

Syllabus: Spring 2019
University of Wyoming Geol 4835/5835
Applied/Exploration Geophysics: 3 credits

Time and Place:

Mondays & Wednesdays: 9:00am-9:50am (50 min. lecture) Room 318

Tuesdays: 8:00am (50 min. lecture) Room 318

Fridays:

Either: Lab 8:00am-9:50am (1 hour 50min) (e.g. week 2, 11, 12).

OR 9:00-9:50am (a 50min lecture)

Room 318

or ESB1004 when there's a computer lab (e.g. week 3, 4 & 14).

Instructor: Dr. Mike Cheadle
Office: 221
Email: cheadle@uwyo.edu
Office Hours: Mon. Weds, Fri 10:00-11:00
Phone: 721-5082

Synopsis:

This course presents the fundamentals of **Seismic Refraction, Seismic Reflection, Gravity, and Magnetism** as used in Applied or Exploration Geophysics. It involves lecture, laboratory classes and discussion of case histories. The course provides a solid grounding about the exploration of the Earth's subsurface for mineral and hydrocarbon resources, and environmental issues.

Course Prerequisites: Junior or higher standing; Calc 1

Course Aims:

The aim of this course is to give you a sound knowledge of the fundamentals of three of the core subjects (seismics, gravity & magnetism) of Applied or Exploration Geophysics. The course will hopefully provide you with a solid grounding for a future career and/or future study and research into both how we explore the subsurface of the Earth for mineral and hydrocarbon resources and in the basic physics that we use to do this. Although the main application of exploration geophysics is in prospecting for natural resources, the methods are also used, for example, as an aid to geological surveying, as a means of learning more about the internal properties of the Earth and in environmental, engineering and archeological investigations.

The following exploration methods will be covered: **Gravity, Magnetism, Seismic Refraction, Seismic Reflection.**

However, the main emphasis will be on seismics, simply because seismics is the most extensively used technique, being routinely used by the oil industry in prospecting for hydrocarbons.

In every sub-topic I will try to teach you the physical principles, the methodology, how we interpret the data and how each method is used for different applications (I will try to make it fun & relevant! And I will also try to make the material relevant to the geology of Wyoming. For example, we will read geophysical papers about the crustal structure of Wyoming.). Knowledge of calculus, algebra & trigonometry will be required. In all cases we will try to use a minimum of mathematical complexity, but **we will be using math.**

Course Skills/Learning Outcomes:

To learn the ability to understand how geophysical data is collected and the ability to process and interpret it and to understand the limitations and non-uniqueness of the data. Basic computing and modeling skills.

Class Format:

The class will consist of either three 50min sessions per week **or** two 50min lectures and a 1 hour 50 minute lab. We will do at least 6 problem classes/labs to solve both paper-based exercises and computer-based exercises (see syllabus below) during the semester. Approximately 5 homework problem sheets will be issued during weeks without a lab. The best way to study for this course is to **attend the lectures and solve the problems!** Each lab or homework will be worth about 5% of your final mark. You will be able to discard the homework or lab. with the lowest mark. i.e. I will count your 10 best marks.

All problem sheets and labs and will be due one week after they have been set (late papers will not be accepted, without an excellent reason) and will be returned to you one week later.

Final Project: Around Spring Break, I will expect you to get into pairs and choose one paper from the list at the end of this syllabus. The papers are chosen to be interesting case studies using geophysical techniques. They range from academic to applied, and from archeology to paleontology. Each pair of students will give a 10 minute oral presentation in the final week as though they were the geophysicists who did the survey. You will explain the problem, the methods used and the results achieved. Each student will also independently provide a 1 page extended abstract on the case study.

