

PERMEABILITY ENHANCEMENT OF CONSOLIDATED  
BEDROCK MATERIALS: HYDROFRACTURING FOR  
WATER PRODUCTION AND REMEDIATION

- I'M SORRY STATISTICIANS

- PLUTONIC IGNEOUS

GRANITE

DIORITE

GABBRO

METAMORPHIC

GNEISS

SCHIST

CLAYSTONE

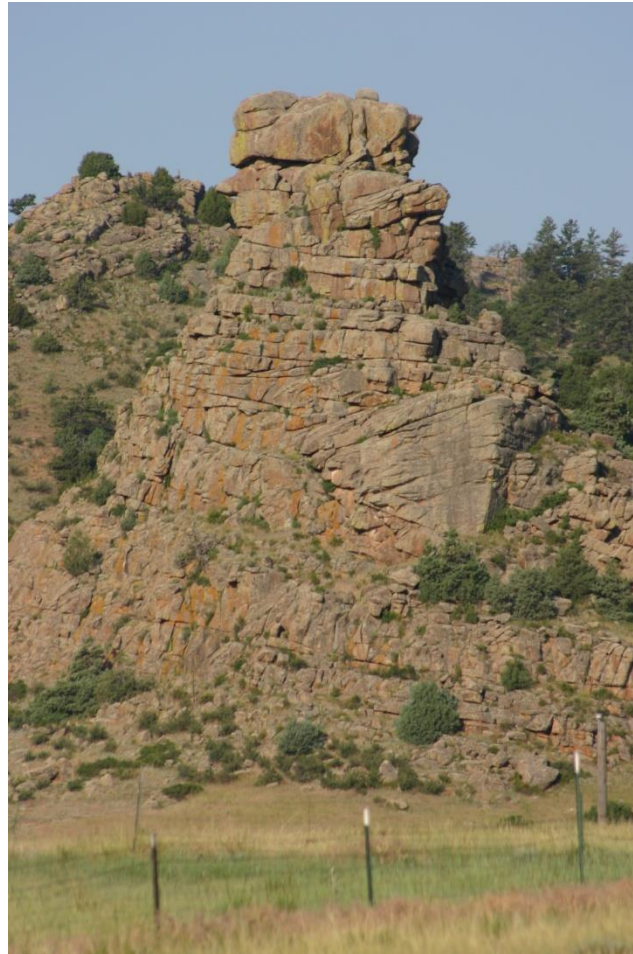
VARYING AMOUNTS OF FINE SAND AND SILT

LIMESTONE

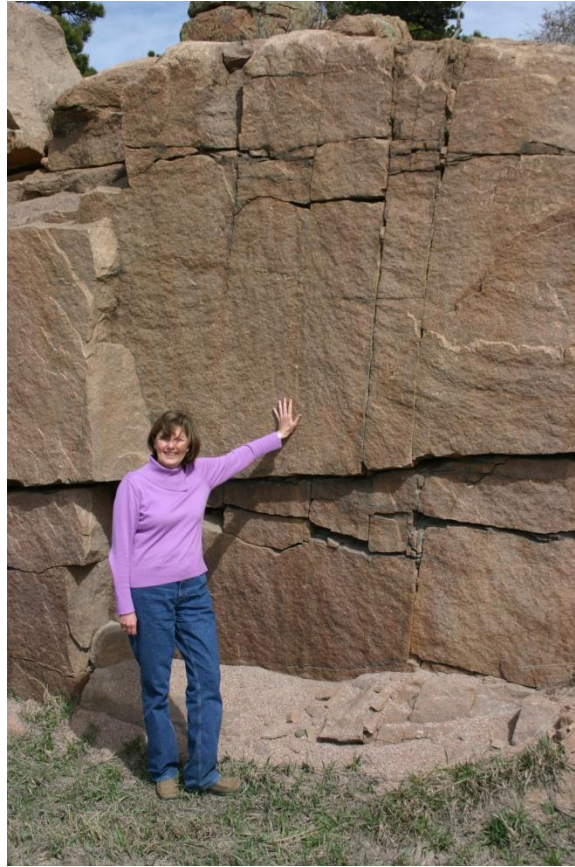
KARST

COMPLEX BEDDING

# GRANITE WITH ORTHOGONAL FRACTURES



# FRACTURE PLANES CLEARLY PRESENT



# INTERLOCKING GRAINS



# TYPICAL FIELD SET-UP FOR HYDROFRACTURING IN IGNEOUS AND METAMORPHIC MATERIALS



# HYDROFRACTURE PACKER SHOWN INFLATED





# COLOR BANDING DUE TO MINERAL SEGREGATION



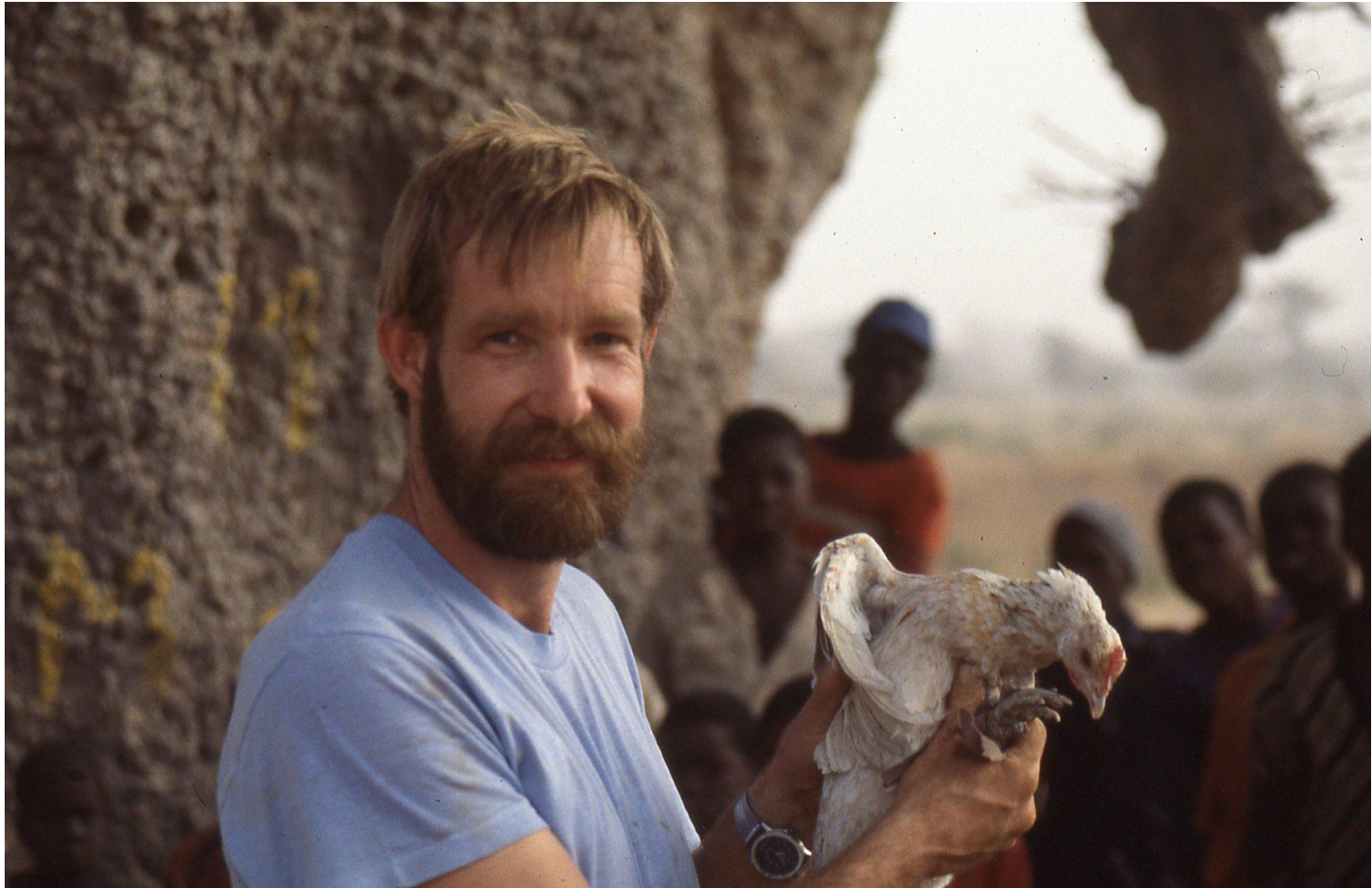
# COMPLEX METMORPHIC SEQUENCE



# EVERYBODY LIKES A GOOD FRAC JOB



# PAYDAY



# CLAYSTONE



# CLAYSTONE INJECTION SITE AT OIL BUNKER



# THE ALLMIGHTY KENTUCKY LIMESTONE



# SHORT-INTERVAL INJECTION AND SAMPLE PACKERS





# 18-INCH SAMPLE/INJECTION INTERVAL



# INJECTION PUMP

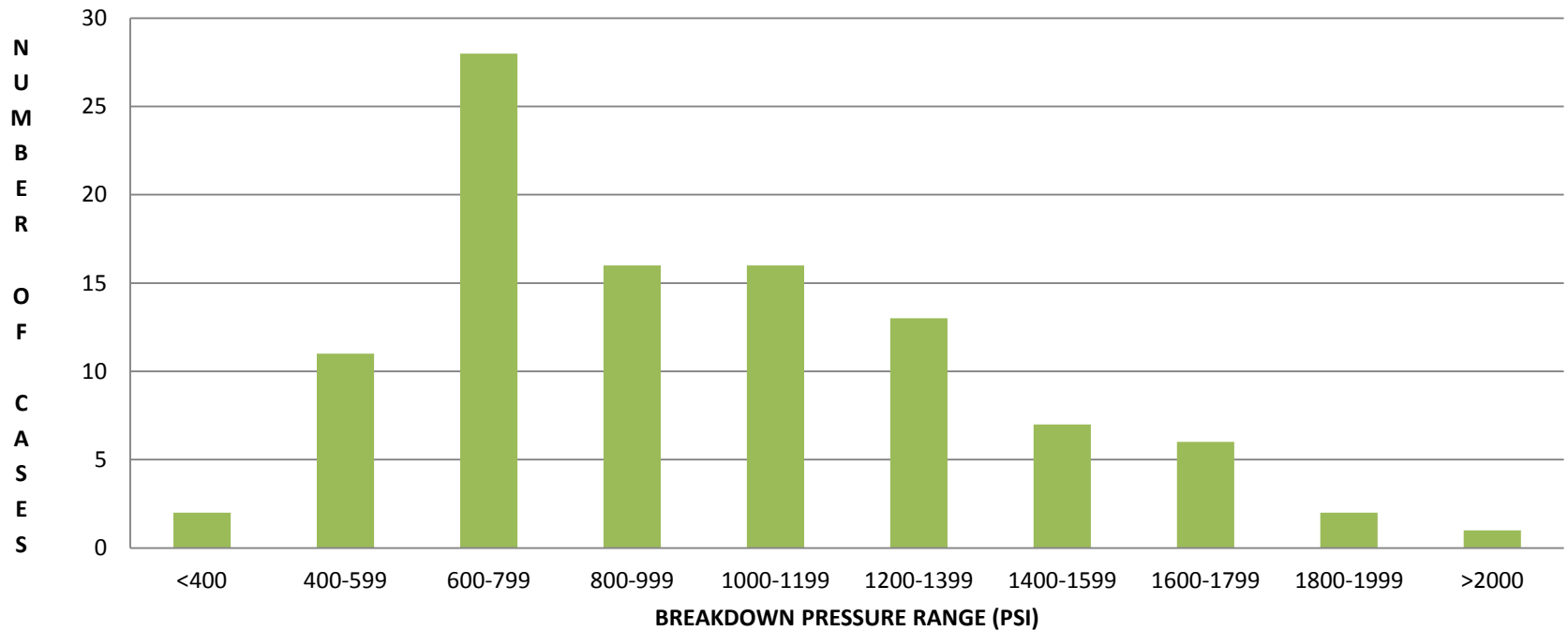


