EASTERN INSTITUTE OF TECHNOLOGY, NINGBO
THE HONG KONG POLYTECHNIC UNIVERSITY

Understanding the Heterogeneity and Anisotropy of Permeability in Carbonate Rocks Within a Fault Network

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INTRODUCTION

Significance:

- Fluid pulse and flow channeling [1, 2]
- CO_2 & oil leakage [1]
- High fluid pressure [2]
- Earthquake risks [3]
- Thermal alterations [4]

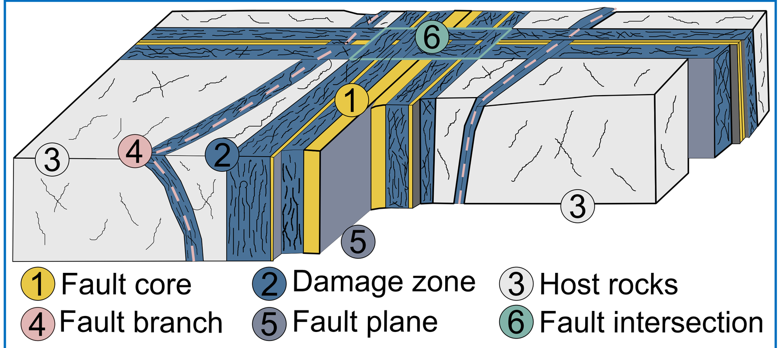

Fig. 1. A schematic view of the fault structure and complex alterations

Challenges and Limitations:

- In situ data sparsity: core integrity concerns & technical difficulties [5-8]
- Laboratory experiments: equipment disparities & damage threshold [5, 7, 8]
- Outcrop measurements: diverse methods, dissimilar sites, weathering, and sampling [5-8]

K_{DZ}=Permeability of damage zones; K_H=permeability of host rocks; *DI*=Damage intensity; *D*= displacement; *r*= distance from core; *DZ*=damage zone; *RMP*=Rock mass permeability

Scaling relationships:

$DI = C.r^{-0.8}$ Various lithology and *D* (C fault dependent) [8]

$DI = DI_0.r^{-a}$ Carbonate rocks; 0.5<*D*<516 m; DI_0=1.6
a=0.95 (*D*<100 m); a=0.82 (*D*>100 m) [7]

$K=C.(DI_0.e^{(-r(b+D)/aD)})^y$ C=2.45×10^{-20} & y=1.48; Granite [5]

Questions: How does the presence of complex fault structures, such as branches, multiple cores, and asymmetric damage zones, impact permeability?

