Fault Sealing and Mechanical Stratigraphy in Carbonate Rocks, Southeast Guizhou, China*

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Abstract

Thrust faults in Paleozoic carbonates of the Southeast Guizhou fold-thrust belt provide important analogs for fault deformation and sealing in marine carbonate reservoirs in South China. Based on the structural elements from photomicrographs, outcrops, seismic cross-sections, and laboratory data including mechanical properties, petrophysical properties, and capillary pressure, we studied the mechanisms and intensity of deformation across a large, active, uplift-bounding thrust fault zone in platform carbonates.

General observations include: (1) The relatively higher-angle breakthrough faults with large propagation-to-slip develop in massive, competent, clay-poor dolomites, and is where the bitumen is distributed. Faults in massive, incompetent marlites tend to breakup on lower-angle. (2) In less competent clay-rich strata, shale and mudstone beds impede fault propagation across the strike, resulting in fault-related folding. (3) Higher compressive strength associated with massive, clay-poor dolomites generate more fractures for fluid flow. Conversely, the pressure solution seams, later filled with clay, develop in the lower compressive strength rocks associated with marlites. (4) The high density pressure solution seams are found between overstepping thrust faults, which have raised both the effective length of the barrier to fluid flow and the fault sealing potential.

References

Ferrill, D.A. and A.P. Morris, 2008, Fault zone deformation controlled by carbonate mechanical stratigraphy, Balcones fault system, Texas: AAPG Bulletin, v. 92/3, p. 359-380.

Agosta, F., M. Prasad, and A. Aydin, 2007, Physical properties of carbonate fault rocks, Fucino Basin (central Italy); implications for fault seal in platform carbonates: Geofluides 7/1, p. 19-32.

Fault Sealing and Mechanical Stratigraphy in Carbonate Rocks, Southeast Guizhou, China

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(China University of Petroleum, Beijing）

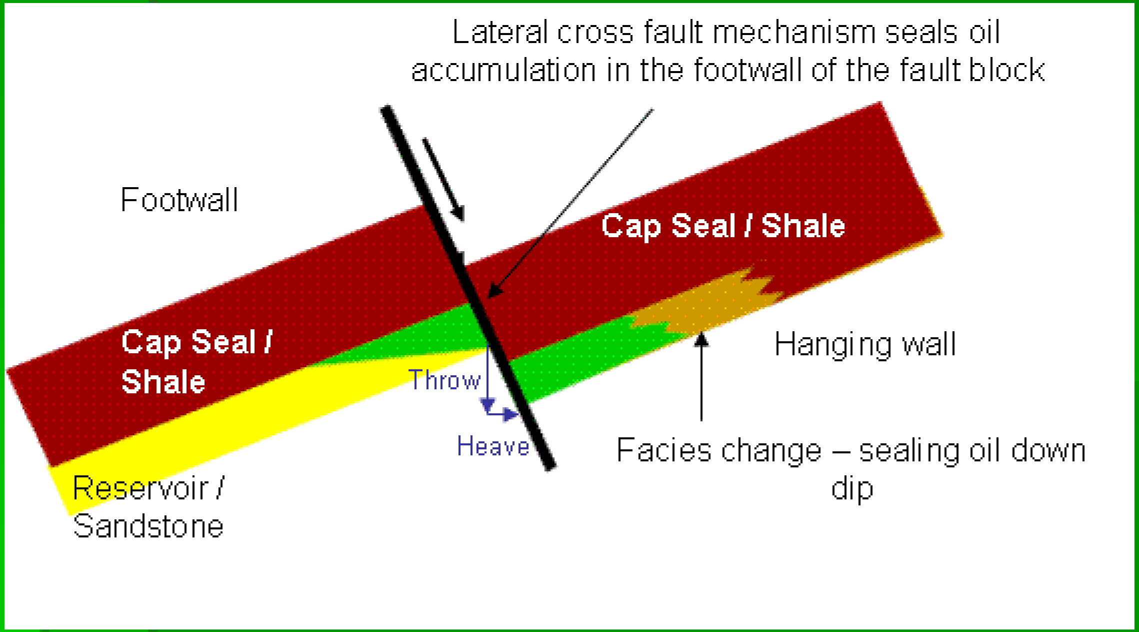
OUTLINE

- Introduction
- Geological Setting
- Mechanical Stratigraphy
- Fault zone and deformation of carbonate
- Implication for fault sealing

Introduction

Fault sealing in siliciclastic rocks

Juxtaposition Seal
Fault Block Seal and Shale Dominated Fault Block



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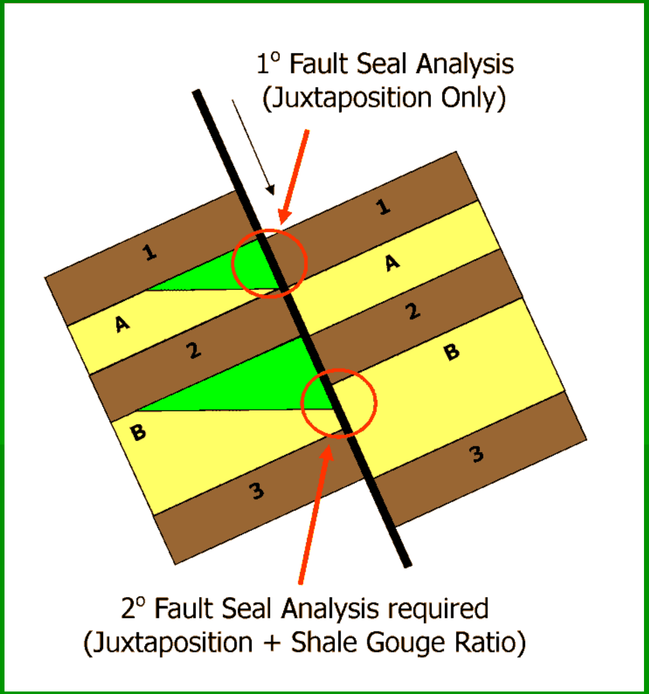
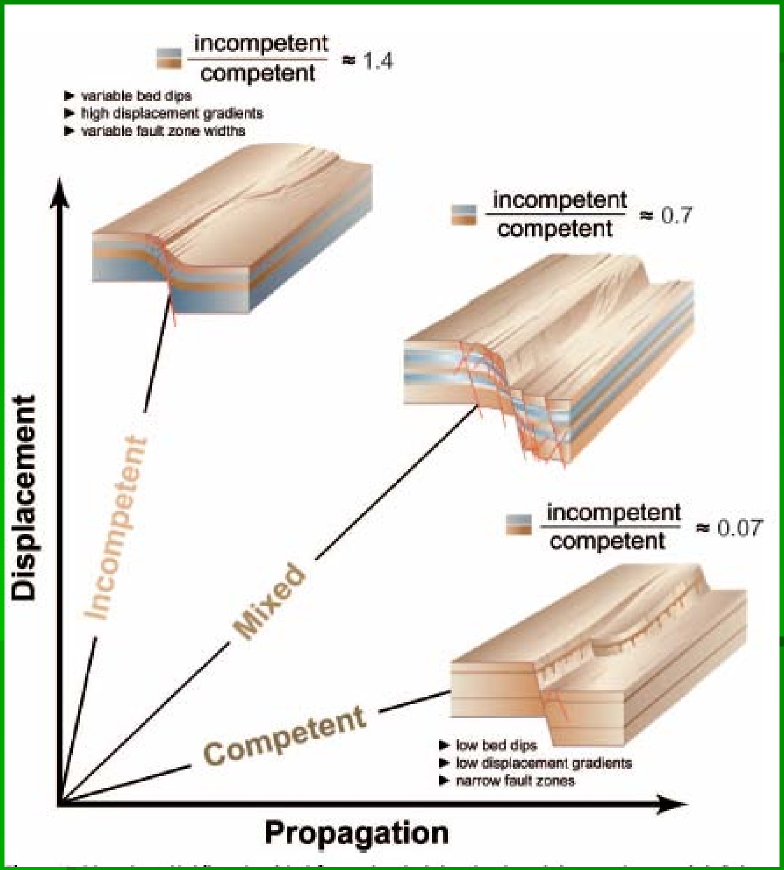
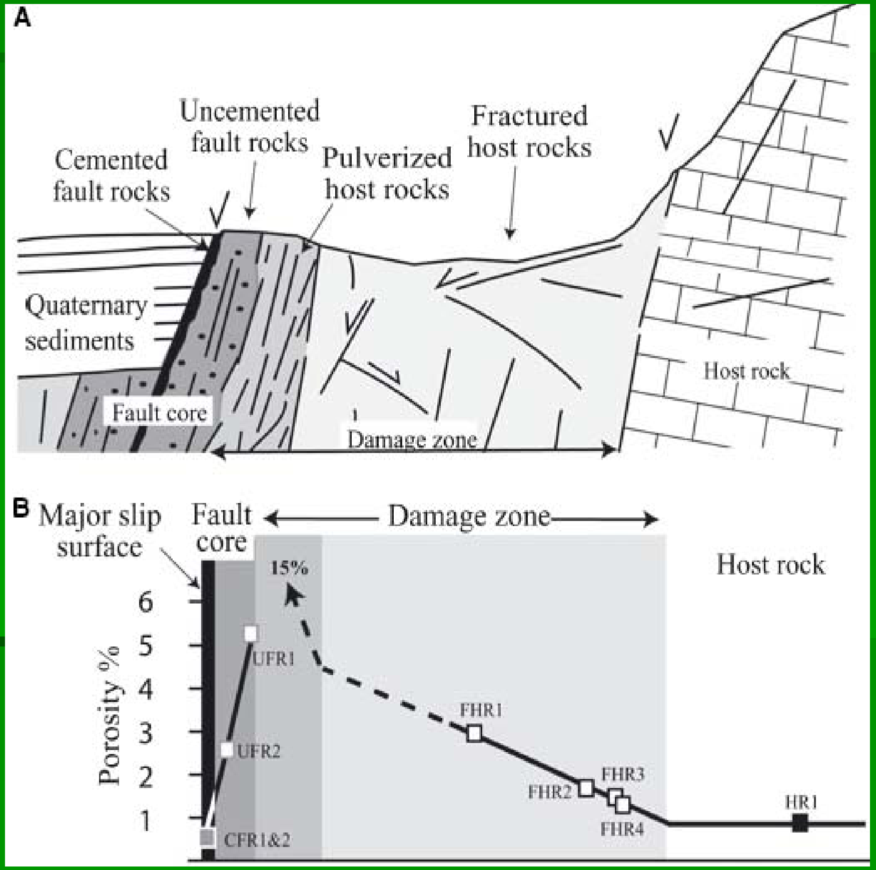


From Internet

Several models of fault permeability and deformation in carbonate rocks



The graph of the influence of mechanical stratigraphy on fault propagation versus fault displacement (Ferrill, D.A. and A.P. Morris, 2008)

