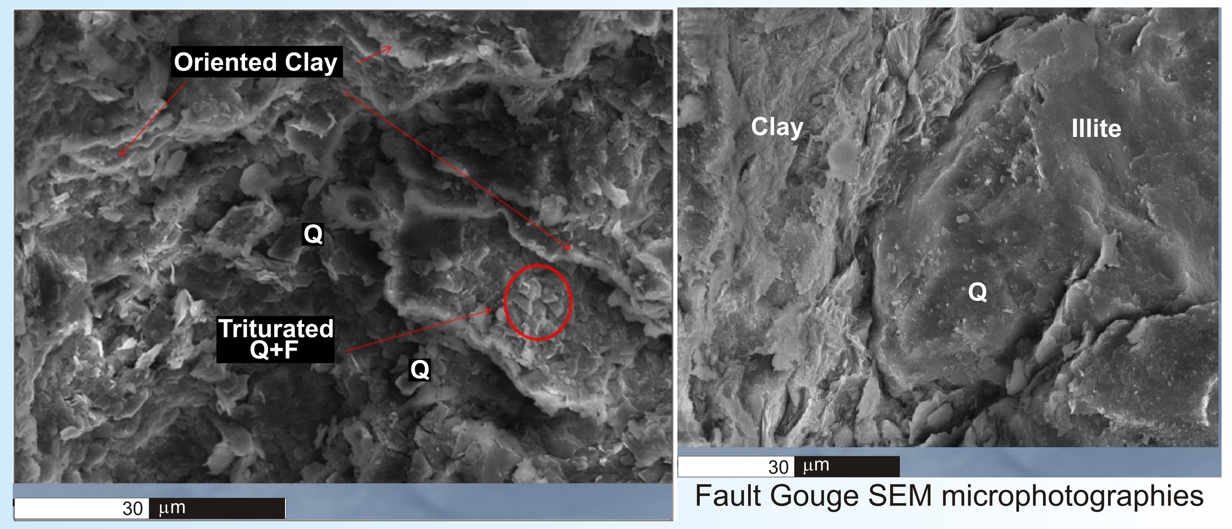


Results

Mineralogy and Microfabric

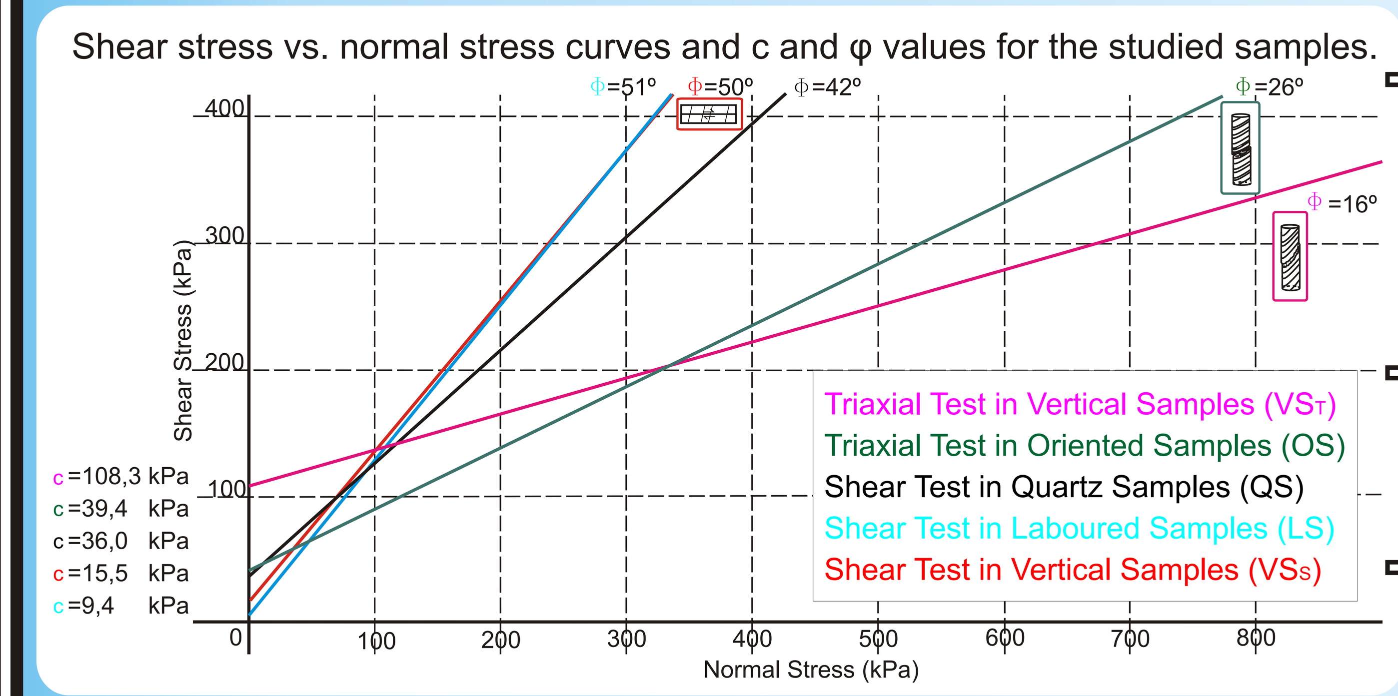
FG mineralogy is represented mainly by **potasic and sodic mica**, **quartz** in similar proportions and **carbonates** (**dolomite**, **calcite** and **ankerite**) in a lower amount. **Chlorite** was also found in some samples. **Clay minerals** are mainly represented by **illite** and **paragonite** with a very low amount of **kaolinite**.

