Introductions and Overview

H. Roice Nelson, Jr.

Course Overview

Day 1

Session 1: **Introductions, Need, Workflow, & Data**

The Brain Exercise: **Workflow Design Exercise**

Session 2: **Acquisition-Processing-Interpretation ties to Subsurface Properties**

SketchUp Exercise: **Freeware 3-D Models of Legacy Data for Interpretation**

SALNOR Workshop: **3-D seismic interpretation of North Sea physical model data**

Day 2

Session 3: **Interpreting structure, stratigraphy, salt, fault shadows for exploration, reservoir delineation, documentation, and display**

Contouring Exercise: **Importance of 3-D when contouring**

Carbonate Outcrop Workshop: **Importance of Outcrop Analogs to guide interpretation**

Carbonate Patterns Workshop: **Analog Examples to Guide Interpretation**

Session 4: **Seismic Attributes tie to structure, stratigraphy, reservoir delineation**

ResolveGeo Exercise: **SeisShow Interactive Attribute Analysis Center Field, WY**

Day 3

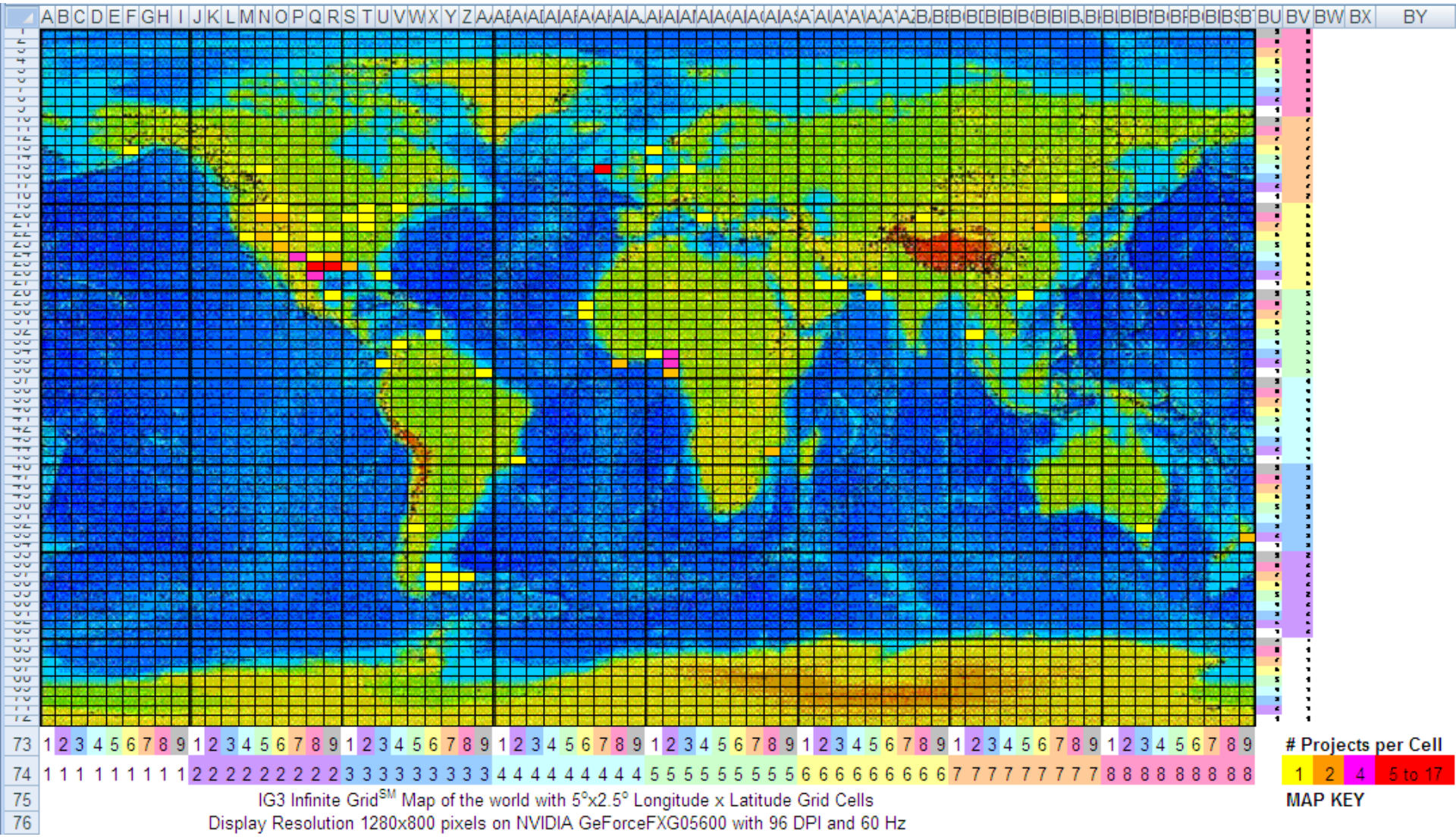
Session 5: **Reservoir Characterization and Advanced Interpretation**

Session 6: **Seismic Exploration and Reservoir Evaluation Breakthroughs**

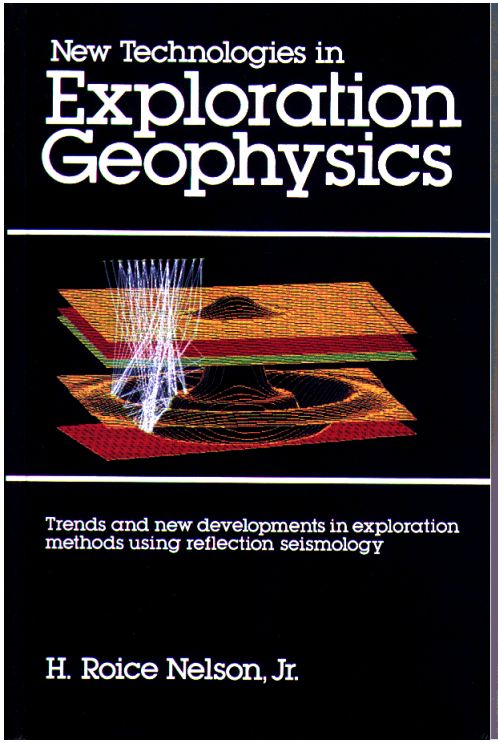
Day 1 Session 1

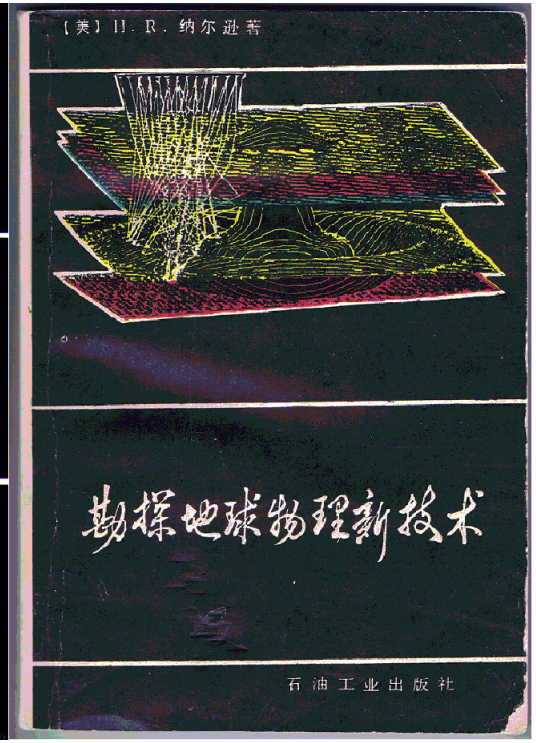
- Introductions
- Need for seismic analysis and reservoir analysis
- Interpretation workflow
- Data to integrate with seismic interpretations
  - Satellite data
  - Gravity and magnetic data
  - Geochemistry data
  - Lightning and other electromagnetic data
  - Well cuttings (cores)
  - Well logs and image logs
  - Temperature and pressure data
  - Reservoir parameters
  - Production histories
- Overview of worldwide case histories to be covered
- Overview of practical seismology solutions for carbonate terrains

Introductions: Roice's Projects



Founder Landmark Graphics Corporation



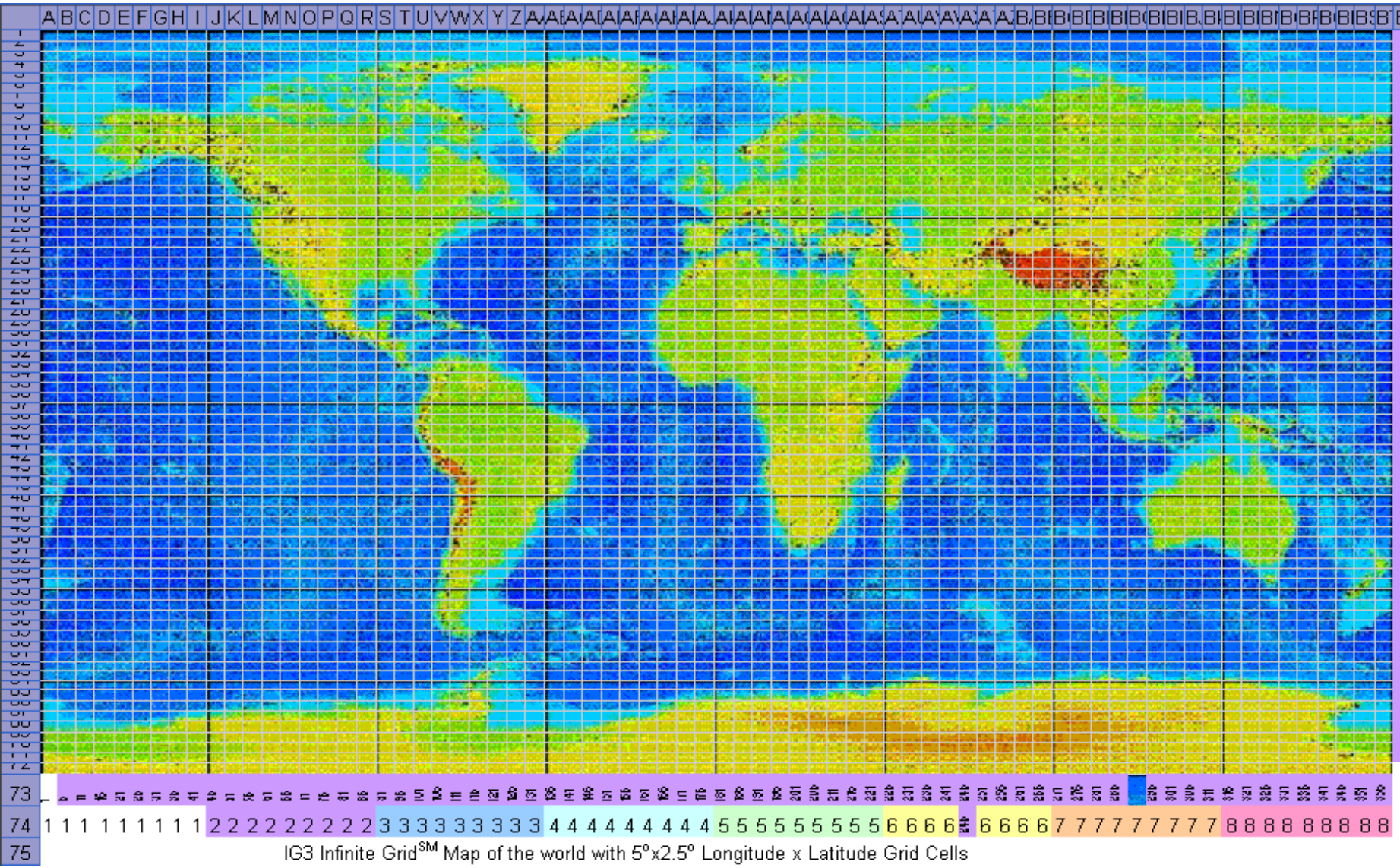


Landmark Graphics was founded in July 1982 at a time when 3-D seismic interpretation was performed on massive, expensive mainframe computers. Its four founders — Roice Nelson, Andy Hildebrand, John Mouton and Bob Limbaugh — set their sights on delivering innovation that would create new opportunities and significant value for clients. Combining their skills with a vision of what the future could be led to Landmark revolutionizing the oil and gas industry with an affordable "console-sized" workstation from which geoscientists could more quickly and accurately visualize and interpret their 3-D seismic data.

Landmark has historically been an international company. Its first three systems were shipped to BHP in Melbourne, Australia, Enterprise Oil [actually ICI Petroleum] in London and Sun Oil in Dallas. Since the beginning, Landmark and its acquired companies have shipped more than 75,000 software licenses to more than 90 percent of the world's largest oil and gas companies worldwide.

http://www.oilcareers.com/content/coprofile/Halliburton_Software_and_Asset_Solutions.asp

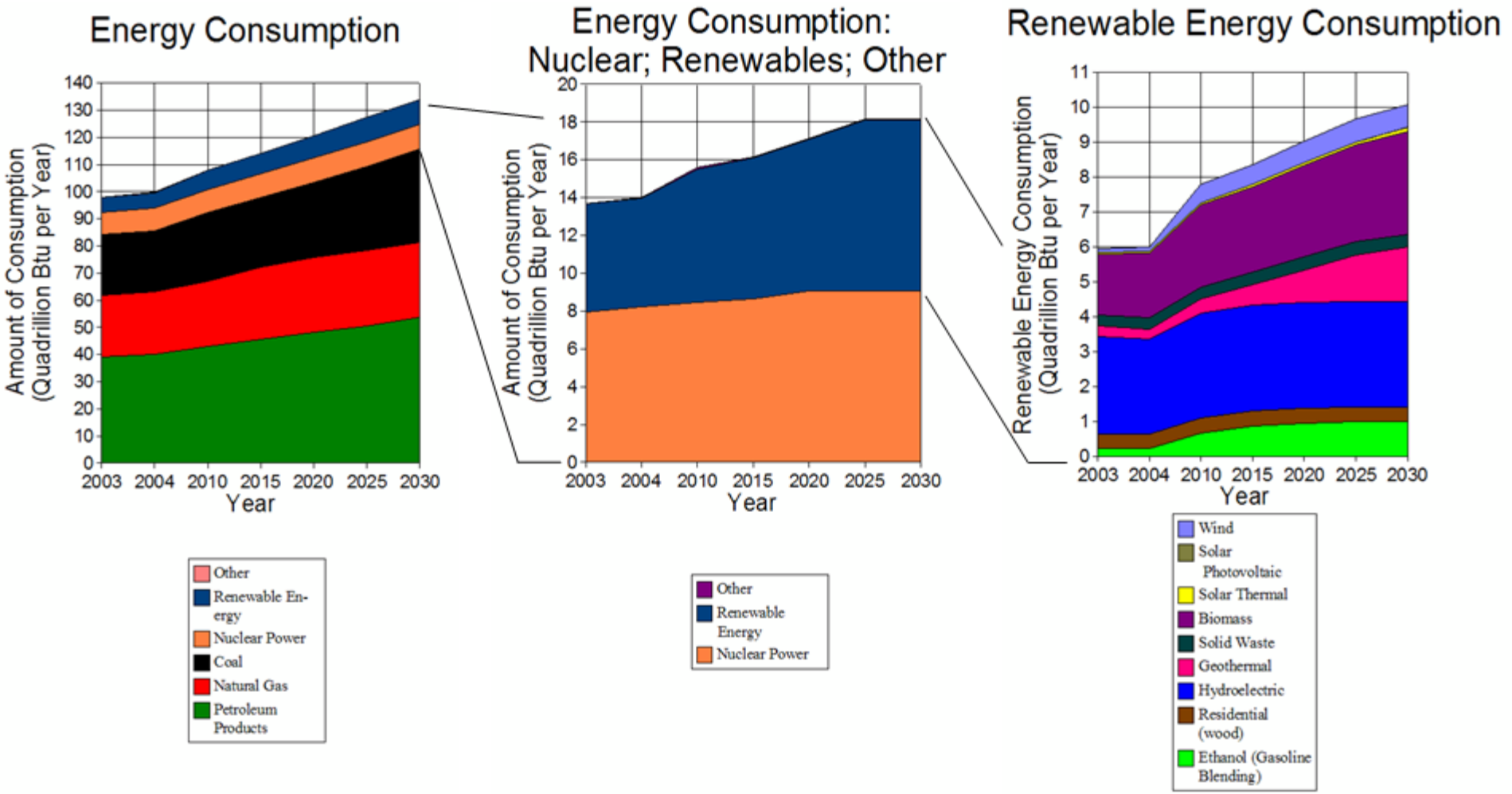
Introductions: Attendee Circle Your Project Locations



