on Figure 11C a portion of the FMI log of the Tensleep “B” sand, which had been analyzed by Schwartz et al. (2005) for fracture trends. In future studies, we will attempt to position the seismic attribute windows to correspond more closely to the stratigraphic zone of interest and not to overlap zones. If this methology proves to be useful for characterizing reservoir properties, we would focus specifically on the Goose Egg Formation (reservoir seal rock), the Tensleep “A” and “B” sands, the Tensleep “B” Dolostone and and an interval at the top of granite basement. We also might expand the scope of the study to include the Crow Mountain Formation, a saline reservoir with possible potential for CO2 sequestration in the region (Tom Anderson, RMOTC, personal communication).

In our last report, we suggested that lineaments on attribute maps that do not correlate with the known larger faults on the Teapot Dome structure might indicate fractures or small displacement faults, which could compartmentalize reservoirs. To evaluate this idea, we have begun a detailed analysis of the lineaments on most negative curvature attribute maps near the top of the basement and near the base of the Tensleep “B” sand. The basement is an important horizon to include in the analysis because (1) the Teapot Dome structure is directly related to basement-forced faulting and uplift, (2) the basement to Tensleep interval likely deformed as a single, mechanically competent unit, and (3) lineaments are well illuminated on curvature maps of the basement (Figure 12A). We have applied a program developed by Guo (2007) to automatically generate rose diagrams of curvature lineation azimuths across the survey area for the basement curvature map (Figure 12B). By observation, clear similarities between rose diagram and attribute map lineations suggest that the this new methodology can produce accurate analyses of very complicated lineament maps in a fraction of the time required to carry out a similar analysis using manual methods. We plan to compare the results of manually-generated rose diagrams to auto-generated rose diagrams in local areas to evaluate further the methodology.

The lineaments on the most negative curvature attribute map near the Tensleep “B” sand are not as sharply defined as those on the basement attribute map, but the auto-generated rose diagrams appear to be similar to the basement rose diagrams, at least superficially (Figures 13A and 13B). The dominant lineation directions are N48W and N46E. Neither trend is coincident with the strong N59E and EW trends of the acquisition footprints (See Figure 3). Although the scale difference between the data on which the seismic attribute-derived rose diagrams are based and the data that Schwartz et al. (2005) used to manually generate FMI log-derived rose diagrams to show fracture lineation azimuths in the “B” sand in five wells are different by a couple orders of magnitude, rose diagrams from both sets of data are similar near the 48-X-28 and 71-1-X-4 wells. The predominant lineation azimuths on rose diagrams from both sets of data for the other wells are not similar. The greatest disimilarity is the complete absence from the FMI log-derived rose diagrams that show the strong NE lineation direction that is apparent on many of the attribute-derived rose diagrams. Areally, neither set of rose diagrams appears to show a relationship between the orientations of the Teapot Dome fold axis at the Tensleep level, which changes from approximately NS along the southern part of the structure to N32W along the northern part of the structure, and the lineation azmuths.