# BROAD RANGE IN OUTPUT

DISCHARGE RATES FOR NATIONAL JWS-165L PUMP WITH 4" PLUNGERS.											
GAL/RPM = 0.816 GAL			REDUCTION CASE RATIO = 5:1								
TRANSMISSION RATIOS		LL	L	1	2	3	4	5	6	7	8
		15.22	9.95	6.24	4.63	3.40	2.53	1.83	1.36	1.00	0.74
FORMULA FOR OUTPUT: GAL/MIN=PUMP RPM* 0.816 GAL											
=(( ENGINE RPM/(TRANSMISSION GEAR RATIO * REDUCTION CASE RATIO))*0.816											
OUTPUT IN GPM FOR VARIOUS GEARS AND ENGINE RPMS.											
	GEAR	LL	L	1	2	3	4	5	6	7	8
RPM											
700		8	11	18	25	34	45	62	84	114	154
800		9	13	21	28	38	52	71	96	131	176
900		10	15	24	32	43	58	80	108	147	198
1000		11	16	26	35	48	65	89	120	163	221
1100		12	18	29	39	53	71	98	132	180	243
1200		13	20	31	42	58	77	107	144	196	265
1300		14	21	34	46	62	84	116	156	212	287
1400		15	23	37	49	67	90	125	168	228	309
1500		16	25	39	53	72	97	134	180	245	331
1600		17	26	42	56	77	103	143	192	261	353
1700		18	28	44	60	82	110	152	204	277	375

