

# Elemental Yields to Minerals

Mineral Identification and Volumetrics from  
Pulsed Neutron Induced Spectra-Logs

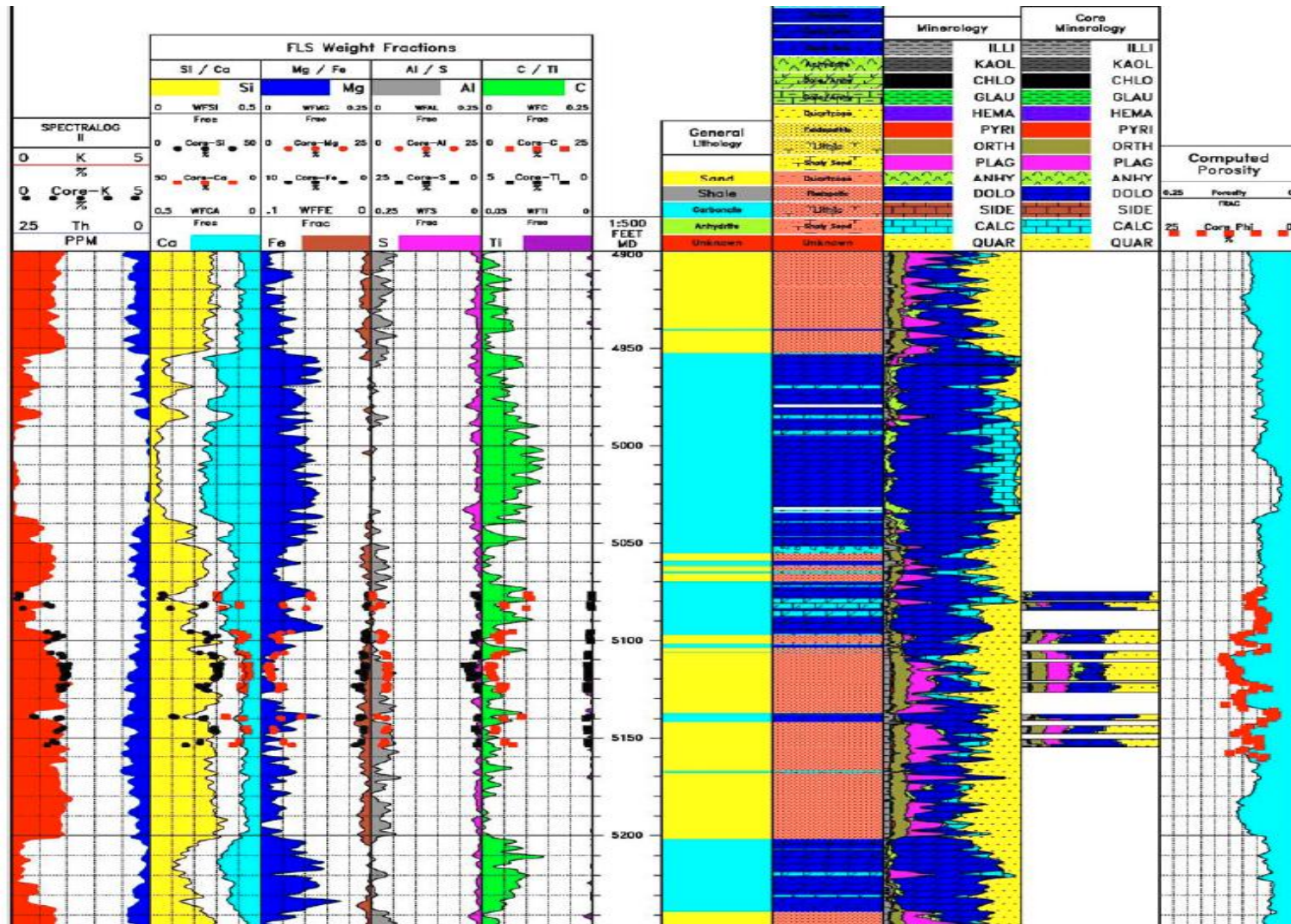
Ulrich Herz

Local SPWLA chapter meeting Abu Dhabi, October 2010

# Outline

- Why minerals and how to determine them?
- Spectroscopy and elements
- Expert System to determine Minerals
  - General Lithology
  - Specific Lithology
  - Mineral Weight Fractions
- Combined Volumetric Analysis

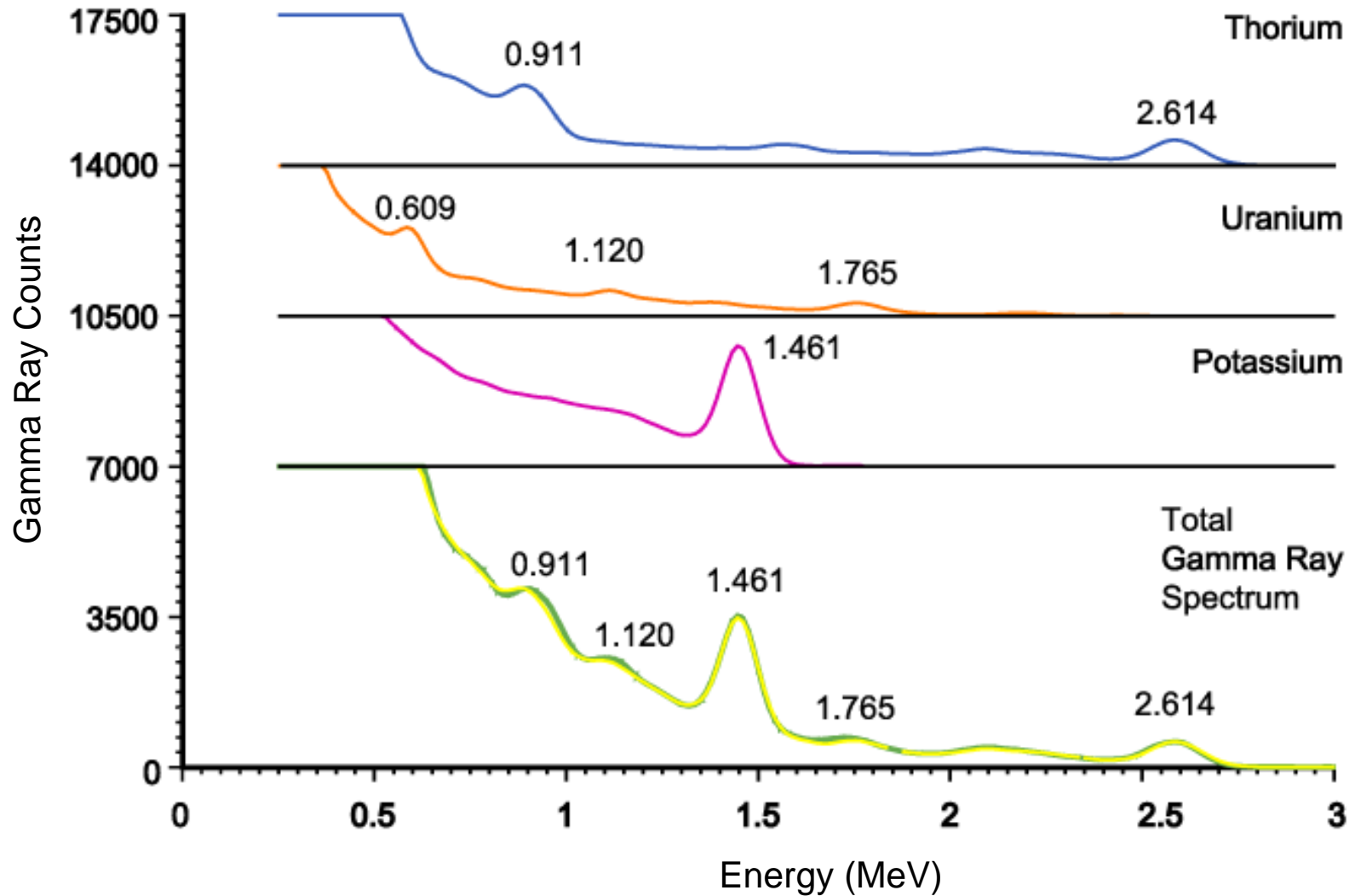
# Why Minerals ?