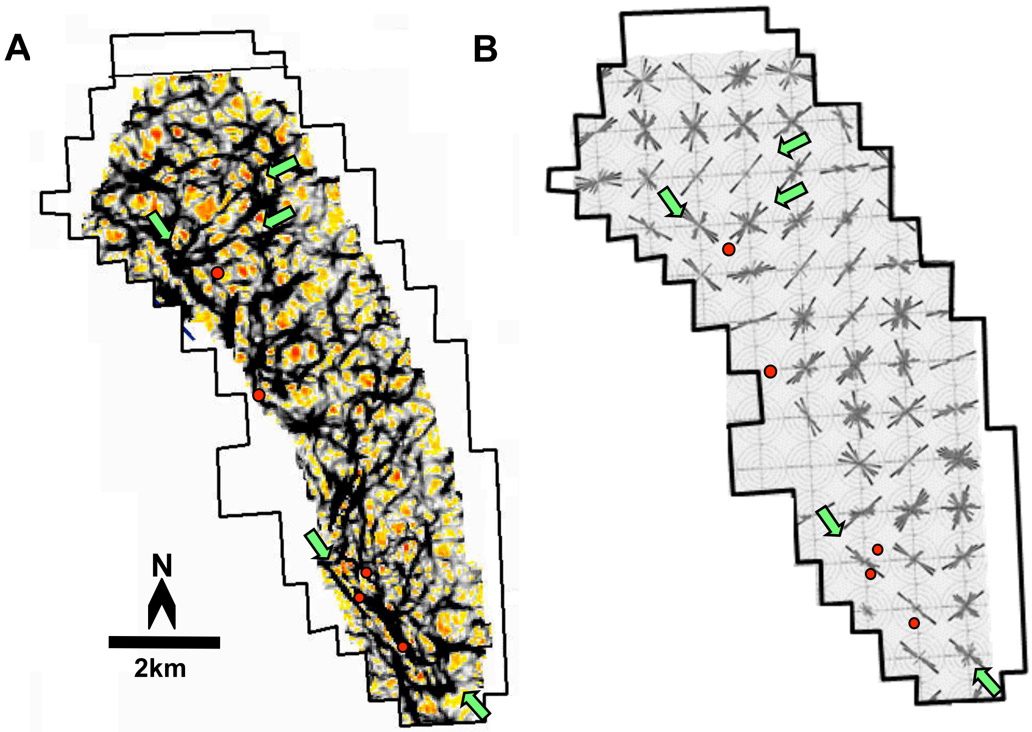

Figure 12. Analysis of seismic attribute lineaments near top basement. The red circles are the locations of wells with FMI logs, which have been analyzed by Schwartz, et al. (2005). **A.** Most negative curvature attribute map near basement top showing lineaments (See Figure 11A for attribute window.). **B.** Auto-generated rose diagrams showing distribution of seismic lineation azimuths on a 20 x 20 line grid for the attribute map area. The green arrows point to some of the areas where the matches between the lineaments on the attribute map and rose diagram azimuth distributions are quite good.

Understanding how lineations observed on attribute maps and FMI logs and fractures observed in cores relate to compartmentalization of the reservoir and fluid flow remains a major unresolved issue in this study. Remarkably, Schwartz et al. (2005) have interpreted some of the vertical fractures observed on FMI logs as naturally occurring fractures and not drilling induced fractures *in every FMI-logged well.* For every well to have penetrated natural vertical fractures would seem to imply a very closely spaced fracture network. The coincidence of the orientations of natural and induced fractures is also problematic. Since seismic data would probably not delineate a single fracture plane like those observed in cores and on FMI logs, the presence of lineations on attribute maps that are similar in orientation to FMI log lineations might support the presence of zones of closely spaced fractures, which seismic data could delineate. To address the fundamental problem of the role of fractures in Tensleep productivity, we plan initially to carry out the following tasks.

1. Compare rose diagrams manually-generated from attribute maps to auto-generated rose diagrams in local areas around wells with FMI logs.
2. Compare both sets of rose diagrams with the FMI-derived rose diagrams.
3. Determine if the vertical extent and continuity of mapped lineation trends can be mapped on vertical slices of seismic attribute volumes.

4. Analyze variations of lineation orientations relative to the orientation of the fold axe at the Tensleep and basement levels across the Teapot Dome structure.
5. Revisit the criteria for characterizing natural fractures on FMI logs.
6. Extend the detailed fracture analysis to include the Goose Egg Formation (seal rock), the Tensleep "A" sand and "B" dolostone and possibly selected lower units.

This work may involve recalculating attribute volumes using pre-stack depth migrated seismic volumes, which will facilitate the positioning of seismic data with log depths and may result in higher resolution attribute maps. In the longer term, matching a Tensleep reservoir model, which incorporates a deterministic fracture system, with well production data would be the best test of the viability of the reservoir model. Our aim in this study is to develop a well-constrained, dual-permeability reservoir model for fluid-flow simulation studies of the Tensleep and to demonstrate a seismic-based modeling process with wide applicability in a range of geologic settings.

