بسم الله الرحمن الرحيم

FRACTURE TOUGHNESS
and
TENSILE STRENGTH
of
GHAWAR-KHUFF ROCK FORMATION

By

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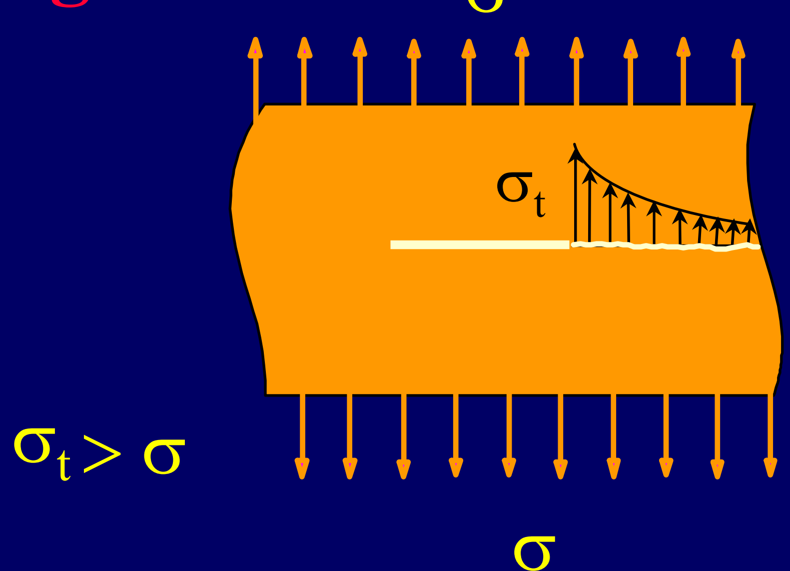
OUTLINE

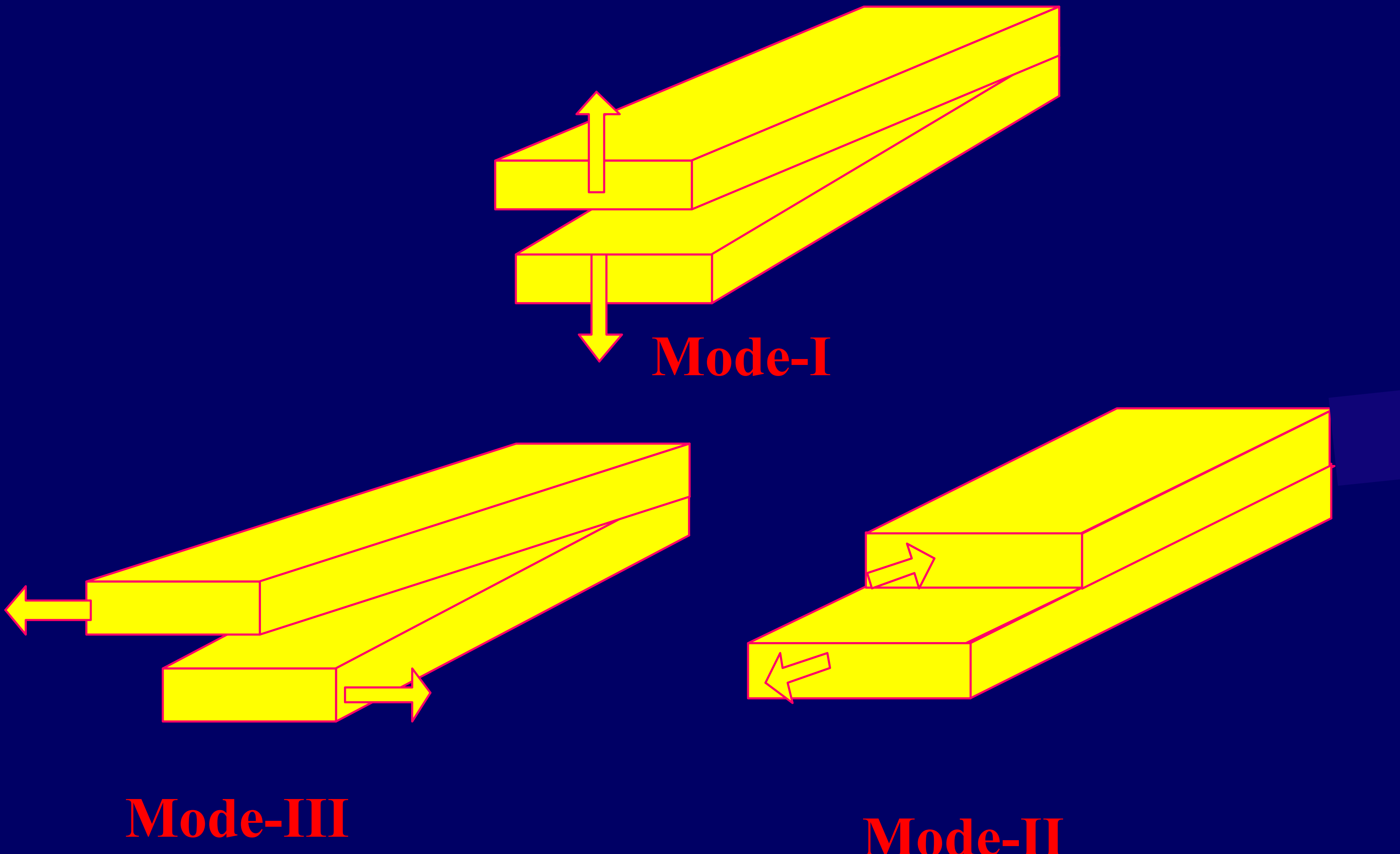
- Introduction
- Objectives
- Experimental Program
- Results &Discussions
- Conclusions

Fracture Toughness

- **Rocks contain cracks, joints & fissures etc..**
- **Resistance against crack initiation and propagation.**



Crack Propagation Modes



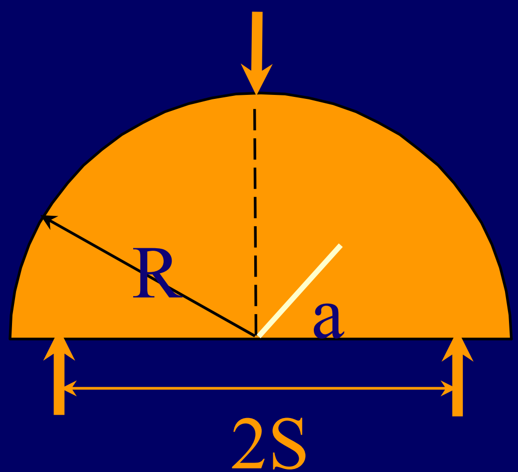
Hydrofracturing

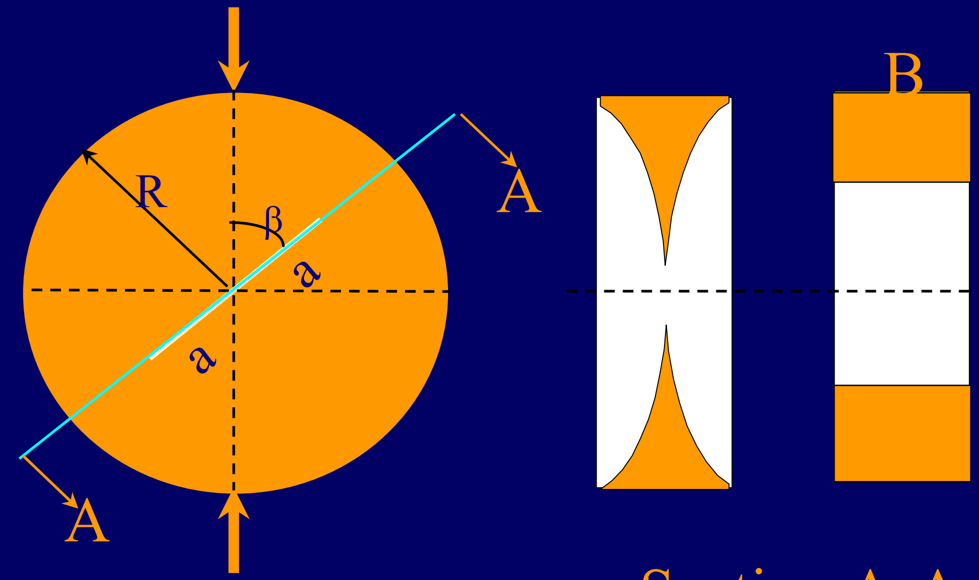
- **Used to enhance oil and gas recovery from the reservoir.**
- **Depends on**
  - Characteristics of rock formation.
  - Depth and inclination of borehole.
- **To model hydraulic fracturing, fracture toughness value is required.**
- **Fracture toughness value should be representative of *in-situ* conditions (Temperature & Pressure).**

