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Spectral Signatures of Hydrocarbons

Signal Estimation Technology Inc.
Total Depth (Exploration Services) Pty. Ltd.

Introduction

- In this talk we will demonstrate the use of spectral analysis as an effective tool for the detection of lithologic changes and spectral attenuation associated with hydrocarbon bearing reservoirs.

Topics of Discussion

- Motivation
- Spectral Attributes (using *Spectra)*
- Comparison of *Spectra* and other attributes
- Examples
- Conclusion

Motivation

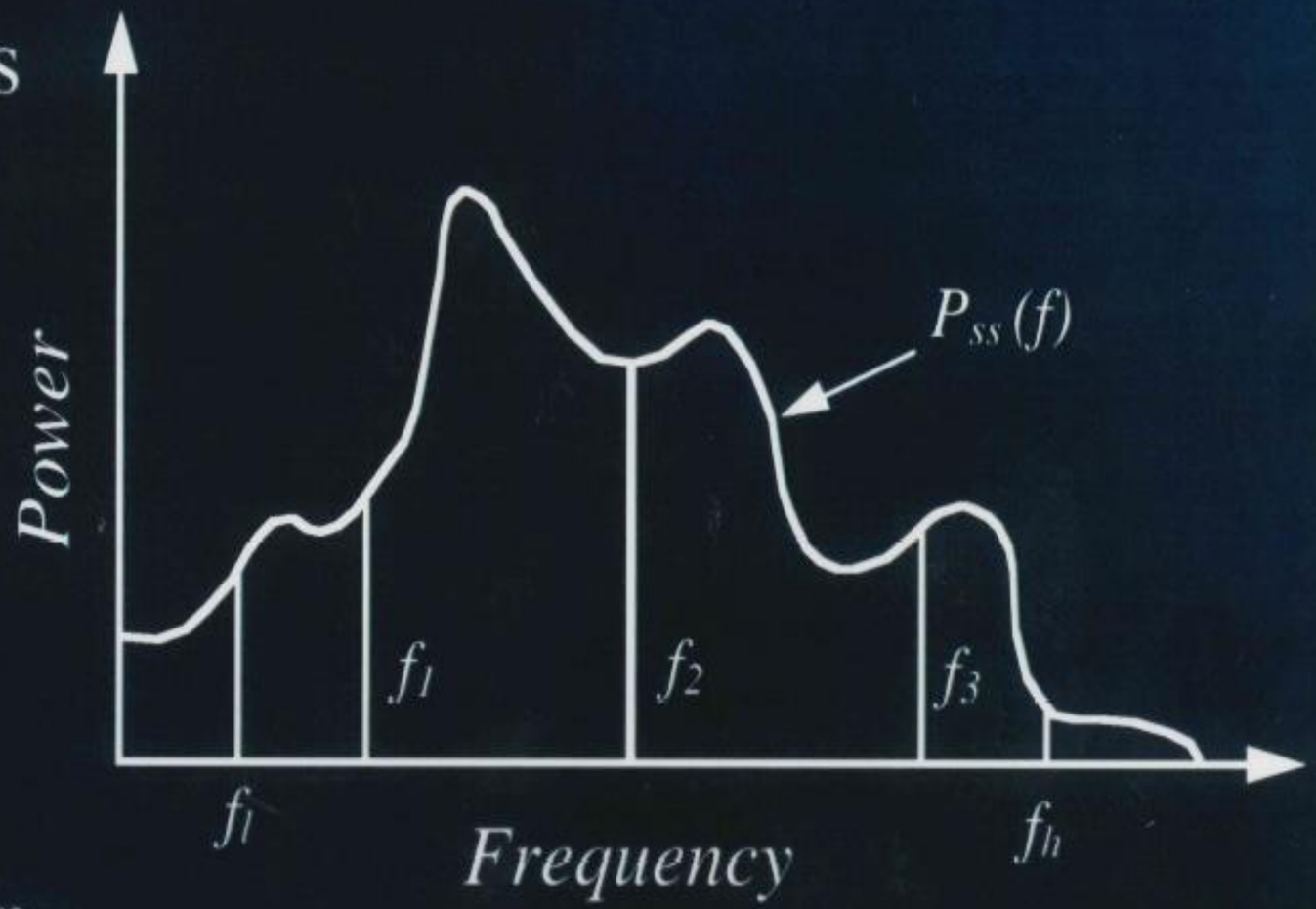
- Seismic attributes are used for the delineation of structural and stratigraphic features, hydrocarbon detection, pattern recognition, EOR, and reservoir monitoring
- Traditional seismic attributes are often insufficient to accurately meet the explorationists needs.
- We need to acquire additional meaningful seismic attributes
- We need to improve upon our techniques of estimating seismic attributes

Spectral Signatures

- Lithological
  - Tuning effects, e.g. pinch-outs
  - Time sagging due to changes in velocity or thickness
- Petrophysical
  - Attenuation (Generally gas attenuates more than oil more than water)