Objective: Scaling relationships for permeability of the fault structures

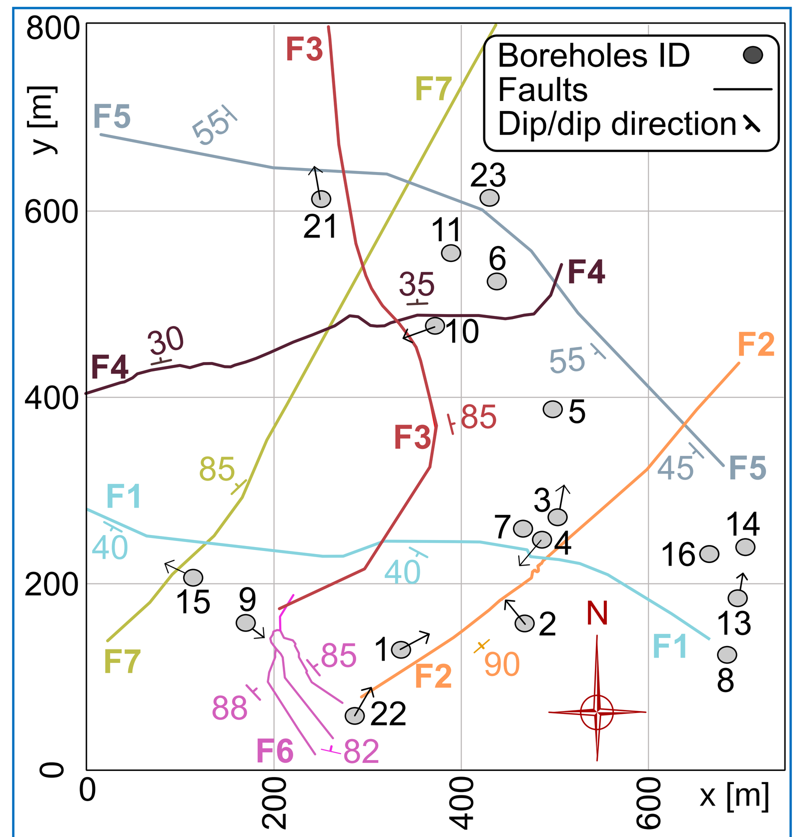

Fig. 2. The study area

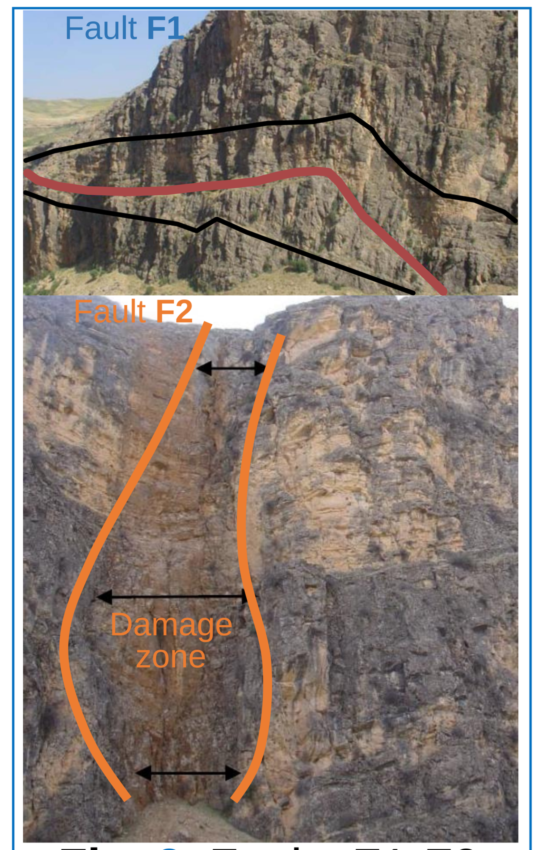

Fig. 3. Faults F1-F2

METHODS

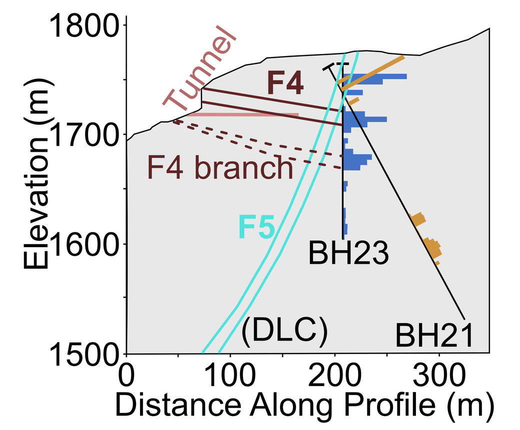

Fig. 4. Faults F4-F5

