High-Angle and Horizontal Well Special Interest Group  
September 20, 2005  
Location: ExxonMobil Upstream Technical Training Center, Houston, Texas

**Attendees** - approximately 70 people. Those who signed the attendance list included:

<table>
<thead>
<tr>
<th>Attendee</th>
<th>Company/Position</th>
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<tbody>
<tr>
<td>Rob Algie (Schlumberger)</td>
<td>Mark Haugland (Pathfinder)</td>
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<td>Ismail Altintutar (BHI)</td>
<td>Denis Heliot (Schlumberger)</td>
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<td>Eugene Badea (Pathfinder)</td>
<td>Frank Hearn (Baker Hughes)</td>
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<td>Ahmed Badruzaman (Chevron)</td>
<td>Jack Horkowitz (Schlumberger)</td>
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<td>Matt Benefield (Baker Hughes)</td>
<td>Dave Hinz (Halliburton)</td>
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<td>William Blount (ExxonMobil)</td>
<td>Jim Holl (ExxonMobil)</td>
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<td>Jeff Brami (ExxonMobil)</td>
<td>Herb Illfelder (Pathfinder)</td>
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<td>Andy Brooks (Inteq)</td>
<td>Segun Jebutu (Baker Hughes)</td>
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<td>Michael Bittar (Halliburton)</td>
<td>Stu Keller (ExxonMobil)</td>
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<td>David Byrd (Devon)</td>
<td>Jim Klein (ConocoPhillips)</td>
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<tr>
<td>Thierry Chabernaud (Schlumberger)</td>
<td>Shanjun Li (UH)</td>
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<td>Ji Chen (UH)</td>
<td>Qiming Li (Schlumberger)</td>
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<td>J. B. Clavaud (Chevron)</td>
<td>Bob Lieber (BP)</td>
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<td>Carlos Contreras (Pathfinder)</td>
<td>Richard Liu (UH)</td>
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<td>Sofia Davydycheva (Schlumberger)</td>
<td>Darren McLendon (ExxonMobil)</td>
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<td>Michael Frenkel (Baker Atlas)</td>
<td>Steve Mack (Precision)</td>
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<td>Ingo Geldmacher (Precision)</td>
<td>Alberto Mendoza (UT-Austin)</td>
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<td>Allen Gilchrist (Baker Hughes)</td>
<td>Rune Musum (ExxonMobil)</td>
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<td>Dean Gallick (Chevron)</td>
<td>Jim Oberkircher (IADD)</td>
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<td>Wei Jun Guo (Pathfinder)</td>
<td>Quinn Passey (ExxonMobil)</td>
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<td>Terry Hagiwarra (Shell)</td>
<td>Neal Peeler (Baker Hughes)</td>
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<td>Rich Hardman (6FF40)</td>
<td>Richard Pelling (Paradigm)</td>
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**Agenda:**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session Content</th>
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<tr>
<td>9:00 - 9:15</td>
<td>Welcome, Logistics, and Introductions (Michele Thomas/Quinn Passey)</td>
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<tr>
<td>9:15 - 9:45</td>
<td>SIG organization and business (Terry Quinn)</td>
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<td>- Overview of SIG objectives</td>
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<td>- Election of officers</td>
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<td>- House rules</td>
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<td>9:45 - 11:30</td>
<td>Introduction of HA/HZ issues - invited talks</td>
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<td>9:45 - 10:15</td>
<td>Drilling process and depth control – Jim Oberkircher (IADD)</td>
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<td>10:00 - 10:15</td>
<td>Break</td>
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<td>10:15 - 10:45</td>
<td>FE issues – Jim Klein (Conoco Phillips)</td>
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<td>10:45 - 11:15</td>
<td>Integration of data and visualization – Lisa Towery (BP)</td>
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<td>11:15 - 11:45</td>
<td>Summary of learnings from Taos – Quinn Passey (ExxonMobil)</td>
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<td>11:45 - 12:30</td>
<td>Lunch</td>
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<td>12:30 - 1:45</td>
<td>Breakout groups - Possible topics could include:</td>
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<tr>
<td></td>
<td>A) Drilling process and depth control</td>
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<td>B) Formation Evaluation 1</td>
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<td>C) Integration of data into geologic and reservoir models</td>
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<td>D) Formation Evaluation 2</td>
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<td>1:45 - 2:00</td>
<td>Break</td>
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<tr>
<td>2:00 - 3:00</td>
<td>Report out from groups 10 minutes each (Flipcharts)</td>
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<td>3:00 - 3:20</td>
<td>Review and/or develop action items (Terry Quinn)</td>
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<td>3:20 - 3:30</td>
<td>Set time and location for next meeting</td>
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<tr>
<td>3:30</td>
<td>Adjourn</td>
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1) **Draft HA/HZ SIG Objective:** The HA/HZ SIG is devoted to help the petroleum community (Geology, Geophysics, Formation Evaluation, Drilling, Reservoir Engineering) understand the challenges associated with the acquisition, interpretation, and integration of HA/HZ wellbore data.