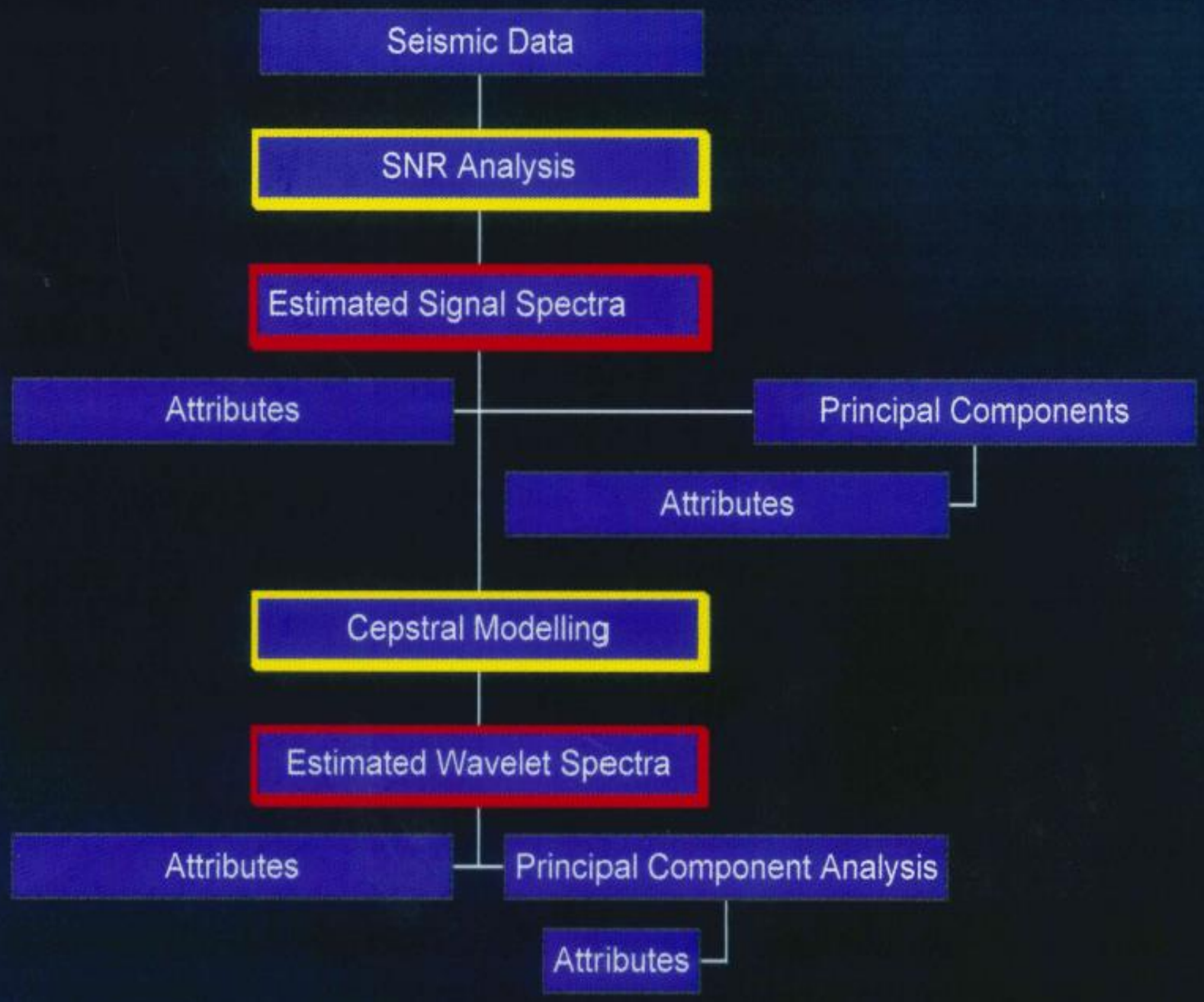
Spectral Attributes

- Quantile Frequencies
- Peak Tracking
- Spectral Ratio
- Bandwidth



E = Energy between *fl* and *fh*
q% of E = energy between *fl* and *f1*
50% of E = energy between *fl* and *f2*
(100-q)% of E = Energy between *fl* and *f3*

Spectral detection of lithologic changes and seismic attenuation (*Spectra)*



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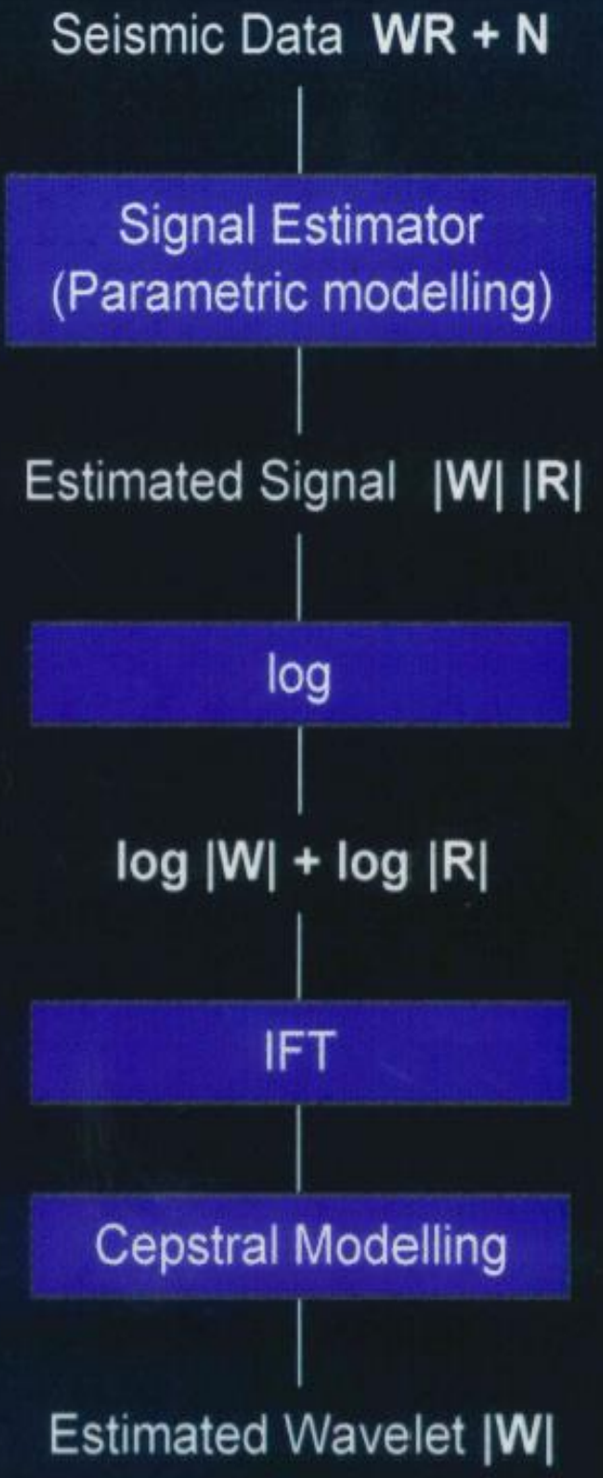
Signal and Wavelet Estimation



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Instantaneous Frequency vs. Spectra

Instantaneous Frequency

- Point-by-point calculations
- Sensitive to noise
- Physically meaningless (e.g. signal with more than one freq., -ve freq., etc.)

Spectra

- Uses a time window (interaction of events)
- Robust to noise
- Physically meaningful

AVO vs. Spectra

AVO

- Point-by-point
- Sensitive to noise
- Sensitive to AGC, NMO, decon and demultiple
- Requires good resolution seismic data
- Sensitive to dips