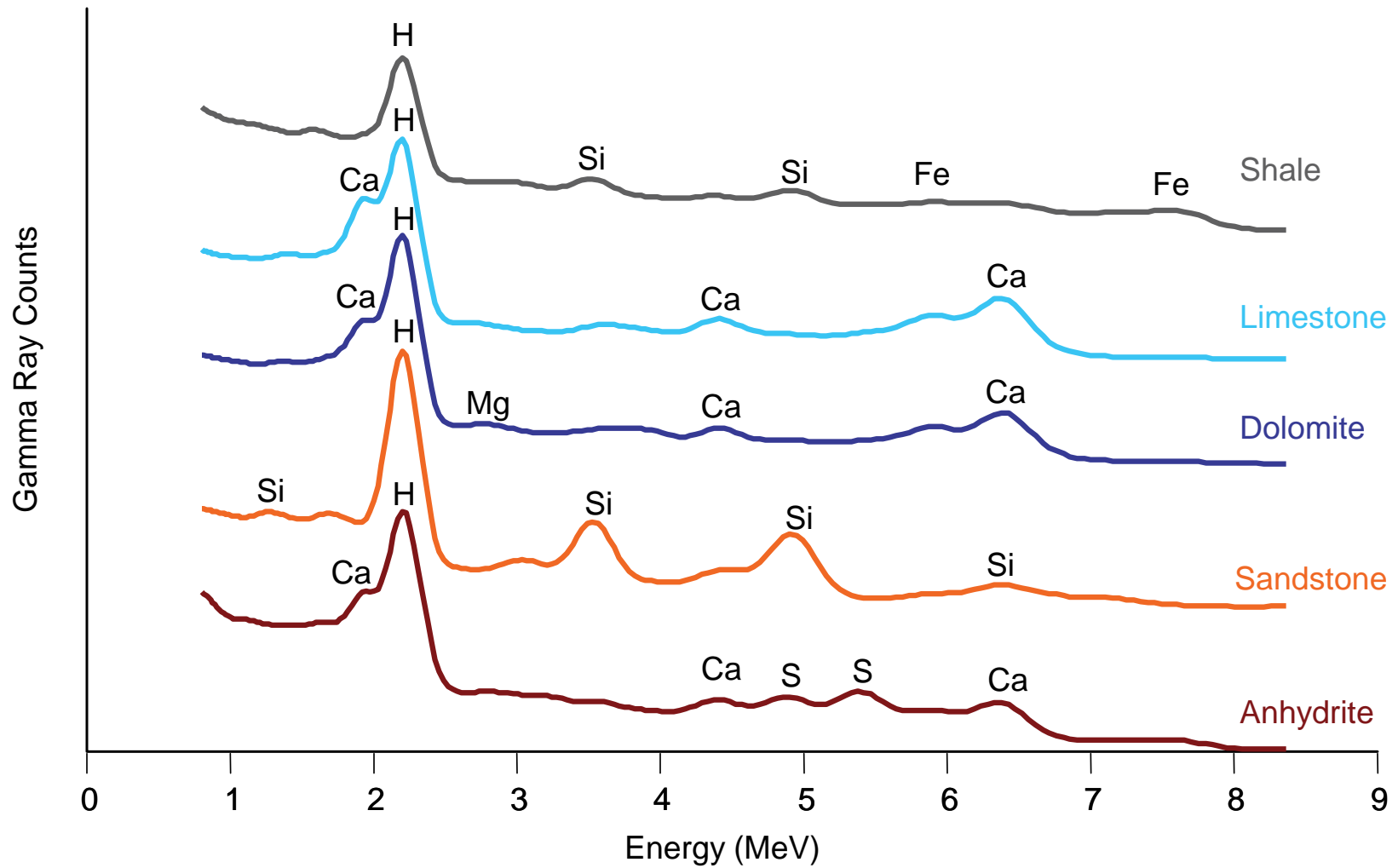
# How to determine minerals ?

- Full core analysis
  - Macroscopic and microscopic description
  - Thin sections
  - Full Chemical analysis
- X-Ray Diffraction
  - Crystallography, chemical composition, physical properties
- Spectral Analysis Logs
  - Yields of selected elements

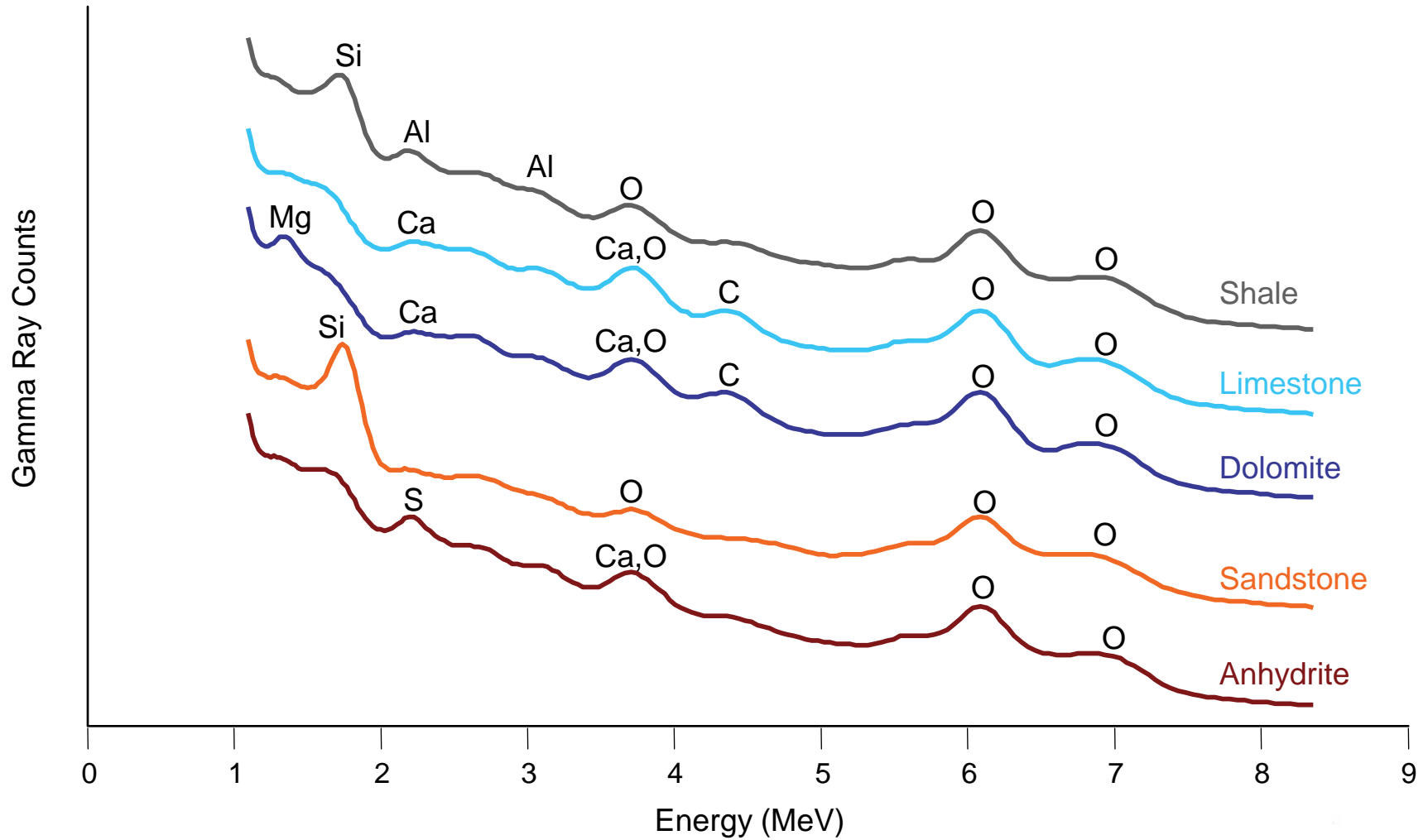
# Natural Gamma Ray Spectroscopy



# Capture Gamma Ray Spectroscopy



# Inelastic Gamma Ray Spectroscopy



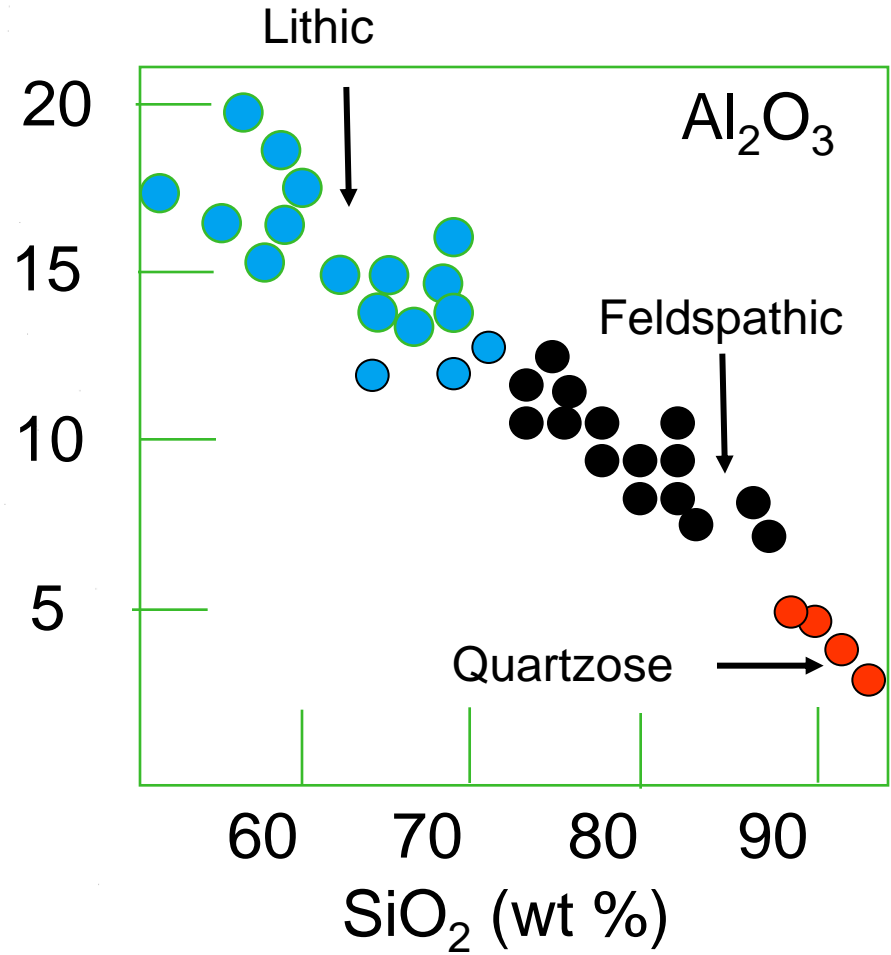
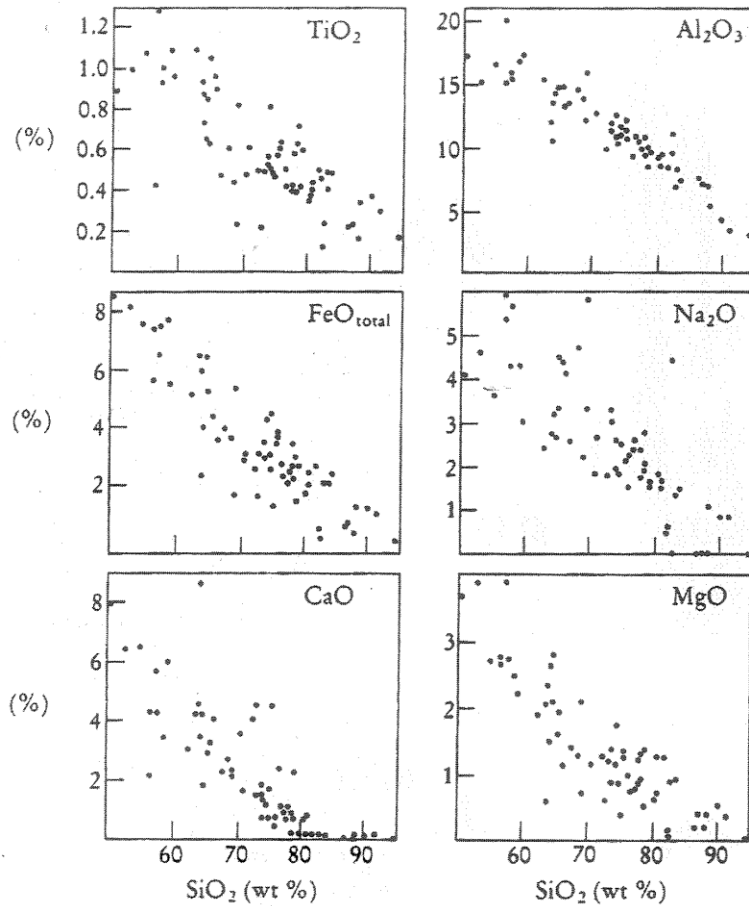
# Chemistry

