GEOTHERMAL POTENTIAL OF ST. KITTS AND NEVIS ISLANDS

By

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For the

Eastern Caribbean Geothermal Energy Project
("Geo- Caraibes"; "G-C")

Presented Using Data From:

- GeoSys, Inc.
- GeothermEx, Inc.
- Massachusetts Institute of Technology
- SP International, Inc.
- University of the West Indies – Seismic Research Unit

Selected Previous Investigations

- P.H.A. Martin-Kaye 1959
- Hutton and Nockholds 1978
- Geotermica Italiana 1992
- G. W. Huttrer 1998

Regional Setting

- The islands are two of eleven Caribbean islands of volcanic origin.
- The dome within Mt. Nevis is ~ 60,000 years old.
- Earthquakes are common, with a notable swarm in 1950-1951.
- Dominant regional fault orientations are NE-SW and NW-SE.

The following four slides list the geothermal indicia identified by previous investigators on St. Kitts and Nevis. They are intended to serve as a concise summary of “what geothermally-relevant information was known” prior to the G-C PDF-B phase studies.

Geothermal Indicia of St. Kitts (1/2)

- Small solfataras in the Mt. Liamuiga crater.
- Several reported offshore warm springs.
- Sulfurous warm spring near the base of Brimstone Hill.
- Reported “scalding” well water near Brimstone Hill.
- Phreatic explosion craters “Toomba” and “Round Hole”, NW of Mt. Liamuiga.

Geothermal Indicia of St. Kitts (2/2)

- Warm (35C) waters in Basseterre Basin wells.
- A paleo-solfatara near the north end of Frigate Bay and Fort Tyson.
- Young “Steel Dust” pyroclastic deposits.

Geothermal Indicia of Nevis (1/2)

- Active solfataras at Farms Estate, Cades Estate and along the road to Long Point.
- Temperatures up to 100C at all three sites.
- A paleo-solfatara, with abundant siliceous rocks, on the SE flank of Saddle Hill.
- An extensive, thick, paleo-solfatara and “hot, smelly” waters beneath much of the Belmont region.

Geothermal Indicia of Nevis (2/2)

- Warm (~43C) waters flowing from the Charlestown Fault at The Baths.
- Warm (35-43C) waters reported from wells drilled in the Stony Grove, Belmont, Indian Castle and Charlestown areas.
- Reports of “scalding” waters in a well drilled on the Brown Estate.
- Warm springs and wells along the western coast, near Mt. Lilly, at Spring Hill and offshore.

Why the G-C focus on Nevis ?

- Though both St. Kitts and Nevis have geothermal potential, the indicia on Nevis are larger, hotter, and more geographically constrained than those on St. Kitts. Accordingly, G-C geoscientists believe that a Nevis geothermal resource can be characterized and developed more rapidly and less expensively than one on St. Kitts.

Geoscientific Studies on Nevis during the G-C PDF-B phase

- Geological reconnaissance mapping of western Nevis.
- Geochemical sampling and evaluations of thermal waters, on and offshore, with emphasis on the western side of Nevis.
- Gravity and geographic positioning surveys in the SW part of the island.
- A Self-Potential (“S-P”) survey in the SW part of the island.

Geological Reconnaissance Mapping Results (1/2)

- Heat Source – Likely to be centrally located beneath Nevis Peak.
- Fluid Source – Meteoric waters, heated at depth, then rising buoyantly to enter one or more geothermal reservoir zones.
- Thermal Fluid Movement – Laterally outward from Nevis Peak to the NW, SW, and West.

Geological Mapping Results (2/2)

- Geothermal Reservoir Rocks – Likely to comprise various igneous and sedimentary formations, with enhanced permeability due to alteration, brecciation, and/or tectonic deformation.
- Fluid Conduits – Fracture systems allow leakage of thermal fluids to the surface and facilitate subsurface circulation.
- Reservoir Depth and Thickness – Probably 200-300 hundred meters down and <500 meters thick. Shape and extent are as yet undefined.

