# *Geology and Conceptual Modeling of the Silver Peak Geothermal Prospect, Esmeralda County, Nevada*

*report for*

***Sierra Geothermal Power Corporation***
666 Burrard Street, Suite 500
Vancouver, British Columbia, Canada V6C 3P6

*by*

***Jeffrey B. Hulen,*** *PG*
Consulting Geologist
1375 Talachiro Circle, Ivins, UT 84738
435-634-8046 801-641-8460 (mobile)
jbh_rmh@kayenta.net

July 31, 2008

## *Contents*

*page*

## *Appendices*

## *Figures*

## *Executive Summary*

Sierra Geothermal Power Corporation's Silver Peak geothermal prospect, in Esmeralda County, Nevada, encompasses a "deep-circulation (amagmatic)" meteoric-geothermal system circulating beneath basin-fill sediments locally blanketed with travertine in western Clayton Valley (lithium-rich brines from which have been mined for several decades). Spring- and shallow-borehole thermal-water geochemistry and geothermometry suggest that a Silver Peak geothermal reservoir is very likely to attain the temperature range 260-300$^{o}$F (~125-150$^{o}$C), and may reach 300-340$^{o}$F (~150-170$^{o}$C) or higher *(GeothermEx, Inc., 2006)*. Results of detailed geologic mapping, structural analysis, and conceptual modeling of the prospect (**1**) support the *GeothermEx (op. cit.)* assertion that the Silver Peak prospect has good potential for geothermal-power production; and (**2**) provide a theoretical geologic framework for further exploration and development of the resource.

The Silver Peak prospect is situated in the transtensional (regional shearing coupled with extension) Walker Lane structural belt, and squarely within the late Miocene to Pliocene (11 Ma to ~5 Ma) Silver Peak-Lone Mountain metamorphic core complex (SPCC), a feature that accommodated initial displacement transfer between major right-lateral strike-slip fault zones on opposite sides of the Walker Lane. The SPCC consists essentially of a ductiley-deformed lower plate, or "core," of Proterozoic metamorphic tectonites and tectonized Mesozoic granitoids separated by a regionally extensive, low-angle detachment fault from an upper plate of severely stretched and fractured structural slices of brittle, Proterozoic to Miocene-age lithologies. From a geothermal perspective, the detachment fault itself and some of the upper-plate structural sheets could function as important, if secondary, subhorizontal thermal-fluid aquifers in a Silver Peak hydrothermal system.

The mapping and modeling indicate that the principal structural aquifers for the hydrothermal system—the conduits most likely to focus upwelling, high-volume, high-temperature geofluids—will be post-core-complex, moderate- to high-angle, normal- to oblique-slip faults and fracture zones oriented NNW and, to a lesser extent, NNE: Faults of the first orientation, as indicated by mapping and gravity inversion, underlie all modern hot-spring deposits and recently active thermal phenomena in western Clayton valley. A preliminary conceptual geohydrologic model of the Silver Peak hydrothermal system calls for (**1**) broad-scale, downward percolation of brines—principally evolved "fossil" waters of late Pleistocene age from Clayton Valley basin—into subjacent, fractured but sparingly permeable, brittle basement rocks; (**2**) heating of these brines in response to an elevated regional thermal gradient of, say, 50$^{o}$C/km (2.8$^{o}$F/100 ft); and (**3**) coalescence and buoyant upwelling of the heated brines in northerly-trending fault zones rendered selectively permeable as a consequence of oblique extension. Results of the modeling suggest that commercially-producible geothermal brines could be advecting upward in these structures only a few thousand feet beneath the newly-mapped travertine mounds.

## *Introduction and Prospect History*

At the request of Sierra Geothermal Power Corporation (SGP), the writer has geologically mapped (***Appendix 1***) and conceptually modeled the company's Silver Peak geothermal prospect, in Esmeralda County, Nevada *(**Figure 1**)*. The work was undertaken in order to significantly improve understanding of the prospect's subsurface structural setting and geothermics, thus assisting SGP with optimization of its ongoing and planned Silver Peak exploration and drilling activities.

The prospect is centered on a narrow, 1.6 km-long, NNW-trending belt of travertine and algal tufa deposits at the western margin of the Clayton Valley playa, where that feature—best known for its lithium-rich brines *(Zampirro, 2003)*—abuts Mineral Ridge, the easternmost salient of the Silver Peak Range *(**Figure 2**)*. Hot springs (up to 118$^{o}$F/48$^{o}$C) historically active in the travertine-tufa belt *(Garside and Schilling, 1979)* are now extinct as a result of a recent drop in the water table.

The Silver Peak prospect's commercial-geothermal potential was first investigated by Phillips Petroleum Corporation, the Geothermal Division of which drilled four shallow temperature-gradient holes within and near the current leasehold-area in the early 1980s. One of these holes encountered a temperature of 123$^{o}$F at only 130 ft (51$^{o}$C @ 40 m), but the company abandoned its exploration efforts here shortly thereafter. The prospect languished until late 2005 and early 2006, when *Western Geothermal Partners (WGP; 2006)*—in collaboration with Clayton Valley lithium producer Chemetall-Foote—drilled two more thermal-gradient holes on and adjacent to the travertine-tufa belt. The deeper of these holes revealed a promising shallow thermal gradient of 14.1$^{o}$F/100 ft (256$^{o}$C/km) to a depth of 400 ft (122 m). Shortly following completion and logging of these two boreholes, SGP purchased the leases from WGP (which retains a royalty interest). SGP immediately designed for the property an aggressive exploration program, one module of which is documented by the present report.

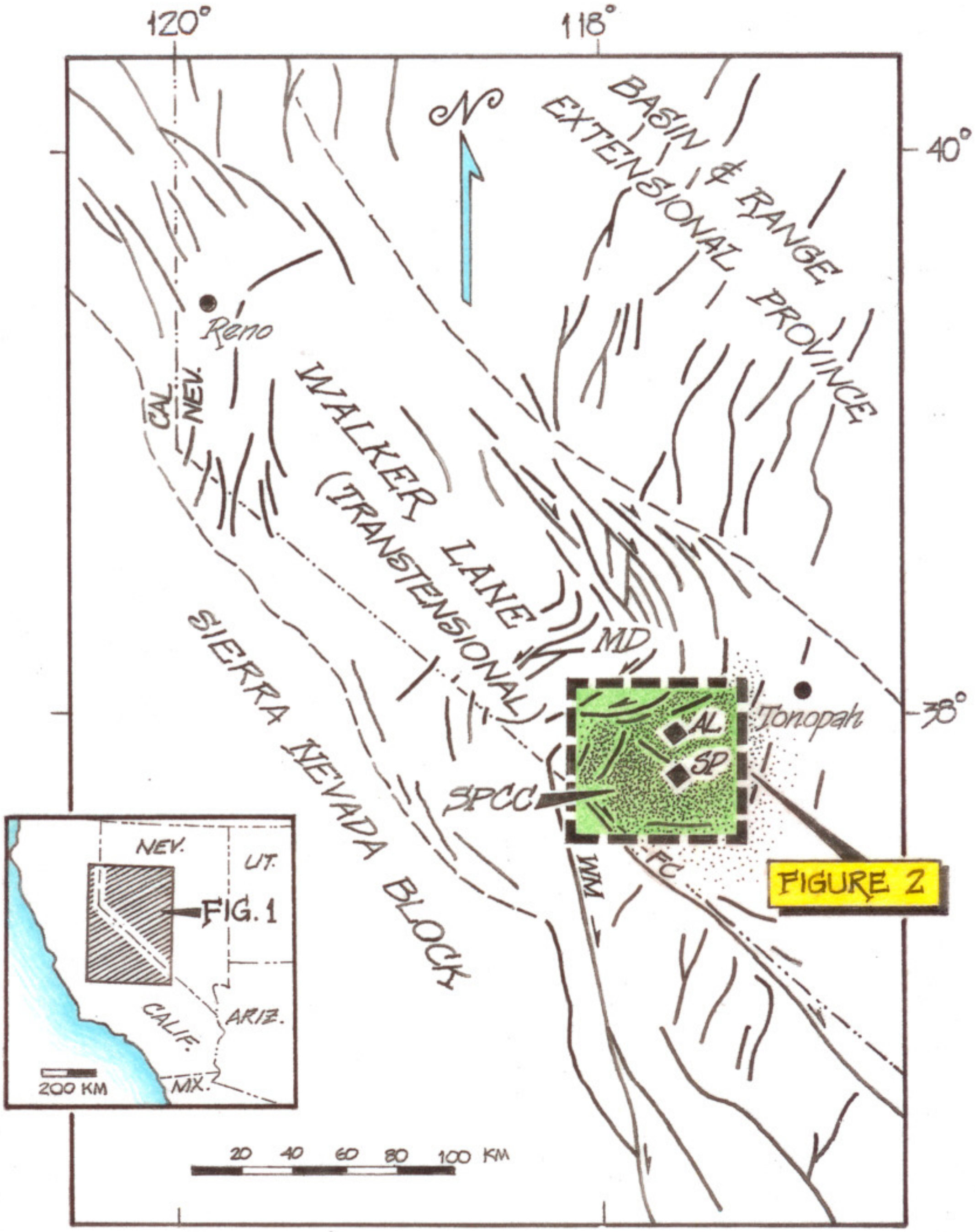



**Figure 1.** Location and late Cenozoic high-angle-fault map of west-central Nevada and east-central California, showing positions of the Silver Peak (**SP**) and Alum (**AL**) geothermal prospects (filled diamonds) within the Silver Peak-Lone Mountain metamorphic core complex (**SPCC**; stippled area), a recently-active (*i.e.,* geologically; through late Miocene at least) displacement-transfer feature in the transtensional Walker Lane structural belt. Other abbreviations: **FC**—Furnace Creek fault zone; **MD**—Mina Deflection; **WM**—White Mountains fault zone. Please refer to text for additional explanation. Map minimally modified for this report from *Oldow (2003b).*

## *Previous Work*

The Silver Peak property has been geologically mapped previously as a portion of numerous regional but small-scale (1:62,500 and smaller) mapping efforts, most notable among which have been those of *Kirsch, 1971; Albers and Stewart, 1972; Diamond, 1990; Price et al., 2000; Oldow et al., 2003; Zampirro, 2003; Petronis et al., 2003, 2007;* and *Elias, 2005*. *Western Geothermal Partners (2006)* completed semi-detailed geologic mapping and evaluation of the prospect (and its surroundings; with selected borehole data) specifically directed toward better understanding the property's geothermal potential (***Appendix 2***). Several studies have been aimed at elucidating the hydrogeology and origin of the lithium-rich Clayton valley brines *(Kunasz, 1970; Davis and Vine, 1979; Davis et al., 1986; Price et al., op. cit.;* and *Zampirro, op. cit.)*. *Spurr (1906)* mapped some of the metallic ore deposits of the Silver Peak quadrangle, including the precious-metal orebodies of Mineral Ridge later characterized in detail by *Craig (2003)*. The most comprehensive treatise and evaluation of the Silver Peak prospect to date is that of *GeothermEx, Inc. (2006; see also **Appendix 3**)*, which prepared a comprehensive "43-101" Independent Technical Report on the property for SGP.

## *Geologic Setting*

Silver Peak is one of two SGP geothermal prospects (the other being Alum, about 10 km to the north) in the Walker Lane structural belt of west-central Nevada and east-central California (***Figure 1;*** *Stewart, 1990; Oldow et al., 2003; Wesnousky, 2005*). The Walker Lane is a generally northwest-trending transition zone separating the rigid Sierra Nevada block, on the west, from the essentially pure-extensional Basin-and-Range province on the east. Results from satellite-based space geodesy *(Dixon et al., 2000)* reveal that the Sierra Nevada block, or microplate, is moving (relative to a stable North America) at a velocity of about 14 mm/yr to the northwest, while the Basin and Range is moving west-northwest at a much slower rate, only about 2-3 mm/yr *(Oldow, 2003a)*. Between these two domains, the Walker Lane accommodates their velocity-vector differential by *transtension*, a type of strain in which, in this case, NW-directed dextral (right-lateral) shear is accompanied by an element of WNW-oriented extension. This strain mode can be particularly amenable to the creation and maintenance of fracture porosity and permeability for geothermal-fluid flow and storage. Indeed, the two biggest active geothermal systems in the United States—at The Geysers *(e.g., Norton and Hulen, 2001)* and the Salton Sea field *(e.g., Elders et al., 1972)* in California—reside in demonstrably transtensional tectonic regimes.

The latitudinal range of the Walker Lane encompassing the Silver Peak and Alum prospects is characterized by eastward *displacement transfer* from major active right-lateral strike-slip fault zones in the western (to the south) and eastern (to the north) portions of the province *(Oldow, 2003b; Oldow et al., 2003;* ***Figure 1****).* The displacement transfer is now accomplished by major left-lateral strike-slip faults of the Mina Deflection *(Oldow et al., op. cit.;* ***Figures 1*** *and* ***2****),* but between ~11 and 5 Ma (million years ago), the transfer was effected via the Silver Peak-Lone Mountain metamorphic core complex (SPCC). Akin to other such structures throughout North America (e.g., *Davis and Lister, 1988),* the SPCC is characterized by a broadly upwarped, locally-exposed, ductiley-deformed, "core"—of commonly mylonitized high-grade Proterozoic metamorphic rocks and similarly but less affected Mesozoic granitoid plutons—separated by a mylonitic, low-angle detachment-fault zone from an overlying, stretched, complexly-faulted, -folded, and brecciated upper plate of brittle lithologies ranging in age from Proterozoic through Mio-Pliocene. Location of Silver Peak and Alum within the SPCC therefore has implications for the fundamental permeability architecture of both of these geothermal prospects.

In essence, initial displacement transfer (11 Ma to ~6 [?] Ma) from the western to the eastern Walker Lane wrench faults *(****Figure 1****)* by the SPCC involved "dragging" of the brittle upper plate northwestward above a laterally-fixed ductile core (see drawings in *Oldow, 2003b)* which, however, locally ascended to the surface as a means of restoring isostatic equilibrium. In latest Miocene to early Pliocene time (~6 Ma [?] to ~5 Ma), deeply-rooted, clockwise, vertical-axis rotation of the SPCC caused widespread folding of both the upper *and* lower plates, and apparently terminated active core-complex evolution *(Petronis et al., 2003, 2007).* Since the latest Miocene or earliest Pliocene, the "immobilized" SPCC has been broken by numerous, generally north-northeast-trending,

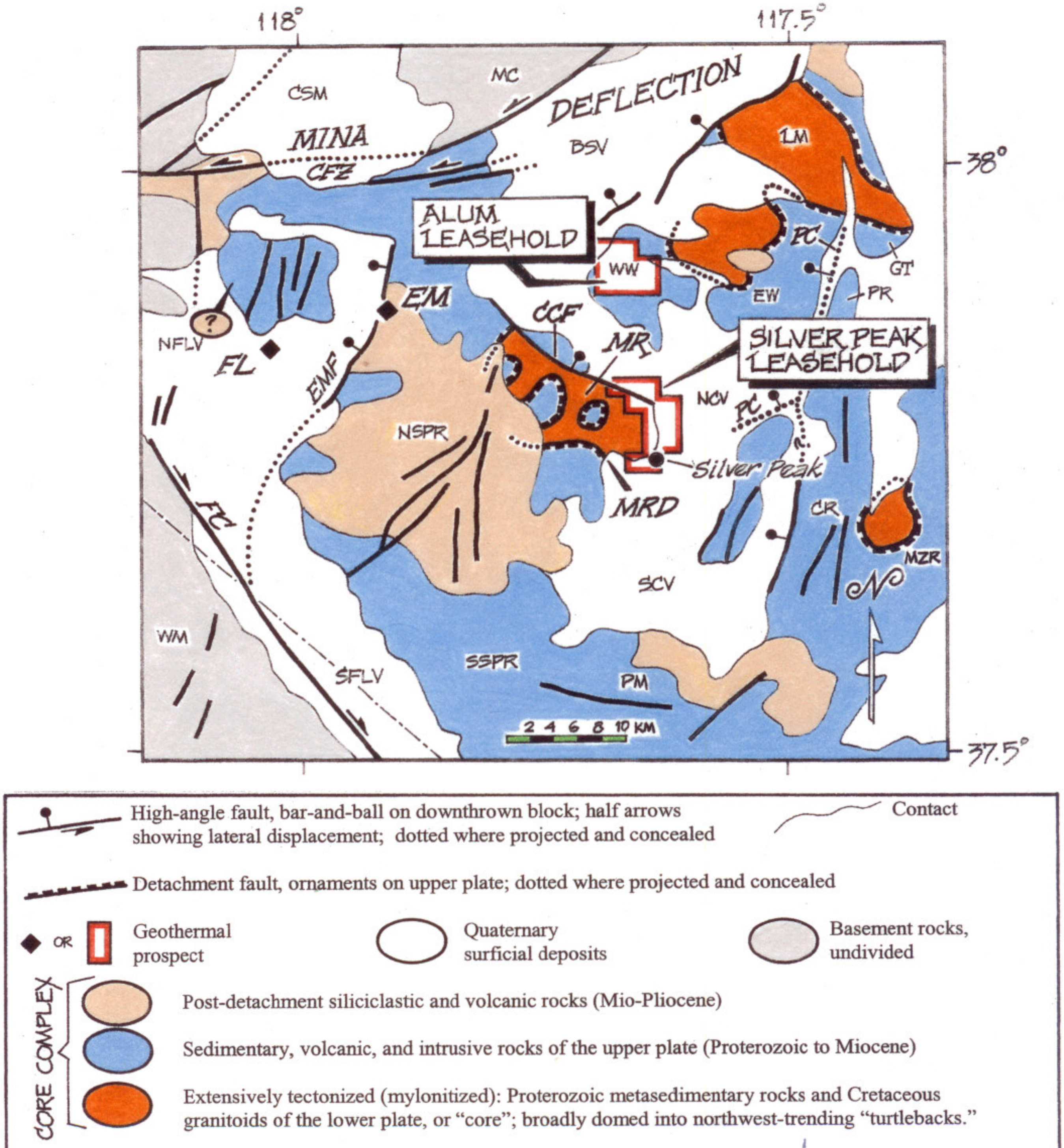



**Figure 2.** Highly generalized geologic map of the Silver Peak-Lone Mountain metamorphic core complex, showing principal structures, lithologic packages, and geothermal prospects, including Silver Peak (this report) and Alum. Map modified from *Oldow (2003b)*.