OBJECTIVES

- To determine tensile strength for outcrop and reservoir specimens.
- To determine fracture toughness for outcrop and reservoir specimens.
- To investigate how closely outcrop specimens can predict the fracture behavior under reservoir conditions.

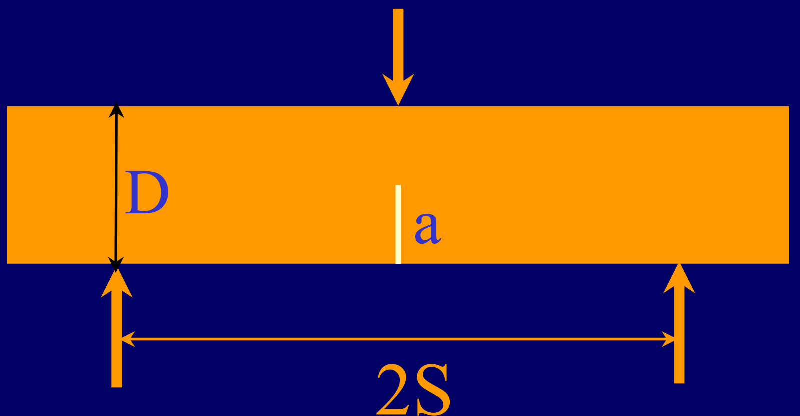
Specimen Type



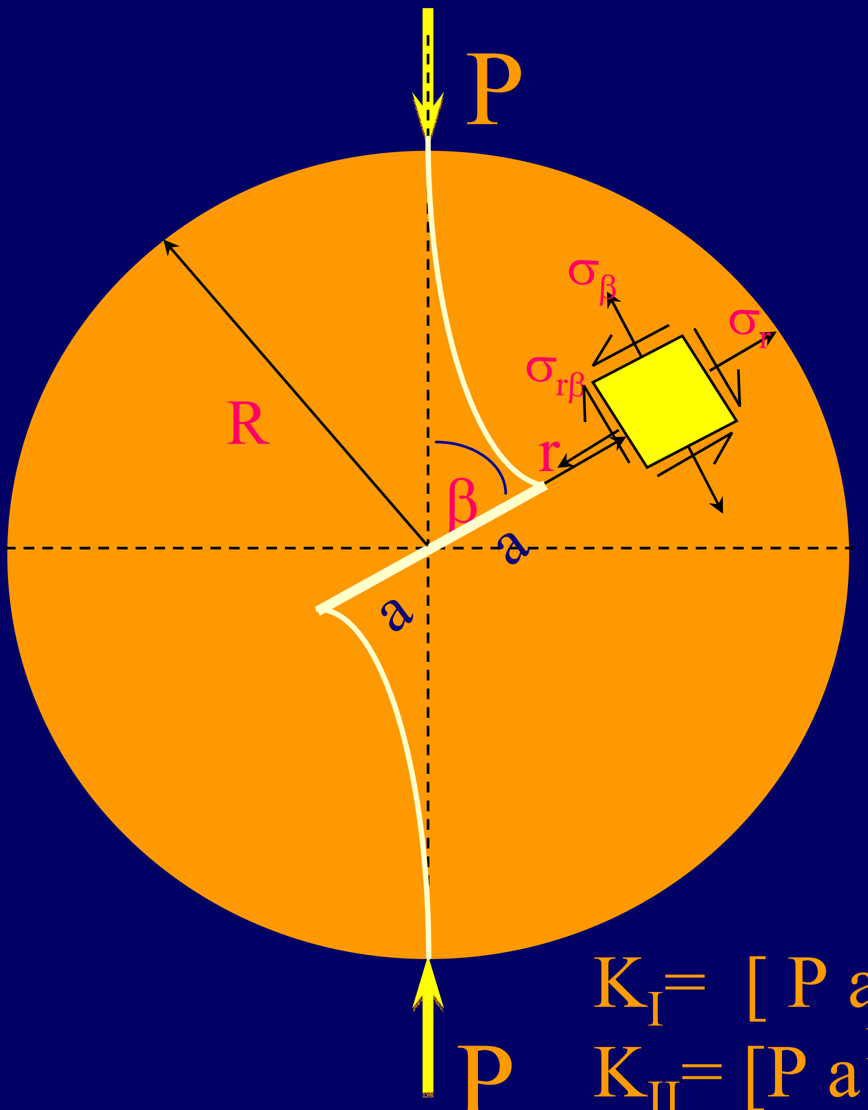


Section A-A

- **Advantages**
- **Core based specimens**
- **Do not require machinig**
- **Saving of material and resources**
- **Versatile specimen**



