Maturation Parameters and Correlations

Visual and Chemical Indicators

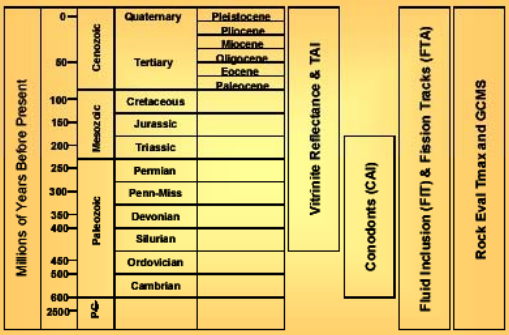
Correlation Chart

ASTM Standards: Carbon Content	ASTM Standards: Coal Rank	Organic Petrology: Vitrinite Reflectance	Organic Petrology: TAI	Organic Petrology: CAI	Organic Geochemistry: GCMS (S/R)	Organic Geochemistry: Rock-Eval Tmax	Inorganic Petrology: FIT (°F / °C)
Calcific Carbon	Peat	0.2	Light Yellow				
	Brown Coal	0.3	Yellow				
6300	Lignite				0.04		77 / 25
8300	Sub-bituminous	0.4	Yellow Orange	1		420	108 / 42
11500	C	0.5	Orange		0.34	425	158 / 70
13000	High Volatile Bituminous B	0.6	Golden		0.55	430	201 / 94
14000	A	0.7				440	268 / 131
		0.8	Amber	1.5	0.96	450	320 / 160
		1.0			1.37		
69		1.1	Red Brown	2		460	361 / 183
	Medium Volatile Bituminous	1.2	Dark Red Brown			470	
78	Low Volatile Bituminous	1.5	Brown	3		480	414 / 212
86	Semi-Anthracite	2.1	Dark Brown	4			491 / 255
92	Anthracite	2.5	Black				532 / 278
98	Meta-Anthracite	6.0		5			

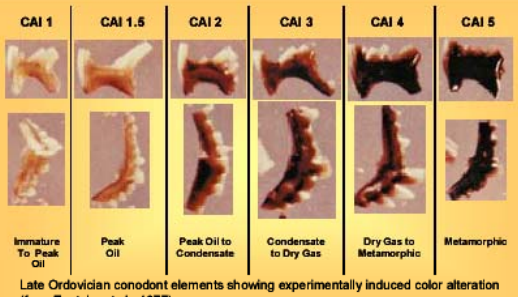
% Fixed Carbon

Thermal Alteration Index (TAI)

Appropriate Age

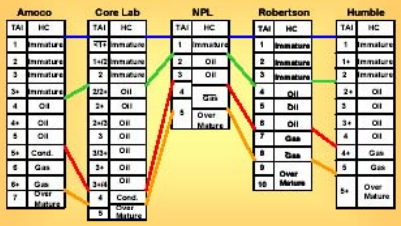


Conodont Alteration Index (CAI)



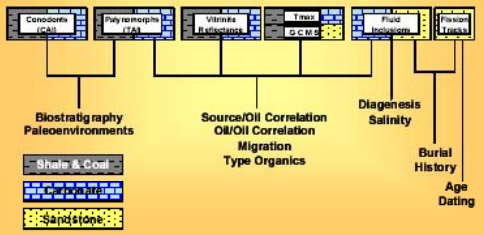
Late Ordovician conodont elements showing experimentally induced color alteration (from Epstein, et al., 1977).

Various TAI Standards



Note the variability in the hydrocarbon window detail and the numbering system (i.e. Amoco 5 = Oil; Core Lab 5 = Over Mature).

Appropriate Lithology



Vitrinite Reflectance

Vitrinite Reflectance (%R_o)

--Measures the intensity of reflected light from polished vitrinite particles
--Reported as mean percent reflectance of indigenous vitrinite particles in oil

Advantages

- Broad thermal range (pre-oil to metamorphism)
- Low cost, rapid turnaround
- Reproducible, detailed scale, calibrated to known coal rank and hydrocarbon phases
- Paleogeothermal gradients can be calculated
- Requires a small amount of sample
- Maceral identification to determine kerogen type

Limitations

- True vitrinite is limited to post-Ordovician strata. Reflectance of non-vitrinite particles has not been rigorously calibrated.