<u>Element</u>	<u>Capture Spectrum</u>	<u>Inelastic Spectrum</u>	<u>Natural Spectrum</u>
Aluminum	Al	Al	
Calcium	Ca	Ca	
Carbon		C	
Chlorine	Cl		
Gadolinium	Gd		
Hydrogen	H		
Iron	Fe	Fe	
Magnesium	Mg	Mg	
Manganese	Mn		
Oxygen		O	
Potassium	K		K
Silicon	Si	Si	
Sulfur	S	S	
Thorium			Th
Titanium	Ti	Ti	
Uranium			U

# Expert System

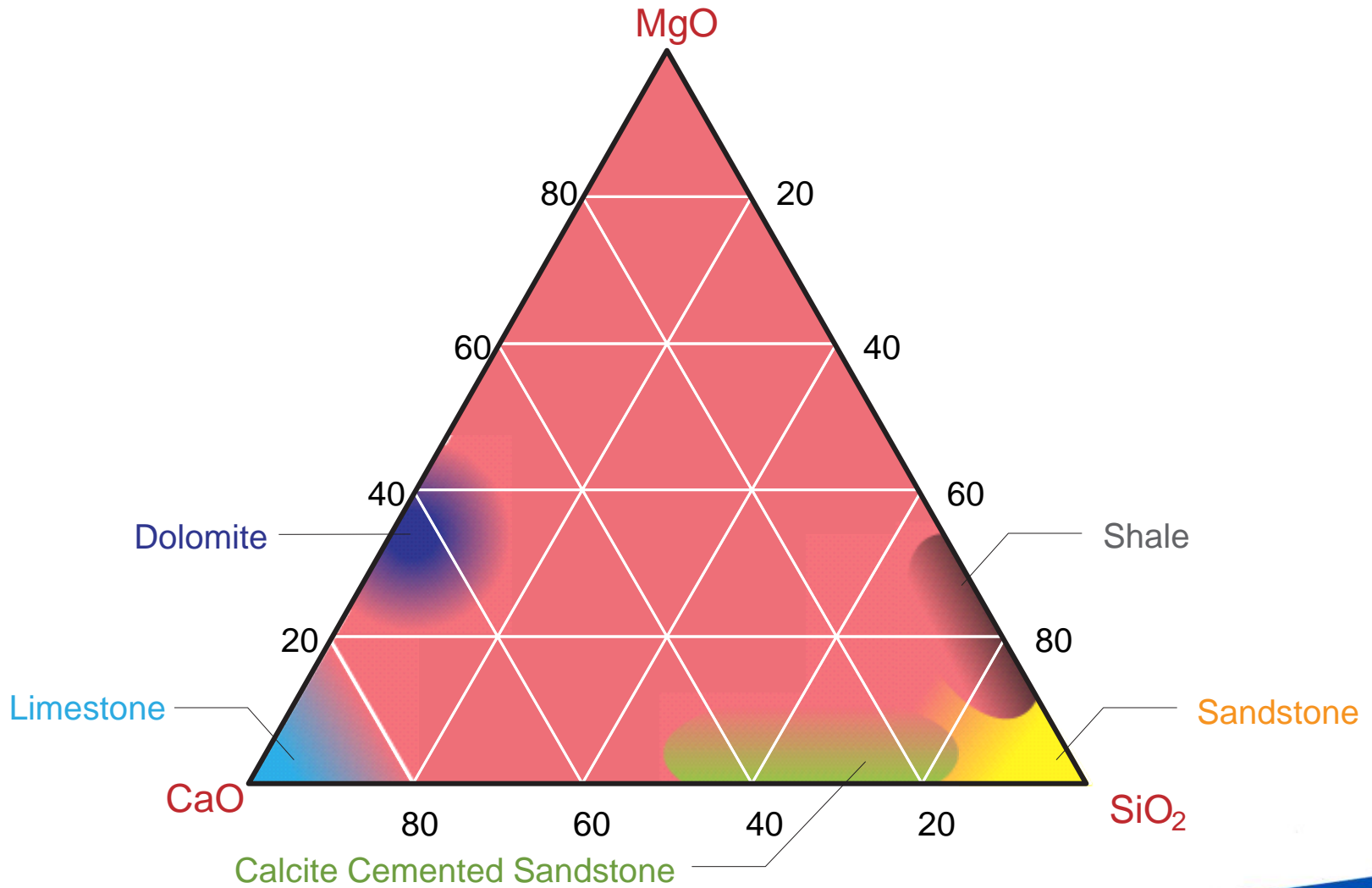
- A computing system capable of representing and reasoning about some knowledge rich domain, which usually requires a human expert, with a view toward solving problems and/or giving advice.
  - The level of performance makes it “expert”
  - Some also require it to be capable of explaining its reasoning.
  - Does not have a psychological model of how the expert thinks, but a model of the expert’s model of the domain.
- Alternatives: simple deterministic, stochastic, neural networks