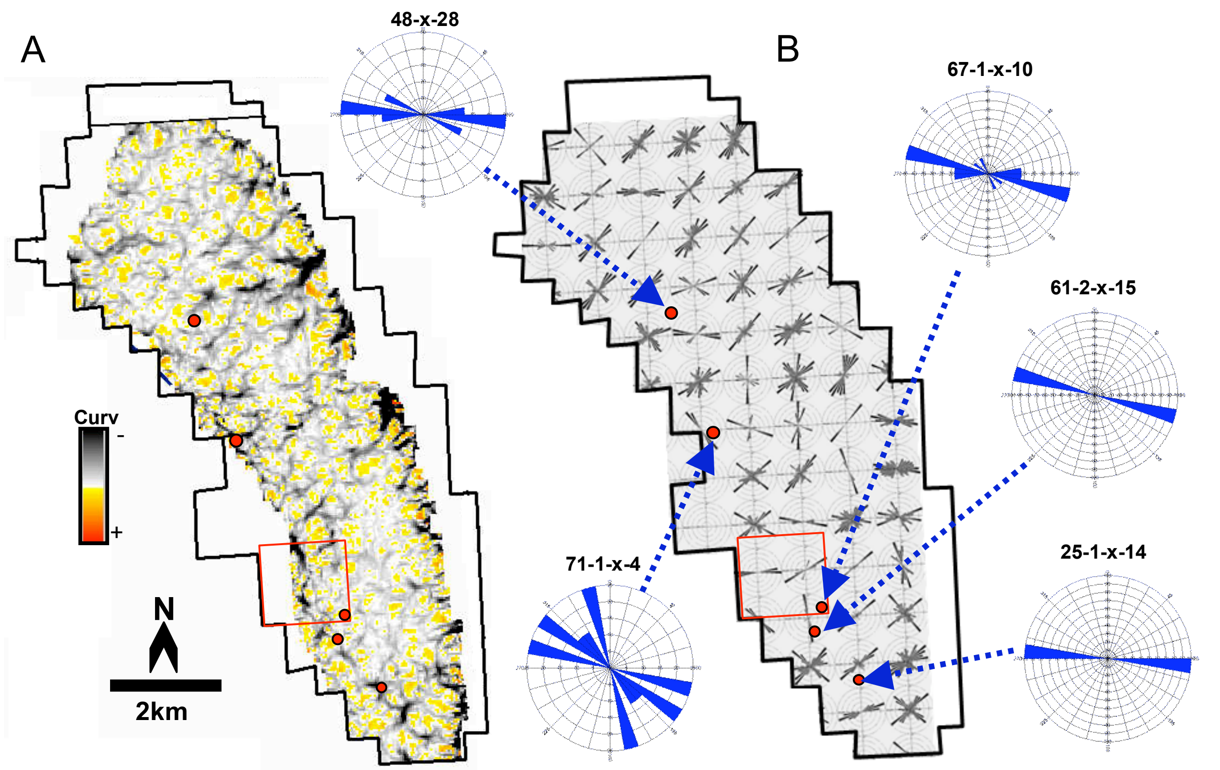

Figure 13. Analysis of seismic attribute lineaments in the Tensleep "B" sand. For reference, the red rectangle is Section 10. The red circles are the locations of wells with FMI logs. **A.** Most negative curvature map of horizon near base of "B" sand (See Figure 1B for attribute window.) **B.** Auto-generated rose diagrams showing distribution of seismic lineation azimuths on a 20 x 20 line grid for the attribute map area. Rose diagrams (blue insets) have been generated by Schwartz, et al. (2005) from interpretations of "B" sand fractures on FMI logs from the five wells. (See Figures 11B and 11C for interval analyzed.). Despite the large difference in resolution between seismic data and log data, the attribute-derived rose diagrams near 48-X-28 and 71-1-X-4 are similar to FMI-derived rose diagrams. The predominant lineation azimuths shown on the attribute-derived rose diagrams and the FMI-derived rose diagrams for the other wells are not similar.

Dickman field: Work on Dickman field has been deferred pending completion of the migration of the pre-stack data. We plan to carry out an impedance inversion when the pre-stack data are available and develop a 3-D model of the porosity and saturation distributions of the porous Mississippian reservoir from the analysis of seismic attributes extracted from the inverted data volume and well data.

Illinois Basin-Patoka and Sciota Fields: Work on Sciota and Patoka fields has been deferred pending completion of the migration of the pre-stack data at Patoka field. We plan to carry out impedance inversions of the data from both fields to determine if we can develop 3-D models of the porosity distribution of the Mt. Simon sandstone from the analysis of seismic attributes extracted from the inverted data volumes

Task 4.0- Calibrate Seismic Attributes with Geological and Engineering Data

Dickman Field: Work on Dickman field has been deferred pending completion of the migration of the pre-stack data.

Task 5.0-Validate Seismic Attribute Analyses Results

We are continuing to process the pre-stack seismic data for Dickman field (See **Subtask 2.2** above). Our sub-recipient, the Kansas Geological Survey, will carry out the major subtasks, which are to construct an integrated geomodel at Dickman field and to carry out a reservoir simulation of the field production history.