Abbreviations as follows: ***BSV***—Big Smoky Valley; ***CCF***—Cross-central fault; ***CFZ***—Coaldale fault zone; ***CR***—Clayton Ridge; ***CSM***—Columbus Salt Marsh; ***EM***—Emigrant geothermal prospect; ***EMF***—Emigrant Peak fault zone; ***EW***—eastern Weepah Hills; ***FC***—Furnace Creek fault zone; ***FL***—Fish Lake geothermal prospect; ***GT***—General Thomas Hills; ***LM***—Lone Mountain; ***MC***—Monte Cristo Range; ***MR***—Mineral Ridge; ***MRD***—Mineral Ridge detachment; ***MZR***—Montezuma Range; ***NCV***—northern Clayton Valley; ***NFLV***—northern Fish Lake Valley; ***NSPR***—northern Silver Peak Range; ***PC***—Paymaster Canyon fault (fr. *Zampirro, 2003*); ***PM***—Palmetto Mountains; ***PR***—Paymaster Ridge; ***SCV***—southern Clayton Valley; ***SFLV***—southern Fish Lake Valley; ***SSPR***—southern Silver Peak Range; ***WM***—White Mountains; ***WW***—western Weepah Hills moderate- to high-angle, normal- and oblique-slip "Basin-and-Range-style" faults *(Elias, 2005)*, including the Paymaster Canyon fault at the eastern edge of Clayton Valley *(Zampirro, 2003)*, and the historically active Emigrant Peak fault zone flanking eastern Fish Lake Valley *(Reheis and Sawyer, 1997; **Figure 2**)*.

Moderately- to steeply-dipping (i.e., >45$^{o}$) Walker Lane faults—whether strike-, oblique-, or normal-slip—and associated fracture networks are those most likely to control deep circulation, heating, and ascent of waters in a Silver Peak geothermal system (there is no evidence for a still-viable shallow magmatic heat source). However, several key components of the SPCC cannot be discounted as subsidiary thermal-fluid-flow conduits: (**1**) The master detachment fault itself; (**2**) secondary low-angle extensional faults above the detachment; and (**3**) intensely attenuated, fractured, and brecciated brittle upper-plate formations. The role of each of these components in the Silver Peak geothermal system is discussed in the text which follows.

## *Methods and Procedures*

In the same approach utilized for the nearby Emigrant geothermal property *(**Figure 2**; Hulen et al., 2005a; 2005b)*, the Silver Peak prospect and vicinity were geologically mapped, at a scale of 1:10,000, using mylar overlays on Digital-Orthophoto-Quadrangle panchromatic imagery (1-m resolution) mathematically fused with multispectral Advanced Spaceborne Thermal-Emission and Reflection Radiometer (ASTER) remote-sensing imagery (30-m resolution). Details of the data-fusion process and its advantages are discussed in *Hulen et al. (2005b)*. The fused imagery, with no spherical aberration, effectively highlights rock types, structural trends, thermal features, and alteration that might otherwise escape detection. Twenty individual 8 1/2 x 11" 1:10,000-scale geologic maps covering the prospect and surroundings are compiled as ***Appendix 1***. This large-scale mapping has been generalized into three 1:30,000-scale maps *(**Figures 3A-3C**)*, with corresponding geologic sections *(**Figure 3D**)*, for ease of reference and discussion.

EXPLANATION FOR FIGURES 3A-3C *(page 1 of 2; figures immediately follow this explanation)*

## 1:30,000-SCALE GEOLOGIC MAPS OF THE SILVER PEAK GEOTHERMAL PROSPECT AND VICINITY

Qt — **Quaternary travertine deposits**, undivided, including limonitic and manganiferous varieties.

Qtf — **Quaternary tufa deposits**, blanket-like, hot-spring-related, algally-precipitated.

Qco — Historically (Holocene) and culturally concealed, obscured, or developed land.

Qb — **Quaternary basalt**

Qbc — **Quaternary basalt cinder cone**

Qbf — **Quaternary basalt flow rock** and **flow breccia**

Qa — **Quaternary alluvium**

Qoa — **Quaternary older alluvium**

Qs — **Quaternary sand**, including lacustrine beach and near-shore deposits as well as dune and affiliated aeolian sands. Pebbly to cobbly where the unit grades into alluvium.

Qp — **Quaternary playa deposits**, principally argillaceous silt and fine sand, commonly sulfate-rich.

Ts — **Miocene to Pliocene,** lacustrine **siliciclastic sedimentary rocks**, undivided. Mostly weakly consolidated (cross sections only).

Tfp — **Tertiary "felsite" porphyry**

Tt — **Tertiary** (probably Miocene) **felsic ignimbrite**, non- to weakly welded

Tdbs — **Tertiary** (probably Miocene) **diabase** and **microdiabase**

SH — **Cambrian silty shale** to **metashale**

ST — **Cambrian siltstone, metasiltstone;** fine-grained **sandstone** and **metasandstone**, undivided.

LS — **Cambrian limestone**

DO — **Cambrian dolomite**

LS/DO — **Cambrian limestone** and **dolomite**, undivided, with minor siltstone and sandstone. Commonly disrupted to the point that the unit verges on being a megabreccia.

ML — **Ordovician melange**—boulder to "house-sized" blocks of limestone encapsulated in a sheared and brecciated matrix of shale, siltstone, and sandstone.

DM — **Proterozoic Reed Dolomite—dolomitic marble**, massive, medium-crystalline.

## EXPLANATION FOR FIGURES 3A-3C, cont'd. *(page 2 of 2)*

### 1:30,000-SCALE GEOLOGIC MAPS OF THE SILVER PEAK GEOTHERMAL PROSPECT AND VICINITY

GR — **Cretaceous granitoid**, commonly "two-mica", extensively sheared, locally mylonitized. Forms stocks, plugs, dikes and sills intruding the Proterozoic Wyman Formation, as well as small local plugs and dikes (generally pegmatitic and *not* mylonitized) in the Proterozoic Reed Dolomite.

TT — **Proterozoic Wyman Formation**, undivided. Siliciclastic and calcareous metasedimentary tectonites, undivided. Locally intruded by small plutons of tectonized Cretaceous granitoid. Mapped in reconnaissance only.

TT/GR — **Proterozoic Wyman Formation** and **Cretacecous granitoid**, as above, in roughly subequal proportions. Mapped in reconnaissance only.

TS — **Proterozoic Wyman Formation**. Variously calcareous, metasiliciclastic tectonites—Phyllite, semi-schist, protomylonite, and mylonite, undivided.

TM — **Proterozoic Wyman Formation**. Marble mylonite.

Contact, dashed where approximate

Moderate- to high-angle fault—Long dashes where approximate; short dashes where inferred; dotted where concealed; broken dotted line where concealed *and* inferred; bar-and-ball on downthrown block; opposing half arrows where oblique-slip, but with sense of displacement uncertain. Arrow indicates dip; short line oblique to arrow shows rake of slickenlines or mullions.

Detachment fault—Dip overall <30°, but locally steeper.

UPPER PLATE

Major concealed fault from gravity (preliminary; from *Quantec, 2008[?]*)—U=Up; D=Down.

Paved road

Gravel or improved dirt road

Initial Sierra Geothermal candidate drill site (now mostly superseded).

Existing borehole

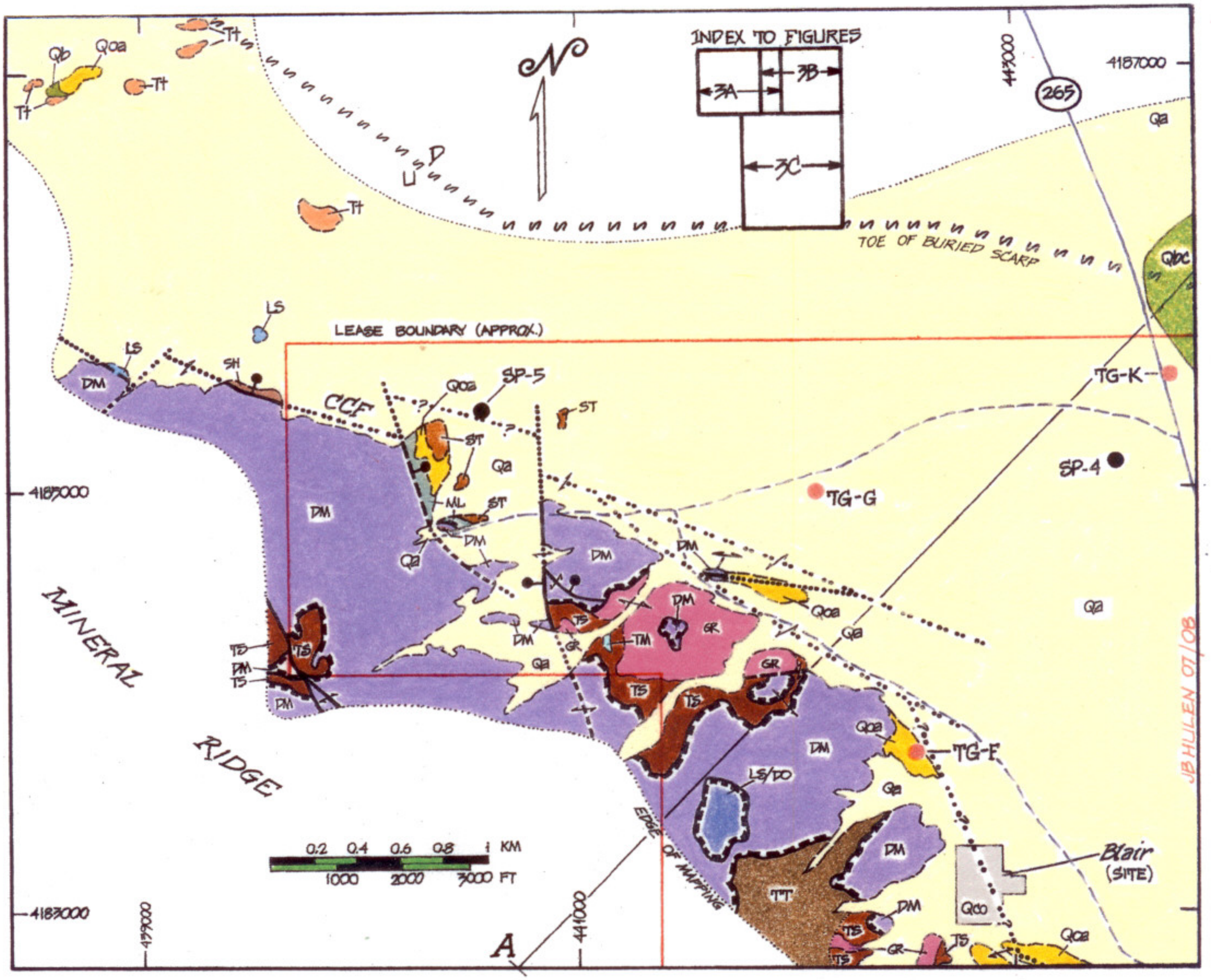



**Figure 3A** *(Explanation on previous two pages)***.** Geologic map of the northwestern Silver Peak geothermal prospect. Geology simplified slightly from 1:10,000-scale field sheets. Key feature on this map is the Cross-central fault **(CCF**; revised from *Zampirro, 2003;* and *Western Geothermal Partners, 2006)*, along the northeastern margin of Mineral Ridge. The CCF, which extends west-northwestward at least 10 km beyond the area of this figure, has a strikingly linear trace—a feature characteristic of strike-slip fault zones worldwide *(Sylvester, 1988)*. The interpretion of the CCF as a strike-slip or oblique-slip fault zone *(this report)* is additionally bolstered by subhorizontal mullions on a strand of the structure exposed in prospects ~700 m south of drill site TG-G.

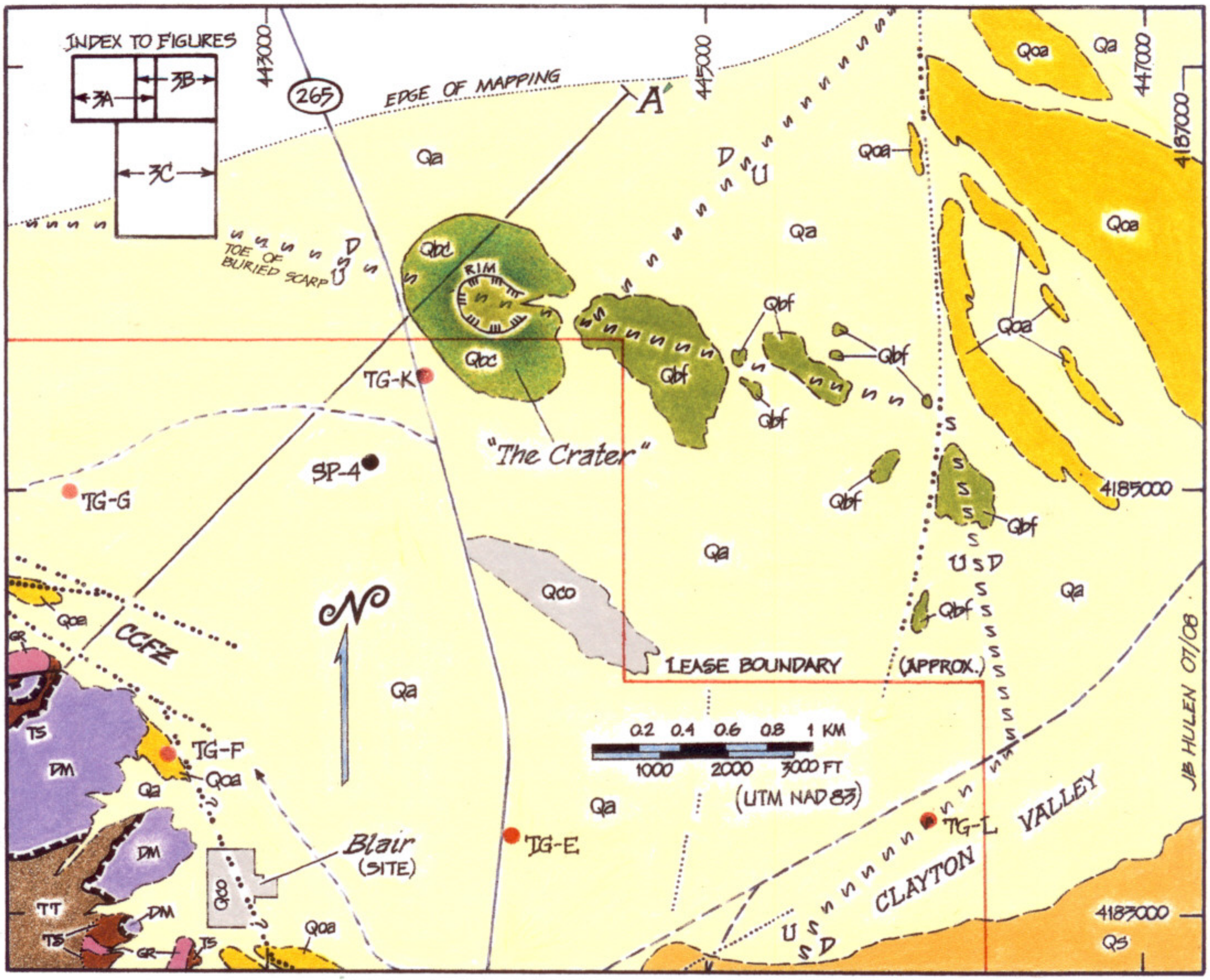



**Figure 3B** *(Explanation precedes Figure 3A)*. Geologic map of the northeastern Silver Peak geothermal prospect. Geology simplified slightly from 1:10,000-scale field sheets (see *Appendix 1)*. **CCFZ**—Cross-central fault zone (see notes accompanying *Figure 3A*). Preliminary results of a detailed gravity survey of the area *(Quantec, 2008 [?])* suggest **(1)** that the CCFZ has only modest normal displacement (the structure is probably an oblique-slip feature); and **(2)** that major down-to-the-north displacement has occurred along a second fault zone trending west-northwest through "The Crater"—a minimally eroded and vegetated Quaternary basaltic cinder-cone. The cone additionally is situated where the interpreted major WNW-trending, normal- or oblique-slip fault intersects a tentatively inferred (by this writer), northeast-trending, down-to-the-northwest subsidiary fault or fault zone.

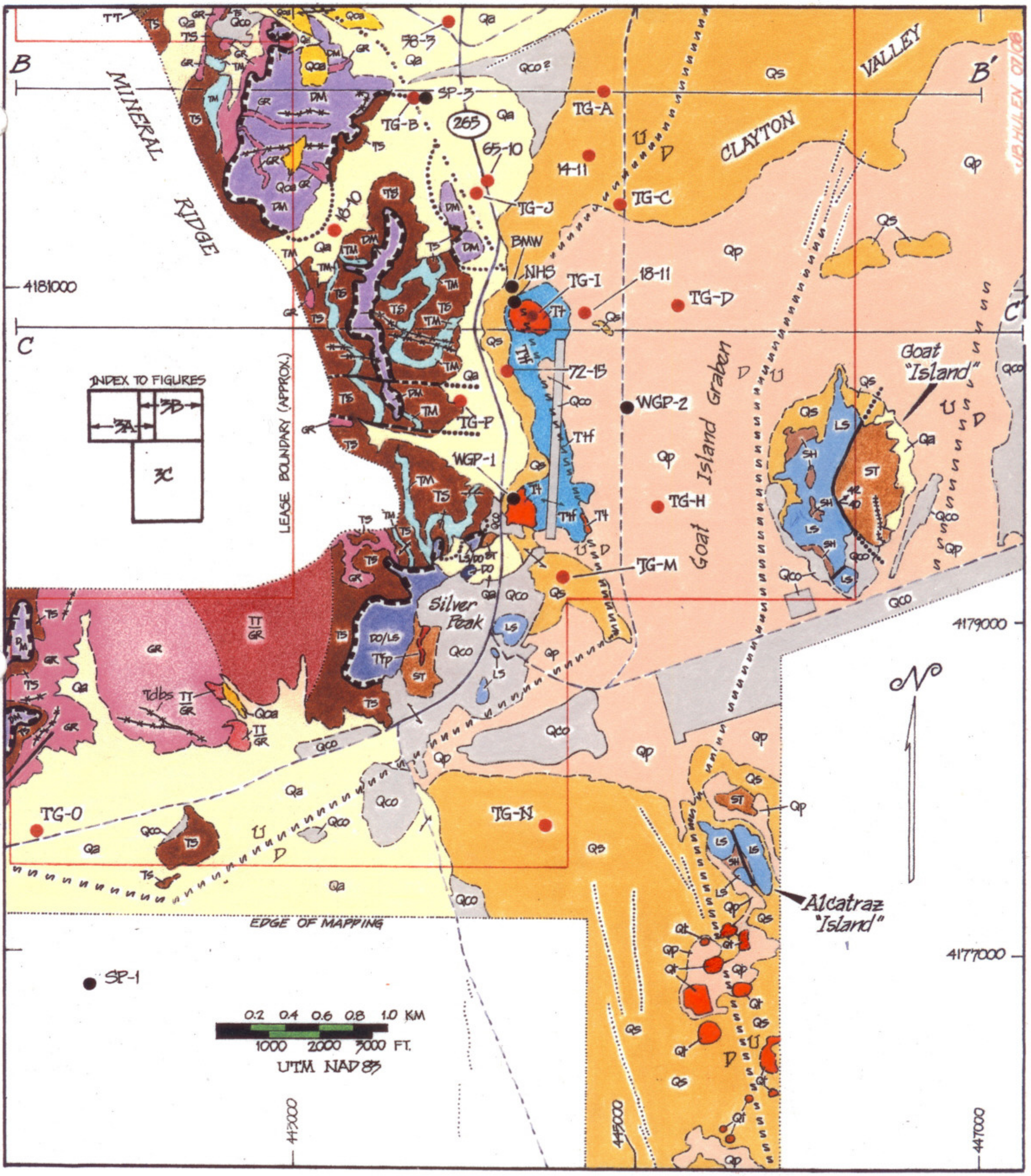



**Figure 3C** *(Explanation precedes Figure 3A)*. Geologic map of the southern Silver Peak geothermal prospect. Geology simplified slightly from 1:10,000-scale field sheets (see *Appendix 1*).