# Geochemical Correlations

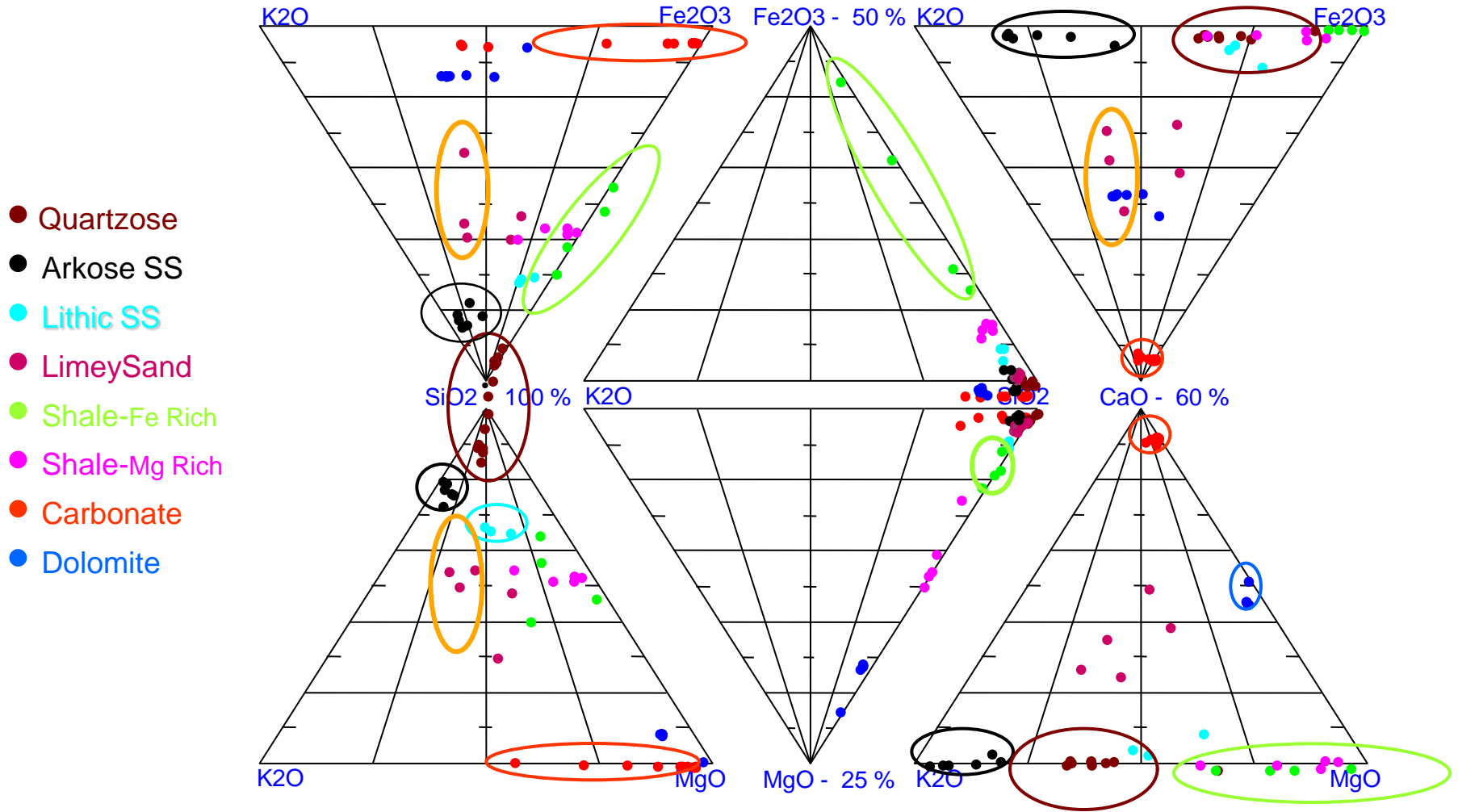


( from Bhatia 1983)

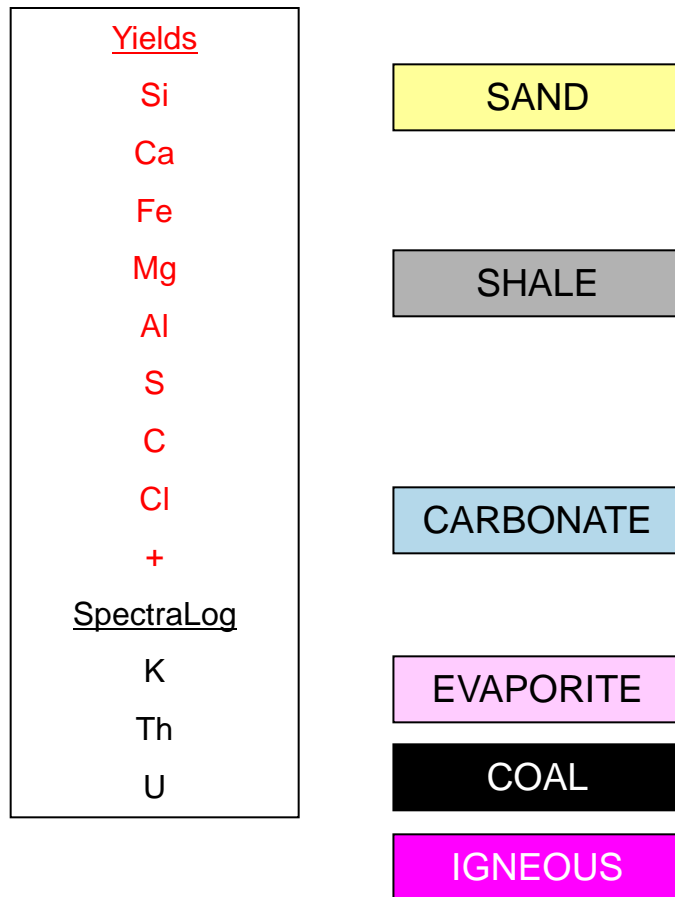
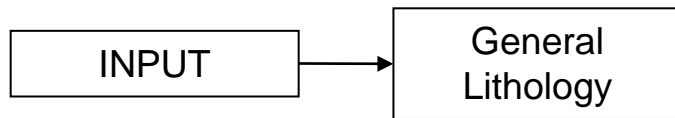
# Ternary diagrams



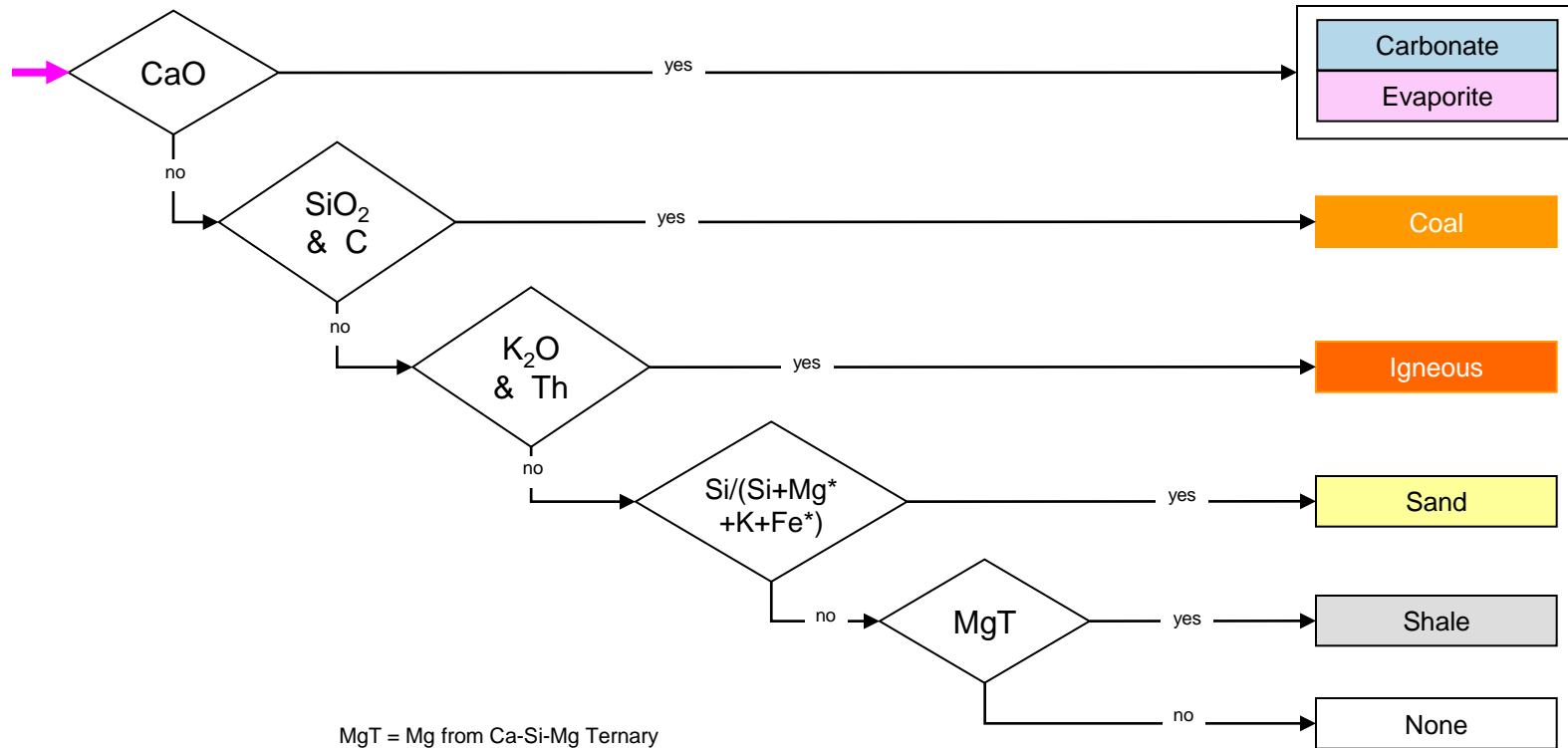
# Hybrid Ternary Diagrams



# Expert System Sequence – General Lithology

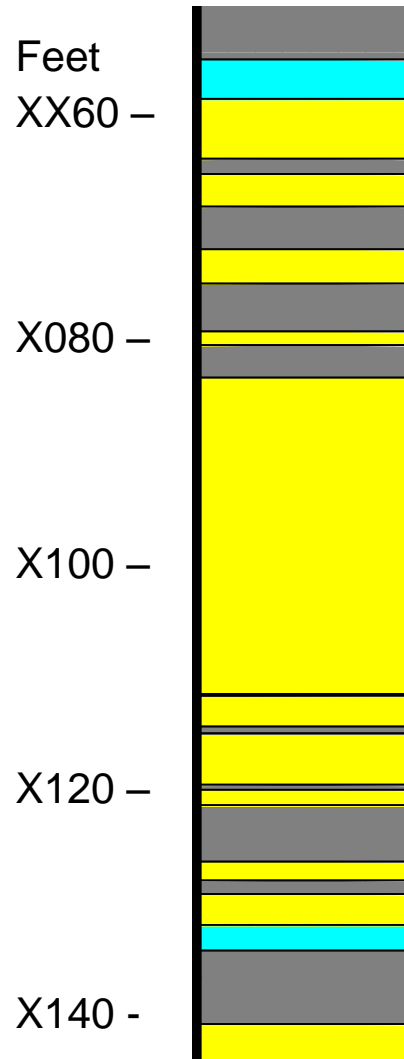
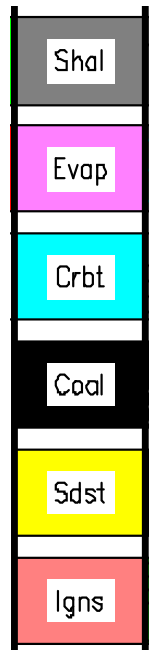


