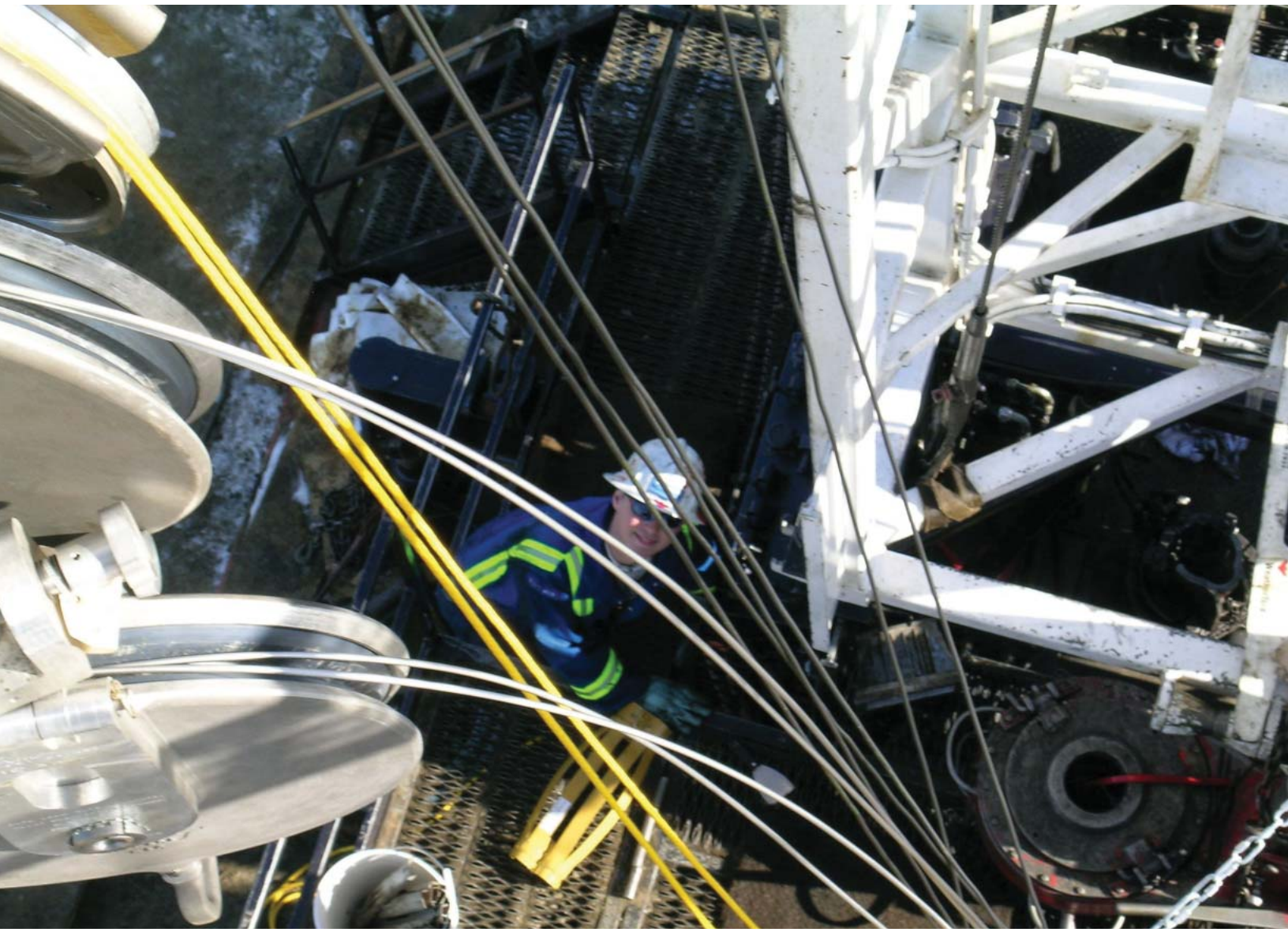
A Consortium Proposal by the

Allied Geophysical Laboratories

Full-wave Seismic Exploration for Reservoir Lithologies and Fluids

From Lab to Oilfield



Allied Geophysical Laboratories

University of Houston
Department of Earth and Atmospheric Sciences
312 Science and Research Building 1
Houston, Texas 77204-5007
Telephone: 713.743.3399
Facsimile: 713.748.7906