Additional Requirements for Geol 5835

Graduate students taking the class at the '5000' level will be required to do an additional **independent project** as part of their studies. I will offer several possibilities, from which you can choose. Projects include:

- i) Interpreting a set of supplied geophysical data and working up a 'publishable' interpretation.
- ii) Writing a fully documented and usable computer program to process geophysical data
- iii) Local fieldwork projects using available geophysical equipment (magnetometer, gravimeter)
- iv) Project based on a literature review

Grading/Evaluation:

GEOL 4835 grading will be as follows:

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|---|-----|
| • Lab exercises/Problem sheets | 50% |
| • Mid-term exam (gravity and magnetics, seismics) | 20% |
| • Final Project | 10% |
| • Final exam (seismics) | 20% |

GEOL 5835 grading will be as follows

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|---|-----|
| • Lab exercises/Problem sheets | 40% |
| • Mid-term exam (gravity and magnetics, seismics) | 20% |
| • Final Project | 5% |
| • Final exam (seismics) | 20% |
| • Independent Project | 15% |

Attendance and Absence policies:

Students are expected to attend every class unless you have an acceptable reason. Experience shows poor attendance will lead to a poor grade.

What Is Expected of You:

- Regular attendance and alert participation. This class will work best if you participate in the labs and do the problem sheets and ask questions!
- Relax and have some fun with the topics in this class. This is useful stuff! The goal is for you to gain a fundamental understanding of some of the most useful geophysics and to learn how to use that geophysics to explore the subsurface of the Earth.

What You Can Expect of Me:

- I will provide lab exercises, and supplementary lecture material (photocopies of key papers and summaries) and help stimulate discussions during class.
- I will be accessible and will always be happy to answer your questions during class, during office hours, and by appointment.
- I would very much like your feedback on how this new course is progressing. The University will perform a formal evaluation at the end of the semester.

If you have a physical, learning, or psychological disability and require accommodations, please let one of us know as soon as possible. You will need to register with, and provide documentation of your disability to, University Disability Support Services (UDSS) in SEO, room 330 Knight Hall, 766-6189, TTY: 766-3073.”

A&S - Students and Teachers Working Together:

Classroom Behavior Policy:

At all times, treat your presence in the classroom and your enrollment in this course as you would a job. Act professionally, arrive on time, pay attention, complete your work in a timely and professional manner, and treat all deadlines seriously. You

will be respectful towards you classmates and instructor. Spirited debate and disagreement are to be expected in any classroom and all views will be heard fully, but at all times we will behave civilly and with respect towards one another. Personal attacks, offensive language, name-calling, and dismissive gestures are not warranted in a learning atmosphere. As the instructors, we have the right to dismiss you from the classroom, study sessions, electronic forums, and other areas where disruptive behavior occurs.

Electronic devices such as mobile phones should be set to silent or turned off. Laptops are, allowed for note-taking purposes. No video or audio recording during class is allowed to protect the privacy of your fellow students.

Classroom Statement on Diversity:

The University of Wyoming values an educational environment that is diverse, equitable, and inclusive. The diversity that students and faculty bring to class, including age, country of origin, culture, disability, economic class, ethnicity, gender identity, immigration status, linguistic, political affiliation, race, religion, sexual orientation, veteran status, worldview, and other social and cultural diversity is valued, respected, and considered a resource for learning.

Disability Support:

The University of Wyoming is committed to providing equitable access to learning opportunities for all students. If you have a disability, including but not limited to physical, learning, sensory or psychological disabilities, and would like to request accommodations in this course due to your disability, please register with and provide documentation of your disability as soon as possible to Disability Support Services (DSS), Room 128 Knight Hall. You may also contact DSS at (307) 766-3073 or udss@uwyo.edu. It is in the student's best interest to request accommodations within the first week of classes, understanding that accommodations are not retroactive. Visit the DSS website for more information at: www.uwyo.edu/udss"

Academic Dishonesty

Academic dishonesty will not be tolerated in this class. Cases of academic dishonesty will be treated in accordance with UW Regulation 2-114. The penalties for academic dishonesty can include, at my discretion, an "F" on an exam, an "F" on the class component exercise, and/or an "F" in the entire course. Academic dishonesty means anything that represents someone else's ideas as your own without attribution. It is intellectual theft – stealing - and includes (but is not limited to) unapproved assistance on examinations, plagiarism (use of any amount of another person's writings, blog posts, publications, and other materials without attributing that material to that person with citations), or fabrication of referenced information. Facilitation of another person's academic dishonesty is also considered academic dishonesty and will be treated identically.