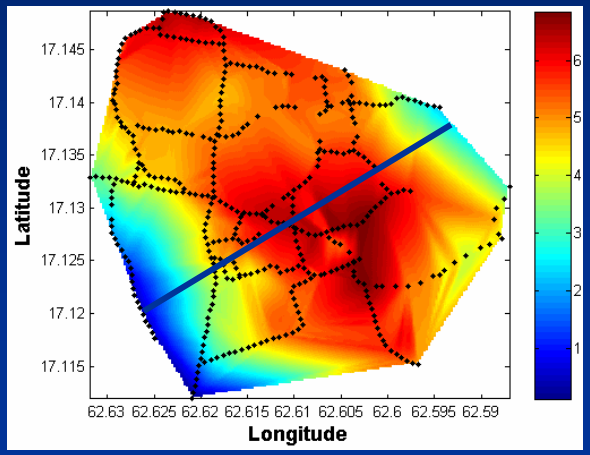
Geochemical Evaluation Results

- Primary thermal fluids are mixed with cold, shallow groundwaters and/or seawater in all onshore samples and their percentages are too small to allow calculation of equilibrium temperatures.
- Several offshore thermal springs appear to have larger percentages of primary thermal fluids; using samples of these waters, equilibrium temperatures have been estimated to be ~170C.

Gravity Survey Results

- A northwest trending region of anomalously high gravity underlies much of the Charlestown area; the highest readings are along the main road between Brown Hill and Church Ground and also north of Craddocks.
- Modeling suggests the top of a dense body, possibly a lava flow acting as an aquatard, to be ~200 meters down, be ~300 meters thick and have a lateral extent of ~ 2.5 kilometers. More geophysical data is desirable.

Bouguer 2.6 g/cc



Self Potential (SP) Survey Results

- Faults and fractures have been confirmed to control the flow of thermal fluids.
- Two sub-parallel S55E trending faults appear to bound the heat source related to the Bath, Farms Estate, and Stony Grove thermal waters.
- Anomalous SP activity near Deep Harbor may comprise a separate system, possibly connected to the hot Brown/Douglas well; further data is needed in this area.