A Proposal Submitted to a Consortium of Companies by the

Allied Geophysical Laboratories (AGL) University of Houston

INVESTIGATORS:

ROBERT STEWART–AGL Director

JOHN CASTAGNA

EVGENI CHESNOKOV

GENNADY GOLOSHUBIN

DE-HUA HAN

FRED HILTERMAN

AIBING LI

CHRISTOPHER LINER

LEON THOMSEN

ROBERT WILEY

Allied Geophysical Laboratories

Institutional Approval by Anne Sherman, University of Houston Office of Grants and Contracts

Annual sponsor contribution	$45 000
Contract Period	June 1, 2009 – May 31, 2010

Summary

This proposal outlines plans for the research and educational efforts of the new Allied Geophysical Laboratory (AGL) at the University of Houston in 2009-2010. We invite potential sponsors of AGL to support and guide our quest to enhance the science of geophysics, develop aspiring scientists, and contribute to economic prosperity. The proposed program will be based on a number of data acquisition and analysis projects directed at improved imaging and analysis of subsurface reservoirs. Research will be driven by ideas and data: novel concepts about acquisition, wave propagation, and imaging in increasingly realistic media will be developed and tested via lab and field experiments. Existing advanced data sets, especially full-wave 3D seismic surveys, will be analyzed to provide improved description of reservoir rocks and fluids. Graduate student education is a key component of this effort.

Laboratory experiments

We will undertake a number of ultrasonic physical modeling experiments using our robotic surveying facility. These will include 3D VSP geometries, fracture zone traverses, rugose scattering, ocean bottom node simulations, and measurements through anisotropic media. We will investigate non-linear imaging concepts in porous fluid-saturated media under controlled lab conditions, including direct imaging of hydrocarbon movement and production through time-lapse models.

Field surveys and tests

AGL's field seismic capability is being expanded with GPS, well logging, VSP, and full-wave surface seismic systems, allowing us to conduct a variety of surveys and tests. We are particularly interested in unconventional resource rocks: shales, and low-porosity, low- permeability reservoirs. In addition, we have two field sites under development. The UH Coastal Field Station is 30 miles south of Houston and includes a producing oilfield. The Yellowstone Bighorn site in Montana is a structurally complex region proximal to oil production. In these and other areas, we intend to evaluate and compare planted geophones and land-streamers, analog and digital sensors, and microphones as auxillary sensors. Our goal is continued development of the technology and methods related to the full seismic wavefield recorded with multicomponent sensors in both land and marine settings. With sponsor collaboration and counsel, we propose to undertake a problem-driven field program addressing fundamental issues of data acquisition, subsurface imaging, and analysis.

Theory and processing

Analysis of field and lab data will drive development of custom algorithms while data preparation and processing will use the latest industry-standard tools. Development of theory and algorithms are of prime importance. Some of our topics of interest and focus include: fluid substitution effects, surface wave and reflectivity inversion, converted-wave analysis, microseismic monitoring, anisotropic wave propagation, seismic attributes, spectral characteristics, and time-lapse phenomena.

Personnel

Professor Robert Stewart (AGL Director) and co-investigators Drs. John Castagna, Evgeni Chesnokov, Christopher Liner, and Robert Wiley are delighted to welcome distinguished colleagues Drs. Gennady Goloshubin, De-hua Han, Fred Hilterman, Aibing Li, and Leon Thomsen as collaborators.

Goals, deliverables, and fees

A primary goal of AGL is the education and professional development of students. Looking forward, some 25 MS and PhD graduate students will be supported annually. Upon graduation, they will be ready for industrial and academic roles in geophysical acquisition, processing, interpretation, or research. Our scientific objective is to better understand and image the subsurface and thus, to enhance the discovery and recovery of resources. Deliverables from this work include ideas, lab and field data, software, reports, newsletters, courses, and presentations. The sponsorship fee for 2009-2010 is US $45 000.

Overview

Geophysical science and resource exploration begin with the acquisition of data. In the new Allied Geophysical Laboratory (AGL), we will start many of our studies with full wavefield generation and measurement. We plan to make measurements in three broad ways: (1) elastic wavefield computer simulation, (2) accurately scaled ultrasonic physical modeling in the lab, and (3) field acquisition over areas of resource interest. In addition, we anticipate collaboration with a number of our sponsoring companies and analysis of their existing data sets. These measurements will be processed through various standard and custom algorithms and procedures, then interpreted. On the other hand, we expect to develop novel ideas about wave propagation and imaging in increasingly complex materials that will be tested with actual experiments. Thus, our work is directed toward developing better seismic imaging techniques for new resource targets.