2) **Business items:**
   - **Objectives of SIG:**
     - Learn how HA/HZ data impacts other geo/eng disciplines
     - Bring in other disciplines
   - **Communicate issues to other disciplines and organizations (e.g., IADD)**
   - **Officers**
     - 2 co-chairs
     - Term 1 year
     - Organize 2 meetings/year
     - Record meeting summary; post on SPWLA website;
     - Possibly publish summary in Petrophysics
     - Maintain e-mail distribution list for SIG (about 200 names currently)
   - **Liaison to other organizations**
     - SPE drilling
     - WITSML data transfer
     - SPWLA and/or other SIGs
     - IADD
   - **Committee chairs for action items; subtopics, subcommittees**

3) **Summary of technical presentations:**
   a) Drilling process and depth control - Jim Oberkircher (IADD)
     - “If you can draw it, you can drill it”
     - Brief history presented on HA/HZ enablers (jetting, BHA control, Mud motors, steering tools, MWD/LWD, steerable motors, adjustable BHAs, Rotary Steerables)
     - Stretching the horizon – now 15-20k meter horizontal wells are possible; imagine the amount of depth control required; new examples – 4 horizontal wells of 15 km length exposes 13.6 km of reservoir, and this has been done
     - Major issues
       - Directional capabilities
       - Spatial orientation – survey and depth control
       - Depth control is a major issue by itself
       - Data rates/data density – always a tradeoff between survey and FE data
       - Hitting a moving a target; geo-steering is hard; when the target moves, a high price may need to be paid as a result of introducing new problems
     - Where are we?
       - Ellipse of uncertainty – the ellipse grows as you extend the well
       - Depth of uncertainty
       - Uncertainty of the uncertainty
     - IADD will be happy to participate in this SIG going forward
- Question from audience: Many in FE are at odds on objectives with drilling. How can communications be improved? Ans: Need to show that objectives are aligned, don’t back down, put needs in money terms

b) Log Interpretation – High Angle & Horizontal Wells - Jim Klein (ConocoPhillips)
- Industry-wide departure data presented. ERD average > 45 deg.
- Advanced objectives
  - Pay properties
  - Horizontal wells give high volumes of data, but not thickness
  - Lithofacies
  - Strength & stress
  - Fractures
  - Vertical distance to boundaries & fluids
- Problems & issues
  - Different geometry between logging tools
  - Data density
  - Positioning control
  - Cannot blindly interpret
- Vertical Well Paradigm
  - 2-D geometry
  - Tool volume of investigation different than radial
  - Thin beds
  - Resistivity logs unaffected by anisotropy
- Horizontal wells
  - 3-D geometry
    - Radial symmetry disappears
    - Non-symmetric geometry relative to the formation
    - Non-symmetric invasion
- Simulation of mud filtrate invasion
- Oil companies may not use porosity tools in HA/HZ wells much if:
  - reservoir is understood
  - reduces drilling rate
  - risk
  - increase expense
  - but later may find that they need the data to insert in model
- Conclusion/summary
  - Geometric effects can greatly complicate evaluation of HA/HZ wells
  - There is a need to see further from the borehole
  - Directional measurements are needed
  - Routine acquisition of image logs needed
  - Azimuthal density & resistivity useful
  - Need horizontal resistivity in horizontal wells
- Audience comments: need drilling friendly tools; sampling in horizontal wells, considering amount of formation traversed, may require different sampling than vertical wells….may actually be getting higher vertical sampling density as a result of small change in vertical distance, but horizontal sampling may be
c) Integration of data and visualization - Lisa Towery (BP)
- Communication is important
- Three essential areas – Well planning, Geosteering, Correlation
- Well Planning
  - Optimize reservoir access
    - stay within the reservoir
    - encounter multiple zones
    - intersect max number of fractures
  - Prevent wellbore collision
- Issues
  - Depth tie
    - are there other wells in the area? checkshots?
  - Seismic image quality
- 3 Examples provided demonstrating well planning for different purposes
  - down dip syncline for steam-gravity drainage
  - attic oil
  - encountering fractures
- various visualization techniques demonstrated for resolving different well planning purposes
- Visualization for Geosteering
  - computer-aided
  - other methods, cuttings samples
- Issues
  - stay within zone of interest
  - react
  - frequency of survey point updates – data may come in quicker than can interpret
- Interpretation of data workflow
  - develop conceptual model
  - generate 3D framework
  - 3D cellular grid
  - populate with rock properties
  - upscale (not always) for flow simulation
- Gridding Issues
  - putting horizontal wells in a grid requires locally refined grids, but is difficult, therefore need radial refinement
  - HA/HZ wells may not represent the reservoir well path; may encounter better or worse reservoir than is the average. This needs to be taken into consideration.
  - Upscaling throws out lots of data by averaging.