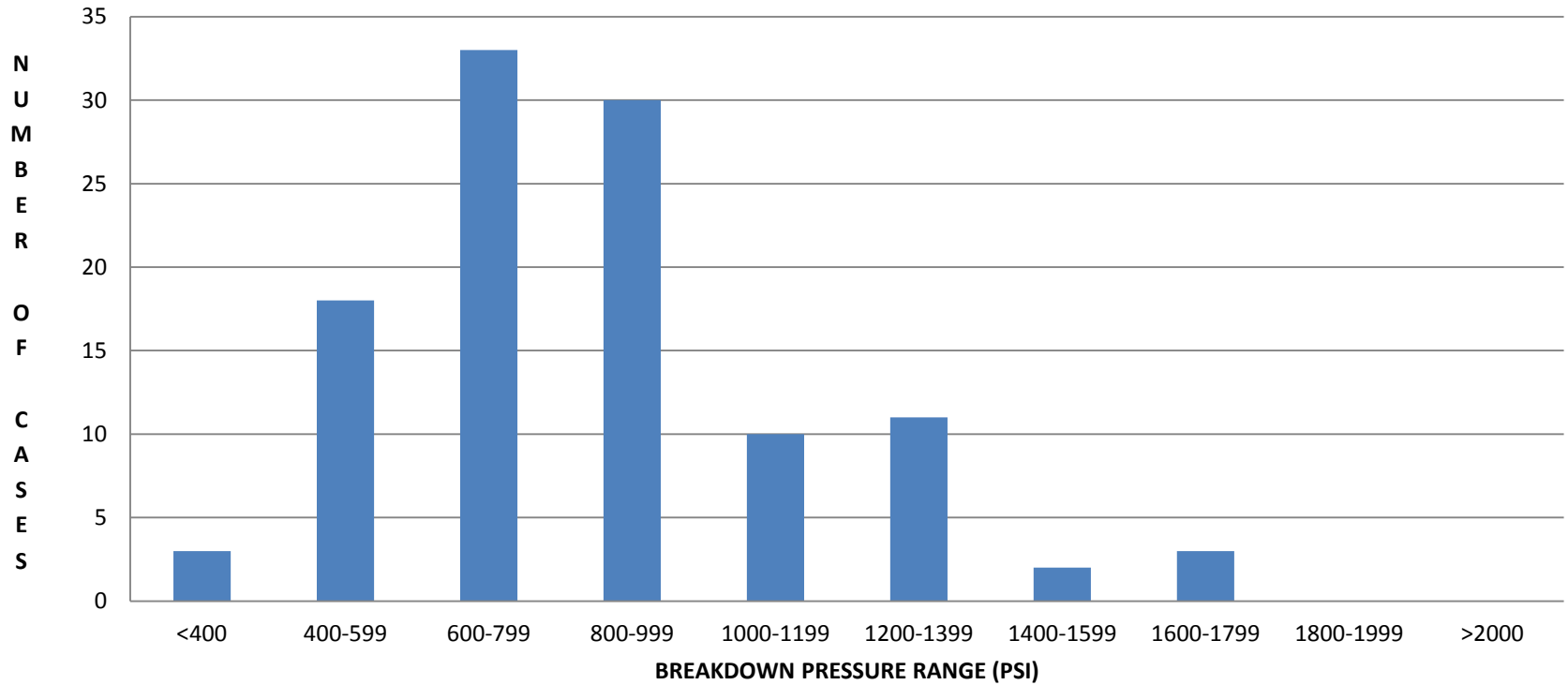
# PLUTONIC IGNEOUS

**DISTRIBUTION OF BREAKDOWN PRESSURES FOR PLUTONIC IGNEOUS ROCKS (103 DATA POINTS).**



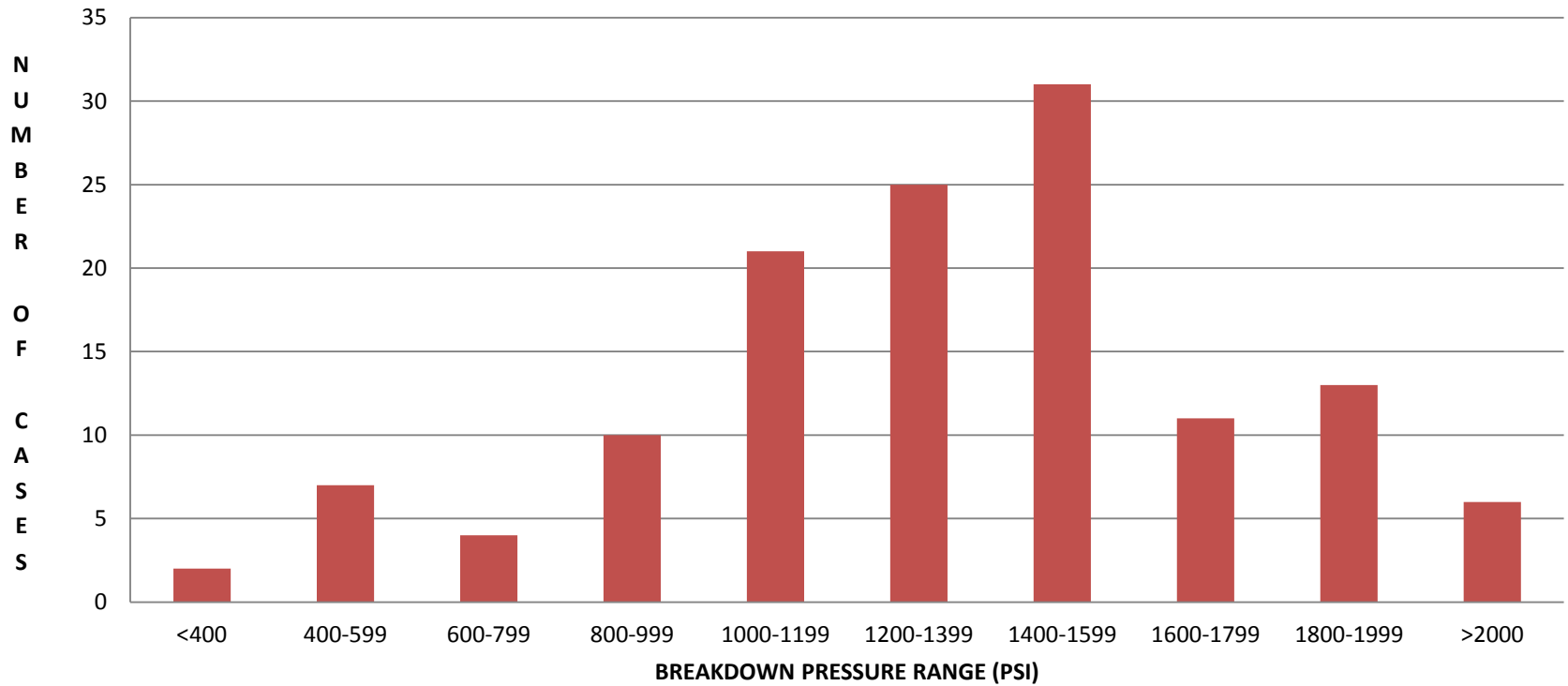
# METAMORPHIC

**DISTRIBUTION OF BREAKDOWN PRESSURES FOR METAMORPHIC ROCKS (111 DATA POINTS).**



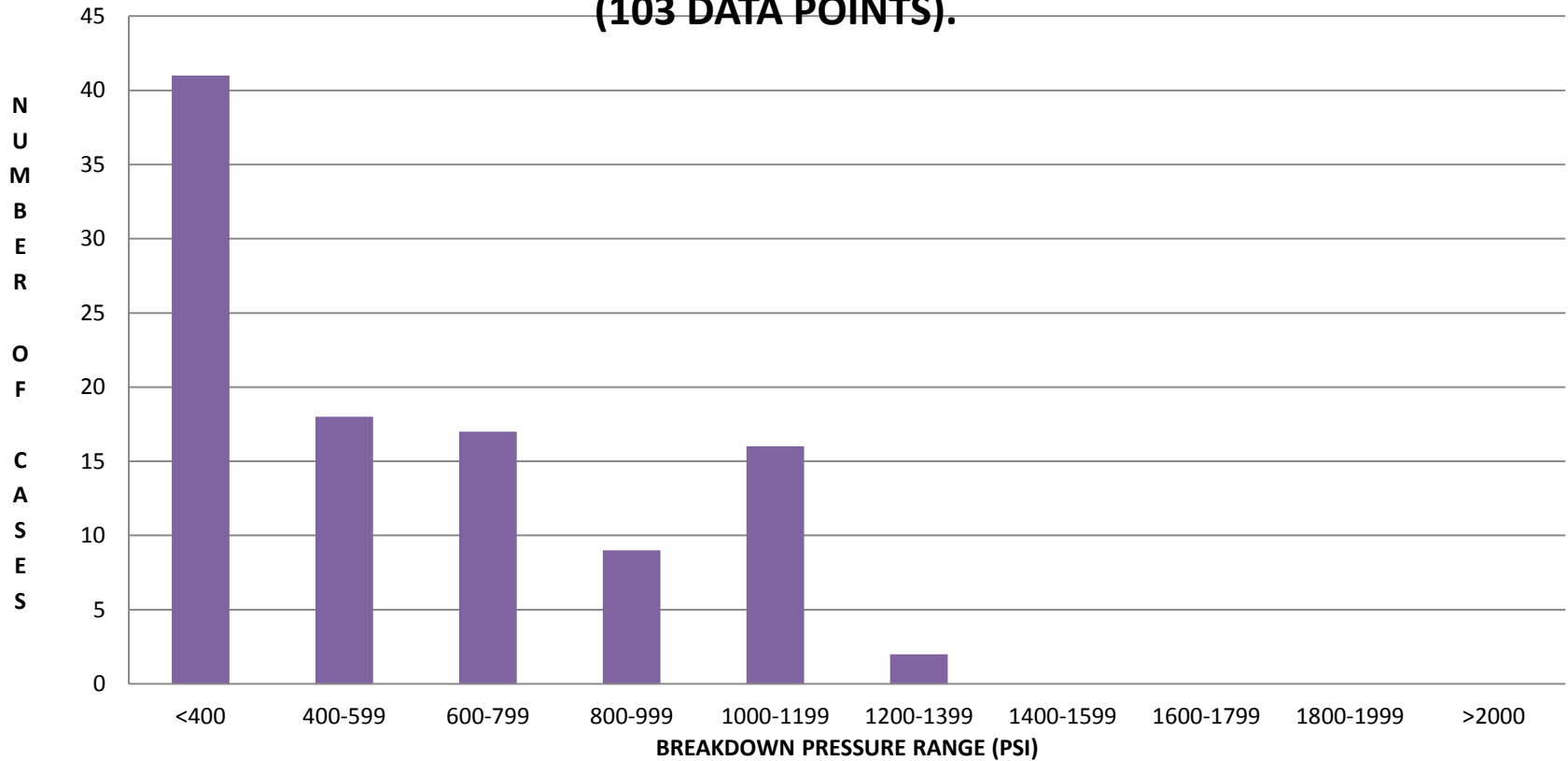