At the university, our mandate is multicomponent or 3C: Create, Conserve and Communicate knowledge. We might add to this Commercialization or transfer our results to receiving groups for application to problems of practical interest. Our role is somewhat complementary to that of the industry. We have educational and research responsibilities, in contrast to largely economic ones. Nonetheless, much of our research is naturally targeted toward problems and areas of current economic interest (Figure 1). Exciting resource targets in 2009 include those overlain by deep water (e.g., the Tupi, Brazil supergiant oil discovery) and hydrocarbons contained in shale (e.g., Bakken or Barnett), or low-permeability sandstone. Monitoring the hydraulic fracturing process or predicting where natural fractures occur continues to be a challenge as does following CO_2 enhanced oil recovery and sequestration.

The full-wave or multicomponent seismic method has much to offer for subsurface imaging and rock property estimation. However, full-wave seismology is more complex than simple acoustic imaging, thus grand challenges remain in improving data acquisition, developing more accurate processing methods, and interpreting the images more usefully. We advocate acquiring elastic (3C or 4C) seismic data whenever possible to advance lithologic and petrophysical aspects of reservoir assessment. Much of our ability to defect fluid movement depends on understanding the changes that a rock undergoes with fluid saturation. Thus, a major component of the project is attached to laboratory measurements on rocks and scaled models, computer simulations, and well log analysis. Acquisition and use of these richer data sets will also help students become familiar with their value and application.

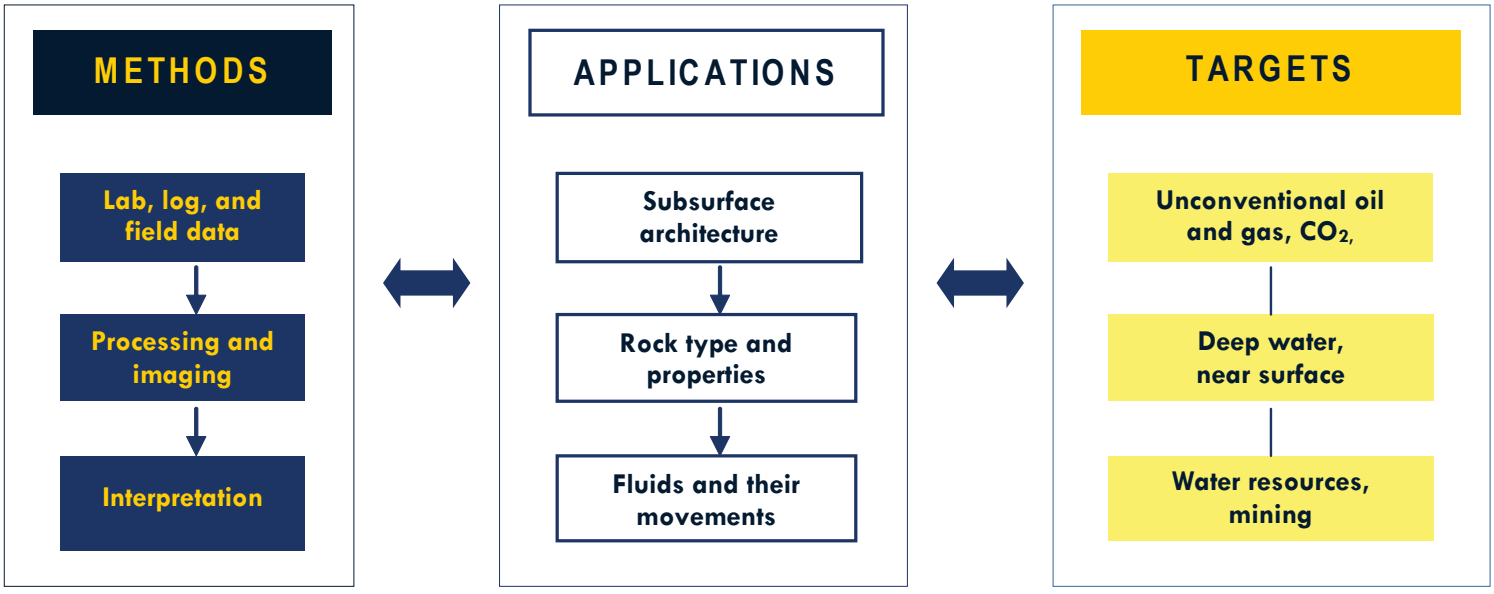


Figure 1.
Schematic overview of the elements of this proposal including methods, their applications, and specific resource targets