Mixed Mode I-II Loading



$$K_I = [P a^{1/2}/(\pi^{1/2} RB)]N_I$$

$$K_{II} = [P a^{1/2}/(\pi^{1/2} RB)]N_{II}$$

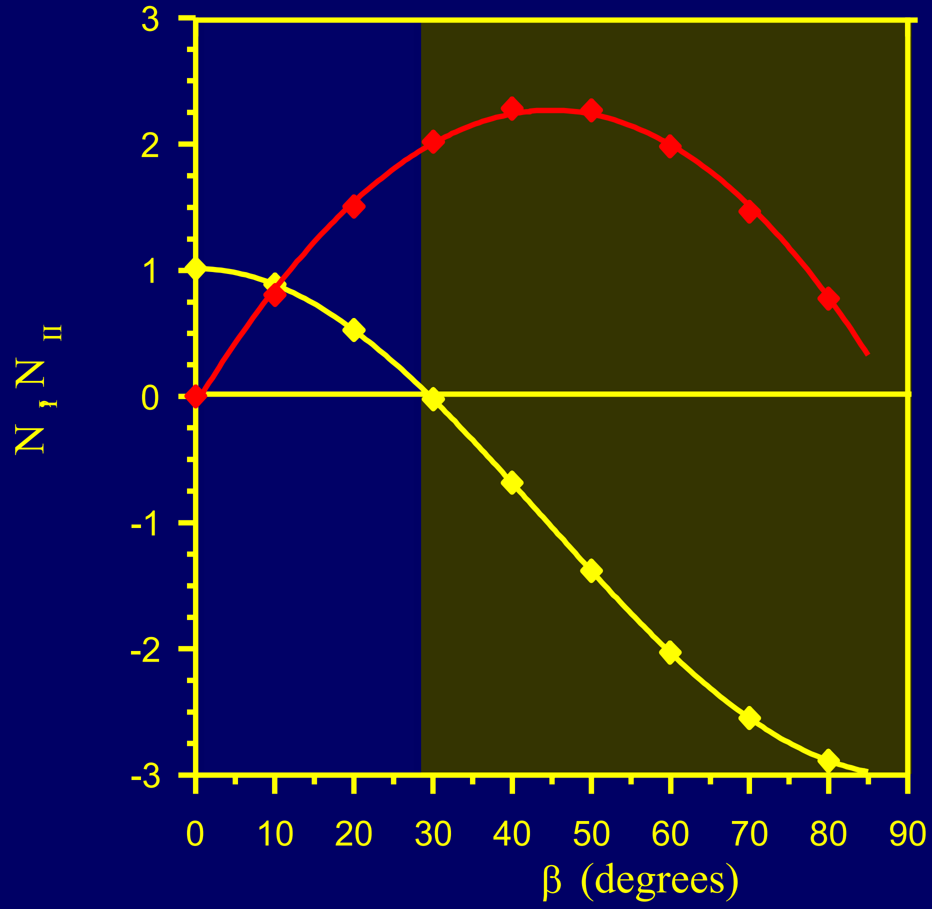
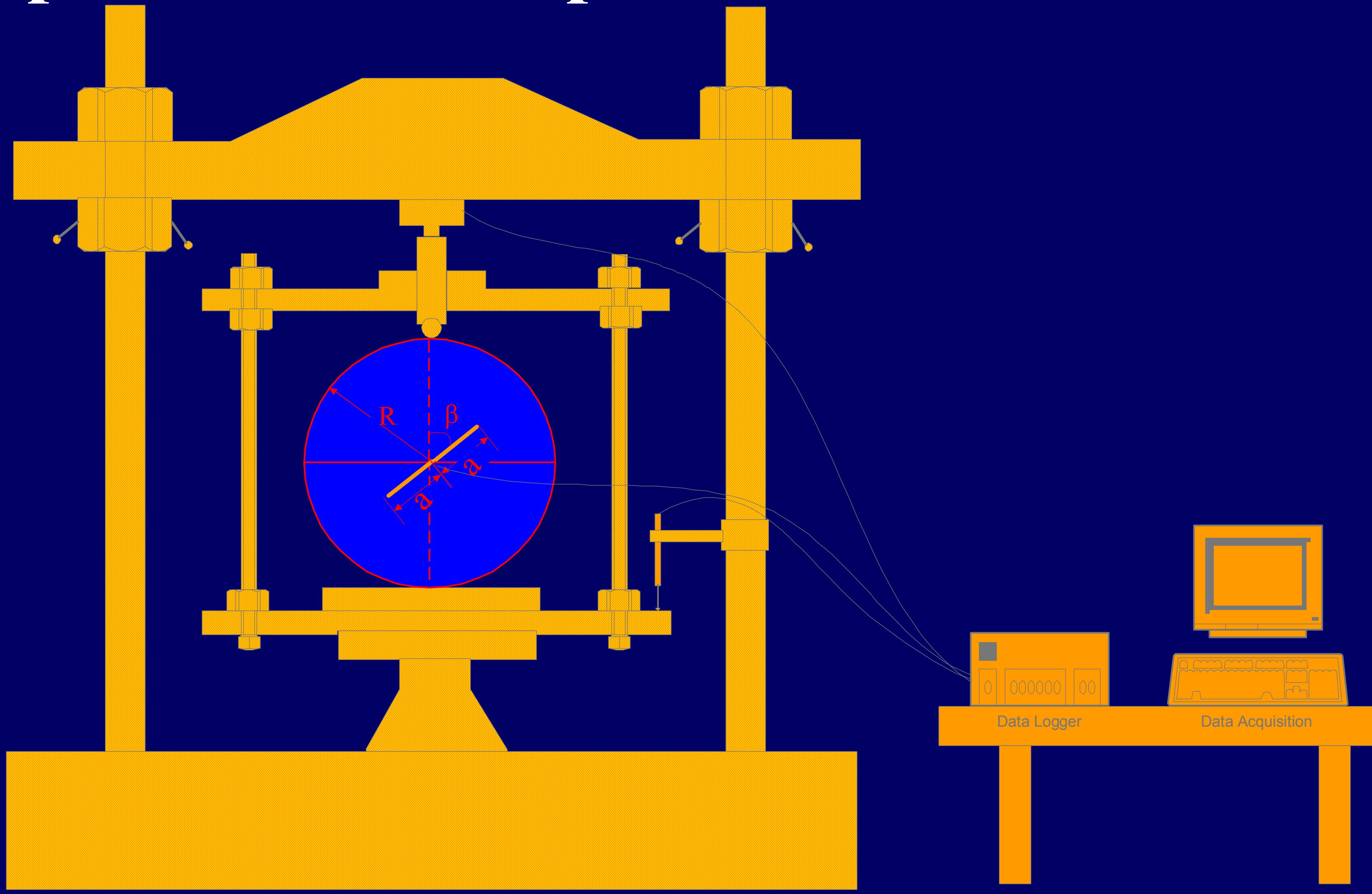


Figure: Normalized Mixed Mode Fracture Toughness Coefficients for Brazilian Disk.