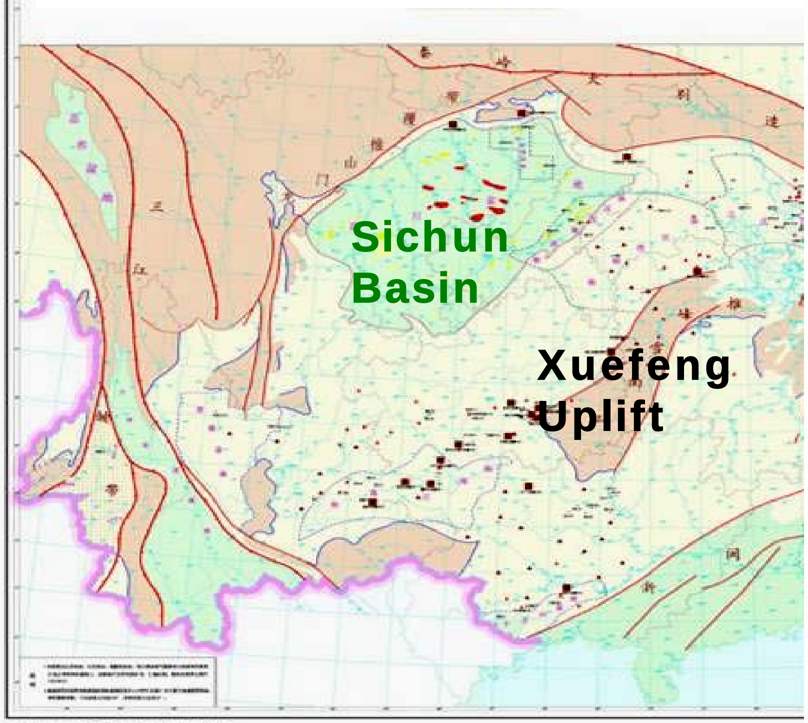


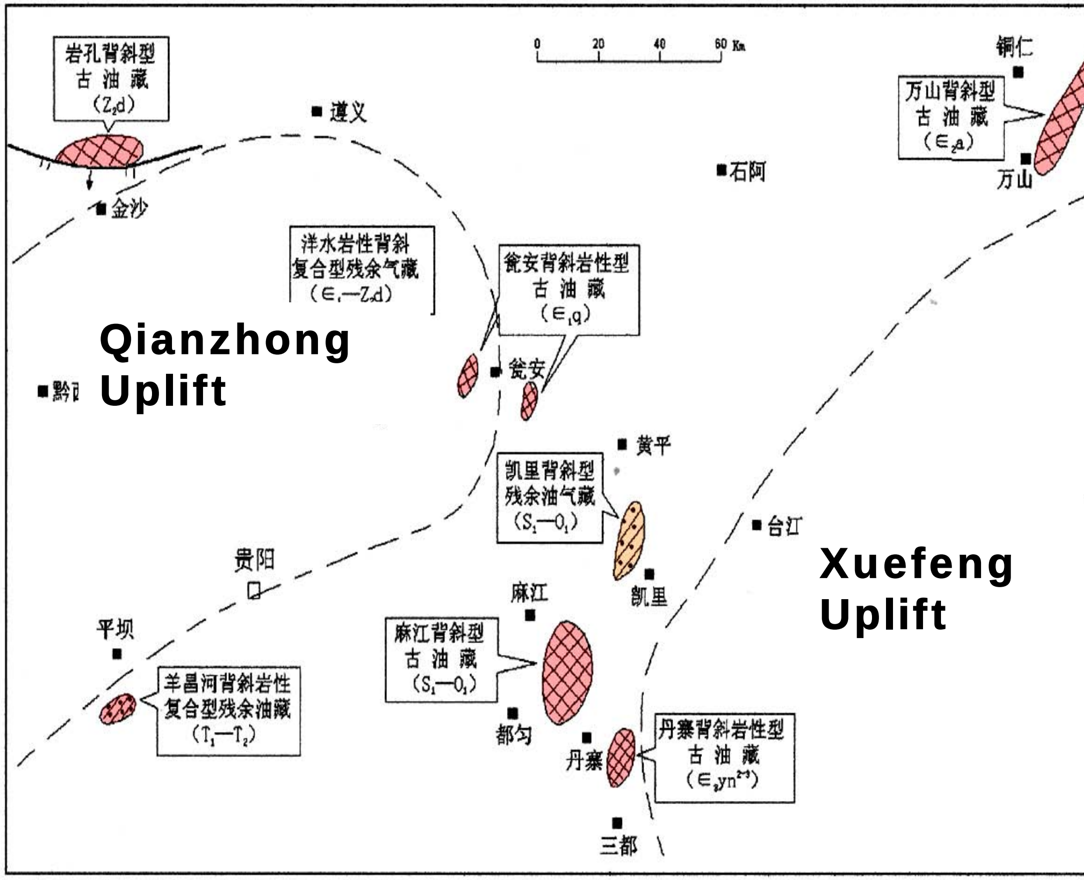
The fault architecture and the corresponding measured porosity (Agosta, F. et.al, 2007)

Introduction

The sealing is the key for exploration, except Sichuan Basin, in South China, where there are almost carbonate rocks.

Oil seepage and bitumen on exp
surface in South China





(After Sinopec PEEI, 2006)

Paleo / Residual Reservoir

Introduction

AIMS:

1) The mechanical parameters and deformation in dolostone and limestone, southeast China;

2) The relationship between the mechanical stratigraphy and calcite vein or bitumen, fluid in carbonate area, implications for fault sealing.

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1 Geological Setting

Tectonic

Stratigraphy

Paleozoic

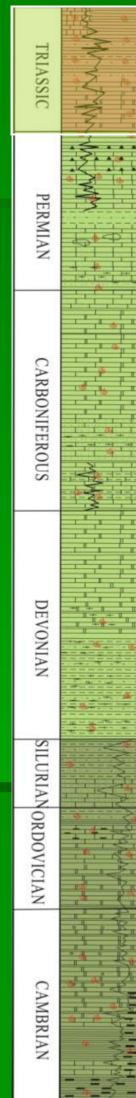
Triassic

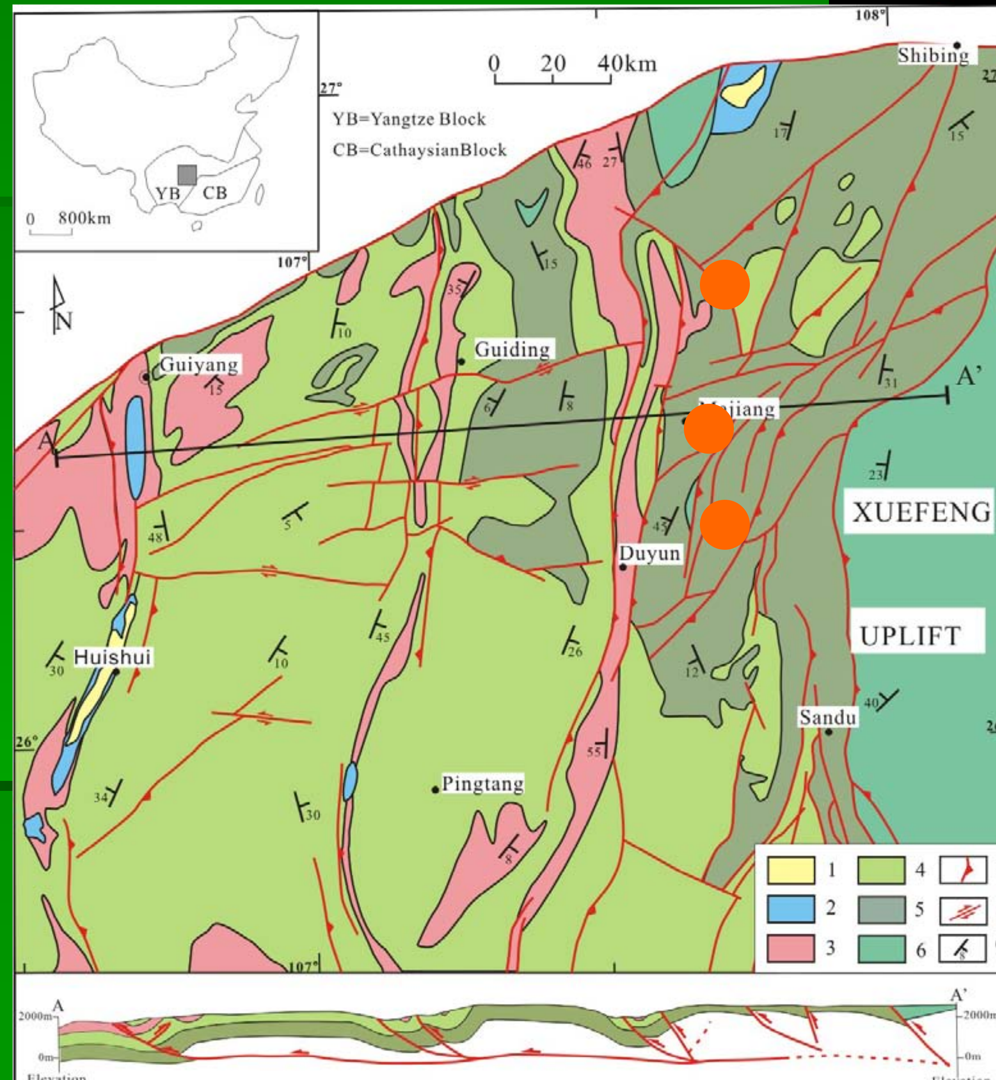
Lithology

Terrestrial facies

Lower Triassic

Marine facies





Paleo / Residual Reservoir

Geological map of the Southeast Guizhou（after Guizhou bureau of geology and mineral resources, 1987）
1-Cenozoic;2-Jurassic and Cretaceous;3-Triassic;4-Upper Paleozoic;5-Lower Paleozoic;
6-Meso-proterozoic and Neo-proterozoic;7-thrust;8-strike-slip fault;9-occurrence of strata