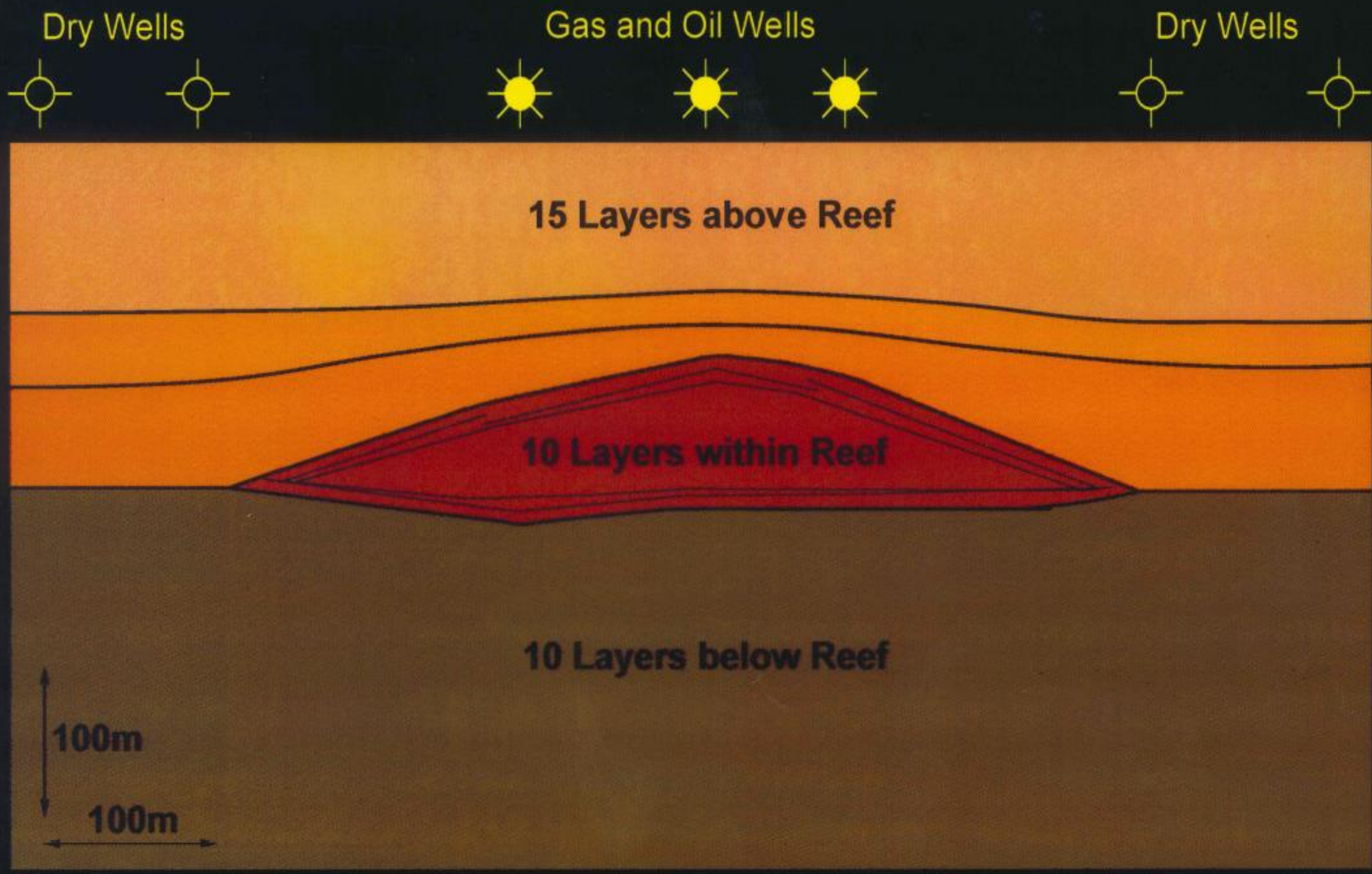
Spectra

- Uses a time window
- Robust to noise
- Robust to AGC, NMO, decon and demultiple
- Can work for thin reservoirs
- Works in dipping environments

Examples

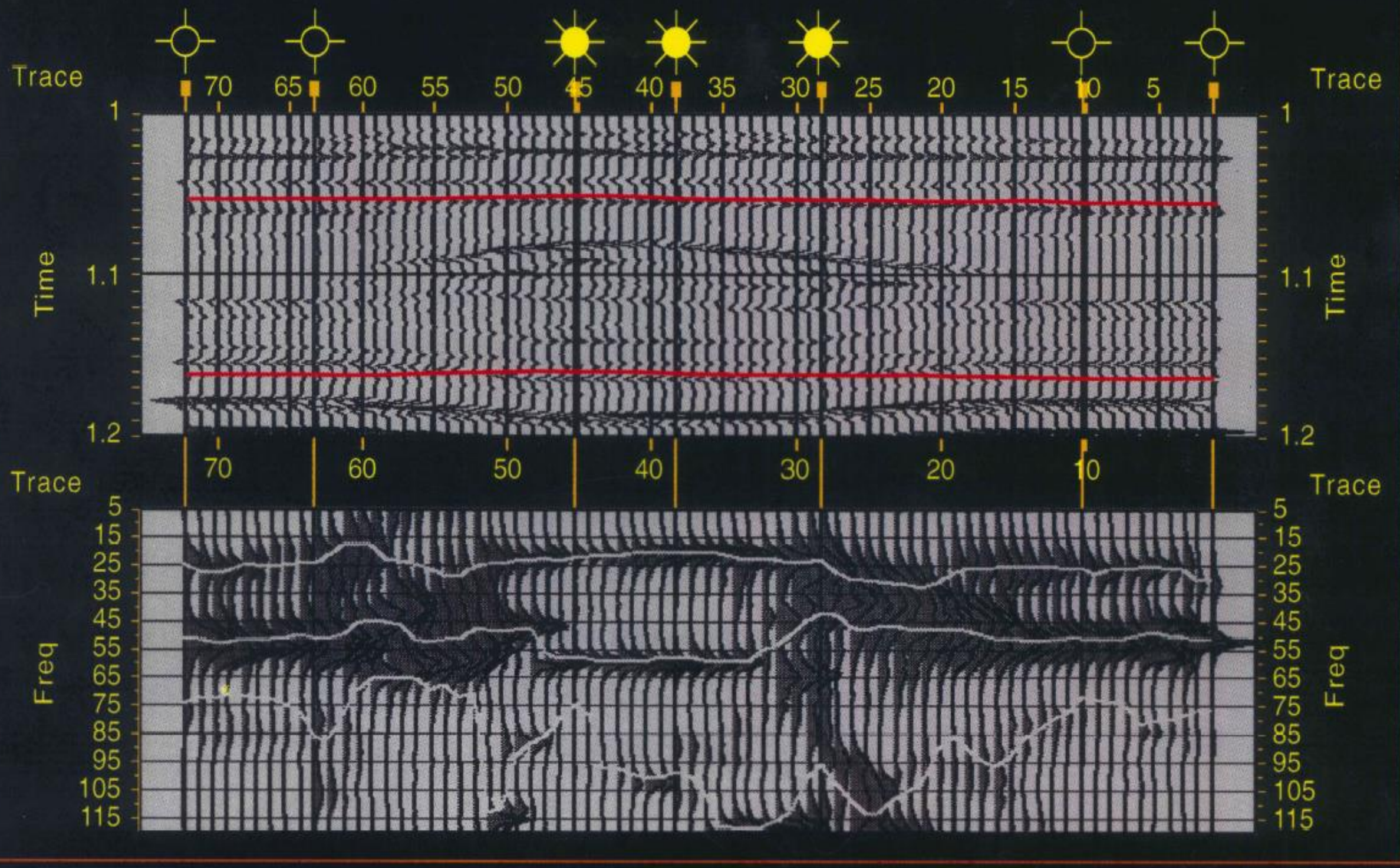
- Middle Devonian Pinnacle Reef (synthetic) Western Canada
- Upper Devonian Pinnacle Reef (real data) Western Canada
- Triassic Channel Sand (real data) Western Canada
- Early Cretaceous Deltaic Sand (real data) Western Australia