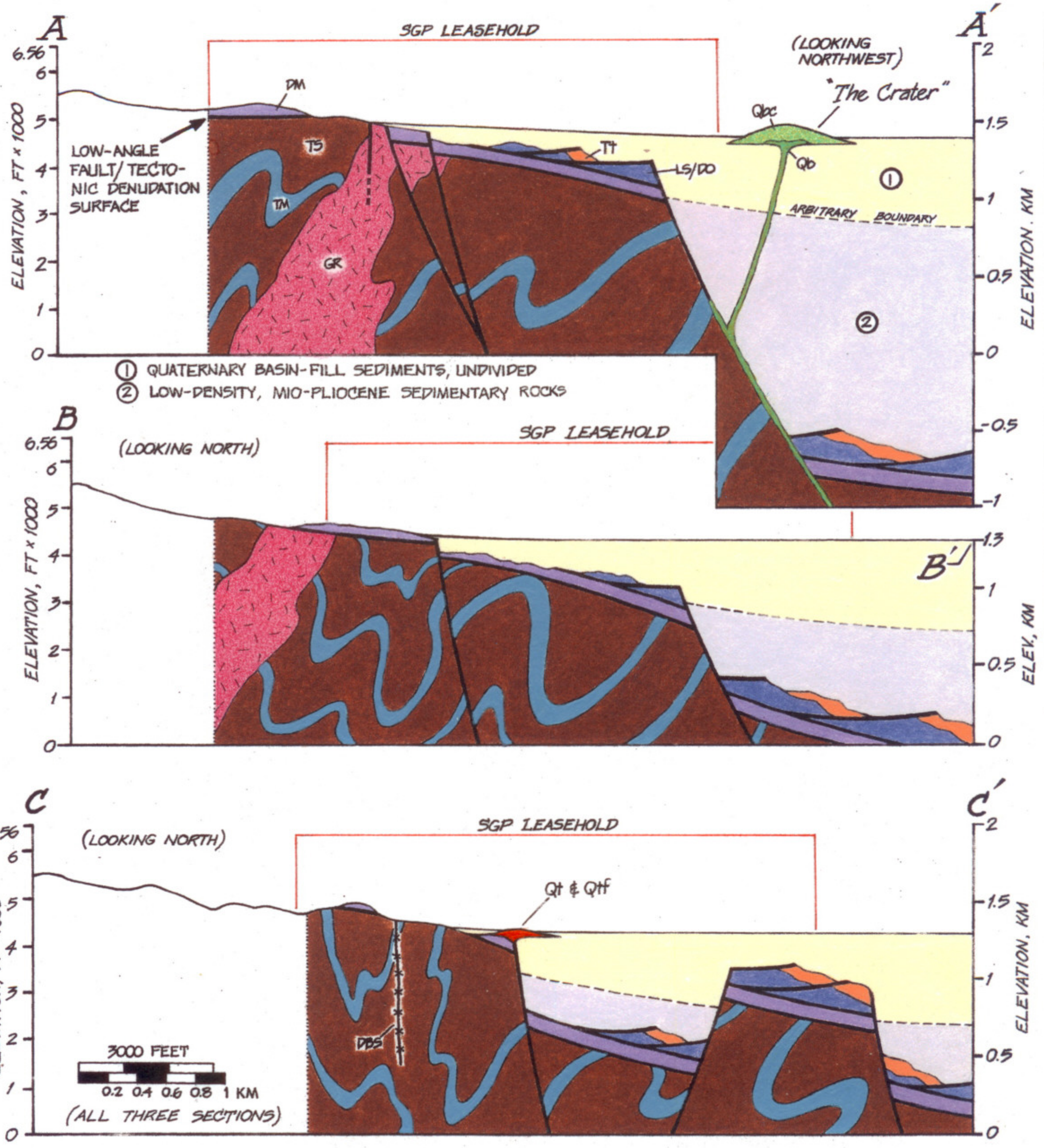



**Figure 3D** *(Additional explanation precedes Figure 3A)***.** Interpretive geologic sections through the Silver Peak geothermal prospect. Subsurface geology extrapolated from detailed geologic mapping (this report; *Figures 3A-3C; Appendix 1)*, with preliminary "depth-to-dense-rock" constrained by gravity inversion *(Petrick, 2008)*.

## *Geology of the Silver Peak Prospect and Vicinity*

Apart from extensive deposits of alluvium, sand, and other Quaternary surficial deposits, the Silver Peak geothermal prospect is dominated by the metamorphic-core-complex exposures of eastern Mineral Ridge at the faulted western margin of Clayton Valley *(**Figures 3A-3C**)*. Here, as inferred from gravity inversion *(Quantec, 2008 [?]; Petrick, 2008)*, the valley is segmented into a northerly-trending, 1-2 km-wide sub-basin—the Goat Island graben *(**Figure 3C**)*—which separates the range front from two prominent inselbergs (Goat and Alcatraz "Islands") of upper-plate Paleozoic rocks that project above the playa surface from a largely concealed, northerly-trending horst block. The exposed geothermal centerpieces of the region are two areas of commonly limonitic travertine that appear to be localized along the western graben-bounding fault and an inferred southern extension with the same trend but reversed displacement polarity (down-to-the west rather than the opposite; ***Figure 3C****)*. Shallow thermal-gradient and lithium-exploration drilling done to date in Clayton Valley indicate, perhaps curiously, that the valley's highest subsurface temperatures may be localized in the Goat Island graben and its structural projections to the northeast and south. Possible reasons for this phenomenon are discussed later in this report.

***Core Complex Lower-Plate Lithologies*****—**The "core" of the SPCC crops out prominently at and near the eastern and southern margins of Mineral Ridge *(**Figures 3A-3C**)*. This lower plate comprises complexly folded, ductiley-deformed, metamorphic tectonites of the Proterozoic Wyman Formation intruded by less extensively tectonized Mesozoic (probably Cretaceous) granitoid plutons (see also *Oldow et al. 2003)*. The Wyman Formation, the base of which is exposed nowhere in Esmeralda County *(Albers and Stewart, 1972)*, consists mostly of very well-foliated, dark gray to brown, siliciclastic and calcareous-siliciclastic mylonite, protomylonite, phyllite, and semischist interstratified with prominent bands of whitish marble mylonite.

The granitoids invading the Wyman range in nature and size from unmappably small dikes and plugs to (in the south) a sizable stock at least 1 $km^2$ in area. These felsic intrusives are commonly pegmatitic and typically contain both biotite and muscovite as accessory minerals. The plutons are much more massive than the Wyman, but nonetheless are locally and extensively sheared, “smeared-out,” and mylonitized, particularly near the detachment separating the lower from the upper plate of the core complex. Both the granitoids and the Wyman Formation lithologies are dense, hard, and brittle, and where fractured should constitute good geothermal-reservoir rocks in the subsurface.

Dark greenish-gray diabase dikes intrude both lower- and upper-plate rocks of the SPCC, but are more prevalent in the former setting. Many of the these dikes, which may be late Miocene in age *(Petronis et al., 2003)*, trend generally east-west, indicating emplacement in a different extensional stress regime (with maximum extension oriented NS) than the one prevailing today (maximum extension ~N75$^{o}$W; more discussion to follow).

***Core Complex Upper-Plate Lithologies*****—**Rocks of the upper plate in the Silver Peak prospect area occur above the master detachment fault: (**1**) as attenuated and dismembered structural slices; (**2**) as scattered small outcrops on an apparent structural “shelf,” or pediment, north of and adjoining Mineral Ridge west of the basaltic cinder cone known as “The Crater” ***(Figure 3A)***; and (**3**) as apparently more intact structural blocks forming the Goat and Alcatraz Island inselbergs ***(Figure 3C)***.

A major difference between the present and previous studies: Dolomitic marble of the Proterozoic to lower Cambrian Reed Dolomite, a regionally distinctive tan to grayish-tan stratigraphic unit, has been re-assigned to the upper rather than the lower plate of the core complex. The main reason for this re-assignment: the Reed, although thoroughly recrystallized, is massive, non-foliated, and *not* ductiley-deformed. The locally rubblized Reed has the potential to be an excellent secondary thermal-fluid aquifer in the Silver Peak geothermal system.

Like the structurally underlying Wyman Formation, the Reed is intruded locally by granitoid plutons. The Reed-hosted plutons, however, are much less prevalent and tend to be pegmatitic and coarse-crystalline; to occur as dikes and small plugs; and to be more massive and non-foliated than their counterparts below the detachment.

Other than the Reed Dolomite, early Paleozoic rocks dominate the upper-plate assemblage in the prospect area. These Paleozoic rocks have been assigned previously *(Albers and Stewart, 1972; Zampirro, 2003; Western Geothermal Partners, 2006)* to regionally prevalent stratigraphic units, including the Cambrian Deep Springs, Poleta, and Harkless Formations as well as the Ordovician Palmetto Formation. For this report, with a view toward reservoir-rock characterization, the Paleozoic units have been mapped simply as their constituent basic lithologies. Of these, carbonate rocks—limestone and dolomite—are most common, but shale, siltstone, sandstone, quartzite, and mélange are locally present ***(Figures 3A-3C)***. The mélange, exposed in the northwestern corner of the property ***(Figure 3A)*** consists of large blocks (lithons) of limestone embedded in a thoroughly sheared and comminuted matrix of shale, siltstone, sandstone, and minor limestone. This megabreccia, based on its similarity to outcrops in the nearby Emigrant prospect *(**Figure 2**; Hulen et al., 2005b)*, is believed to be part of the Ordovician Palmetto Formation.

Small outcrops of non- to weakly welded, crystal-rich felsic ash-flow tuff poke through the pediment gravels several miles west of “The Crater” *(**Figure 3A**)*. This tuff is provisionally assigned to the lower Miocene Icehouse Canyon Assemblage *(Oldow et al., 2003; Elias, 2005)*, emplacement of which occurred on future upper-plate Paleozoic rocks about 10 m.y. prior to inception of the SPCC *(Robinson et al., 1976)*.

Paleozoic siltstones, sandstones, and quartzites on Goat Island and immediately west of the town of Silver Peak are intruded by “felsite” porphyry dikes oriented generally NS ***(Figure 3C)***. The Silver Peak dike is associated with intense hydrothermal silicification, sericitization, and sulfidation (sulfides now oxidized to limonite), which—even though the dikes are more favorably aligned with respect to the modern stress field (see above)—nonetheless appear to significantly predate modern geothermal activity on the prospect.

***Quaternary Surficial Deposits*—**Older rocks throughout much of the Silver Peak prospect are concealed beneath a variety of unconsolidated Quaternary sediments—two ages of alluvial-fan gravels; lacustrine, littoral, and aeolian sands; and broad flat expanses of argillaceous playa silt and fine sand ***(Figures 3A-3C)***. The reader is referred to the detailed explanation preceding ***Figure 3*** for further description of these basin-filling units.

***Quaternary Basalt***—A prominent feature of northwestern Clayton Valley is the bold black cinder cone known as "The Crater" ***(Figures 3A, 3B,** and **3D)***. The cone, some 90 m (300 ft) high, is "moon-like" in appearance—being scarcely eroded and minimally vegetated. Olivine-phyric, the basalt has been K/Ar-dated at ~400,000 years *(J. Witter, pers. comm., 2008)*, but this age is at odds with the cone's barely-disturbed morphology. Accordingly, Witter has submitted a sample of basalt flow rock, clearly sourced from the cinder-cone vent ***(Figure 3B)*** for more reliable $^{40}Ar/^{39}Ar$ age-dating. However, even if The Crater proves, as suspected, to be late Pleistocene (a few tens of thousands of years) or even Holocene (<10,000 yr) in age, its quickly-cooled intrusive counterpart—probably a dike or dike swarm—is unlikely to have remained a viable plutonic heat source for the still-active Silver Peak geothermal system.

***Quaternary Hot-Spring Deposits***—Two clusters of surficial hot-spring deposits occur on and near the Silver Peak prospect ***(Figure 3C)***. One cluster, situated just north of the town of Silver Peak, comprises three low travertine mounds or blankets within a NNW-trending belt of algally precipitated tufa. The second cluster consists of multiple travertine mounds in a 1 x 0.4 km area just south of Alcatraz Island. Both of these spring-deposit clusters occur above major normal- or oblique-slip, NNW-oriented faults inferred from gravity inversion. The faults, with opposite displacement polarities ***(Figure 3C)***, may be the dominant structural controls on hot-aqueous upflow in the Silver Peak geothermal system.

<u>The Northern Spring-Deposit Cluster</u>—The chief feature of the northern spring-deposit cluster is an ovoid, ~50 m-wide, intricately laminated and limonitic (earthy iron-oxide-rich) travertine mound at the northern end of the tufa belt ***(Figures 3C** and **3D; Appendix 1**, p. A1-16)*. This mound, up to at least 3 m in thickness where exposed, boasts multiple

extinct but historically active spring vents (refer also to *Garside and Schilling, 1979)*. Feeble wisps of steam can seen rising from some of these vents on cooler mornings: It remains to be determined if the steam wisps imply boiling of the recently-depressed water table, or if they simply reflect the sort of "steaming" observed when a hot cup of coffee cools.

A curious and still unexplained feature of the northern travertine mound is an annular subsidence "moat," 1-2 m in depth, encircling the spring deposit. Concentric fractures around the margin of the moat appear to have served locally as the mound's youngest spring vents, yielding travertine-precipitating hot waters that are deduced to have flowed inward as the moat was still subsiding. The main mound itself is intricately cracked by open tension fractures that apparently formed as the mound sagged in response to the subsidence; these fractures, too, functioned as latest-stage spring vents, as they are locally and thickly coated with botryoidal, limonitic travertine. Three small sinkholes about 300 m (980 ft) east of the subsided mound *(**Appendix 1**; p. A1-16)* are also clearly subsidence phenomena, and their proximity to the mound suggests that the sinkholes formed in response to the same causative mechanism.

That subsidence trigger remains to be explained unambiguously. Three plausible alternatives have been offered: (**1**) As suggested by *John Deymonaz (pers. comm., 2008)*, the relatively dense travertine may have gravitationally loaded underlying unconsolidated and water-saturated playa sediments, forcing the sediments downward. The central mound, at 50 m in diameter and 3 m thick, would weigh perhaps 150,000 kilograms, or about 165 short tons, seemingly enough to depress the (perhaps fluidized) slurry beneath. However, this process does not explain the proximally-positioned sinkholes. (**2**) As proposed by *Joel Ronne (pers. comm., 2008)*, the subsidence conceptually could have been caused by the dissolution of evaporitic halite in the underlying, basin-filling sedimentary sequence. Halite is known to be common in the deeper portions of Clayton Valley basin *(Davis and Vine, 1979)*, but it is not necessarily present in the gravity-inferred, shallower fill of the Goat Island graben. (**3**) The subsidence may have been caused by cessation of pressure support in the requisite, ascending, hot-water plume, as the water table historically receded. The latter mechanism is favored by the writer, if only because the process might explain both the subsidence moat and the nearby sinkholes.

<u>The Southern Spring-Deposit Cluster</u>—Travertine mounds of the southern cluster ***(Figure 3C; Appendix 1**, p. A1-24)* are more or less erosionally dissected and clearly older than their recently active counterparts to the north. There are at least 27 separate mounds in the southern cluster—mounds ranging in width from a few meters to more than 200 m, and in height from a few cm to more than 3 m. Three types of travertine, singly or in combination, make up these mounds: (**1**) relatively pure, generally porous and "spongy"-textured, white to gray calcium carbonate; (**2**) yellowish- to orange-brown to brownish-gray limonitic travertine; and (**3**) dark gray to coal black, manganese-oxide-rich travertine, containing a visually estimated 25-50% pyrolusite and psilomelane. Type 3 travertine forms all of a few individual mounds, and also occurs as an annular ring in one larger mound otherwise consisting of Type 1 material: This relationship implies a dramatic but temporary shift in spring-water chemistry and hydrology at one point in the spring system's evolution.

***Borehole Geology***—Few boreholes have been drilled to date in the Silver Peak prospect; all have been relatively shallow; and written accounts of the subsurface rocks or sediments intersected in these holes vary in quality, scope, and detail. The deepest holes completed here so far are two adjacent water wells—GPXM-1 and -2—drilled by Mineral Ridge Resources in 1994 in the northwestern corner of the parcel that would later become the Silver Peak leasehold *(**Appendix 1**; p. A1-16)*. Drillers' lithologic logs for these wells *(**Appendix 4**; p. A4-1 and A4-2)* show that the boreholes penetrated, beneath thin gravel cover, about 500-600 ft (~150-180 m) of "siltstone, mudstone, and clay" which could be either Mio-Pliocene siliciclastic sediments of the Coyote Hole Group (former Esmeralda Formation; *Albers and Stewart, 1972; Stewart and Diamond, 1990; Elias, 2005)* or, more likely in view of nearby outcrops, either mélange or siltstone/sandstone of Paleozoic age (possibly the Ordovician Palmetto Formation).