Nirvana – real time model updating!
d) Summary of learnings from 2004 Taos Topical Conference - Quinn Passey (ExxonMobil) - Taken largely from 2005 SPWLA Transactions Paper A by Passey et al.)

- Who’s at the current SIG?
  - 200 people on the e-mail distribution
  - ~ 70 attended
  - 22 attended the Fall 2004 HA/HZ Topical Conference in Taos
  - 55% from service companies or vendors
  - 33% from operating companies
  - 7% from university
  - 5% other

Survey Results:
- Near unanimous agreement between oil and service companies:
  - More geometry information needed
  - More azimuthal sensors
  - Need quantitative interpretation in addition to qualitative
- Slight differences between oil and service companies
  - Lack of correction charts
  - Which single LWD curve should be used for Rt
  - LWD and wireline accuracy

Conference Learnings:
- Our ability to drill HA/HZ wells is ahead of our ability to interpret
- Although qualitative interpretation is common (e.g. geosteering), increasing need for quantitative results - standard logs may not be accurate enough for FE
- Current correction charts (or modeling software) for many instruments are inadequate (or non-existent); however, most interpreters don’t want to become tool physicists
- Different interpretation paradigms exist for vertical and horizontal wells
- Service companies focus on developing new tools and not in understanding response in HA/HZ wells;
- Oil companies need to share data to show issues and limitations
- “As an industry, we are not as smart as we thought we were”

Conference Recommendations:
- Initiate HA/HZ SIG
- More azimuthal/directional instruments
- Tools that are focused on specific depth of investigation (e.g., 2’)
- Technology to look away from the borehole and ahead of the bit

4) Breakout group discussions:

Group A) Drilling and depth control (“All I need is a GR”) -
- Report out by Andy Brooks (Baker Hughes)
  - Depth control
  - Positional control
  - Better measurements – quantify uncertainty; cost effective way of reducing
• Industry standard (?); process
• Intra-discipline bridge to address
• Consistent surveying and calculation methodology
• Pipe measurements
• CCL type marker (?)
• Survey frequency – optimal
• Moving logging data relative to surveys
• Critical measurements and impact on crucial business decisions
• Need a JIP or JI Standard?
• Guidelines for critical wells
• Relative position of sensors
• 3D seismic
• Seeing ahead of the bit
1) The solution is multifaceted and multi-discipline
2) Coordinate activities with SPE sub-committee
3) Need to “advertise” results
4) Presentation to SIG by member of SPE subcommittee

Group B) Formation Evaluation (The Practicals)
- Report out by Richard Pelling (Paradigm)
  • What is FE?
  • Scale – logging tool, DST
  • Mud logging
  • Communicating value of FE
1) What do we need:
  • Visualize 3D system & data
  • Apparent dip
  • Integrate into model
  • Volume of investigation
  • Economic constraints – short or long term view
  • Maturity of field and regulation constraints (not able to drill where we want)
  • Design of logging program
  • Completion design influencing logging
2) Azimuthal density (heart Æ good)
  • GR (heart Æ good)
3) Neutron – questionable values, source? (sad face Æ not good)
  • Too many curves, need them… but good for resistivity inversion
  • Consistency of assumptions between processing and delivery
  • Wellsite data are only initial “quicklook”… simplifying assumptions
  • HZ vs. vertical well; geometry (beds) geology; log measurement
  • Partitioning; horizontal and vertical variation? Can we understand it?
4) Ideal world
  • Better teamwork between service co. and operator and between disciplines
  • Well planned to produce … able to react to changes during job
• Other measurements?
  o Azimuthal resistivity
  o Azimuthal acoustic
  o Anisotropy
  o Deep reading directional resistivity
  o Seismic?