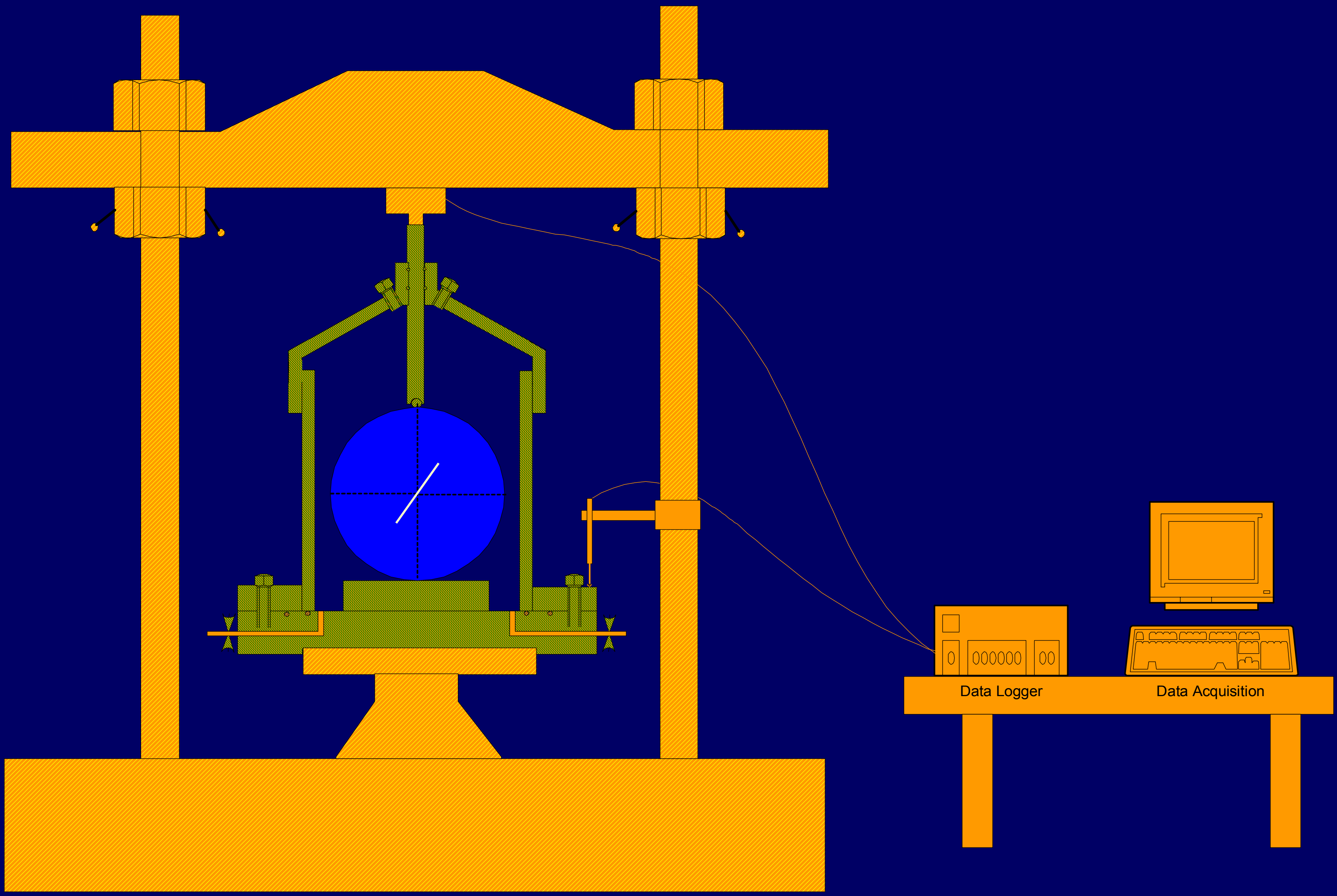
EXPERIMENTAL PROGRAM

Sample Preparation

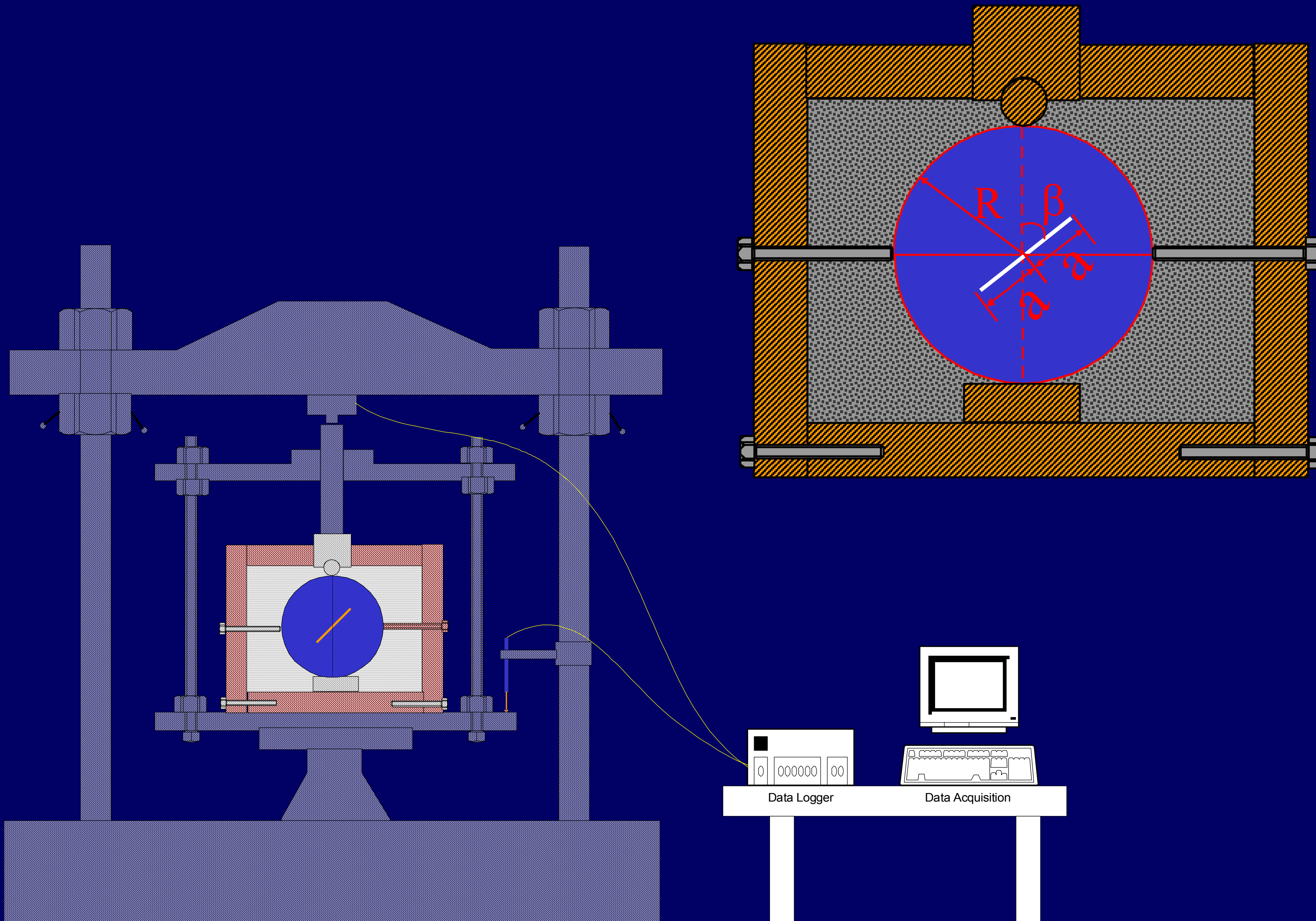
Experimental Setup for Ambient Conditions



Experimental Setup - Res. Press. Condition



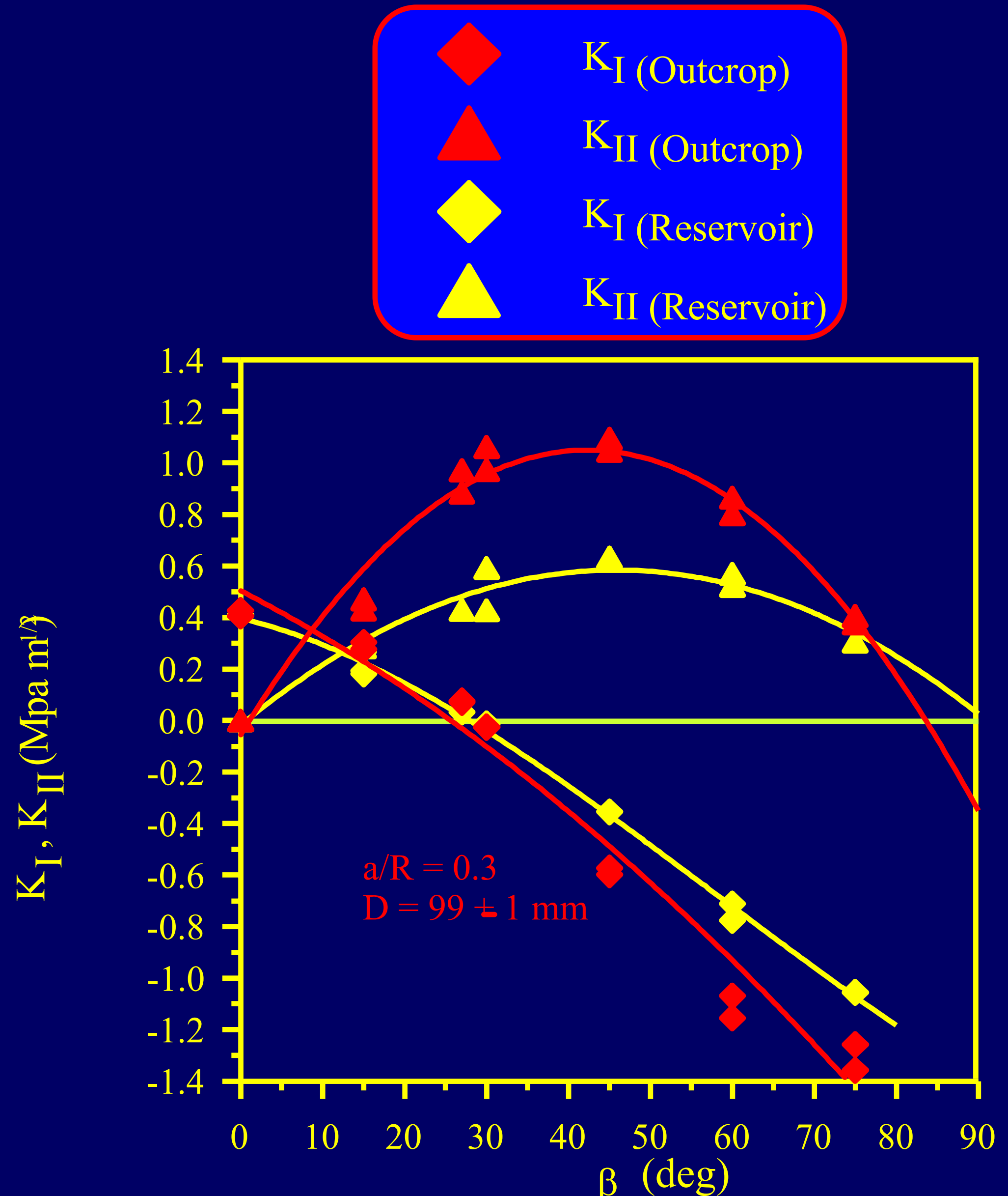
Experimental Setup - Res. Temp. Condition