# CLAYSTONE

**DISTRIBUTION OF BREAKDOWN PRESSURES FOR CLAYSTONE ROCKS  
(148 DATA POINTS).**



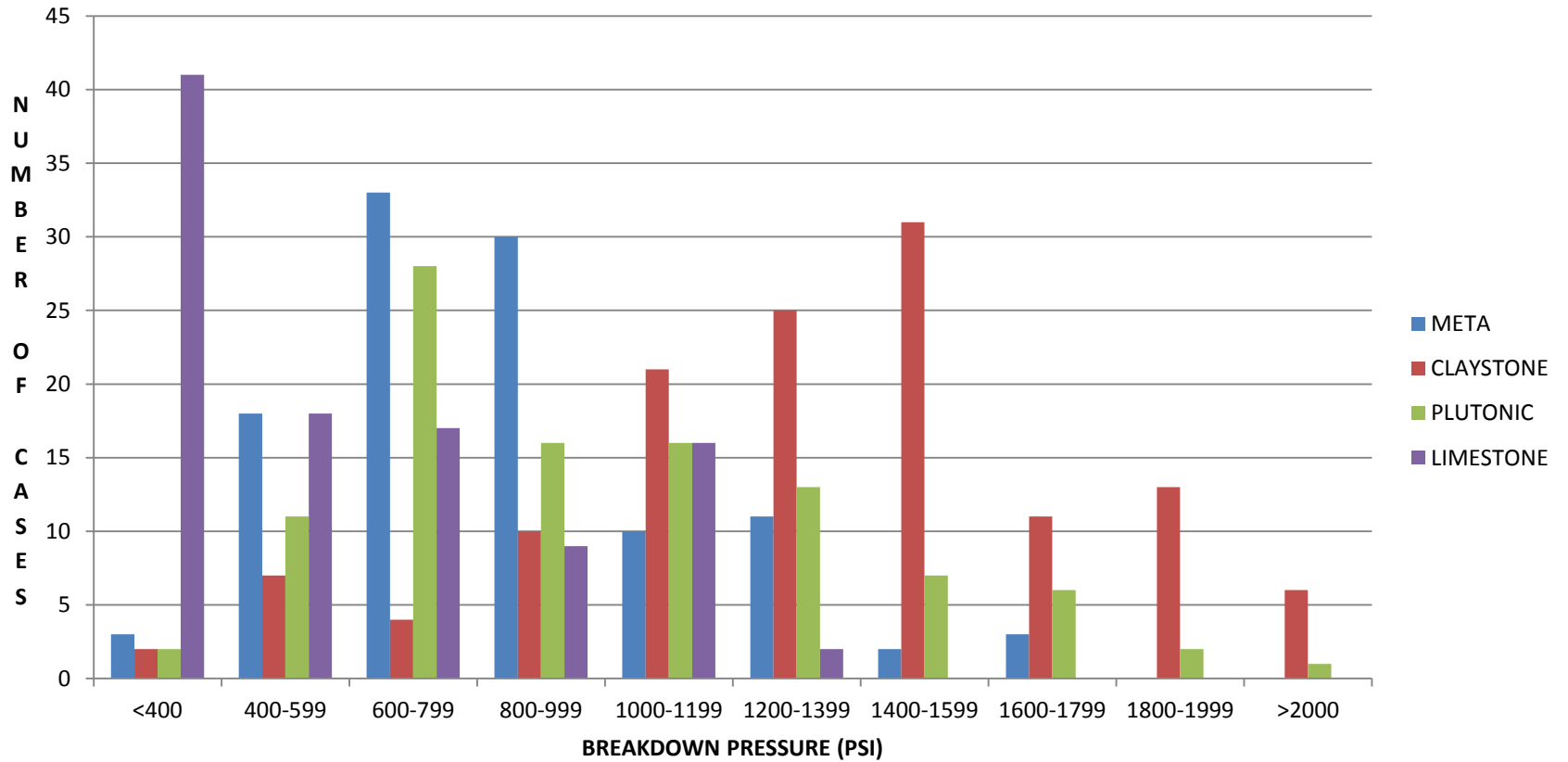
# LIMESTONE

**DISTRIBUTION OF BREAKDOWN PRESSURES FOR LIMESTONE ROCKS  
(103 DATA POINTS).**



# ALL FORMATIONS

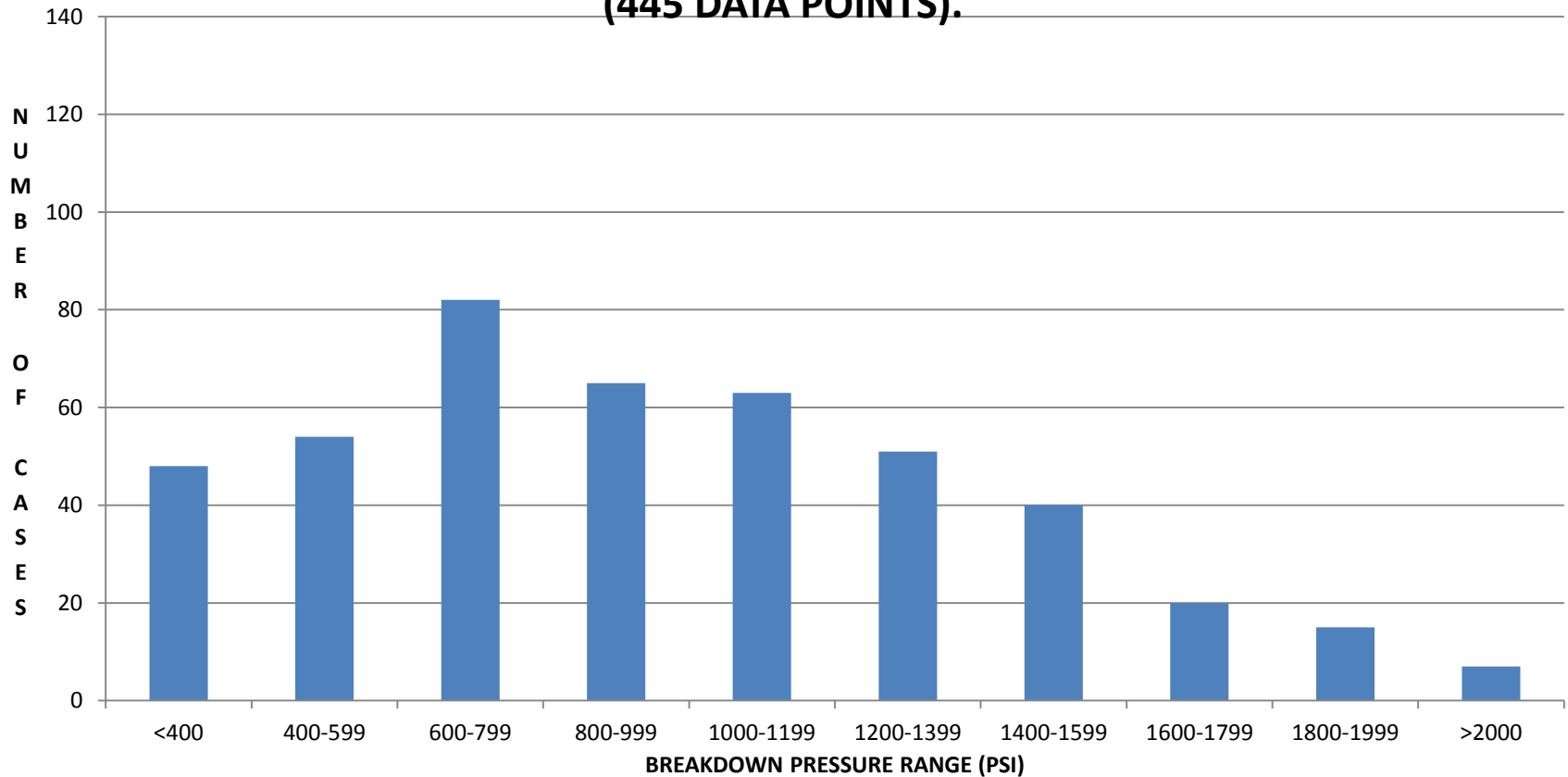