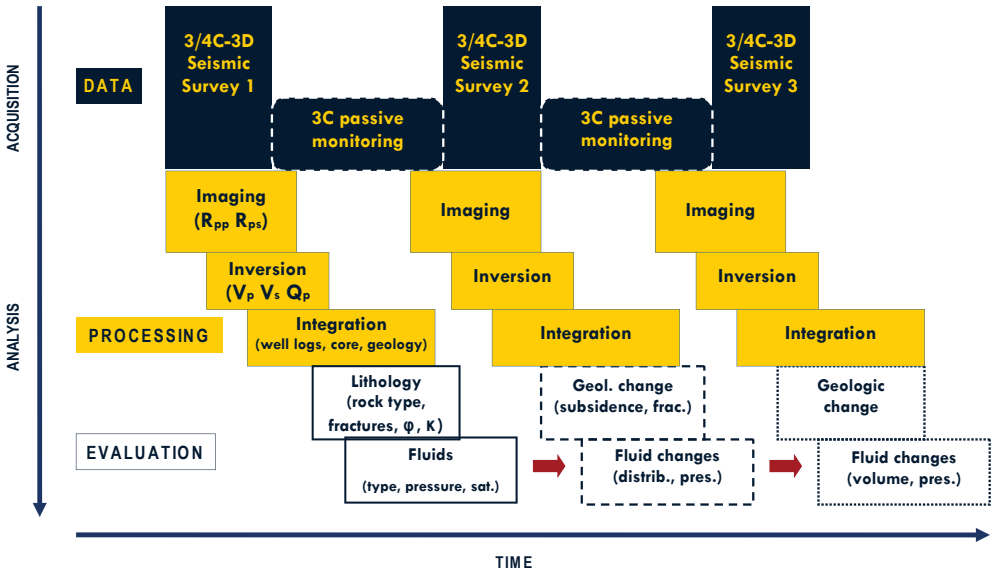


Figure 2.
Schematic diagram of full-wave seismic methodologies to assess reservoir rock and physical model properties, fluids, and their changes

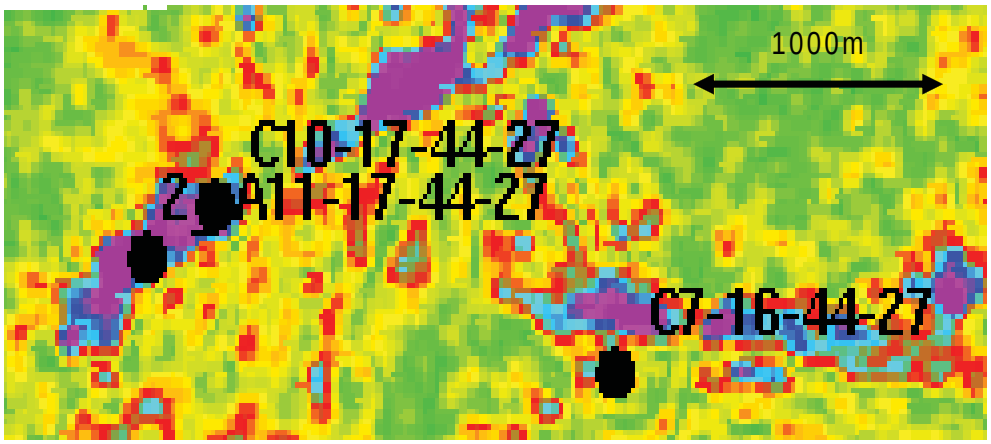


Figure 3.
Amplitude time slice from a 3C–3D seismic volume on a sand channel (Varga and Stewart, 2009, Delineating sand channels using 3C-3D seismic data, Manitou Lk. heavy oil field, Can. Soc. Expl. Geophys. Ann. Mtg.)