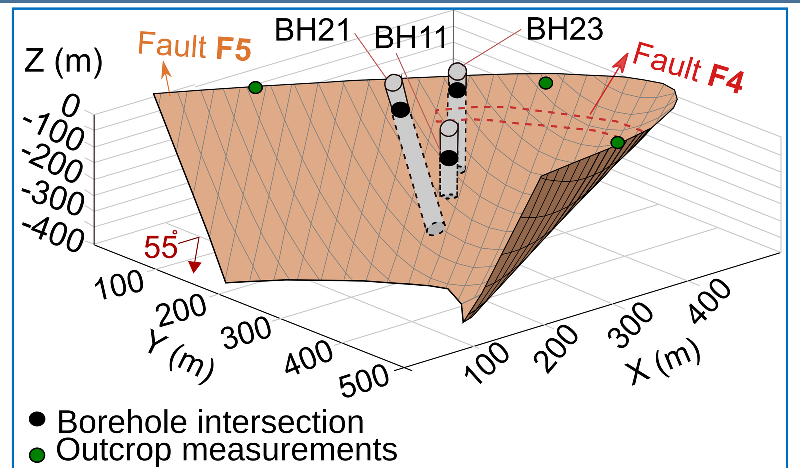

Fig. 5. 3D structure of F4 & F5

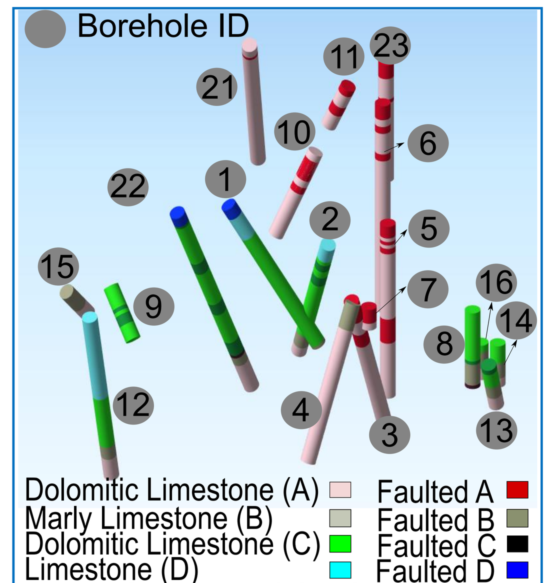

Fig. 6. Lithology

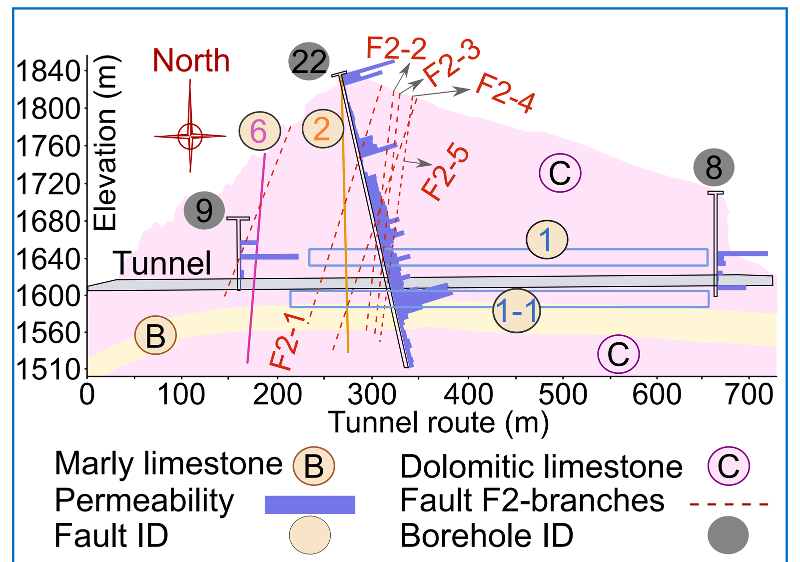

Fig. 7. Faults in the tunnel

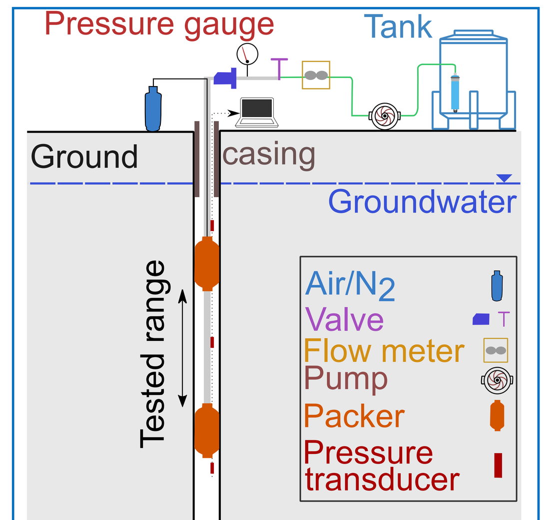

Fig. 8. Pumping tests

Methods:

- Outcrop/subsurface
- 3D models
- Statistics/regression
- Asymmetry

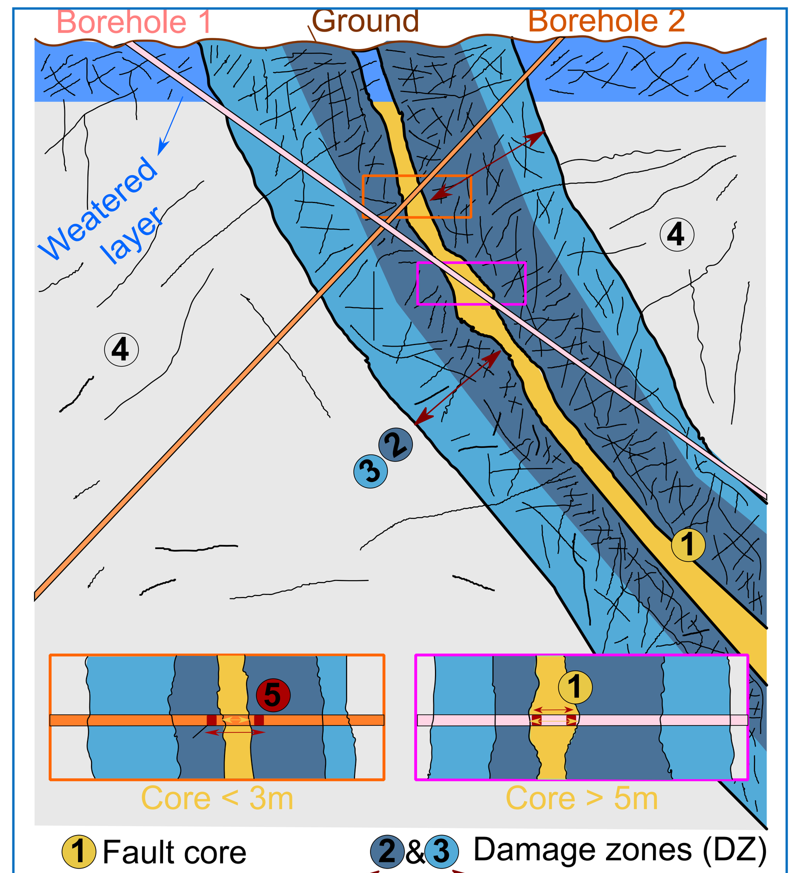

Fig. 9. Schematic asymmetry

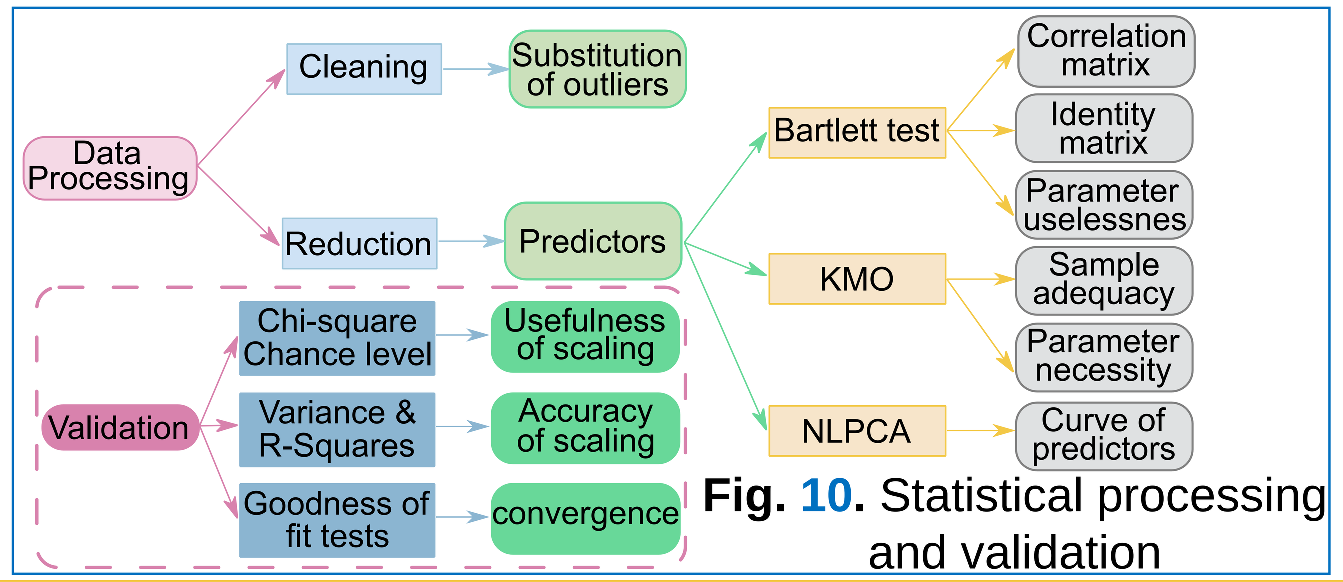

Fig. 10. Statistical processing and validation