Geologic Cross Section



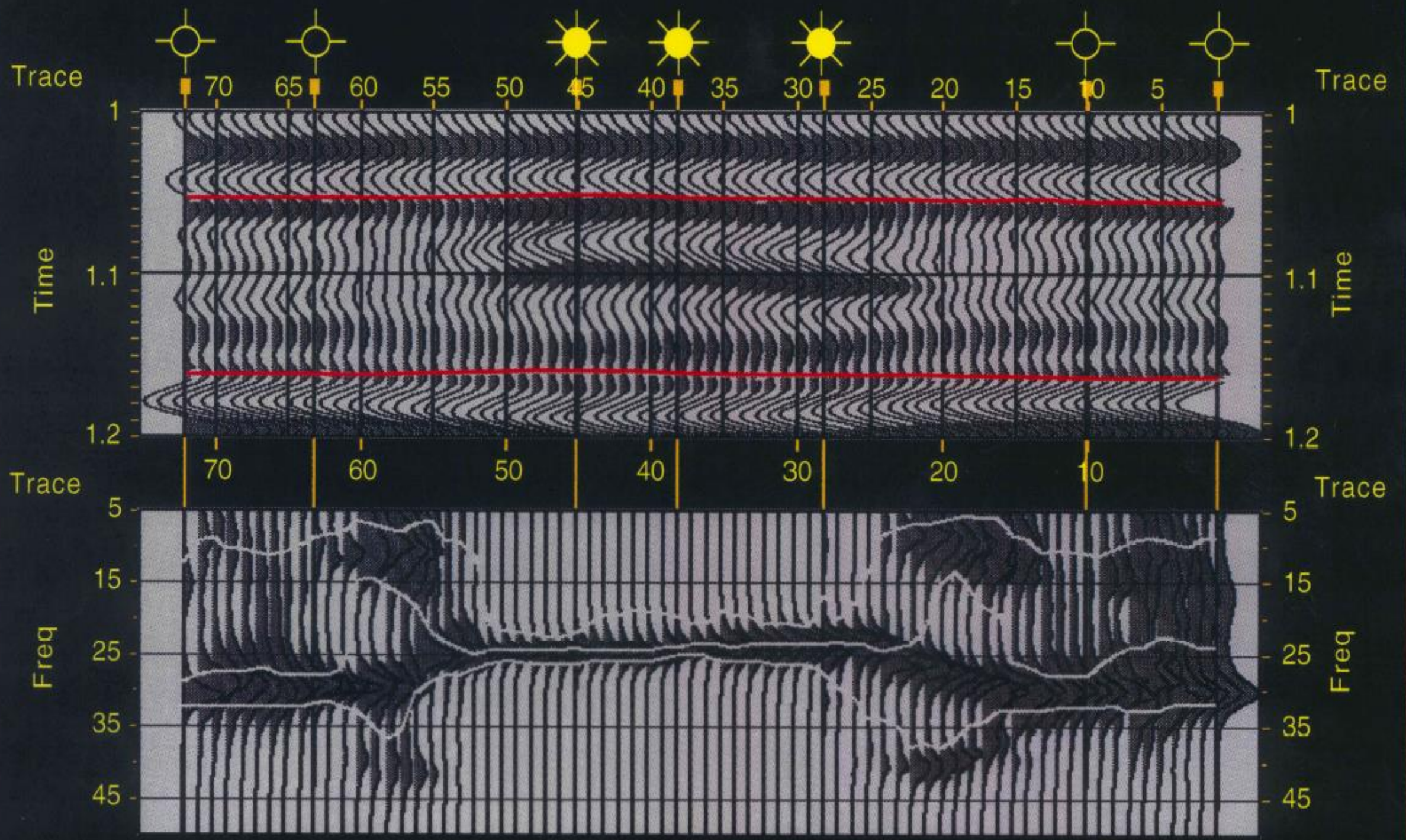
Middle Devonian Pinnacle Reef Model

Reflectivity and Spectra



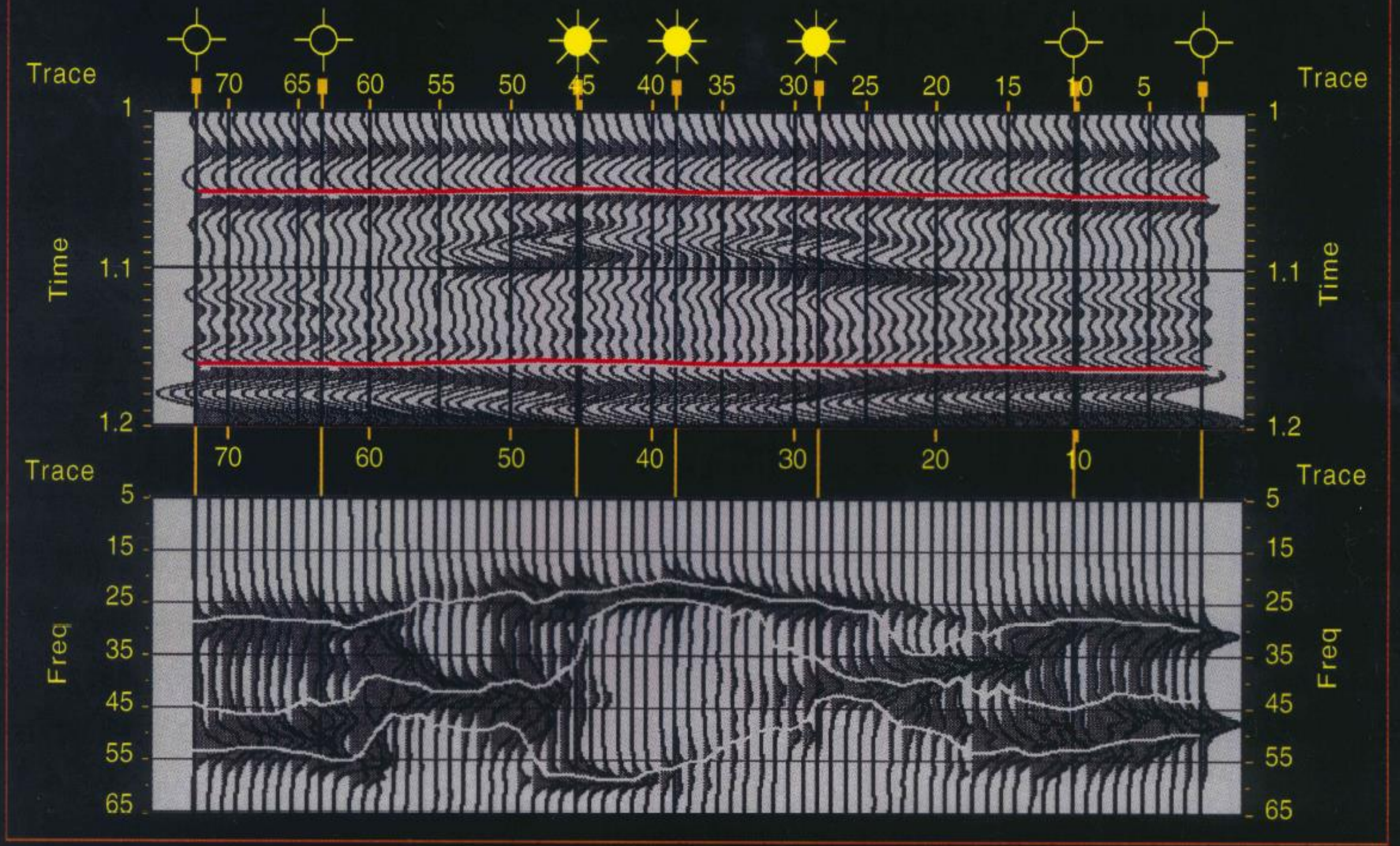
Middle Devonian Pinnacle Reef Model

20 Hz Ricker Wavelet and Spectra