Subtask 5.1 Construct Integrated Geomodel of Dickman Field, Kansas

Our goal is to validate the results of seismic attribute analyses with a reservoir simulation of the pressure and production history of the field. A necessary requirement to achieve this goal is the construction of an integrated geomodel. The following summarizes our state-of-the-knowledge geomodel for Dickman field.

1. A small structural closure has localized an oil accumulation in the porous Mississippian dolomites, which has an OWC at about -1980 feet subsea and an oil column of about 35 feet.
2. The porous Mississippian saline aquifer underlying the oil accumulation ranges from 200 to 300 feet thick and is a CO2 sequestration target in the Mid-Continent area.
3. The contact between the porous Mississippian and the overlying seal (Pennsylvanian shale of the Cherokee Group) is a karst surface and an angular unconformity, which dips to the west.
4. Fractures in the porous Mississippian are aligned N45E and N45W and the two fracture trends formed at different times. Geologic and production data suggest that the northeast-trending fractures are clay and silt-filled and closed while the northwest-trending fractures are open and form conduits for water to move from the underlying aquifer into the oil zone.

5. Basal Pennsylvanian conglomerates were deposited in the topographically low areas on the Mississippian unconformity. The distribution of the thickest conglomerates may correlate with the distribution of closed fractures.

Important missing pieces of the geomodel are the 3-D distributions of porosity and fractures in the porous Mississippian carbonates. To obtain the porosity distribution, we plan to correlate porosities derived from well logs with the seismic impedance data generated from the reprocessed seismic data. To obtain the fracture distribution, we plan to continue with the work described under **Dickman field** in **Task 2.2** in the progress report for the period ending March 31.

CONCLUSIONS

Teapot Dome Field:

1. We have applied a program developed by Guo (2007) to automatically generate rose diagrams of curvature lineation azimuths across the survey area. Clear similarities between rose diagram and attribute map lineations suggest that the this new methodology can produce accurate analyses of very complicated lineament maps in a fraction of the time required to carry out a similar analysis using manual methods.

2. Reprocessing of seismic data by UH appears to have improved reflector continuity and the vertical resolution of horizons compared to the publicly available, commercially processed seismic data. A better evaluation of the quality of the reprocessing will be possible when the depth migrated seismic volumes are available, and we can determine if the spatial relationships of known geologic features are compatible with well data constraints.

COST STATUS

Baseline Costs Compared to Actual Incurred Costs

2007	Baseline Cost	Actual Incurred	Variance
Apr. 1-June 30	**Plan**	**Costs**	
Federal	$34,132	$44,331	-$10,199
Non-Federal	$13,248	$0	$13,248
Total	$47,380	$44,331	$3,049

Table 1. Forecasted Cash Needs vs. Actual Incurred Costs

Analysis of Variance

The Federal shortfall in Table 1 reflects increased labor costs for the period that we expect to balance in the future with reduced labor costs. Several employee changes at Continental Resources of Illinois, Inc, our industry partner, have delayed their participation in the project and the KU Research Center has not submitted a cost share amount for the period, which accounts for the Non-Federal under-expenditure.

MILESTONE PLAN AND STATUS

Specific Critical Project Milestones for 2007-2008 (Refer to Table 2 for general task milestones.)

1. Carry out pre-stack time migrations of Dickman field and Teapot Dome field seismic data by **March 31**.

   We met both milestones, but additional processing is necessary for the Dickman field seismic data, which we expect to complete in the next period.

2. Use Dickman field well log and core data to develop reservoir property dataset for calibration and validation of seismic attributes by **June 30**.

   *We extended the June 30 deadline to **September 30** pending completion of reprocessing of the Dickman field seismic data and the availability of staff for the log analysis. We also extended Milestones 3 and 4 to reflect this change.*

3. Compare resolution of post-stack and pre-stack attributes at Dickman field and Teapot Dome field and assess merits of azimuth-limited attributes or other specialized processing by **December 31**.