RESULTS

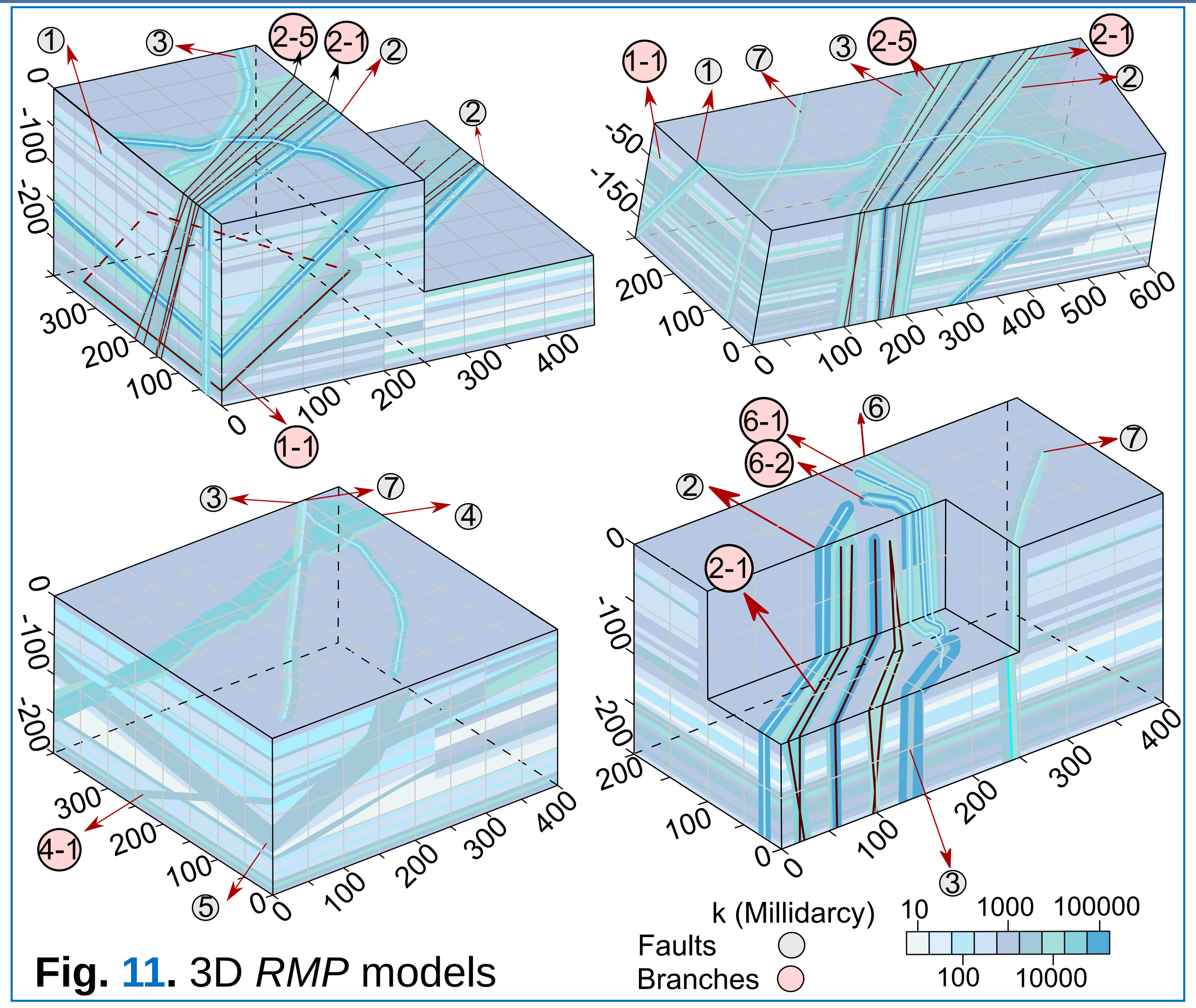

Fig. 11. 3D *RMP* models

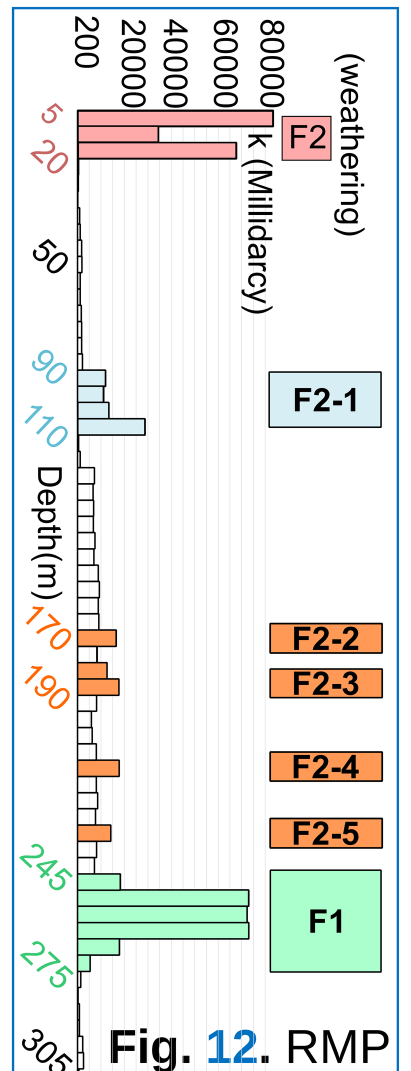

Fig. 12. RMP along BH22

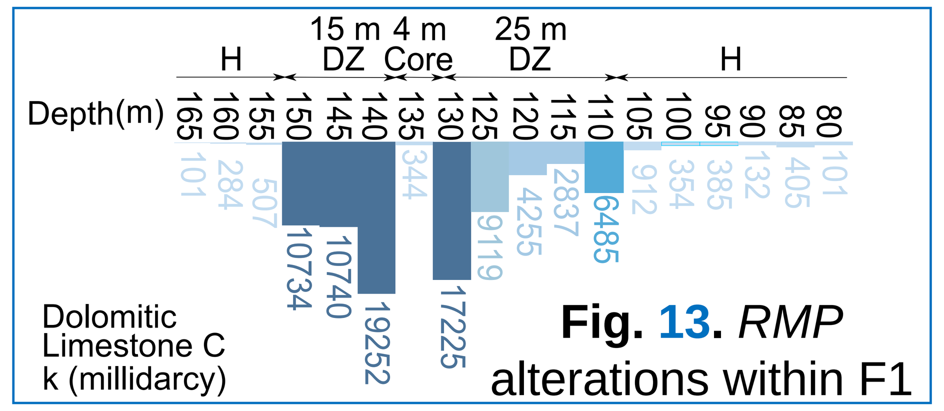

Fig. 13. *RMP* alterations within F1