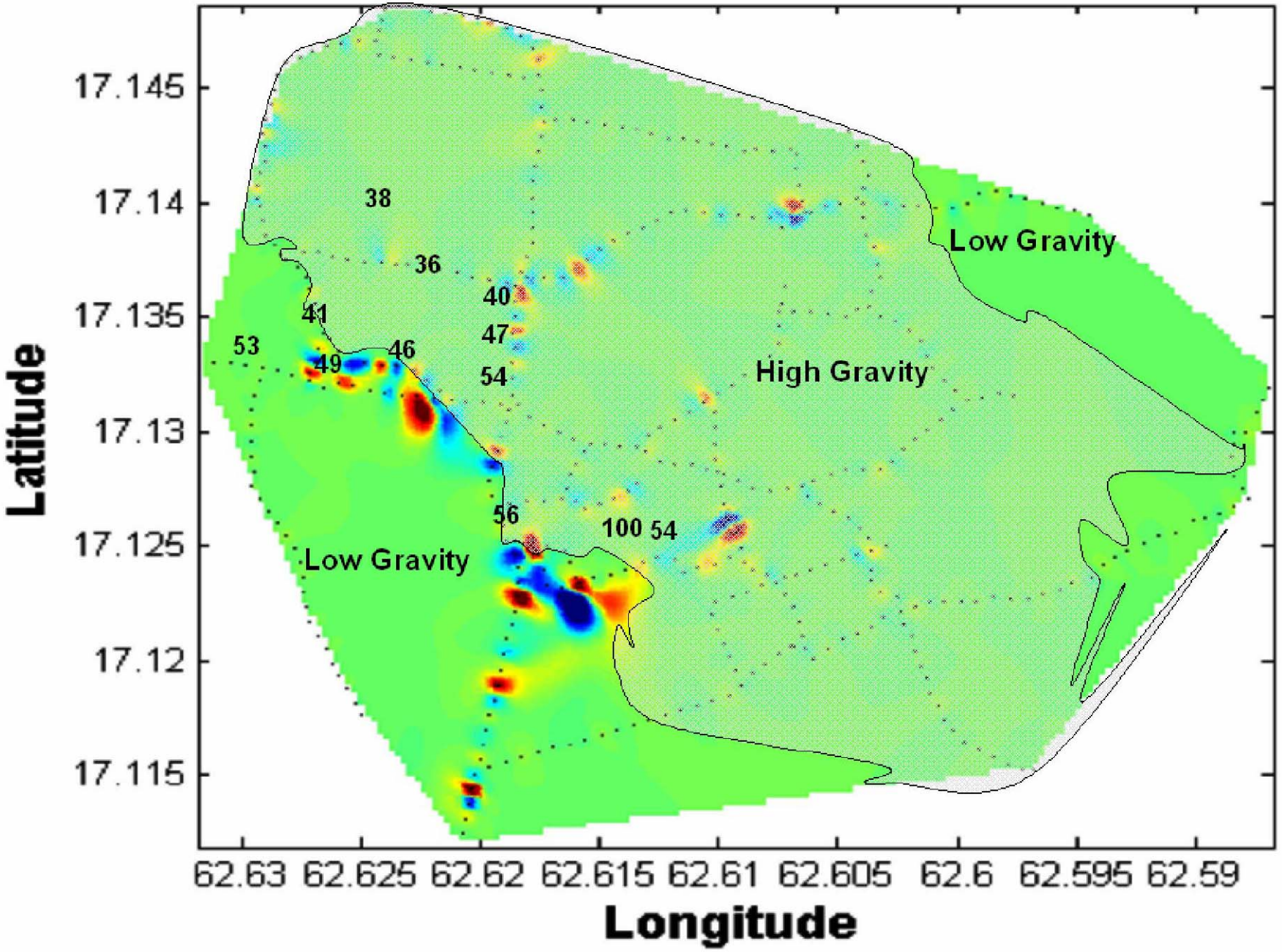


Figure: Possible Extent of Bouguer Gravity Body With SP Current Sources

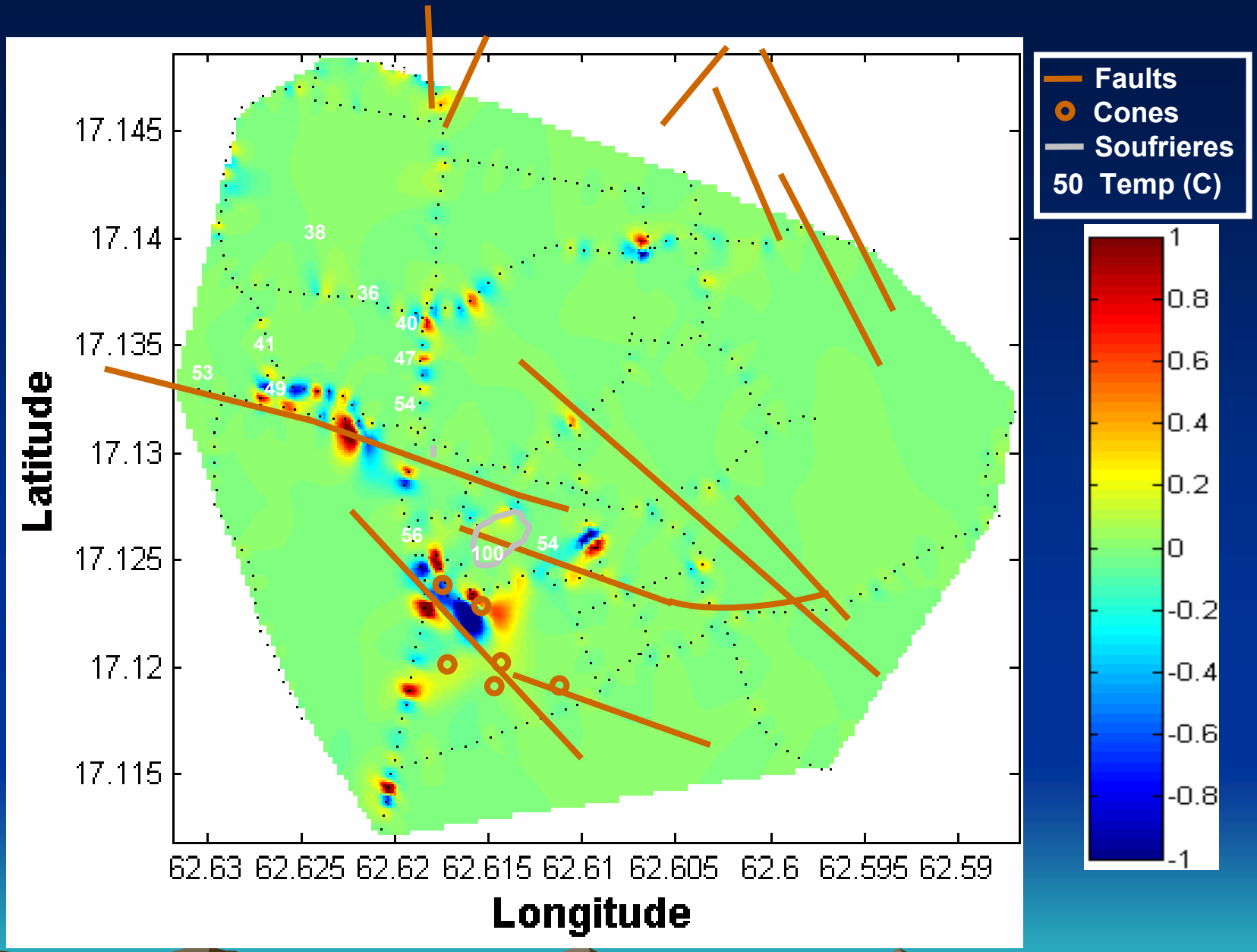


Figure 23: Normalized SP Current Sources. Faults and Cones from Huttrer (1998) and Temperatures from GeothermEx (2004).

Recommended Further Geophysical Exploration

- Conduct a two dimensional (2D) resistivity survey across the gravity high to obtain depth-related information.
- Measure self potentials and gravity along eight lines located so as to fill in data gaps and improve understanding of anomalies including those in the Brown Estate/Douglas well area.
- Consider conduct of a 3D resistivity survey over the areas identified as being especially prospective on the basis of the results of earlier geophysical surveys.

Recommended Drilling

Following the conduct and interpretation of the final geophysical studies:

- Drill six 150 meter deep thermal gradient holes at sites identified on the basis of the combined geoscientific study results.
- Drill two slim exploration wells to ~1,000 meters near the sites having the highest thermal gradients. Test the wells so as to obtain maximum resource information.

SUMMARY (1/6)

1. St. Kitts and Nevis are part of the geothermally prospective volcanic islands of the Caribbean archipelago.
2. Both islands have numerous geothermal indicia, however those on Nevis are larger, hotter, and more geographically concentrated. It therefore, believed that the Nevis Geothermal resource can be characterized and developed faster and for less money than that beneath St. Kitts.

SUMMARY (2/6)

3. Geologic mapping conducted during PDF-B has allowed the conceptualization of a geothermal model including a heat source, a conduit system necessary for transport of thermal fluids, and potential reservoir rocks.
