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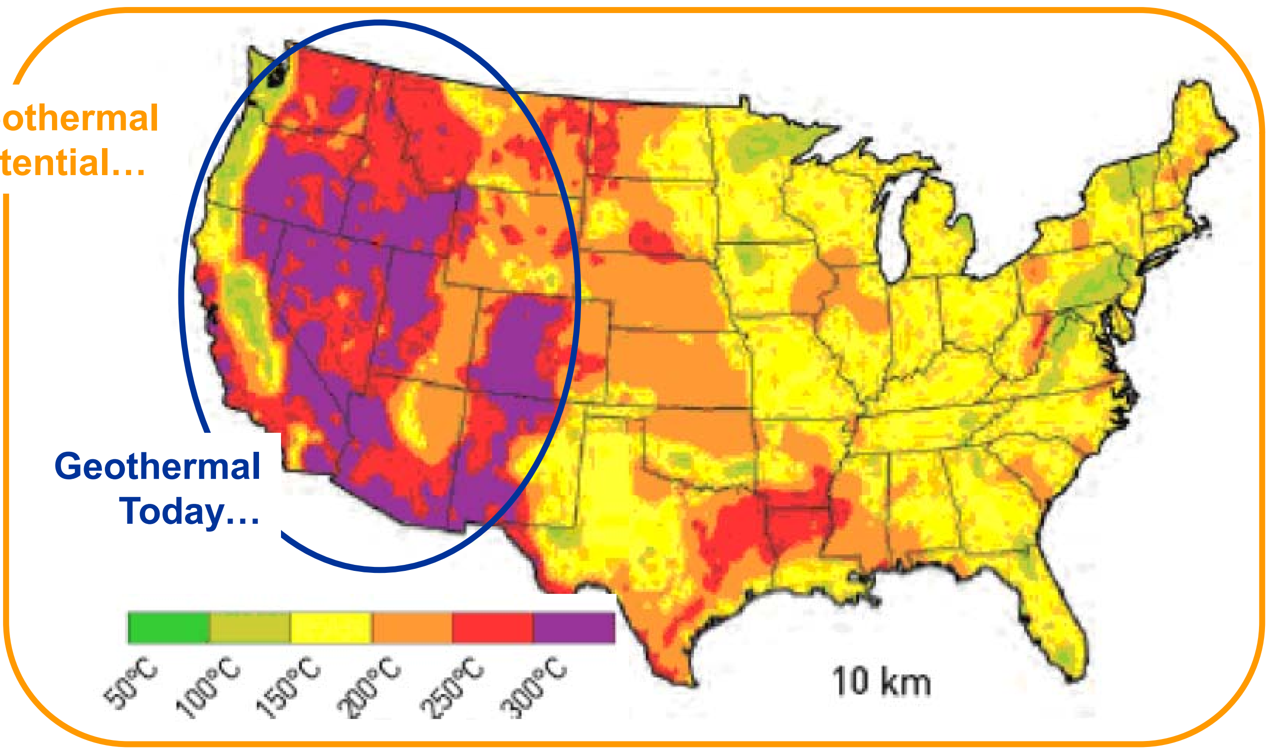

Baseline System Costs for 50.0 MW Enhanced Geothermal System -- A Function of: Working Fluid, Technology, and Location, Location, Location

May 19, 2010

Principal Investigator:
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Gas Equipment Engineering Corporation

Track Name:

Analysis Data System and Education

Overview – 50 MW EGS Cost Analysis

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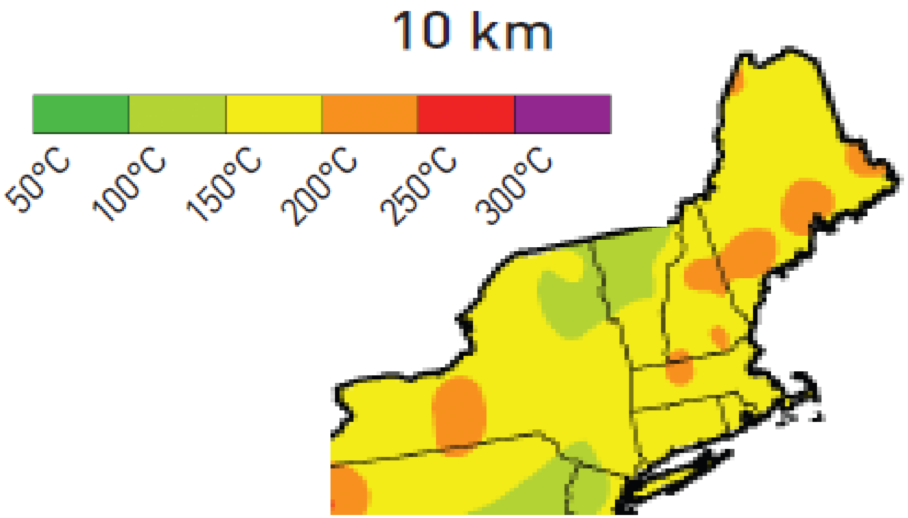

- **Goal: Answer key questions regarding the economic viability of EGS**
  - **Find out to what extent we really can achieve the vision of EGS anywhere**
  - **Starting with a 50 MW plant in South Hadley, MA!!**
- **Overview:**
  - **Timeline**
    - **Start: 4/26/2010; End 12/26/2010; <<10% Complete**
  - **Budget**
    - **$1,660,090 total; $1,243,624 DOE Share; $416,466 Cost Share (~25%)**
  - **Barriers: High Exploration Risks and High Up-front Costs (and poor understanding of costs / ability to predict costs)**
  - **Partners: Fugro NV / Wm. Lettis & Associates; GeothermEx Inc.; POWER Engineers, Inc.; Fairbanks Morse Engines; Plasma Energy, Inc.; Fort Point Associates; Conservation Law Foundation / CLF Ventures; Impact Technologies LLC**