Late in 2005 and early in 2006, Western Geothermal Partners (2006) and Chemetall-Foote Corporation drilled two shallow thermal-gradient boreholes into the basin fill of Goat Island graben. The shallower borehole, WGP-1 *(**Figure 3C**; **Appendix 1**, p. A1-20; **Appendix 4**, p. A4-4)*, was collared in a travertine blanket just north of the town of Silver Peak. This hole penetrated manganese-oxide-rich travertine to a depth of 35 ft; clay, silt, and sand from 35 ft to 85 ft; travertine again from 85 ft to 90 ft; and commonly limonitic sand and gravel between 90 ft and 170 ft. There were no drilling returns between 170 ft and the total depth at 175 ft. *Western Geothermal Partners (2006)* believed that the hole bottomed in "hard siliceous hot-spring sinter deposits" based on the ostensible occurrence of similar such deposits in nearby well WGP-2 (see below). From detailed geologic mapping of this area and the nearby range front, the writer believes it more likely that WGP-1 bottomed in Paleozoic, Proterozoic, or Mesozoic bedrock forming a hard shallow shelf beneath a thin cover of basin-fill sediments. It is additionally suggested here that fracturing and brecciation of this bedrock near the master detachment fault of the SPCC may have focused local lateral up- and outflow of travertine-precipitating thermal waters from the more likely principal conduit immediately to the east—a gravity- and geologically-inferred high-angle fault or fault zone at the western margin of Goat Island graben *(**Figures 3C** and **3D**)*.

Western Geothermal/Chemetall thermal-gradient borehole WGP-2 *(**Figure 3C**; **Appendix 1**, p. A1-16; **Appendix 4**, p. A4-3)* was collared in Goat Island graben about 400 m east of the northern travertine-tufa belt, and was drilled to a total depth of 400 ft (122 m). This borehole, with its conspicuously elevated thermal gradient, penetrated, according to *Western Geothermal Partners (2006)*, a sequence of hot-spring sinters interbedded with clays, silts, and sands. The sinters were provisionally identified as being at least partially siliceous on the basis of the deposits' capacity to scratch a steel geology hammer. An alternative explanation offered here invokes the violent sandstorms that frequently affect Clayton Valley. These storms are known to transport coarse sand to the top of Goat Island, several hundred feet above the playa surface, and would certainly be cabable of contributing substantial volumes of quartz-rich sand to an evolving travertine deposit: The clastic quartz would scratch the pick, even if the spring deposits themselves were not siliceous.

It remains possible that both the borehole-penetrated and surface spring deposits of the Silver Peak prospect do contain siliceous bands or stringers. The writer saw no convincing evidence of this in the surface deposits, but an "acid test" of the assertion would be to dissolve large blocks of the travertine in concentrated HCl, and closely examine the residues. Initially imperceptible silica septa would point to intermittent siliceous sinter precipitation; a residue of sand grains would imply contamination of calcareous spring deposits by windblown sand.

***Structure***—From a geothermal perspective, the main structural elements of the Silver Peak prospect—as determined by detailed geologic mapping and gravity work—are really twofold: (**1**) Low-angle normal faults (including a master detachment) and dismembered, attenuated slices of brittle upper-plate rock in the SPCC; and (**2**) post-core-complex, moderate- to high-angle, normal- to oblique-slip (and rarely, strike-slip) faults grouped into four orientations—WNW to EW; NE; NNE; and NNW. All of the prospect's recently active hot springs and young hot-spring deposits fall along faults or inferred faults of the latter trend.

The master detachment fault (or fault zone) of the SPCC within and near the geothermal prospect typically ranges from a few centimeters to a few meters in thickness, and consists of formerly ductiley deformed, high-grade metasedimentary rocks that were later brittly ruptured as the core of the SPCC was unroofed. Stated another way, the detachment is now a zone of brittle-rock shearing, fracturing, and brecciation that has potential to be an important, if secondary, shallow-dipping thermal-fluid aquifer in the Silver Peak geothermal system.

Likely of greater importance in this regard is the thoroughly broken, supra-detachment Reed Dolomite. The Reed is widely exposed within and to the west of the prospect ***(Figures 3A-3C)***, and is sure to persist in the subsurface into western Clayton Valley

***(Figure 3D)***. In outcrop, upper-plate slices of the Reed reach at least 300 ft (91 m) in thickness. In all cases, the dolomitic marble is thoroughly fractured, with fracture densities ranging from <2 to >100 fractures per meter (fpm) and averaging an estimated 30-40 fpm. In places, the Reed has been reduced to little more than a cataclastic rubble. Many of the conspicuous fractures and interclast pores in the Reed remain open, although these features are locally partially sealed by banded secondary calcium carbonate: It follows from these observations that there is potential for occlusion of the unit's porosity and permeability in the subsurface, but there is an equal chance that substantial volumes of the rock remain open at depth. Other upper-plate rocks are equally disrupted, but are commonly both stratigraphically and structurally intermixed with shale and siltstone, making them, potentially, only sparingly permeable at depth on a geothermal-reservoir scale.

The only (locally) exposed west-northwest-trending, post-core-complex fault is the Cross-central fault ***(Figures 3A and 3B)***. This structure has been postulated to extend eastward, into Clayton Valley, as a potentially important hydrologic barrier *(Zampirro, 2003; Western Geothermal Partners, 2006)* in the lithium-brine reservoir being mined by Chemetall-Foote Corporation. Small-scale fused imagery of the greater Silver Peak prospect area *(**Appendix 5**, p. A5-1 and A5-2)* shows that the previously-mapped Cross-central fault is only the easternmost segment of a prominent and conspicuously straight, WNW-trending, regional image-linear bounding the northern edge of Mineral Ridge. Such pronounced linearity in a fault or fault zone is diagnostic of strike-slip or oblique-slip rather than normal displacement *(Christie-Blick and Biddle, 1985; Sylvester, 1988)*.

That portion of the Cross-central fault occurring within the prospect area is rarely exposed, instead being inferred from the blunt linearity of—and subsidiary shears and fractures in—the adjacent range front. One subsegment of the fault, however, is revealed by a line of prospect pits excavated in search of metallic mineralization and located a little southwest of candidate drill site TG-G ***(Figure 3A)***. The fault here is a vertical breccia zone up to 2 m thick, with walls locally decorated by mullions indicating subhorizontal displacement. If the Cross-central fault projects, as asserted, to the east beneath Clayton Valley, if probably does so as a wrench fault rather than a normal fault.

Results of gravity inversion suggest that a hypothetical eastward extension of the Cross-central fault would likely be truncated by younger, northerly-trending, moderate- to high-angle faults, including the one forming the buried western margin of the Goat Island graben. It is these younger, higher-angle faults that are believed to be the essential structural-permeability controls for the Silver Peak geothermal system, and these key structures will be discussed at length in the next section of this report.

## ***Discussion and Conclusions: Conceptual Modeling***

The work described above sets the stage for refining initial conceptual models of the Silver Peak prospect presented by *Western Geothermal Partners (2006)* and *GeothermEx (2006)*. The essential components of these models, to paraphrase *GeothermEx (op. cit.)*, are as follows: (**1**) The geological controls influencing the location, configuration, and size of the geothermal system and reservoir; (**2**) the location and nature of a heat source for the system; (**3**) the source and physical/chemical characteristics of thermal fluids advecting into, circulating within, and ultimately exiting the geothermal system; and (**4**) the pattern of movement of these geofluids.

***Heat Source*****—**Addressing point (**2**) above at the outset, detailed geologic mapping for this project has revealed no evidence for a young magmatic heat source at Silver Peak. The only igneous body even remotely indicative of youthful igneous intrusion here is “The Crater” and associated basaltic outflow *(**Figures 3B** and **3D**)*. Basaltic eruptions are typically sourced by a dike or dike swarm, features that unless younger than a few thousand years would long since have cooled to local crustal-ambient temperatures. A fully cryptic shallow igneous heat source remains a remote possibility at Silver Peak, but such speculation is of little value to a plausible working conceptual model for the prospect.

Therefore, we can assume that the prospect’s geothermal fluids are heated in response to broad-scale and deep circulation in fractured rocks within a domain of thin crust and consequently elevated regional thermal gradient *(e.g., Blackwell, 1983; Forster et al., 1997; Wisian et al., 1999)*. Regional “background” heat flow for the Silver Peak region and much of west-central Nevada is mapped by *Wisian et al. (1999)* as averaging 100-120 mW/m$^2$, a value less than that prevailing across much of northern Nevada (120-200 mW/m$^2$) but definitely anomalous when compared to the <60 mW/m$^2$ typical of much of the conterminous United States (*Wisian et al., op. cit).*

The Silver Peak regional thermal gradient is clearly amenable to creation of a "deep-circulation" geothermal system. Depending upon the thermal conductivity of the affected rocks, the regional thermal gradient here might approximate, say, 50$^o$C/km (2.8$^o$F/100 ft), so that, assuming an average annual surface-ambient temperature of 15$^o$C (~60$^o$F), deeply-penetrating groundwaters theoretically could be heated to 150$^o$C (~300$^o$F) at a depth of 2.6 km (~8500 ft). Afforded access to a sufficiently permeable, moderately- to steeply-inclined fault/fracture zone, the heated waters could rise rapidly and near-isothermally to depths where they could be tapped commercially for geothermal power production.

***Origin, Composition, and Geothermometry of Geofluids*****—**Through time, the ultimate source of groundwater for a Silver Peak geothermal system will have been meteoric precipitation onto the uplands—particularly the relatively high-elevation Silver Peak Range—encircling Clayton Valley. However, *Flynn and Buchanan (1993)* have shown, convincingly—using hydrogen- and oxygen-isotope geochemistry—that the waters from active Great Basin geothermal systems are overwhelmingly of Late Pleistocene age (that is, 30,000-10,000 years old), having accumulated beneath large pluvial lakes when the climate was much colder and wetter than it is today (*Goff et al. (1994)*, using similar methodology, determined that Great Basin oilfield waters are isotopically indistinguishable from the province's geothermal fluids). This being the case, the most likely source of geofluids for a Silver Peak geothermal system will be late Pleistocene meteoric water that once resided in a Clayton Valley lake and percolated downward from this aqueous body into underlying basin-filling sediments and subjacent "basement" rocks.

Other than in certain shallow gravel aquifers, the Clayton Valley waters are actually brines, with total-dissolved-solids (TDS) contents ranging upward to 17 wt. % (*Zampirro, 2003).* These brines have long been exploited for their high concentrations of lithium. The few brine samples thus far collected from Silver Peak prospect wells and springs (when the latter were active) are chemically similar to but more dilute than the typical Clayton Valley lithium brine (1.4-1.8 wt. % TDS; *GeothermEx, 2006)*. Chalcedony and Na-K-Ca-Mg geothermometer temperatures for the Silver Peak borehole and hot-spring waters suggest that underlying geothermal-reservoir temperatures are quite likely to be in the range 260-300$^{o}$F (~125-150$^{o}$C) and could very well reach into the 300-340$^{o}$F (~150-170$^{o}$C) range at commercially drillable depths; deeper temperatures could be even higher, but the geochemical evidence for this condition is considered tentative *(GeothermEx, op. cit.)*.

***Geological Controls on Thermal-Fluid Flow***—In the "Structure" subsection of this report, it was established that moderate- to high-angle faults and affiliated fracture zones are the presumptive principal controls on the ascent of hot brines in a Silver Peak geothermal system: The master detachment, other low-angle faults, and brittly-fractured slices of Paleozoic rock in the upper SPCC could play lesser roles as subhorizontal aquifers locally connecting the steep faults at depth. Which of the steep faults are most likely to localize major thermal-fluid upflow?

As a first step in answering this question, the detailed Silver Peak geologic maps *(**Appendix 1**; **Figures 3A-3C**)* were distilled to produce a generalized structure map of the geothermal prospect and vicinity *(**Figure 4**)*. This map clarifies—relative to hot-spring and affiliated deposits as well as available shallow thermal gradients—the locations and trends of both low- and higher-angle faults in the area, including those mapped geologically and those inferred from gravity inversion *(Petrick, 2008)*.

The inset for ***Figure 4*** shows, from *Oldow (1992)*, the seismically- and geologically determined "global" maximum extensional axis—N55$^{o}$W—for western Nevada vector-resolved into the prevailing dextral (right-lateral) shear direction (N40$^{o}$W) and magnitude (35 km) and local maximum extensional axis—N75$^{o}$W—in this part of the Walker Lane. "Ideal" normal- or oblique-slip faults in this analysis trend N15$^{o}$E. As suggested by *Hickman and Zoback (1998)* for the Dixie Valley geothermal field (on the major Stillwater fault zone), normal- and oblique-slip faults closest in trend to the "ideal" for the Silver

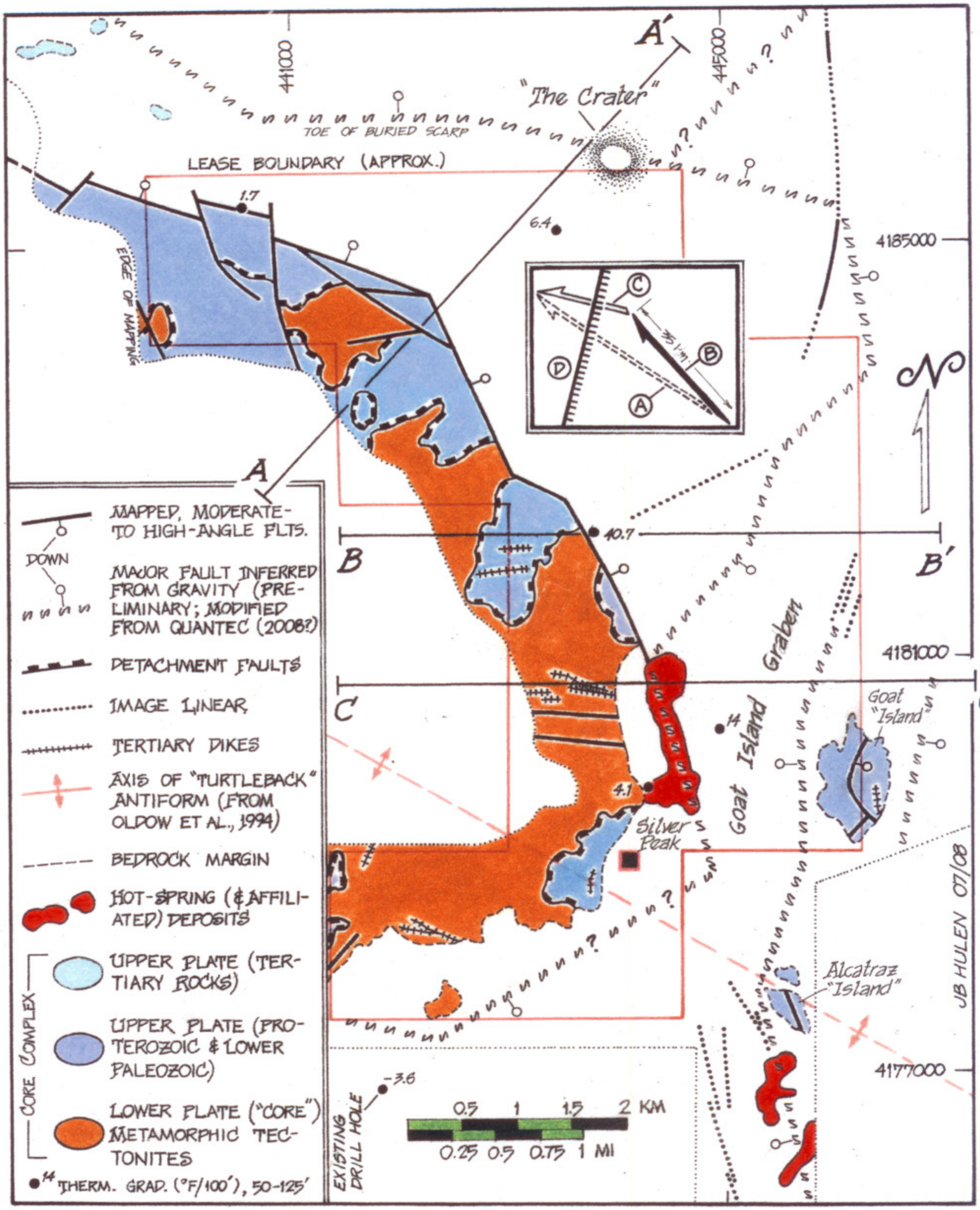



**Figure 4.** Generalized structure map of the Silver Peak geothermal prospect (distilled from *Figures 3A-3C*). Inset (from *Oldow, 1992)* shows regional maximum extensional axis (**A**—N55°W) vector-resolved into prevailing dextral simple-shear direction (**B**—N40°W) and local maximum extensional axis (**C**—N75°W) in the central Walker Lane. In accordance with this analysis, late Cenozoic oblique- or normal-slip faults oriented within an acute arc centered on N15°E (**D**) are likely to be among the most locally permeable structures on the prospect. Additional sites for dilation and permeability would be releasing bends or dilational jogs with respect to the N40°W ideal wrench-fault trend. Please refer to text for additional explanation.

Peak area theoretically would be the structures most apt to be “critically stressed for frictional failure,” and to develop and retain high permeability for geothermal fluid flow.

***Figure 5*** color-codes each of the major Silver Peak fault trends in terms of its departure from the theoretically ideal “high-permeability” high-angle fault trend of N15$^{o}$E. It is immediately apparent from the figure that (perhaps not surprisingly) the northerly-oriented faults at and adjacent to the eastern part of the property should be the most likely candidates as thermal-fluid conduits. Conflicting with this analysis, however, are two observations: (**1**) None of the illustrated most-favorably-oriented faults (those coded red on the figure) is associated with recent hot-spring deposits: these deposits all occur along “orange” faults, that is, those departing 15-30$^{o}$ from the N15$^{o}$E ideal. (**2**) The easternmost “red” fault is flanked by a number of Chemetall-Foote brine-exploration wells, none of which, to depths in excess of several hundred meters, shows an equilibrium temperature in excess of 100$^{o}$F (38$^{o}$C) *(Western Geothermal Partners, 2006)*. Unless deeper temperatures here are masked by a shallow, cool-water aquifer, it seems unlikely that the easternmost “red” fault—even though ostensibly ideally configured—controls major thermal-fluid upflow. It may be that pure extensional (normal-displacement) faults, which by their nature tend to develop subhorizontal domains of greater or lesser permeability and porosity, are, at least here, not the most favorable high-angle structural aquifers.