Reliability

- Technique of first choice
- Severe recycling can create interpretation problems
- Surface weathering could oxidized indigenous vitrinite
- Oil-based mud could suppress vitrinite values

TAI

Technique: Visual estimate of the color (from yellow to black) of palynomorphs in transmitted light. SCI (spore coloration index) is also reported in some instances.

Data Reported: Results are reported as a numerical value and there is no industry standard for the range of values.

- **Advantages**
  - Low cost, rapid turnaround
  - Wide thermal range
  - Scale calibrated to vitrinite reflectance and wt % carbon
  - Small sample size
  - Visual kerogen types
  - Taxonomic identification can distinguish recycled and caved organics
  - Biostratigraphic and paleoenvironmental interpretations
- **Limitations & Factors that Affect Reliability**
  - Post Ordovician strata
  - Barren samples
  - Broad thermal windows
  - Visual scales are not standardized
  - Chemical loss of pigmentation in carbonate or calcareous shale
  - Organic drilling additives
  - Poor kerogen isolation techniques

Kerogen Types

Amorphous Oil Prone | **Mixed Oil & Gas** | **Structured Gas Prone**

Rock-Eval Tmax

Rock-Eval Tmax

--Temperature of maximum evolution of S2 hydrocarbons
-- Reported as °C

Advantages

- Low cost, rapid turnaround
- Reproducible scale calibrated to vitrinite reflectance
- Requires a small amount of sample
- Total Organic Carbon
- Kerogen type (I, II or III)
- Prediction of product type
- Source Potential
- Hydrocarbon staining

Limitations

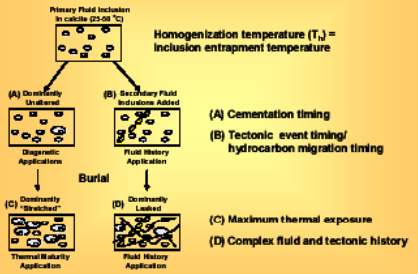
- Affected by low organic content
- Affected when S2 value = <0.50

Reliability

- Severe recycling can create anomalously high values
- Oil-based mud or organic drilling additives create anomalously low values
- To convert Tmax to an equivalent vitrinite reflectance value: $Tmax_{eq}$ %VRo = 0.018(Tmax) – 7.16 (Jarvie et al., 2001)

Fluid Inclusion Thermometry

Evolution of Fluid Inclusion Fabrics During Burial



Technique Comparison

Primary Geothermometers

Technique	Category	Sample Age	Sample Type	Sample Volume	~ Cost / Sample	Time
Vitrinite Reflectance	Organic Petrography	Present - Silurian	Coal, Dark Shale or Limestone	Small ~ 15 grams	$200	3 – 5 days
Thermal Alteration Index	Organic Petrography	Present - Silurian	Coal, Dark Shale or Limestone	Small ~ 15 grams	$150	3 – 5 days
Conodont Alteration Index	Organic Petrography	Triassic - Cambrian	Marine Limestone or Shale	Large 100+ grams - kilograms	$175	1 – 3 weeks
Rock-Eval Tmax	Organic Geochemistry	All	Coal, Dark Shale or Limestone	Small 1 – 3 grams	$50	1 – 2 days
Biomarkers	Organic Geochemistry	All	Oil or Rock Extract	Small 1 – 3 ml	$120	1 – 2 days
Fluid Inclusion Thermometry	Inorganic Petrography	All	Sparry Calcite	Small <1 – 3 grams	$275	1 – 3 weeks
Apatite Fission Tracks	Inorganic Petrography	All	Lithic / Arkosic Sandstone	Large kilograms	$1300	3 – 6 months