## DISTRIBUTION OF BREAKDOWN PRESSURES FOR ALL MATERIALS





# ALL MATERIALS AS ONE POPULATION

**DISTRIBUTION OF BREAKDOWN PRESSURES FOR ALL MATERIALS  
(445 DATA POINTS).**



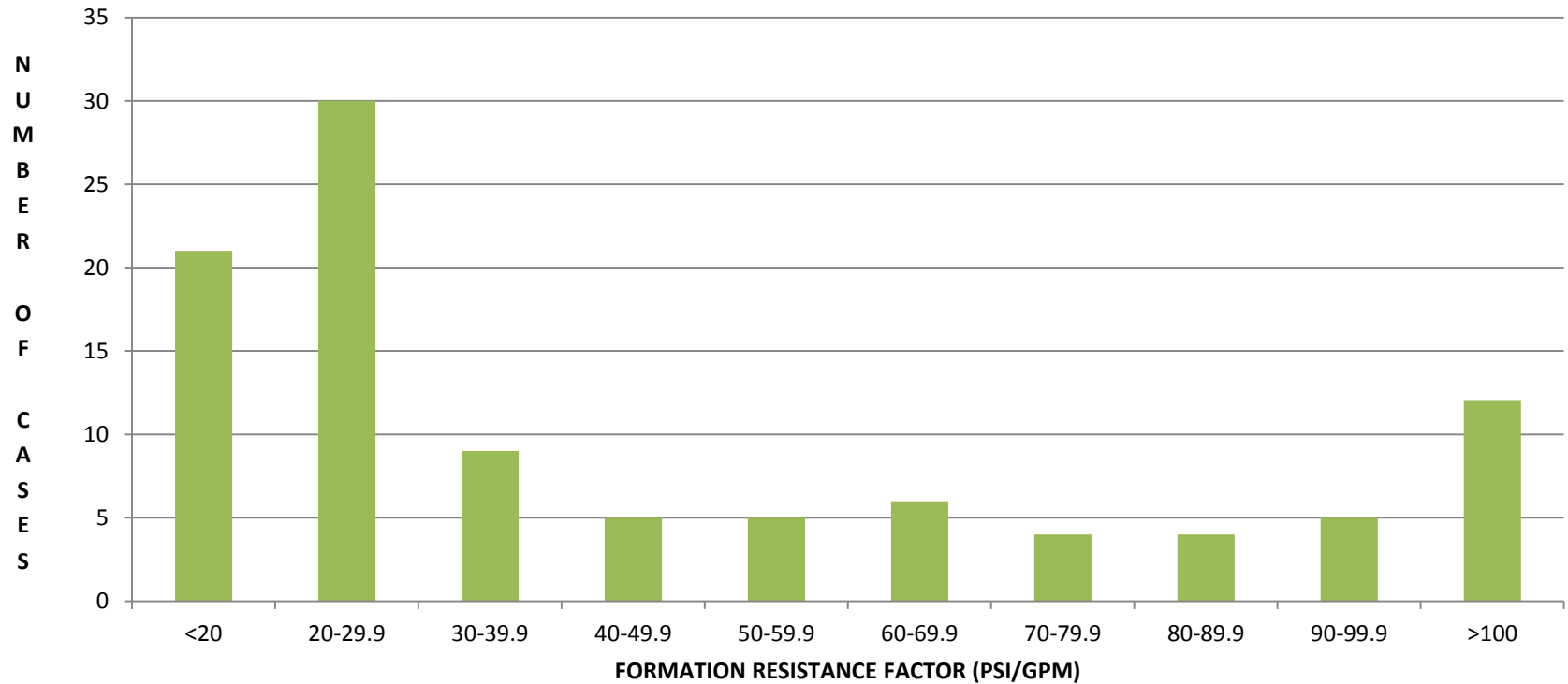
THERE'S A PROBLEM WITH THESE BREAKDOWN  
PRESSURE CURVES