# Flow Diagram – General Lithology

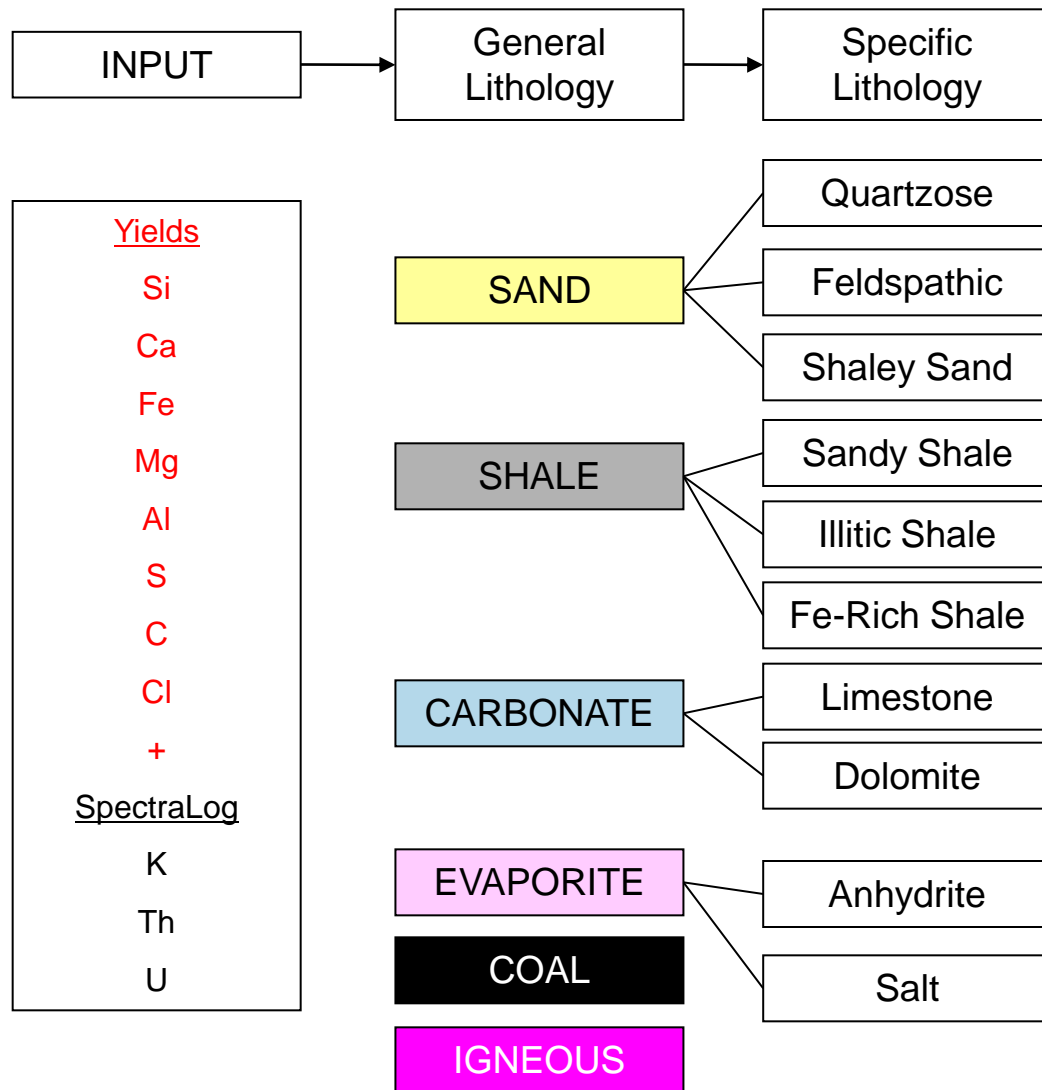


# First Step – General Lithology

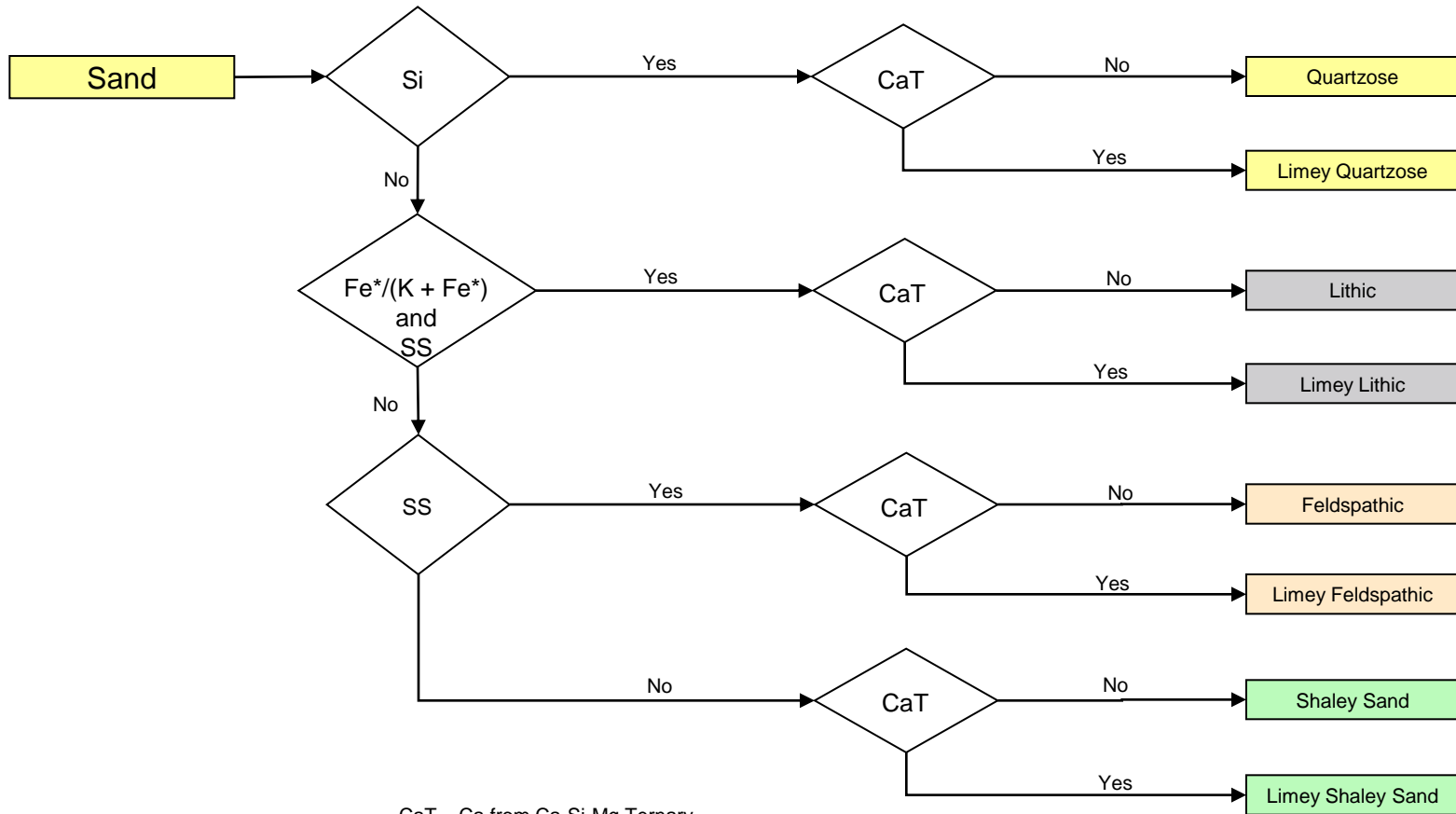
General Lithology



# Expert System Sequence – Specific Lithology

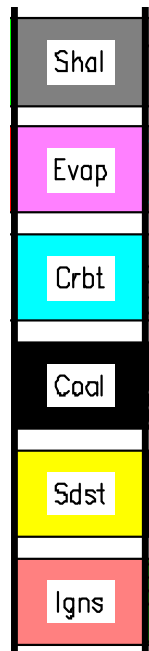


# Flow Diagram – Specific Lithology



# Second Step – Specific Lithology

General Lithology



