GEOPHYS 242: Near Surface Geophysical Imaging

Lecture Schedule: Mon, Wed, Fri (1:15 – 2:15pm), Mitch 452
Computer Lab: Location: Mitch 452; Time:
Instructor: Jie Zhang (Office: Mitch 401, Ph: 721-2421)

General:
This course is going to cover theories and applications of seismic methodologies for the near-surface imaging. It starts with fundamental seismic methods and leads to the high-end imaging technologies to address industry exploration problems.

Class 1: Introduction
Mon, April 4, 2011

- Near-surface geology and velocity structures
- Seismic wave propagation in the near-surface area
- Near-surface seismic statics corrections
- Review of seismic data processing workflow

This session starts with general introduction to near-surface problems, and reviews the theories of seismic wave propagation in the near-surface area. Since making near-surface statics corrections is the driving force for imaging the near-surface structures in the seismic industry, we shall review reflection seismic data processing workflow and understand the roles of near-surface imaging in the seismic data processing.

Class 2: Land and Shallow Marine Near-Surface Problems
Tue, April 6, 2011

- Rugged topography, large velocity variations, and hidden layers
- Review of near-surface imaging technologies and their assumptions
- Case histories of near-surface imaging

Review general problems in the near-surface areas, and the challenges for seismic imaging. We shall briefly review current geophysical imaging technologies available in the industry, and case histories worldwide. We will try to understand the reasons of maintaining many near-surface imaging technologies by studying the assumptions that they apply.

Class 3: Refraction Traveltime Interpretation
Fri, April 8, 2011

- Analytical refraction solutions for 1D velocity models
- Delay-time method, presentation by Mr. Chuck Diggins
- Generalized Linear Inversion (GLI)
- Review of commercial software solutions
- Examples of shallow geophysical imaging - presentation by Oz Yilmaz

This class introduces the conventional refraction traveltime methods for near-surface structure interpretation. These approaches produce layered models, appropriate for relatively simple velocity structures. Two influential approaches include delay-time method and generalized liner inversion method. Mr. Chuck Diggins designed and implemented a commercial version of delay-time solution for GMG (Fathom) and later for Renegade (Seismic Studio). Dr. Dan Hampson, President of Hampson-Russell, along with Dr. Brian Russell, developed GLI3D. These software solutions established the industry standards for the conventional near-surface imaging.

Class 4: First-Arrival Traveltime Tomography
Mon, April 11, 2011

- Wavefront tracing methods
- Inversion algorithms
- Model regularization
- Review of tomography case histories
- Near-surface problems and solutions, presentation by Dr. Lee Bell
- Computer exercise – process synthetic and real 2D data
- Program implementation – code a 2D wavefront tracer

From this class and later, we shall introduce high-end near-surface imaging technologies. This class shall focus on the traveltime tomography, look into the details inside this approach, and discuss key technical issues. We will also invite Dr. Lee Bell, Chief Geophysicist at Geokinetics, Stanford Alumni, former VP of WesternGeo, President of GeoSignal and GDC, to address the land and shallow marine near-surface problems in the United States. Students are going to process synthetic and real data by applying the traveltime tomography approach from a commercial software package TomoPlus. Students are also going to learn to implement a wavefront raytracing code. After learning a few tricks, students can realize how easy to code a raytracer!

Class 5: Refraction Migration Methods
Wed, April 13, 2011

- Migration versus tomography
- Refraction traveltime and wavefield migration
- The theory of interferometry
- Refraction wavefield interferometry
- Computer exercise – image synthetic data with interferometry

Seismic migration is mostly referred to subsurface imaging with reflection data. However, the idea can be also applied to refraction data. This class shall discuss the concepts of migration and tomography, their differences, and advantage and disadvantage of each approach. It also introduces the most recent development – applying interferometric approach to convert refraction data to "reflection data" and then to image the near-surface structures by applying migration to the converted "reflection data".

Class 6: Early-Arrival Waveform Tomography
Fri, April 15, 2011

- Acoustic- and elastic-wave equations
- Finite-difference wavefield simulation
- Signal processing and wavelet extraction
- Time-domain versus frequency-domain inversion strategy
- Computer exercise – invert synthetic waveform data

This class introduces a high-end imaging technology that is currently under research and development in academia and industry. Early-arrival waveform tomography is very promising in resolving hidden layers and complex velocity structures, and the computer capacity today is sufficient enough to deal with waveform tomography. This class shall offer a new commercial program that helps students to perform full wavefield modeling and waveform tomography.

Class 7: Surface Wave and Dispersion Curve Inversion Methods
Mon, April 18, 2011

- Global surface-wave studies, presentation by Prof. Rob van der Hilst (MIT)
- Review of shallow surface-wave applications
- Dispersion curve inversion, presentation by Dr. Fabian Ernst (Shell)

Surface-wave inversion is needed in the seismic industry to provide with near-surface shear-wave velocity structures for making statics corrections when processing converted-wave data. This technology has been widely explored in the global seismology for imaging the Earth, and consistent efforts have also been made for

shallow engineering applications. We shall invite a few experts in this area to review the technology, including Prof. Rob van der Hilst (MIT), and Dr. Fabian Ernst (Shell).

Class 8: Joint Seismic and Gravity inversions
Wed, April 20, 2011

- Benefits of joint geophysical inversion
- Joint inversion algorithm - tight versus loose constraints
- Gravity forward modeling and inversion
- Workflow and examples

Joint seismic and gravity inversion has been already applied in seismic industry for solving the near-surface problems. Inclusion of multiple geophysical data in inversion can provide more information about the earth structures. However, the inversion problems can be large and complicated. We shall discuss some practical approaches that can help us to address the issues.

Class 9: Short-Wavelength Residual Statics Corrections
Fri, April 22, 2011

- Refraction traveltime methods
- Refraction wavefield methods
- Reflection wavefield methods
- Computer exercise – calculate refraction traveltime residuals

Short-wavelength residual statics may not be able to be resolved through imaging. This class shall review the technologies for deriving residual statics after obtaining long-wavelength statics solutions. Students shall use a processing software package to derive residual statics, apply to data, and observe the differences in imaging due to residual statics corrections.

Class 10: Beyond Seismic Statics Corrections
Mon, April 25, 2011

- Skipping the near-surface by interferometry
- Common-Focus Point (CFP) method
- Dynamic corrections: wave-equation versus wavefield methods

This class introduces the most recent research topics in dealing with the near-surface problems in seismic imaging. Some of the methods are still in the research stage, but promising. We will also introduce alternative dynamic-correction approaches as opposed to statics-correction approach in handling the near-surface effects.