RESULTS

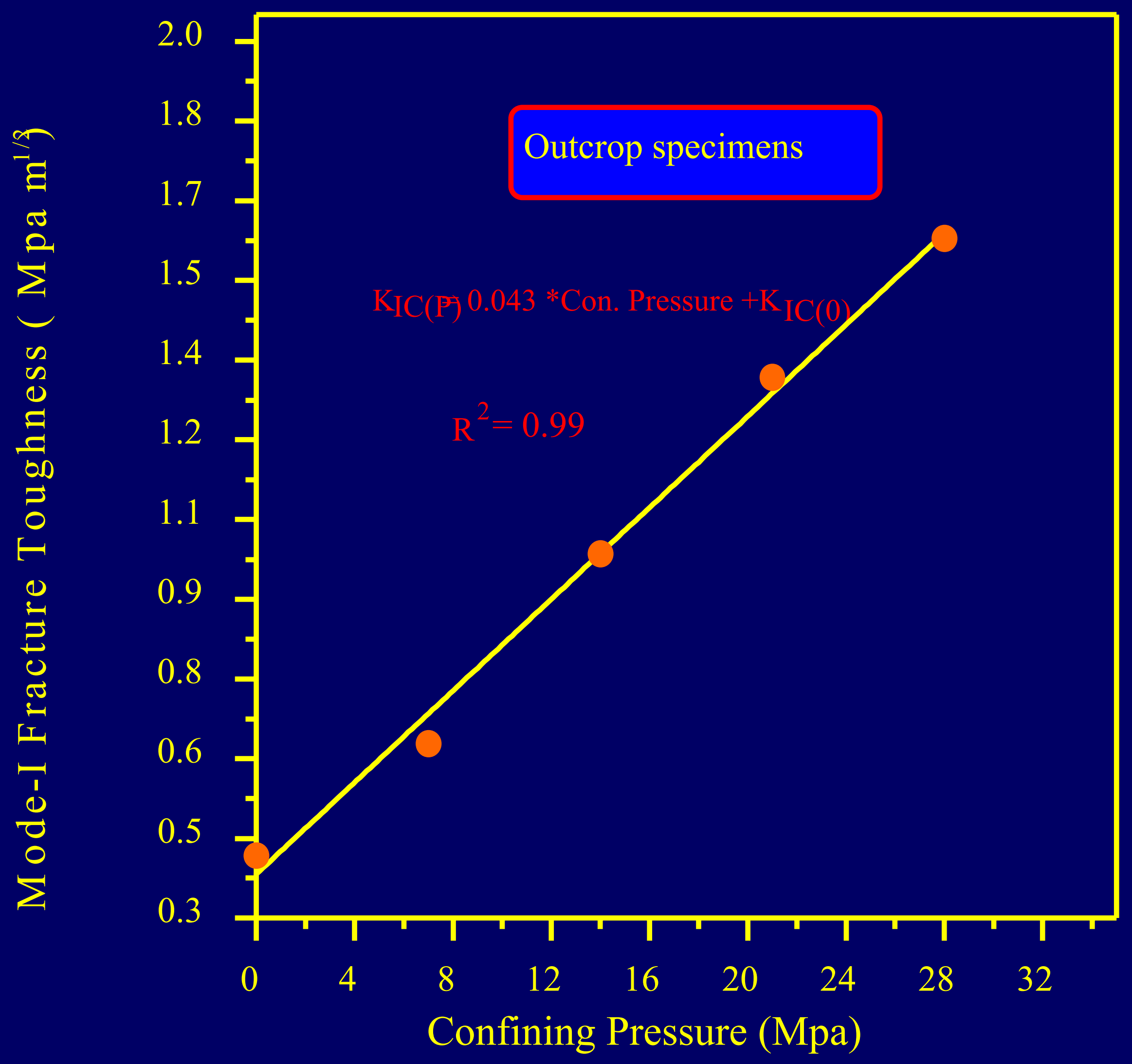
AMBIENT CONDITIONS

Effect of Specimen Origin on K_I & K_{II}

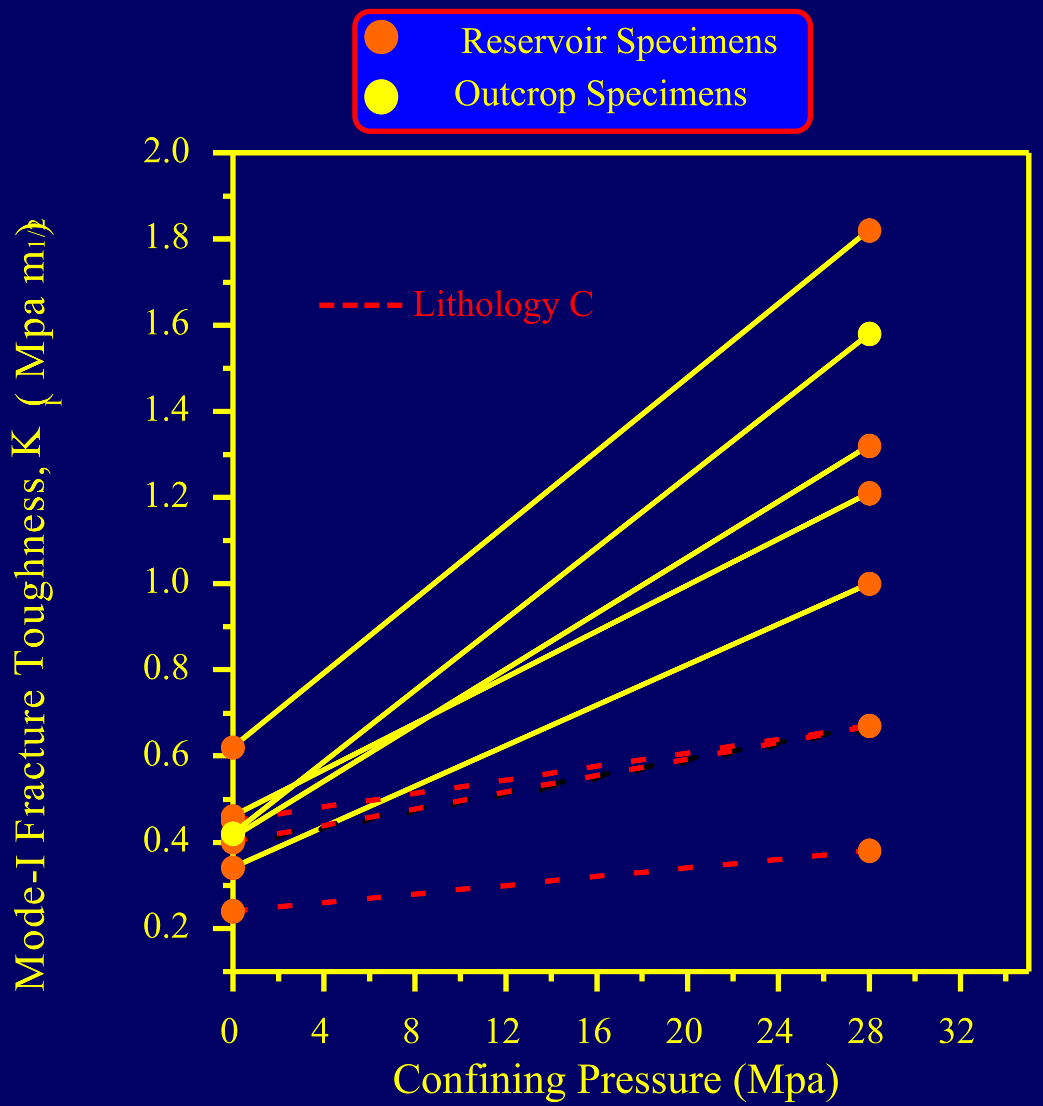