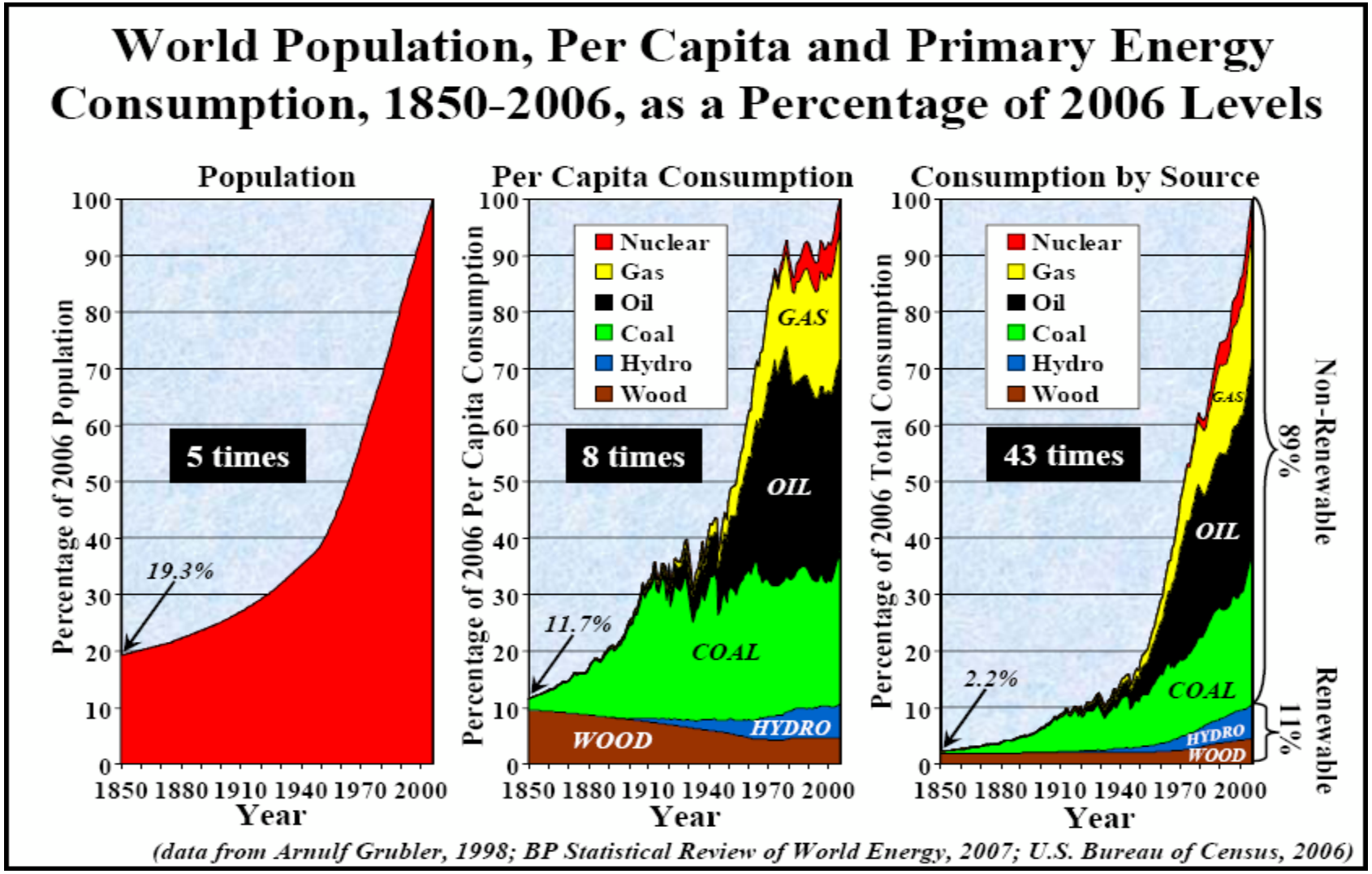
Three-Dimensional Seismic Surveys

- Continue to revolutionize the geophysical industry helping to find new energy.
- Are a powerful tool for imaging the subsurface.
- Demonstrating high cost/benefit ratios:
  - Reducing dry-hole risk; and
  - Providing better well placement for flow rates and drainage.
- Improve reserves estimates.
- Shorten cycle times for appraisal and development project planning.

Need Driven by Energy Consumption

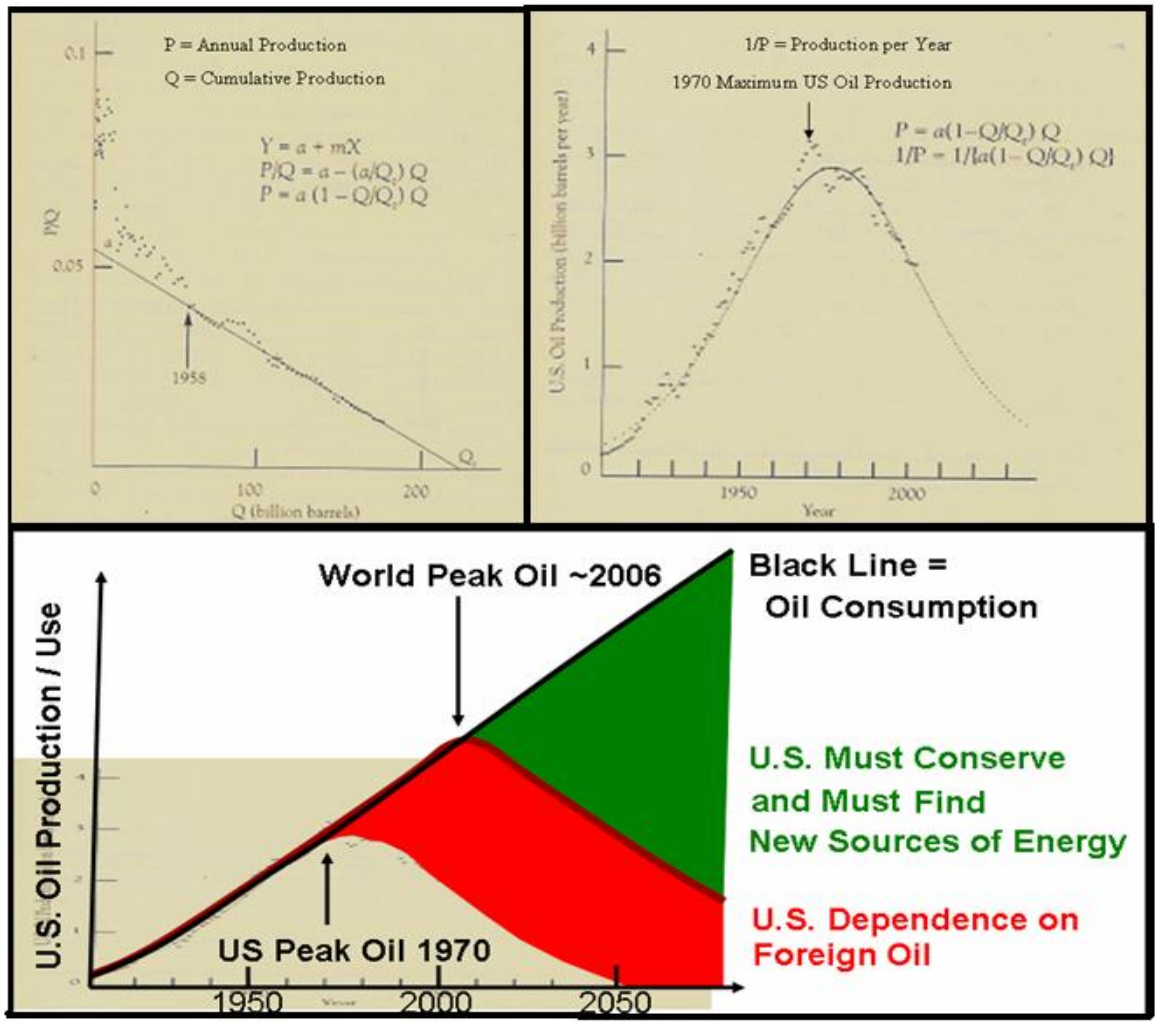


Which Consumption Continues to Grow



All of which is tied to Peak Oil

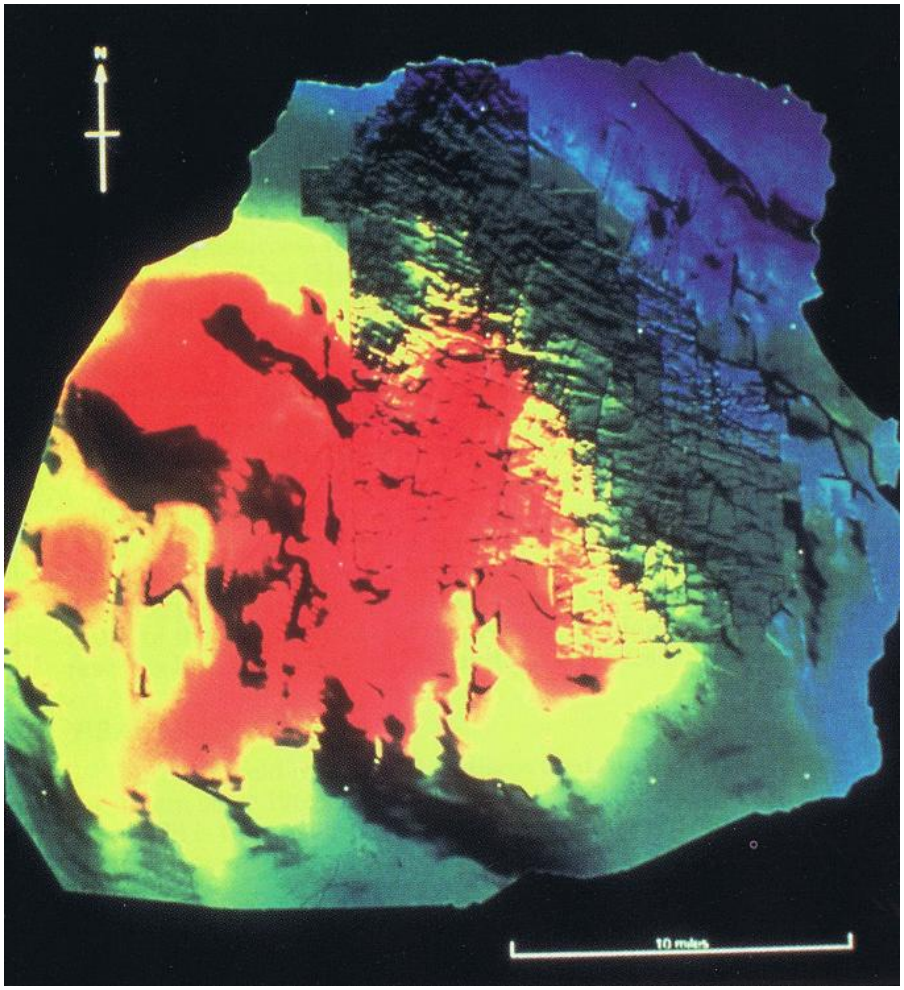
M. King Hubbert published this geostatistical summary of oil production in 1969.



Definitions

- **Interactive**: finding an answer before forgetting the question.
- **Three-Dimensional**:
  - Line, Trace, Offset
  - Line, Trace, Time
  - Line, Trace, Attribute
  - Line, Trace, Angle
  - • • •
- **Interpretation**: integrating all available data and reducing large data volumes to create a geological model for an economic prospect with acceptable risk.

Top of Kuparuk field, North Alaska



To Find an Economic Prospect with Acceptable Risk:

- Structural High
- Fracture System
- Source
- Seal
- Trap
- Migration
- Timing
- Reservoir
- Rule of Law

Image: E.O. Nestvold in **Application of 3-D Seismic Data to Exploration and Production**, page 6, data from BP Exploration (Alaska) and Arco.

The Need for Seismic Analysis

- Is shown by the fact many companies will not drill a well now without a 3-D seismic survey.
- Was initially so expensive it was only used by major oil companies, and 3-D seismic is now routinely used among independents and national oil companies.
- Has had limited documentation of successes, like most new and emerging technologies.
- Has grown because 3-D seismic images provide a clear definition of the subsurface for the first time;

The Need for Reservoir Analysis

- 3-D seismic meets oil company requirements for low-risk ways to increase reserves, and by increasing reserves oil companies reduce finding costs.
- 3-D seismic reduces development costs by improving drilling success rates dramatically.
- 3-D seismic rejuvenating producing fields, even fields with hundreds of wells and declining production profiles.
- 3-D seismic integrates technology because all disciplines use them as a basis for reservoir modeling during the life history of each field, including by repeat 3-D surveys.

Interpretation Workflow

Best Practices Bridge Different Perspectives

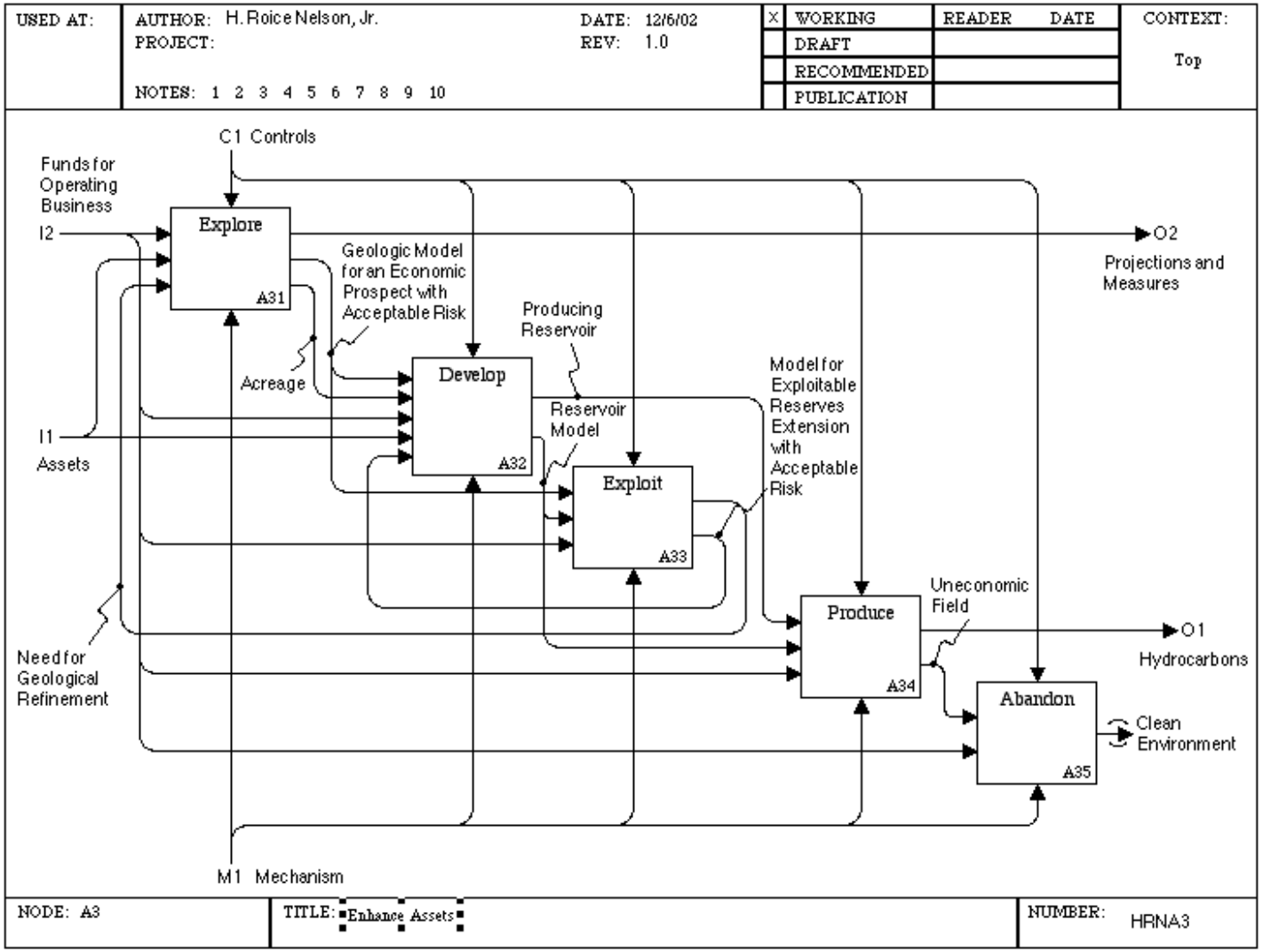
Leadership Perspective (community needs)					
Vision	Strategy Drivers	Key Value Indicators	Critical Performance Factors	Success	Competencies
Customer Requirements	Plan	Value Creators	Performance Evaluation and Areas	Actions	Knowledge
Organization Perspective (end user needs)					