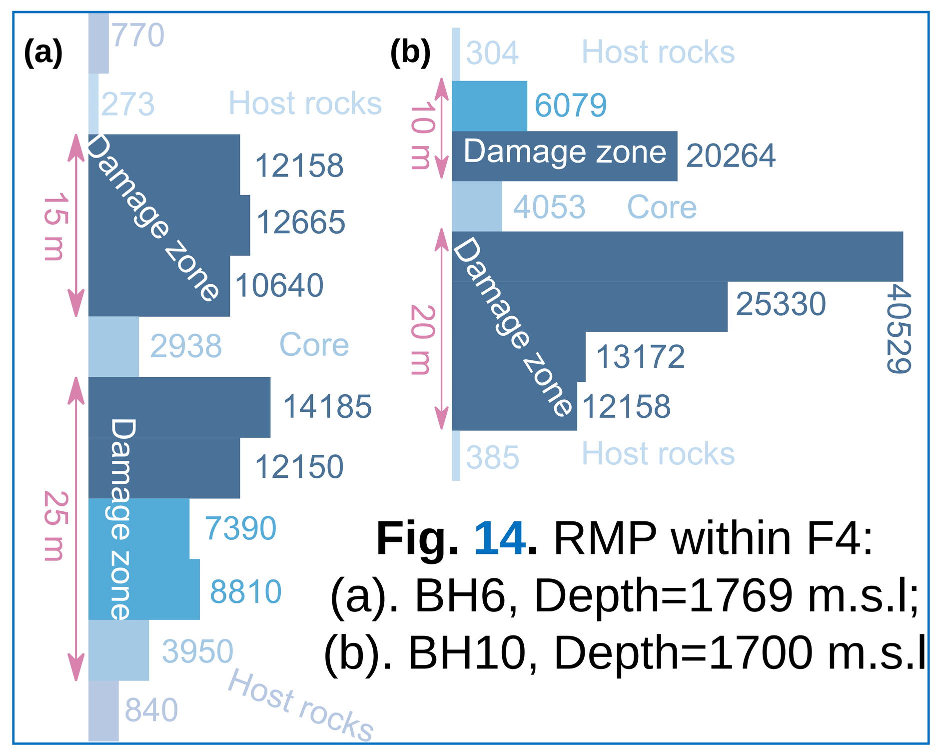

Fig. 14. RMP within F4: (a). BH6, Depth=1769 m.s.l; (b). BH10, Depth=1700 m.s.l

- Significant factors: *E* (elastic modulus (GPa)), *n* (porosity) (%), *r* (distance from the core r (m))
- Power law results in the highest R-square
- RMP (millidarcy)=102129.8($r^{-0.678}$).(n/E)$^{1.443}$
- Validation database confirmed no overfitting
- Limitations: sedimentary rocks, D<5 m, and depth<300 m