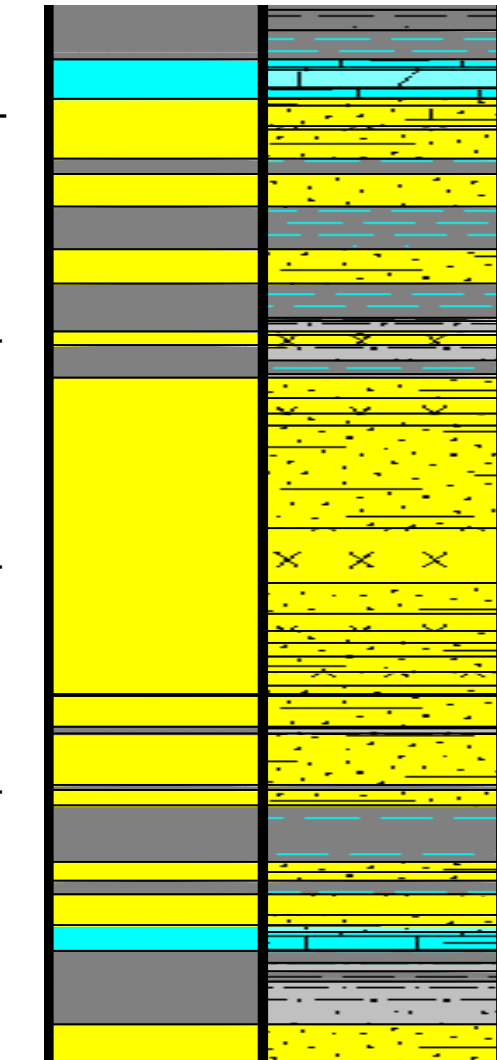
Feet  
XX60 –

X080 –

X100 –

X120 –

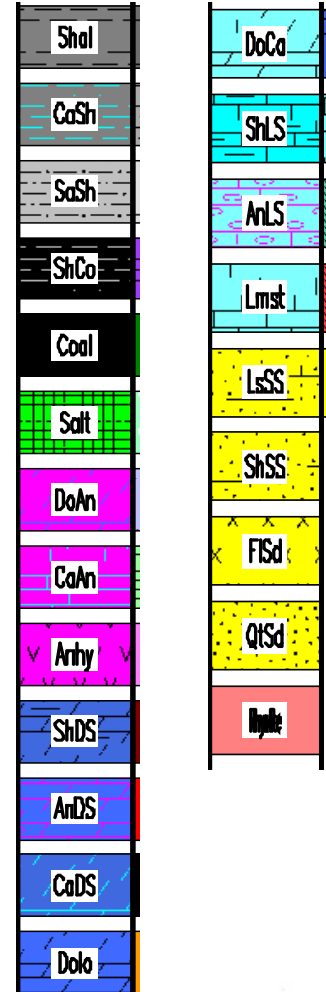
X140 –



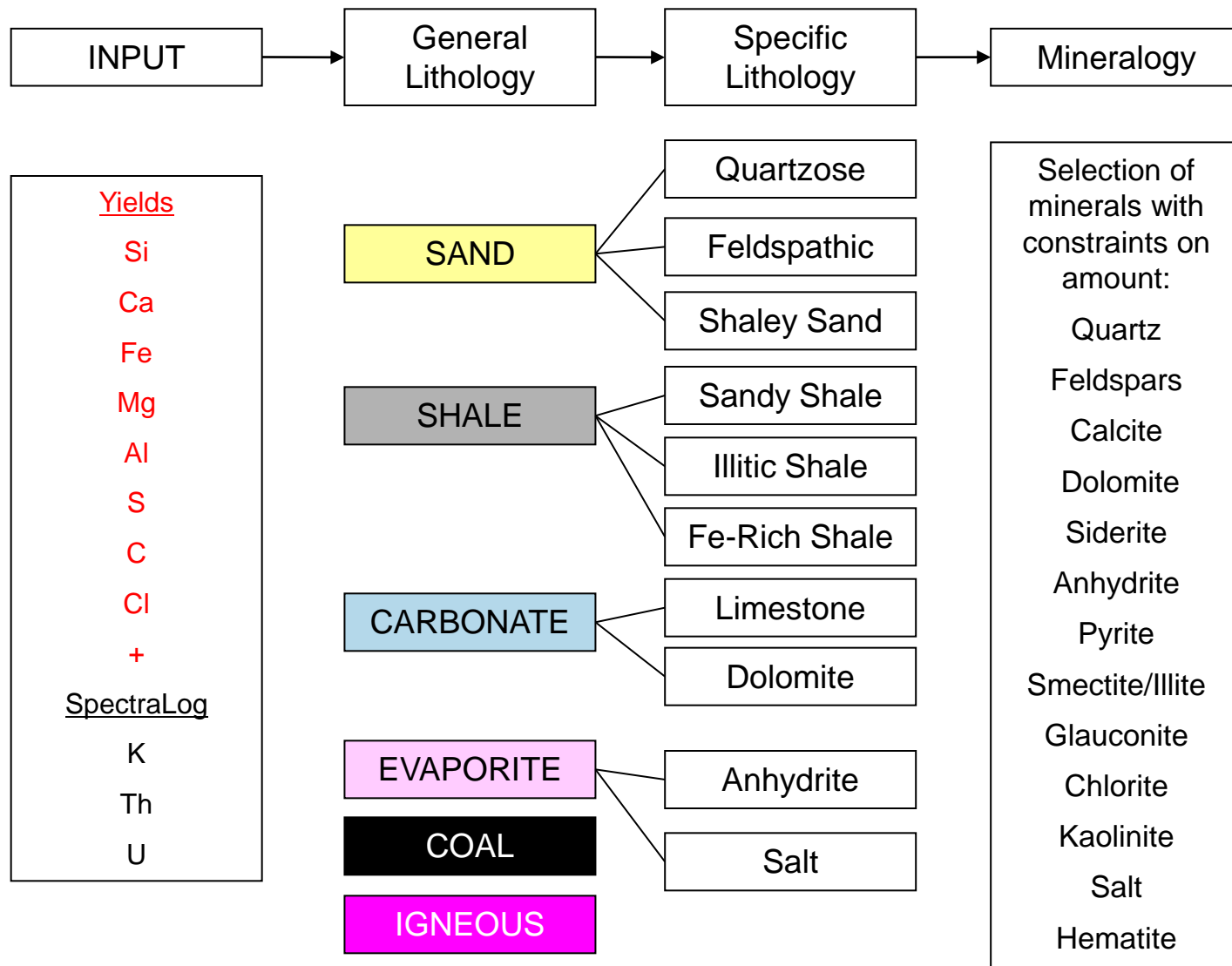
General  
Lithology

Specific

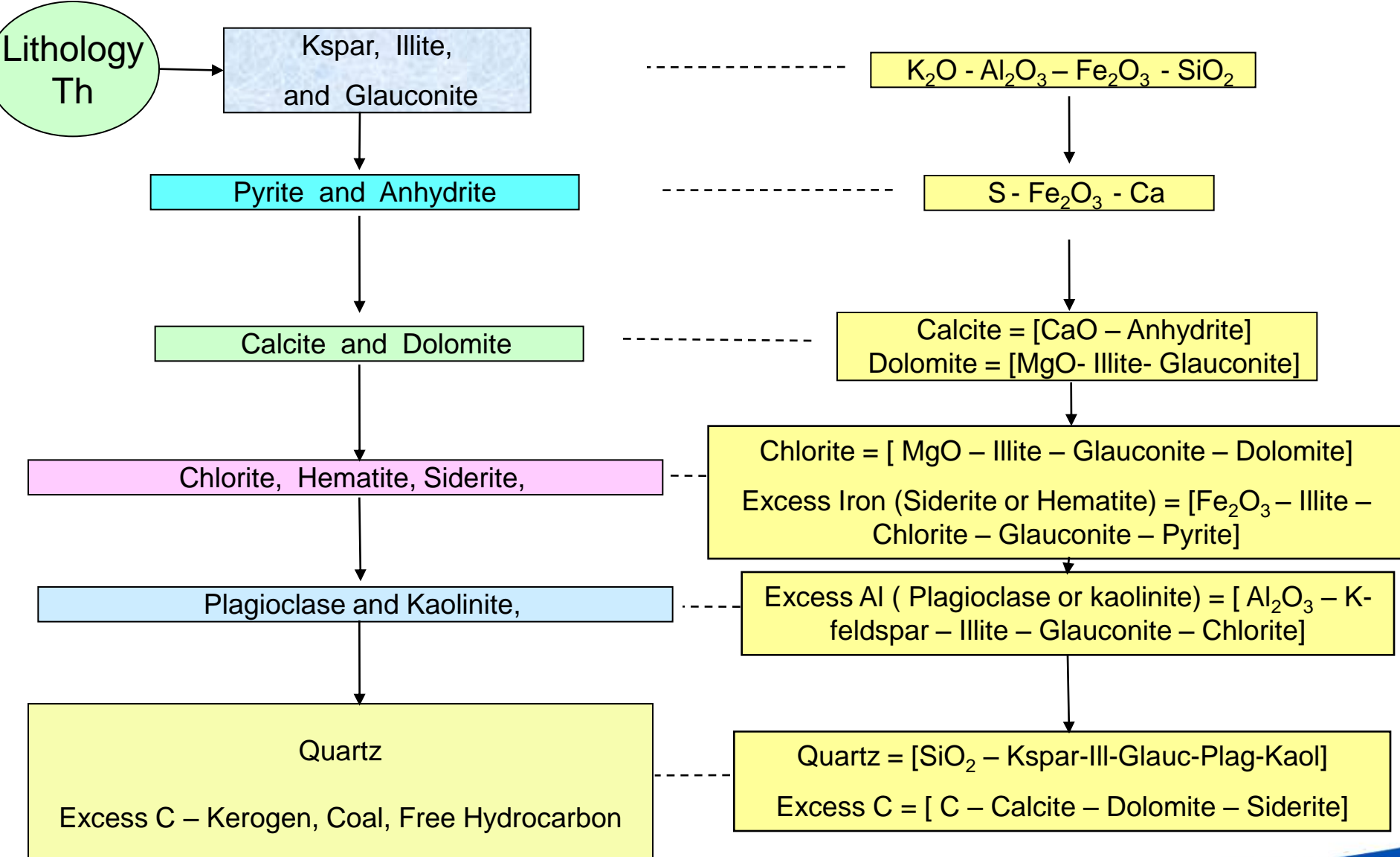
Specific Lithology



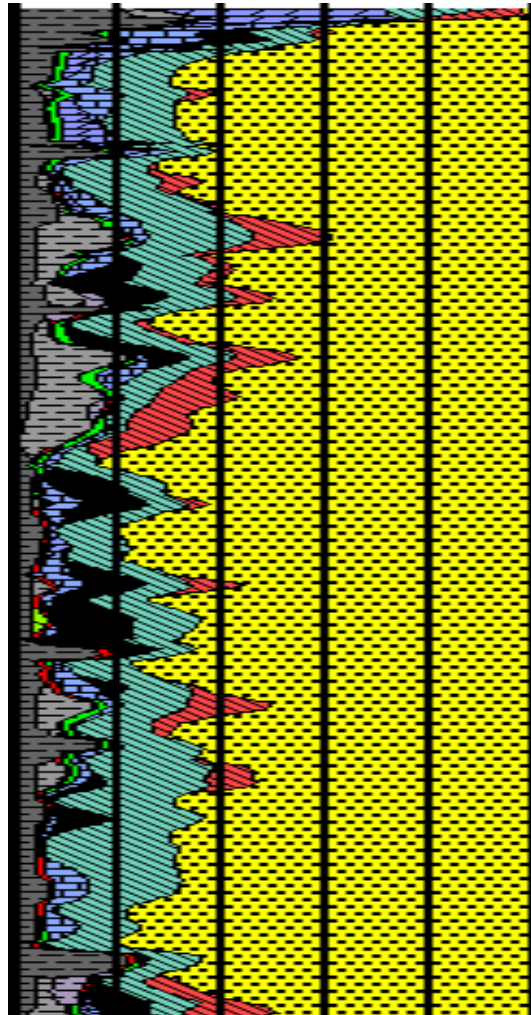