RESERVOIR CONDITIONS

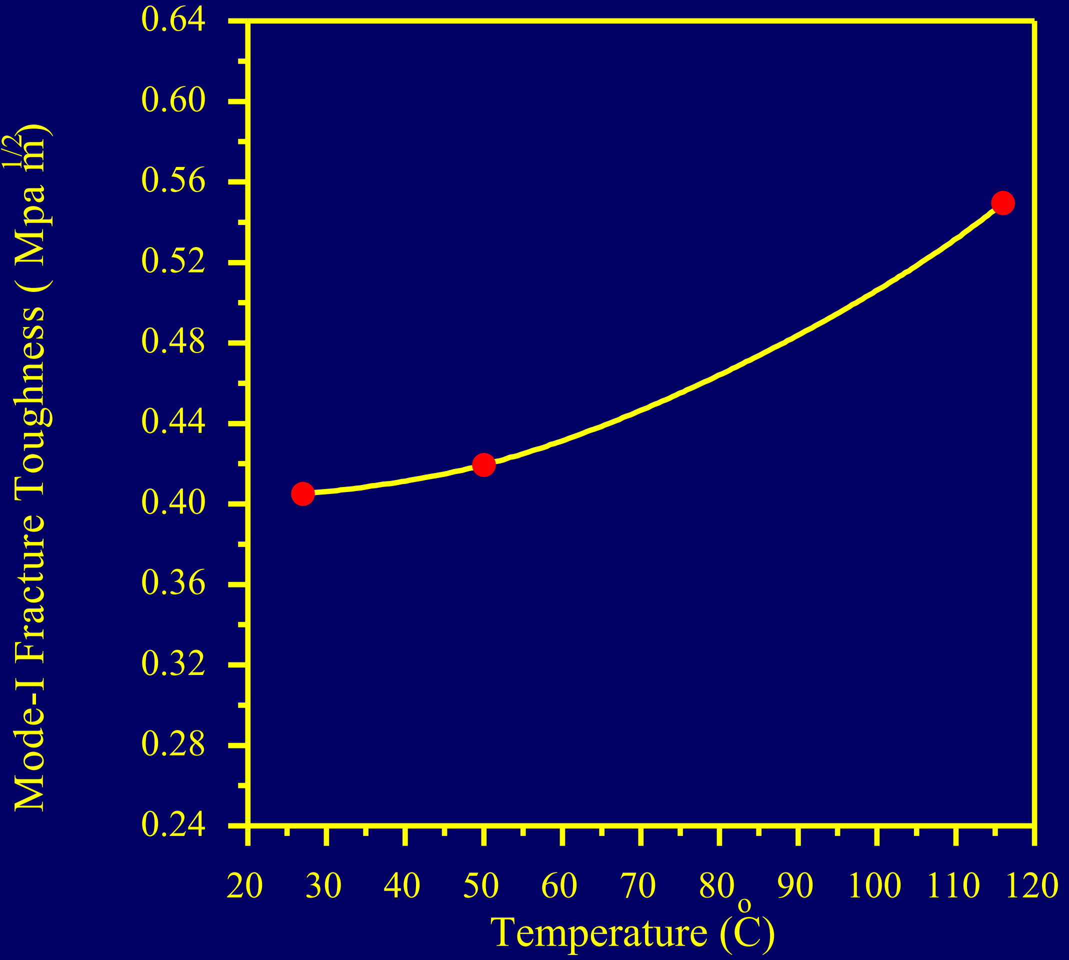
K_I Under Confining Pressure



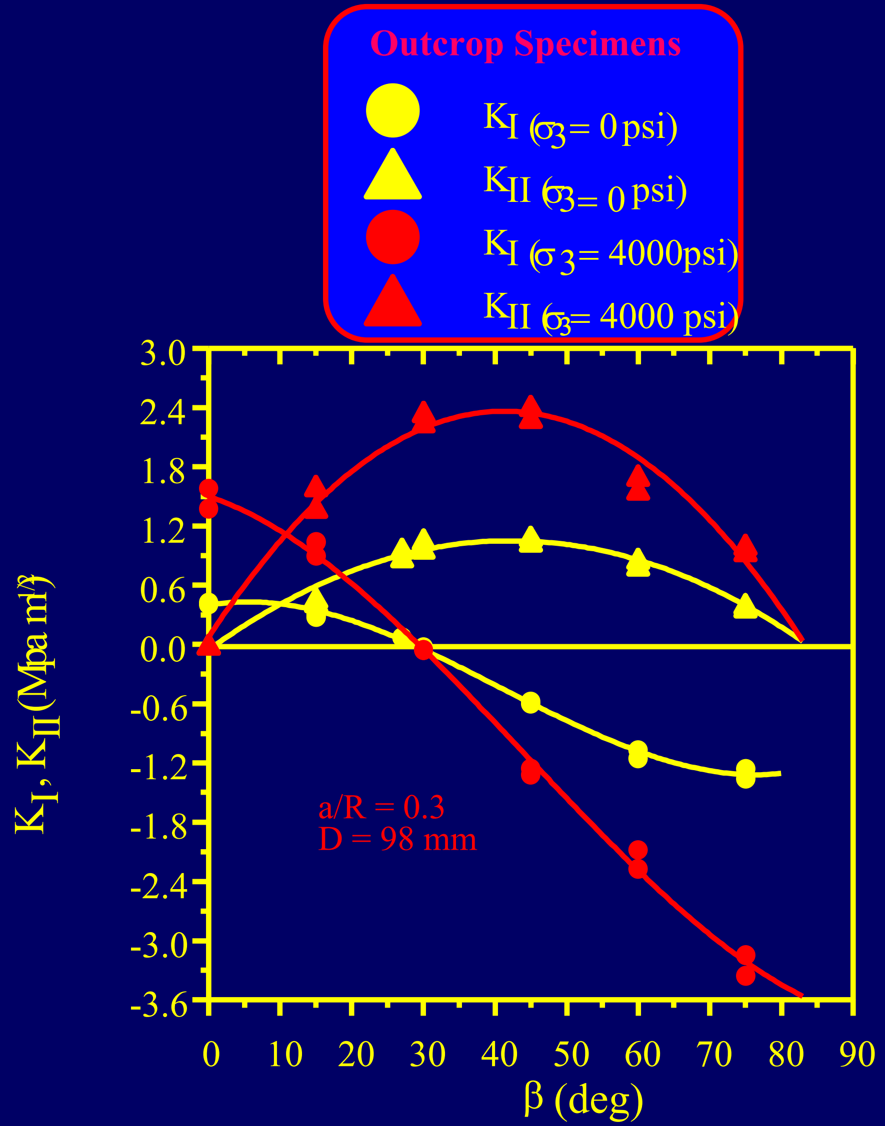
K_I Under Confining Pressure