Interpretation Workflow

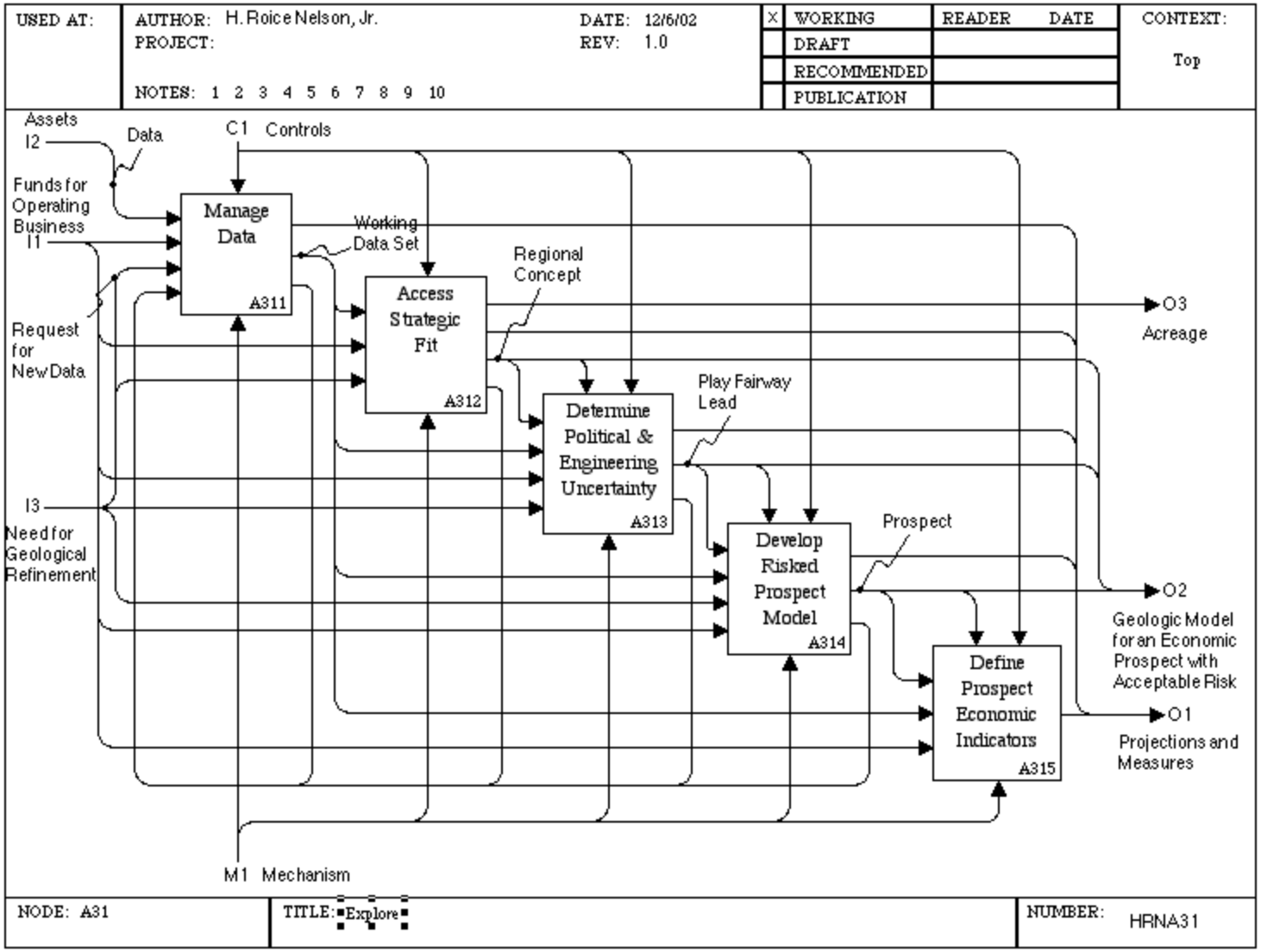
The IDEF Big Picture

IDEF-0	Function / Activity Modeling
IDEF-1	Information / Data Modeling
IDEF-2	Simulation Modeling
IDEF-1X	Data Modeling
IDEF-3	Process Description Capture
IDEF-4	Object Oriented Design
IDEF-5	Ontology Description Capture
IDEF-6	Design Rationale Capture
IDEF-7	Information System Audit Method
IDEF-8	User Interface Modeling
IDEF-9	Scenario Driven Information System Design Specification
IDEF-10	Implementation Architecture Modeling
IDEF-11	Information Artifact Modeling
IDEF-12	Organization Modeling
IDEF-13	Three Schema Mapping Design
IDEF-14	Network Design

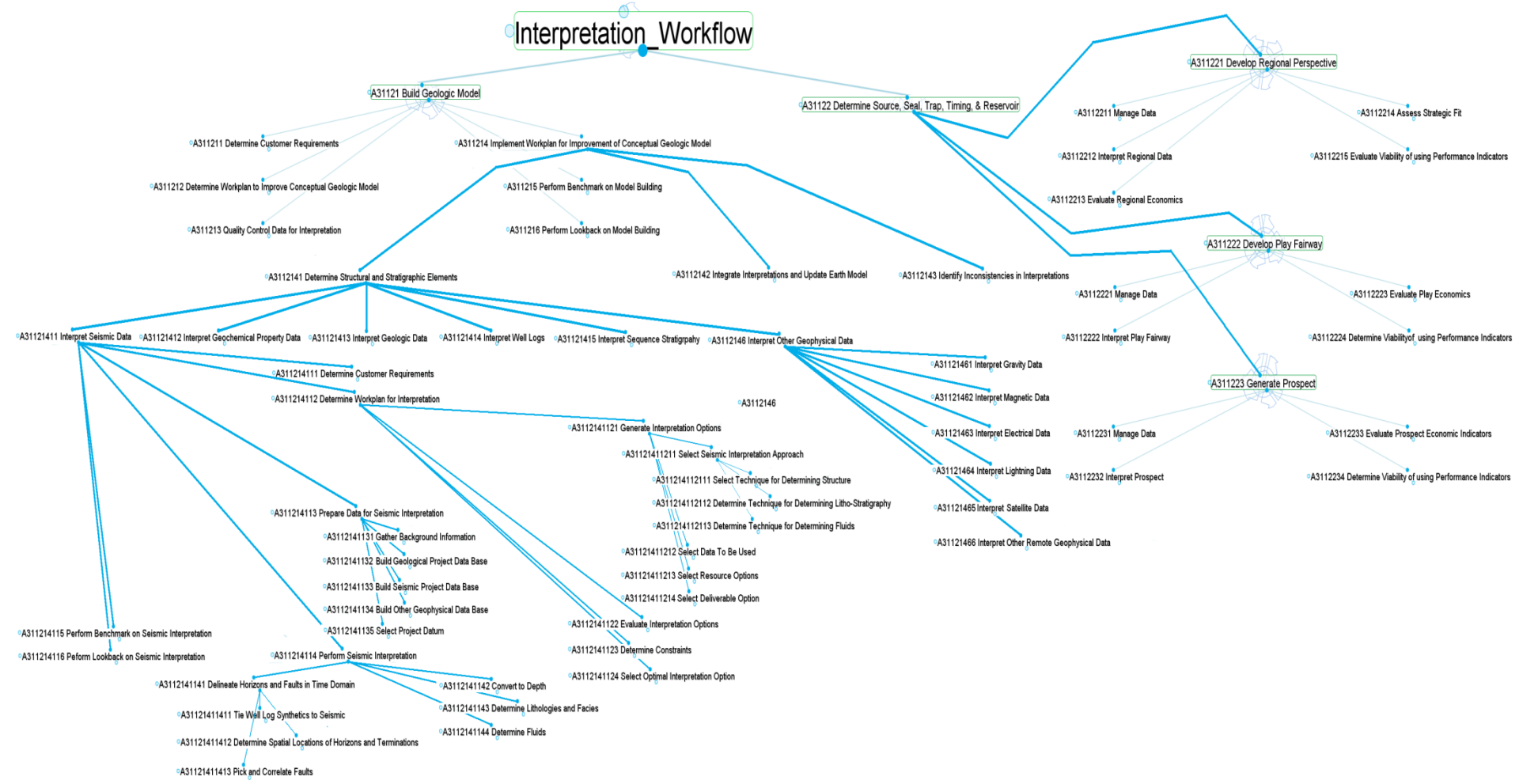
IDEF 1-X Interpretation Workflow



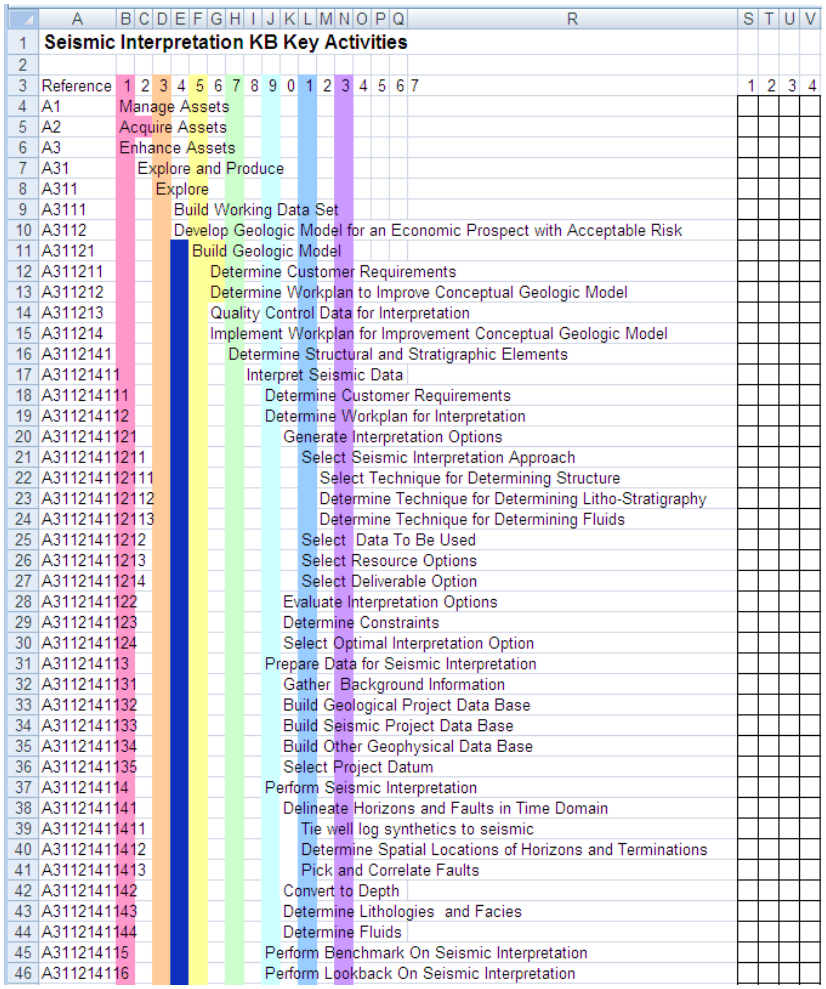
Interpretation Workflow Decomposed



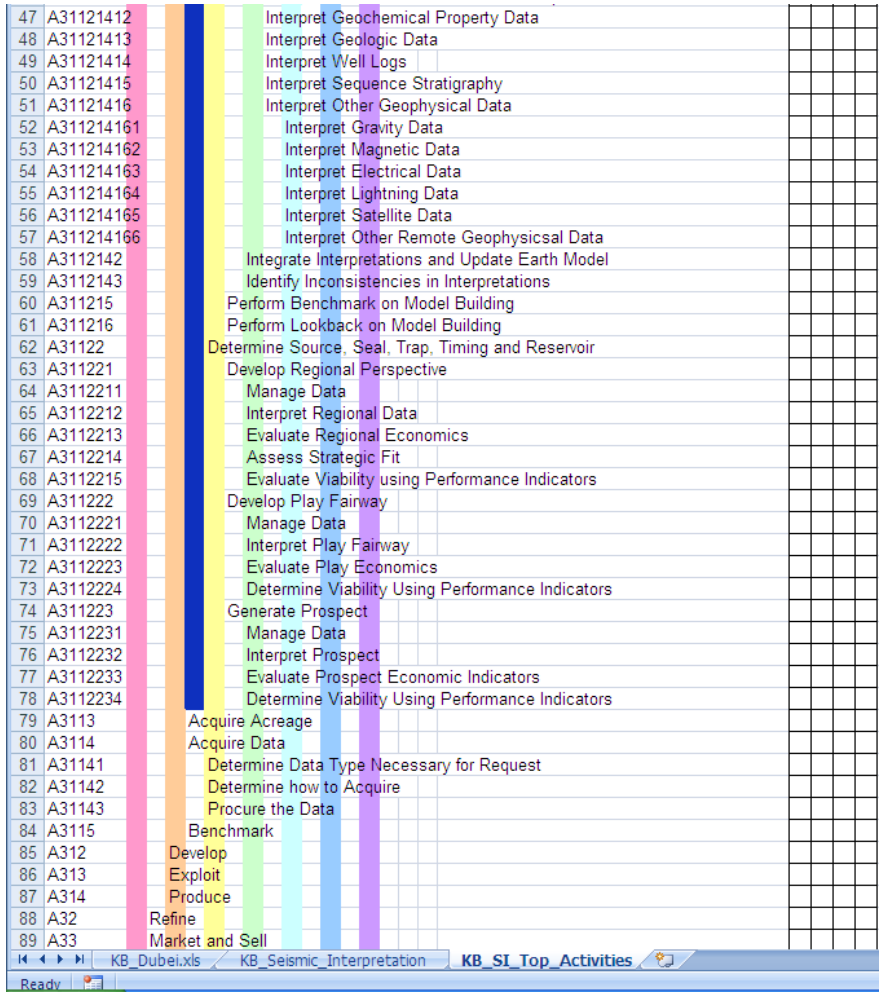
Interpretation Workflow – The Brain



Interpretation Workflow – KB



	Seismic Interpretation KB Key Activities
Reference	
A1	Manage Assets
A2	Acquire Assets
A3	Enhance Assets
A31	Explore and Produce
A311	Explore
A3111	Build Working Data Set
A3112	Develop Geologic Model for an Economic Prospect with Acceptable Risk
A31121	Build Geologic Model
A311211	Determine Customer Requirements
A311212	Determine Workplan to Improve Conceptual Geologic Model
A311213	Quality Control Data for Interpretation
A311214	Implement Workplan for Improvement Conceptual Geologic Model
A3112141	Determine Structural and Stratigraphic Elements
A31121411	Interpret Seismic Data
A311214111	Determine Customer Requirements
A311214112	Determine Workplan for Interpretation
A3112141121	Generate Interpretation Options
A31121411211	Select Seismic Interpretation Approach
A311214112111	Select Technique for Determining Structure
A311214112112	Determine Technique for Determining Litho-Stratigraphy
A311214112113	Determine Technique for Determining Fluids
A31121411212	Select Data To Be Used
A31121411213	Select Resource Options
A31121411214	Select Deliverable Option
A3112141122	Evaluate Interpretation Options
A3112141123	Determine Constraints
A3112141124	Select Optimal Interpretation Option
A311214113	Prepare Data for Seismic Interpretation
A3112141131	Gather Background Information
A3112141132	Build Geological Project Data Base
A3112141133	Build Seismic Project Data Base
A3112141134	Build Other Geophysical Data Base
A3112141135	Select Project Datum
A311214114	Perform Seismic Interpretation
A3112141141	Delineate Horizons and Faults in Time Domain
A31121411411	Tie well log synthetics to seismic
A31121411412	Determine Spatial Locations of Horizons and Terminations
A31121411413	Pick and Correlate Faults
A3112141142	Convert to Depth
A3112141143	Determine Lithologies and Facies
A3112141144	Determine Fluids
A311214115	Perform Benchmark On Seismic Interpretation
A311214116	Perform Lookback On Seismic Interpretation

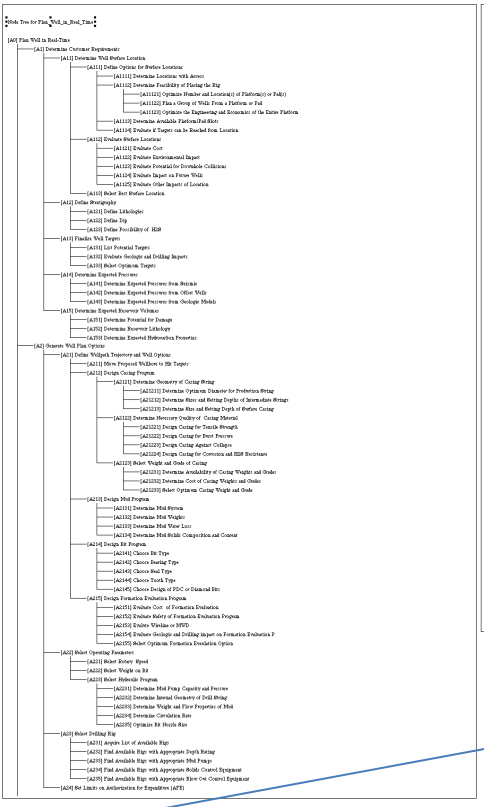


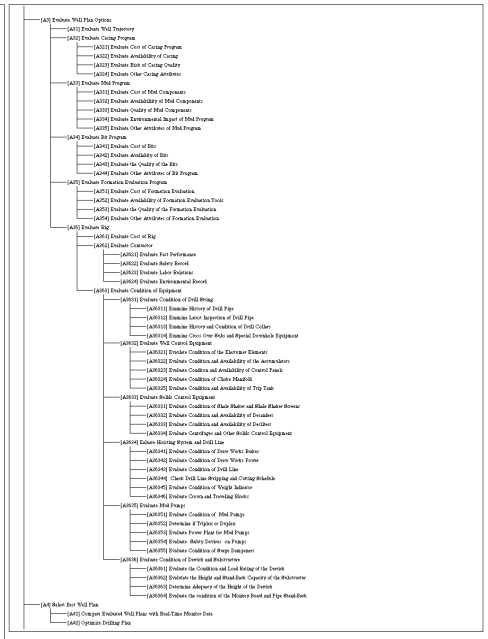
47	A31121412	Interpret Geochemical Property Data
48	A31121413	Interpret Geologic Data
49	A31121414	Interpret Well Logs
50	A31121415	Interpret Sequence Stratigraphy
51	A31121416	Interpret Other Geophysical Data
52	A311214161	Interpret Gravity Data
53	A311214162	Interpret Magnetic Data
54	A311214163	Interpret Electrical Data
55	A311214164	Interpret Lightning Data
56	A311214165	Interpret Satellite Data
57	A311214166	Interpret Other Remote Geophysicsal Data
58	A3112142	Integrate Interpretations and Update Earth Model
59	A3112143	Identify Inconsistencies in Interpretations
60	A311215	Perform Benchmark on Model Building
61	A311216	Perform Lookback on Model Building
62	A31122	Determine Source, Seal, Trap, Timing and Reservoir
63	A311221	Develop Regional Perspective
64	A3112211	Manage Data
65	A3112212	Interpret Regional Data
66	A3112213	Evaluate Regional Economics
67	A3112214	Assess Strategic Fit
68	A3112215	Evaluate Viability using Performance Indicators
69	A311222	Develop Play Fairway
70	A3112221	Manage Data
71	A3112222	Interpret Play Fairway
72	A3112223	Evaluate Play Economics
73	A3112224	Determine Viability Using Performance Indicators
74	A311223	Generate Prospect
75	A3112231	Manage Data
76	A3112232	Interpret Prospect
77	A3112233	Evaluate Prospect Economic Indicators
78	A3112234	Determine Viability Using Performance Indicators
79	A3113	Acquire Acreage
80	A3114	Acquire Data
81	A31141	Determine Data Type Necessary for Request
82	A31142	Determine how to Acquire
83	A31143	Procure the Data
84	A3115	Benchmark
85	A312	Develop
86	A313	Exploit
87	A314	Produce
88	A32	Refine
89	A33	Market and Sell