In other words, no cheating! This is an important aspect of scientific ethics. In this class you will have to quote or otherwise use material from various other sources. To avoid 'academic dishonesty' in this context, you will have to be careful to clearly distinguish between ideas that you have obtained from other sources, and ideas that you have generated yourself. In the course of class discussions, this will be a challenge that will be part of your responsibility in passing the course. Please note I expect you to use

outside sources, and that is fine as long as you do not say or even imply they are your own and not somebody else's ideas.

Duty to Report:

UW faculty are committed to supporting students and upholding the University's non-discrimination policy. Under Title IX, discrimination based upon sex and gender is prohibited. If you experience an incident of sex- or gender-based discrimination, we encourage you to report it. While you may talk to a faculty member, understand that as a "Responsible Employee" of the University, the faculty member MUST report information you share about the incident to the university's Title IX Coordinator (you may choose whether you or anyone involved is identified by name). If you would like to speak with someone who may be able to afford you privacy or confidentiality, there are people who can meet with you. Faculty can help direct you or you may find info about UW policy and resources at <http://www.uwyo.edu/reportit>

You do not have to go through the experience alone. Assistance and resources are available, and you are not required to make a formal complaint or participate in an investigation to access them.

Student Resources:

CAMPUS RESOURCES

DISABILITY SUPPORT SERVICES: udss@uwyo.edu, 766-3073, 128 Knight Hall,
www.uwyo.edu/udss

COUNSELING CENTER: uccstaff@uwyo.edu, 766-2187, 766-8989 (After hours), 341
Knight Hall, www.uwyo.edu/ucc

ACADEMIC AFFAIRS: 766-4286, 312 Old Main, www.uwyo.edu/acadaffairs

DEAN OF STUDENTS OFFICE: dos@uwyo.edu, 766-3296, 128 Knight Hall,
www.uwyo.edu/dos

UW POLICE DEPARTMENT: uwpd@uwyo.edu, 766-5179, 1426 E Flint St,
www.uwyo.edu/uwpd

STUDENT CODE OF CONDUCT WEBSITE: www.uwyo.edu/dos/conduct

Course Texts

I will supply you with many handouts during the course of this class to supplement the class lectures. Consequently, you should only buy the course text if you want to. However, I do recommend the following texts as resource texts. I have not placed them on reserve in the Brinkerhoff Library for 24-hour loan, but will do so if that's best for the class as a whole.

Recommended Resource Texts: An Introduction to Applied and Environmental Geophysics, John M. Reynolds 2nd edition, Wiley-Blackwell, 2011. (Call number QC808.5.R49 2011).

*Note The Brinkerhoff Library also has the 1st edition
An Introduction to Applied and Environmental Geophysics, John M. Reynolds, Wiley, 1997. (Call number QC808.5.R49 1997).

Other Useful Texts: An Introduction to Geophysical Exploration (3rd Ed), P. Keary, M. Brooks and I. Hill, Blackwell Science, 2002. (Call number TN 269.K37)

*Note The Brinkerhoff Library also has both the 1st and the 2nd edition by just Keary & Brooks (same title: Call number: TN 269.K37) .

Basic Exploration Geophysics
E. Robinson & C. Coruh
Wiley, 1988. (Call number TN269.R54)

Introduction to Applied Geophysics
H. Robert Burger, Anne Sheehan & Craig Jones
Norton, 2006.