Another way of examining the Silver Peak fault sets, then, is to consider them in terms of the idealized subsidiary faults known from geological examples and laboratory experiments to form in dextral wrench-fault regimes (e.g., *Harding et al., 1985; Sylvester, 1988)*. ***Figure 6*** shows these idealized secondary fault trends as an inset on a duplicate of the generalized Silver Peak structural map ***(Figure 4)***. In this analysis, the master right-lateral wrench fault (**M**), or principal displacement zone, is oriented N40$^{o}$W to parallel the major dextral wrench faults of this part of the Walker Lane. Subsidiary high-angle faults expected to form in this regime are dextral, synthetic, ***R*** and ***P*** shears; and sinistral (left-lateral), antithetic ***R’*** shears ***(Figure 6)***. Note that accompanying normal-oblique ***(N)*** faults have the same orientation as the idealized normal faults of the previous analysis ***(Figures 4*** *and* ***5)***, and presumably should be similarly permeable.

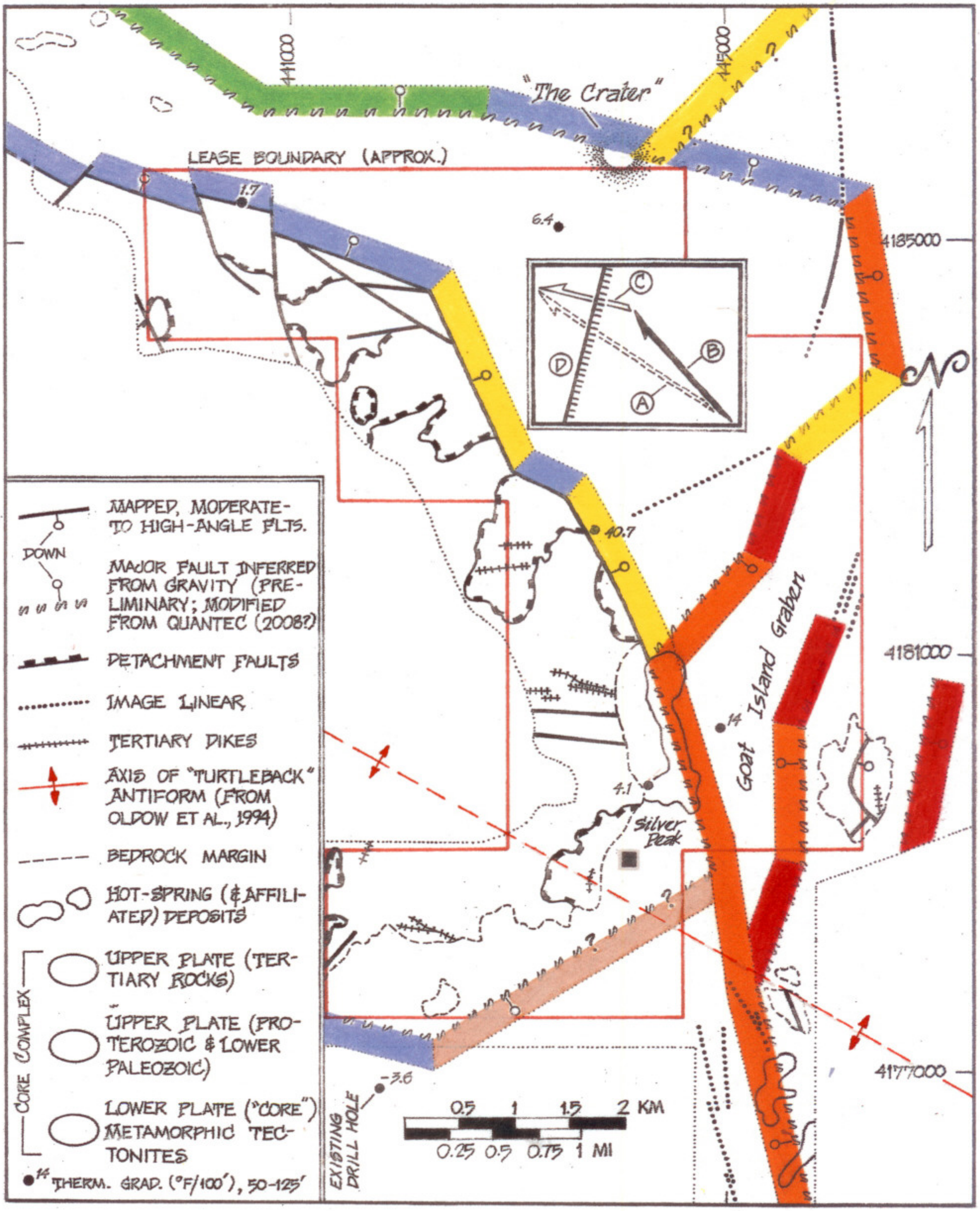



**Figure 5.** Structure map of *Figure 4* with major mapped and inferred, moderate- to high-angle faults color coded to indicate departure of fault trends from strike of theoretically "ideal" normal fault corresponding to maximum extension (see inset) in the central Walker Lane (see *Figure 4* inset). **Red**—fault departs 0-15° from the ideal normal-fault strike; **Orange**—15-30°; **Yellow**—30-45°; **Beige**—45-60°; **Green**—60-75°; **Blue**—75-90°. In this simple analysis, mapped and inferred faults with smaller arcs of departure from the ideal (N15°E) are more likely to have domains of enhanced porosity and permeability for thermal-fluid flow.

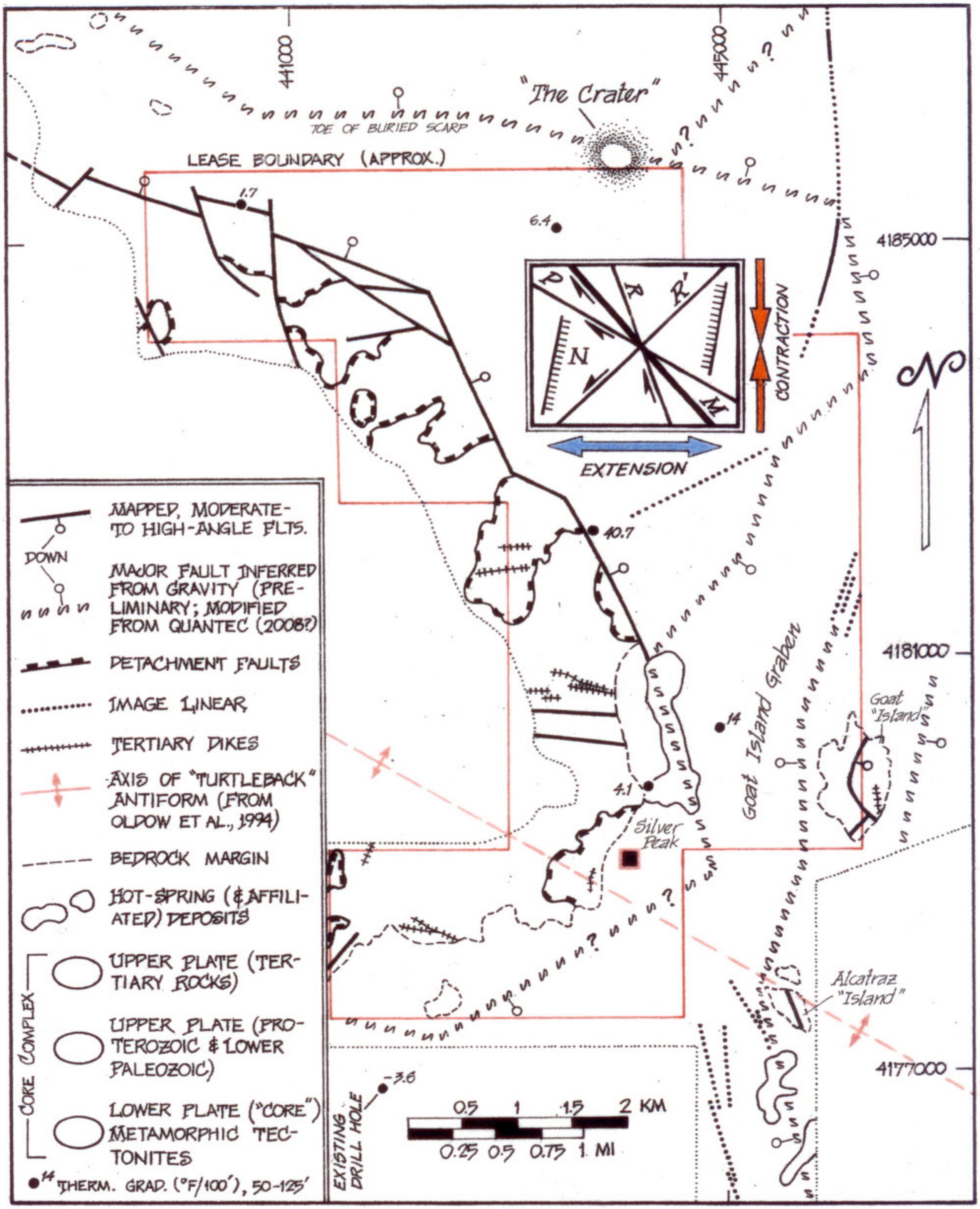



**Figure 6.** Structure map of *Figure 4* relative to idealized fault trends and styles (***new inset***) predicted—from laboratory experiments and geologic examples—for a transtensional dextral strike-slip faulting regime (from *Sylvester, 1988)*. In this model, the "master" strike-slip fault (***M***) is oriented N40°W, to parallel analogous structures in the central Walker Lane. Subsidiary strike-slip faults expected to form in this regime: ***R***, or synthetic dextral shears; ***R'***, or antithetic sinistral (left-lateral) shears; and dextral ***P*** shears. Note that (optimally permeable) normal-oblique extensional faults (**N**), as in *Figure 4*, are oriented north-northeast. Additional sites for enhanced permeability would be releasing bends, dilational jogs, and appropriately oriented stepovers along the subsidiary strike-slip faults.

In the hypothetical structural setting depicted by ***Figure 6***, fault permeability would be maximimized not only along the normal-oblique faults, but in *releasing segments* of subsidiary strike-slip faults , that is, where lateral shearing has been accompanied by an element of “pull-apart.” Permeability might also be expected to develop at *dilational jogs (Sibson, 1986)* along the strike-slip faults—in other words, at prominent bends where the faults “step over” in the same sense as the shearing motion: right steps for right-lateral wrench faults; left steps for left-lateral ones.

***Figure 7*** color codes the Silver Peak fault sets to show their conceptual restraining (compressional) and releasing (dilational = potentially permeable) segments relative to the closest ideal subsidiary strike-slip fault trend ***(Figure 6)***. In this analysis, the “favorable” faults are even more conspicuously clustered within and near the eastern portion of the prospect: NW-, WNW-, EW-, and ENE-trending mapped and inferred faults show up in this analysis as distinctly unfavorable in terms of controlling upflow. The property’s easternmost NNE-trending fault appears as favorable in this analysis as in the previous one, and its apparent lack of thermal activity likewise remains to be satisfactorily explained.

***Pattern of Fluid Flow***—To depths of at least several hundred meters, there is little evidence of geothermal activity in that portion of Clayton Valley east of and within a few kilometers of Goat Island *(Western Geothermal Partners, 2006)*. On the other hand, extinct hot springs, recent hot-spring deposits, and results from scattered shallow thermal-gradient boreholes point to such activity in the western part of the valley. This being the case, a plausible working conceptual model for the Silver Peak geothermal system invokes: (**1**) the entire Clayton Valley basin as the major brine source, with the fluids percolating downward and mostly westward into fractured basement beneath the valley fill, heating in response to an elevated regional thermal gradient; (**2**) a northerly-trending fault and fracture belt extending southward from Silver Peak, northward along the Goat Island graben, thence northeastward in a fashion as yet little understood. In the model, deeply westward-percolating brines encounter the “Goat Island structural belt” and begin to

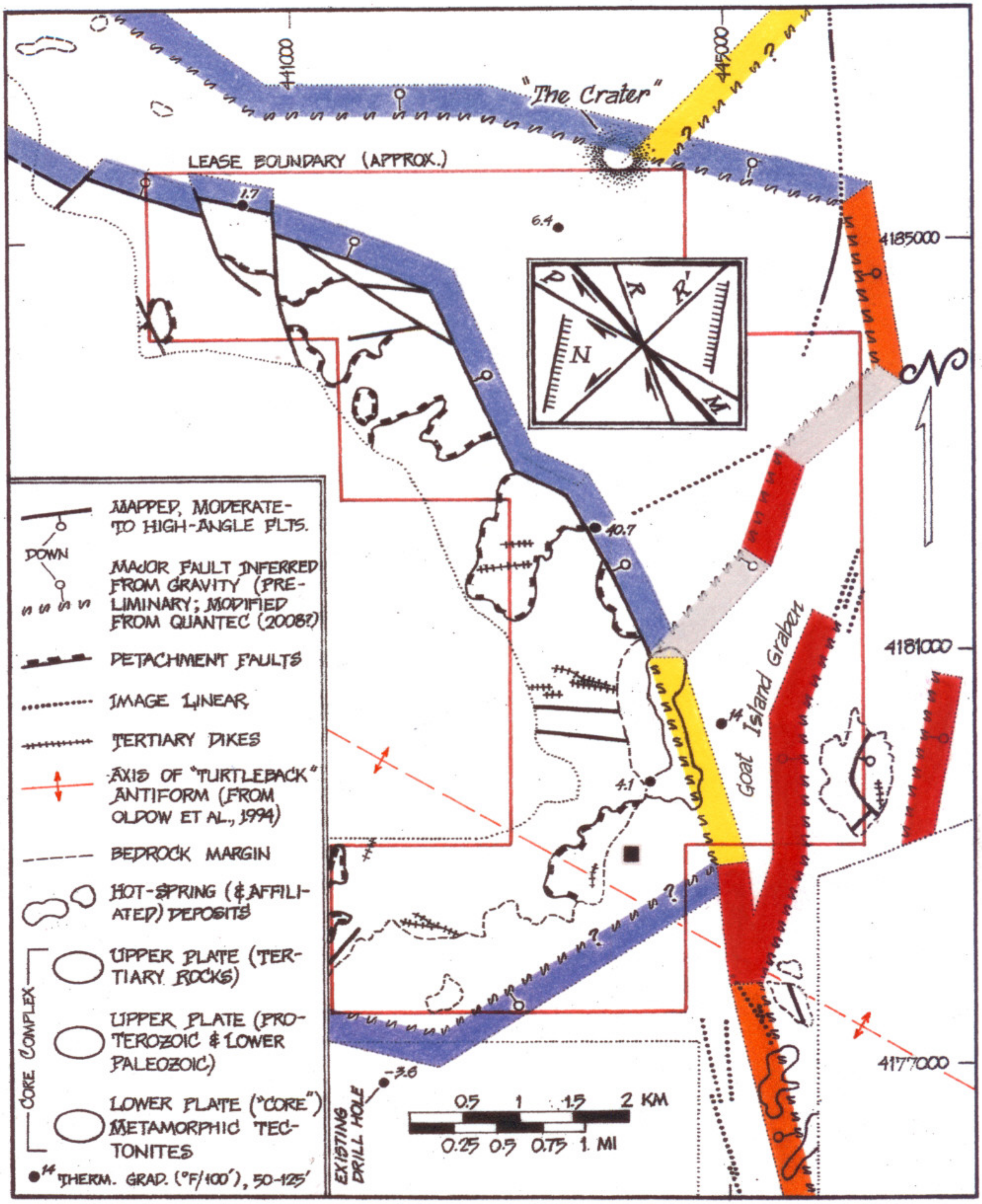



**Figure 7.** Structure map of *Figure 6* with major mapped and inferred, moderate- to high-angle faults considered as strike- or oblique-slip structures, and color coded to show conceptual restraining (contractional; **blue**) and releasing (dilational = potentially permeable; other colors) segments relative to the closest "ideal" subsidiary strike-slip fault trends (**R**, **R'**, **P**; *see inset*) in the central Walker Lane. **Gray** = <2° releasing segment; **Yellow** = 2-5°; **Orange** = 5-10°; **Red** = >10°.

ascend to the north, initially breaching the surface at the southern travertine cluster; and venting most recently in travertine mounds along the northern tufa belt. Cross-flow of the brines at depth may occur within brittly-ruptured, subhorizontal, pre-Mesozoic rock slices in the downdropped upper plate of the core complex. Outflow from the system is presumably toward the northeast, but confirmation or dismissal of this assertion must await more extensive thermal-gradient drilling and subsurface brine sampling.

At this stage of the investigation, preparation of an intricate and comprehensive 3D graphical conceptual model of the Silver Peak geothermal system is unwarranted by the scanty subsurface data set (soon, however, to be bolstered by drilling). In the interim, ***Figure 8*** summarizes the writer's concept of that portion of the system circulating in the upper reaches of the Goat Island graben (along section C-C'; see also ***Figure 3D)***. If the model has merit, then production wells drilled east of the travertine-tufa belt in Goat Island graben could encounter producible volumes of 300$^{o}$F (~150$^{o}$C) geothermal fluid within a few thousand feet below the playa surface.

## *References*


Albers, J.P., and Stewart, J.H., 1972, Geology and mineral deposits of Esmeralda County, Nevada: *Nevada Bureau of Mines and Geology*, Bulletin 78, 80 p.

Blackwell, D.D., 1983, Heat flow in the northern Basin and Range province, in The role of heat in the development of energy and mineral resources in the northern Basin and Range province (anonymous editor): *Geothermal Resources Council*, Special Report 13, p. 81-92.

Christie-Blick, N., and Biddle, K.T., 1985, Deformation and basin formation along strike-slip faults, in Strike-slip deformation, basin formation, and sedimentation (K.T. Biddle and N. Christie-Blick, editors): *Society of Economic Paleontologists and Mineralogists*, Special Publication 37, p. 1-34.

Craig, S.D., 2003, Geology and gold mineralization of the Mineral Ridge gold mine, Esmeralda County, Nevada, in Regional geology and gold deposits of the Silver Peak area, Nevada (H.G. Brown, editor): *Geological Society of Nevada*, 2003 Fall Field Trip Guidebook, Special Publication 38, p. 81-93.

Davis, G.A., and Lister, G.S., 1988, Detachment faulting in continental extension—Perspectives from the southwestern U.S. cordillera: *Geological Society of America*, Special Paper 218, p. 133-159.

