Seismic Amplitude Interpretation Course – GEOL 6393

University of Houston
June 18 – July 9, 2021

Professional Masters Degree Program
With Specialization in Petroleum Geology and Geophysics

Course Overview: "Seismic Amplitude Interpretation" A geophysical interpretation of a seismic anomaly consists of two general components. One relates to the amplitude and the other to the spatial distribution of the anomaly. The interpretation of the amplitude validates the composition of the reservoir while the interpretation of the spatial distribution validates the structural and stratigraphic framework. This course deals with amplitude interpretation.

Course Objective: At the end of the course, the participant should be able to

- include well-log curves in seismic interpretation
- recognize hydrocarbon signatures in different rock-property environments
- model and interpret Amplitude Variation with Offset (AVO) synthetics
- model seismic rock properties as a function of porosity, rock type, pore fluid
- estimate reservoir rock type and pore fluid
- conduct an AVO interpretation for reservoir characterization

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Textbook and Notes:
Hilterman, F., 2001, Seismic Amplitude Interpretation: Society of Exploration Geophysicists 2001 - Distinguished Instructor Short Course (DISC). Additional PDF handouts provided.

Supplement PDF articles: Geophysics, Geophysical Prospecting, The Leading Edge and First Break will be supplied.

Computer Programs:
Numerous EXCEL interactive programs will be distributed to compliment the 15 workshop exercises distributed throughout the lecture series. In addition, an AVO modeling program with fluid-substitution capabilities, numerous AVO cross plots, Zoeppritz plots, etc. will be given.

Time and Place:

Friday	1:00pm-6:00pm
Saturday	8:30am-5:00pm

Grades:
40% - Daily exams on reading assignments – ten short quizzes (5-10 minute)
50% - Final Quiz
10% - Class Participation

Schedule: Seismic Amplitude Interpretation Course

Saturday	June 18	Section 1 - Introduction
		Section 1 - Additional - Well-log Analysis
Friday	June 24	Section 1 - Additional - Well-log Analysis
		Section 2 - Rock Physics
Saturday	June 25	Section 3 - Seismic Reflection Amplitude
Friday	July 1	Section 3 – cont'd. Seismic Reflection Amplitude
		Section 4 - Recognizing Hydrocarbon Signatures
		Section 5 - "Quick-Look" Rules of Thumb
Friday	July 8	AVO Modeling Exercise
		Section 6 - AVO Slope and Intercept Attributes
Saturday	July 9	Section 6 - cont'd. AVO Slope and Intercept Attributes
		Section 7 - Case Histories
		Section 8 - Checklist & Final Comments – *Quiz Topics*
Wednesday	July 13	Final Exam 6-9 pm

Reading Assignment and Quizzes

Date Due	***DISC 2001 Book***	***CD_AVO Articles***	***5-Minute Quizzes***
June 18	DISC Sec. 1	**Handout 28**	1
June 24	DISC Sec. 2	**Handout 7**	2
June 25	DISC Sec. 3	**Handout 12**	3
July 1	DISC Sec. 3, 4, 5	**Handout 13, 17**	4, 5
July 8	DISC Sec. 6	**Handout 47, 22**	6, 7
July 9	DISC Sec. 6, 7, 8	**Handout 44, 49**	8, 9
July 13	Quiz		

Outline

Section 1 – Introduction

- Philosophy
- History
- Overview AVO Principles

Reading Assignment:

DISC '01: Sec 1

1. *Handout: Acquisition to Amplitude-vs-Offset (AVO)*
2. *Handout: Acquisition Pitfalls from 3D Geologic Structures*
3. *Koefoed, O., 1955, On the effect of Poisson's ratios of rock strata on the reflection coefficients of plane waves: Geophys. Prosp., **3**, p.381-387.*

28. Blau, L.W., 1936, Black magic in geophysical prospecting: Geophysics, 1, p.1-8.

Section 1 Additional - Well-Log Analysis

- Sedimentary rock properties
- Basics of well-log curves
- Well-log interpretation

Ex. Interpretation of typical well-log responses

Reading Assignment

4. *Handout: Chap 1 – Basic reservoir consideration*
5. *Handout: Chap 2 – Borehole measurements of reservoir properties*
6. *Handout: Well-log curves from typical environments*
7. *Handout: Welex: An introduction to well log analysis p.1-47*

Section 2 – Rock Physics

- Velocity and elastic constants
- Factors affecting velocity
- Velocity-density models
- Grain and pore-fluid properties
- Gassmann and pore-fluid substitution
- Velocity vs. porosity crossplot from seed point