Schedule

- Week 1 (28 Jan). **Introduction to Course & Seismic Waves** (topics: types of seismic waves, velocities of rocks and fluids, attenuation, amplitudes, reflection, diffraction and refraction) (*Seismic waves Homework*)
- Week 2 (4 Feb) **Seismic refraction** (review: 2 and 3 layered case, reduced travel time plots, hidden and blind layers, faulted interfaces) (*Seismic Refraction Lab 1: Slope-Intercept interpretations of crustal refraction data in 318*)
- Week 3 (11 Feb) **Seismic refraction** (dipping and irregular layers. Amplitude modeling, lateral velocity gradients and worldwide results). (*Seismic Refraction Lab 2: Computer Modeling: Raytracing and Amplitude Modeling. In computer lab Rm 1004.*)
- Mike Away**
- Week 4 (18 Feb) **Seismic refraction ONLY CLASS ON FRIDAY** (*Seismic Refraction Lab 3: Modeling 2-D structures: computer lab. Rm 1004*)
- Week 5 (25 Feb) No class
- Week 6 (4 Mar) No Class
- Week 7 (11 Mar) No Class
- Week 8 (18 Mar) Spring Break. Choose a paper from the list at the end of this syllabus for your presentation in the final week. **Let me know via e-mail**
- Week 9 (25 Mar) **Seismic reflection** (Review, geometry of ray paths, NMO, dipping reflectors). Taught by Michelle Gess
- Mike Returns on the 2nd of April No class Monday 1st April**
- Week 10 (1 Apr) **Seismic reflection** (velocities and layer thicknesses, CDP gathers, stacking, velocity analysis) (*seismic reflection homework I*)
Students registered for GEOL 5835 to decide projects
- Week 11 (8 Apr) **Seismic reflection** (migration) (*Seismic reflection Lab 1: Migration in 318*) **Mid-term exam on seismics; Monday 8th April).**

- Week 12 (15 Apr) **Seismic reflection** Seismic Interpretation: Pitfalls) (*Seismic Reflection Lab 2: Seismic Interpretation of sedimentary basins in 318*)
- Week 13 (22 Apr) **Seismic reflection** ((Resolution, the Processing Sequence Sequence Stratigraphy). (*Seismic Reflection Homework II: various questions*)
- Week 14 (29 Apr) **Gravity.** (Elementary theory and the Geoid, Instruments and techniques Interpretation Methods) (*Gravity Lab 1: Indirect interpretation: Modeling of Gravity Anomalies, in the computer Lab*). (*Gravity Homework: various questions*)
- Week 15 (6 May) **Magnetics** ((Elementary theory and instruments Susceptibility, remanence shapes of magnetic anomalies, interpreting magnetic data). (*Magnetics Homework: various questions*) **Friday 10th May is course project day.** You will be expected to present the exploration geophysics paper you have chosen to read. You will give a 10 minute oral presentation as though you were the geophysicist who carried out the experiment. (You will also produce a 1 page executive summary). What was your objective? What techniques did you use? What results did you get? Should we hire you for future contracts?
- Finals Week (13 May) **Final exam (1 hour) on all material after the mid-term** (seismics (since the midterm), **gravity and magnetics**).
1 page executive summary due. Independent projects due for GEOL 5835

Substantive changes to syllabus:

All deadlines, requirements, and course structure is subject to change if deemed necessary by the instructor. Students will be notified in advance both verbally in class, and via email if any changes are needed. It is unlikely that there will be any substantive changes.

Applied Geophysics: Case Studies

1. Seismic Refraction

Assessing the integrity of a landfill site *

Carpenter, P.J., Calkin, S.F., and Kaufmann, R.S., 1991, Assessing a fractured landfill cover using electrical resistivity and seismic refraction techniques: *Geophysics*, **56**(11), 1896-1904.

Refraction studies of a Roman temple

Cadarelli, E., and Nardis, R., 2001, Seismic Refraction, isotropic anisotropic seismic tomography on an ancient monument (Antonio and Faustina temple AD141): *Geophysical Prospecting*, **49**, 228-240.