Relevance/Impact of Research

Statement of Project Objectives:

1. **Develop a baseline cost model of a 50.0 MW Enhanced Geothermal System, including all aspects of the project, from finding the resource through to operation, for a particularly challenging scenario: the deep, radioactively decaying granitic rock of the Pioneer Valley in Western Massachusetts.**

2. **Develop an understanding of how that cost model changes / improves with the change from H_2O EGS to CO_2 EGS.**

3. **Develop an understanding of how that cost model changes / improves with respect to key technologies, specifically:**
   a) **Conventional (Auger & Bit) vs. New Technology Drilling, and**
   b) **CO_2 EGS hybrid power system gas generation and processing approaches.**
   c) **What will be the cost at key Geothermal Technologies Program goal years given an assumed level of Government investment – zero, target and over-target from a baseline 2010, 2015, 2030 and 2050**

4. **Develop an understanding of how that cost model changes / improves with respect to location, specifically:**
   a) **Temperature profile vs. depth**
   b) **Geology, geo chemistry (rock type, porosity, etc)**
   c) **Local electric rates (as they apply to the effective cost of CO_2 and EGS ROI overall).**

Scientific/Technical Approach: Work Breakdown Structure Based Costing

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- **Development of the baseline cost of an Enhanced Geothermal System, whether conventional pumped water or a novel hybrid CO2 system, and regardless of power level, requires a understanding of the "sequence of events" and the cost drivers associated with the sequence of events…i.e Work Breakdown Structure**

    1. **ID / Qualify / Quantify**
    2. **Develop Reservoir**
    3. **Generate / Manage Fluids**
    4. **Make Power**
    5. **Local Hook Up / Distribution**
    6. **Grid Hook Up / Distribution**
    7. **Top Side Facilities / Equipment**
    8. **Land Acquisition / Royalty**
    9. **Permits / Approvals**
    10. **Management and Operation**

Scientific / Technical Approach (Continued)

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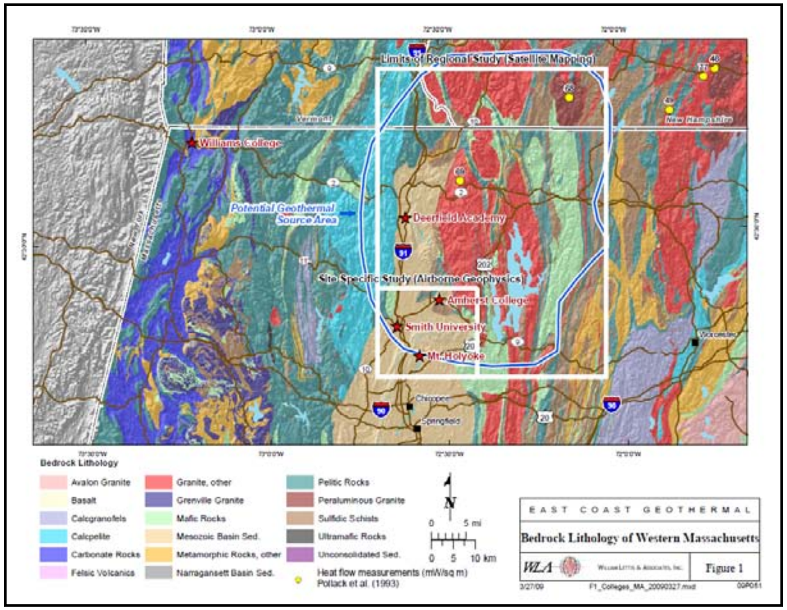
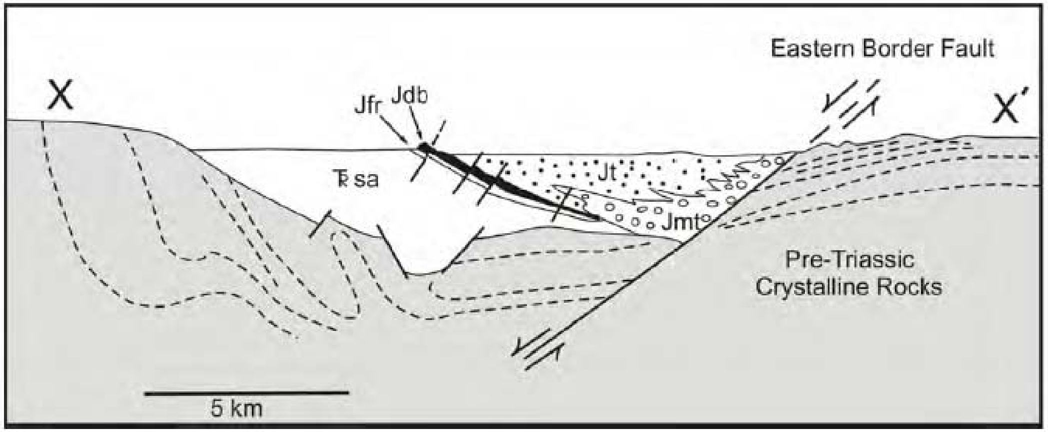
Design Based Cost Analysis:

- **Task 1.0 H_2O & CO_2 Geothermal Resource Identification, Qualification, Analysis and Quantification**
- **Task 2.0 Geothermal Resource Acquisition, Access (Leases, Royalty Agreements, and Revenue Sharing), and Permits. Approvals & Incentives and Valuation: PPA & Incentives**
- **Task 3.0 CO_2 EGS and H_2O EGS Geothermal Reservoir Analysis and Planning**
- **Task 4.0 Top-of-Well Fluid Management & Electricity Generation Equipment, Facilities and Electric Grid Integration**
- **Task 5.0 Project Management and Reporting**





Accomplishments, Expected Outcomes and Progress

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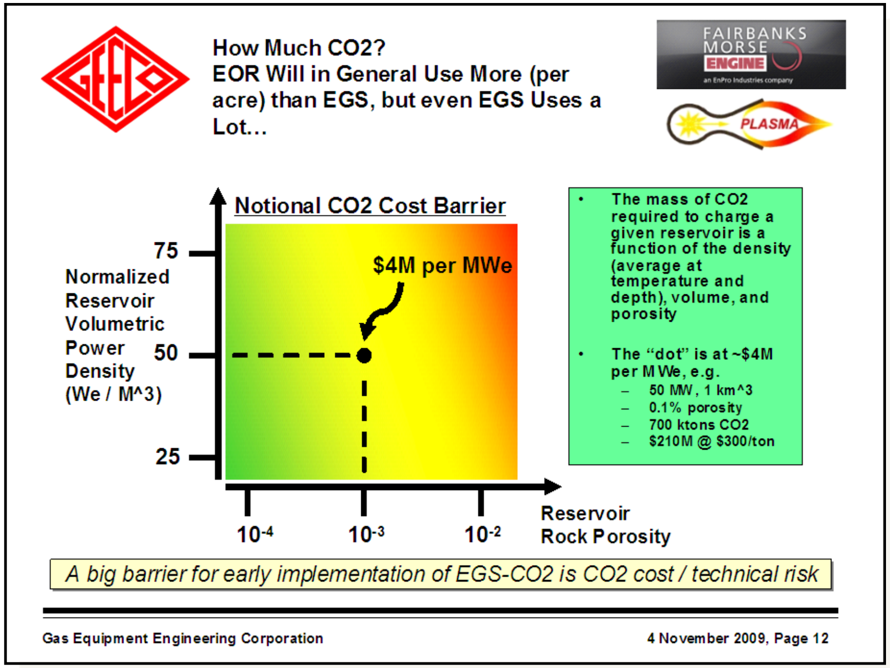
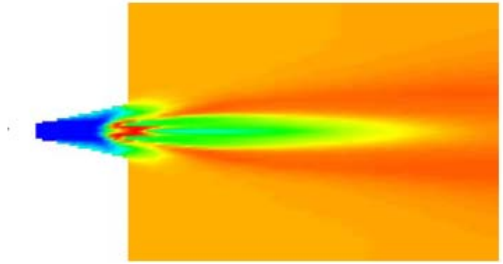
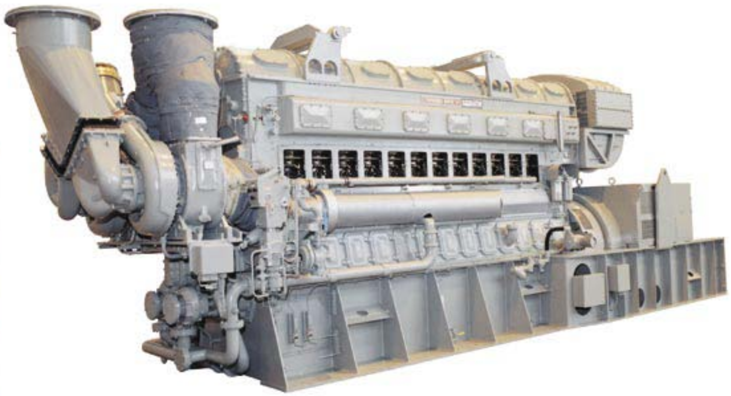
- **Accomplishments / Progress: (Not Much Yet)**
  - Contract awarded (conditions removed) on 26 April 2010 (less than one month ago)
  - Met with K. Oglesby of Impact Technologies LLC on 28 April 2010; Impact Technologies LLC will be part of this effort



- **Expected Outcome: (Success!!)**
  - Partners: Fugro NV / Wm. Lettis & Associates; GeothermEx Inc.; POWER Engineers, Inc.; Fairbanks Morse Engines; Plasma Energy, Inc.; Fort Point Associates; Conservation Law Foundation / CLF Ventures; Impact Technologies LLC are extremely well qualified
  - “Carbon Dioxide Sequestration / Generation and Top Side Equipment in Support of Enhanced Oil Recovery, Enhanced Geothermal Systems, or Both!”; published SMU Geothermal Conference, 4 November 2009





Project Management/Coordination

- Initial efforts have just been associated with getting contracts / funding to team
- We will have monthly virtual meetings and weekly status calls
  - Initial meeting focused on determining inter team deliverables / schedule
- There will likely be three full team face to face meetings (at least the first one will be in the Mohegan Sun area)
  - Kickoff / defined inter team deliverable / schedule
  - Mid-Point, initial deliverables
  - Near-End, finalize cost model
- Sub-contract funding and project billing will follow a 40 / 30 / 30 plan nominally associated with these meetings / deliverables
- We will also attend DOE quarterly meetings and try to time our meetings to feed into the DOE events
- To the extent that new data is gathered, we will work with the National Geothermal Data System to ensure data are provided to the system
  - We will also endeavor to have the state geologic survey people at appropriate meetings