Geological Setting

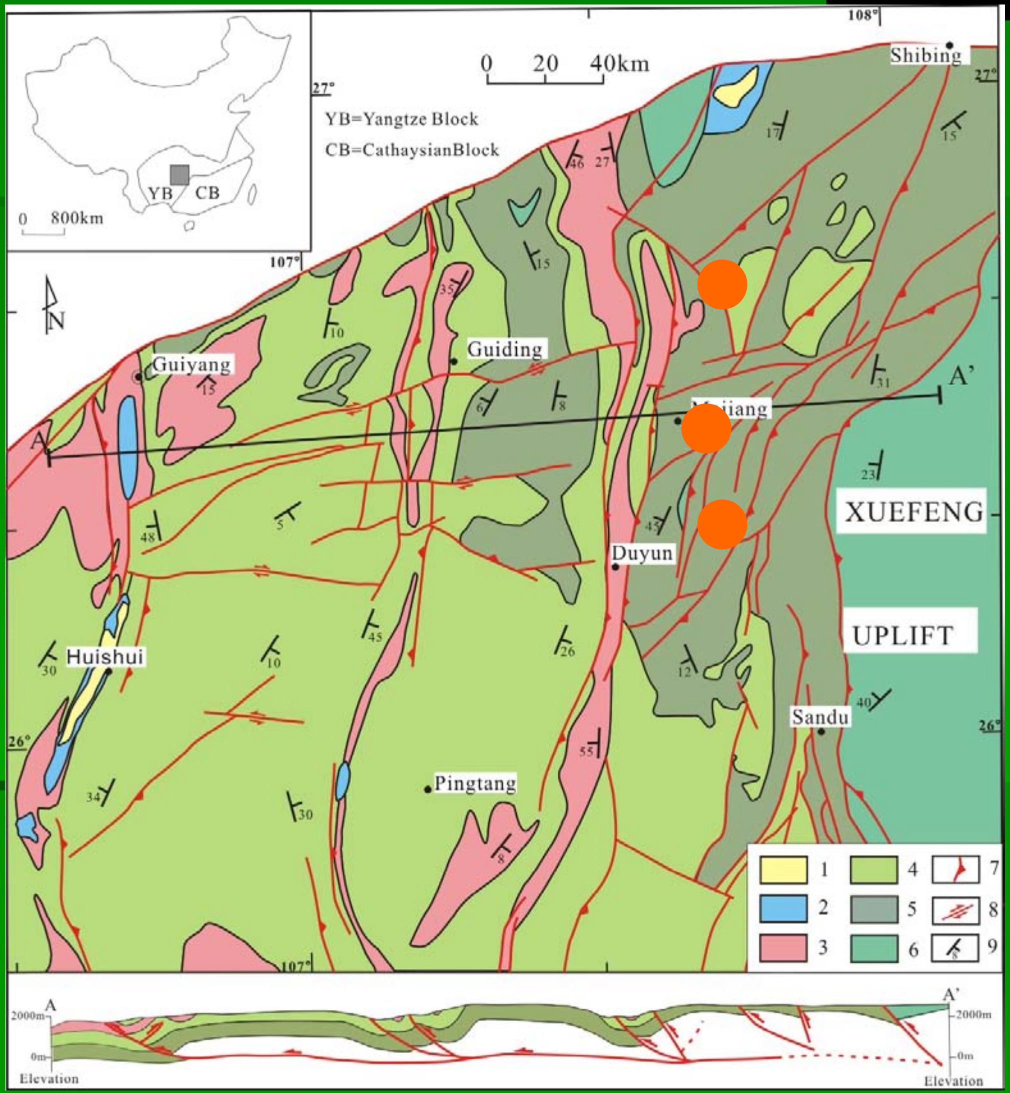
Structural Geology

Thrust Strike NNE,SN

Folds SN

Chevron Syncline

Box Anticline



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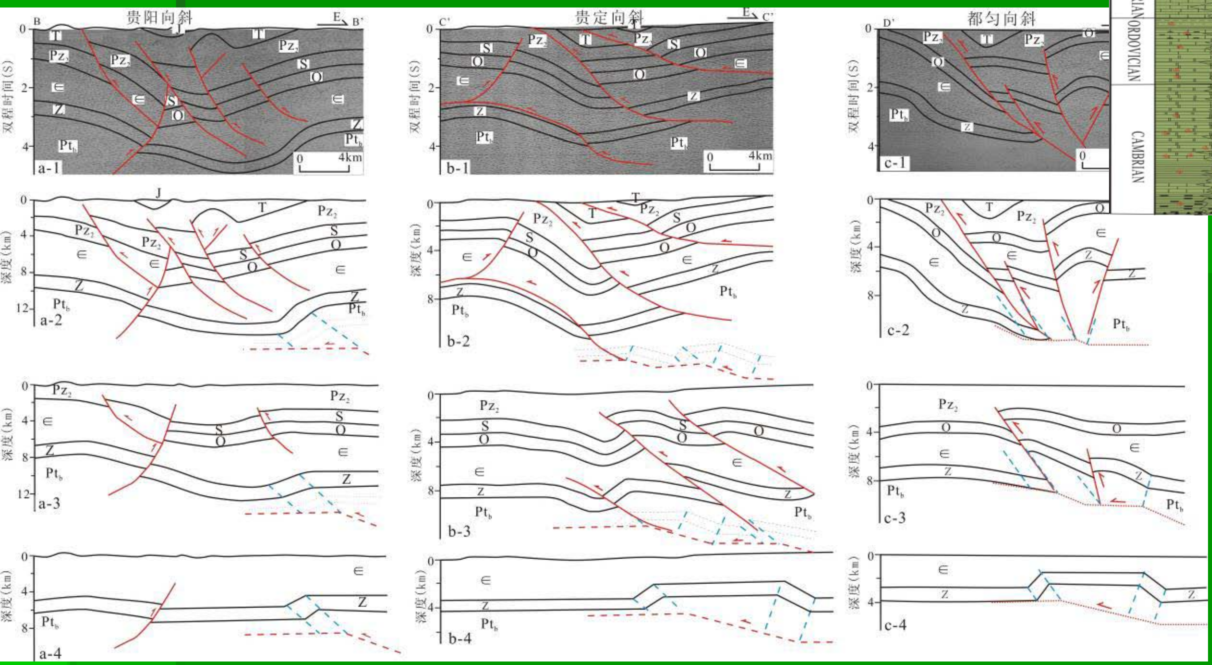
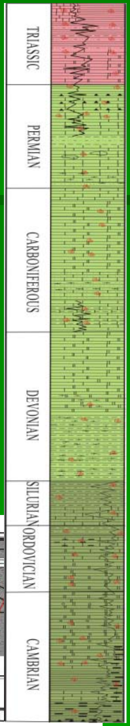
● Paleo / Residual Reservoir

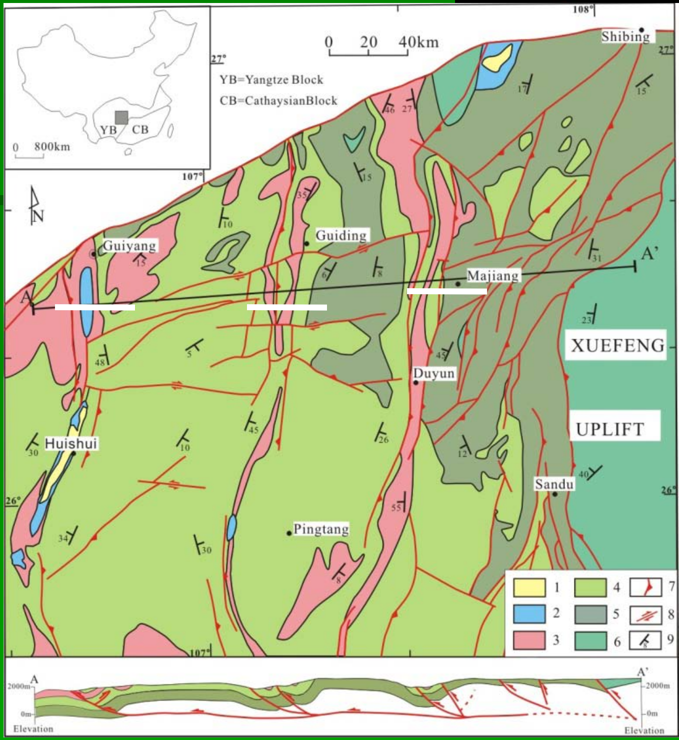
Geological Setting

Structural Geology

Seismic Cross Section and Balanced



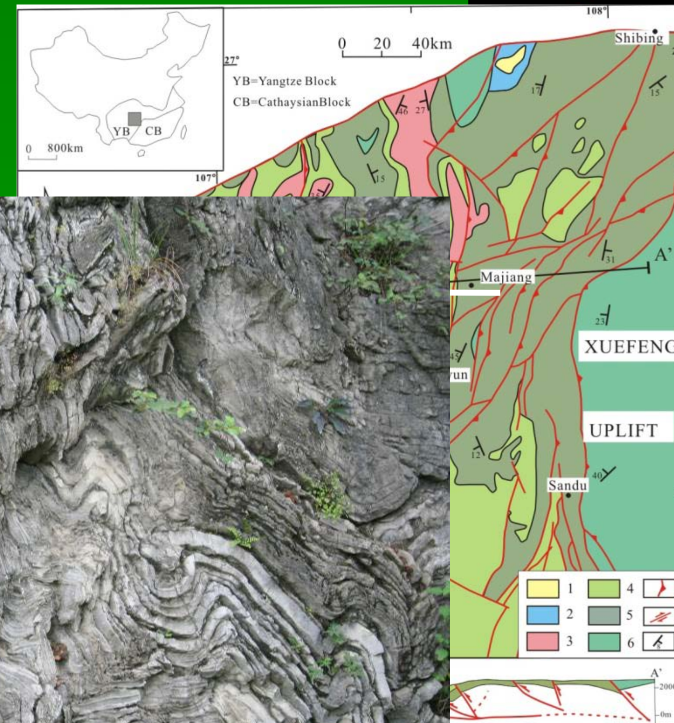


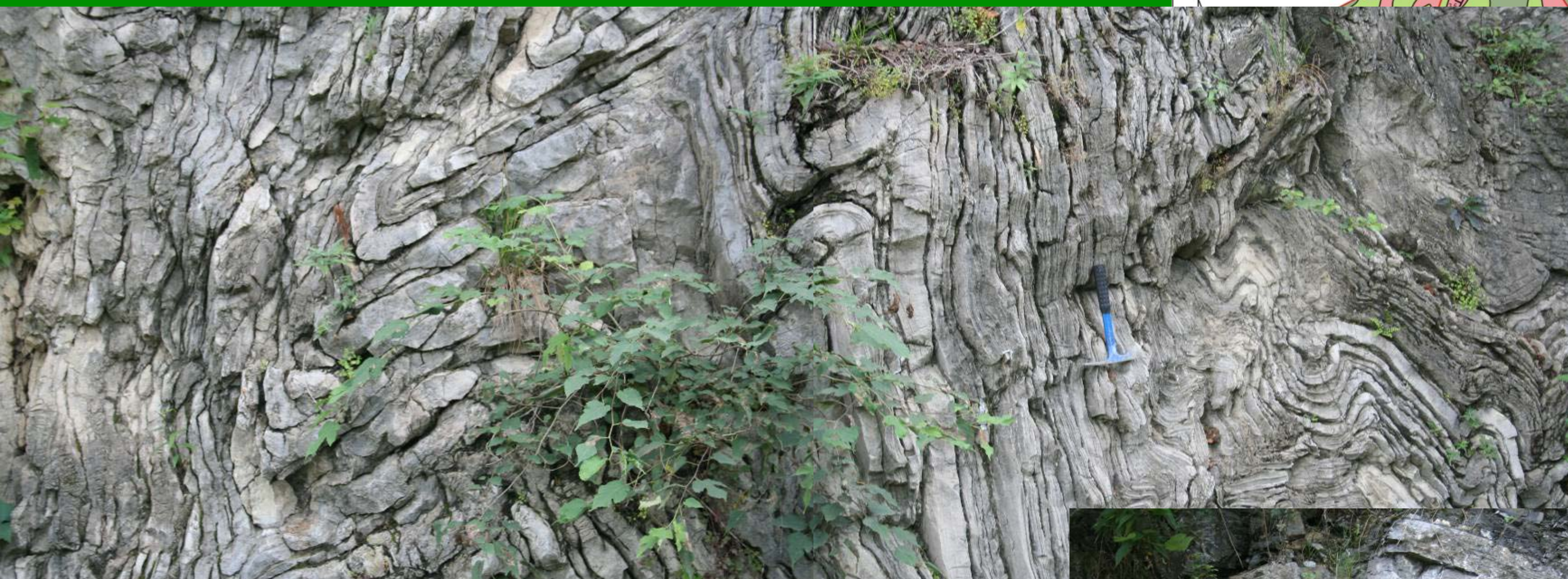


Geological Setting

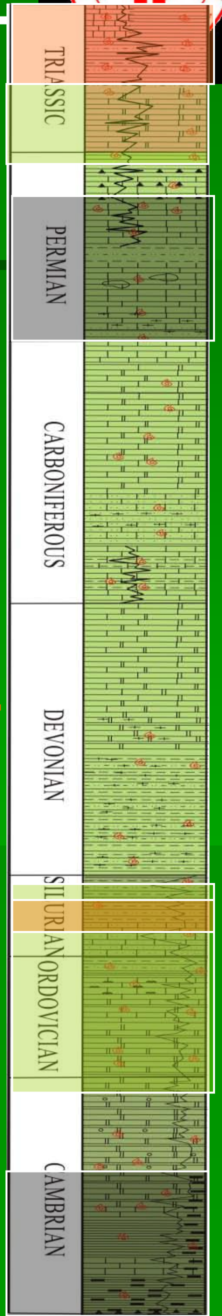
Structural Geology

Photography on the outcrop





Geological Setting



Source Rock

Lower Permian P_1 q(Qixia Formation, Black Shale and limestone)

Lower Cambrian $\in_1$n (Niutitang Formation, Black Shale)

Reservoir

Lower Ordovician carbonate rocks

Lower Silurian sandstone

Lower Triassic carbonate rocks

Fault sealing~

Seal

Middle and Upper Triassic mudstone and shale

Lower Silurian mudstone and shale

Geological Setting

Bitumen and calcite vein

OUTLINE

- Introduction
- Geological Setting
- Mechanical Stratigraphy
- Fault zone and deformation of carbonate
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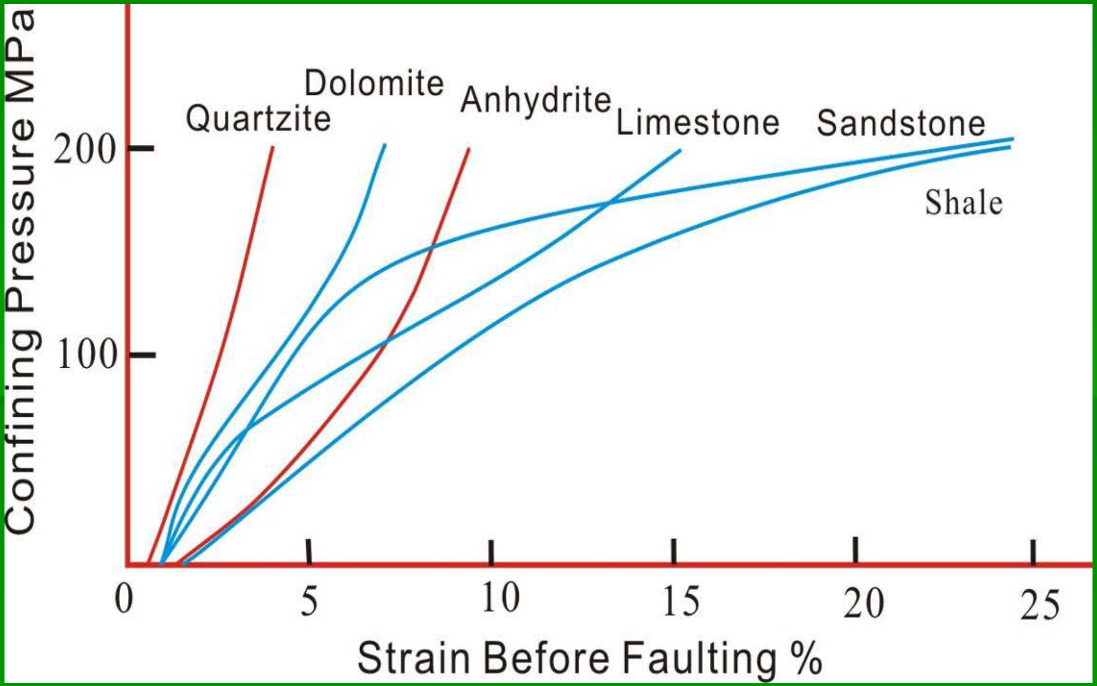
Mechanical Stratigraphy

Dolostones and limestones are relatively competent strata, shale and anhydrite are relatively incompetent strata.
Clay-rich limestones or marls are likely to exhibit incompetent behavior in comparison with clay poor limestones.