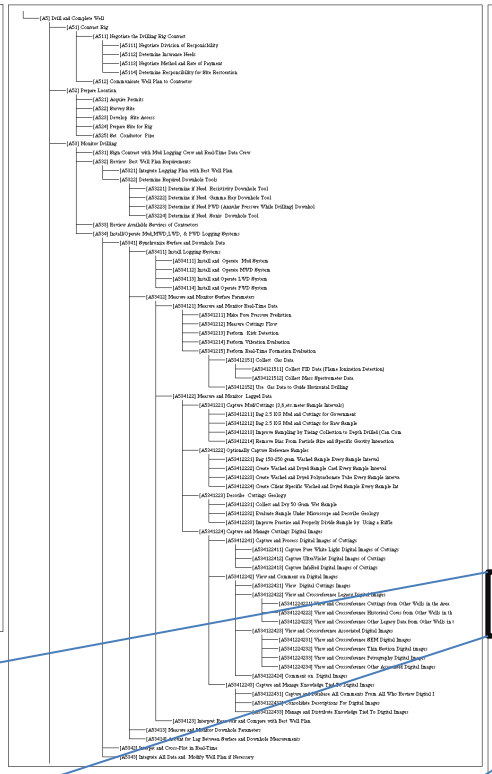
KB_Dubei.xls | KB_Seismic_Interpretation | KB_SI_Top_Activities

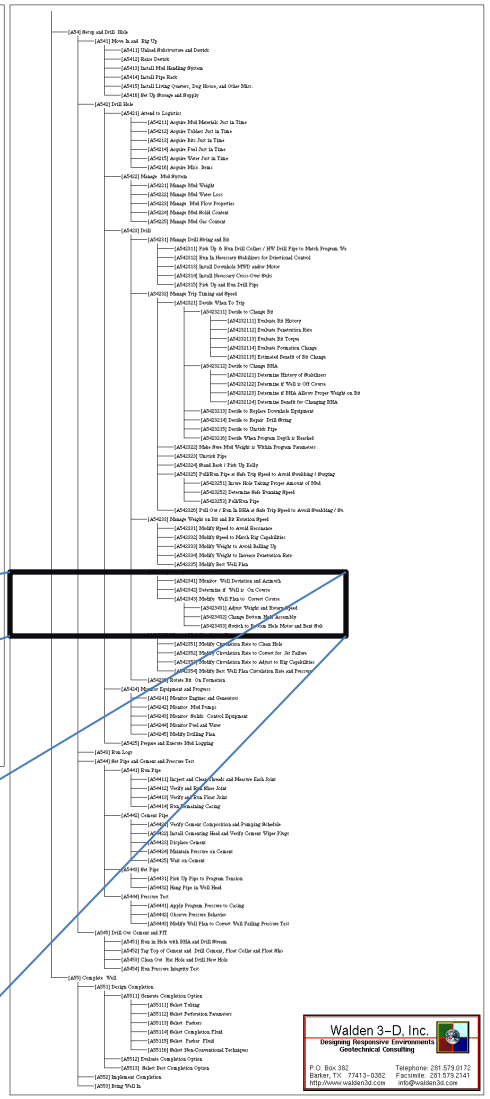
Ready

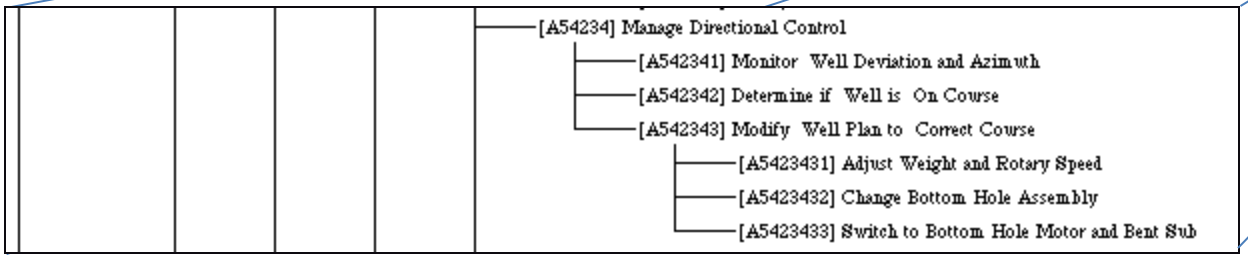
KB of Real Time Drilling







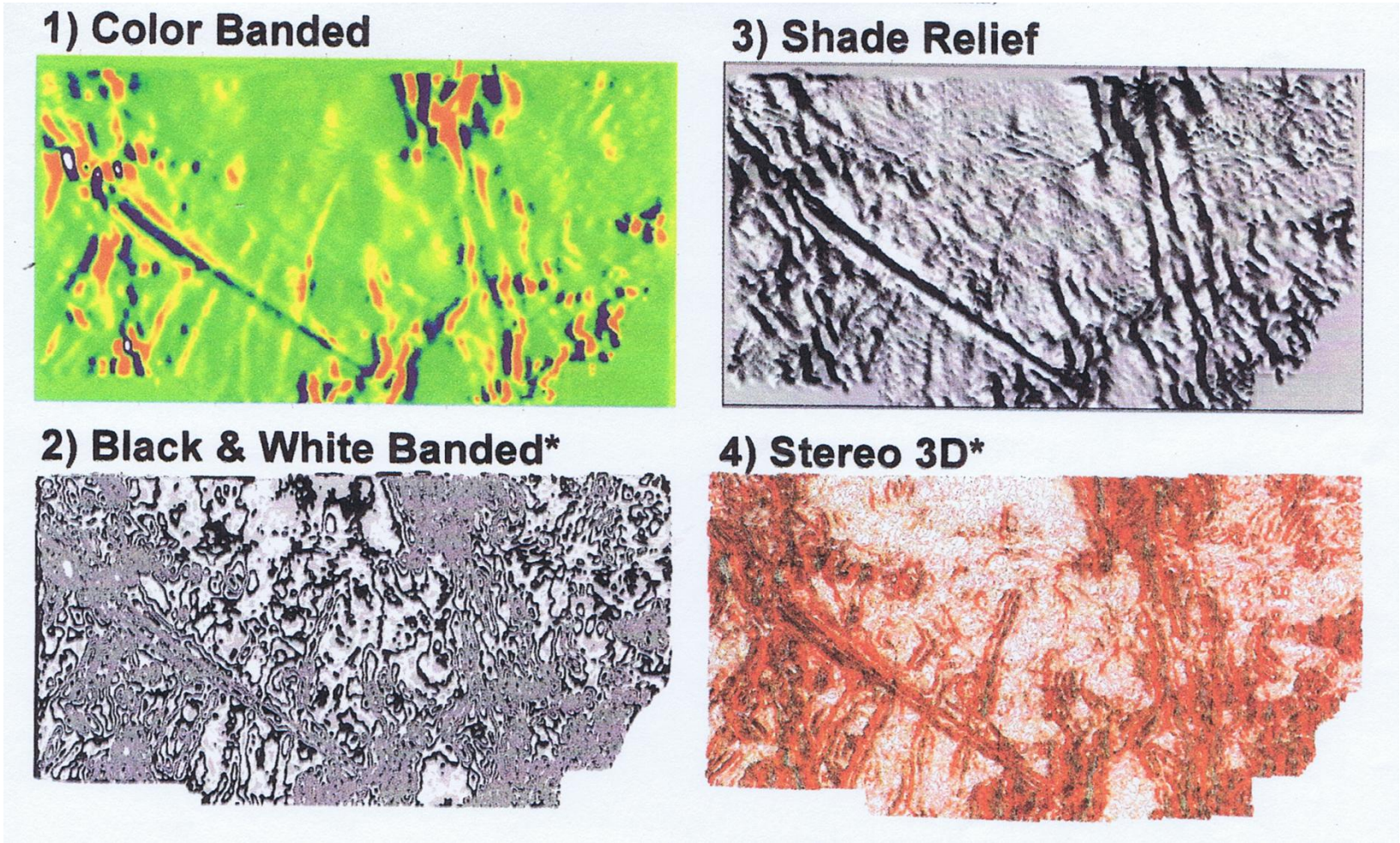




Data To Integrate with Seismic Interpretations

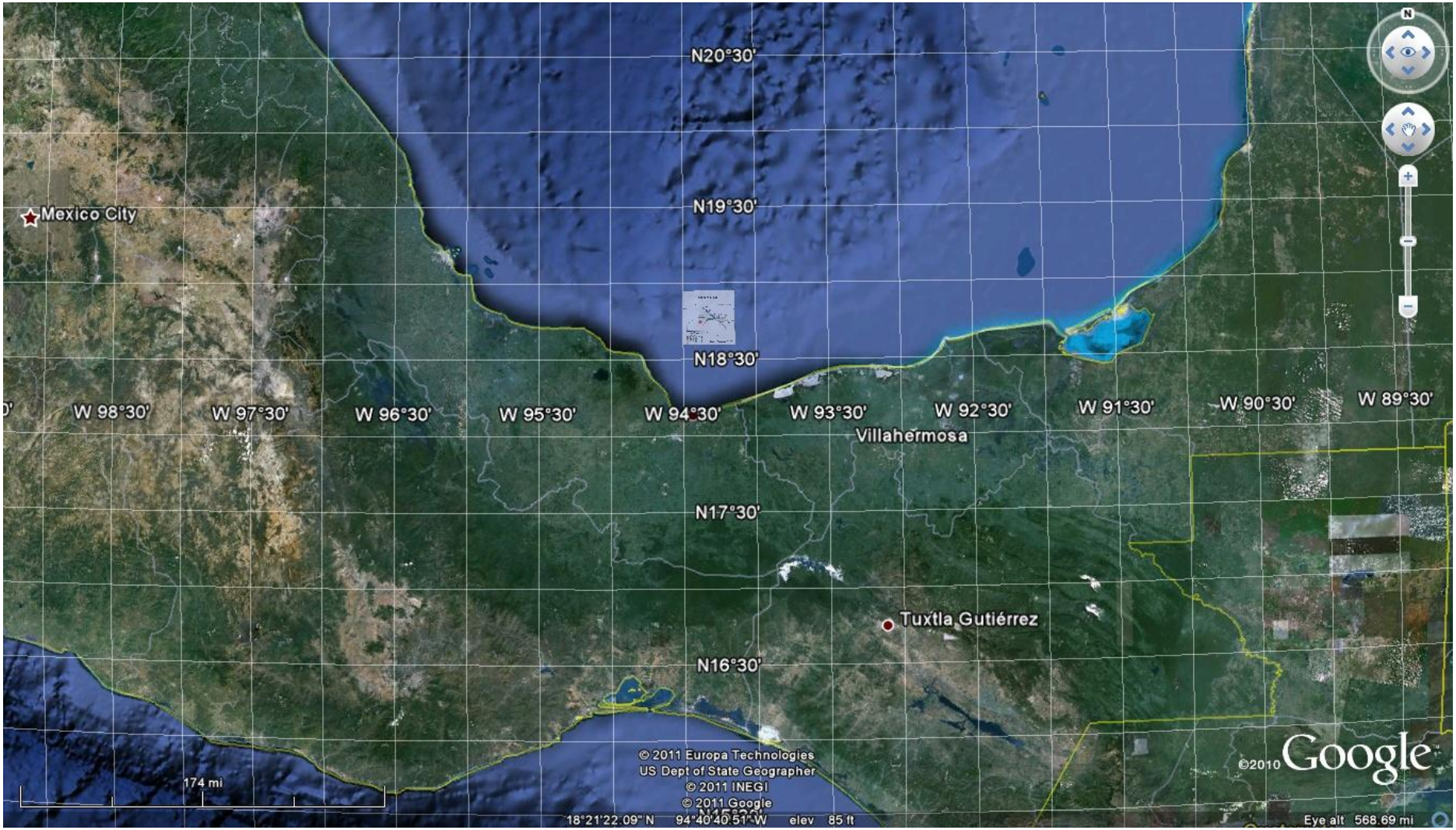
- Satellite data
- Gravity and magnetic data
- Geochemistry data
- CSEM, Lightning, and other electromagnetic data
- Well cuttings (cores)
- Well logs
- Image Logs
- Temperature and Pressure Data
- Reservoir parameters
- Production Histories