Future Directions

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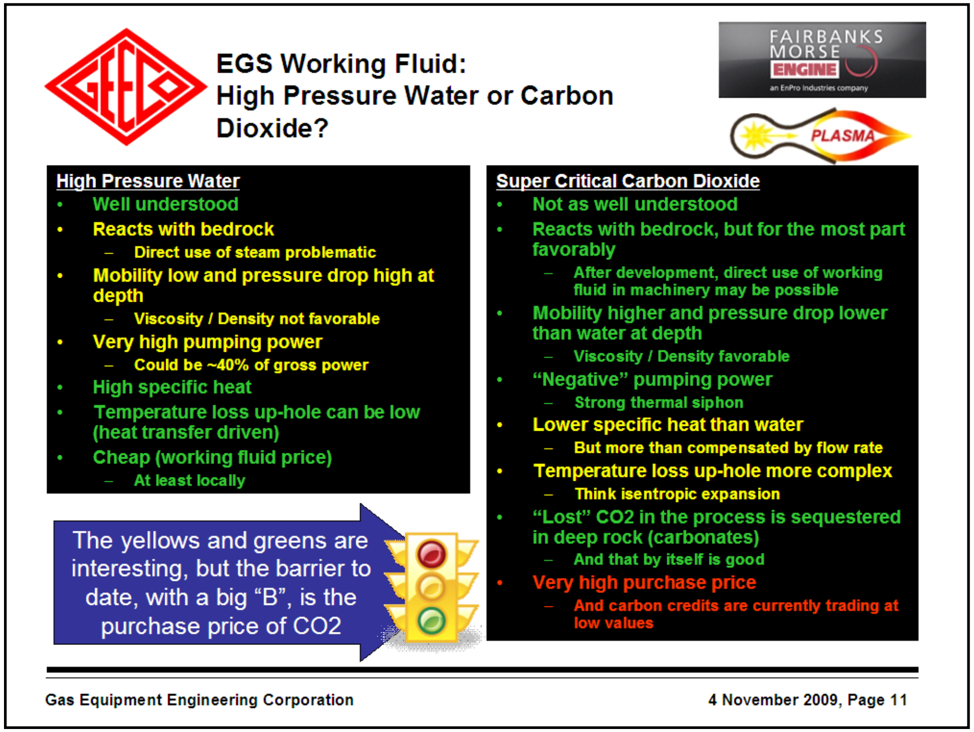
- The specifics of the future direction will depend on the cost analysis results, but as a minimum it will be necessary at some point to:
  - – Lower the cost of CO_2 generation
    - If not for EGS, for EOR!!
  - – Demonstrate substantially reduced drilling and reservoir development costs
  - – Assuming CO_2 remains favored over water (as we suspect it will), develop top side equipment (power generation) to take advantage of both the thermal energy and pressure energy available (probably low pressure ratio direct turbine)
  - – Build a pilot plant in a favorable location that integrates these concepts



- We hope to deliver an analysis and cost tool / methodology that will help steer the future direction

Summary

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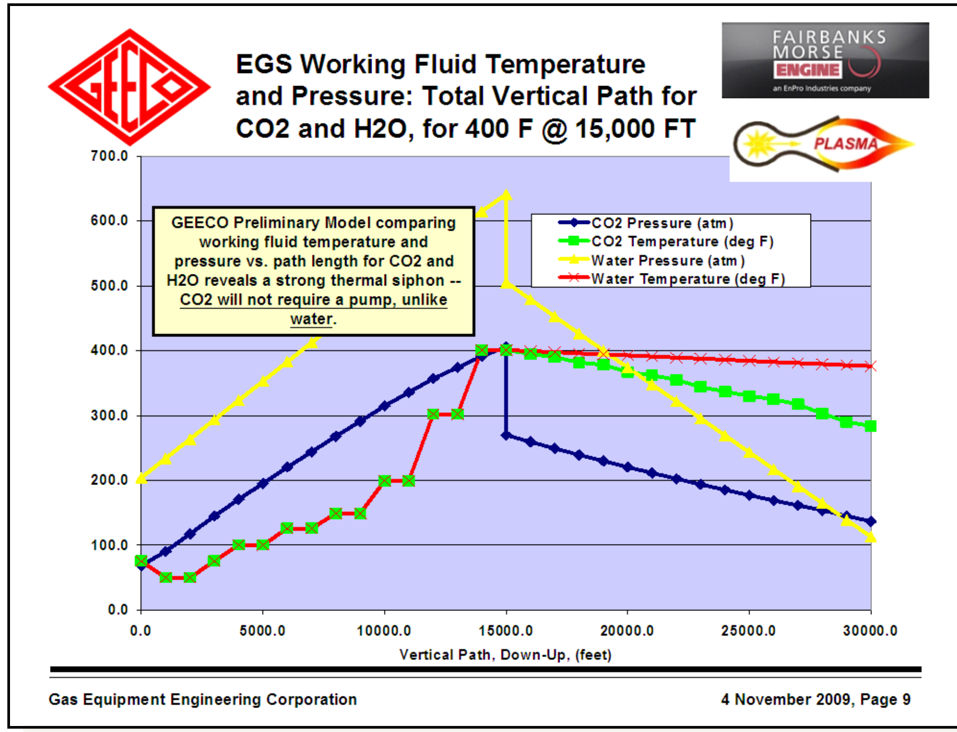
- **GEECO and a team of 7 others were awarded a contract last month for "Baseline System Costs for 50.0 MW Enhanced Geothermal System"**