- $1000 \text{ PSI}/50 \text{ GPM} = 20 \text{ PSI/GPM}$

- **FORMATION RESISTANCE FACTOR**

# PLUTONIC IGNEOUS

**DISTRIBUTION OF FORMATION RESISTANCE FACTORS FOR PLUTONIC IGNEOUS ROCKS (103 DATA POINTS).**

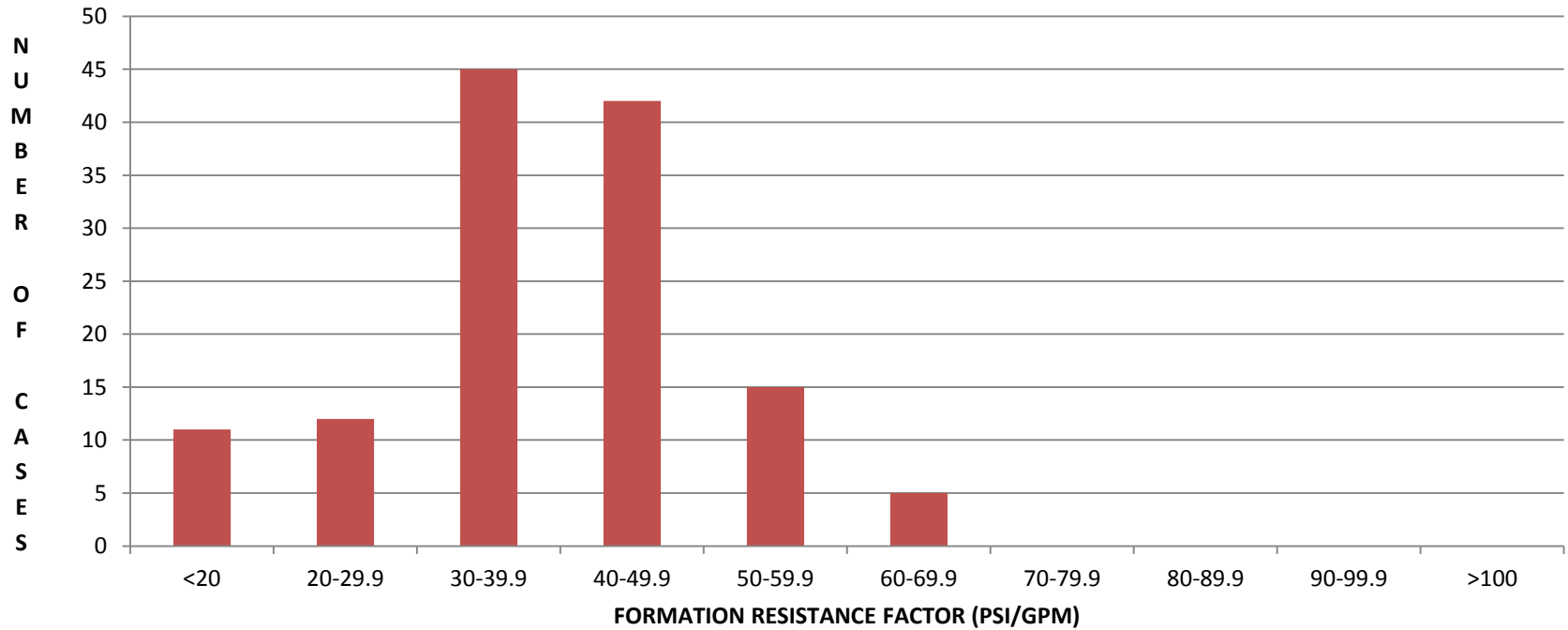


# METAMORPHIC

- COULD NOT FIND GRAPH...TIME'S UP