Davis, J.R., and Vine, J.D., 1979, Stratigraphic and tectonic setting of the lithium brine field, Clayton Valley, Nevada, in Basin and Range Symposium (G.W., Newman and H.D. Goode, editors): Denver, Colorado, *Rocky Mountain Association of Geologists*, p. 421-430.

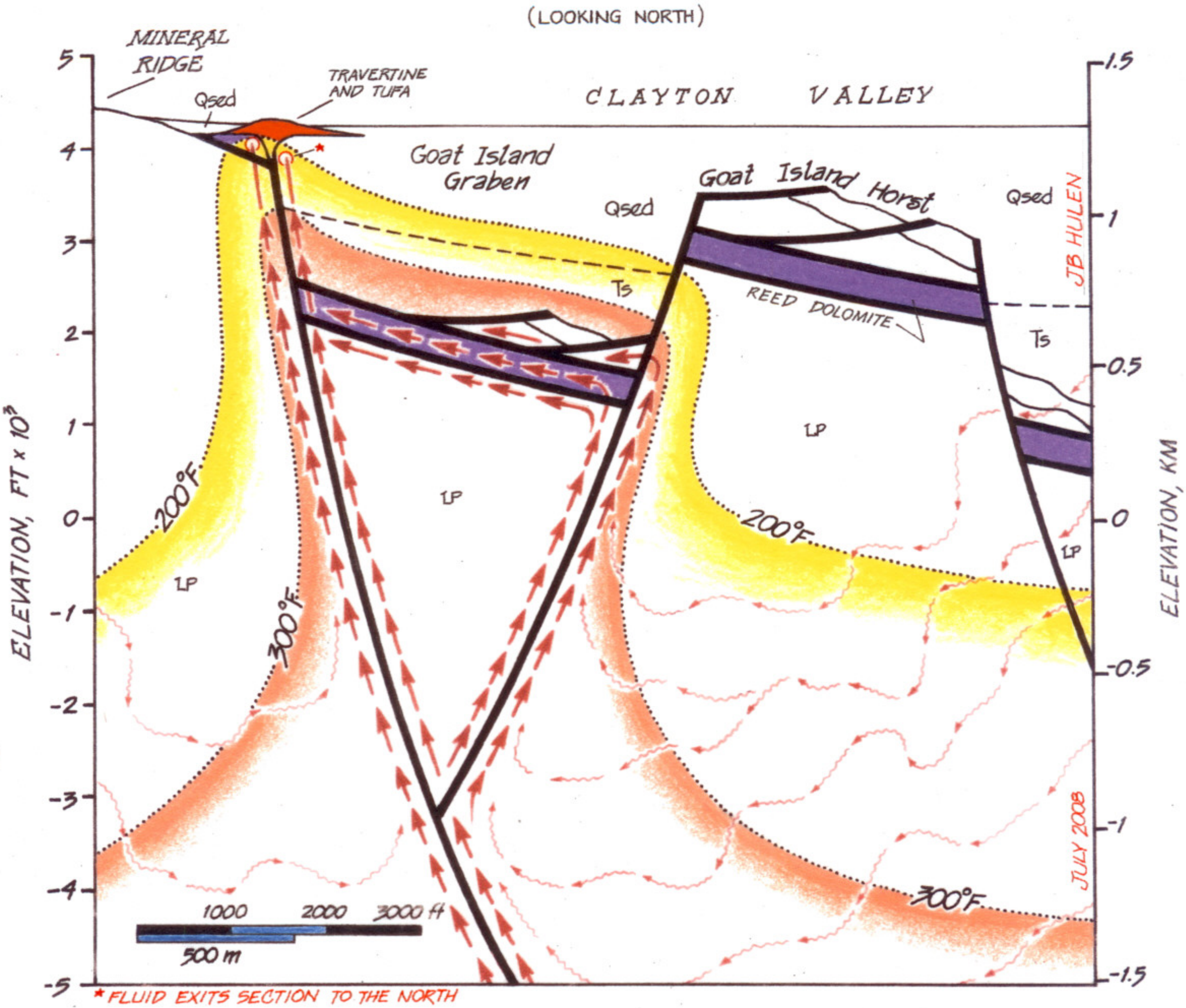



**Figure 8.** Conceptual 2D geohydrologic model for the Silver Peak geothermal system along an east-west transect (a portion of geologic section C-C'; ***Figure 3D***) through Goat Island graben and horst. *Small wavy red arrows* depict tortuous, low-[fluid]-volume, downward percolation of basinal waters and brines (mostly from the east) into fractured but low-permeability basement rock beneath the Holocene to Miocene basin-fill sediments of Clayton Valley. In response to a regionally elevated thermal gradient, these fluids are gradually heated, become buoyant as a consequence, and begin to ascend toward the surface. Encountering the high-permeabity faults and allied fracture zones bordering Goat Island graben, the fluids coalesce into focused, high-volume, high-temperature geothermal-upflow zones *(bold red arrows)*, ascending rapidly enough that temperatures normally encountered at much greater depth are near-isothermally transported to shallower levels ideally permissive for commercial extraction via drilling. Cross-flow between hypothetical thermal plumes on opposite sides of the graben conceptually occurs in an attenuated, intensely fractured and brecciated slice of Proterozoic-Cambrian Reed dolomitic marble—and possibly in immediately overlying Cambrian carbonates—in the buried upper plate of the Silver Peak-Lone Mountain metamorphic core complex. The heated brines locally vent to the surface (or into a contemporaneous shallow lake), in the process forming small travertine mounds, and fostering deposition of tufa by algae. **Qsed**—Quaternary basin-fill sediments, undivided; **Ts**—Low-density, Mio-Pliocene sedimentary rocks; **LP**—Core-complex, lower-plate, metasedimentary tectonites and tectonized granitoids.

Davis, J.R., Friedman, I., and Gleason, J.D., 1986, Origin of the lithium-rich brine, Clayton Valley, Nevada: *U.S. Geological Survey,* Bulletin 1622, Chapter "L," p. 132-138.

Diamond, D.S., 1990, Structural and sedimentological evolution of an extensional orogen, Silver Peak Range and adjacent areas, west-central Nevada: *University of California* at Los Angeles, Ph.D. Dissertation, 360 p.

Dixon, T.H., Miller, M., Farina, F., Wang, H., and Johnson, D., 2000, Present-day motion of the Sierra Nevada block and some tectonic implications for the Basin-Range province, North American cordillera: *Tectonics*, v. 19, p. 1-24.

Elders, W.A., Rex, R.W., Meidav, T., Robinson, P.T., and Biehler, S., 1972, Crustal spreading in southern California: *Science*, v. 178, p. 15-24.

Elias, E.A., 2005, Structural control of late Miocene to Pliocene volcanic and volcaniclastic deposition during upper-plate fragmentation in the Silver Peak extensional complex, west-central Great Basin: *University of Idaho* at Moscow, M.Sc. Thesis, 68 p.

Flynn, T., and Buchanan, P.K., 1993, Pleistocene origin of geothermal fluids in the Great Basin, western United States: *Resource Geology*, v. 16, p. 60-68.

Forster, C.B., Caine, J.S., Schulz, S., and Nielson, D.L., 1997, Fault zone architecture and fluid flow—An example from Dixie Valley, Nevada: *Stanford University*, 21st Workshop on Geothermal Reservoir Engineering, Proceedings, 8 p. paper.

Garside, L.J., and Schilling, J.S., 1979, Thermal waters of Nevada: *Nevada Bureau of Mines and Geology,* Bulletin 91, 163 p.

*GeothermEx, Inc.*, 2006, Independent technical report—Resource evaluation of the Silver Peak geothermal project, Esmeralda County, Nevada: "43-101" Report for Sierra Geothermal Power Corporation, 50 p.

Goff, F., Hulen, J.B., Adams, A.I., Trujillo, P.E., Counce, D., and Evans, W.C., 1994, Geothermal characteristics of some oil field waters in the Great Basin, Nevada, *in* Oil fields of the Great Basin (R.A. Schalla and E.H. Johnson, editors): Reno, *Nevada Petroleum Society*, p. 93-106).

Harding, T.P., Vierbuchen, R.C., and Christie-Blick, N., 1985, Structural styles, plate-tectonic settings, and hydrocarbon traps of divergent (transtensional) wrench faults, *in* Strike-slip deformation, basin formation, and sedimentation: *Society of Economic Paleontologists and Mineralogists,* Special Publication 37, p. 51-78.

Hickman, S., and Zoback, M., 1998, In-situ stress in a fault-hosted geothermal reservoir at Dixie Valley, Nevada: *Stanford University*, 22nd Workshop on Geothermal Reservoir Engineering, Proceedings, p. 141-146.

Hulen, J.B., Nash, G.D., Deymonaz, J., and Schriener, A., 2005a, Hot prospect—DOE enables the Emigrant geothermal exploration and slimhole drilling project in Fish Lake Valley, Nevada: *Geothermal Resources Counci*, Bulletin, v. 34, p. 176-183.

Hulen, J.B., Nash, G.D., and Deymonaz, J., 2005b, Geology of the Emigrant geothermal prospect, Esmeralda County, Nevada: *Geothermal Resources Council*, Transactions, v. 29, 22 p.

Kirsch, S.A., 1971, Chaos structure and turtleback dome, Mineral Ridge, Esmeralda County, Nevada: *Geological Society of America,* Bulletin, v. 82, p. 3169-3176.

Kunasz, J.A., 1970, Geology and chenmistry of the lithium deposit in Clayton Valley, Esmeralda County, Nevada: *Pennsylvania State University*, Ph.D. Dissertation, 114 p.

Norton, D.L., and Hulen, J.B., 2001, Preliminary numerical analysis of the magma-hydrothermal history of The Geysers geothermal system, California, USA, *in* The Geysers coring project and The Geysers/Clear Lake igneous-geothermal regime (J.B. Hulen, editor): *Geothermics*, v. 30, p. 211-234.

Oldow, J.S., 1992, Late Cenozoic displacement partitioning in the northwestern Great Basin, *in* Walker Lane symposium—Structure, tectonics, and mineralization of the Walker Lane (S.D. Craig, editor): Reno, *Geological Society of Nevada*, Symposium Proceedings, p. 17-52.

Oldow, J.S., 2003a, Active transtensional boundary zone between the western Great Basin and Sierra Nevada block, western U.S. cordillera: *Geology*, v. 31, p. 1033-1036.

Oldow, J.S., 2003b, Late Cenozoic displacement partitioning in the northwestern Great Basin, *in* Regional geology and gold deposits of the Silver Peak area, Nevada (H.G. Brown, editor): *Geological Society of Nevada*, 2003 Fall Field Trip Guidebook, Special Publication 38, p. 113-152.

Oldow, J.S., Kohler, G., and Donelick, R.A., 2003, Late Cenozoic extensional transfer in the Walker Lane strike-slip belt, Nevada, *in* Regional geology and gold deposits of the Silver Peak area, Nevada (H.G. Brown, editor): *Geological Society of Nevada*, 2003 Fall Field Trip Guidebook, Special Publication 38, p. 153-161.

Petrick, W. (Industrial Imaging, Inc.), 2008, Silver Peak geothermal prospect—Depth estimate from gravity (see Quantec, 2008 [?]).

Petronis, M.S., Geismann, J.W., Oldow, J.S., and McIntosh, W.C., 2003, Paleomagnetic and $^{40}Ar/^{39}Ar$ geochronologic data bearing on the structural evolution of the Silver Peak extensional complex, west-central Nevada, *in* Regional geology and gold deposits of the Silver Peak area, Nevada (H.G. Brown, editor): *Geological Society of Nevada,* 2003 Fall Field Trip Guidebook, Special Publication 38, p. 177-211 (Reprinted with permission from the *Geological Society of America,* Bulletin, v. 114, p. 1108-1130).

Petronis, M.S., Geismann, J.W., Oldow, J.S., and McIntosh, W.C., 2007, Tectonism of the southern Silver Peak Range—Paleomagnetic and geochronologic data bearing on the Neogene development of a regional extensional complex, central Walker Lane, Nevada, *in* Exhumation associated with continental strike-slip fault systems (A.B. Till, S.M. Roeske, J.C. Sample, and D.A. Foster, editors): *Geological Society of America,* Special Paper 434, p. 81-106

Price, J.G., Lechler, P.J., Lear, M.B., and Giles, T.F., 2000, Possible volcanic source of lithium in brines in Clayton Valley, Nevada, *in* Geology and ore Deposits 2000—The Great Basin and beyond (J.K. Cluer, J.G. Price, E.M. Struhsacker, R.F. Hardyman, and C.L. Morris, editors): *Geological Society of Nevada,* Symposium Proceedings (May 15-18, 2000), p. 241-248.

Quantec, Inc., 2008 (?), Results of a detailed gravity survey of the Silver Peak geothermal prospect.

Reheis, M.C., and Sawyer, T.L., 1997, Late Cenozoic history and slip rates of the Fish Lake Valley, Emigrant Peak, and Deep Springs fault zones, Nevada and California: *Geological Society of America*, Bulletin, v. 109, p. 280-299).

Robinson, P.T., Stewart, J.H., Moiola, R.J., and Albers, J.P., 1976, Geologic map of the Rhyolite Ridge (15') quadrangle, Esmeralda County, Nevada: *U.S. Geological Survey, Geological Survel*, Quadrangle map GQ-1325, scale 1:24,000.

Sibson, R.H., 1986, Brecciation processes in fault zones—Inferences from earthquake rupturing: *Pageoph*, v. 124, p. 159-175.

Spurr, J.E., 1906, Ore deposits of the Silver Peak quadrangle, Nevada: *U.S. Geological Survey*, Professional Paper 55.

Stewart, J.H., 1990, Tectonics of the Walker Lane belt, western Great Basin—Mesozoic and Cenozoic deformation in a zone of shear, *in* Metamorphism and crustal evolution of the western U.S. (Ruby Volume VII; W.G. Ernst, editor): Upper Saddle River, New Jersey, *Prentice-Hall*, p. 685-713.

Stewart, J.H., and and Diamond, D.S., 1990, Changing patterns of extensional tectonics—Overprinting of the basin of the middle and upper Miocene Esmeralda Formation in western Nevada by younger structural basins, *in* Basin and Range extensional tectonics near the latitude of Las Vegas, Nevada (B.P. Wernicke, editor): *Geological Society of America*, Memoir 176.

Sylvester, A.G., 1988, Strike-slip faults: *Geological Society of America*, Bulletin, v. 100, p. 1666-1703.

Wesnousky, S.G., 2005, Active faulting in the Walker Lane: *Tectonics*, *v. 24*, ms. TC3009, 35 p.

*Western Geothermal Partners, LLC,* 2006, Silver Peak geothermal prospect, Esmeralda County, Nevada—direct-use Potential: Internal Report, 15 p.

Wisian, K.W., Blackwell, D.D., and Richards, M., 1999, Heat flow in the western United States and extensional geothermal systems: *Stanford University*, 24th Workshop on Geothermal Reservoir Engineering, Proceedings, 8 p. paper.

Zampirro, D., 2003, Hydrogeology of Clayton Valley brine deposits, Esmeralda County, Nevada: *Nevada Bureau of Mines and Geology*, Special Publication 33, p. 271-280.

## ***APPENDIX 1***

### 1:10,000-Scale Imagery and Detailed Geologic Maps of the Silver Peak Geothermal Prospect and Vicinity, Esmeralda County, Nevada

*(Map index and 20 individual geologic maps follow the explanation)*

EXPLANATION *(page 1 of 3)*

Qco — Ground surface historically and culturally concealed, obscured, or developed (e.g., towns and townsites; mine dumps and mill tailings; brine-evaporation ponds; waste-disposal facilities

Qa — Quaternary alluvium—Unconsolidated, sandy pebble to cobble fan-gravel

Qoa — Quaternary older alluvium—Same as, but elevated above and commonly incised by, **Qa**

Qt — Quaternary travertine—Low-relief mounds, blankets, and sheets of white to gray, hot-spring precipitated calcium carbonate

Qtl — Quaternary limonitic travertine—Same as **Qt**, but with light to dark yellow-brown to orange-brown and grayish-brown bands, lenses, and clots containing abundant limonite (mostly goethite) and lesser manganese oxide

Qtm — Quaternary manganiferous travertine—Same as **Qt** and **Qtl**, but medium to dark gray to coal black due to abundant manganese oxide (likely pyrolusite and psilomelane). Unit forms individual mounds, as well as a distinct annular band (implying a dramatic but temporary perturbation in thermal-water chemistry) in one **Qt**-dominated travertine mound south of Alcatraz "Island" *(Map E4)*.

Qtf — Quaternary tufa—Broad blankets of light to medium gray, porous, algally-precipitated calcium carbonate with subdued "biscuit-and-bowl" morphology. Unit flanks **Qt** mounds north of the town of Silver Peak *(Maps C4 and D4)*.

Qp — Quaternary playa deposits—Flat-lying, principally argillaceous silt and fine sand, locally sulfate-rich

Qpt — Quaternary playa silt and sand with small, scattered travertine deposits

Qst — Quaternary lacustrine and aeolian sand with small, scattered travertine deposits

$Qs_1$ — Quaternary pebbly sand deposits, where alluvium merges basinward into lacustrine and aeolian sand sheets

$Qs_2$ — Quaternary lacustrine, littoral, and aeolian sand deposits, undivided

$Qs_3$ — Quaternary aeolian sand dunes, veils, and sheets

BST — Quaternary olivine-phyric basalt, intrusive or extrusive *(Map A1)*

Qbc — Quaternary olivine-phyric basalt cinder cone *(Maps A3 and A4)*

## *APPENDIX 1—*EXPLANATION *(page 2 of 3)*

**Qbf** — Quaternary olivine-phyric basalt flow rock and flow breccia, seemingly sourced from the same vent as **Qbc** *(Maps A4, A5, and B5)*

**RP/FP** — Tertiary rhyolite or "felsite" porphyry

**DBS** — Tertiary (Miocene?) diabase and microdiabase

**AFT** — Tertiary (Miocene?) felsic ash-flow tuff, non- to weakly welded (WW)

**GD** — Mesozoic (Cretaceous?) granodiorite, apparently not tectonized

**GR** — Mesozoic (Cretaceous?) granite to quartz monzonite, commonly pegmatitic, extensively tectonized to mylonite and protomylonite where intruding the Proterozoic Wyman Formation; less tectonized where intruding the Proterozoic to Cambrian Reed Dolomite

**SH/ST** — Paleozoic shale/argillite and siltstone/siltite

**ST/QT** — Paleozoic siltite and fine-grained metasandstone to quartzite

**ST/SS** — Paleozoic siltstone and fine-grained sandstone

**LS** — Paleozoic limestone

**DO** — Paleozoic dolomite

**LS/DO** — Paleozoic limestone and dolomite, undivided

**MBX** — Paleozoic limestone-dolomite megabreccia, incorporating minor siltstone and fine-grained sandstone

**ML** — Paleozoic mélange—Lithons of limestone embedded in a complexly sheared matrix of shale, siltstone, and sandstone

**DM** — Proterozoic to Cambrian dolomitic marble (Reed Dolomite)—Extensively attenuated, fractured, and brecciated, but not sheared or ductiley deformed like the underlying Proterozoic Wyman Formation metamorphic tectonites

**TW** — Proterozoic Wyman Formation, undivided

**TW/GR** — Proterozoic Wyman Formation and tectonized Mezozoic granitoid, in subequal proportions

**TS/TSC** — Proterozoic Wyman Formation—Siliciclastic to calcareous-siliciclastic tectonites, typically intricately folded mylonite, protomylonite, phyllite, and semi-schist

**TM** — Proterozoic Wyman Formation—Marble mylonite and protomylonite. Unit forms bold, folded white "stripes" in the otherwise drab gray to brown Wyman (stripes prominently visible in the range front west of the travertine/tufa deposit north of the town of Silver Peak; *Map C3)*

**TMZ** — Proterozoic Wyman Formation—Mixed-zone tectonites. The above two rock types with tectonized granitoid in various proportions, but with no one rock type extensively predominant.