(from Ferrill, D.A. and A.P. Morris,2008）

Mechanical Stratigraphy

57 samples in filed and make the Tensile Strength and compressive Strength test, here is the result.

Tensile Strength Test Results

Compressive Strength Test Results

Mechanical Stratigraphy

Tensile Strength Test Results

NO.	Tensile Strength
N1-1	8.33
N1-2	11.44
N1-3	10.22
N2-1	3.67
N2-2	4.05
N2-3	3.13
N3-1	6.31
N3-2	5.81
N3-3	12.01
N4-1	9.32
N4-2	4.49
N4-3	10.62
N5-1	12.17
N5-2	12.38
N5-3	11.64
N6-1	14.88
N6-2	10.49
N6-3	9.78

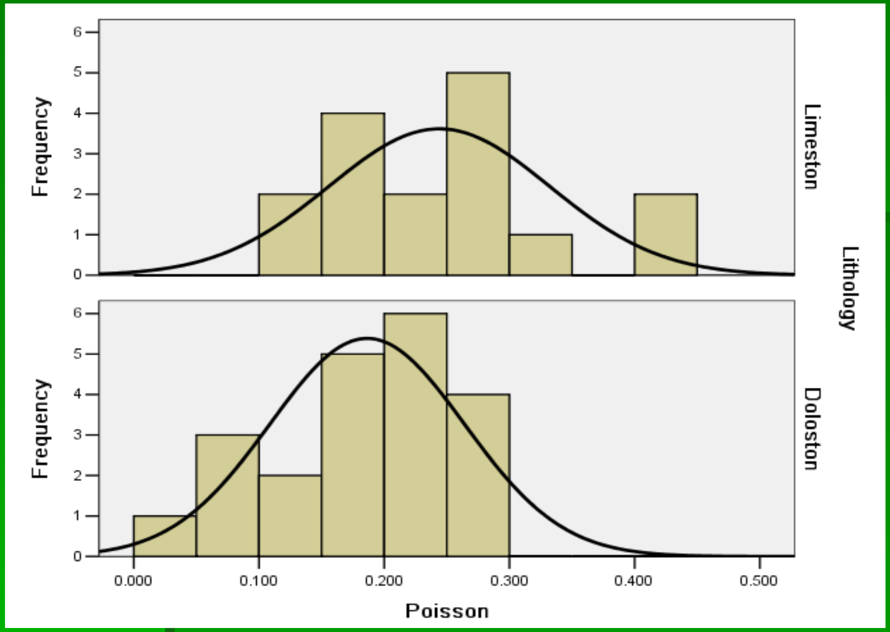
NO.	Tensile Strength
N7-1	4.62
N7-2	4.48
N7-3	4.26
N8-1	6.40
N8-2	7.68
N8-3	8.40
N9-1	1.72
N9-2	6.21
N9-3	1.87
N10-1	11.62
N10-2	6.00
N10-3	11.02
N11-1	4.32
N11-2	5.84
N11-3	4.26
N12-1	7.69
N12-2	9.86
N12-3	5.85

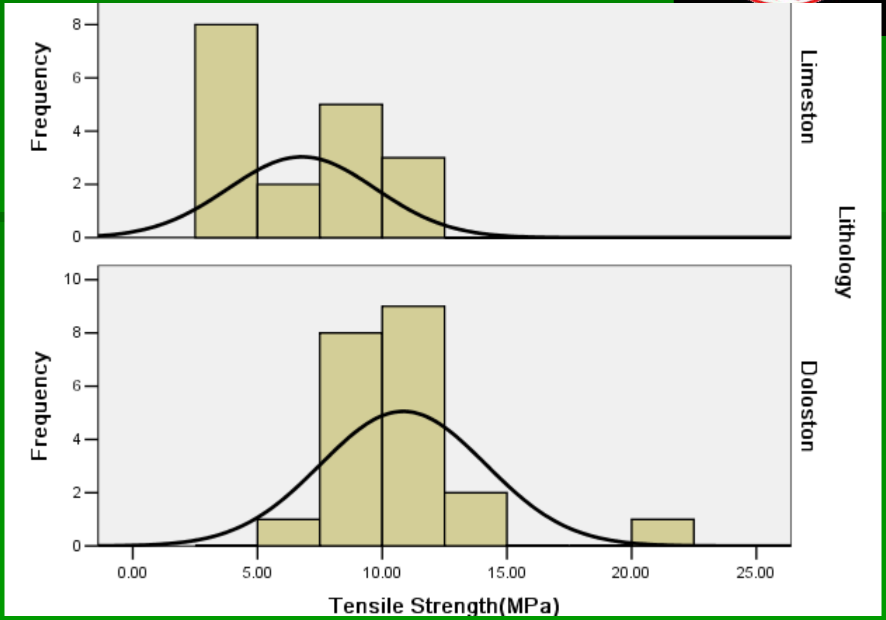
Compressive Strength Test Results

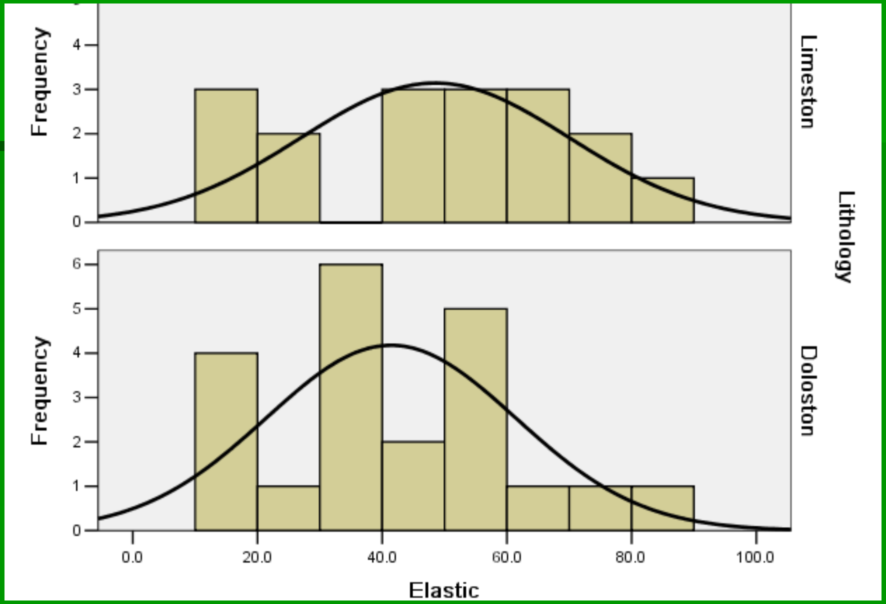
Strength(Ma)		E(MPa)	μ
N1-4	111.84	37.88	0.153
N1-5	127.63	35.53	0.180
N1-6	82.46	52.06	0.296
N2-4	61.04	19.90	0.417
N2-5	64.96	12.46	0.162
N2-6	34.33	18.66	0.184
N5-4	97.62	15.73	0.097
N5-5	80.38	14.31	0.067
N5-6	115.08	14.95	0.037
N6-4	83.87	50.16	0.234
N6-5	163.91	36.50	0.230
N6-6	167.26	32.47	0.174

Strength(Ma)		E(MPa)	μ
N7-4	74.96	51.93	0.164
N7-5	82.59	40.23	0.288
N7-6	77.65	26.46	
N8-4	77.61	29.15	0.147
N8-5	90.32	55.18	0.282
N8-6	87.64	61.01	0.325
N9-4	**9.39**	**7.12**	**0.103**
N9-5	**13.76**	**16.16**	**0.081**
N9-6	**16.96**	**24.53**	**0.093**
N10-4	**95.22**	**31.78**	**0.088**
N10-5	**98.59**	**42.17**	**0.110**
N10-6	**123.84**	**34.21**	**0.229**

Mechanical Stratigraphy



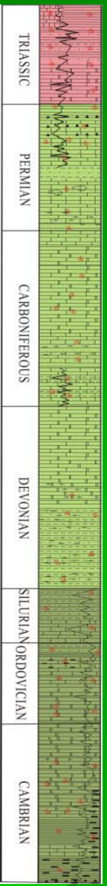


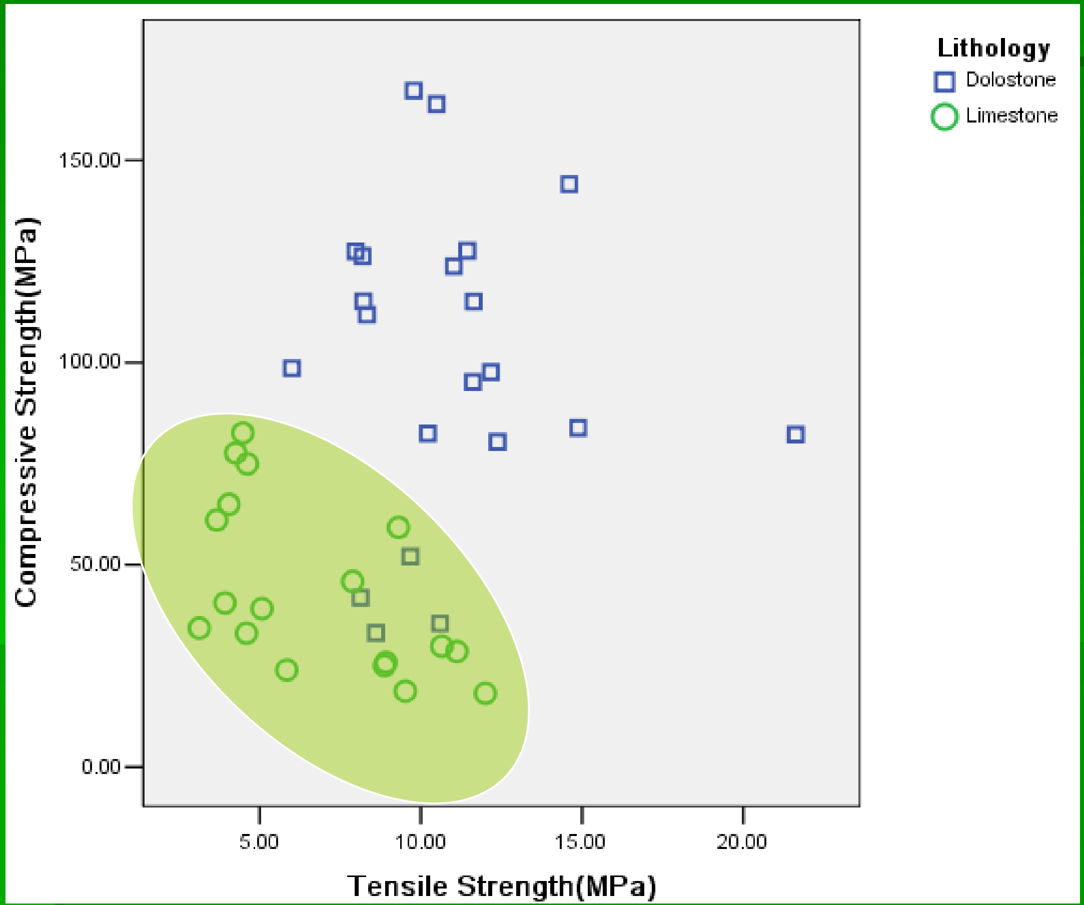


There is only a little difference on poisson, elastic and tensile between limestone and dolostone.