Going beyond the lab and logs, seismic methodology for subsurface imaging and monitoring is often divided into three broad categories: data acquisition, processing, and interpretation. As we believe that all three categories are intimately and inextricably connected, we will conduct research in all three areas. Seismic data are often first collected for exploration purposes, but then possibly repeated for reservoir development and management (Figure 2). Initially, the data are processed into a reflection image (to provide a band-limited subsurface architecture – see Figure 3) then, with supporting information, they may be analyzed further into pictures of estimated lithology and other properties. Integrating these images with follow-on survey results leads to indicators of geologic and fluid change. To this end, we will undertake time-lapse, full-wave experiments in the lab and field.

Most of the methodology that we are developing for imaging hydrocarbon reservoirs can be applied to making images of greenhouse or waste gases injected into the subsurface. We aspire to find improved ways of understanding gas emplacement and containment. Detecting and mapping water and its flows may be amenable to similar seismic methodologies. In fact, sophisticated seismic analysis has found significant application in the mining industry, especially as related to faults and aquifer flows.

The New Allied Geophysical Lab

The original Allied Geophysical Lab came to life under the tutelage of Dr. Fred Hilterman some 30 years ago. It was founded by associating disparate exploration-related projects: physical modeling, well log analysis, seismic data processing, and interpretation. In the following years, AGL made outstanding contributions to exploration geophysics while educating generations of students. We intend to return to some of the AGL's geophysical roots, but with energetic new growth. The new AGL will focus on experimental geophysics and associated theory, data assessment, and application. We plan to carefully collect and thoroughly analyze a wide variety of geophysical data, from the lab to field scale. The Department of Earth and Atmospheric Sciences at the University of Houston is broadly expanding its geophysical capabilities with the recent hiring of four geophysics professors: Evgeni Chesnokov, Christopher Liner, Robert Stewart, and Leon Thomsen. Dr. Stewart was appointed as Director of AGL and Drs. Castagna, Chesnokov, Liner, and Wiley are co-investigators. Collaborators include Drs. Gennady Goloshubin, De-hua Han, Hilterman, Aibing Li, and Thomsen. These individuals and their students bring a wealth of experience and expertise to AGL efforts. As part of a presidential initiative, the university intends to hire further geophysics faculty in the coming months. We anticipate that some will undertake joint projects with AGL personnel.

Research Personnel and Expertise

The AGL group of experienced and enthusiastic geophysicists are uniquely suited to the challenge of lab-to-field experimentation, analysis, and application. They are committed to working together as a team and advancing the field of exploration geophysics. Their backgrounds and general areas of expertise are outlined below.

Investigator	General expertise
Robert Stewart PhD, Massachusetts Institute of Technology Chevron, ARCO, Veritas, University of Calgary	Borehole geophysics (well logging, VSP, crosswell analysis), multicomponent seismic methods
John Castagna PhD, University of Texas at Austin ARCO, Fusion Geophysical	Rock properties, seismic attributes, AVO
Evgeni Chesnokov PhD, Moscow State University University College of London, University of Oklahoma	Theoretical seismology, anisotropy, fracture monitoring
Gennady Goloshubin PhD, Institute of Solid Earth, Moscow Western Siberian Institute	Seismic exploration, reservoir analysis, permeability prediction
De-hua Han PhD, Stanford University Unocal, HARC	Laboratory rock properties, seismic monitoring
Fred Hilterman PhD, Colorado School of Mines Geophysical Development Corp., Mobil	AVO, seismic processing, petrophysics
Aibing Li PhD, Brown University Woods Hole Institute	Seismic tomography, inversion, crustal structure
Christopher Liner PhD, Colorado School of Mines U. Tulsa, Aramco, Conoco, Western Geo	Seismic data processing, seismic interpretation, time series analysis, CO_2 sequestration
Leon Thomsen PhD, Columbia University Amoco, BP, Delta Geophysics	Anisotropy, seismic processing, EM analysis
Robert Wiley PhD, Colorado School of Mines Marathon Oil	Physical modeling, instrumentation, shallow seismic analysis

Current Resources and Work

AGL operates a fully equipped modeling tank (2m x 4m x 1.5m) with acoustic and elastic measurement capability. Dr. Robert Wiley is currently conducting a 3D VSP survey in the Vinton Dome model (Figure 4) simulating a wide-azimuth field experiment. These measurements will be processed and compared to the actual field VSP recorded in a well near the actual Vinton Dome (Gherasim, 2005, 3-D Elastic Kirchhoff Pre-stack Depth Migration – Vinton Dome, Louisiana, Ph.D. thesis, University of Houston). Dr. Wiley has recently completed a reverse 3D VSP using the borehole transducer as source. We will use these data to simulate hydraulic fracturing completions.