4. Geochemical studies suggest that primary thermal fluids and cooler waters are mixed and that equilibrated resource temperatures may approximate 170 degrees Celsius. ***This temperature would be adequate for power generation via Binary Cycle facilities***.

SUMMARY (3/6)

5. Gravity surveys have identified an anomalous gravity high beneath the Charlestown region. This may be due to an especially dense rock mass and/or shallow burial of an intrusive body.
6. One reasonable model for this mass shows its top to be 200 meters down, its thickness to be about 300 meters, and a lateral extent of about 2.5 kilometers.

SUMMARY (4/6)

7. Self Potential survey results confirm that faults are conducting thermal waters to the surface, that thermal waters are rising around the edges of the gravity high, and that the thermal waters in and around Charlestown are bounded by two S55E striking fracture systems. A second thermal system appears possible in the Brown Estate/Douglas well region.

SUMMARY (5/6)

8. Conduct of additional gravity, self potential and resistivity studies in selected areas are recommended to fill in data gaps and enable creation of more precise geo-structural and geothermal models.
9. The drilling first, of 6 thermal gradient holes and second, 2 slim exploratory wells is recommended. The bores would be sited at locations determined by synthesis of all previously generated geoscientific data.

SUMMARY (6/6)

10. If all of the exploration summarily described above is successful, it may be possible to develop a moderate temperature geothermal resource for the generation of electric power using Binary Cycle equipment. This power could be used on Nevis and also be transmitted via sub-sea cable to St. Kitts and possibly to other nearby islands.