Mechanical Stratigraphy

The dolostone is competent unit, whose compressive pressure is higher than limestone

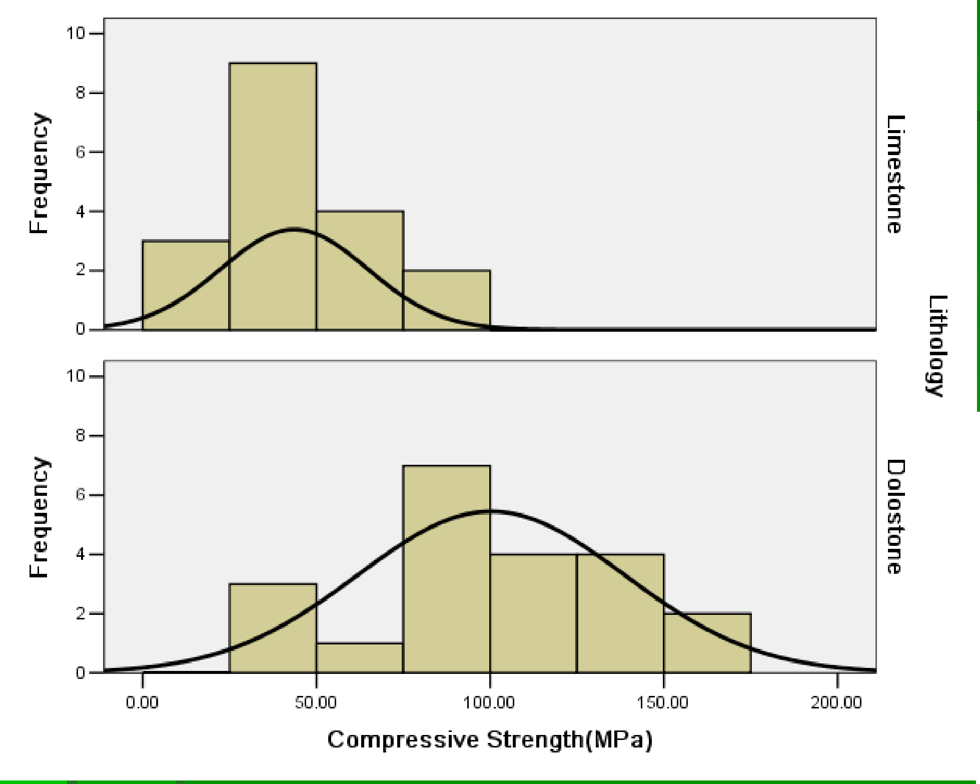


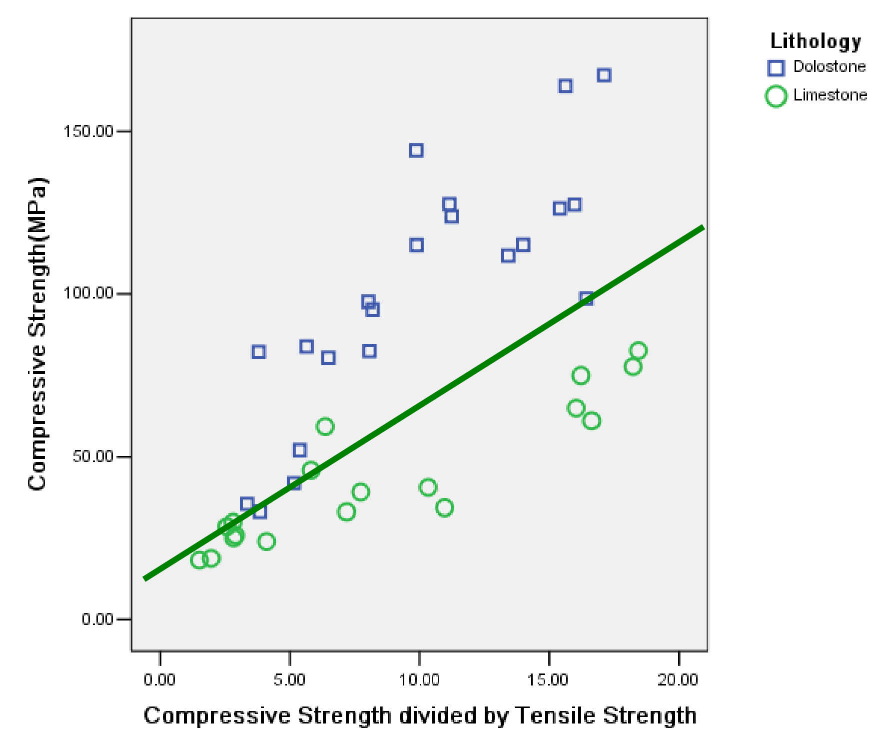


The Rock Mechanics Parameters of Carbonate Rocks in Southeast Guizhou, China

	Strength(Ma)	E(MPa)	μ
A1	29.86	69.30	0.235
A2	23.97		
A3	40.58	50.41	0.205
D1	18.21	73.01	0.421
D2	25.05	62.15	0.259
D3	28.56	47.92	0.161
E1	41.86	59.33	0.246
E2	52.02	11.68	0.178
E3	126.30	22.02	0.166
G1	45.87	83.89	0.149
G2	18.74	47.56	0.254
G3	59.25	26.97	0.135
I1	115.13	72.16	0.274
I2	127.49	67.58	0.297
I3	33.13	51.27	0.219
L1	39.15	74.12	0.313
L2	25.86	63.27	0.285
L3	33.06	56.01	0.271
M1	35.49	45.46	0.116
M2	144.12	84.70	0.246

Mechanical Stratigraphy



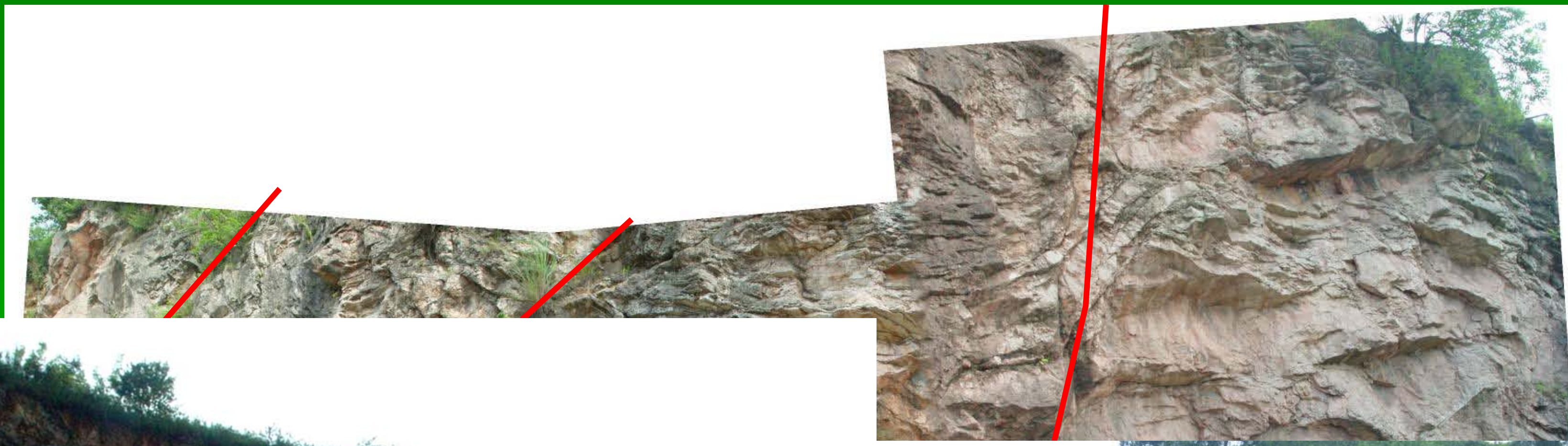


OUTLINE

- Introduction
- Geological Setting
- Mechanical Stratigraphy
- Fault zone and deformation of carbonate
- Implication for fault sealing

Fault zone and deformation of carbonate

Fault and joints well develope in P_1 grey-white thick massive dolostone in Southeast Guizhou