Ex. Prog2_SW Pore-fluid substitution

Reading Assignment:

DISC '01: Sec 2

8. Wang, Z., 2001, Fundamentals of seismic rock physics: Geophysics, 66, p.398-412

9. *Smith, T., Sondergeld, C.H., and Rai, C.S., 2003, Gassmann fluid substitutions: A tutorial: Geophysics, 68,p. 430-440.*
10. *Batzle, M. and Wang, Z., 1992, Seismic properties of pore fluids: Geophysics, **57**, p. 1396-1408.*
11. *Greenberg, M.L., and Castagna, J.P., 1992, Shear-wave velocity estimation in porous rocks: Theoretical formulation, preliminary verification and applications: Geophys. Prosp., **40**, p.195-210.*

37. Krief, M., Garat, J., Stellingwerff, J., Ventre,J, 1989, A petrophysical interpretation using the velocities of P and S waves (Full-waveform sonic); Log Analyst, Nov-Dec, 355-369.

38. Mavko, G. and Mukerji, 1998, Comparison of the Krief and critical porosity models for prediction of porosity and VP/VS; Geophysics, Short Note, 63, p925-927.

39. Keys, R.G. and Xu, S., 2002, An approximation for the Xu-White velocity model; Geophysics, 67, No.5, p1406-1414.

45. Han, De-hua, Nur, A., Morgan,D., 1986, Effects of porosity and clay content on wave velocities in sandstones; Geophysics, 51, 2093-2107.

Section 3 – Seismic Reflection Amplitude

- 2D seismic amplitude pitfalls
- Normal-incident (NI) amplitude
- Synthetics: Well ties … Internal multiples
- Amplitude vs. bed geometry
  Ex. Prog4 Thin-bed modeling
- AVO equations and rock-property correlation
- Weak anisotropy
  Ex. Prog17 Attenuation Dispersion
- Workshops

Reading Assignment:

DISC '01: Sec 3

12. Widess, M.B., 1973, How thin is a thin bed? Geophysics, 38, p.1176-1180.

13. Ostrander, W.J., 1984, Plane wave reflection coefficients for gas sands at nonnormal angles of incidence: Geophysics, 49, p.1637-1648.

*14. Bortfeld, R., 1961, Approximation to the reflection and transmission coefficients of plane longitudinal and transverse waves: Geophys. Prosp., **9**,485-503.*

*15. Shuey, R.T., 1985, A simplification of the Zoeppritz equations: Geophysics, **50**, p.609-614.*

16. Handout: Sec 5. Forwarded Modeling Handout

Section 4 – Recognizing Hydrocarbon Signatures

- 1970 and 1990 hydrocarbon classification
- Class 1, 2, and 3 AVO field examples
- Hydrocarbon indicators – HCI
- AVO stratigraphic modeling

Reading Assignment:

DISC '01: Sec 4

17. Rutherford, S.R., and Williams, R.H., 1989, Amplitude-versus-offset in gas sands: Geophysics, 54, p.680-688.

18. Hilterman, F., Zhou, Z., and Ren, H., 2006 Seismic interpretation of water saturation based on reflectivity transforms: World Oil, April, p.121-129.

29. Liu, E. and Chapman, M., 2006, Applications of spectral decomposition for AVO analysis in the west of Shetland, 76th Annual International Meeting, SEG, Expanded Abstracts, 279-283

Section 5 - "Quick-Look" Rules-of-Thumb

- Crossplotting Shuey's equation
- GOM rock-property template
  Ex. AVO Modeling Salt vs. Gas
- AVO stratigraphic models

Reading Assignment:

DISC '01: Sec 5

19. Castagna, J.P., and Smith, S.W., 1994, Comparison of AVO indicators: A modeling Study: Geophysics, 59, p.1849-1855.

Section 6 – Reservoir Characterization

- Post-stack attributes
- AVO reflectivity inversion
- Reflectivity attributes
  - Calibrated Crossplots
  - Sensitivity analysis
  - Fluid factor (Horizon)
- Layer attributes
  - Acoustic impedance
  - Rock property inversion
  - Extended elastic impedance
- Sensitivity analysis GOM vs. SGB

Ex. TIPS – "Quick Look" AVO Calibration With Thin-Bed Modeling **AFTERNOON DAY 4**

Reading Assignment:

DISC '01:Sec 6

20. *Smith, G.C., and Gidlow, P.M., 1987, Weighted stacking for rock property estimation and detection of gas: Geophys. Prosp., vol. 35, p.993-1014.*
21. *Russell, B.H., Hedlin, K., Hilterman, F.J., and Lines, L.R., 2003, Fluid-property discrimination with AVO: A Biot-Gassmann perspective: Geophysics, vol.68, p.29-39.*
22. ***Connolly, P., 1999, Elastic impedance: The Leading Edge, vol.18, p.438-452.***
23. *Whitcombe, D.N., 2002, Elastic impedance normalization: Geophysics, vol.67, p60-62.*
24. *Whitcombe, D.N., Connolly, P.A., Reagan, R.L., and Redshaw,T.C., 2002, Extended elastic impedance for fluid and lithology prediction: Geophysics, vol. 67, p63-67.*
25. ***Simm, R., White, and R., Uden, R., 2000, The anatomy of AVO crossplots:The Leading Edge, Feb., p150-155.***
26. *Simm, R., Kemper, M., and Deo, J., 2002, AVOImpedance: A new attribute for lithology and fluid discrimination: Petex presentation, Dec. 12.*
27. *Latimer, R.B., Davison, R., and van Riel, P., 2000, An interpreter's guide to understanding and working with seismic-derived acoustic impedance data: The Leading Edge, March, p242-256*
31. Landro, M., 2001, Discrimination between pressure and fluid saturation changes from time-lapse seismic data; Geophysics, 66, no.3, 836-844.
32. *Cambois, G., 2000, AVO inversion and elastic impedance, 70th Annual International Meeting, SEG Expanded Abstracts.*
33. *Castagna, J.P., Swan, H.W., 1997, Principles of AVO crossplotting: The Leading Edge, April*
34. *Gray, D., 2005, Estimating compressibility from seismic data; 67th Conference and Exhibition. EAGE, Expanded Abstracts.*
35. *Lancaster, S. and Whitcombe,D., 2000, Fast-track 'colored' inversion, 70th Annual International Meeting, SEG Expanded Abstracts.*
36. *Gray, D., Elastic inversion for Lame parameters.*
40. *Gray, D., Goodway, B., and Chen T., 1999, Bridging the gap – using AVO to detect changes in fundamental elastic constants, 61st Mtg.: Europen Assn. Geosci. Eng., Session: 6050.*
41. *Russell, B. and Hampson, D., 1991, Comparison of poststack seismic inversion methods, Annual International Meeting, SEG, Expanded Abstracts, 876-878*

42. Quakenbush, M., Shang, B.,and Tuttle, C., 2006, Poisson Impedance: The Leading Edge, Feb., 128-138.
43. Fatti. J.L., Smith, G.C., Vail, P.J., Strauss, P.J., Levitt, P. R., 1994, Detection of gas in sandstone reservoirs using the Geostack: Geophysics, 59, 1362-1376.
44. Goodway, B., Chen,T., Downton, J.,1997,Improved AVO fluid detection and lithology discrimination using Lame petrophysical parameters; "$\lambda\rho$" and "$\mu\rho$" λ/μ fluid stack, from P and S inversions; 67th Annual International Meeting, SEG, Expanded Abstracts, 183-186.
46. Chaveste, Alvaro and Hilterman, F., 2007, Well-log inversion and modeling – A tool for understanding ambiguity and sensitivity of seismic data to changes in petrophysical properties; The Leading Edge, July, 812-817.
47. Verm, R. and Hilterman, F, 1995, Lithology color-coded seismic sections: The calibration of AVO crossplotting ro rock properties; TLE, 847-853.

Section 7 – Case Histories

- Class 3 – Lithologic identification
- Class 2 – Axis rotation and Crossplotting
- Class 2 – Lithostratigraphic and chronostratigraphic reflections
- Class 2 – Pore-fluid identification and anisotropic NMO
- Class 1 – Pore-fluid identification with anisotropic NMO and modeling

Reading Assignment:

DISC '01:Sec 7

30. Gonzalez, E.F., Mukerji,T., Mako, G., Michelena, 2003, Near and far P-to-S elastic impedance for discriminating fizz water from commercial gas; The Leading Edge, Oct., 1012-1015.
49. Foster, D., Keys, R., and Lane, D., 2010, Interpretation of AVO anomalies; Geophysics, 75, 75A3-t5A13

Section 8 – Final Comments with Check List and Future Expectations

- Summary of AVO procedure and checklist
- Future amplitude interpretations

Reading Assignment:

DISC '01:Sec 8

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