Aeromagnetic Displays used for Basement Mapping

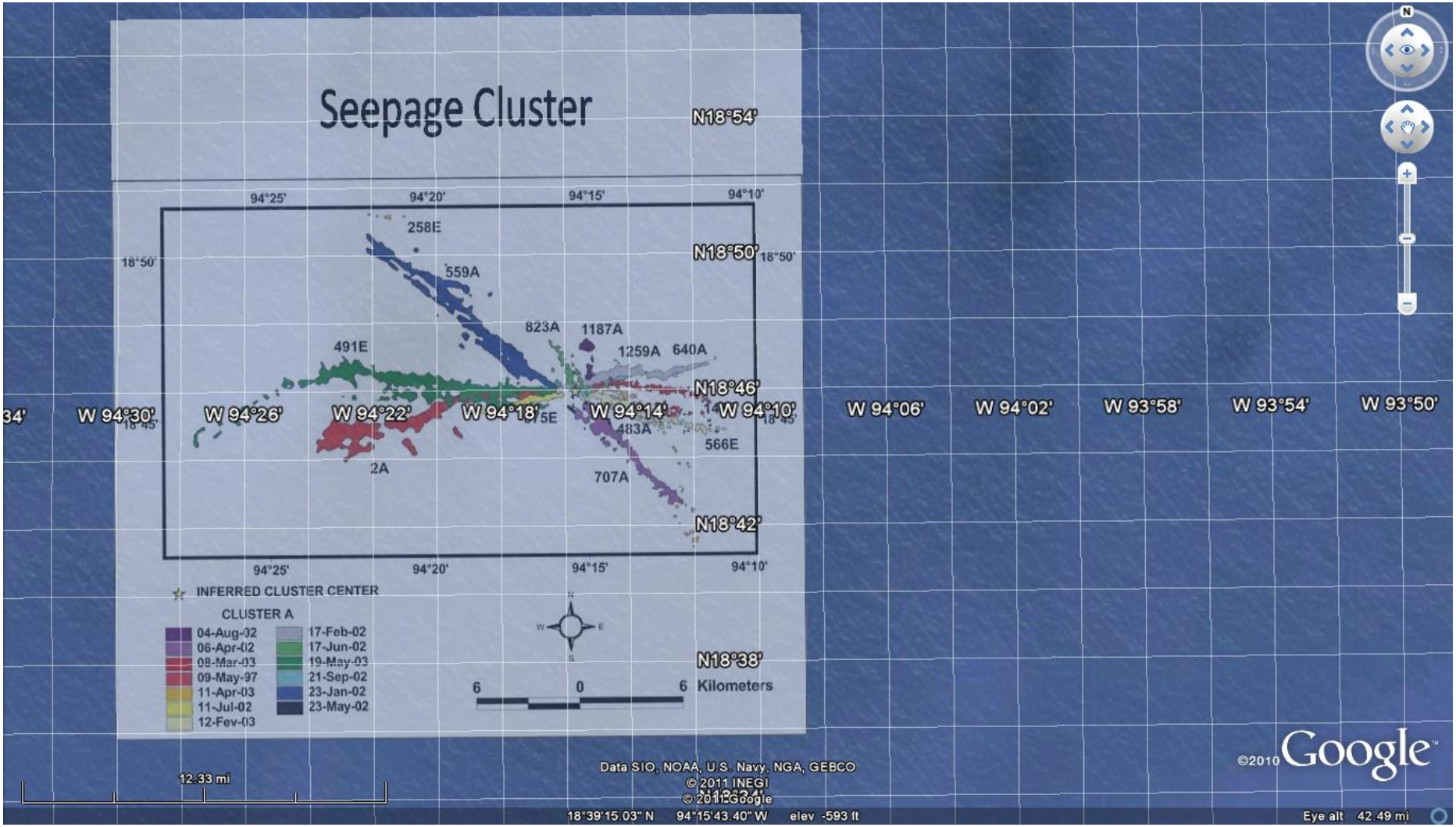


S. Parker Gay, Jr., **Applied Geophysics**, Personal Communication.

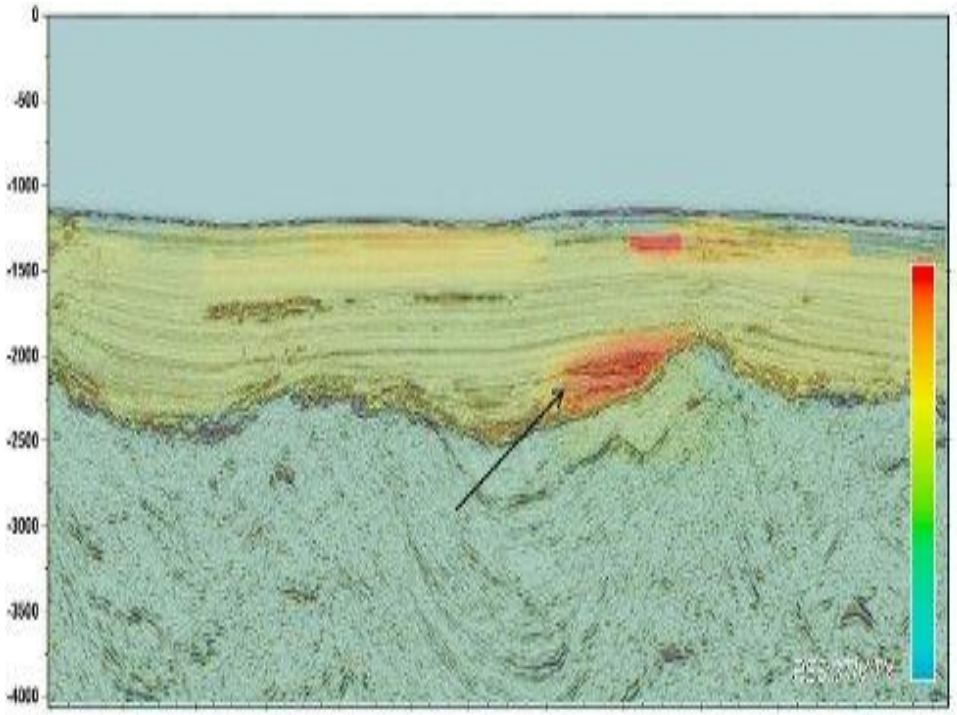
Satellite Data



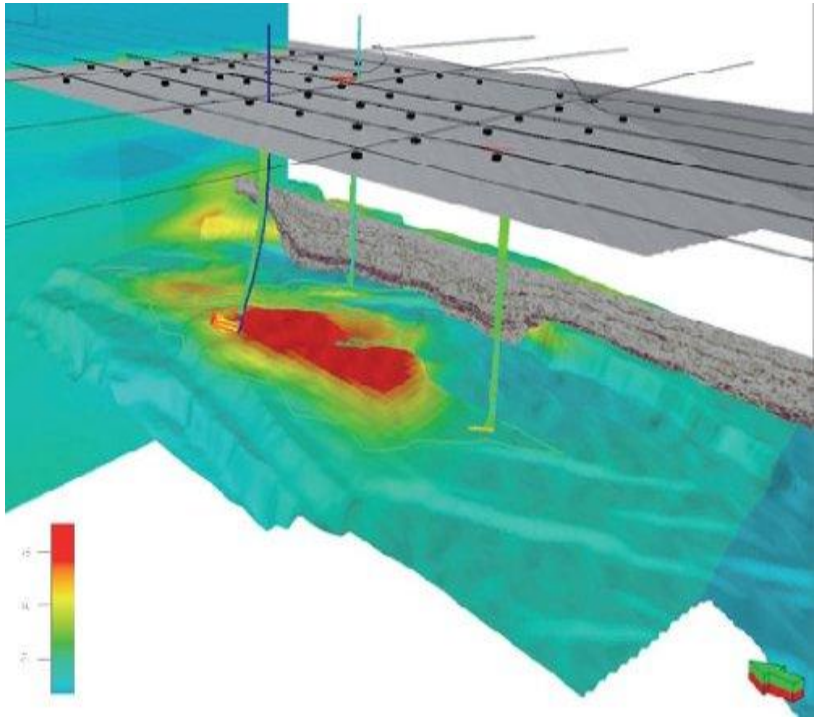
Seepage Cluster Geochemistry



CSEM
Controlled Source ElectroMagnetics



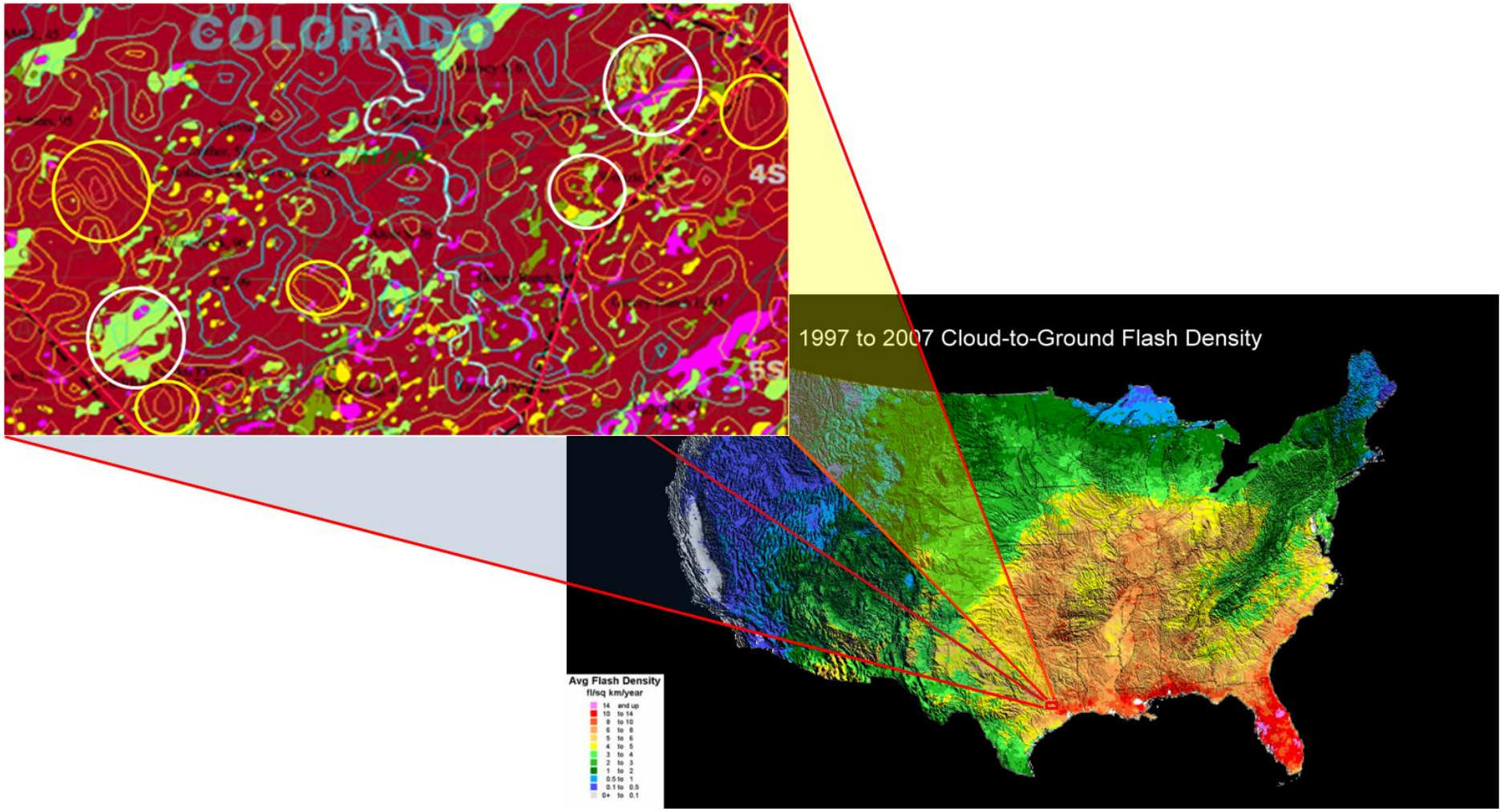
2.5-D CSEM Inversion



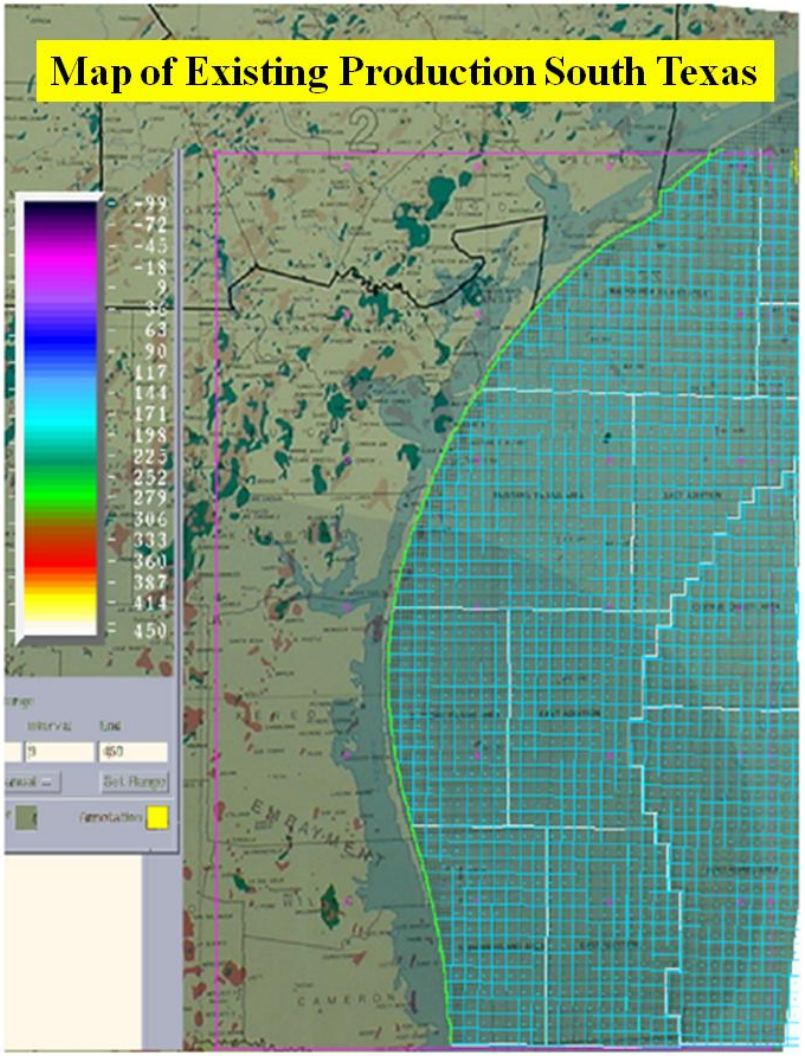
3-D CSEM Inversion

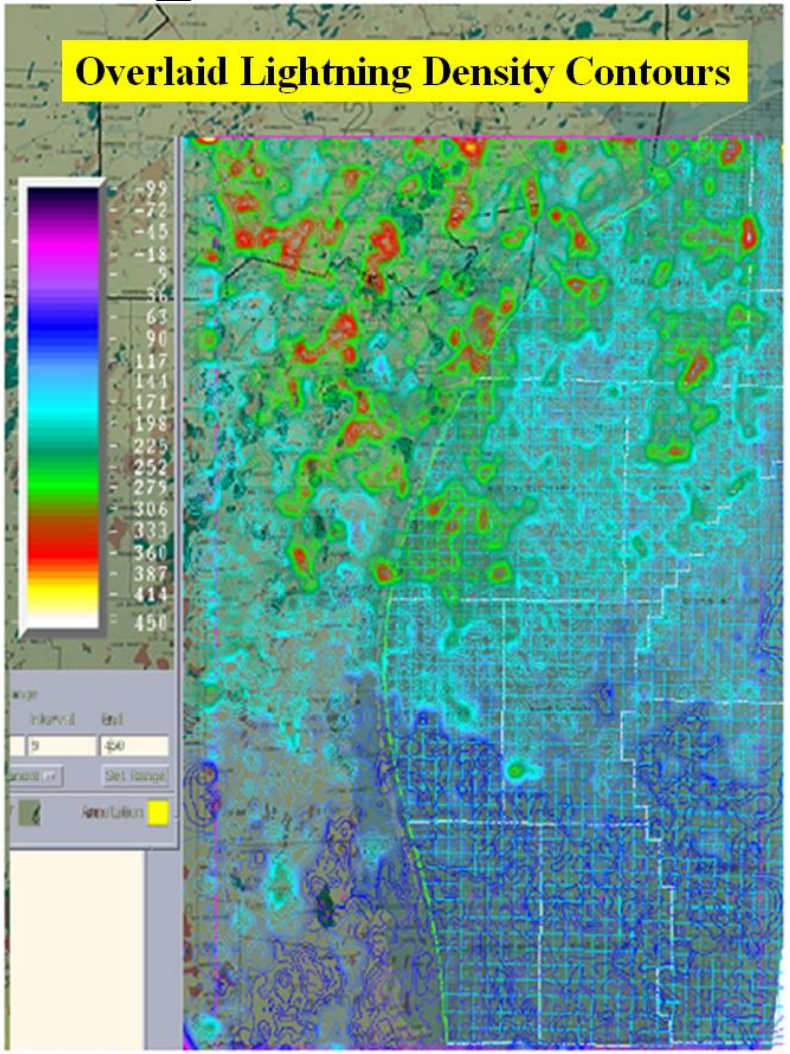
Dave Ridyard, **EMGS Americas**, Personal Communication.

Lightning Is Not Random
Strike Locations Tie Telluric Currents



Lightning Strike Density Correlates with Existing Production

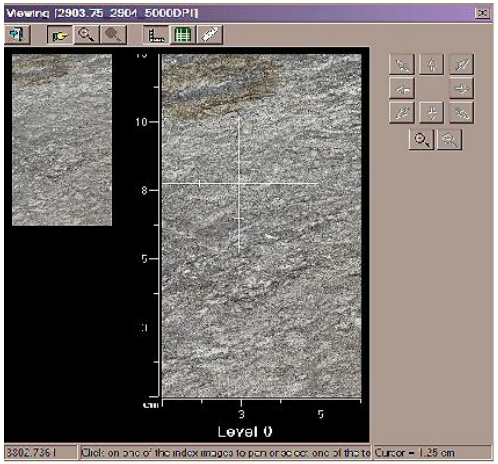


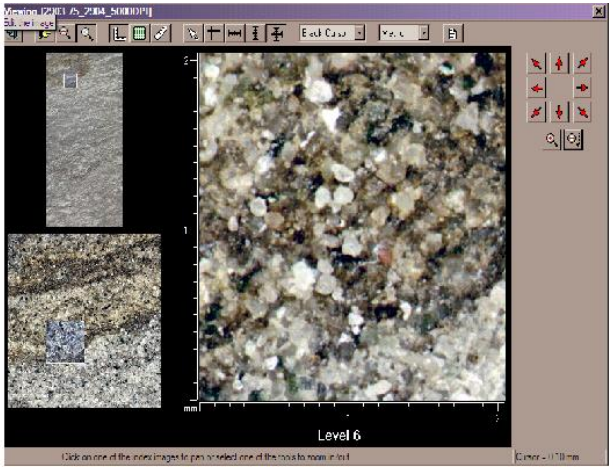


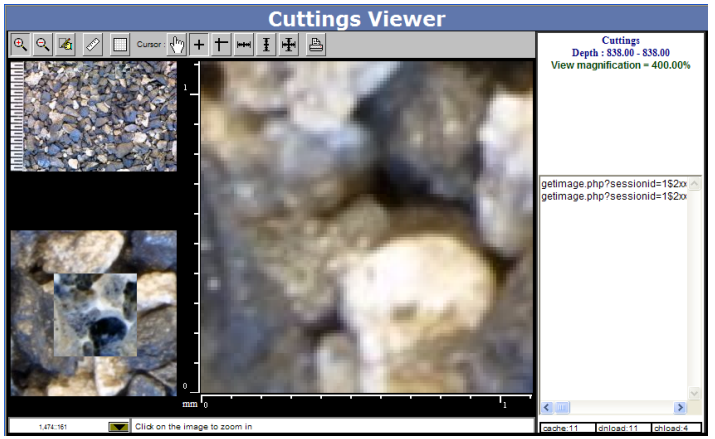
Well Core and Cuttings Capture

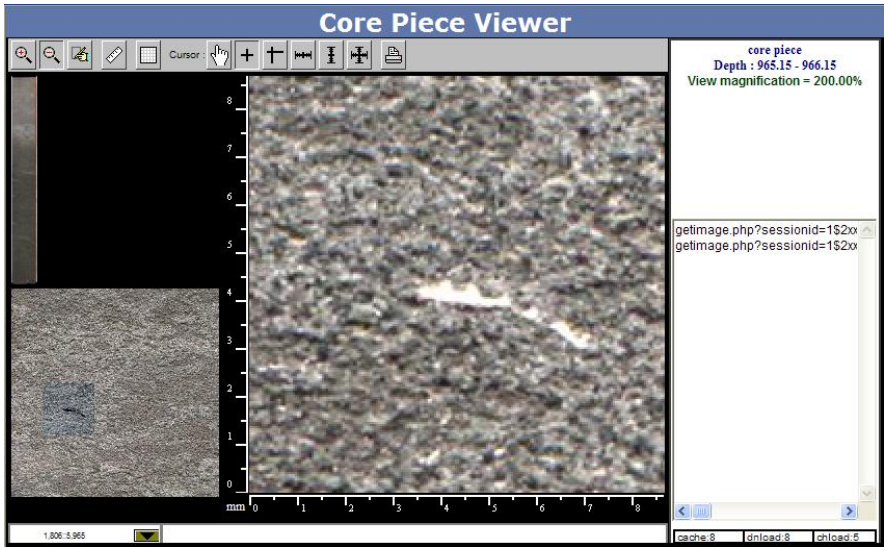
Christian Singfield, **FSI International**,
Brisbane, Australia.