- **There is a four part Statement of Project Objectives:**
  1. **Develop a baseline cost model of a 50.0 MW Enhanced Geothermal System…**
  2. **Develop an understanding of … cost model changes… from H2O-EGS to CO2-EGS...**
  3. **Develop an understanding of … cost model changes… with respect to key technologies…**
  4. **Develop an understanding of … cost model changes… with respect to "location, location, location" …**



- **We expect to complete contract efforts this year**

Supplemental Slides

Scientific/Technical Approach: Work Breakdown Structure Based Costing

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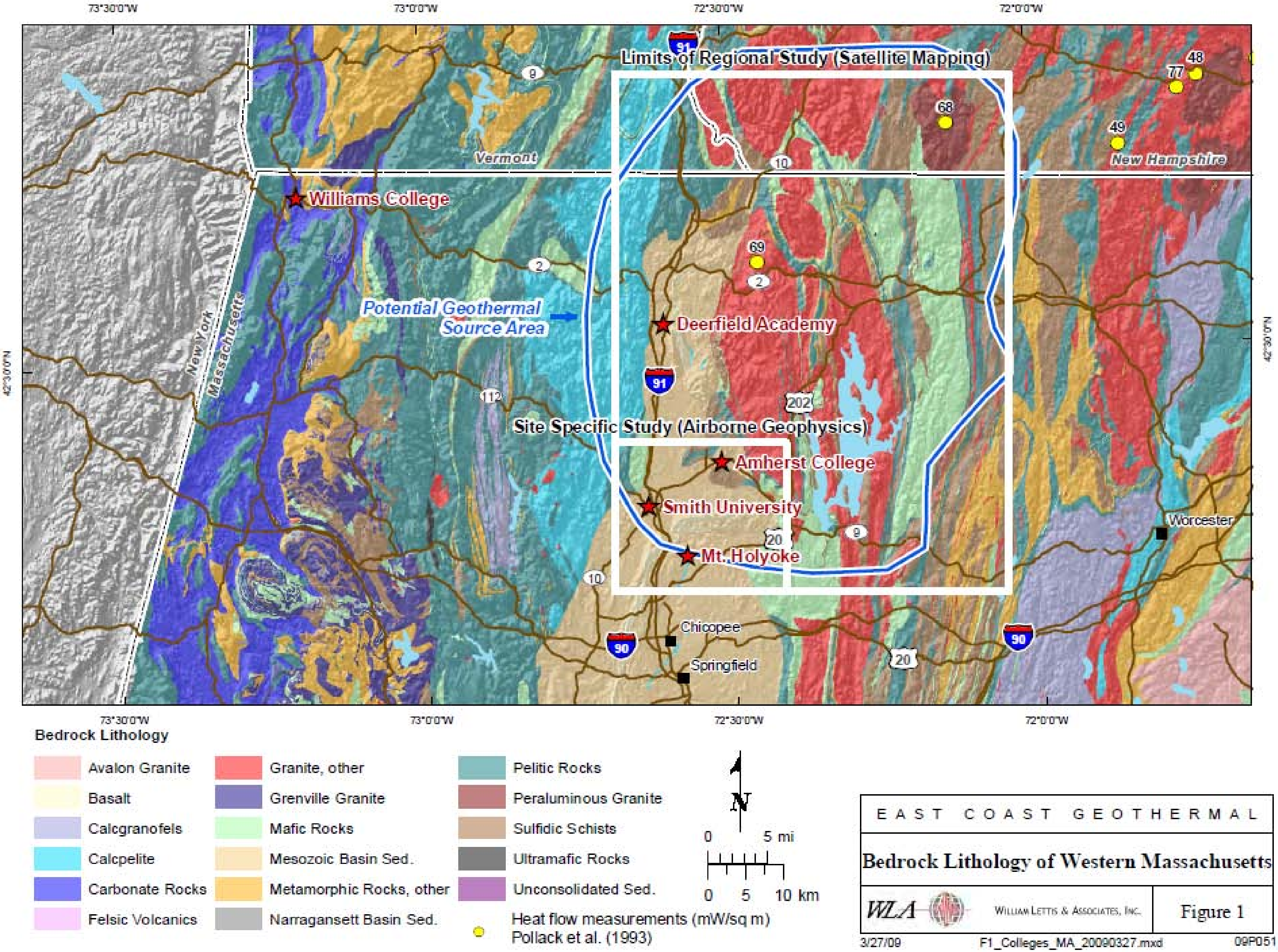
- **Development of the baseline cost of an Enhanced Geothermal System, whether conventional pumped water or a novel hybrid CO2 system, and regardless of power level, requires a understanding of the "sequence of events" and the cost drivers associated with the sequence of events that must occur through the process of scouting, assessing, selecting, designing, constructing, developing / starting, and operating an EGS. Baseline cost must consider, but is not limited to, the designs, work plans, and systems costs associated with:**

