PROPOSAL OUTLINE for GEOLOGIC ANALYSIS AND CONCEPTUAL MODELING OF THE GLASS MOUNTAIN HYDROTHERMAL SYSTEM, SISKIYOU COUNTY, CALIFORNIA

A planning document for

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Introduction

It is our understanding that Calpine Corporation, now the sole geothermal leaseholder at the Glass Mountain (Medicine Lake) geothermal property, is planning an ambitious exploration and development drilling program there to commence in mid-2002. Calpine, which has long controlled the Fourmile Hill region in the northern part of the system, recently acquired the larger Telephone Flat area (adjacent and to the south) from CalEnergy Company. The combined Telephone Flat-Fourmile Hill sample and database now makes it possible, for the first time, to complete an integrated, field-wide geologic analysis at Glass Mountain. The governing objective of this analysis is to help Calpine reduce risks and costs in exploration and development of the Glass Mountain resource; for example, to permit siting of wells with the best calculated chance for producing high-temperature geothermal fluid, or conversely to accept injectate with minimal impact on reservoir performance.

The Principal Investigators (PIs) are particularly well suited to complete this work for Calpine. D. Norton's unique knowledge base and numerical-modeling capabilities enable the placement of tight constraints on the evolution of magmatically-heated high-temperature hydrothermal systems such as the one now active at Glass Mountain. These constraints are directly germane to exploration and development planning, as they encompass heat centers, permeability "sweet spots", and the most copious fluid-flow conduits.

Norton's theoretical work is nicely complemented by the petrographic, mineralogic, igneous-petrogenetic, volcanological, and 3-D graphic approach of J. Hulen. Moreover, Hulen and colleague S.J. Lutz completed, in the 1980s and early 1990s, most if not all the X-ray diffraction (XRD) and reconnaissance petrographic work at Glass Mountain, both for CalEnergy and its predecessor at the site, Unocal geothermal. With minimal review and refinement, the results of those proprietary studies can be brought directly to bear on the new resource assessment. Geomatics Laboratory Director Greg Nash has devised a plan to assemble the large Glass Mountain database into an extremely "user-friendly", GIS centered format.

We will be focused on improving knowledge of the following critical parameters of the Glass Mountain hydrothermal system:

- Igneous heat source (or sources); active and fossil (crystallized plutons) – Age, composition, geometry, depth
- Hydrothermal alteration mineralogy and zoning as guides to configuration of the active geothermal system and any fossil equivalents. In other words, is the present distribution of hydrothermal alteration the result of a single system, or is it imprinted on the effects of one or more older systems?
- Porosity and permeability -- primary vs secondary (e.g. cinder beds vs faults), geometry, magnitude, and distribution.
- Structure – faults, fracture zones, stockworks, breccia bodies
- Overall system geometry – Area, thickness, volume, limits
- Fluid chemistry
- Temperature distribution

- Inflow, upflow, and outflow zones
- Vertical and lateral permeability barriers (seals)
- Volcanic stratigraphy and chronology
- Vein mineralogy and paragenesis; metallic mineralization (e.g., a possible porphyry copper connection).

We will also provide an independent analysis of a long-standing controversy for the Glass Mountain area – Is Medicine Lake volcano surmounted by a classical caldera, or are the apical summit depression and surrounding subsidiary volcanics merely suggestive of such an origin?

Finally, we will analyze and numerically constrain the curiously cold isothermal upper part of the Glass Mountain system (as low as 15°C isothermal in the upper several hundred meters of the system). This phenomenon (the so-called "rain curtain") makes it permissible that other large Glass Mountain-type hydrothermal systems occur completely "blind" along the entire eastern flank of the Cascade Range. The better we understand this phenomenon, the more likely such potential, wholly-concealed systems will be found and developed in the future.

The proposed work is organized into the following tasks:

1. (Hulen, Norton) -- In preparation for the new geologic analysis and conceptual modeling effort -- Assemble and review published and proprietary literature on Medicine Lake volcano and the Fourmile Hill and Telephone Flat portions of the Glass Mountain hydrothermal system.
    - 20 person days
    - Estimated cost – (***Total: $11K***); Hulen: $7.5K; Norton: $3.5K

2. (Hulen, Lutz) -- Log in detail the core from recently deepened Calpine Fourmile Hill corehole 88-28. Emphasis here on lithology, volcanic stratigraphy, fracturing and vein mineralization, hydrothermal alteration. Complete reconnaissance petrographic and XRD work similar to that performed for other Glass Mountain boreholes in the past.
    - 15 person days; 50 polished thin sections; 50 bulk XRD analyses; 30 clay XRD analyses.
    - Estimated cost – (***Total: $21K***); Hulen and Lutz: $7.5K; Thin sections: $1.5K; Bulk XRD: $5K; Clay XRD: $4.5K; Administrative support: $1K; Illustration: $1.5K

3. (Hulen, Lutz) -- Critically compare hydrothermal alteration mineralogy and zoning in 88-28 with that intersected in productive Telephone Flat geothermal wells. Although the alteration (particularly propylitic alteration) may be superficially similar between these wells and the relatively impermeable 88-28, are there subtle differences that can be practically used to discriminate the "productive" from the "nonproductive" varieties? This will involve reviewing existing petrographic work and thin sections from (for example) Telephone Flat well 87-13, completing more detailed petrographic work on selected samples and intervals of that well, probably logging selected lengths of altered core in that well, then comparing and contrasting the alteration styles of 87-13 and 88-28.