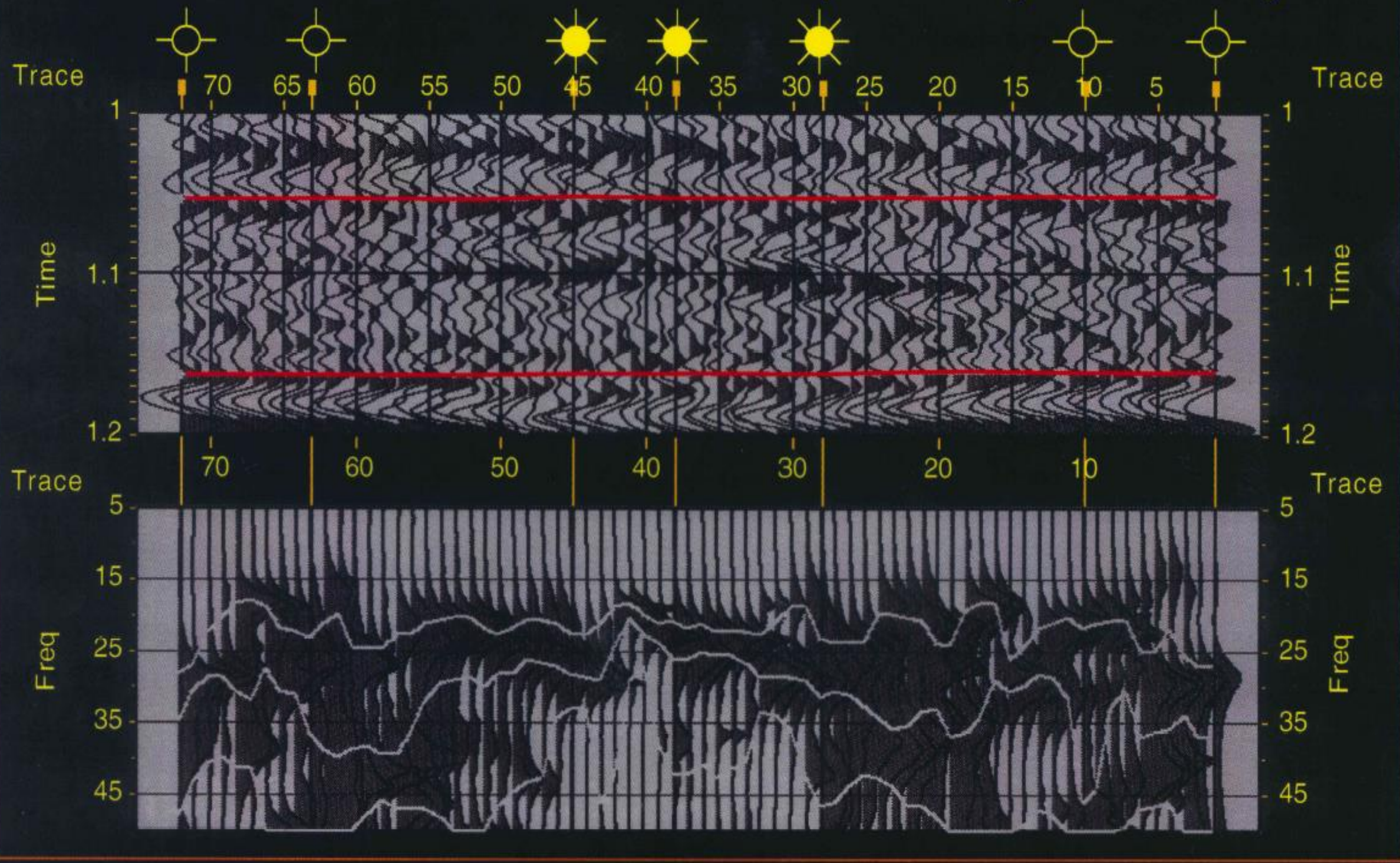
Middle Devonian Pinnacle Reef Model

35 Hz Ricker Wavelet and Spectra



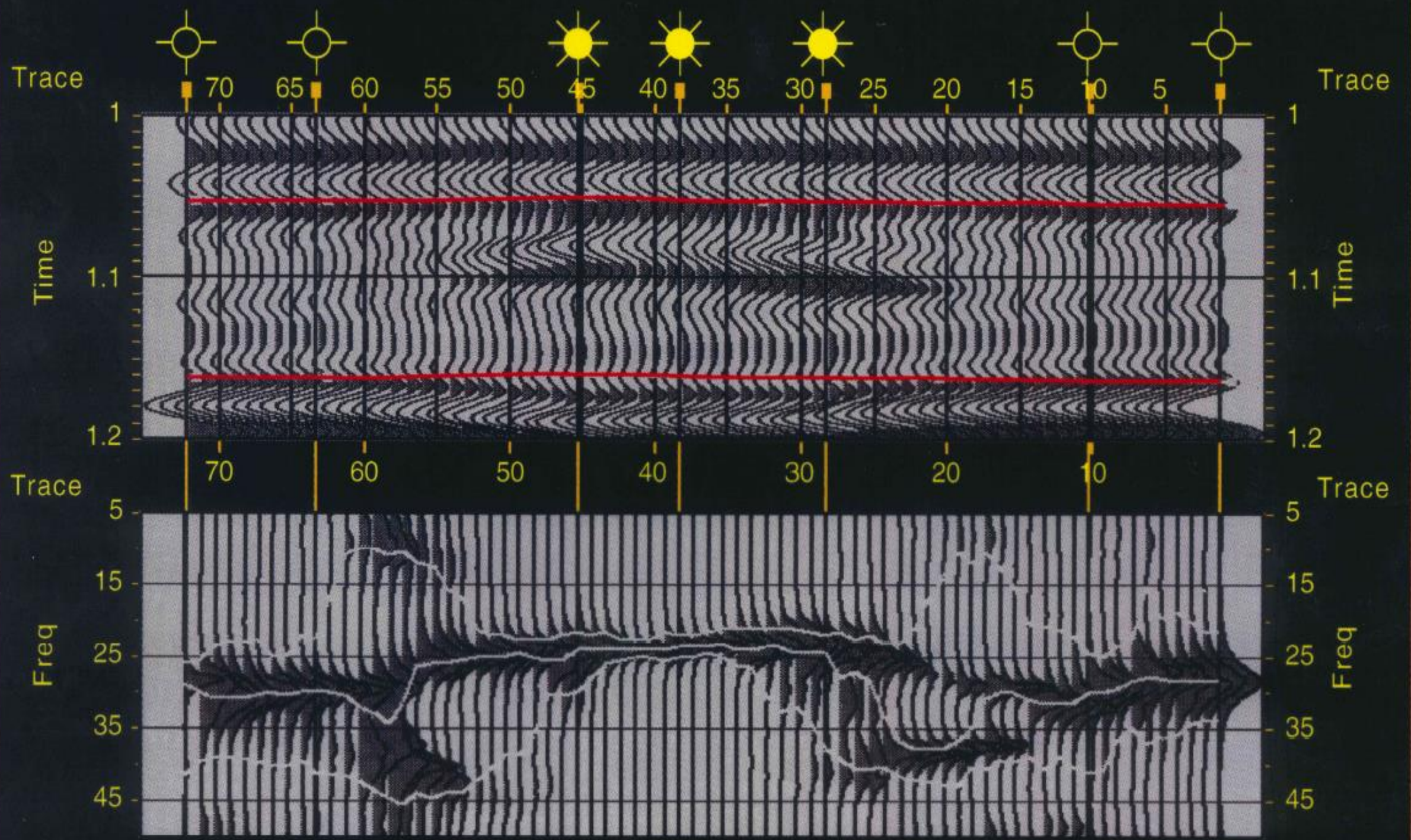
Middle Devonian Pinnacle Reef Model

25 Hz Ricker Wavelet and Spectra (SNR=0.1)