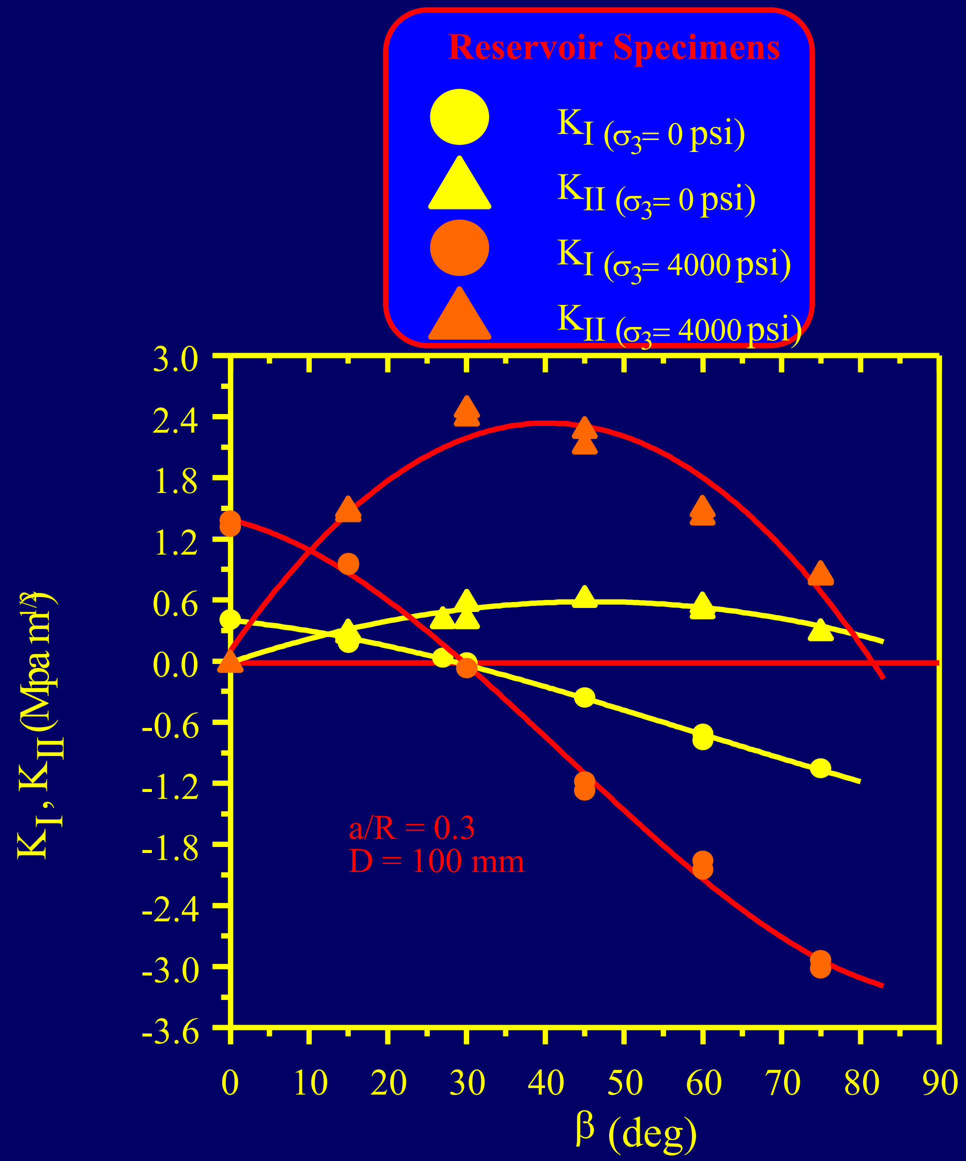
Effect of Temperature on K_I



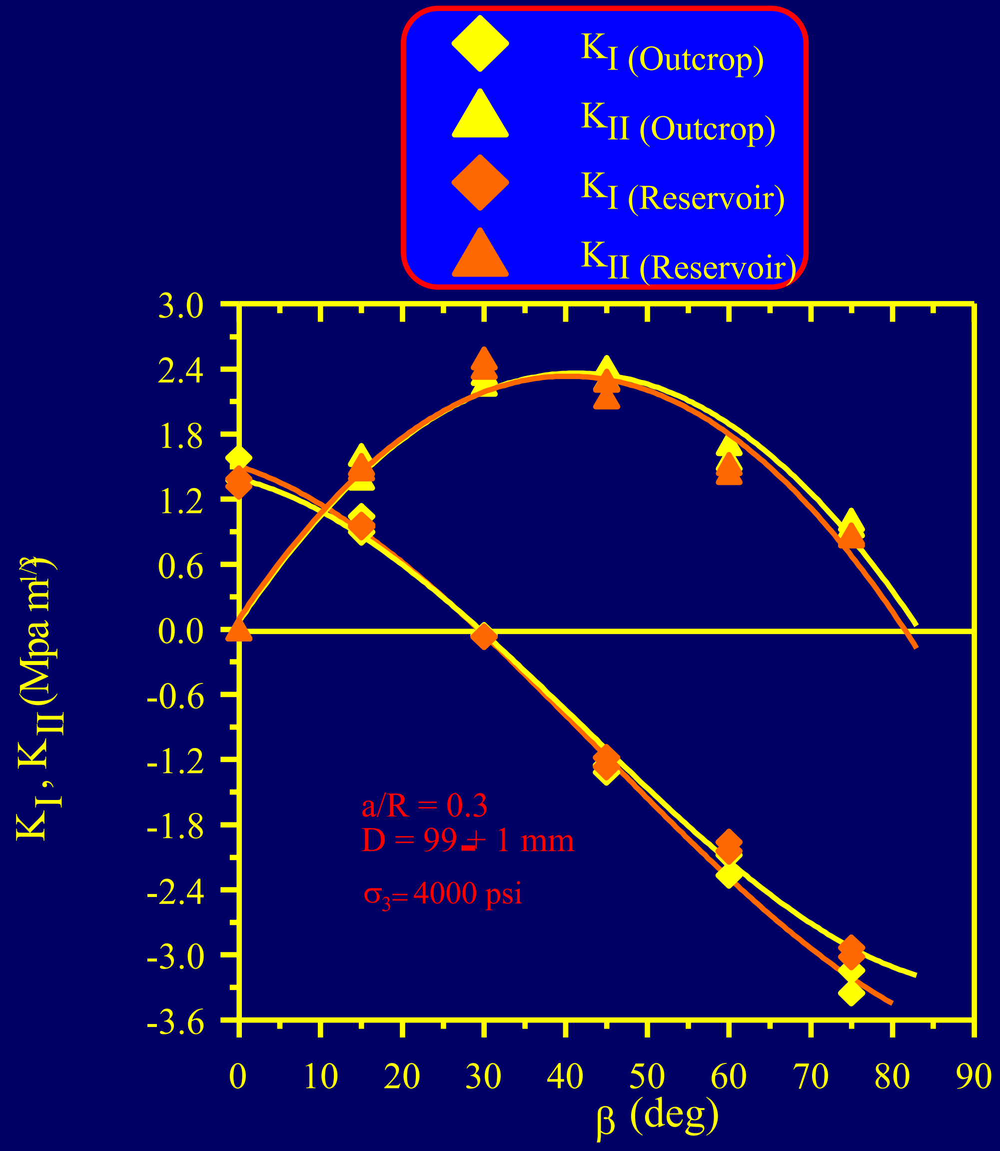
Ambient vs. Confined (outcrop)