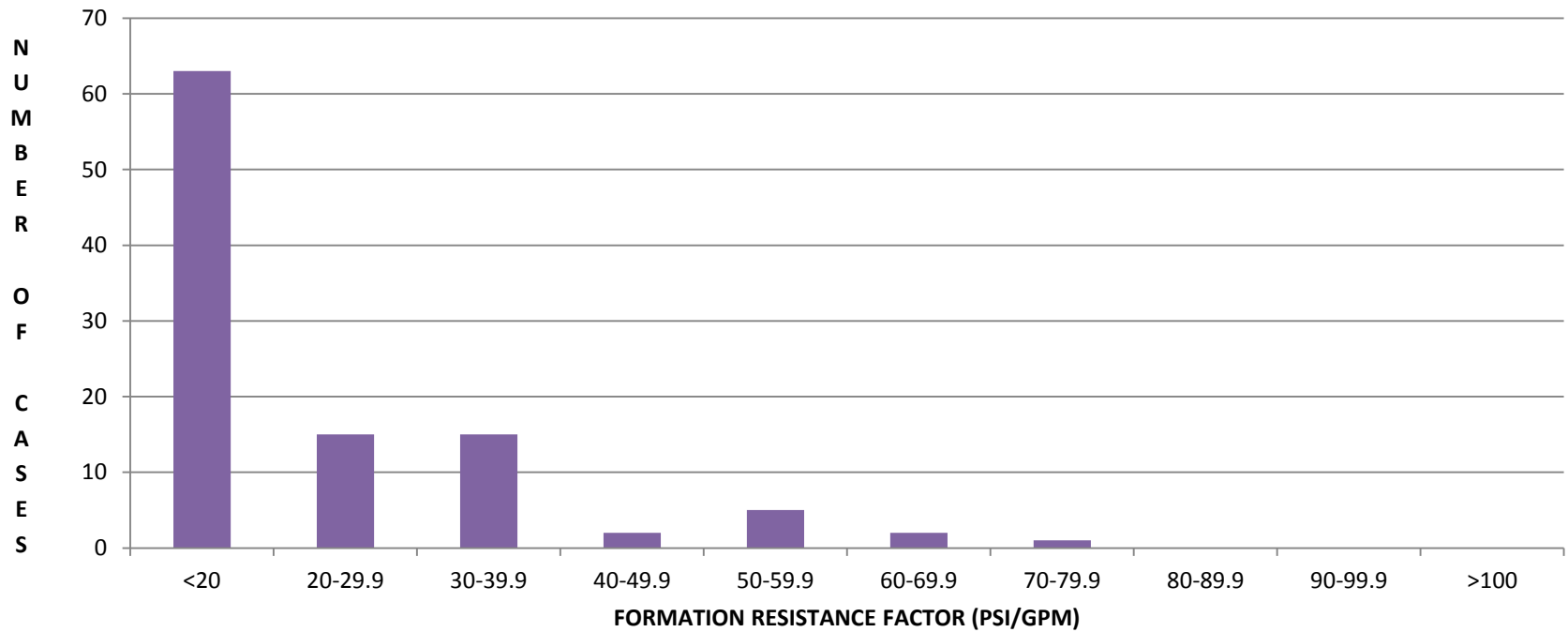
# CLAYSTONE

**DISTRIBUTION OF FORMATION RESISTANCE FACTORS FOR  
CLAYSTONE  
ROCKS (148 DATA POINTS).**



# LIMESTONE

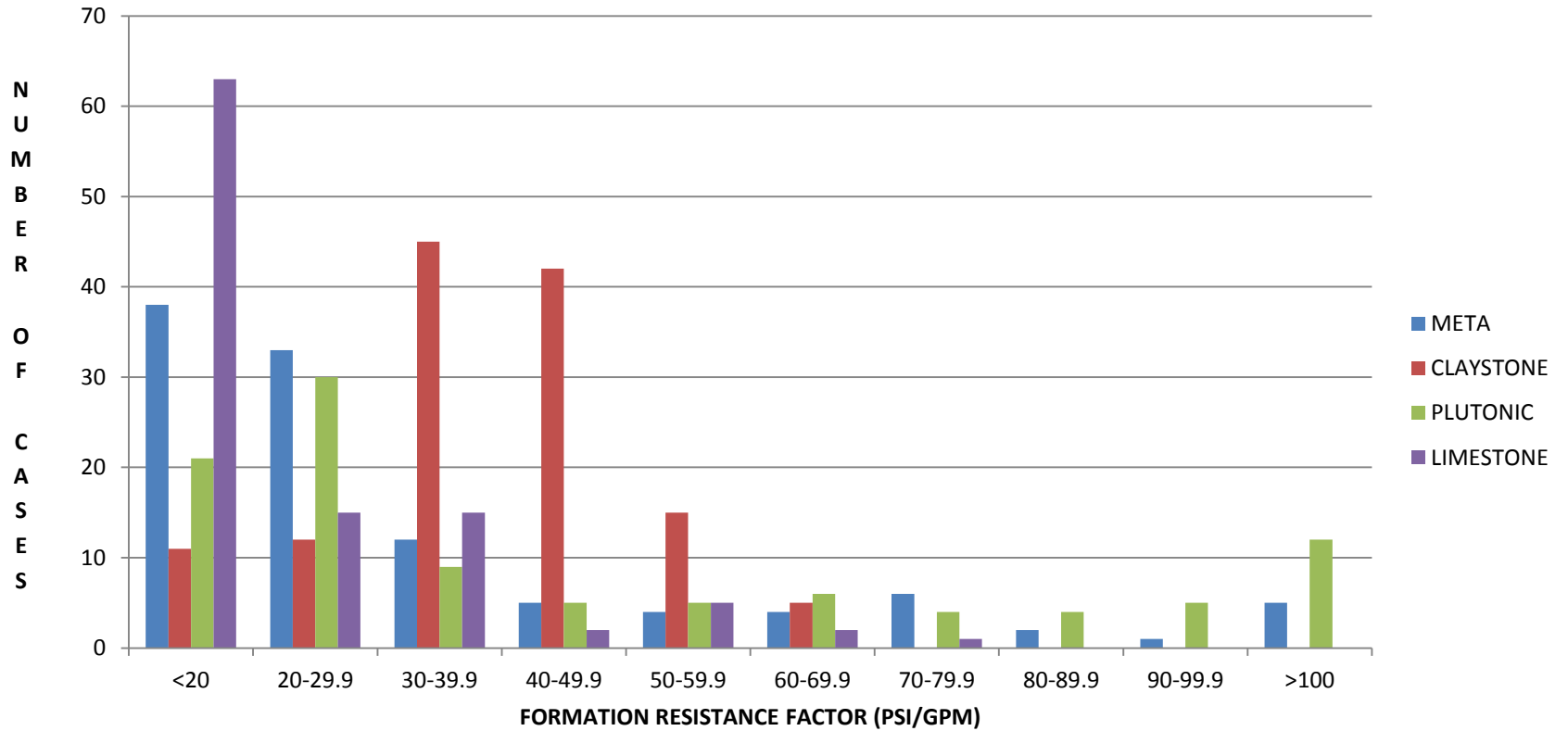
**DISTRIBUTION OF FORMATION RESISTANCE FACTORS FOR  
LIMESTONE  
ROCKS (103 DATA POINTS).**