Crustal structure beneath Wyoming

Gorman, A.R., et al., 2002, Deep Probe: Imaging the roots of western N.America: *Canadian Journal of Earth Science*, **39**(3), 375-398.

3D seismic refraction travelttime tomography at a groundwater contamination site

Zelt, C.A., Azaria, A., & Levander, A. 2006 Imaging a palaeochannel beneath Hill Air Force Base. *Geophysics Volume 71 No 5 P H67-78*

Assessing the Critical Zone

K.M. Befus, A.F. Sheehan, M. Leopold, S.P. Anderson & R.S. Anderson, 2011; Seismic Constraints on Critical Zone Architecture, Boulder Creek Watershed, Front Range, Colorado; *Vadose Zone J.* 10:915.–927, doi:10.2136/vzj2010.0108

2. Seismic Reflection

Detecting gas in a laterally variable Formation.

Focht, G.W., and Baker, F.E., 1985, Geophysical case history of the Two Hills Colony gas field of Alberta: *Geophysics*, **50**(7), 1061-1076.

Diffraction Tomography to locate buried dinosaur bones *

Witten, A., Gillette, D.D., Sypniewski, J., and King, W.C., 1992, Geophysical diffraction tomography at a dinosaur site: *Geophysics*, **57**(1), 187-195. (Also see *Seismosaurus: The Earth Shaker*, by D. Gillette. Columbia University Press. Call Number QE862.S3 G56 1994.

Mapping Gas Hydrates

Lieven Naudts, Marc De Batist, Jens Greinert, and Yuriy Artemov, 2009. Geo- and hydro-acoustic manifestations of shallow gas and gas seeps in the Dnepr paleodelta, northwestern Black Sea *The Leading Edge, September 2009, v. 28, p. 1030-1040, doi:10.1190/l.3236372*

Geotechnical assessment of a shale diapir

Henriet, J.P., Vershuren, M., and Versteeg, W., 1992, Very high resolution 3D seismic reflection imaging of small-scale structural deformation: *First Break*, **10**(3), 81-88.

Surveying a proposed hazardous waste facility

Slaine, D.D., et al., 1990: Mapping Overburden stratigraphy at a proposed hazardous waste facility using shallow seismic reflection methods: In: *Geotechnical and Environmental Geophysics. Volume II-Environmental and Groundwater*, Tulsa(OK), Society of Exploration Geophysicists, 273-280.

Seismic Investigations in the Vicinity of the Great Sphinx of Giza, Egypt

Thomas L. Dobecki and Robert M. Stoch, 1992: Reflection & refraction surveys of the ground around the Sphinx, looking at weathering and for cavities: *Geoarcheology: An International Journal*, Vol 7., No.6, 527-544. And see <http://www.smithsonianmag.com/history-archaeology/Uncovering-Secrets-of-the-Sphinx.html>

Testing the confinement of waste injection wells

Zinni, E.V., 1995 Sub-surface fault detection using seismic data for hazardous-waste-injection well permitting: an example from St John the Baptist Parish, Louisiana, *Geophysics* vol 60, p 468-475

High-resolution seismic characterization in an urban area: Subway tunnel construction in Barcelona, Spain.

D. Martí, R. Carbonell, I. Flecha, I. Palomeras, J. Font-Capó, E. Vázquez-Suñé and A. Pérez-Estaún 2008. Traveltime seismic tomography used to aid subway tunnel drilling in Barcelona, Spain, provides a detailed characterization of the shallow subsurface, including a complex network of faults and dikes. *Geophysics* vol 73 no.2, pp B41-B50.

3. Gravity

Finding cavities in the great Pyramid

Lakshmanan, J. and Montlucon, J., 1987, Microgravity probes the Great Pyramid: *Geophysics: The Leading Edge of Exploration*, **6**(1), 10-17.

Locating Caves

Rybakov, M., Goldshmidt, V., Fleischer, L. and Rotstein, Y., 2001, Cave detection and 4D monitoring: A microgravity case history near the Dead Sea: *The Leading Edge*, **20**, 896-900.