Well Core and Cuttings On-Line Display

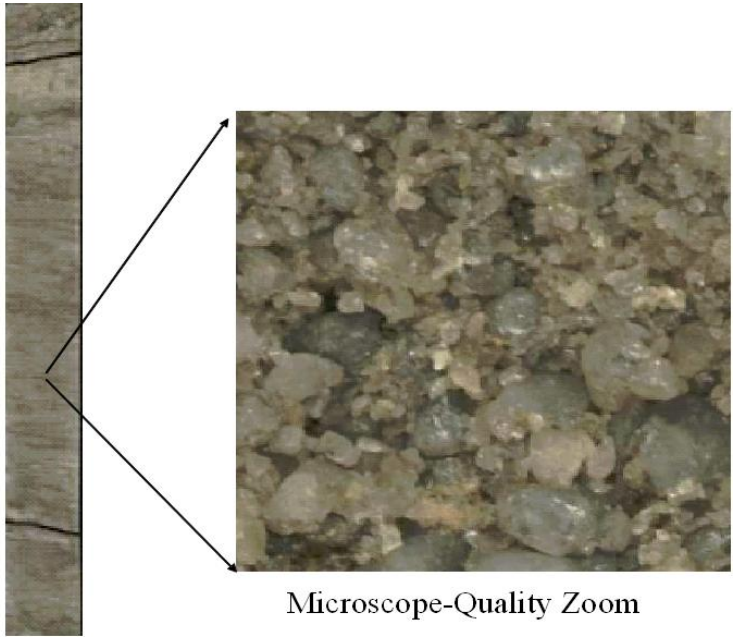








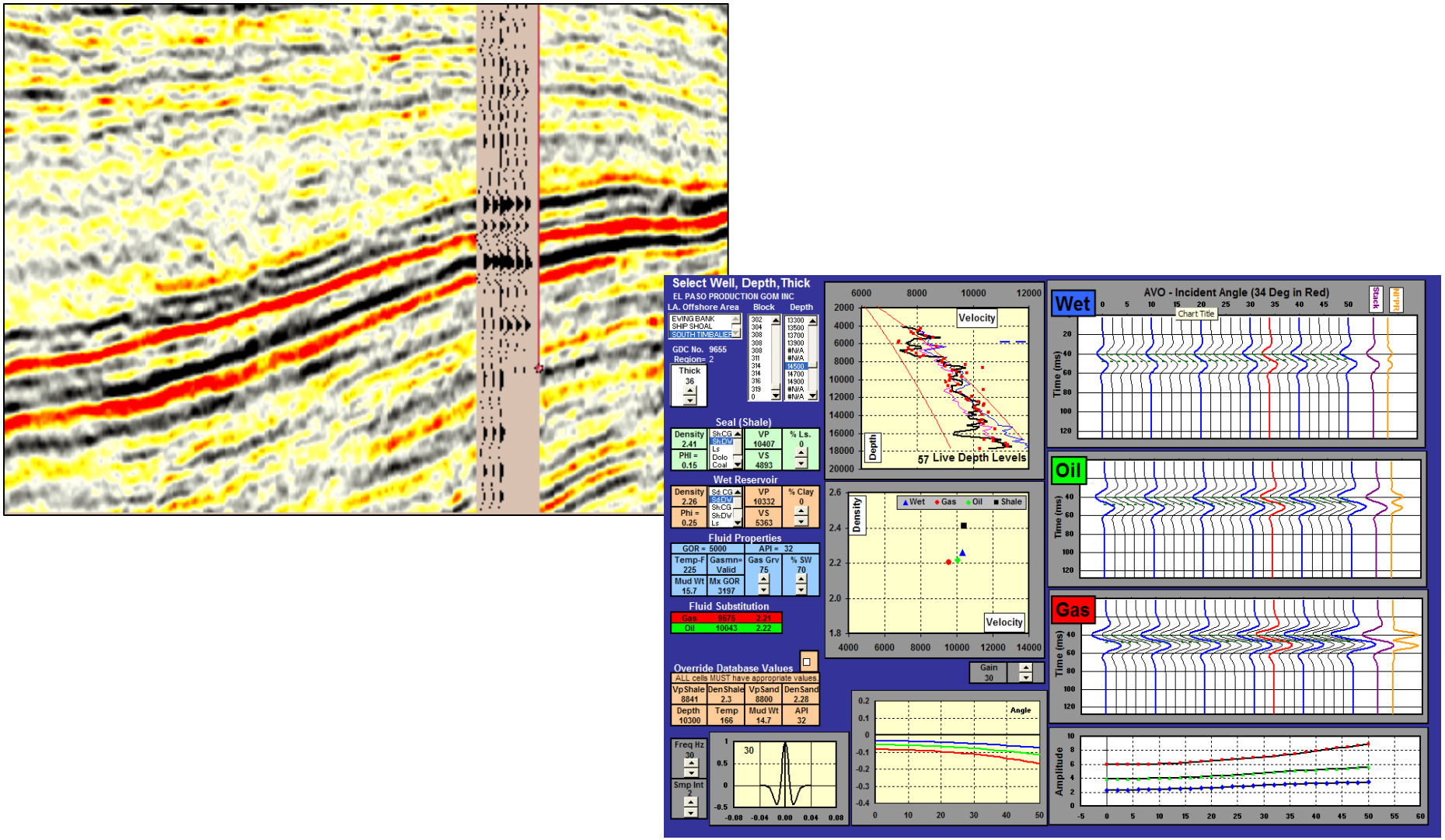
1:1 Scale Acquisition



Microscope-Quality Zoom

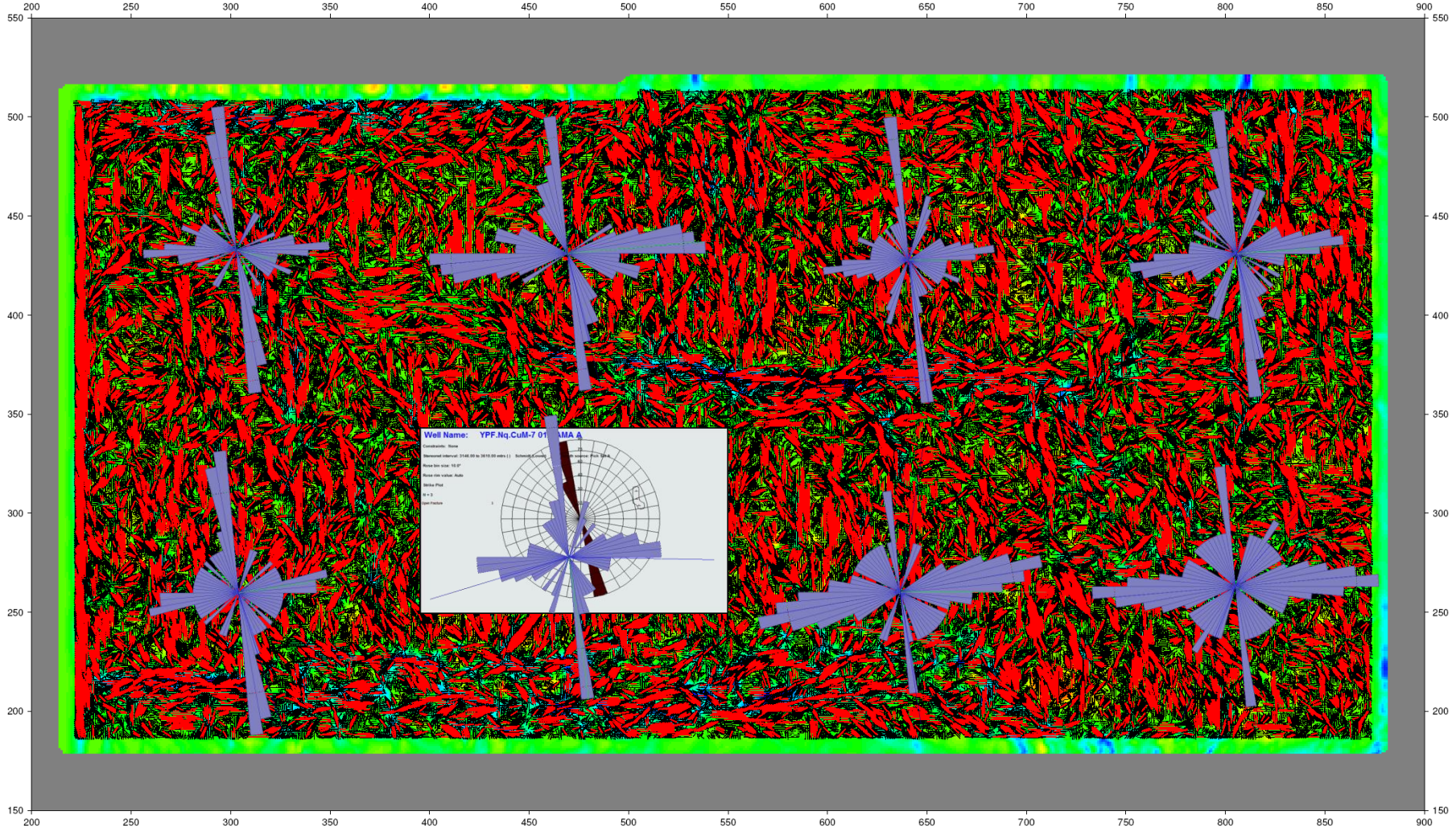
Christian Singfield, **FSI International**, Brisbane, Australia.

Well Logs / Synthetics



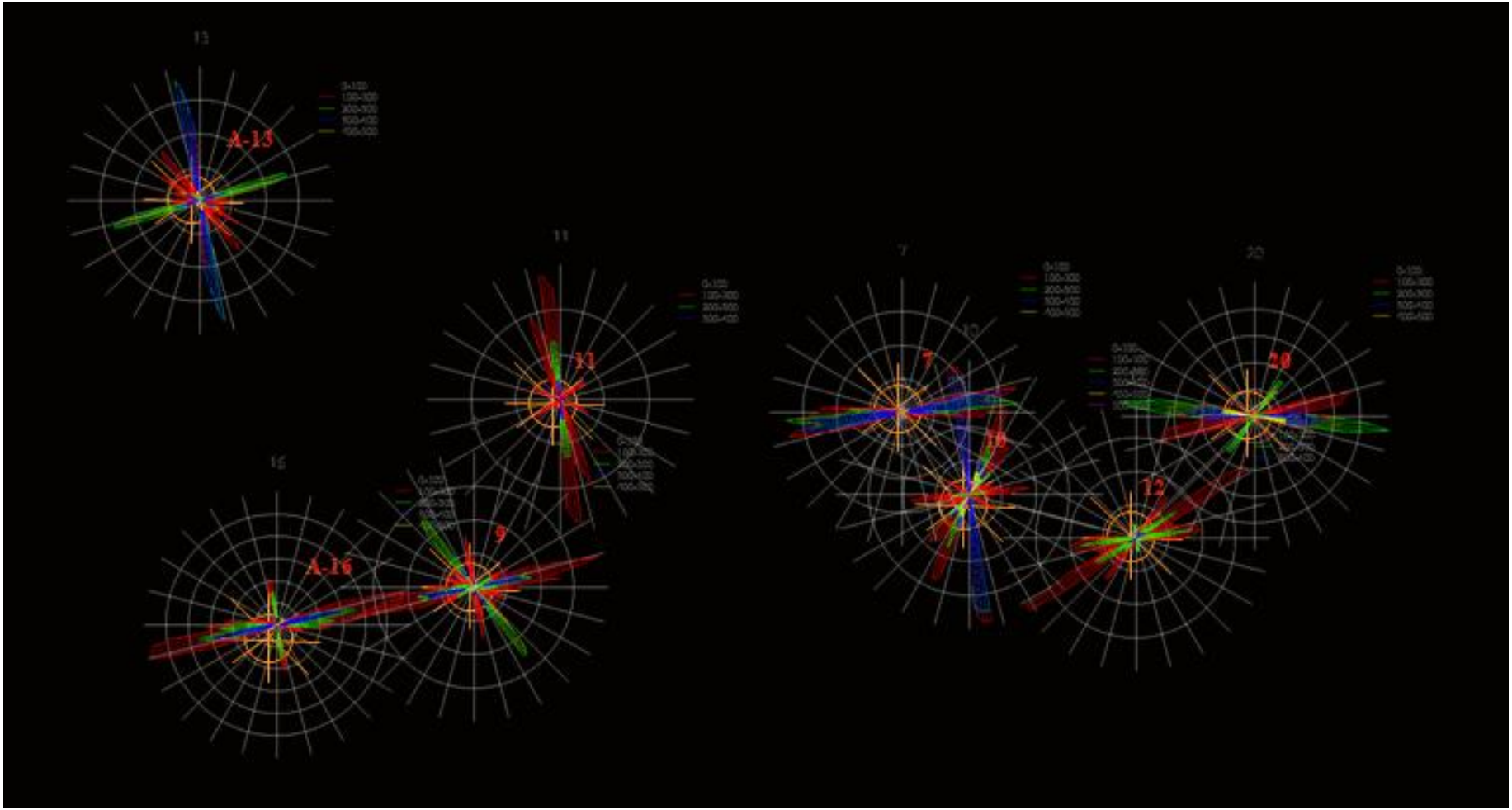
Fred Hilterman, **Geokinetics**, Personal Communication.