1. **Geothermal resource identification, qualification, analysis and quantification;**
2. **Engineered CO2 EGS and H2O EGS geothermal reservoir planning, development ,management and ongoing monitoring;**
3. **CO2 gas management (generation, purification, dehydration, pressurization and temperature control) systems and equipment and H2O EGS fluid management (replenishment, purification, phased, porosity-tailored, mixed viscosity) systems and equipment**
4. **Integrated or and standalone direct high pressure CO2 gas flow through high speed turbine generators and super heated CO2 gas and H2O fluid flow through modified ORC binary electric generators to produce electricity**
5. **CO2 EGS and / or H2O EGS integration and hook up to local heat and power generation and distribution infrastructure**
6. **CO2 EGS and / or H2O EGS integration and hook-up to the commercial power grid;**
7. **Top of well sites and facilities to house surface elements of 50.0MW CO2 EGS and 50.0MW H2O EGS applications;**
8. **Land acquisition and / or land use w/ royalty agreements;**
9. **Federal, State local and private (stakeholders) permits, approvals incentives leading to and enabling construction and operation of CO2 EGS and H2O EGS applications at 50.0MW;**
10. **Project management requirements and costs associated with a 50.0MW CO2 EGS and 50.0MW H2OEGS application of this scale and magnitude.**



73°30'0"W
73°0'0"W
72°30'0"W
72°0'0"W
42°30'0"N
42°30'0"N
Limits of Regional Study (Satellite Mapping)
Site Specific Study (Airborne Geophysics)
Potential Geothermal Source Area
Vermont
New Hampshire
New York
Massachusetts
Williams College
Deerfield Academy
Amherst College
Smith University
Mt. Holyoke
Worcester
Chicopee
Springfield
91
90
9
10
2
112
202
20
48
77
68
49
69
Bedrock Lithology
Avalon Granite
Basalt
Calcgranofels
Calcpelite
Carbonate Rocks
Felsic Volcanics
Granite, other
Grenville Granite
Mafic Rocks
Mesozoic Basin Sed.
Metamorphic Rocks, other
Narragansett Basin Sed.
Pelitic Rocks
Peraluminous Granite
Sulfidic Schists
Ultramafic Rocks
Unconsolidated Sed.
Heat flow measurements (mW/sq m)
Pollack et al. (1993)
N
0 5 mi
0 5 10 km
EAST COAST GEOTHERMAL
Bedrock Lithology of Western Massachusetts
WLA
William Lettis & Associates, Inc.
Figure 1
3/27/09
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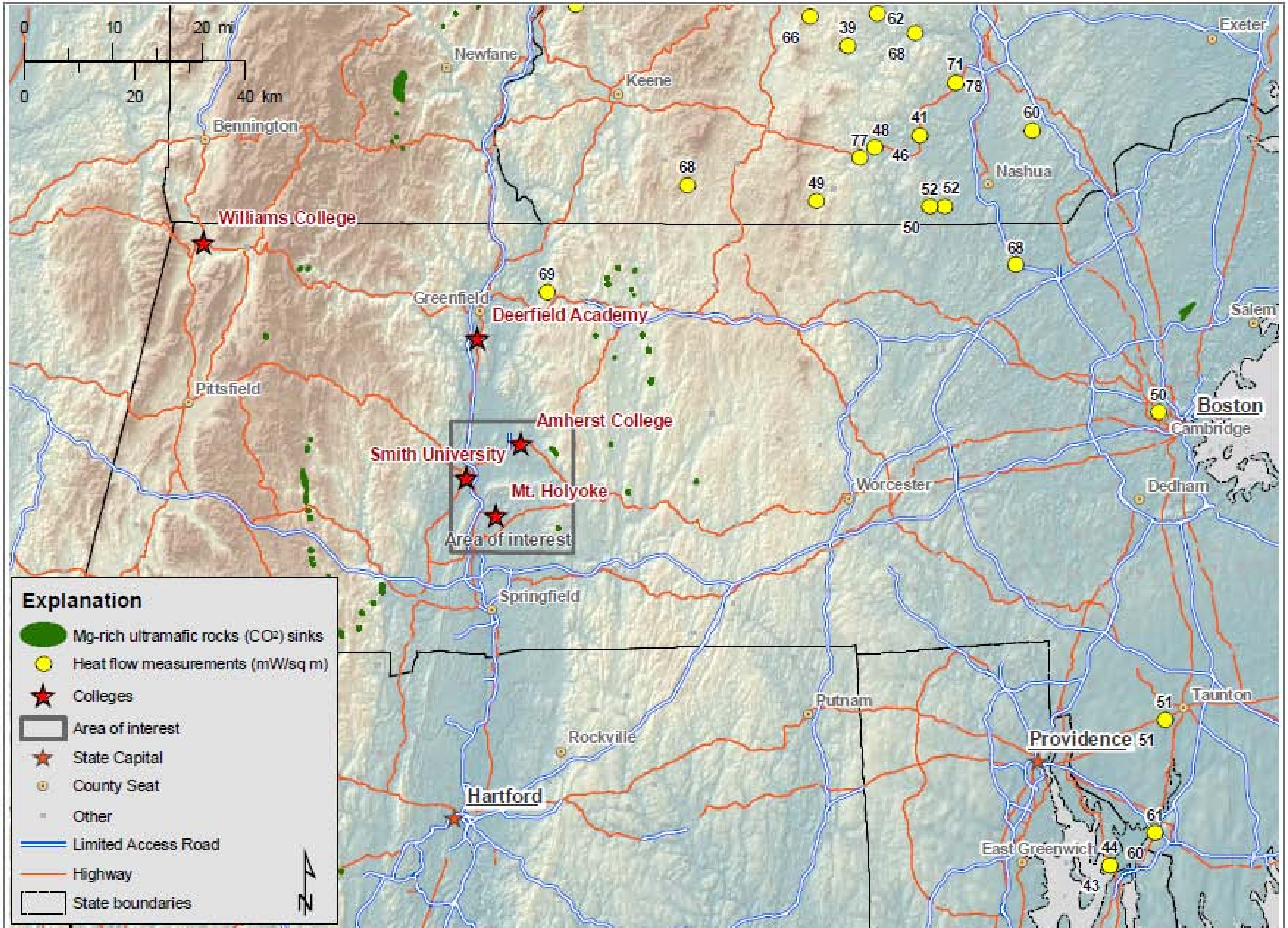