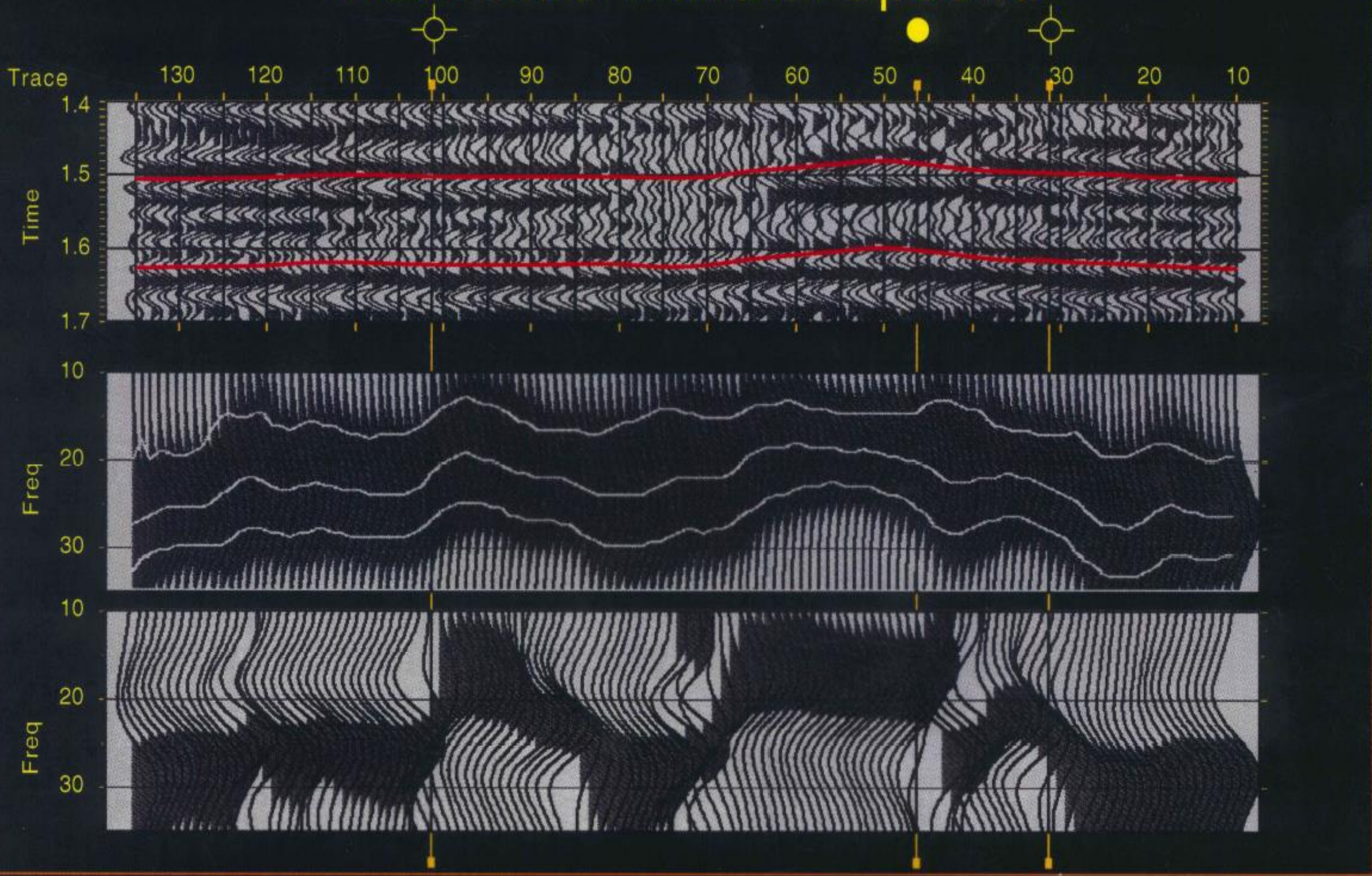
Middle Devonian Pinnacle Reef Model

25 Hz Ricker Wavelet and Spectra (Noise Free)

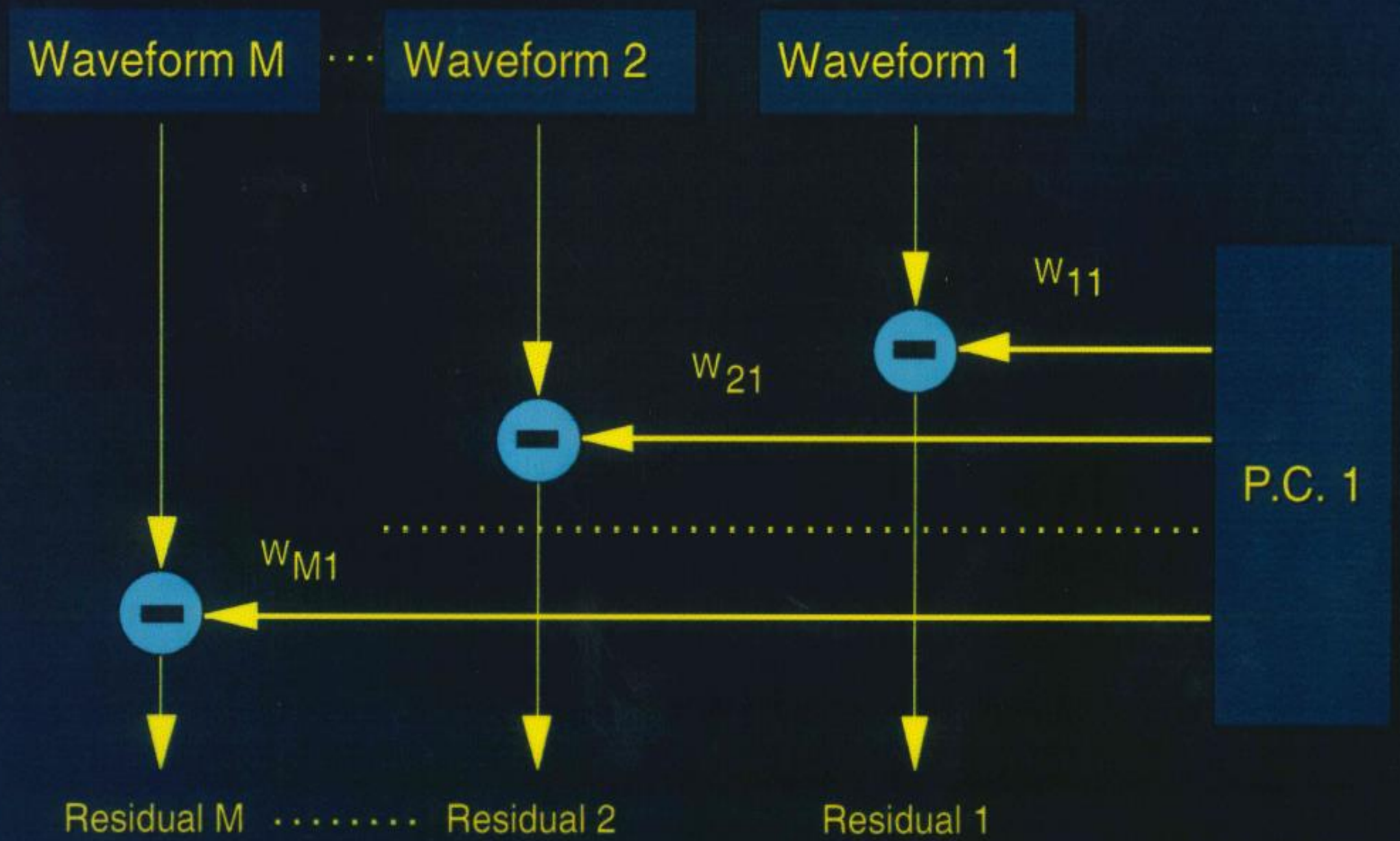


Upper Devonian Pinnacle Reef Example (Real Data)