## *APPENDIX 1*—EXPLANATION *(page 3 of 3)*

Contact, dashed where approximate

Moderate- to high-angle fault—Long dashes where approximate; short dashes where inferred; dotted where concealed; broken dotted line where inferred *and* concealed; bar-and-ball on downthrown block; opposing half-arrows where oblique- or strike-slip, but with sense of lateral displacement cryptic; arrow indicates dip; short line oblique to arrow shows rake of slickensides or mullions

Detachment fault—Dip overall >30° but locally steeper; long dashes where approximate; dotted where concealed; numbered arrow indicates direction and magnitude of dip

Strike and dip of bedding

Strike and dip of vertical bedding

Strike and dip of foliation

Strike and dip of vertical foliation

Extinct hot-spring vent

Mine shaft

Prospect

Adit

Existing drill hole

Initial Sierra Geothermal candidate thermal-gradient-borehole site; now largely superseded

Highway

Well-maintained dirt, gravel, or locally paved road

Dirt road

Old railroad grade

Geothermal lease boundary (approximate)

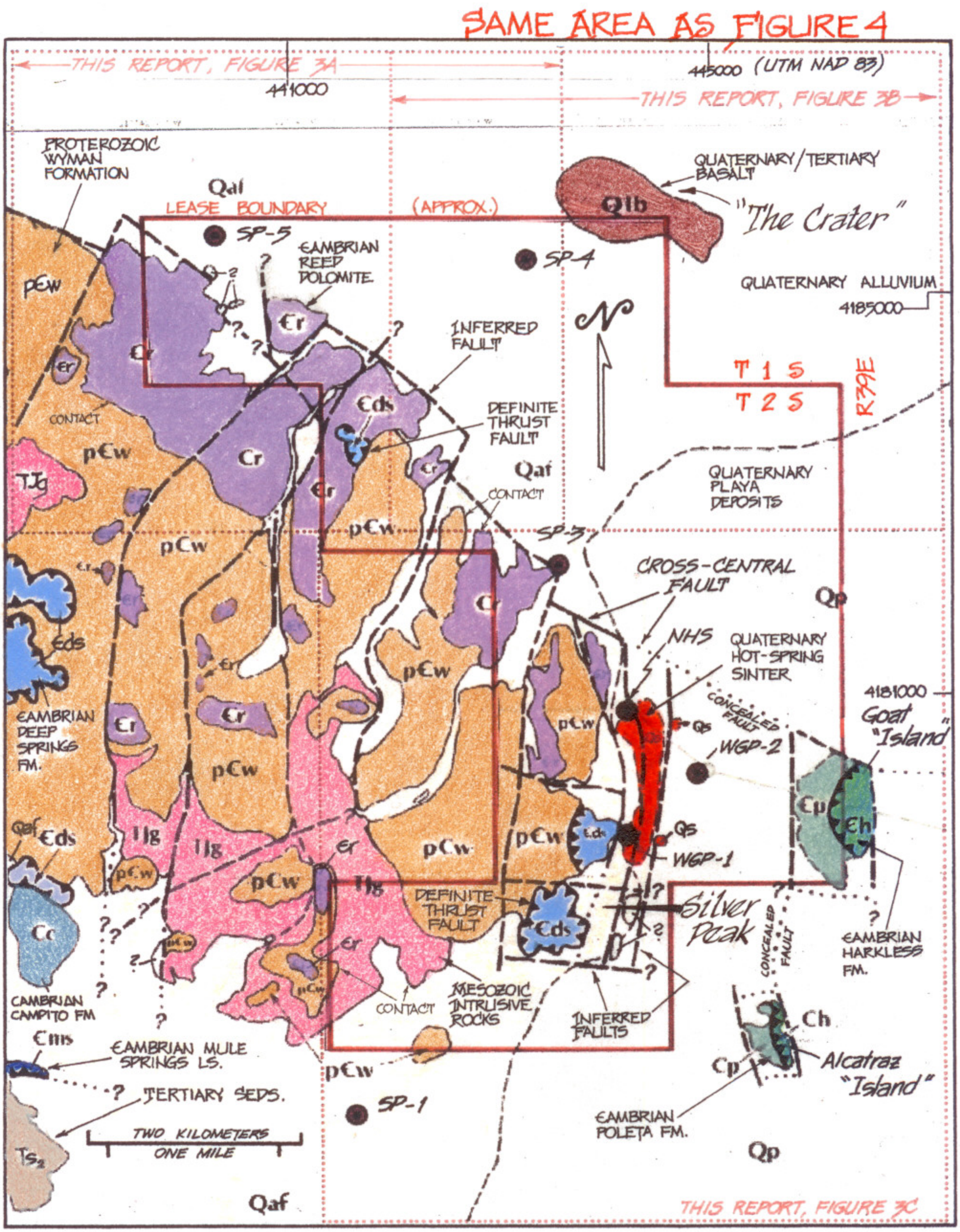
Image-linear for field checking

Perimeter of subsidence "moat" around travertine mound

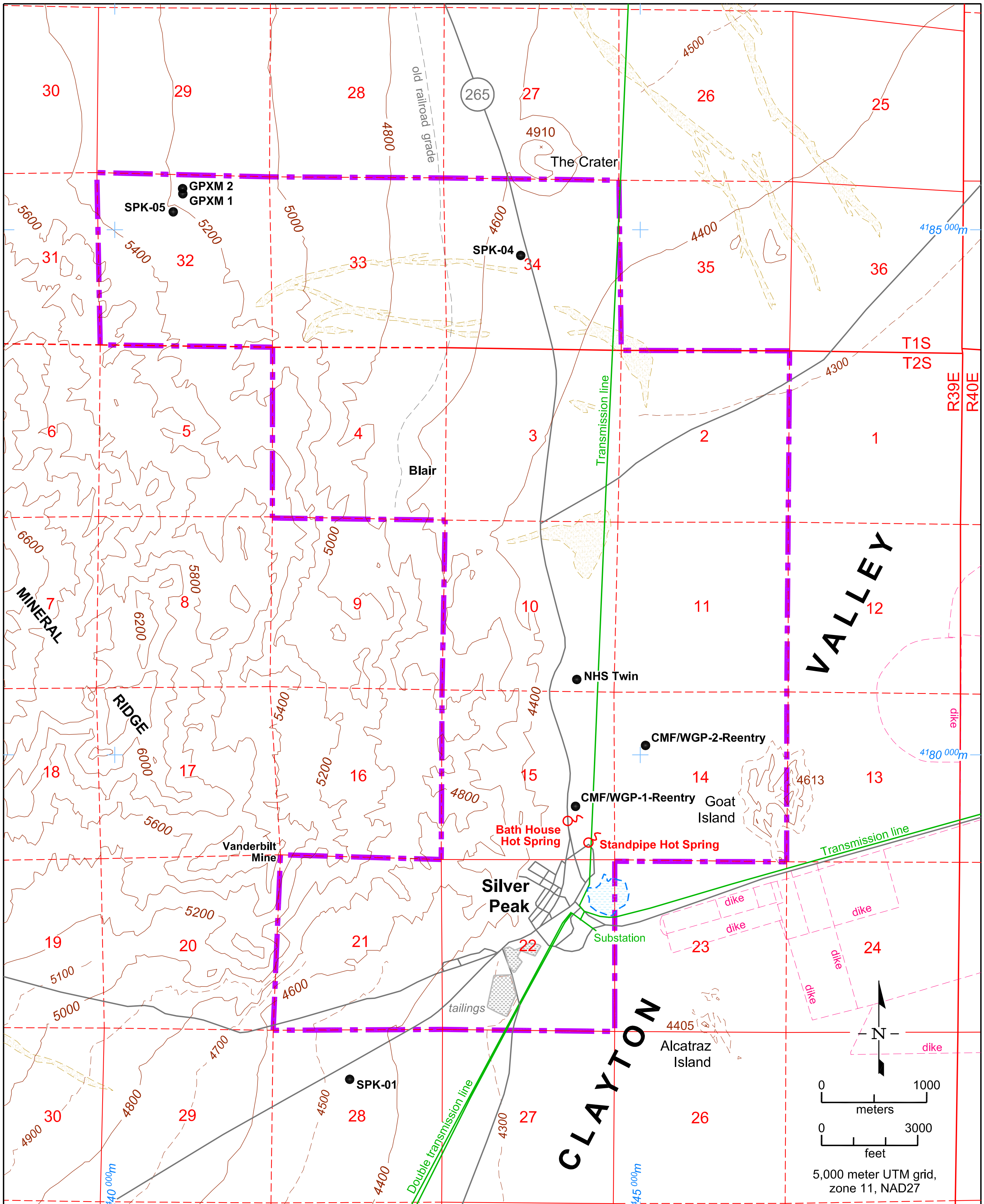
Sinkhole

Major fault inferred from gravity (preliminary; from Quantec, 2008 [?]); U = up; D = down

Massive, white, "bull" quartz (probably Mesozoic-age)




*Appendix 2. Geologic map of the Silver Peak Geothermal Prospect and vicinity. Extracted, enlarged, and annotated from WESTERN GEOTHERMAL PARTNERS, 2006.*




LEGEND

- ● Existing well
- Hot spring
- 4800 Elevation contour, feet (interval 200ft, supplemental intervals at 100ft)
- Lease area

Figure 5.2: Location of thermal features and drillholes in the Silver Peak area

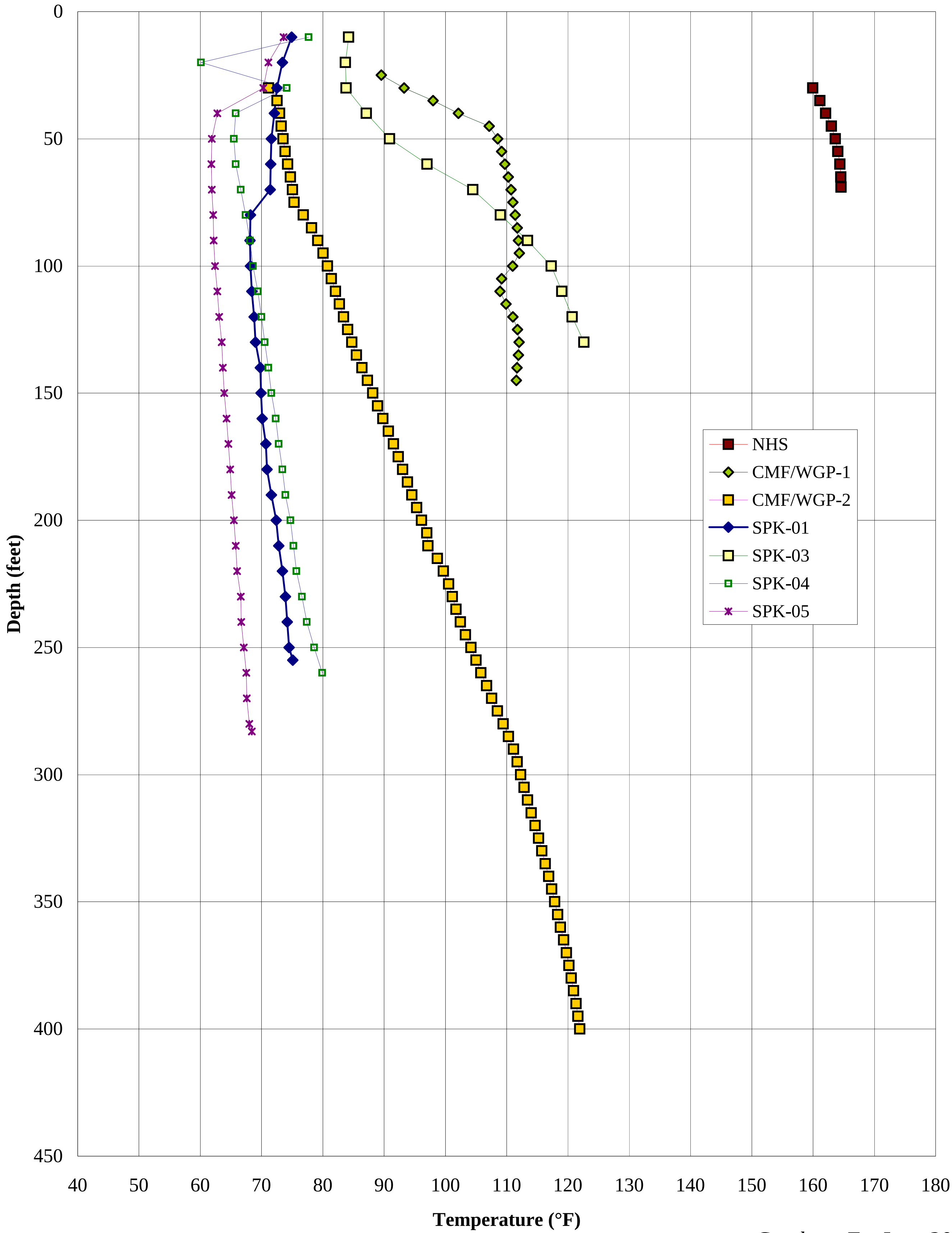
GeothermEx, Inc.
GEOTHERMAL EXPLORATION DEVELOPMENT AND OPERATIONS
5221 Central Ave., Suite 201, Richmond, CA 94804
TEL (510) 527-9876 FAX (510) 527-8164 EMAIL MW@GEOTHERMEX.COM

| | | |
|---|---|---|
| FILE: SILVER PEAK EXISTING WELLS ONLY.DWG | | |
| PLOTDATE: 25SEP2006 | DRAWN: RRS | APP.: RCH |

**Table 5.1. Summary of Temperature Data from Drillholes in the Silver Peak Prospect Area**

| Drillhole Name | Depth (feet) | Maximum Temperature (°F) | Temperature Gradient (°F/100 feet) | |
|---|---|---|---|---|
| | | | Overall | Bottomhole |
| SPK-01 | 255 | 75.1 | 5.9 | 2.2 |
| SPK-03 | 130 | 122.6 | 48 | 17 |
| SPK-04 | 260 | 79.9 | 7.7 | 11.6 |
| SPK-05 | 283 | 68.4 | 3.1 | 3.1 |
| NHS | 69 | 167 | >100 | 0 |
| CMF/WGP-1 | 145 | 112.0 | 35 | 0 |
| CMF/WGP-2 | 400 | 121.9 | 15 | 8.2 |

## Figure 5.3. Measured Temperature Gradients in the Silver Peak Prospect Area




*GeothermEx, Inc. 2006*

SEE APPENDIX 3 FOR LOC. → WELL GPXM-1

WHITE—DIVISION OF WATER RESOURCES
CANARY—CLIENT'S COPY
PINK—WELL DRILLER'S COPY

PRINT OR TYPE ONLY
DO NOT WRITE ON BACK

# STATE OF NEVADA
## DIVISION OF WATER RESOURCES
## WELL DRILLER'S REPORT

Please complete this form in its entirety in accordance with NRS 534.170 and NAC 534.340

OFFICE USE ONLY
Log No. 66213
Permit No. 66034A
Basin 143

NOTICE OF INTENT NO. 24568

1. OWNER Mineral Ridge Resources, Inc.
MAILING ADDRESS P. O. Box 67
Silver Peak, NV 89047

ADDRESS AT WELL LOCATION same

2. LOCATION NE ¼ NW ¼ Sec. 32 T. 1 N/(S) R. 39 E. Esmeralda County
PERMIT NO. 60034A (Issued by Water Resources) Parcel No. Subdivision Name

3. WORK PERFORMED
☒ New Well ☐ Replace ☐ Recondition ☐ Deepen ☐ Abandon ☐ Other

4. PROPOSED USE mining
☐ Domestic ☐ Irrigation ☐ Test ☐ Municipal/Industrial ☒ Monitor ☐ Stock

5. WELL TYPE
☐ Cable ☐ Rotary ☒ RVC ☐ Air ☐ Other

6. LITHOLOGIC LOG

| Material | Water Strata | From | To | Thickness |
|---|---|---|---|---|
| Gravel overburden | | 0 | 65 | 65 |
| Brown clay | | 65 | 75 | 10 |
| Green slightly calcarous | | 75 | 435 | 360 |
| mudstone to siltstone (soft) | | | | |
| Clay rich section of unit | | 435 | 505 | 70 |
| described above | | | | |
| Green siltstone to mudstone | | 505 | 565 | 60 |
| Alaskite (F20x stained) | | 565 | 610 | 45 |
| No return | | 610 | 625 | 15 |
| Orange ochre limestone | | 625 | 730 | 70 |
| Breccia ( poor return) | | | | |
| Wyman FM calc.silicate | | 730 | 795 | 65 |
| Alaskite | | | | |
| No return | | 795 | 860 | 65 |
| Wyman formation | | 860 | 1340 | 480 |
| calc. silicate and | | | | |
| Alaskite | | | | |
| Gravel packed from 1340 | | | | |
| to 10' cement 10- +2 | | | | |



Date started 9-26, 19 94
Date completed 10-5, 19 94

7. WELL TEST DATA
TEST METHOD: ☐ Bailer ☐ Pump ☒ Air Lift

| | G.P.M. | Draw Down (Feet Below Static) | Time (Hours) |
|---|---|---|---|
| 1035 | 30 | | 2 min. |
| | 35-40 | | 2 min. |
| 1220 | 60 | | 2 min. |
| 1325 | 65 | | 2 min. |

8. WELL CONSTRUCTION
Depth Drilled 1340 Feet Depth Cased 1338 Feet

HOLE DIAMETER (BIT SIZE)

| Inches | From (Feet) | To (Feet) |
|---|---|---|
| 10 | 0 | 50 |
| 6 | 50 | 800 |
| 5 3/4 | 800 | 1340 |

CASING SCHEDULE

| Size O.D. (Inches) | Weight/Ft. (Pounds) | Wall Thickness (Inches) | From (Feet) | To (Feet) |
|---|---|---|---|---|
| 1 1/2 | | SCH80 | +2 | 1340 |

Perforations:
Type perforation .020 horz. slots
Size perforation .020 horz.
From 1340 feet to 1040 slot feet
From 1040 feet to +2 blank feet

Surface Seal: ☒ Yes ☐ No
Depth of Seal 0-50
Placement Method: ☐ Pumped ☒ Poured
Seal Type: ☒ Neat Cement ☐ Cement Grout ☐ Concrete Grout

Gravel Packed: ☒ Yes ☐ No
From 1340 feet to 10- +2 feet

9. WATER LEVEL
Static water level 720 feet below land surface
Artesian flow G.P.M. P.S.I.
Water temperature °F Quality

10. DRILLER'S CERTIFICATION
This well was drilled under my supervision and the report is true to the best of my knowledge.