Automatic Lineaments from 3-D Seismic Compared to Image Log



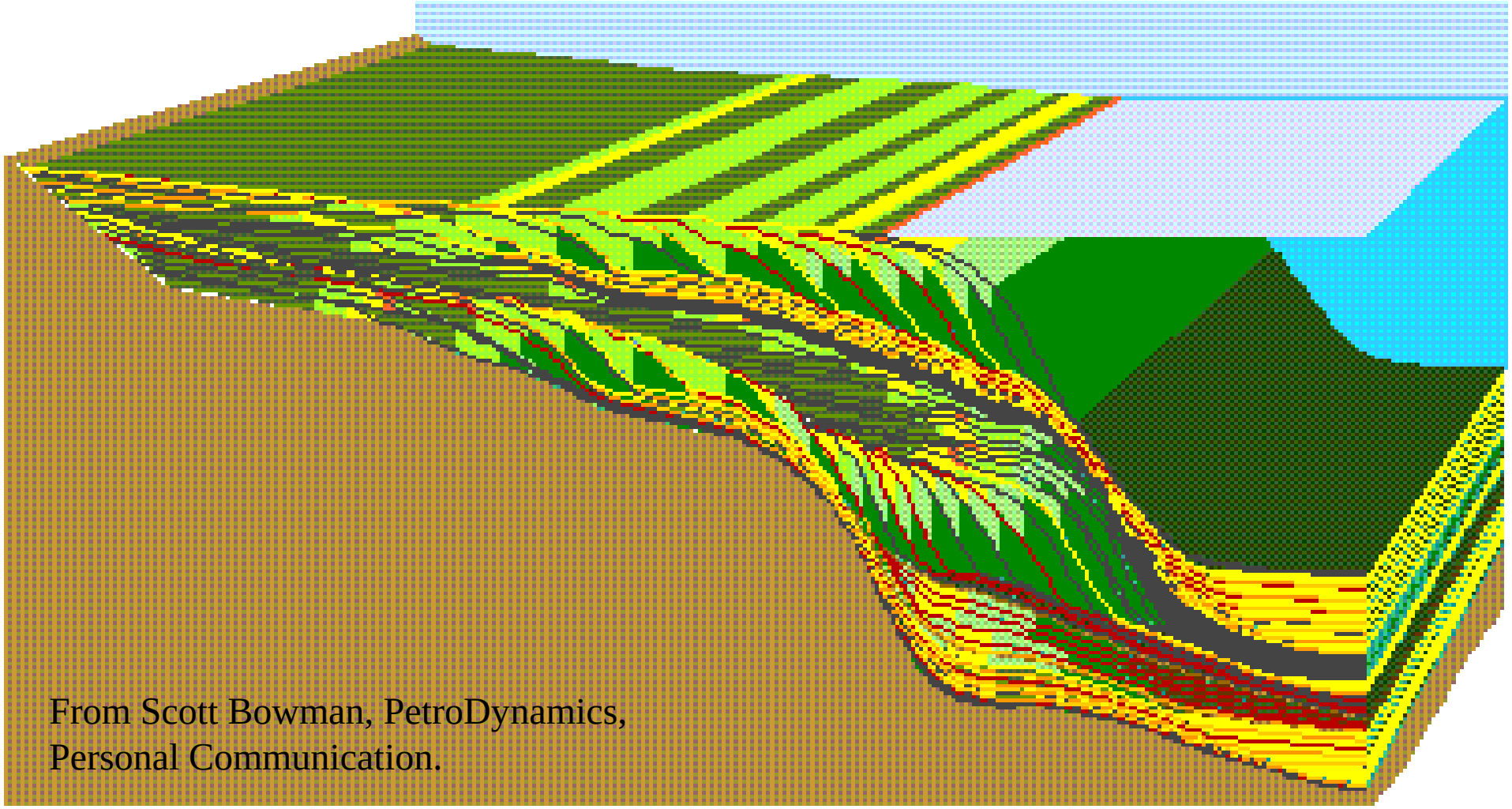
Les Denham, **II&T**, Personal Communication.

Image Log Interpretations



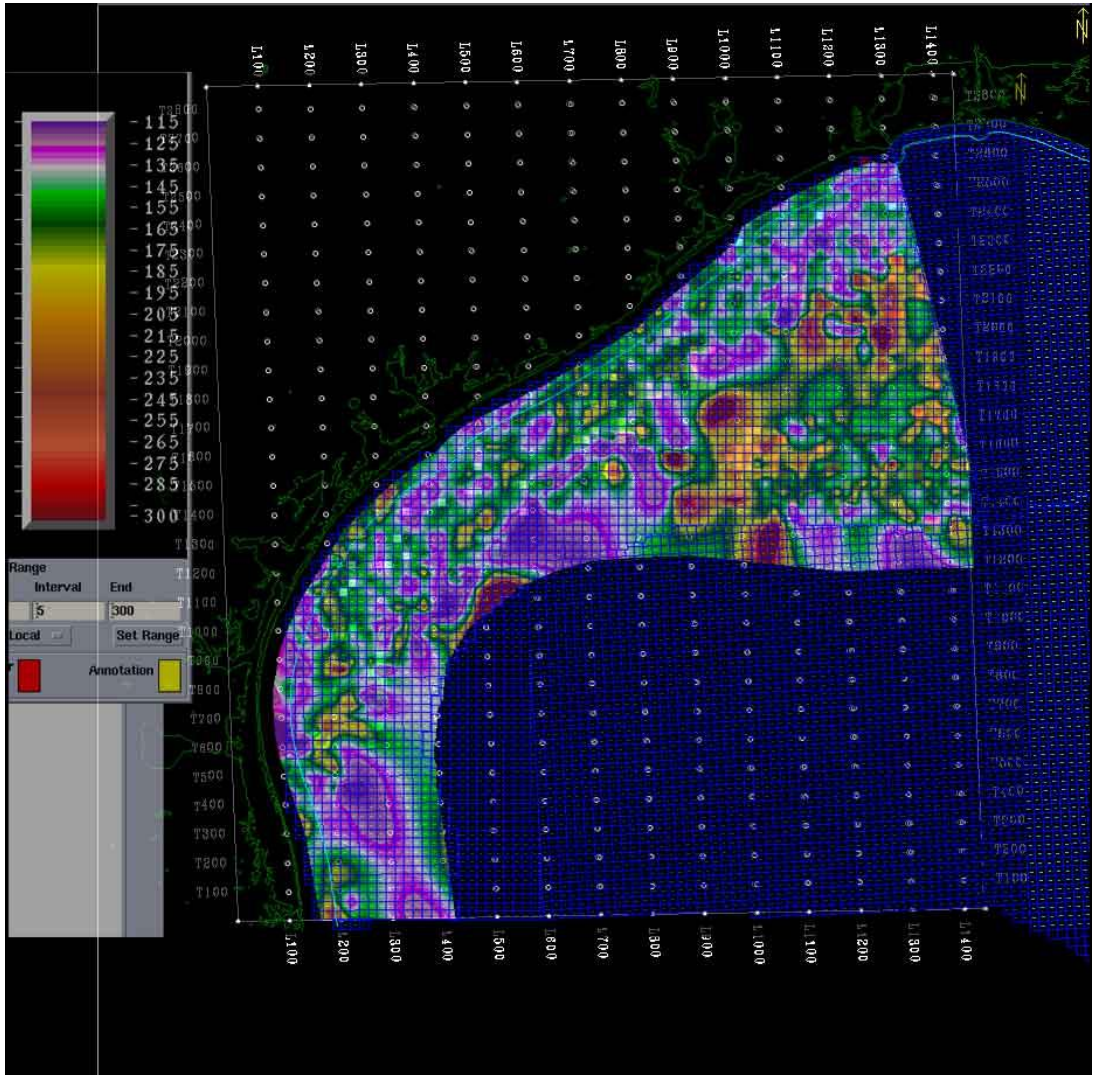
Les Denham, **II&T**, Personal Communication.

Models of Sea Level Driven Deposition

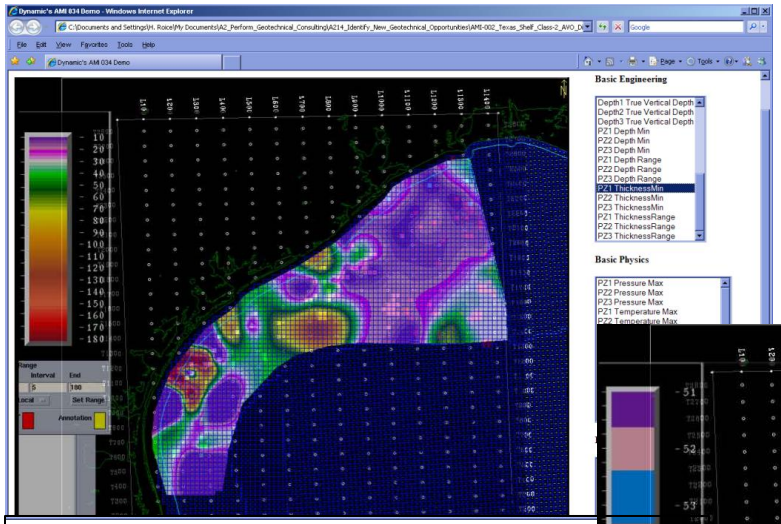


From Scott Bowman, PetroDynamics,
Personal Communication.

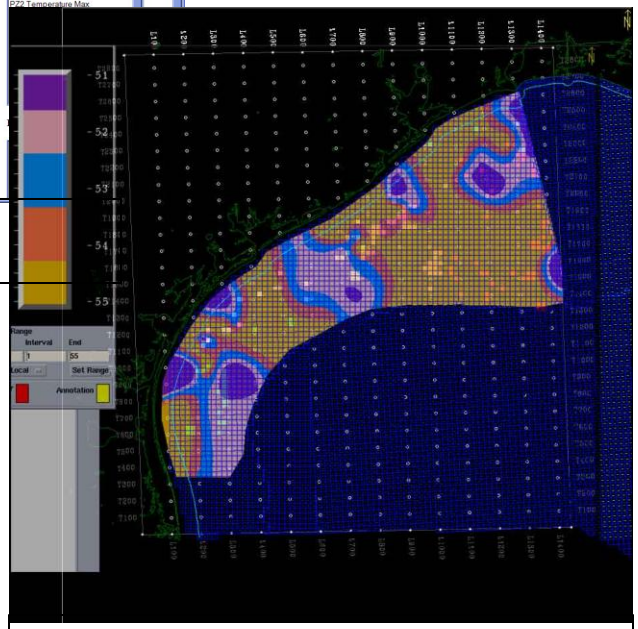
Adjusted Bottom Hole Temperature



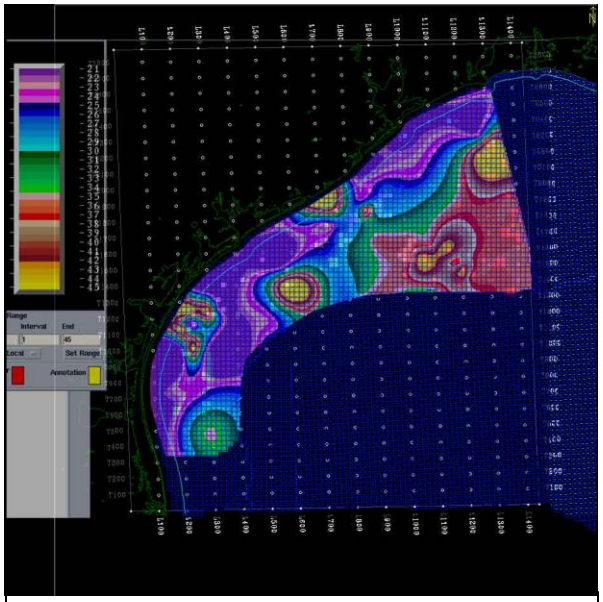
Reservoir Parameters
Nehring U.S. Reservoir Database



Maximum Thickness PZ1

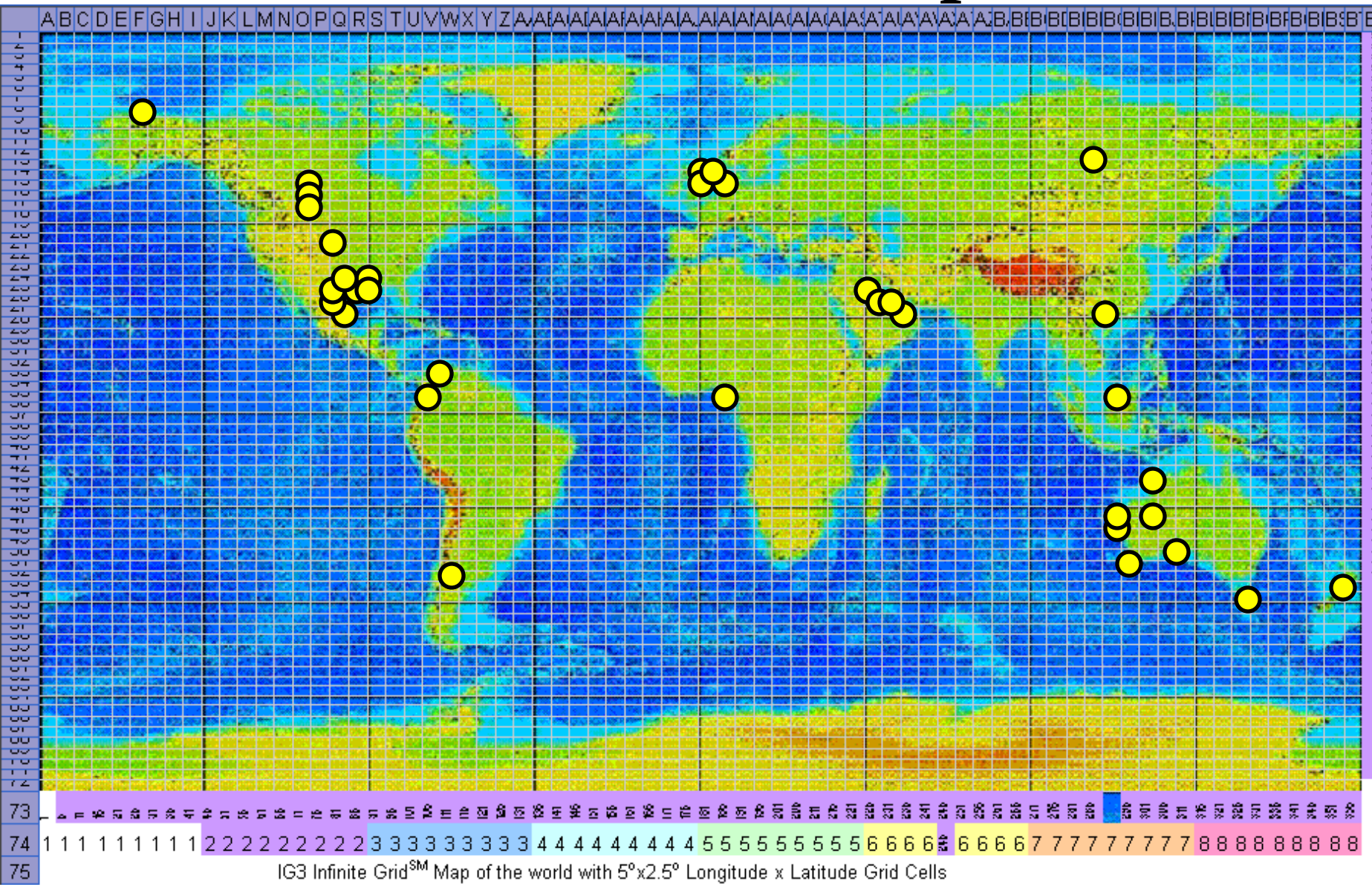


Formations Potential Zone 1

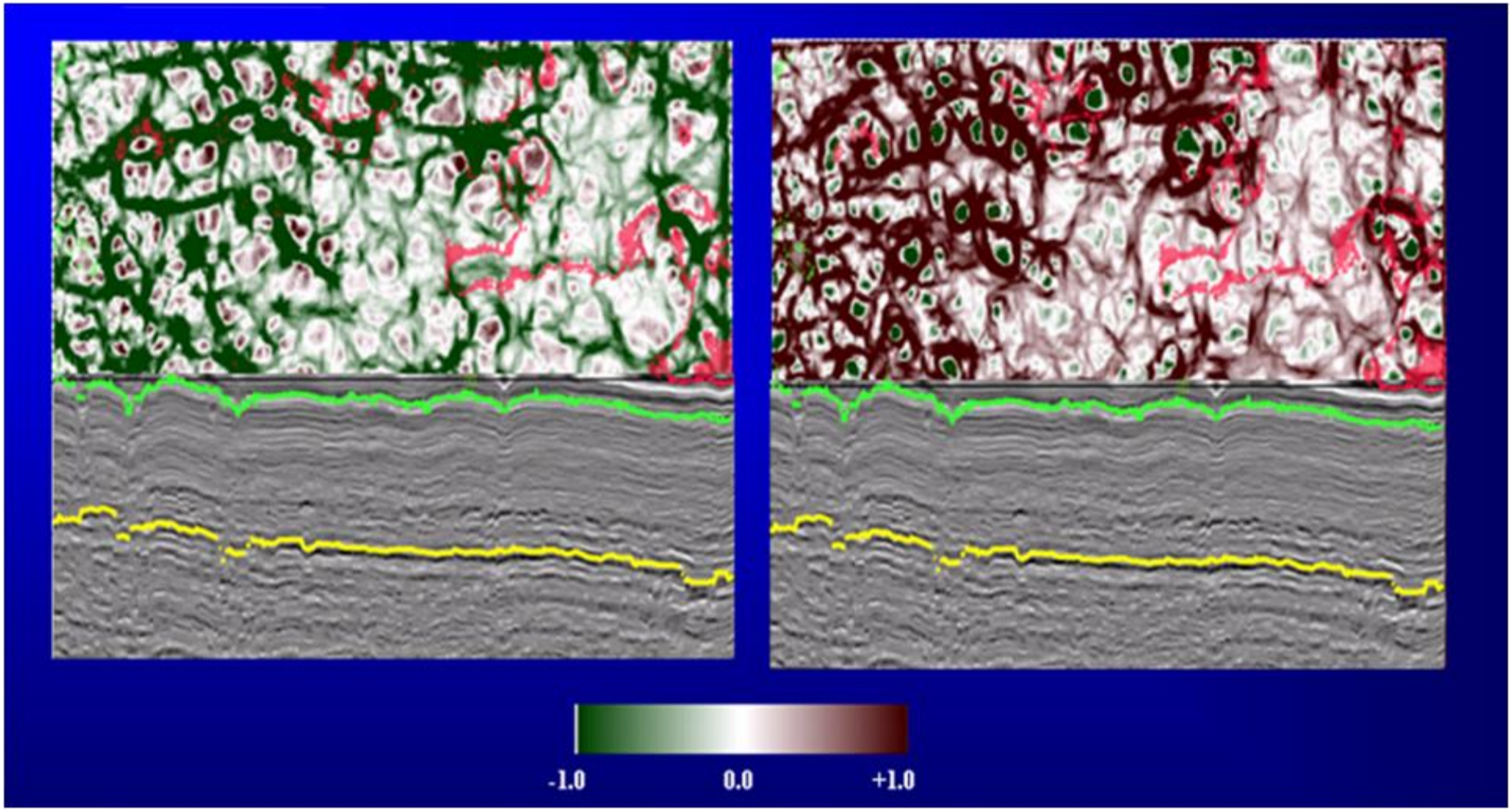


Depositional Styles PZ1

Overview of Seismic Example Locations



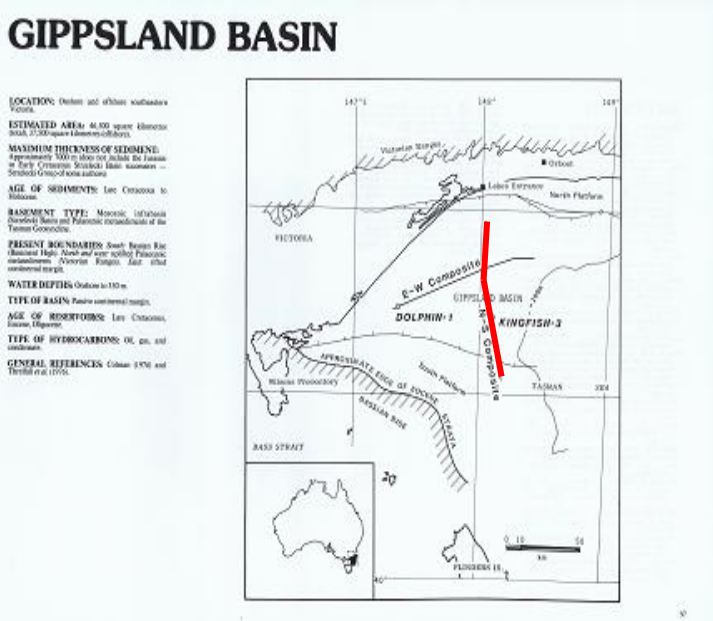
Practical Seismology Solutions
Carbonate Terrains