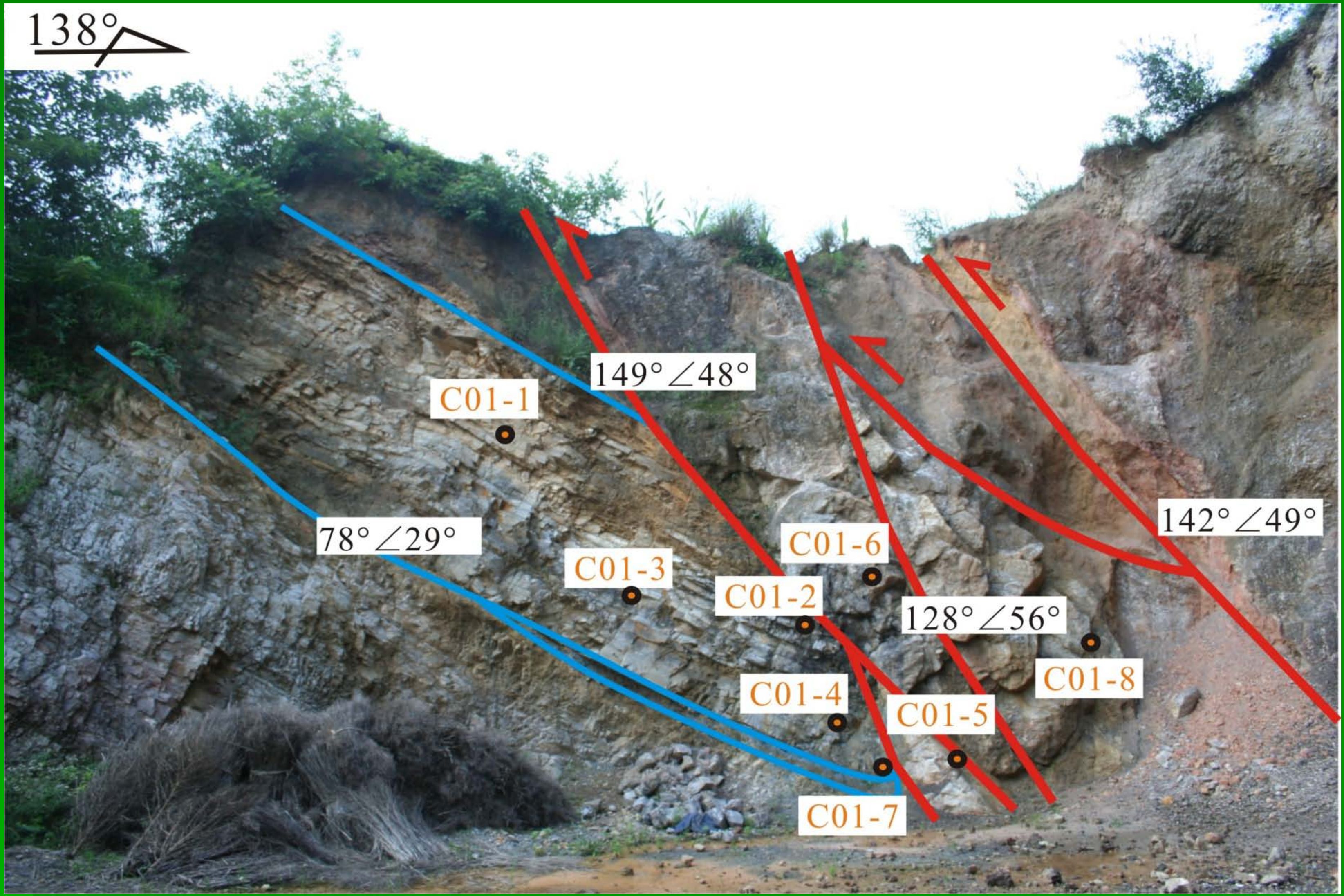


Fault zone and deformation of carbonate

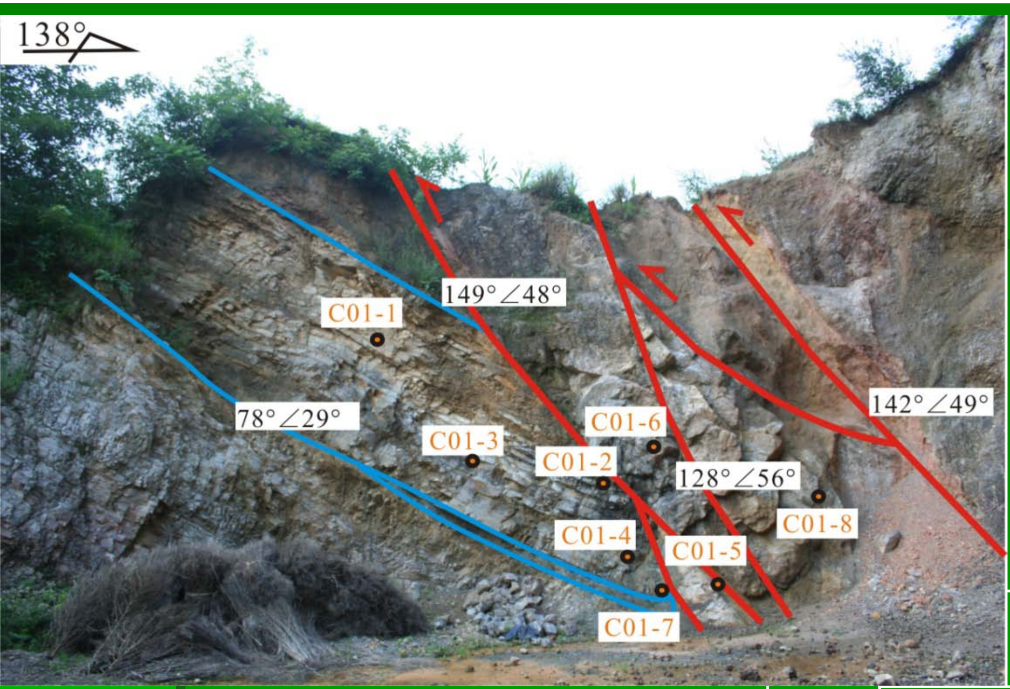
The relatively higher-angle breakthrough faults in massive dolostone

Fault zone and deformation of carbonate

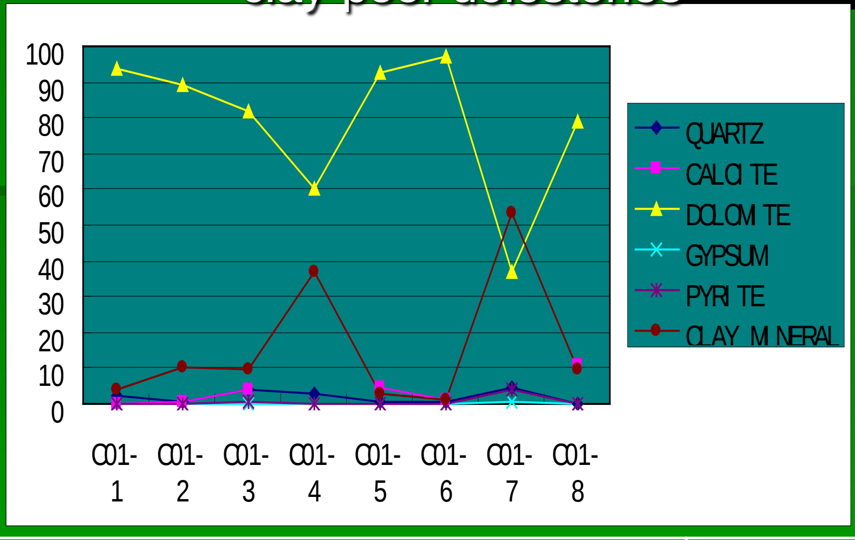
The relatively higher-angle breakthrough faults in massive dolostone



Fault zone and deformation of carbonate

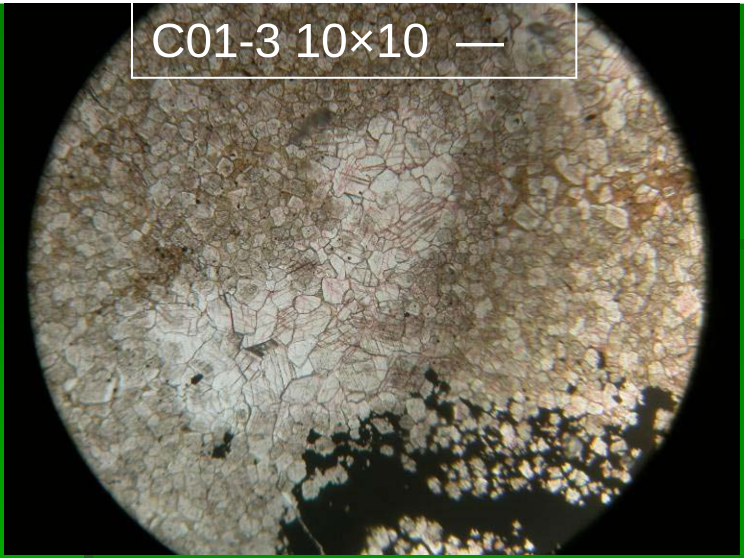


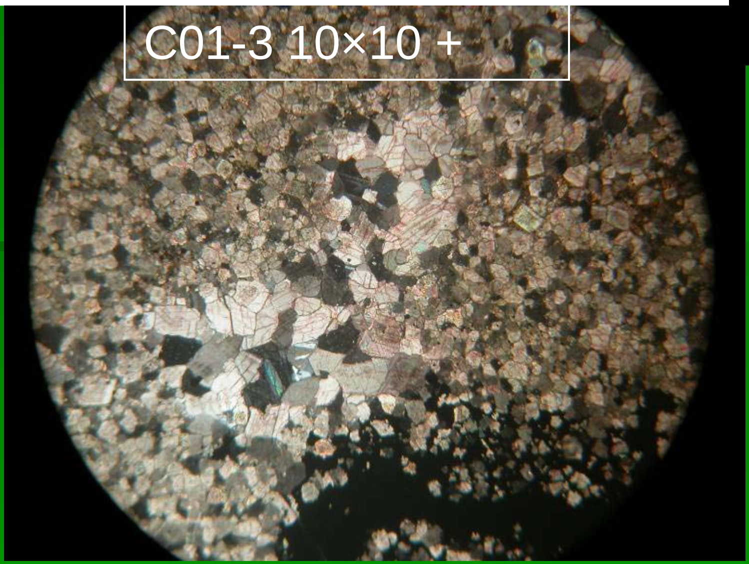
clay-poor dolostones



	Type and content of minerals（%）					Content of Clay mineral
	QUARTZ	CALCITE	DOLOMITE	GYPSUM	PYRITE	
C01-1	2.2	0.2	93.5			4.1
C01-2	0.3	0.5	89.2			10.0
C01-3	3.7	3.9	81.8		0.7	9.9
C01-4	2.8		60.0			37.2
C01-5	0.4	4.6	92.4			2.6
C01-6	0.3	1.4	96.9			1.4
C01-7	4.8		37.1	0.7	4.1	53.3
C01-8	0.2	10.9	79.2			9.7

Fault zone and deformation of carbonate





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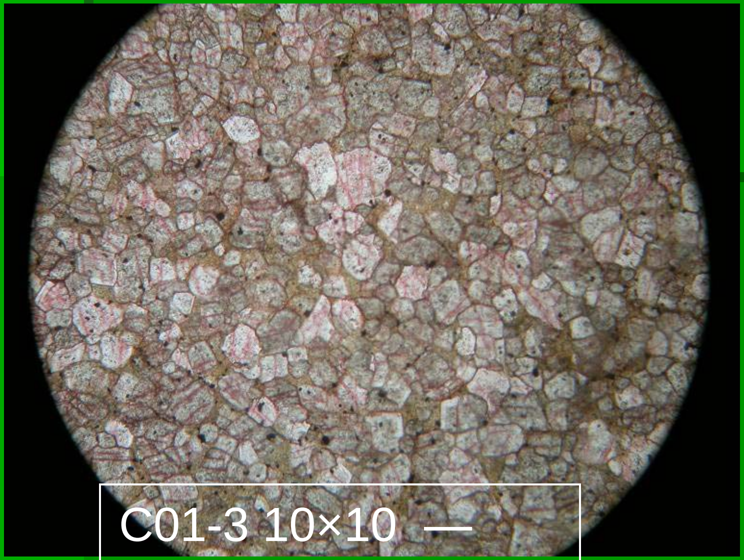
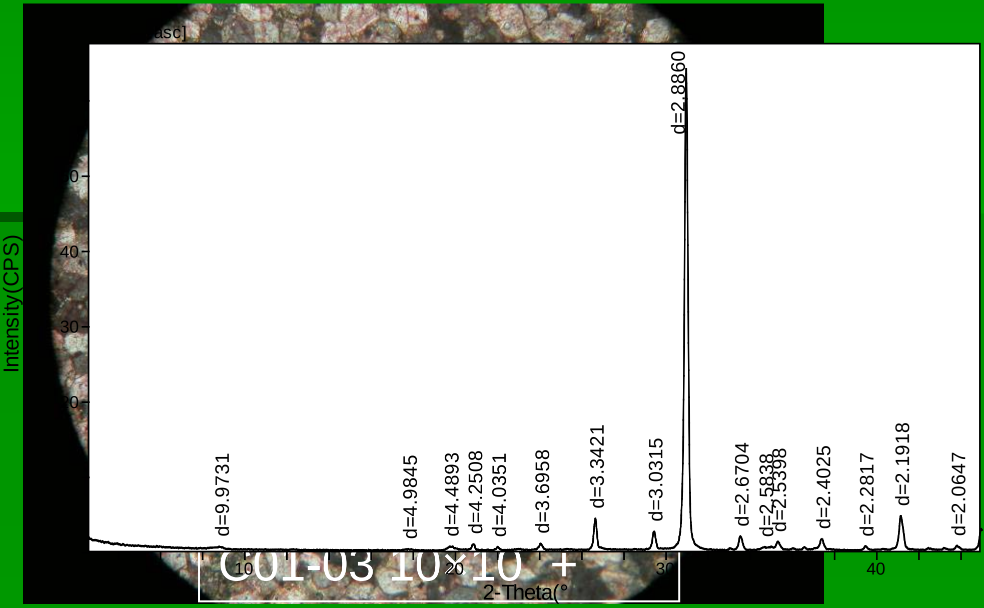




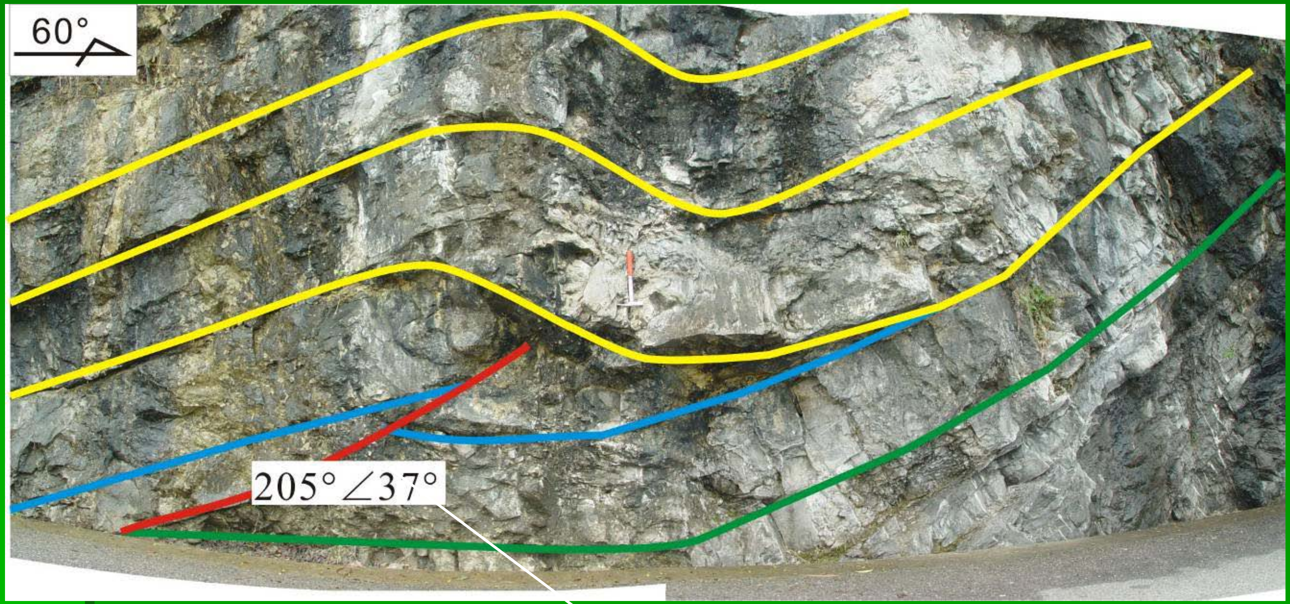
C01-3 X-Ray Diffraction Diagram

Fault zone and deformation of carbonate

Bitumen distributes

Fault zone and deformation of carbonate

Faults in massive, incompetent marlites tend to breakup on lower-angle.