Several years ago, an ultrasonic survey was conducted across a model that had a glass-slide vertical zone constructed to simulate an anisotropic fault zone (Golden, 2007, Geometric attribute analysis on a physical model of horizontal transverse isotropy, M.S. thesis, University of Houston). We anticipate returning to this model and conducting a full 3C-3D survey across the fault zone, again simulating wide-azimuth shooting. The analysis objective is detection and mapping of the fractured region, including crack orientation and density.

We have access to the UH Texas Learning and Computation Center (TLC2). This is a first-class visualization facility for demonstrations, analysis, and development. For example, we are very interested in building tools for interactive 3D visualization of time-lapse phenomena. AGL has access to a Departmental computational network consisting of a Sun Starfire 880 server with dozens of Sun Ultra workstations augmented by a Beowolf computing cluster. Additionally, TLC2 operates a 500 CPU Titanium cluster and two 64 CPU SGI Altix clusters. We also use a wide variety of commercial software for seismic processing, imaging, visualization, interpretation, reservoir calibration, and flow simulation. AGL has a large inventory of previously shot physical and numerical modeling data sets, including the Marmousi elastic wave numerical model. These will be made available to sponsors. In addition, there are several dozen industry seismic data sets currently available for processing and interpretation.

The University of Houston has assumed management of the Yellowstone Bighorn Research Association (YBRA) Field Camp near Red Lodge, Montana (Figure 5), and we will convene a geophysical field school there in the summer of 2009. Students will undertake experimental, hands-on acquisition of 3C seismic surveys as well as GPS, GPR, well logging, and VSP data.

A little closer to UH, we are developing a field geophysics test site on university-owned land. This facility is part of UH's Coastal Center and includes a producing oilfield (Figure 6). This key site will be used to test equipment, acquire repeat surveys, and conduct field schools. We will work to extend use to drilling of test wells for field-scale injection and monitoring experiments.

Dr. Castagna and students have a number of research projects concerning AVO, spectral decomposition, and various seismic attributes. Much of this work will be continued under the auspices of AGL. Similarly, Dr. Liner's work on 3D seismic processing and interpretation will be supported by the Lab.

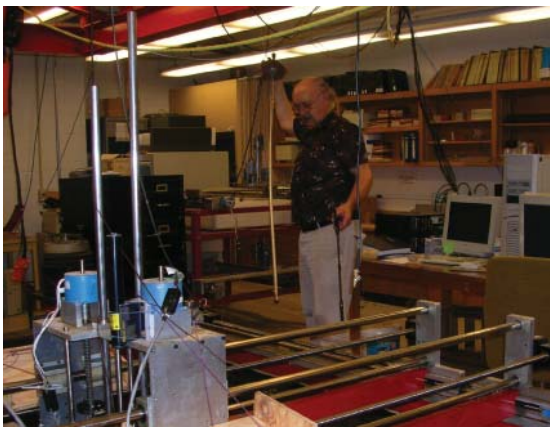


Figure 4.
Physical modeling facility at AGL with Dr. Wiley configuring the Vinton Dome 3D VSP model

Figure 5.
Classroom at the YBRA field site (photo by Mike Murphy)

Figure 6.
UH faculty near the Coastal Field Site

Specific Research Topics

Investigator	Topics
Robert Stewart 5 students	Microphone suppression of geophone noise; 3C land streamer assessment; MEMS response; surface-wave inversion; full-wave case histories; microseismic monitoring (Figure 7)
John Castagna 5 students	Spectral decomposition and AVO
Evgeni Chesnokov 5 students	Wave propagation in anisotropic media, fracture characterization, hypocenter location
Gennady Goloshubin 1 student	Waves in porous media and 3C seismic analysis
De-hua Han 1 student	Seismic monitoring and rock properties
Fred Hilterman 1 student	AVO and attributes
Aibing Li 1 student	Surface-wave inversion, 3C continuous monitoring, microseismic analysis
Christopher Liner 5 students	Visualization, acoustic scattering, CO_2 sequestration
Leon Thomsen 1 student	Anisotropy and rock properties
Robert Wiley 1 student	Physical modeling: Vinton Dome 3D VSP and RVSP, anistropic fault 3C-3D

Figure 7.
Testing true amplitude seismic response in the field to calibrate microseismic monitoring instruments