4. Develop structural and stratigraphic models for Dickman field, Teapot Dome field and Patoka field by **March 31**.

Actual Progress Compared to Milestones

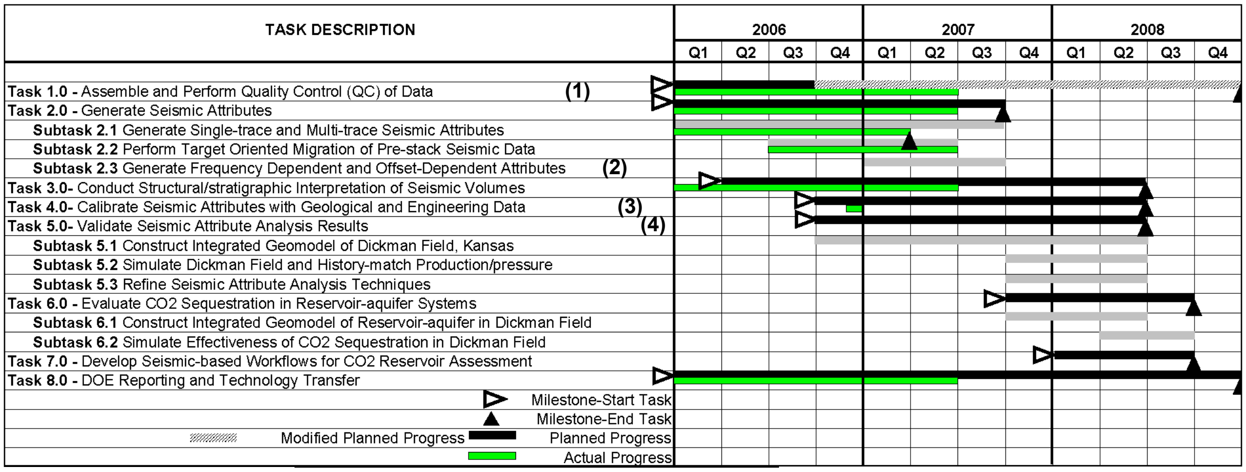

Table 2. Gantt chart

(1) QC of data will continue throughout project.
(2) Deferred pending evaluation of alternatives.
(3) Further work deferred until next period.
(4) Deferred until next period.

SUMMARY OF SIGNIFICANT ACCOMPLISHMENTS

We have applied a program developed by Guo (2007) to automatically generate rose diagrams of curvature lineation azimuths across the seismic survey area of **Teapot Dome Field.** Clear similarities between rose diagram and attribute map lineations suggest that the this new methodology can produce accurate analyses of very complicated lineament maps in a fraction of the time required to carry out a similar analysis using manual methods, and the methodology should be broadly applicable to the analysis of seismic data.

ACTUAL OR ANTICIPATED PROBLEMS

Several key employees of our industry partner, **Continental Resources of Illinois**, have resigned since the beginning of this project. These resignations have adversely affected the capability of **Continental** to consult on the project. **Continental's** management has repeatedly assured us that they intend to meet their in-kind contribution commitment over the three-year period of the project, but their follow-through has not been satisfactory. We hope to resolve this matter during the next period.

TECHNOLOGY TRANSFER ACTIVITIES

Paper in review:

Aktepe, S., *in review*, Depth Imaging of Basement Control of Shallow Deformation; Application to Fort Worth Basin and the Teapot Dome Data Sets, Master's thesis, University of Houston.

Presentation:

Bjorklund, T., 2007, Application of Cutting-Edge 3-D Seismic Attribute Technology to the Assessment of Geological Reservoirs for CO2 Sequestration, NETL University Coal Research Contractors Review Conference, Pittsburg, PA., June 5.

Other:

As our project progresses, we will add new results to the KU CO2 sequestration studies website and the CAGE website at UH.

REFERENCES

Guo, H., *in review,* Methods to improve computer-assisted seismic interpretation using seismic attributes, Ph.D. dissertation, University of Houston.

Perez, G. and K. J. Marfurt, 2006, Correcting for wavelet stretch in common-angle migration improves vertical and lateral resolution: 76th Annual International Meeting, Society of Exploration Geophysicists, Expanded Abstracts, 254-258.

Perez, G. and K. J. Marfurt, *in review*, Improving lateral and vertical resolution of seismic images by correcting for wavelet stretch in common-angle migration, Geophysics.

Schwartz, B., Wilson, T. H. and D. H. Smith, 2005, Fracture Pattern Analysis using FMI Logs of the Tensleep Formation, Teapot Dome, Wyoming, Master's Thesis, West Virginia University.

CONTRIBUTORS

University of Houston

Tayo Akintokunbo
Suat Aktepe
Hao Guo
Kurt Marfurt (Co-P.I.)
Kui Zhang
Jenny Zhou

Consultant for KGS

Susan Nissen