MULTIPLE CORE

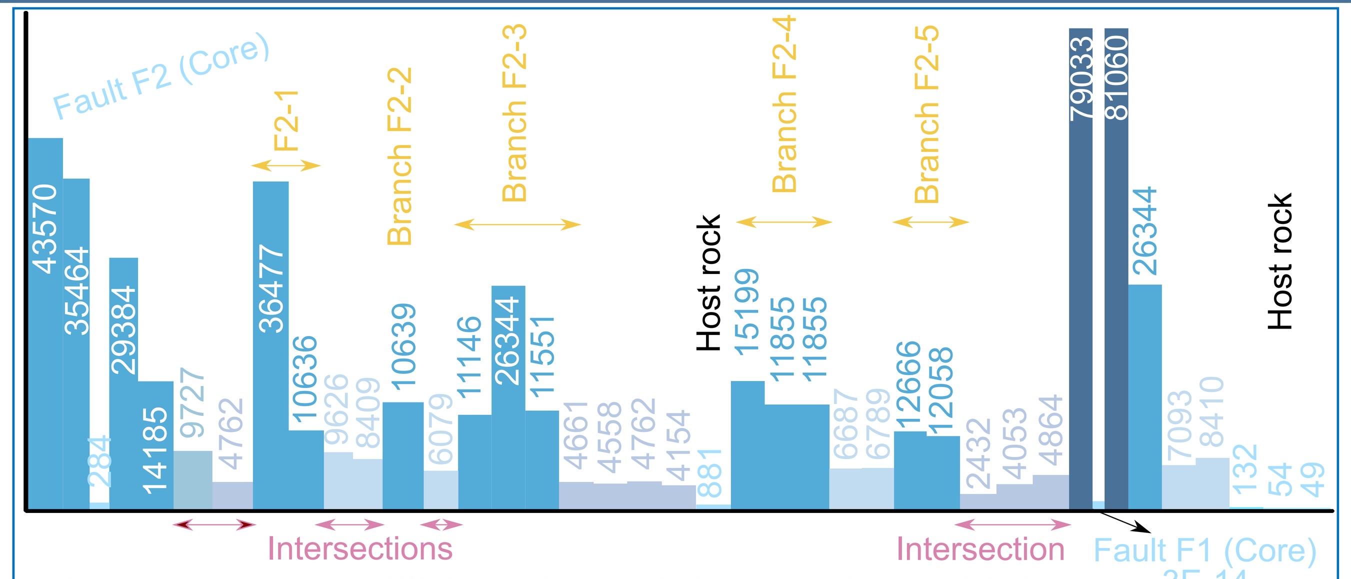

Fig. 15. RMP (millidarcy) modulations in multiple core Fault F2 in BH2

Intersections:

- Higher damage intensity & RMP value within intersections
- Similarities to multiple core faults
- A scaling equation?

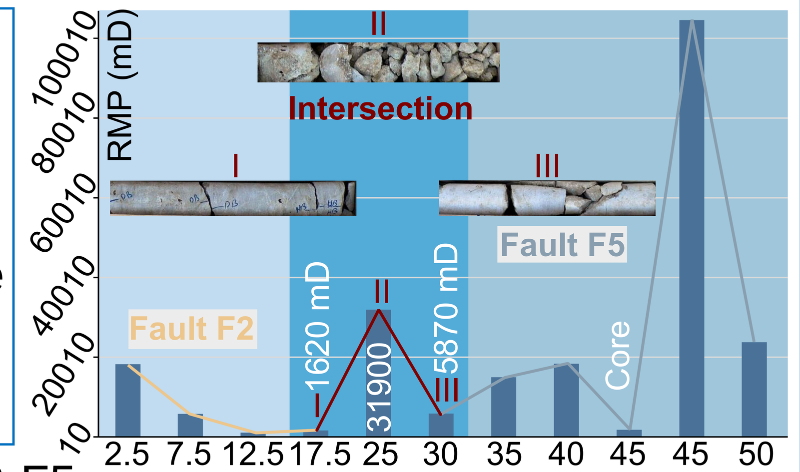

Fig. 16. Intersection F2-F5

CONCLUSIONS

- This scaling relationship incorporates damage asymmetry
- Utilizing in situ data circumvents the impacts of weathering, sampling bias, and assumptions inherent in micro-damage analysis on outcrops or laboratory experiments
- Having a power of -0.678, relatively comparable to previous works' value of -0.8 [7,8], can confirm the generality of RMP=102129.8($r^{-0.678}$).(n/E)$^{1.443}$
- This scaling relationship is developed for faults with *D*<5 m within carbonate rocks
- RMP values enhance within intersections of two damage zones

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