Estimated Wavelet Spectra



A Schematic diagram of Principal Component Analysis
First Component



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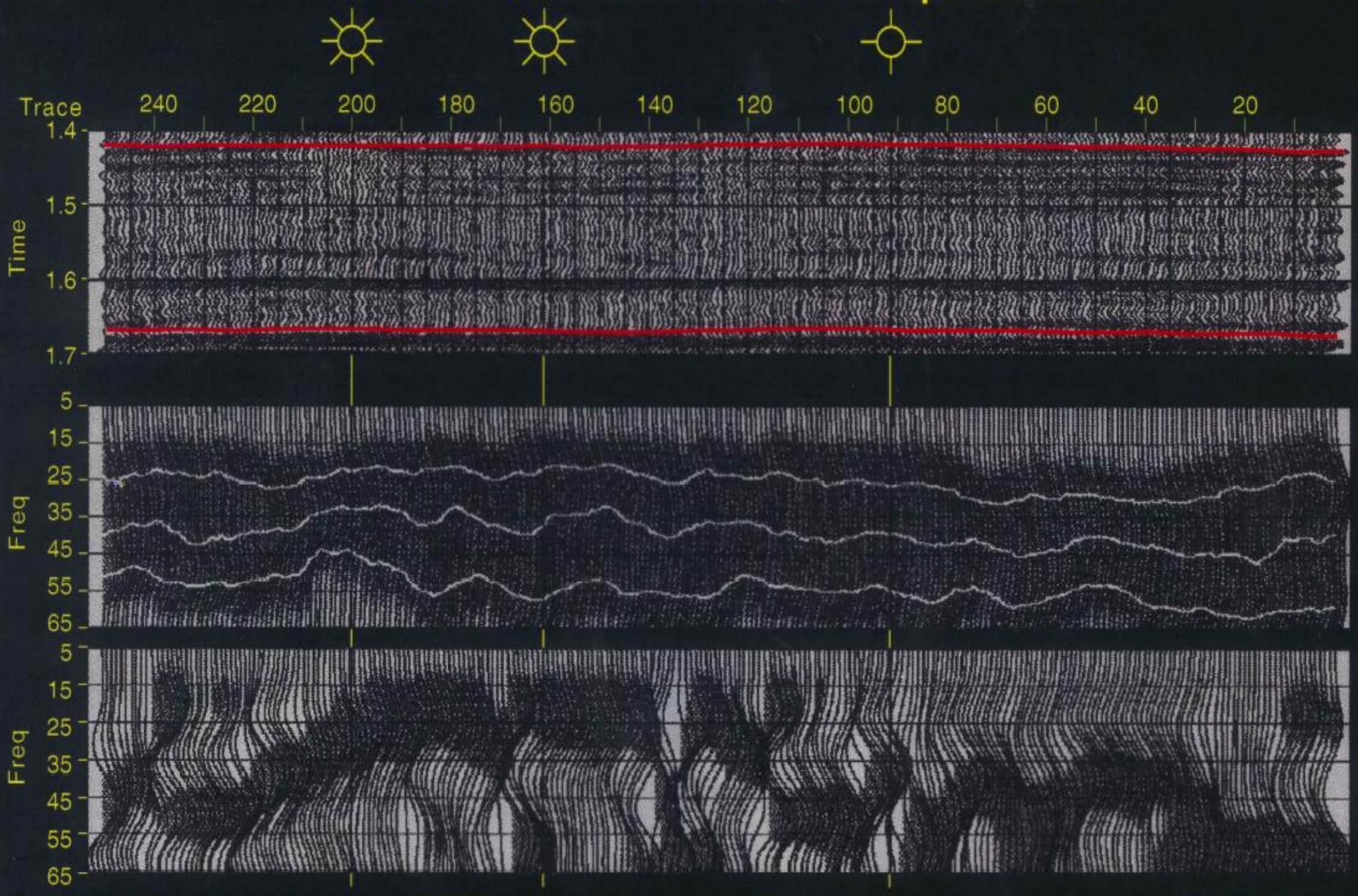
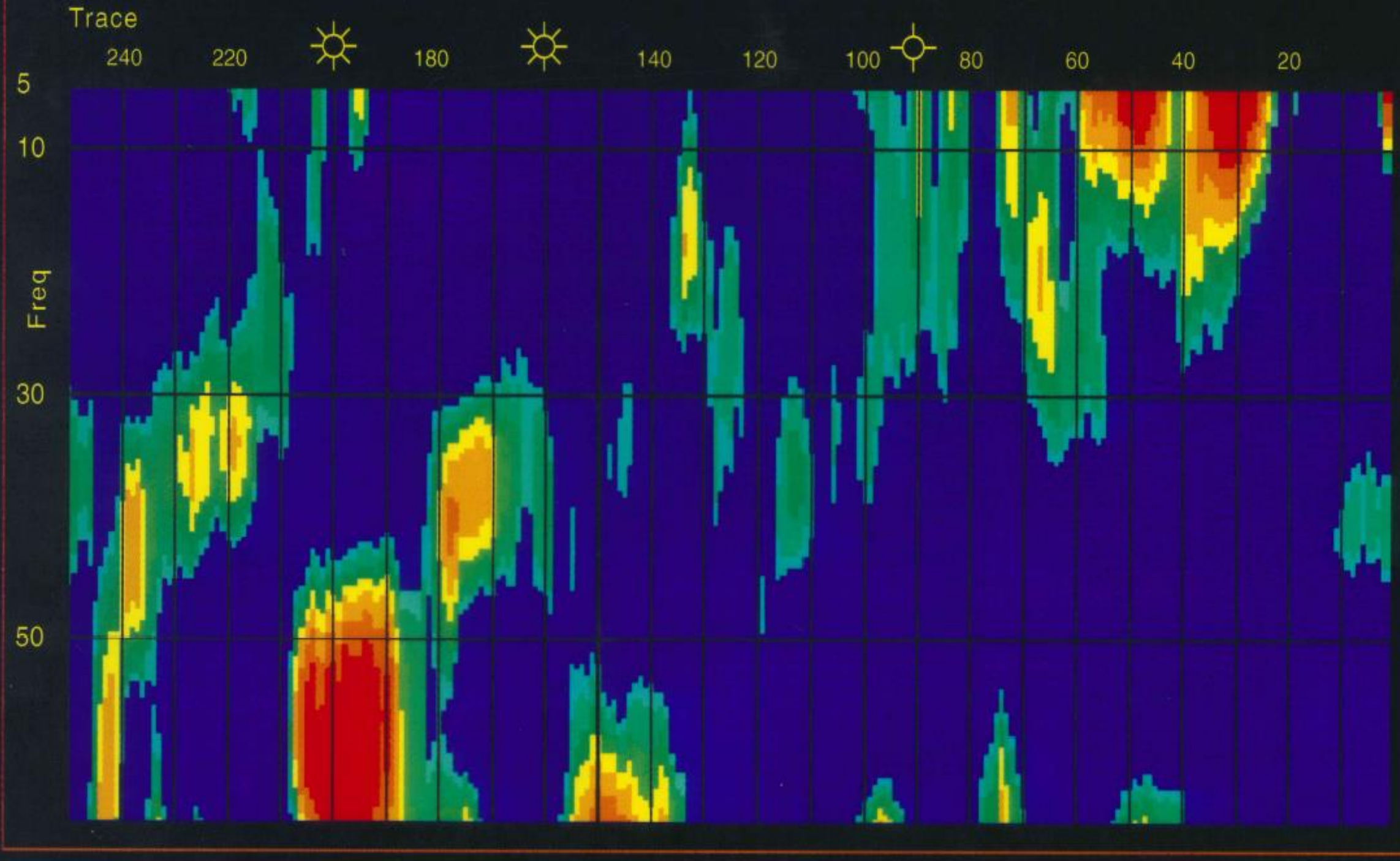
Triassic Sand Example Real Data

