IPGT Reservoir Modeling Working Group

Summary of Recommendations &
Geothermal Reservoir Benchmarking Workshop

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Who/What is IPGT?

- Forum for geothermal leaders from government, industry and academia to coordinate their efforts and collaborate on projects
- Accelerate the development of geothermal technology
- Coordinate efforts to reduce duplication

Working Groups

- Seven areas of technology focus
  - drilling, zonal isolation, high temp tools, stimulation, reservoir modeling, exploration, and induced seismicity
- Summarize the current state of the art and provide recommendations on ways to advance the technology
- Development of technology roadmaps
Reservoir Modeling Working Group

- Has held two formal workshops/meetings
- Drafted a reservoir modeling white paper
- Has begun to identify potentially collaborative projects
- Is gathering information…..
  - Revise whitepaper
  - Further engage industry
  - In-depth summary of current model capabilities
  - Gathering data for code benchmarking exercise
Drivers for Technology Development
Whitepaper

- Dynamic changes in permeability – current models are ill-equipped
  - Short-term, fracturing and reservoir creation
  - Long-term, reactive geochemistry within the fractures and matrix
  - Also near-field and far-field
- There have been substantial advances over the past several decades
  - Incorporation of more accurate EOS for the fluid system, an increased ability to represent geometric complexity and heterogeneity, treatment of material heterogeneity in space and time
  - Increase of computational power, code capabilities, faster and more robust computational schemes
- Conceptual models need to be further developed and/or updated
  - Thermodynamics, geochemistry, mechanics
Technology Development Vision

- Goal: Fully-coupled thermal-hydro-mechanical-chemical simulator by 2020
- Hierarchical building of key components
  - Development or collection of laboratory and field datasets
  - Model-component development exercises
  - Physically realistic model(s)
- Support improved predictions of reservoir performance
- Predict permeability enhancement and evolution over varying spatial and temporal scales
- Help elucidate system behavior
2020 Goal
Reliable Software Tools Aiding Decision Making in Engineering, Managing and Optimizing Geothermal Reservoirs

Tier 1
- Thermodynamics and Kinetics
- Mechanics, Fluid Flow, and Heat Transport
- Mass and Energy Balance & Observational Data
- Field/Reservoir Scale Geologic Problems

Tier 2
- Geochemistry, Permeability Evolution
- Constitutive Relations, EOSs, Mechanics
- Pore-scale modeling, SPH, DPD, Lattice-Boltzmann
- Hybrid DEM-FE/FV, Gridless methods

Tier 3
- Advanced Thermo-Hydro-Chemical Models
- Advanced Thermo-Hydro-Mechanical Models
- Alternatives to Continuum Approaches

Tier 4
- Validated and Verified Modeling Tools
- Continuum and Hybrid Field Scale Models
- Understanding Subgrid-Scale Processes
- Datasets, Conceptual Models, and Challenge Problems

Put the pieces together
Build the tools and capabilities to describe controlling physics within continuum based models
The base upon which credible models are built and compared
Tier 1

- Laboratory-scale to well-scale to reservoir-scale datasets
- Examine phenomena in isolation from one another
- Build or compile a series of benchmarking, validation, and challenge problems
  - Code comparison efforts
- Support process conceptualization and numerical simulation of sub-grid scale properties
IPGT Inaugural Workshop on Geothermal Reservoir Simulator Benchmarking

- Villa Garbald, Castasegna, Switzerland, September 22-28, 2012
- Goal is to develop the framework for benchmarking—physics, dimensionality, comparison methods, etc.
- Identify the various types of benchmarking problems
  - Basic code testing and verification
  - Defining meaningful problems and standards for reservoir management simulations
  - Challenge problems that test the capabilities of simulation codes to treat complex, coupled processes occurring in geothermal reservoirs
  - Shape benchmarking such that future developments can be integrated smoothly
- Event limited to ~3 people from each IPGT country (16 -18 total)
- Expected to form the basis for an open, international workshop in 2013 or 2014
Problem Examples-Analytical Solution Based

- Laplacian type problems—conductive heat transfer, pressure diffusion
- Poisson type problems
- Equations of state (What would be the reference? IAPWS-97?, What about brines?)
- Convection-Diffusion problems
- Reactive transport (Can we define a set of simple (fictitious) minerals/species and controlling kinetics?)
- Mechanics
  - 2D compression/tension around circular opening,
  - shear displacement on a plate
  - Terghazzi compaction problems
- Given a reasonable set of boundary and initial conditions, problems such as these should come to a consistent result no matter what code does the calculations.
Challenge Problems

• We may not know the "correct" answer a priori, we may have strong guesses (or observations), but emergent behavior may be a possibility
  – Use certain coupling from the previous slide
  – Can be either analytical or field based
  – Problems with known numerical difficulties

• Specific problems for specific classes of codes

• Coupling methods for “fully coupled” applications
  – Globally implicit
  – Sequential
    • Between different codes
    • Within same code
  – Iterative vs. non-iterative
  – Data transfer

• Method of Manufactured Solutions

• More……
Some Laboratory and Field Data Examples

- Early Stanford papers on two-phase flow experiments
- Icelandic meso-scale relative permeability experiments
- Need more, have seen several in presentations this week…..
• Injectivity low for hot water injection—1.4lps/bar
• Cold water injectivity significantly higher—8.2lps/bar
• Behavior counter to what would be expected due to viscosity changes
  – Viscosity ~5X higher at 20°C
• Injectivity ~6X greater with cold water

Courtesy G. Gunnarsson, Reykjavik Energy
Summary

• If you have a relevant dataset that can be openly shared, please contact me (robert.podgorney@inl.gov)

• If interested to participate in workshop, please email Lauren Boyd (Lauren.Boyd@ee.doe.gov) at GTP
  – Summarize background and area of expertise
  – Why interested?
  – What you can offer?
  – Dataset you can bring?

• Things are developing quickly……
Acknowledgements

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