FG presents an **anastomosing microfabric** (**turbostratic microstructure**) with a very fine matrix. This matrix, with a cataclastic appearance, is composed by a mineral aggregates mixture with a preferred orientation wich are coating a pulverized quartz.



Fault Gouge SEM microphotographies

Strength parameters



➩ FG shows **very low resistance to simple compression.** Uniaxial tests show values of σc from 0,7 to 1,5 Mpa. It was also obtained indirectly by triaxial tests. By this method σc fluctuates depending on the tectonic fabric orientation regarding to the axial stress (σc = 0,1 - 0,3 Mpa).

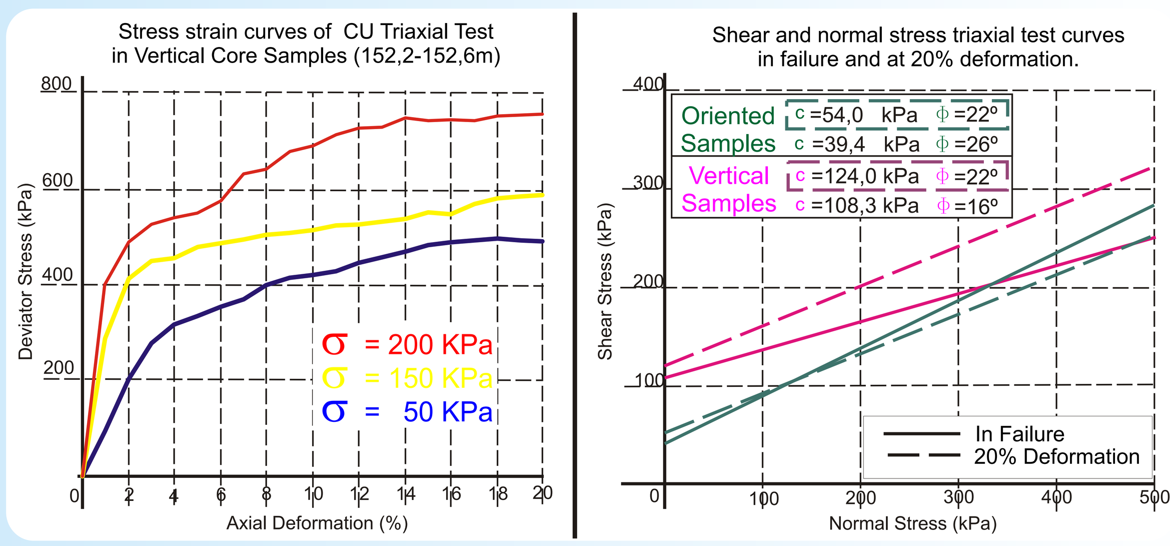
➩ **Cohesion values are remarkably low**, mostly beneath 0,1 MPa, and **fluctuate regarding tectonic fabric orientation.**

➩ **Friction angles** obtained also **depend on fabric orientation** and applied stresses.

Strain Hardening

FG presents a **strain hardening behaviour with large deformation (>10%)**, manifested by a mild increase of cohesion which can be seen on the shear vs. normal stress curves.

Friction angles tend to stabilize for high deformations showing **values around 22º.**



Elastic Properties of FG from *in situ* tests

In situ Pressuremeter test

P1	0,04	Initial pressure of pseudo-elastic phase
P2	1,08	Final pressure of pseudo-elastic phase
Plm	**2,5**	**Calculated limit pressure**
Epr1	109,3	Cycle Pressuremeter Modulus
Ep	**35,68**	**Pressuremeter Modulus**
Gr1	41,2	Cycle Shear Modulus
G	**13,8**	**Shear Modulus**

Units: MPa

In situ Geophysical velocity test

	Vs (m/s)	Vp (m/s)	Vp/Vs	ν	E (GPa)	K (GPa)	G (GPa)
Minimum	891	1595	1,67	0,17	4,23	2,17	3,36
Medium	965	1742	1,80	0,28	4,77	3,56	3,95
Maximum	1138	1994	1,87	0,40	6,20	10,25	5,49

Vs: Secondary waves velocity, **Vp** :Primary waves velocity, ν: Poisson ratio,
E: Young Modulus, **K:** Bulk Modulus, **G**:Shear Modulus

Material velocity clasification

Soil and rock type	Vp	Vs	Vp/Vs
Hard and massive rocks	6000-4200	4000-2700	1,45-1,5
Very stiff	4200-3000	2700-1500	1,5-2,0
Stiff	3000-2000	1500-700	2-3
Moderate stiff but altered	2000-1500	700-400	3-4
Loose and soft	1500-600	400-100	4-6
Soft and saturated	>1300	>100	5-8

Protolith | Fault gouge

Salacak Mh., 2012

Conclusions

- **FAM Fault gouge has geomechanical and geotechnical properties between hard soil and soft rock** (σc<2Mpa).
- **Samples exhibit dramatic differences in strength properties.** Friction varies from μ = 0,3 to 1,2 depending on the applied stress orientation in relation to tectonic fabric. This is related to the phyllosilicates orientation.
- **Strain hardening** behavior was seen with large deformations wich increases material rigidity by compaction. It has been observed in all samples that **friction angles stabilize around 22º.** This might be related to reorientation of the phyllosilicates.
- *In situ*, compressional and shear wave velocity and elastic modulus results, show an homogeneous material. However, there is a **big difference between indirect and direct tests.**

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