Fault zone and deformation of carbonate

- In less competent clay-rich strata, shale and mudstone beds impede fault propagation across the strike, resulting in fault-related folding.

Fault zone and deformation of carbonate

Shale and mudstone beds
impede fault propagation

Fault zone and deformation of carbonate

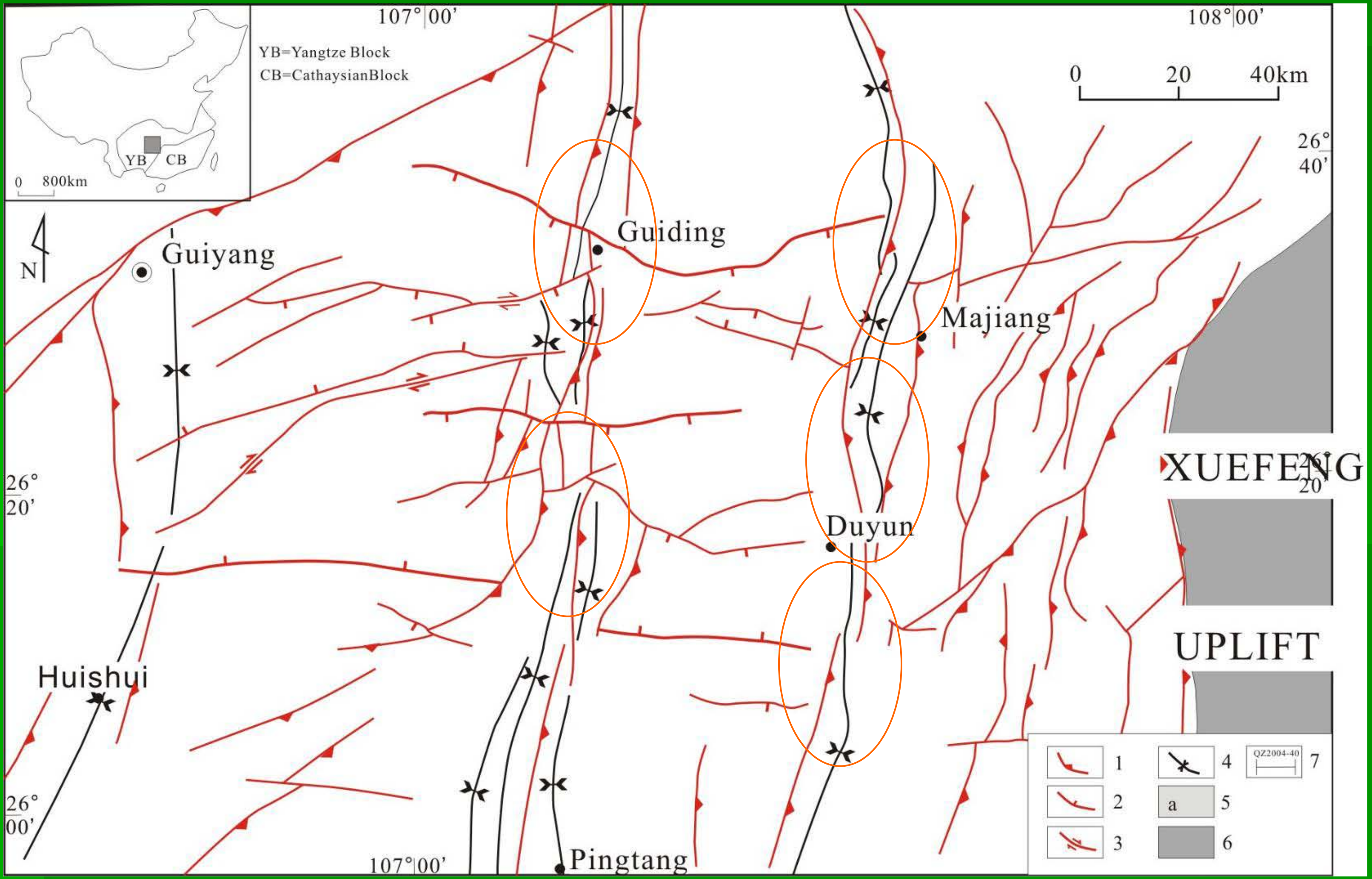
Shale and mudstone beds impede fault propagation

Deformation in Sandstone and Mudstone, Triassic

Chicken

Fault zone and deformation of carbonate

Shale and mudstone beds impede fault propagation



OUTLINE

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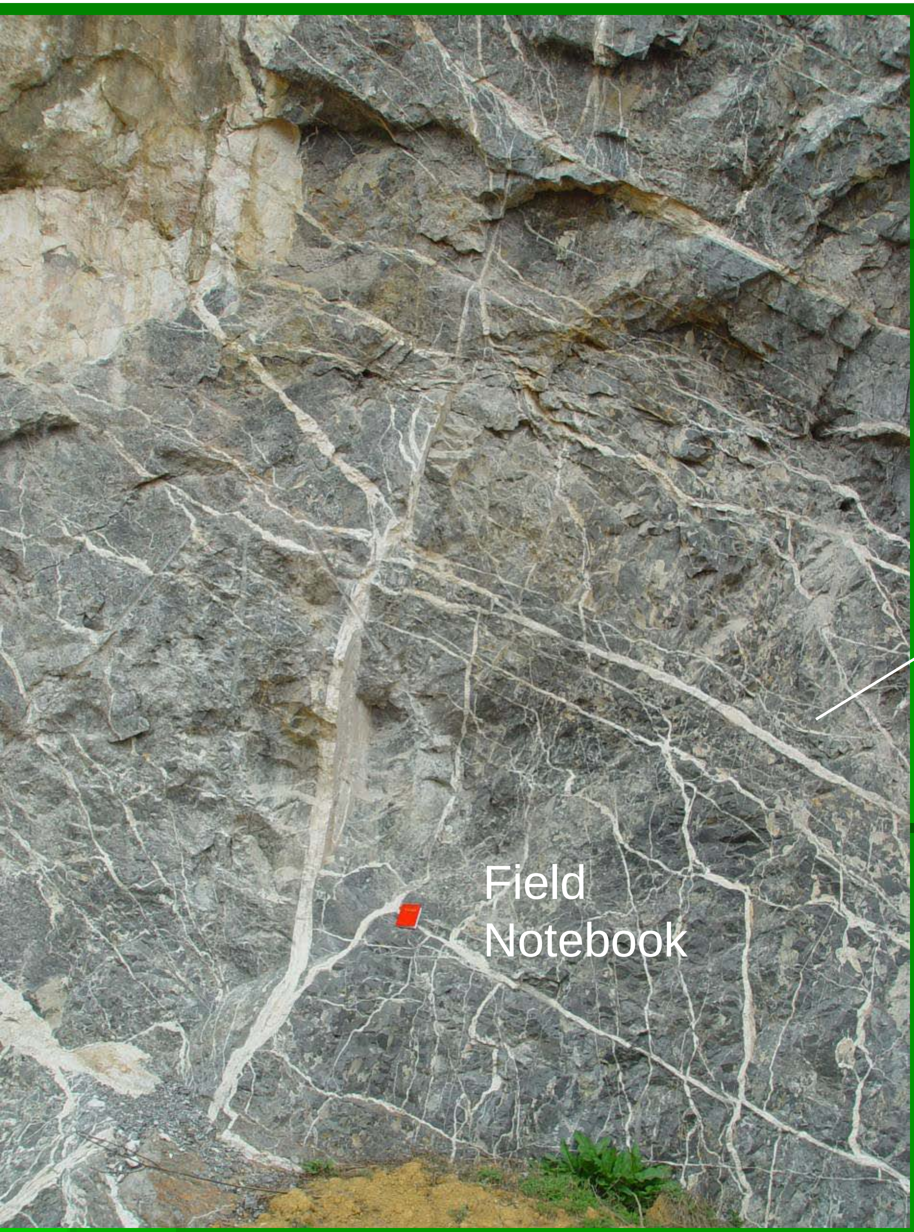
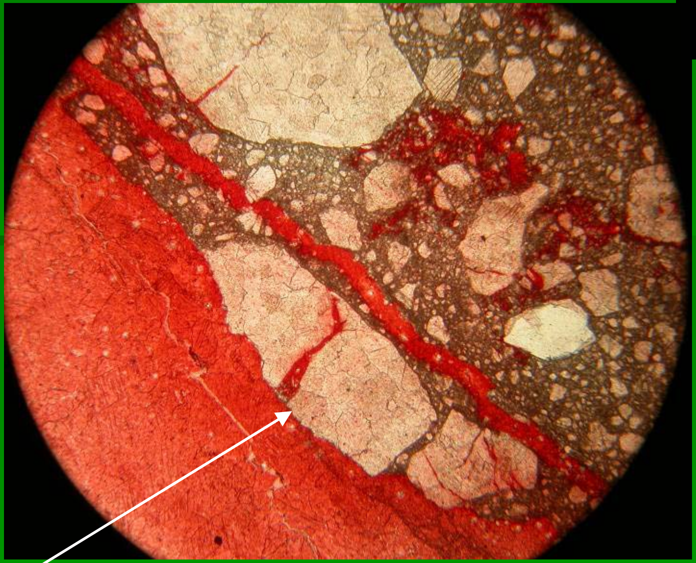
Implication for fault sealing

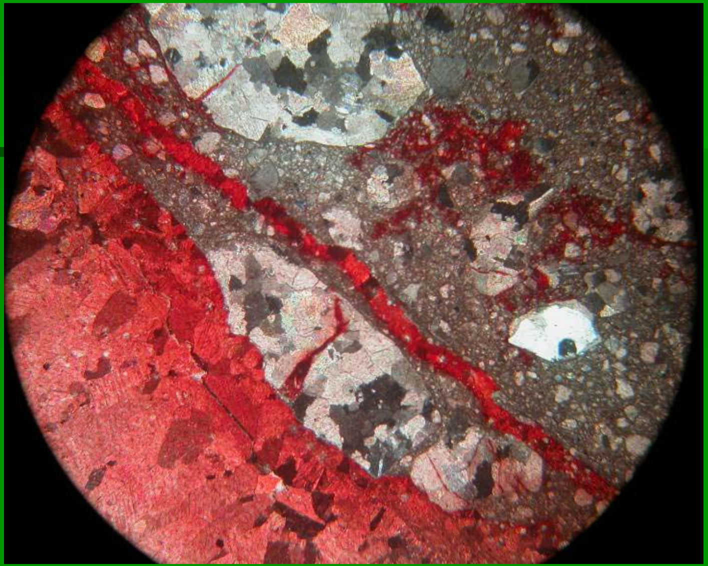
Higher compressive strength associated with massive, clay-poor dolostones generate more fractures for fluid flow.