WLA

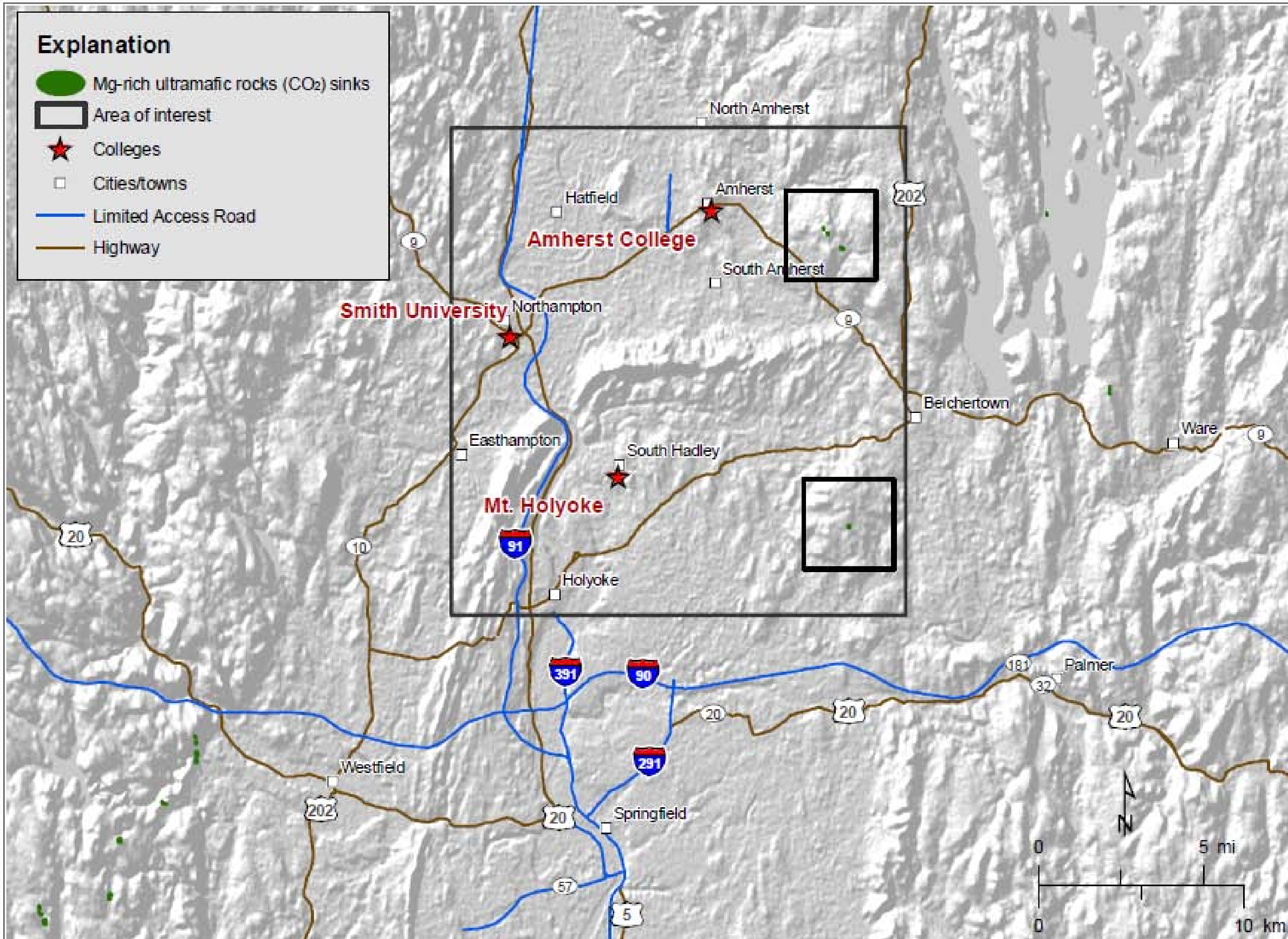
Regional Heat Flow Measurements and Ultramafic Rock Outcrops (CO_2) Sinks