Estimated Wavelet Spectra



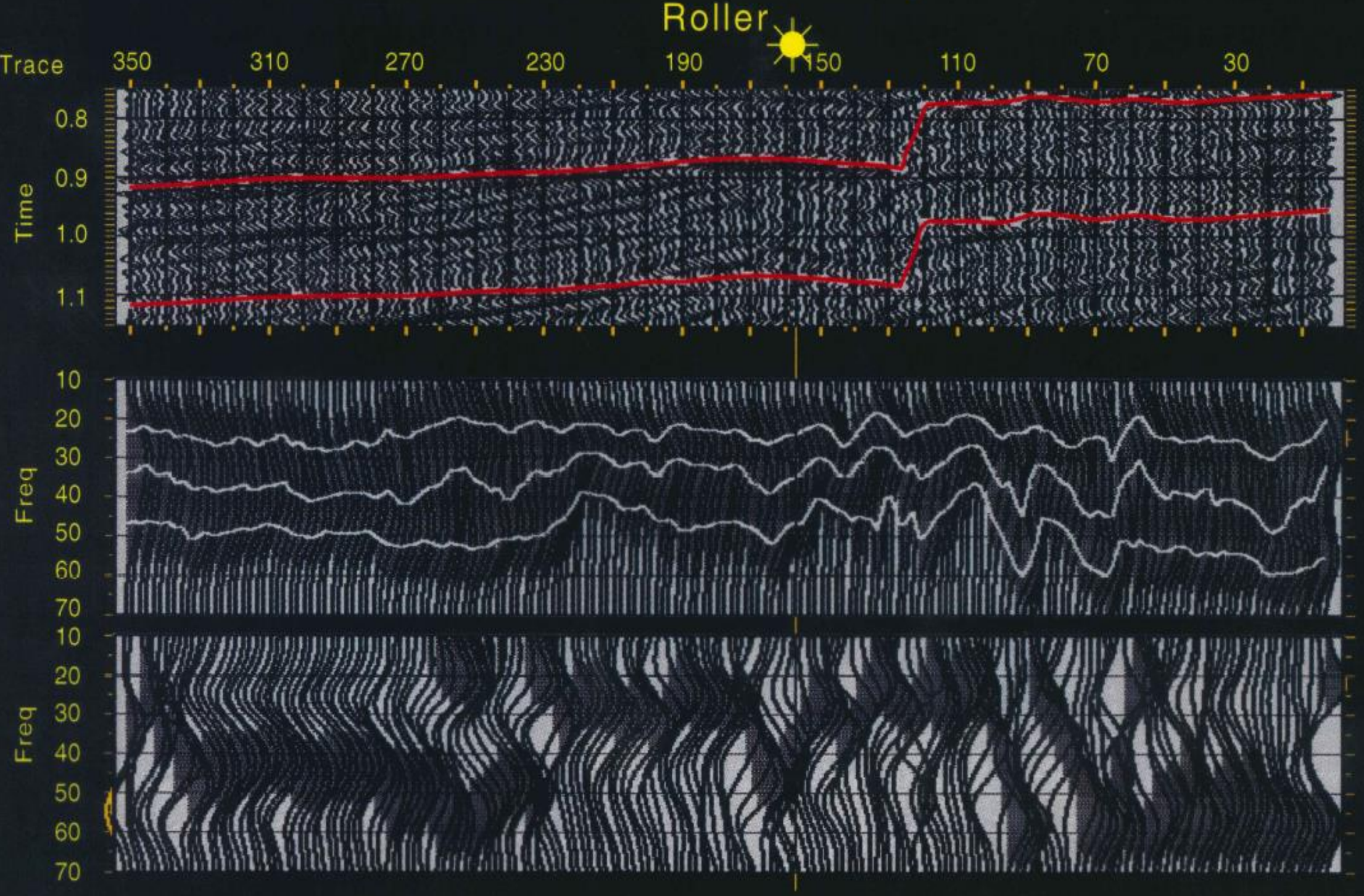
Triassic Sand Example

Normalised Attenuation Spectra



Base Cretaceous Deltaic Sand (Roller Field)

Estimated Wavelet Spectra

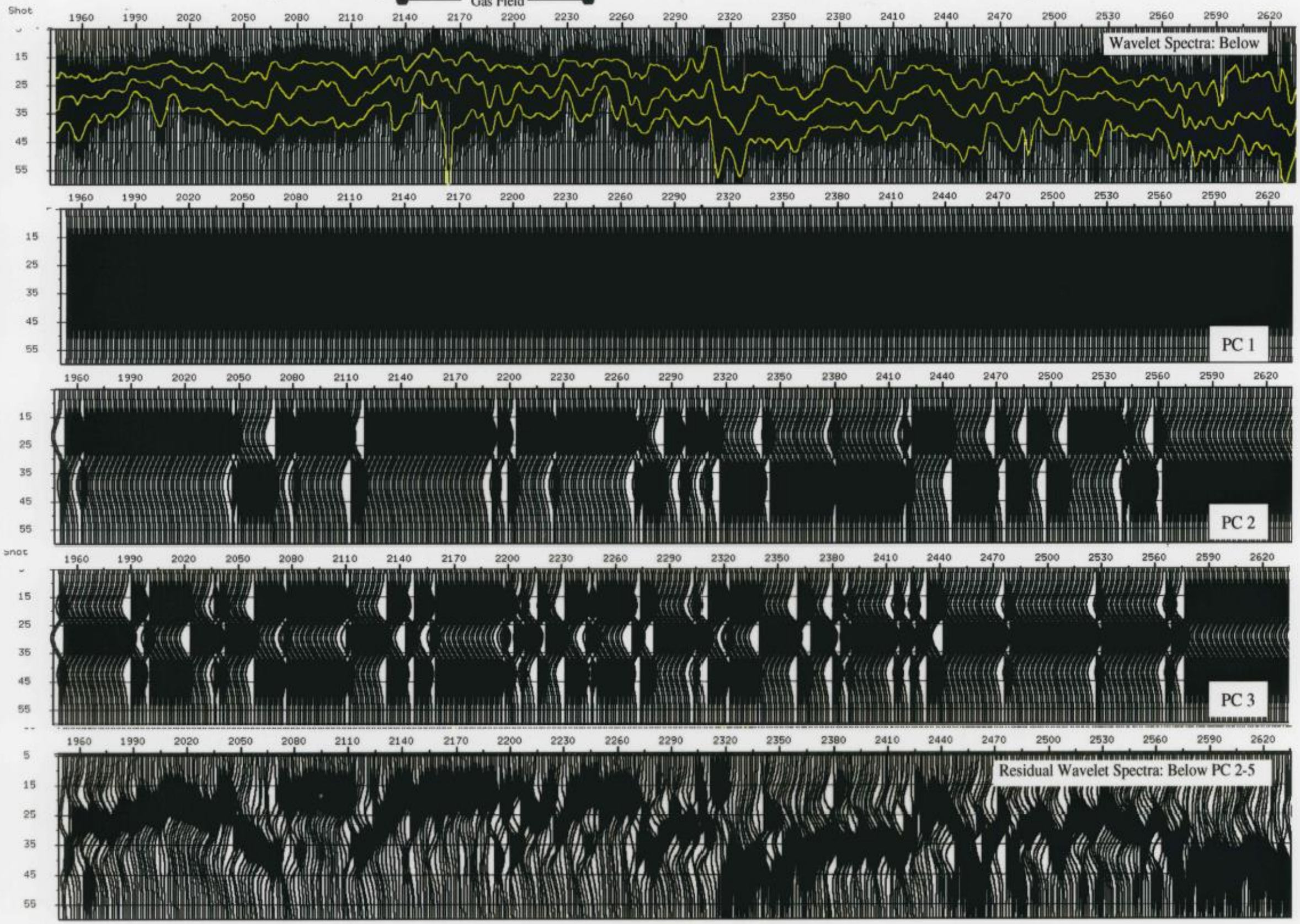


Conclusions

- We have outlined techniques for estimating the signal and wavelet spectra from noisy seismic data.
- Spectral analysis is an effective tool for the detection of lithologic changes and spectral attenuation associated with fluid saturated rocks
- Spectral attenuation can be used to detect hydrocarbon reservoirs whose thickness is below seismic resolution
- Spectral signatures contain useful seismic attributes which can make a significant contribution to the successful, evaluation and exploitation of hydrocarbons in a variety of geological settings

Principal Component Analysis: Estimated and Residual Wavelet Spectra

Gas Field



Western Australia

Estimated Wavelet Spectra