- 20 person-days; 20 polished thin sections; 10 electron-microprobe microchemical analyses of selected alteration and vein minerals (especially epidote); 10 bulk XRD; 10 clay XRD
- Estimated cost: (***Total: $14.6K***); Hulen and Lutz: $10K; Thin sections: $600; Electron microprobe analyses: $1K; Bulk XRD: $1K; Clay XRD: $1.5K; Administrative support: $200; Illustration: $300

4. Complete a detailed investigation of the igneous intrusions encountered at depth in the Telephone Flat area (Hulen, Norton). Determine compositions, ages, geometries (to the extent possible), relation to overlying and internal hydrothermal alteration mineralogy and zoning. Determine whether or not these intrusions could be the heat source(s) for the active Glass Mountain hydrothermal system. Determine the role of these intrusions in creating fracture permeability. As the granodiorite encountered in well 31-17 is potassically altered (secondary biotite and K-feldspar), ascertain the applicability of porphyry copper intrusion, cooling, hydrothermal circulation, and permeability creation models (a focus for Norton while Professor of Geology at the University of Arizona).
   - 25 person days; 50 polished thin sections; 50 bulk XRD analyses; 30 clay XRD analyses; 30 electron-microprobe microchemical analyses of selected secondary phases; 7 $^{40}Ar/^{39}Ar$ age dates and mineral thermal-history models
   - Estimated cost: (***Total: $32K***); Hulen: $7.5K; Norton: $7K; Thin sections: $1.5K; Electron microprobe analyses: $3K; Bulk XRD: $5K; Clay XRD: $4.5K; Administrative support: $1.4K; Illustration: $2.1K.

5. Utilization of existing temperature, fluid composition, lithology, structural disruption, and hydrothermal alteration data (Calpine, CalEnergy, Unocal, Occidental, etc.) to construct a series of cross sections and level maps through the entire Glass Mountain hydrothermal system (Hulen). Selected parameters to be plotted in 3-D for full clarity and predictive capability. Temperature, for example, to be plotted at 250 m elevation increments to the deepest levels encountered; to be plotted on at least 7 mutually intersecting cross-sections; and finally to be visualized in three dimensions. Same for lithology and alteration.
   - 35 person-days
   - Estimated cost: (***Total: $23.6K***); Hulen: $17.5K; Illustration $5K; Administrative support: $1.1K.

6. Develop and prepare a reference set of rock type, alteration, and vein-mineral types for use in logging future exploration and development wells at Glass Mountain (Hulen). Prepare a corresponding well-site logging manual, similar to the one put together for The Geysers Coring Project in the mid-1990s, but tailored to the local geologic setting.
   - 25 person-days; 50 polished thin sections; 50 bulk XRD; 30 clay XRD; 25 high-precision, full-spectrum geochemical analyses, including trace elements (especially REE).
   - Estimated cost: (***Total: $29.9K***); Hulen: $12.5K; Thin sections: $1.5K; Bulk XRD: $5K; Clay XRD: $4.5K; Geochemical analyses: $2.5K; Administrative support: $1.3K; Illustration: $2.6K.

7. Independently assess the validity of the existence of a caldera atop Medicine Lake volcano (Hulen, Lutz). This will involve selective logging, petrographic analysis, and detailed geochemical analysis of felsic volcanic units as potentially excellent marker horizons as encountered in the Glass Mountain boreholes. Also will involve construction

of several geologic sections through the summit depression and constructive volcanic ring at the apex of the volcano.

- 25 person-days; 30 detailed geochemical analyses; 7 radiometric age dates; 30 polished thin sections; 20 electron-microprobe microchemical analyses of accessory phases in the felsic volcanics.
- Estimated cost: (***Total: $29.9K***); Hulen and Lutz: $12.5K; Geochemical analyses: $3K; Radiometric age dates: $8.5K; Thin sections: $600; Electron microprobe analyses: $2K; Administrative support: $1.3K; Illustration: $2K.

8. (D. Norton, with support from J. Hulen) -- Numerical modeling of heat and mass transfer through time above and around cooling igneous intrusions in the Glass Mountain system. Ultimately to include, and to be based upon, new information gained through the tasks outlined above, but to begin immediately utilizing existing data and to modify as new information becomes available.
   - 30 person days
   - Estimated cost: ***$21K***

9. G. Nash) – Data Handling, visualization, analysis, and archiving, Glass Mountain project -- Assemble the extensive Glass Mountain database in readily accessible and usable GIS format, so that, for example, versions of any field parameter can be instantly viewed, and, where appropriate, from any imaginary angle. Nash has prepared a separate write-up for this task (attached).
   - Estimated Cost: ***Total: ~$25K***

We also welcome the opportunity to work closely not only with you in carrying out the above tasks, but with our friends and colleagues Mark Walters and Alex Schriener, both of whom, at this point, know a lot more about the Glass Mountain system than any of us do.

Please consider this proposal outline a draft (planning document), and feel free to suggest modifications to be more in line with Calpine philosophy and objectives. The University of Utah's Office of Sponsored Projects will also need to review the final contract(s); they have a standard one that they prefer us to use, and we'd be glad to send a sample copy for your legal staff to review. I believe it's pretty straightforward, the only stipulation being that, as a university project, results of the study can be published after a suitable period of confidentiality.

We look forward to hearing from you.

Sincerely yours,

Jeff Hulen
January 7, 2002