# Expert System Sequence – Mineral Weights



# Quantification of Mineralogy – Mass Balance



# Third Step – Mineralogy

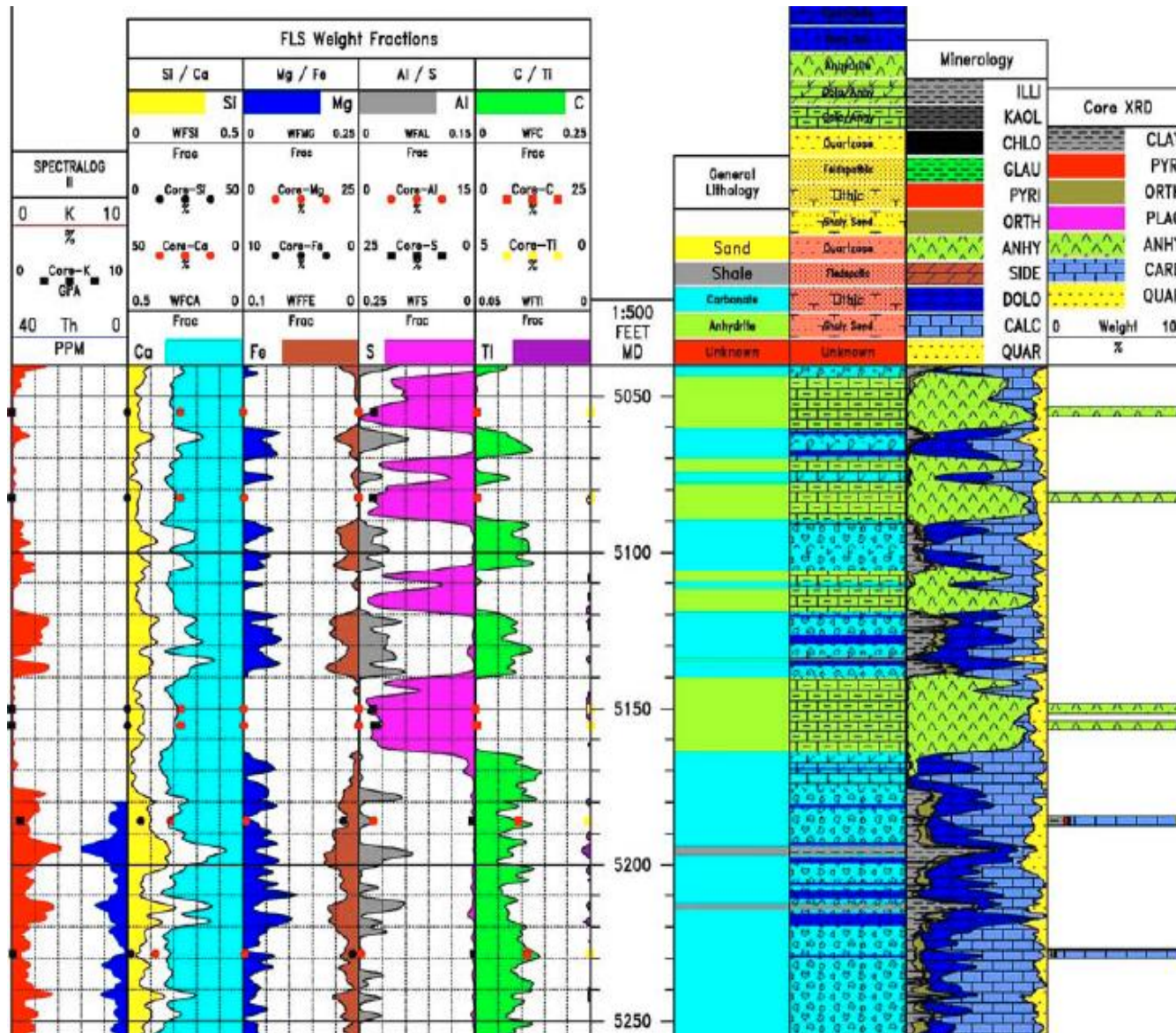


Minerals
ILLITE
KAOLINITE
CHLORITE
GLAUCONITE
ANHYDRITE
HEMATITE
PYRITE
SIDERITE
DOLOMITE
CALCITE
Excess C
K-FELDSPAR
PLAG
QUARTZ

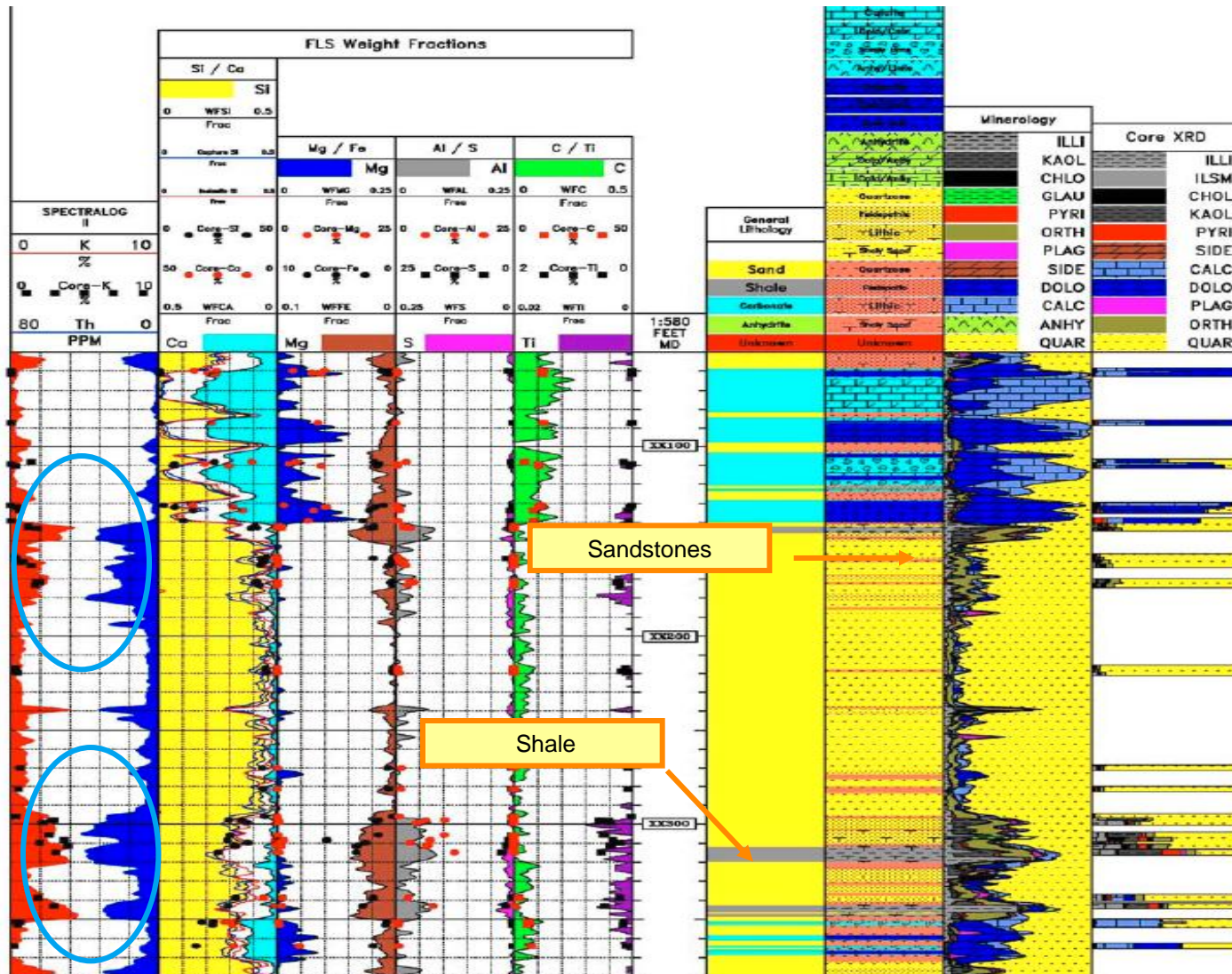
# Minerals derived from the expert system