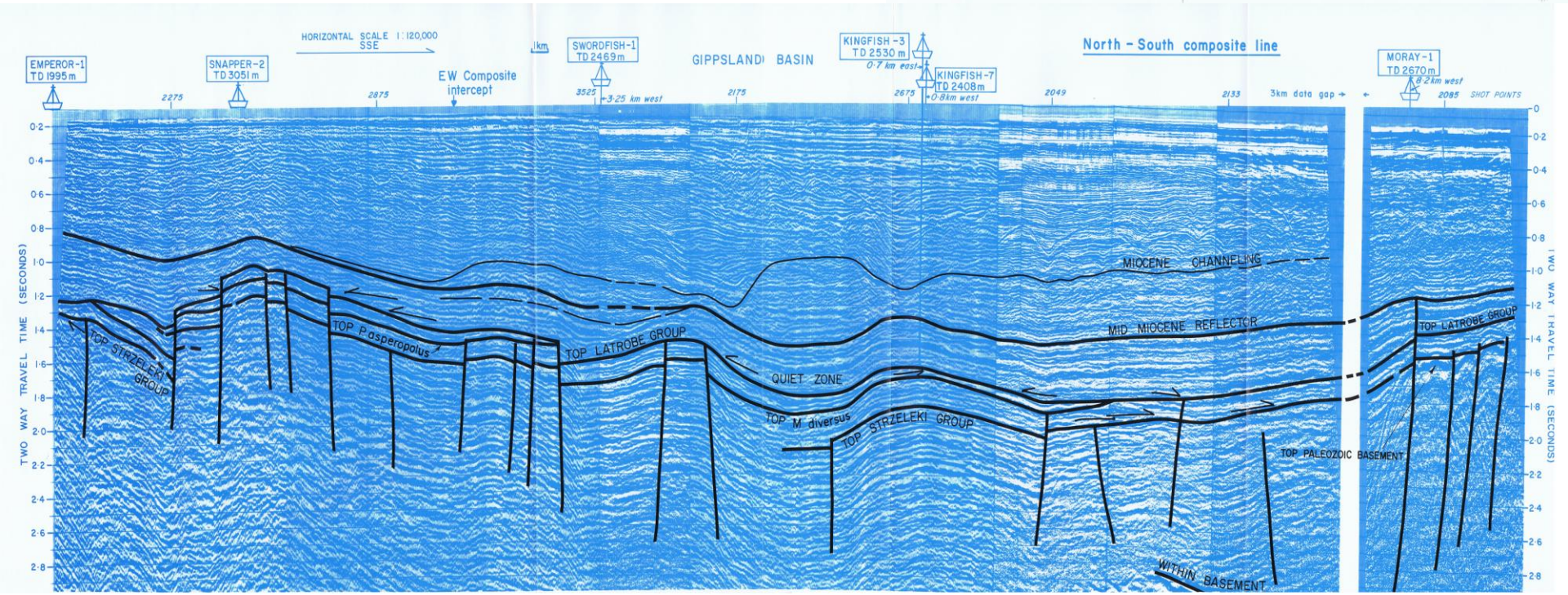


Volumetric Curvature Analysis Data courteous L. Viertel.

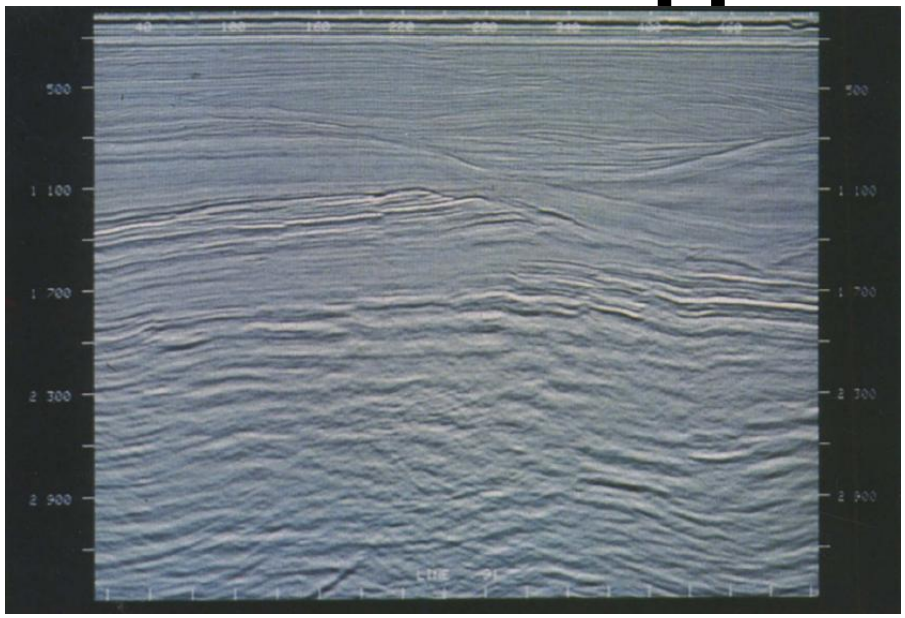
Latrobe Group

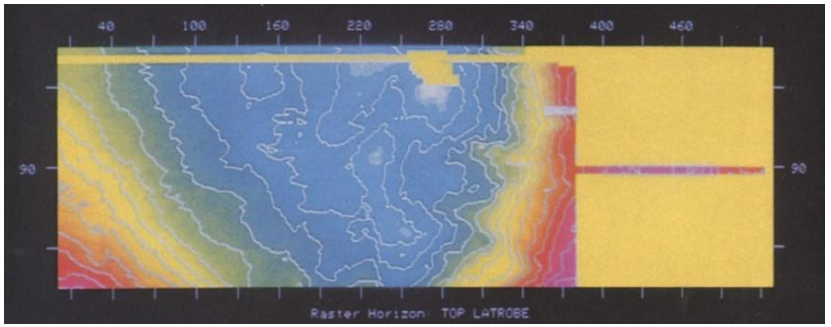
The Seismic Atlas of Australian and New Zealand Sedimentary Basins, Edited by: C. Gregory Skilbeck and Malcom J. Lennox, pages 97 & 108.

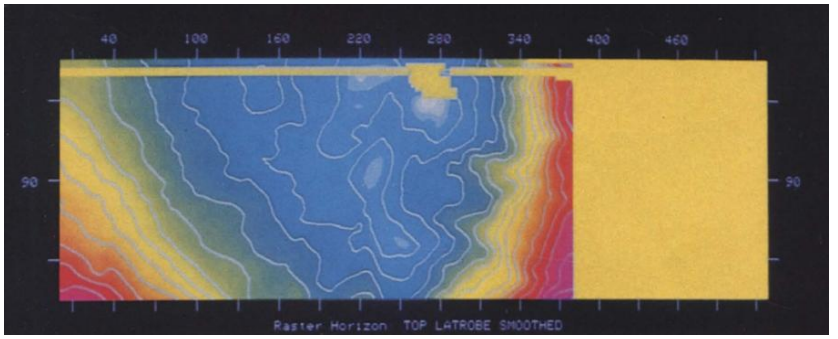


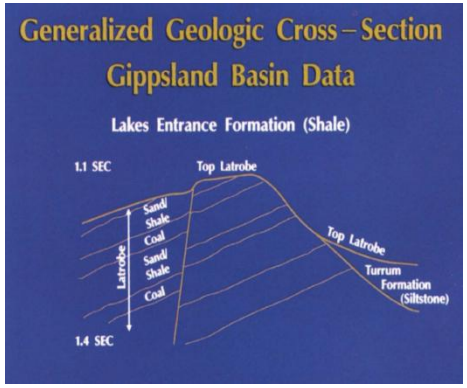


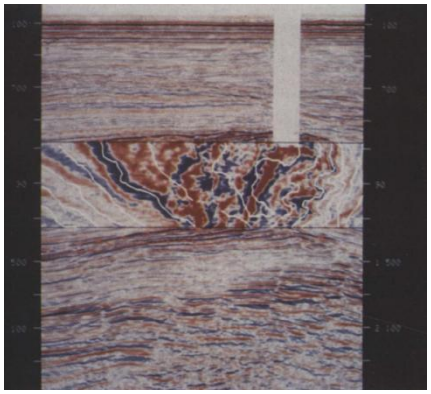
Top Latrobe Maps from the Gippsland Basin 3-D

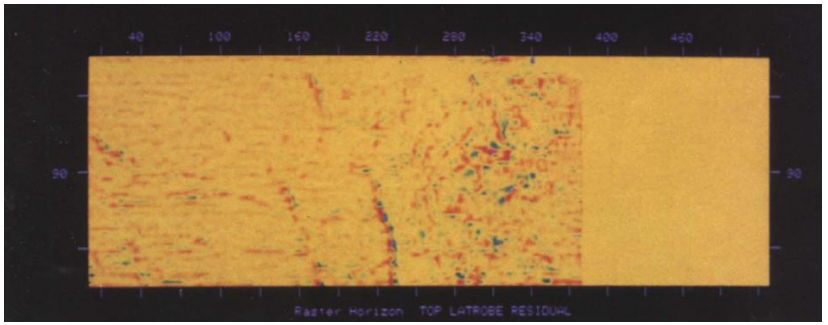












J.I. Denham and H.R. Nelson, Jr. in **Geophysics**, 1986, v. 7, n. 3, pages 86-95, data from BHP Petroleum, Bass Straits, Australia.

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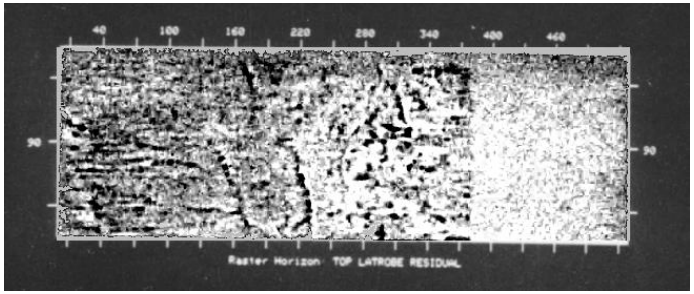

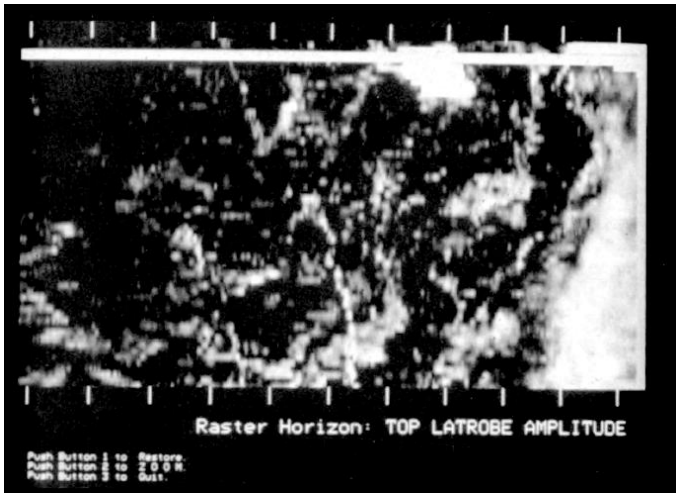

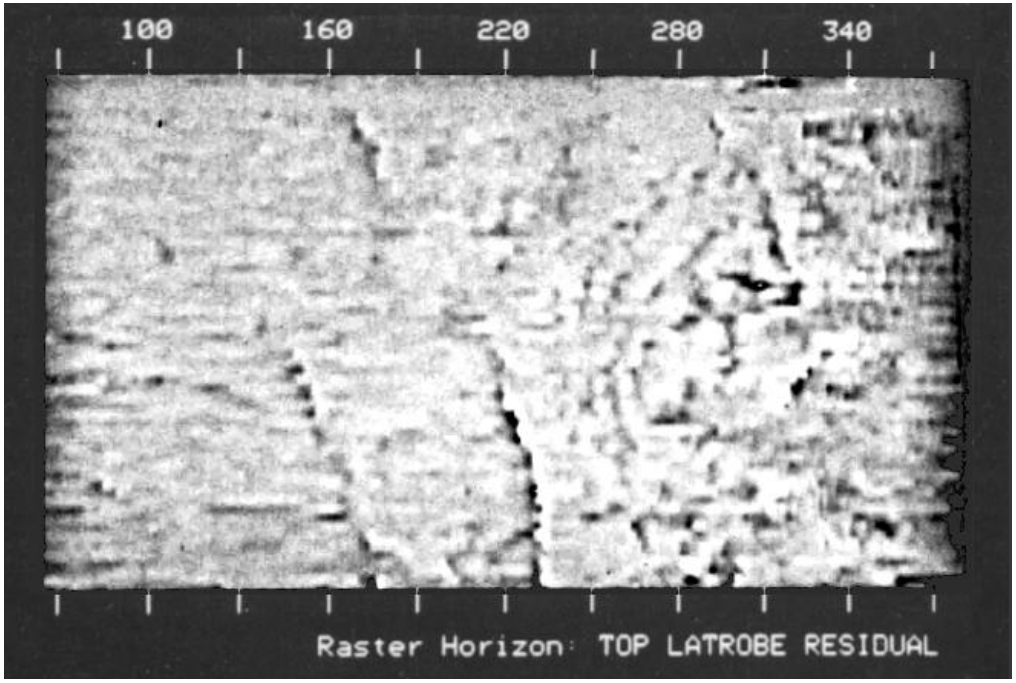

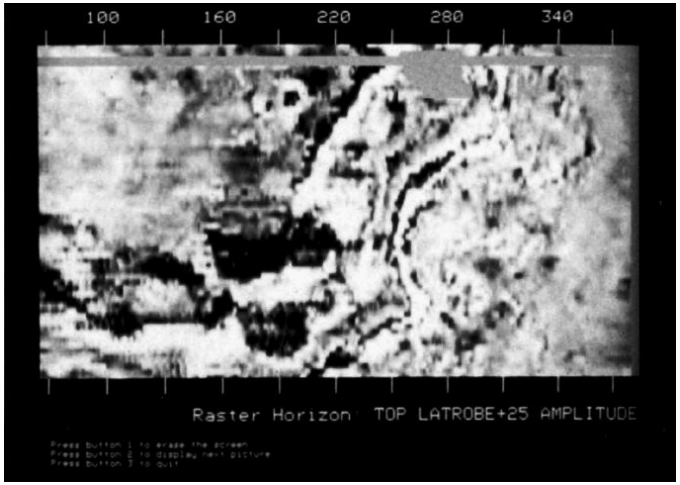

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Pre-Program Questionnaire

- What is a basic interpretation workflow?
  - How does this workflow vary for interpretation of siliciclastics and carbonate environments?
  - Why integrate other type of data?
    - Satellite data?
    - Gravity data?
    - Magnetic data?
    - Geochemistry data?
    - Lightning data?
    - Electromagnetic data?
    - Well cuttings (cores)?
    - Well logs?
    - Temperature and pressure data?
    - Image logs?
    - Reservoir parameters?
    - Production histories?
  - What physical properties can be derived from a seismic interpretation?
  - How does seismic interpretation help reservoir analysis?