Groundwater and Bedrock

Carmichael, R., and Henry, G., 1977, Gravity exploration for groundwater and bedrock topography in glaciated areas: *Geophysics*, vol. 42, no. 4, p. 850-859.

Monitoring CO₂ Sequestration

Håvard Alnes, Ola Eiken, and Torkjell Stenvold, 2008. Monitoring gas production CO₂ injection at the Sleipner field using time-lapse gravimetry *Geophysics*, November-December 2008, v. 73, p. WA155-WA161, doi:10.1190/1.2991119

Monitoring Volcanoes

Maurizio Battaglia, Joachim Gottsmann, Daniele Carbone, and José Fernández. 2008, 4D volcano gravimetry *Geophysics*, November-December 2008, v. 73, p. WA3-WA18, doi:10.1190/1.2977792

Time Lapse microgravity & Collapsing Houses

M.W. Branston and P. Styles, 2003. The application of Time-Lapse Microgravity for the Investigation and Monitoring of Subsidence at Northwich, Cheshire. *Quarterly Journal of Engineering Geology and Hydrogeology*, August 2003, v. 36, p. 231-244, doi:10.1144/1470-9236/03-243

4. Magnetism

Mineral Exploration

Ketola, M., (1979) On the application of geophysics in the indirect exploration for copper sulphide ores in Finland. In Hood, P.J. (ed), Geophysics and Geochemistry in the search for Metallic Ores, Geological Survey of Canada, Economic Geology Report 31, 665-684.

Archeology: (must do both papers)

von der Osten-Woldenburg, H., et al., 2002, Magnetic mapping of a Bronze Age tumulus in France before and during excavation: The Leading Edge, vol.21, no.5, p. 465- 466.

Carderelli, E., et al., 2002, Integrated geophysical surveys to investigate the Scarsella vault of St. John's Baptistry in Florence: The Leading Edge, vol.21, no.5, p. 467-470.

Finding unexploded bombs

Les P. Beard, William E. Doll, T. Jeffrey Gamey, J. Scott Holladay, James L.C. Lee, Nathan W. Eklund, Jacob R. Sheehan, and Jeannemarie Norton, 2008. Comparison of Performance of Airborne Magnetic and Transient Electromagnetic Systems for Ordnance Detection and Mapping J ENVIRON ENG GEOPHYS, September 2008, v. 13, p. 291-305, doi:10.2113/JEEG13.3.291

5. Multi-disciplinary

Chicxulub Impact Crater (Reflection and Gravity)

Hildebrand, A.R., et al., 1998, Mapping Chicxulub crater structure with gravity and seismic reflection data: In; Meteorites: Flux with Time and Impact Effects, Eds. M.M. Grady, R. Hutchinson, G.J.H. McCall and D.A. Rotherby, Geol. Soc. Spec. Publ., **140**, 153-173.

Determining the source of water for a national landmark (Gravity and Refraction)

Wolfe, P.J., and Richards, B.H., 1990, Geophysical Studies of Cedar Bog: In; Geotechnical and Environmental Geophysics. Volume II-Environmental and Groundwater, Tulsa(OK), Society of Exploration Geophysicists, 281-288.

Relating seismic damage to geological structure (Gravity and Refraction) Virginia & Karri

Alvarez, R., 1990, Structure of the Basin of Mexico City and its Relation to Destruction in the Earthquake of 1985: In; Geotechnical and Environmental Geophysics. Volume III-Geotechnical, Tulsa(OK), Society of Exploration Geophysicists, 263-280.

Exploring old waste sites (Refraction and magnetism)

Reynolds, J. M., 2002 The role of environmental geophysics in the investigation of an acid tar lagoon, Llwyneinion, North Wales, UK. First Break, vol 20, p 630-636.
For good quality pictures, you will need to get the paper copy from the library.