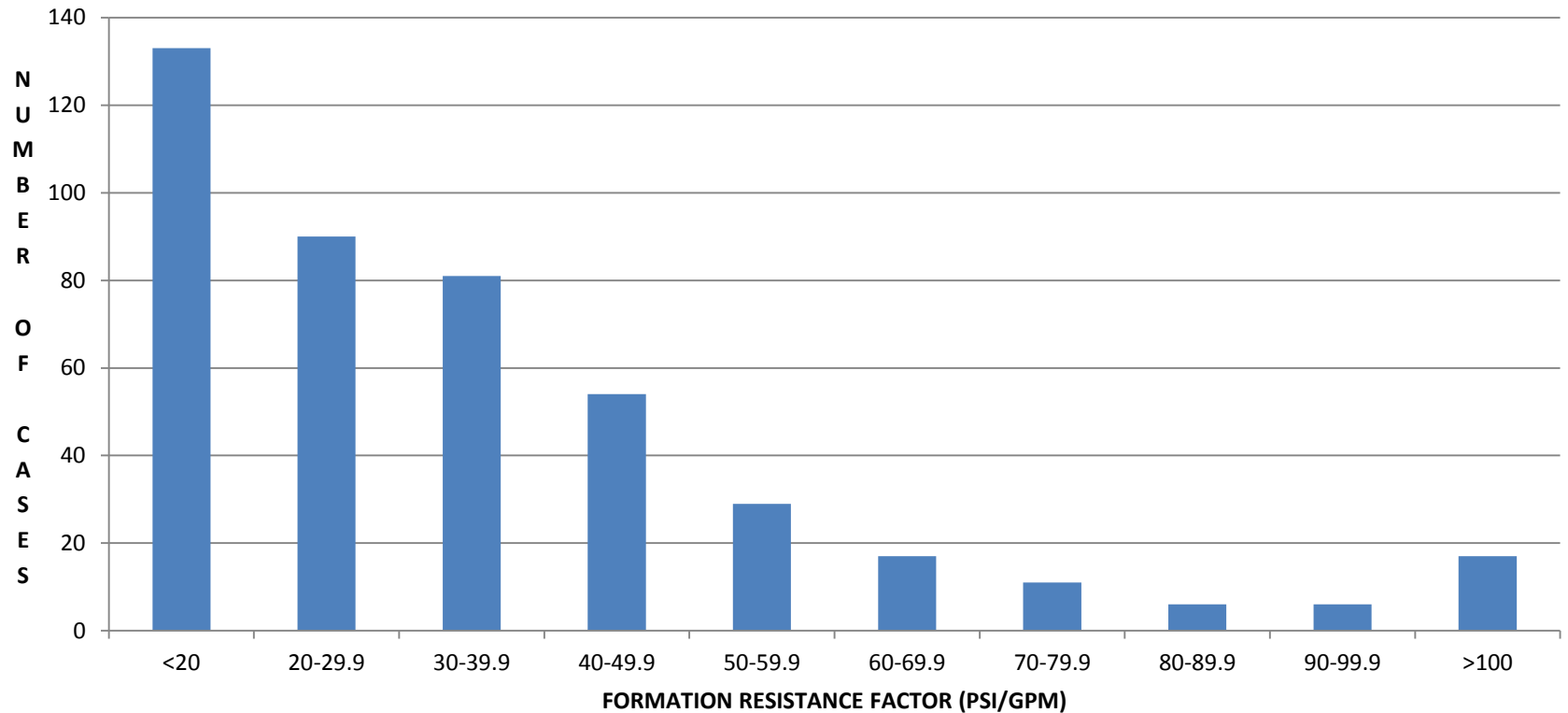
# ALL MATERIALS

## DISTRIBUTION OF FORMATION RESISTANCE FOR ALL MATERIALS



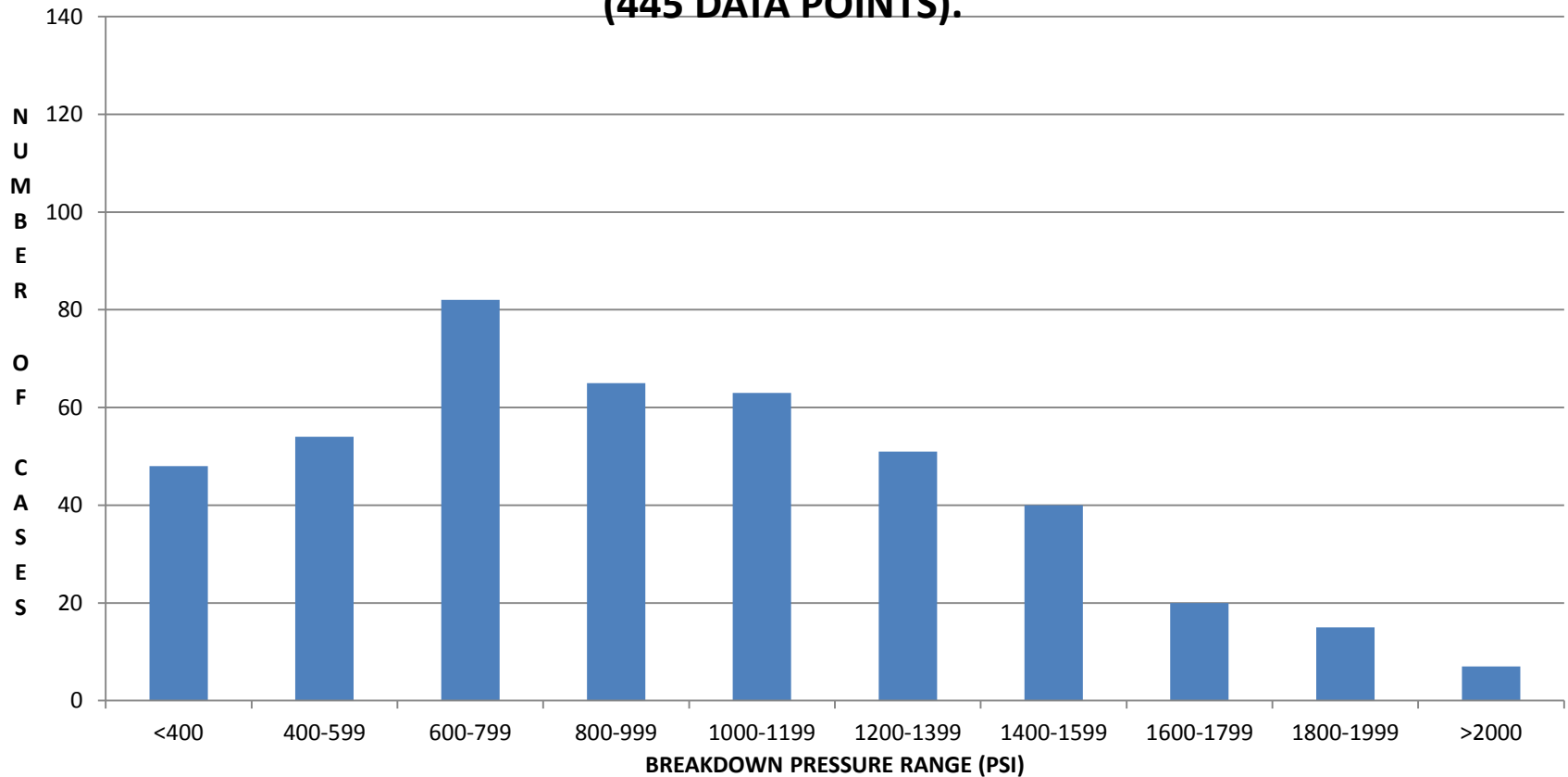
# ALL MATERIALS, ONE POPULATION

**DISTRIBUTION OF FORMATION RESISTANCE FACTORS FOR ALL MATERIALS (445 DATA POINTS).**



# ALL MATERIALS, ONE POPULATION

**DISTRIBUTION OF BREAKDOWN PRESSURES FOR ALL MATERIALS  
(445 DATA POINTS).**



# QUESTIONS?