EAST COAST GEOTHERMAL

Figure 2

F2_ECG_REGIONAL_20090327.MXD

27 MAR 09, 09P051, ECG REGIONAL, DLS



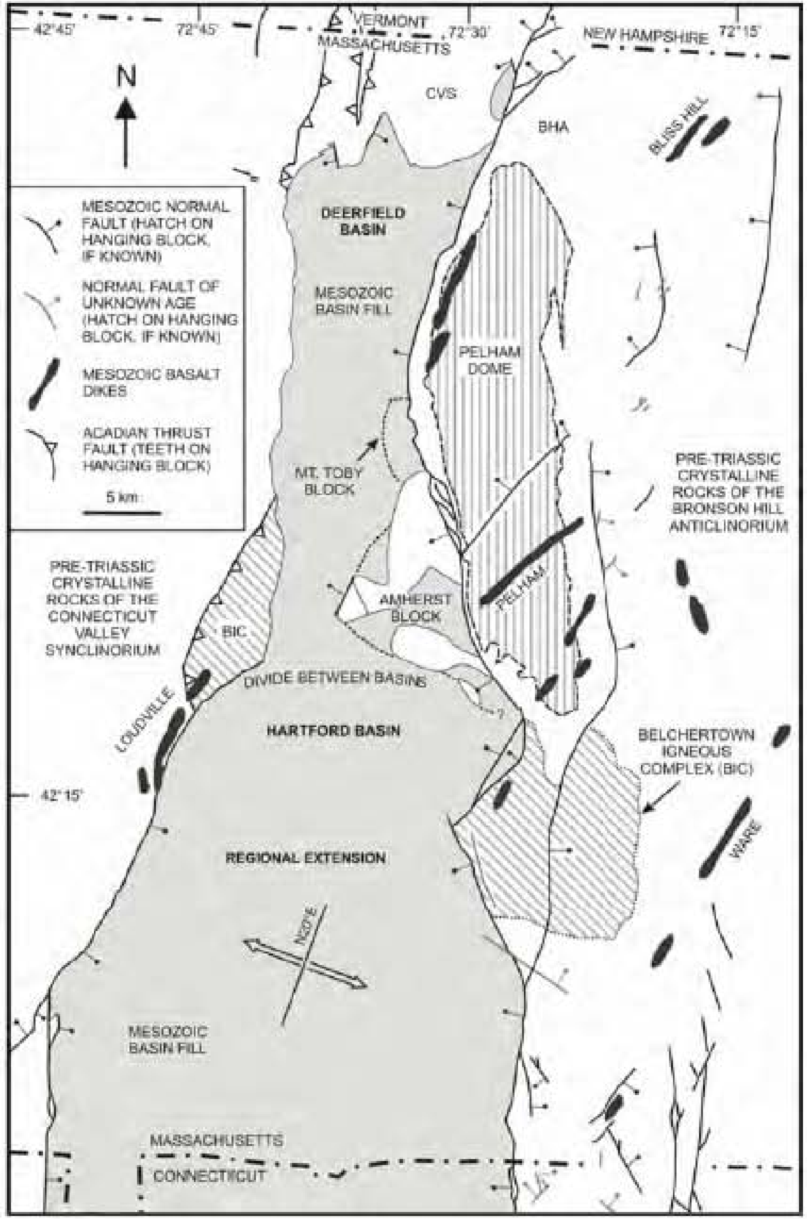
WLA

Detailed Area of Geothermal Interest
Western Massachusetts

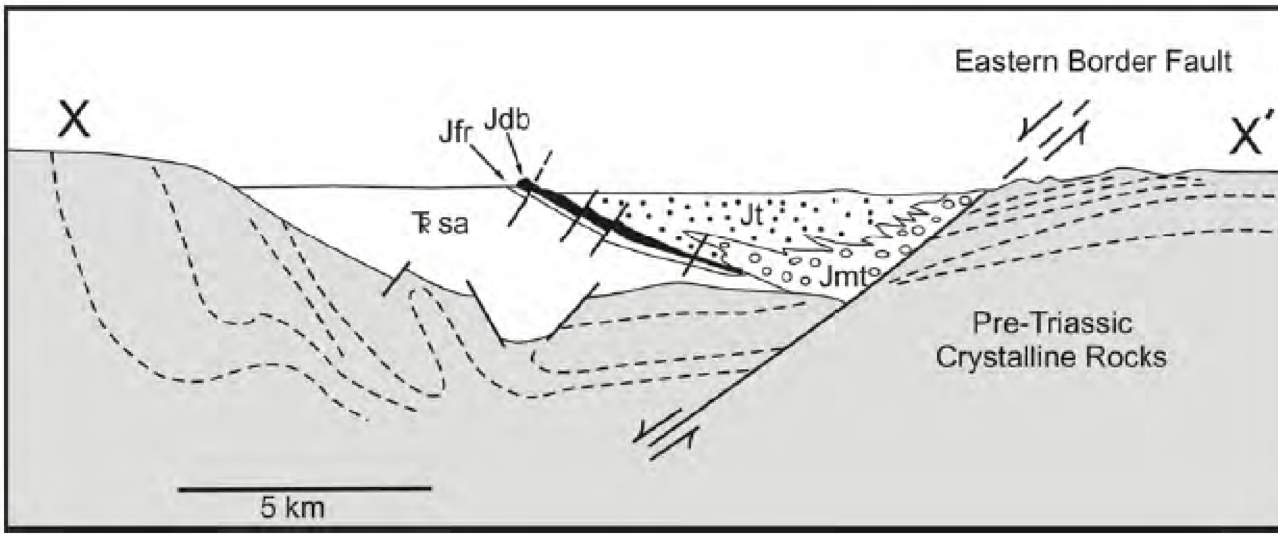
EAST COAST GEOTHERMAL
Figure 3

F3_ECG_GEOTHERMAL_ZONES_20090327.MXD

27 MAR 09, 09P051, GEOTHERMAL ZONES, DLS



Generalized geologic map of Mt. Holyoke College area (from Walsh, 2008)



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WLA

Representative geologic cross section north of Mt. Holyoke College area (from Walsh, 2008)

EAST COAST GEOTHERMAL
Figure 5

F2_ECG_REGIONAL_20090327.MXD

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