Name	Formula
Quartz	$\text{SiO}_2$
K-Spar	$\text{KAlSi}_3\text{O}_8$
Albite	$\text{NaAlSi}_3\text{O}_8$
Calcite	$\text{CaCO}_3$
Dolomite	$\text{Ca}_{.5}\text{Mg}_{.5}\text{CO}_3$
Siderite	$\text{FeCO}_3$
Anhydrite	$\text{CaSO}_4$
Illite	$\text{K}_{.67}[\text{Al}_2](\text{Al}_{.67}\text{Si}_{3.3})\text{O}_{10}(\text{OH})_2$
Smectite	$\text{Na}_{.33}[\text{Al}_2](\text{Al},\text{Si})_4\text{O}_{10}(\text{OH})_2-n\text{H}_2\text{O}$
Chlorite	$[\text{Mg}_3\text{Fe}_3](\text{AlSi}_3)\text{O}_{10}(\text{OH})_8$
Kaolinite	$\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$
Glaucosite	$\text{K}_{.8}[\text{Fe}_{1.2}\text{Al}_{.4}\text{Mg}_{.4}](\text{Al}_{.35}\text{Si}_{3.65})\text{O}_{10}(\text{OH})_2$
Pyrite	$\text{FeS}_2$
Hematite	$\text{Fe}_2\text{O}_3$
Halite	$\text{NaCl}$
Coal	$\text{C}$

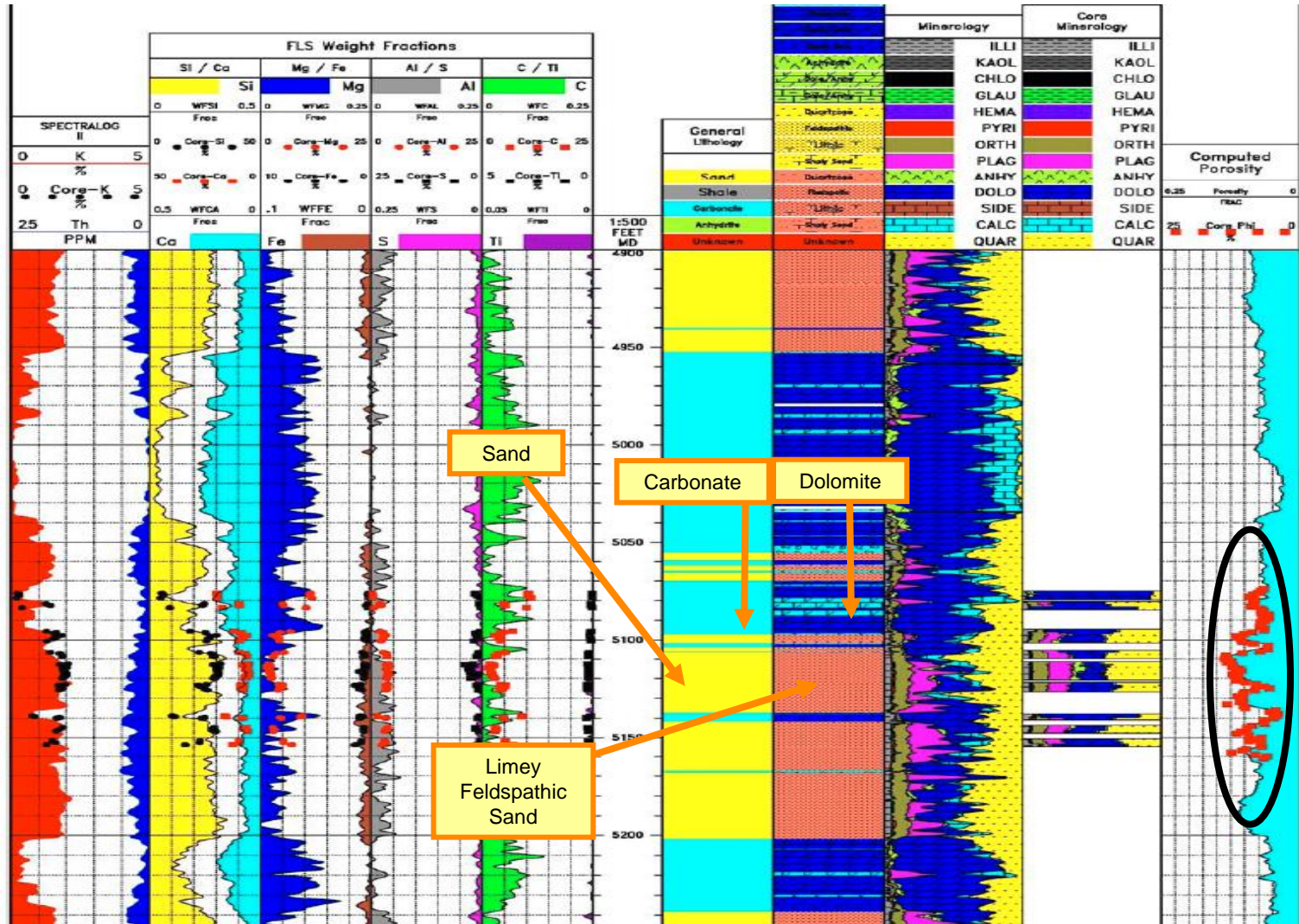
# Evaporites and Carbonates



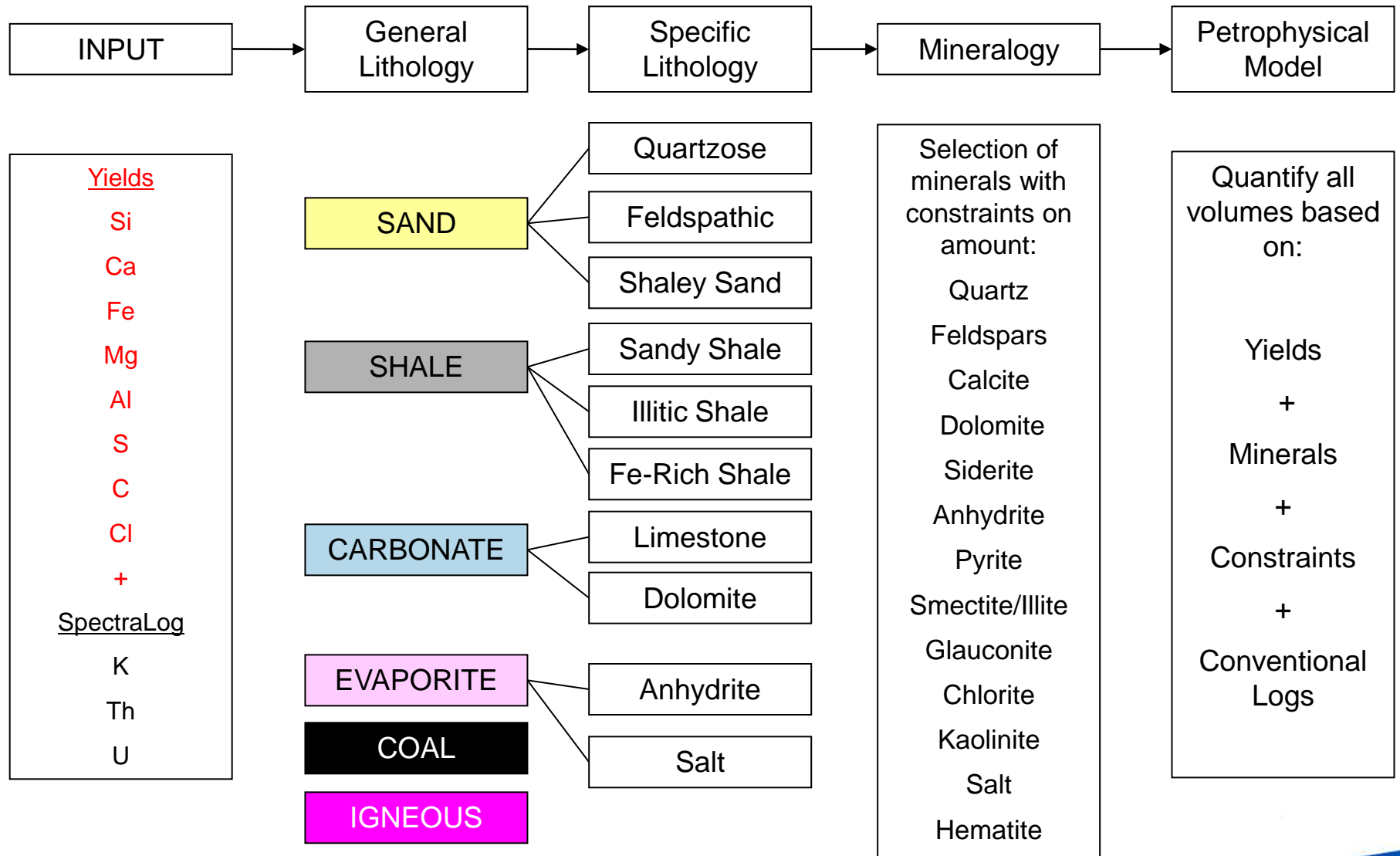
# Resolving Ambiguities



# Accurate Porosity



# Complete System Sequence



# Conclusion – Expert System

- Method is effective for mineral quantification
- Improves final petrophysical solution by providing valuable additional input
- Model can be modified to accommodate complex lithology