Group C) Geologic and Reservoir Modeling (The Integrators)
- Reported out by Cesar Portilla (Inteq)
  • Issues “problems”
  • Cost to obtain the correct data (time is a key parameter when acquiring data)
  • In exploration, getting data is possible only when critical
  • Management needs to be aware of the importance
  • Not getting enough data in development wells
  • Development wells are horizontal, and there are problems when incorporating these wells to the original model
  • HA wells – own by drillers
  • Additional data can reduce the uncertainty
  • Real time model update
  • Joint inversion concept incorporating all tool measurements
  • Depth issues
  • Some challenges currently exist that are not handled by current technology – new tools needed
  • Upscaling issues
  • HA data handling when doing Reservoir/Geologic models
  • Porosity bias in HA wells

Group D) Formation Evaluation 2 (The Troublemakers)
- Report out by Ahmed Badruzzaman (Chevron)
1) Issues
  • GR only – cost of logging; losing data
  • “Quality” of data – information content
  • Lack of experience with LWD data
  • Lack of typical models (need OpCo input)
  • Tool response in HA/HZ of current tools?
  • Different DOI (depth of investigation); which curve(s) to use?
2) Good
  • Image log: bed boundary; dip picking
  • Resistivity inversion: Where it exists, it adds value
  • Density being directional; other sensor and becoming directional
  • More than GR are being run; more R de ore (couldn’t read?)
3) Bad
  • Available inversion technology under developed or underutilized
  • Value proposition? Have “we” made a case
• OpCo's not using available advanced (3D) processing software service companies have – OPCO’s don’t want to pay for it; lots of manpower involved for service companies
• Education – service companies and OPCOs; value at BU level
• Resistivity is “biggest” question? What about porosity?

4) Ideal
a) New tools and more inversion; more sensors
   o Azimuthal neutron
   o All sensors Azimuthal, similar DOI? Similar tool axis resolution
   o Nuclear tools with better statistics
b) Induction-type inversion of nuclear tools; non-Monte Carlo modeling
c) Low cost
d) Drill vertical for information; HA/HZ to maximize production

5) SIG Business:
• Terry Quinn and Quinn Passey (“paraquins”) elected to serve as SIG co-chairs for next 1 year (two additional meetings)
• In addition, a steering committee was formed to better define objective of SIG and agenda for the next meeting, with the following volunteers:
   o Ed Stockhausen – Chevron
   o Jeff Brami – ExxonMobil
   o Mark Hoagland – Pathfinder
   o J. B. Clavaud – Chevron
   o Jim Klein – Conoco Phillips
   o John Rasmus – Schlumberger
   o Terry Quinn – Baker Hughes
   o David Byrd - Devon
   o TBD – BP

6) Parking Lot (items that may or may not have been addressed adequately):
• Define roles and direction
• SPE Technical group on wellbore positioning
• Liaisons with other groups
• Log-resolution 3D seismic (wish list)
• Continuous coring in HZ wells
• Difficult to determine value of data if we didn’t collect info initially

7) Action Items:
• SIG to begin to develop value proposition (what went right vs. where went wrong with decision based on HA/HZ wells)
• OpCo’s bring an example to share at next SIG meeting
• Post-mortem – share (form subcommittee in each OpCo)
• Scope out issues for publication
• All to look for published HA/HZ examples for discussion at next SIG meeting
• Next SIG meeting January or February 2006 – location TBD
8) Meeting Performance:

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<th>What went well?</th>
<th>What would you change?</th>
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<tr>
<td>• Location</td>
<td>• Hands-on examples</td>
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<tr>
<td>• Lunch/food</td>
<td>• More “meat”</td>
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<td>• FE centric (perhaps too much so?)</td>
<td>• Too FE centric audience</td>
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<td>• Breakouts</td>
<td>• Light OpCo participation</td>
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<td>• Invited presentations</td>
<td>• Better tie with SPE</td>
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<tr>
<td>• Brain teasers (ice breaker)</td>
<td>• Better tie with other SIGs</td>
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<tr>
<td>• Technical topic (HA/HZ)</td>
<td>• Marketing – need to spread word of our existence</td>
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<td>• Format of meeting</td>
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<tr>
<td>• Length of meeting</td>
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