Fractures well developed in dolostones

Implication for fault sealing







Implication for fault sealing

Conversely, the pressure solution seams, develop in the lower compressive strength associated with marlites.

filled with clay later,

Implication for fault sealing

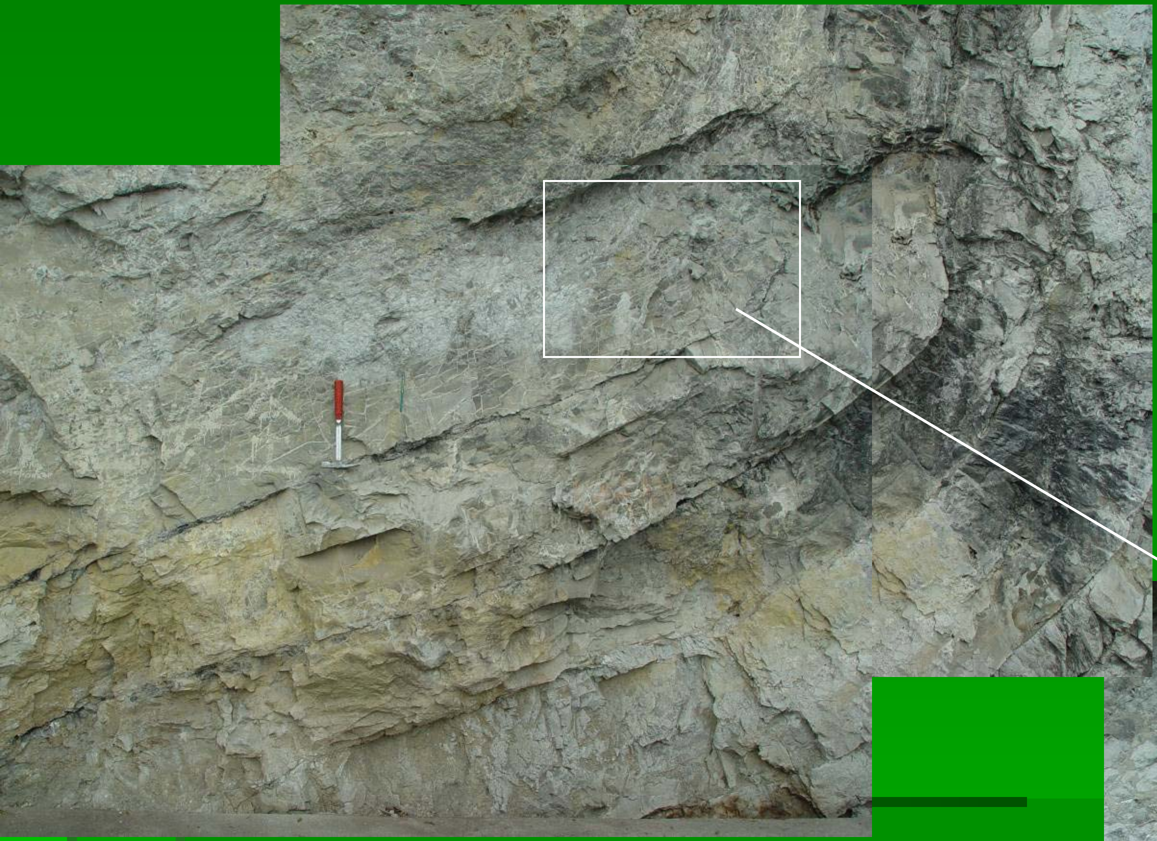
Conversely, the pressure solution seams, develop in the lower compressive strength associated with marlites.

filled with clay later,

Implication for fault sealing

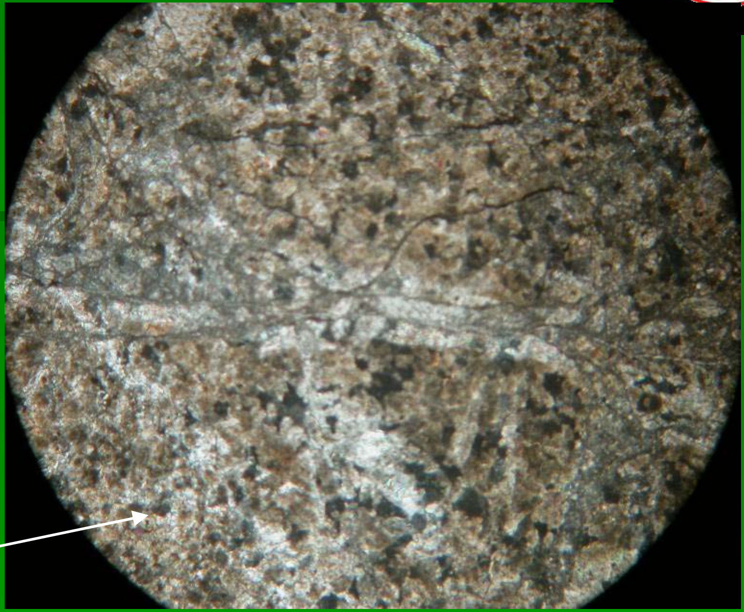
- The high density of pressure solution seams between overstepping thrust faults are found, which have raised both the effective length of the barrier to fluid flow and the fault sealing potential.

Implication for fault sealing



Soft link between fault brings on stress relaxation

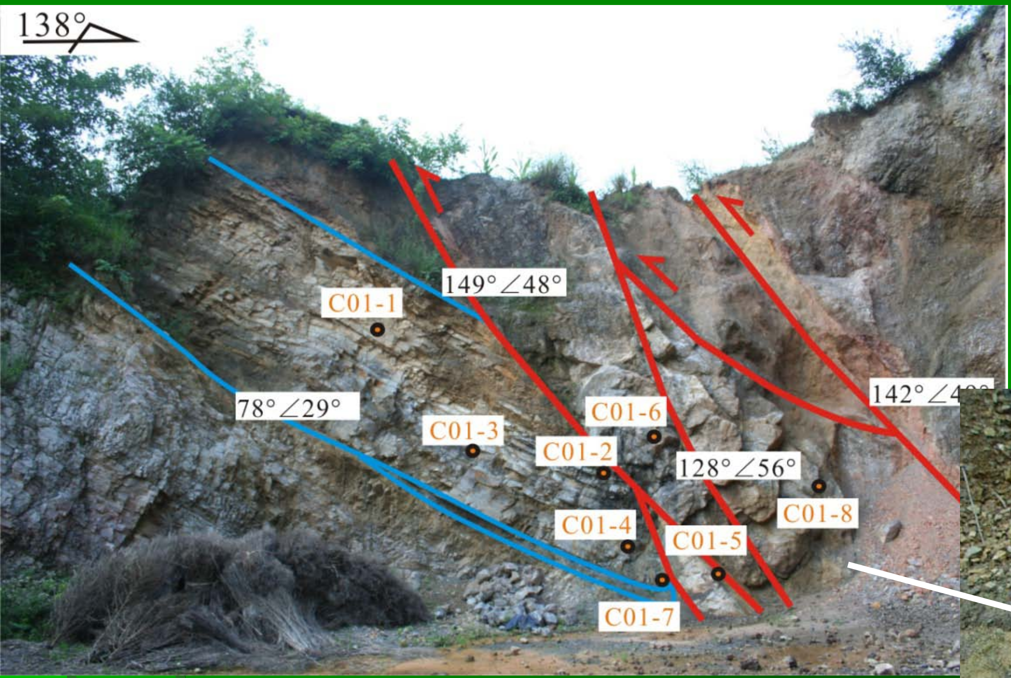
Implication for fault sealing



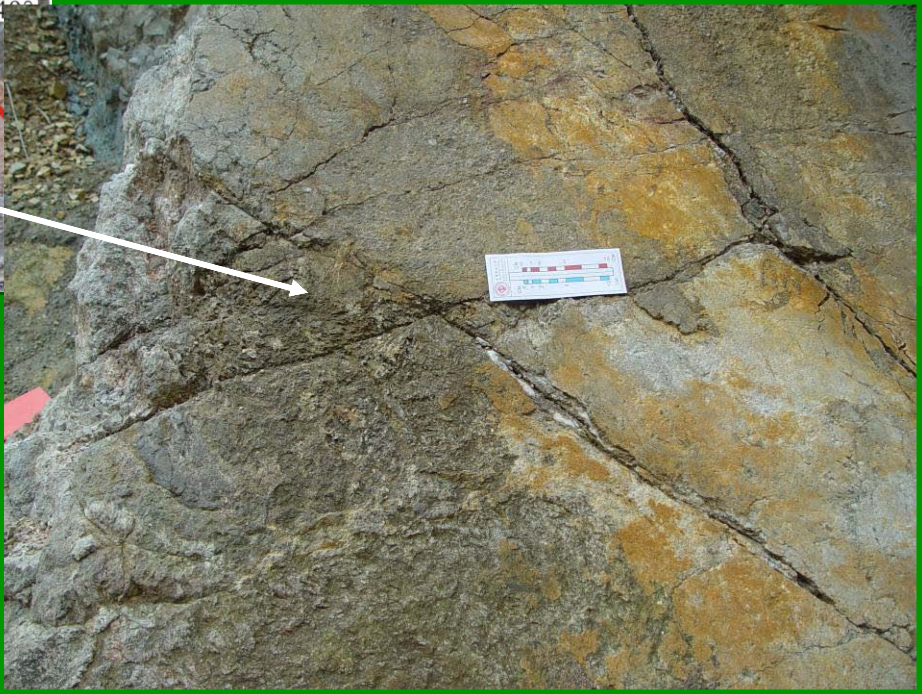
Because of the compressive friction, there some phyllosilicates are generated along the fault plane in clay-rich carbonate.

Implication for fault sealing

Because of the compressive friction, there some phyllosilicates are generated along the fault plane in clay-rich carbonate.

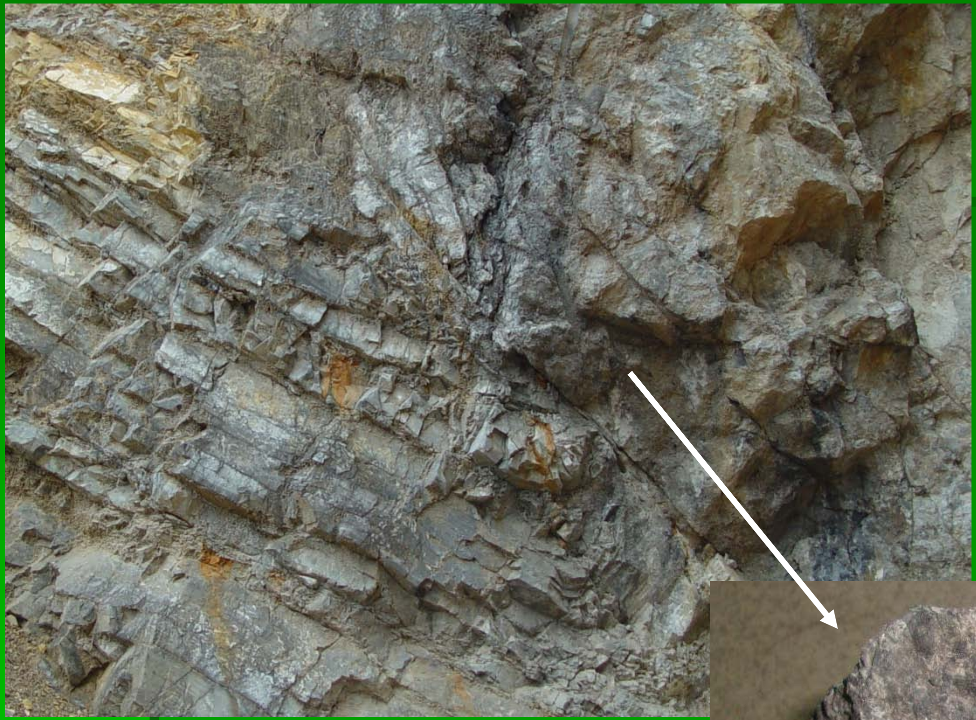


They can Impede the fluid flow effectively



Vein in the hangwall, not in footwall

Implication for fault sealing



Pressure solution in carbonate sediments acts to concentrate phyllosilicates to form phyllosilicates-rich fault gouges resembling clay-smears.

The features have the potential to act as barriers to fluid flow.

Conclusions

- 1) Clay-rich limestones or marls are likely to exhibit incompetent behavior in comparison with clay poor limestones.
- 2) Higher compressive strength associated with massive, clay-poor dolostones generate more fractures for fluid flow.

Conclusions

- 3) The pressure solution seams, filled with clay later, develop in the lower compressive strength associated with marlites.
- 4) High density of pressure solution seams between overstepping thrust faults are found, which have raised both the effective length of the barrier to fluid flow and the fault sealing potential.

Thanks for your attention

If you have questions or want to discuss this, E-mail me.

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