Name EKLUND DRILLING COMPANY, INC. (Contractor)
Address P. o. Box 2786 (Contractor)
Elko, NV 89803

Nevada contractor's license number issued by the State Contractor's Board 0030823
Nevada driller's license number issued by the Division of Water Resources, the on-site driller M-1819

Signed Greg Aerist (By driller performing actual drilling on site or contractor)
Date 10-17-94

(Rev. 3-91) USE ADDITIONAL SHEETS IF NECESSARY (01-627)

RECEIVED COURTESY OF JOHN DEYMONAZ

WELL GPXM-2 (SEE APPENDIX 3 FOR LOCATION)

WHITE—DIVISION OF WATER RESOURCES
CANARY—CLIENT'S COPY
PINK—WELL DRILLER'S COPY

PRINT OR TYPE ONLY
DO NOT WRITE ON BACK

STATE OF NEVADA
DIVISION OF WATER RESOURCES

# WELL DRILLER'S REPORT

Please complete this form in its entirety in accordance with NRS 534.170 and NAC 534.340

OFFICE USE ONLY
Log No. 66214
Permit No. 60034A
Basin 143

NOTICE OF INTENT NO. 24568

1. OWNER Mineral Ridge Resources, Inc.
MAILING ADDRESS P. O. Box 67
Silver Peak, NV 89047

ADDRESS AT WELL LOCATION same

2. LOCATION NE ¼ NW ¼ Sec. 32 T. 1 N/S R 39 E Esmeralda County
PERMIT NO. 60034A (Issued by Water Resources) Parcel No. Subdivision Name

3. WORK PERFORMED
[X] New Well [ ] Replace [ ] Recondition
[ ] Deepen [ ] Abandon [ ] Other

4. PROPOSED USE Mining
[ ] Domestic [ ] Irrigation [ ] Test
[ ] Municipal/Industrial [X] Monitor [ ] Stock

5. WELL TYPE
[ ] Cable [ ] Rotary [X] RVC
[X] Air [ ] Other

6. LITHOLOGIC LOG

| Material | Water Strata | From | To | Thickness |
|---|---|---|---|---|
| Overburden gravel | | 0 | 130 | 130 |
| Green to olive green | | 130 | 640 | 510 |
| siltstone, mudstone | | | | |
| and clay | | | | |
| Alaskite (oxidized) | | 640 | 720 | 80 |
| (weathered at unconformity) | | | | |
| Alaskite (weakly fractured) | | 720 | 840 | 120 |
| Calcarous calc. silicate | | 840 | 960 | 120 |
| (Wyman Fm.) | | | | |
| Interlayered Alaskite | | 960 | 1115 | 155 |
| & calcarous calc-silicate | | | | |
| Diabase dike | | 1115 | 1125 | 10 |
| Calcarous calc-silicate | | 1125 | 1195 | 70 |
| Fault zone | | 1195 | 1215 | 20 |
| Alaskite and calcarous | | 1215 | 1225 | 10 |
| calc-silicate | | | | |
| (Wyman fm.) | | | | |

'94 OCT 20 P1 13
STATE ENGINEERS

RECEIVED
OCT 27 1994
Div. of Water Resources
Branch Office - Las Vegas, NV

Date started 10-5, 19 94
Date completed 10-7, 19 94

7. WELL TEST DATA

TEST METHOD: [ ] Bailer [ ] Pump [ ] Air Lift

| | G.P.M. | Draw Down (Feet Below Static) | Time (Hours) |
|---|---|---|---|
| 1000 | 10 | | 2 min. |
| 1125 | 40 | | 2 min. |
| 1225 | 40-45 | | 2 min. |

8. WELL CONSTRUCTION

Depth Drilled 1225 Feet Depth Cased 1070 Feet

HOLE DIAMETER (BIT SIZE)

| Inches | From (Feet) | To (Feet) |
|---|---|---|
| 10 | 0 | 50 |
| 6 | 50 | 1225 |
| | | |

CASING SCHEDULE

| Size O.D. (Inches) | Weight/Ft. (Pounds) | Wall Thickness (Inches) | From (Feet) | To (Feet) |
|---|---|---|---|---|
| 2 | | SCH80 | +2 | 1070 |
| | | | | |
| | | | | |

Perforations:
Type perforation Drilled hole
Size perforation 1/4 hole every 3'
From 1070 feet to 850 holes feet
From 850 feet to +2 blank feet
From feet to feet
From feet to feet
From feet to feet

Surface Seal: [X] Yes [ ] No
Depth of Seal 50'
Placement Method: [ ] Pumped [X] Poured
Seal Type: [X] Neat Cement [ ] Cement Grout [ ] Concrete Grout

Gravel Packed: [ ] Yes [ ] No
From 1070 feet to 0 feet

9. WATER LEVEL

Static water level 818 feet below land surface
Artesian flow G.P.M. P.S.I.
Water temperature °F Quality

10. DRILLER'S CERTIFICATION

This well was drilled under my supervision and the report is true to the best of my knowledge.

Name EKLUND DRILLING COMPANY, INC. (Contractor)
Address P. O. Box 2786 (Contractor)
Elko, NV 89803

Nevada contractor's license number issued by the State Contractor's Board 0030823

Nevada driller's license number issued by the Division of Water Resources, the on-site driller M-1819

Signed Greg Secrist (By driller performing actual drilling on site or contractor)

Date 11-17-94

(Rev. 3-91) USE ADDITIONAL SHEETS IF NECESSARY 101-A37

RECEIVED COURTESY OF JOHN DEYMONAZ

Description and geology of thermal-gradient borehole WGP-2 (from WESTERN GEOTHERMAL PARTNERS, 2006, page 7)

**CMF / WGP #2** – This well was drilled between 1/03 and 1/06/2006. The well was drilled with a 12 ¾" bit to 80 ft and then cased with 8 " steel surface casing (cemented) to 80 ft. The well was then advanced with a 6 ¾" bit from 80 to 400 (limit of budgeted funds). The well was cased with 2 ½" steel sealed casing to 405 ft. The casing was filled with water after installation in order that temperatures would be able to equilibrate for later temperature logging.

The well encountered predominately calcareous hot springs deposits from 5 ft. – 10 ft. At 10 ft., sinter was encountered that was logged as siliceous, as pieces of it scratched a steel geology hammer. Circulation was lost at 20 ft.; the well absorbed 1800 gal of drill water mixed with abundant lost circulation material in 5 minutes time without advancing the bore hole. The well was advanced from 20 to 80 ft., with no returns. At just above 80 ft., a few returns of siliceous sinter appeared. Surface casing was then installed, and the well was advanced to TD without further lost circulation problems.

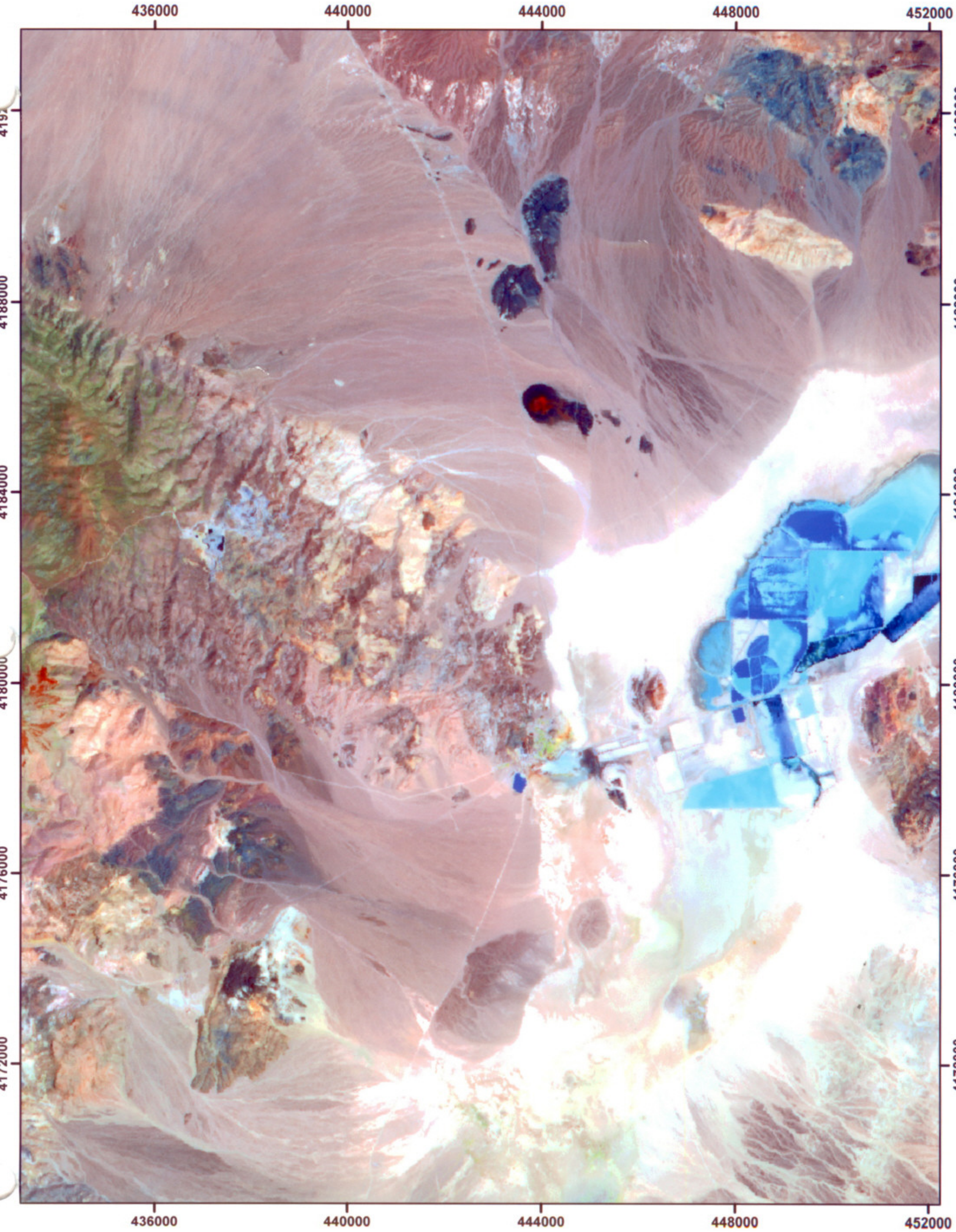
Because of the rocks encountered above and below, the interval from 20 to 80 ft. is interpreted as hot springs deposits, even though this was drilled blind. From 80 to 143 ft., predominately dolomitic sinter interbedded with green fine sands and silts were encountered. From 143 to 185 ft., green, fine grained sediments logged as clay – silt – sand (80% to 90%) with minor coarse sinter was encountered. From 185 – 280 ft., an interbedded sequence of dolomitic and siliceous sinter, bedded manganese oxide and green clays and silts were encountered. Hot springs deposits within this interval ranged from as low as 10% to as high as 70% of the returns that were logged.

From 280 – to 305 ft., fine grained green sand and silt logged as volcanic ash was encountered. This unit may be correlative to the Main Ash Aquifer, which is a marker bed in other areas of the Clayton Valley Basin. From 305 – 405 ft., fine to medium grained, angular gravel and sand was encountered. Gravel percentage ranged from 20% to 70%, but was mostly above 50%. The fine sand and silt percentage of this unit appeared to contain abundant volcanic ash grains. Vein quartz was noted in the gravels at 350 ft.

Description and Geology of thermal-gradient borehole WGP-1 (from WESTERN GEO-THERMAL PARTNERS, 2006, page 6)

**CMF / WGP #1** – This well was drilled on 12/22 and 12/23/2005. The well was drilled with a 12 ¾" bit to 40 ft and then cased with 8 " steel surface casing (cemented) to 40 ft. The well was then advanced with a 6 ¾" bit from 40 to 175 (refusal). The well was cased with 2 ½" steel sealed casing to 175 ft. and a bentonite seal was emplaced from 0 to 40 ft. The casing was filled with water after installation in order that temperatures would be able to equilibrate for later temperature logging.

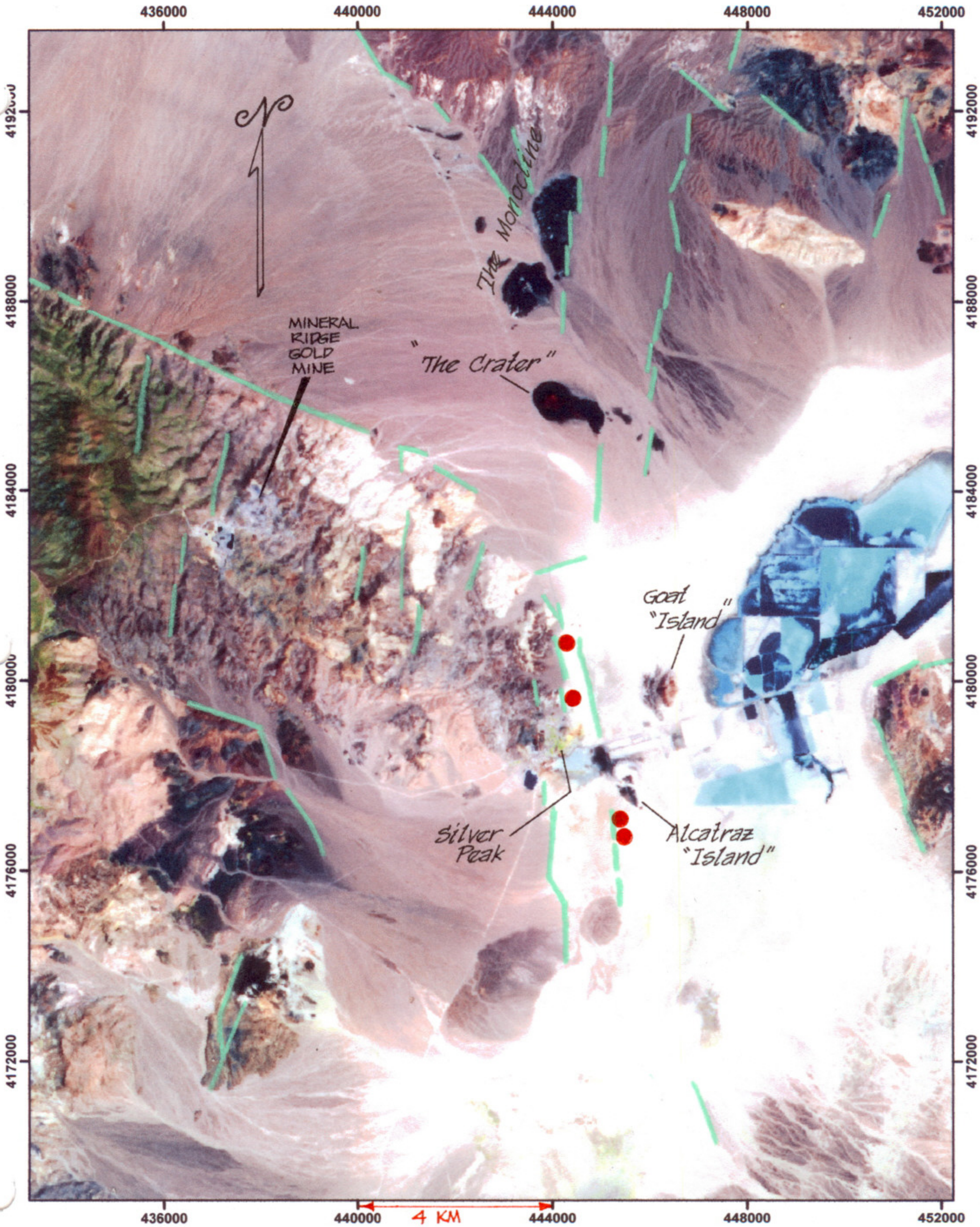
The well encountered hot springs deposits from 0 – 35 ft. Interbedded calcareous hot springs sinter and silt beds with manganese dioxide (?) staining predominated from 0 – 25 ft. From 25 – 35 ft., interbedded dolomitic sinter and prolific manganese dioxide (?) – estimated as high as 90% by volume were encountered. From 35 – 65 ft., silty clay and clayey silts were encountered. From 65 – 85 ft., green silty sand was encountered. From 85 – 90 ft. calcareous sinter was again encountered. From 90 – 155 ft., fine sands and gravels were encountered these sediments changed color to a dark red – brown at ~ 135 ft. From 155 – 170 ft., dark red – brown fine sands and silts were encountered (originally these sands were questionably interpreted as weathered bed rock. From 170 – 175 ft. there were no returns. The bit was in very hard rock, taking 5 min/ft to drill. Circulation was totally lost and could not be regained. It was assumed that the drill was in bed rock and drilling operations were terminated. This initial interpretation is now questioned by both WGP's and CFC's geologists. We now believe that the well bottomed in hard siliceous hot spring sinter deposits since very thick sinter deposits were found in CMF / WGP #2.




Scale 1:100,000 Silver Peak Area. Nevada

(Annotated on following page)

A5-1




Scale 1:100,000 Silver Peak Area, Nevada

● HOT-SPRING DEPOSITS

PROMINENT IMAGE-LINEARS

A5-2