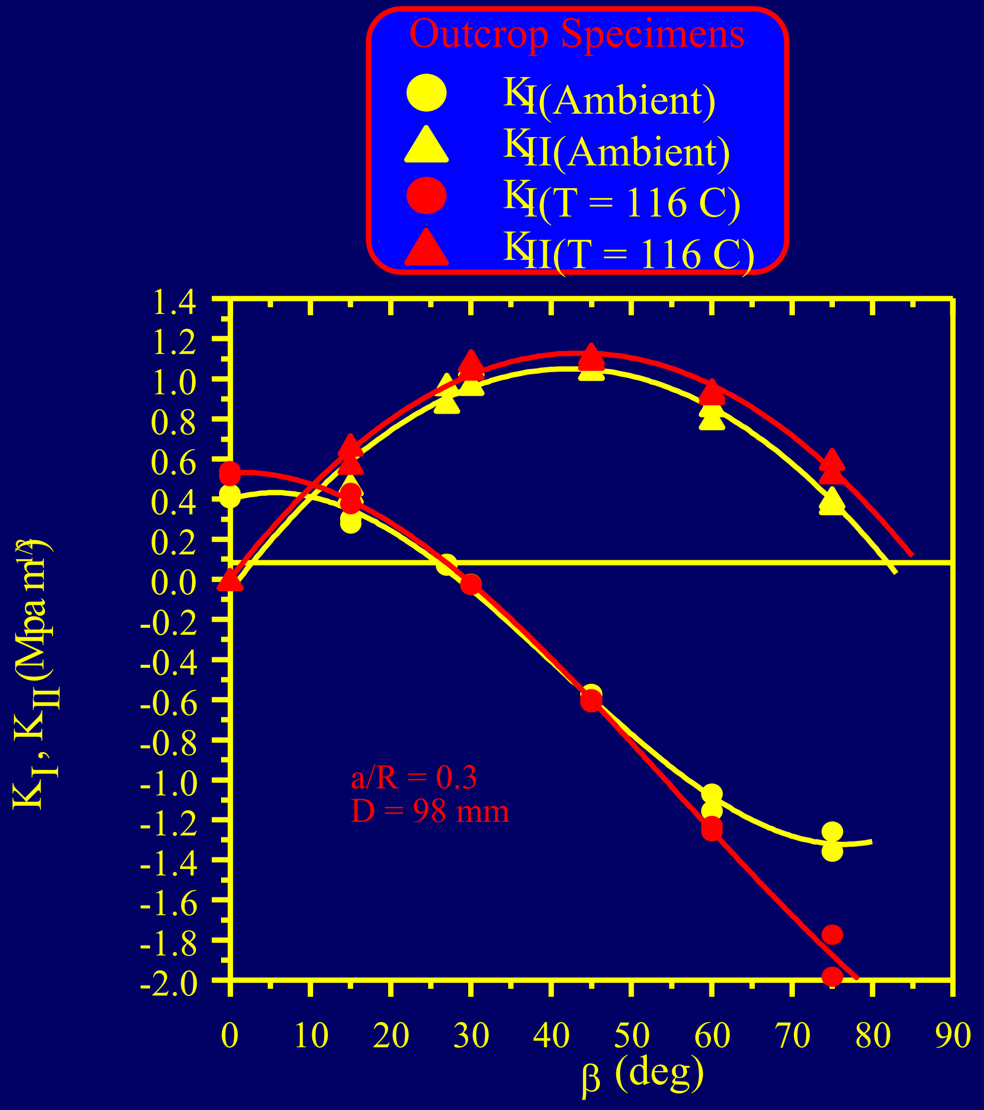
Ambient vs. Confined (reservoir)



Outcrop vs. Reservoir (confined)



Temperature Effects on K_I & K_{II}



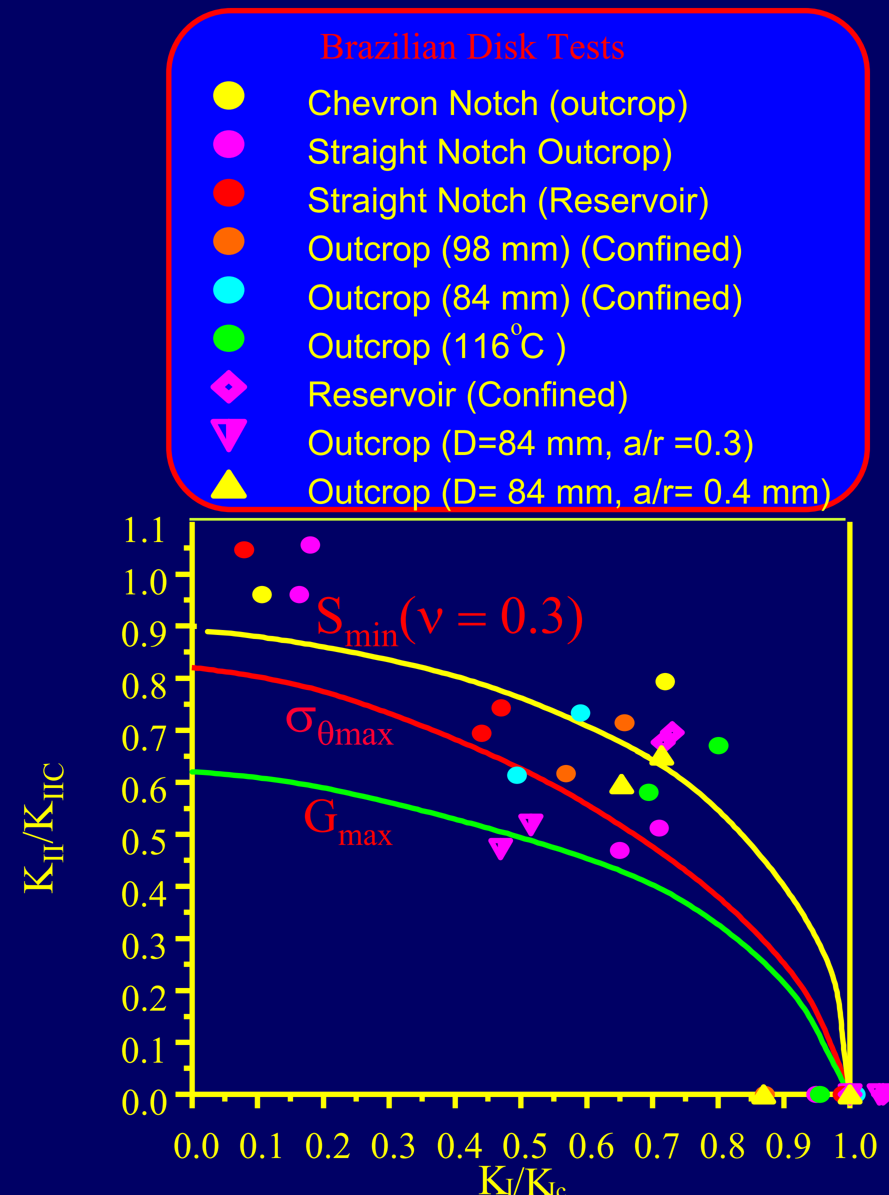
Summary of Results

Samples	D (mm)	K_{IC} Mpa $(m)^{1/2}$	K_{IIC} Mpa $(m)^{1/2}$	K_{IIC}/K_{IC}	Test condition	% Increase K_{IC}	% Increase K_{IIC}
Outcrop	98	0.43	0.92	2.140	Ambient*		
Outcrop	98	0.529	1.07	2.023	Temperature*	23	16
Outcrop	98	1.58	2.18	1.380	Confined*	267	137
Outcrop	84	0.35	0.65	1.857	Ambient**		
Outcrop	84	0.37	0.68	1.838	Ambient*		
Outcrop	84	1.2	1.49	1.242	Confined**	243	129
Reservoir	100	0.408	0.513	1.257	Ambient*		
Reservoir	100	1.32	2.18	1.652	Confined*	224	325
Reservoir	100	0.61	0.56	0.918	Temperature*	50	9

* a/R = 0.3

** a/R = 0.4

Fracture Toughness Envelope



CONCLUSIONS

- Confining pressure has significant effect on fracture toughness value; whereas effect of temperature is marginal.
- Mixed mode I-II fracture toughness results for outcrop and reservoir specimens under confining pressure are very close despite the fact that the behavior is not comparable at ambient conditions.

- The crack propagation in these rocks is best predicted by maximum stress criterion.
- Crack mostly initiated at the tip.
- Crack initiation and propagation is independent of both specimen origin and testing condition.

THANK YOU