Activities and Timeline: 2009-2010

Aspect \ Time	June 2009	Sept 2009	Dec 2009	June 2010
Equipment	112-ch seismic, GPR, ultrasonic upgrade, GPS, microphones	VSP, logging tools, land streamer	1000-ch seismic vibroseis (specify, order)	OBS (specify, order)
Facilities and software	VISTA, Visualization Center	Kingdom Hampson-Russell	Transform	ProMax
Personnel	Geophysical technician	Geophysical post-doctoral fellow	System/data geophysicists	Administrative manager
Physical modeling	3D VSP, fracture/fault	Time-lapse sand	3C structure nonlinear	3C-3D anisotropy
Field work	Houston/local (shallow faults)	Montana (deeper structure)	Houston/local (deeper fractures)	Gulf of Mexico (shallow tests)

Our goals are ambitious and moving forward will require sponsorship for the purchase of equipment, instruments, computers, and software. New personnel are needed to undertake research, maintain and operate equipment, as well as for administrative operations, university reporting, safety compliance, and sponsor communications. An overview of our proposed activities in 2009-2010 is shown above.

Deliverables and Other Benefits

The new AGL aspires to make a significant impact on the science of geophysics and deliver clear benefit and advantage to our sponsors. A list of deliverables and other benefits follows:

- All AGL-sponsored physical modeling data will be available to sponsoring organizations
- All field data acquired by AGL will be available to sponsors
- All AGL-supported theses, posters, preprints, expanded abstracts, and technical papers and reports will be provided to sponsors
- Sponsor representatives will be invited to the AGL Annual Meeting in late May summarizing the year's research activities. Each sponsor will receive the AGL Annual Report
- Each sponsor will receive periodic communication about AGL personnel, activities, and research
- Sponsors will have a voice on the AGL Industrial Advisory Board to provide guidance and counsel to the Lab
- Sponsors have the opportunity to become familiar with students (prospective staff) and their work

Budget Overview: 2009-2010

Through 2009 and into 2010, we intend to purchase a substantial amount of geophysical equipment. The University of Houston has committed $335K toward this effort. We seek further contribution from the industry and various other agencies. Equipment purchases are to upgrade the existing physical modeling facility as well as provide an augmented field acquisition and data processing capability. Our first step is a portable seismic system, but we look forward to assembling a full industry-standard vibroseis system and set of ocean-bottom seismometers. Other supporting equipment includes GPS, well logging, and VSP tools.

2009 - 2010 Budget	Expenses	Revenue
Equipment, salaries, operating	$1 055 000	
University contribution (cash)		$335 000
Industry sponsorship (cash)		$720 000
Total	**$1 055 000**	**$1 055 000**

Equipment – $665 000
Laboratory instrumentation (transducers, A/D converters, software upgrades) $50K
Vector acoustic lab set up and instrumentation $100K
112-channel seismic recorder (Geometrics/Geodes), cables and 3C geophones $170K
GPS $25K
Logging tools, cable, winch $100K
VSP tools, cable, and recorders $80K
Ground-penetrating radar (GPR) – SmartCart and bistatic system $90K
Computers $20K
Visualization equipment $20K
Incidentals $10K
1000-channel seismic system with support vehicles and IVI envirovibe - $1300K (Year 2010)
Ocean-bottom seismometers (OBS) - $300K (Year 2010)
Field work - $50 000
Communication - $40 000
Publication costs, newsletters, seminars, and meeting participation
Students - $100 000
Staff - $200 000

Total 2009-2010 expenses - $1 055 000

We require a number of additional staff to operate and maintain the various computer and measurement systems as well as facilitate research. We anticipate hiring four staff throughout 2009 - 2010. They would include a geophysical technician, geophysics postdoctoral fellow, system and data manager, and an administrative assistant.

We seek AGL industrial sponsors from the energy, mining, engineering and related sectors. Annual sponsorship cost is $45K for 2009-2010. A reduced rate of $15K is available for smaller enterprises (under $5 million annual revenue). We anticipate that this support and collaboration will arise primarily from the energy industry.

We also offer a limited number of Founding and Sustaining Memberships that allow more direct involvement and impact on the future of AGL and its people. Contact director Robert Stewart for further information.

Contact Information:
Dr. Robert Stewart – (713) 743.8230 or rrstewart@uh.edu
Dr. Christopher Liner – (713) 743.9119 or cliner@uh.edu

Allied Geophysical Laboratories


Allied
Geophysical
Laboratories