

Compilation Surface Geologic Map for Use in Three-Dimensional Structural Model Building at The Geysers Geothermal Field, Northern California

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ABSTRACT

A digital surface geology map of The Geysers geothermal field was constructed to provide an additional surface constraint for a three-dimensional structural model being constructed by Calpine Corporation. Twenty, hand-drawn and mostly unpublished, paper maps of portions of the surface geology at The Geysers were compiled and digitized in ArcGIS. The names of the lithologic units from the individual maps, as well as the unit descriptions, were standardized across The Geysers to conform to the surface expression and near-surface well log descriptions. Prior to this compilation there was not a complete and consistent geologic map of the entire Geysers geothermal field.

By assembling and unifying the various geologic maps, spatial correlations between surface geology and subsurface discontinuities became more apparent. The compilation shows the northwest Geysers area is lithologically distinct from the southeast Geysers, with the geothermal field divided by the previously described, northeast-oriented Cobb Creek fault zone. This compilation also confirmed the dominance of northwest-striking lithologic units and faults, and revealed numerous younger (Quaternary) steeply dipping faults and discontinuous shear zones striking north-northeast and northeast throughout The Geysers geothermal field. Subtle geomorphologic features, such as faceted spurs – combined with the distribution of hydrothermal alteration, and outcrop characteristics – identify the surface expression of these northeast-striking faults and shear zones. Some of these northeast-striking, steeply-dipping, trans-tensional structures are shown by others to extend into the subsurface and hydraulically compartmentalize The Geysers steam reservoir between the dominant northwest-striking faults that limit the extent of the Geysers steam reservoir. The surface expressions of two additional shear zones in the southeast Geysers, herein called the Felsite fault and the Magnitude 4 Divide shear zone, were previously identified in the subsurface by utilizing lithology logs and induced seismicity patterns. The Geysers digital compilation map with updates from additional field mapping (2014-2015) further constrains the surface boundary of Calpine Corporation's development of a three-dimensional, structural model using Paradigm Geophysical SKUA GOCAD software (see companion paper, this workshop, Hartline et al., 2016), and allows increased confidence in the interpretation of structural features that appear to compartmentalize The Geysers steam reservoir.

1. INTRODUCTION

This paper presents the compilation map of the surface geology at The Geysers geothermal field as assembled from numerous geologic maps from the 1970s through today. Prior to this map compilation, most existing geologic maps for The Geysers were solely in paper format and not publicly available. Digitization of each paper map is the first step to making these legacy data readily available. Additionally, each of these legacy maps only covered portions of The Geysers geothermal field, and were not necessarily consistent with the adjoining maps. Digitizing each of the geologic maps and unifying the lithologic units across the geothermal field was crucial in identifying trends in structure and major lithologic breaks across the field. The purpose of this paper is to demonstrate the need for a compilation map to constrain the surface of the Calpine three-dimensional structural model, describe how the map was assembled, and highlight results which resulted from its completion.

Having an assembled map allows for spatial correlations between surface geology and subsurface discontinuities to become more apparent. By combining the unified surface geology with the myriad of subsurface data (Hartline et al, 2015; 2016 this workshop), geologists at The Geysers can correlate major faults and shear zones with subsurface discontinuities. The Northwest Geysers Enhanced Geothermal System (EGS) Demonstration Project (Rutqvist et al., 2015), and the Caldwell Ranch Exploration and Confirmation Project (Walters 2013), both established that northeast- and north-northeast-striking faults and shear zones (including the Caldwell Pines and Caldwell Ranch faults), extend to depth into the reservoir and constitute hydraulic discontinuities which act in a similar manner to faults that constrain near-surface groundwater. These hydraulic discontinuities are further supported by analysis of seismic events including tensor analyses, (Boyle and Zoback, 2013), which show that injected water moves parallel to these faults but not across them (Jeanne et al., 2014).

1.1 The Geysers Geothermal System

The Geysers-Clear Lake area of northern California is an active geothermal region – with numerous hot springs, fumaroles, hydrothermal ore deposits, and on-going geothermal development and power generation. Prior to development of The Geysers steamfield, the area was known for mercury deposits (Bailey, 1946; Rytuba et al., 1994a; Sherlock, 2005). These deposits are found on the periphery of the geothermal reservoir and the underlying Quaternary granitic pluton and are commonly referred to by economic geologists as an ‘alteration halo’ surrounding the reservoir (Hulen and Walters, 1993). Within The Geysers geothermal field it has long been recognized that the locations of surficial hydrothermal features are closely tied to the active steam reservoir below.

The faults and shear zones together with the granitic pluton underlying The Geysers reservoir play a major role in the “ground preparation” of both the hydrothermal ore deposits and hydrothermal geothermal systems (Walters et al., 1992). Major dilational structures associated with the Mercuryville fault and the Big Sulphur Creek fault act as crustal conduits for hydrothermal fluid flow from depth to the surface, or near surface, as evidenced by mercury mines, as well as active surficial hydrothermal features (Sherlock, 2005) (**Figure 1**). The present day reservoir conditions allow hydrothermal fluids to travel along these major structures – and are expressed as hot springs and fumaroles at the surface today – and are similar to the conditions responsible for ore deposition ~0.75 Ma (Bailey, 1946; Lehrman, 1986; Sherlock, 2005), suggesting hydrothermal activity is long lived in this area. By carefully mapping and updating the locations and extent of hydrothermal features and alteration zones, geologists can better identify faults and shear zones at The Geysers, which can be incorporated into a 3D geologic model using advanced software packages such as SKUA GOCAD.

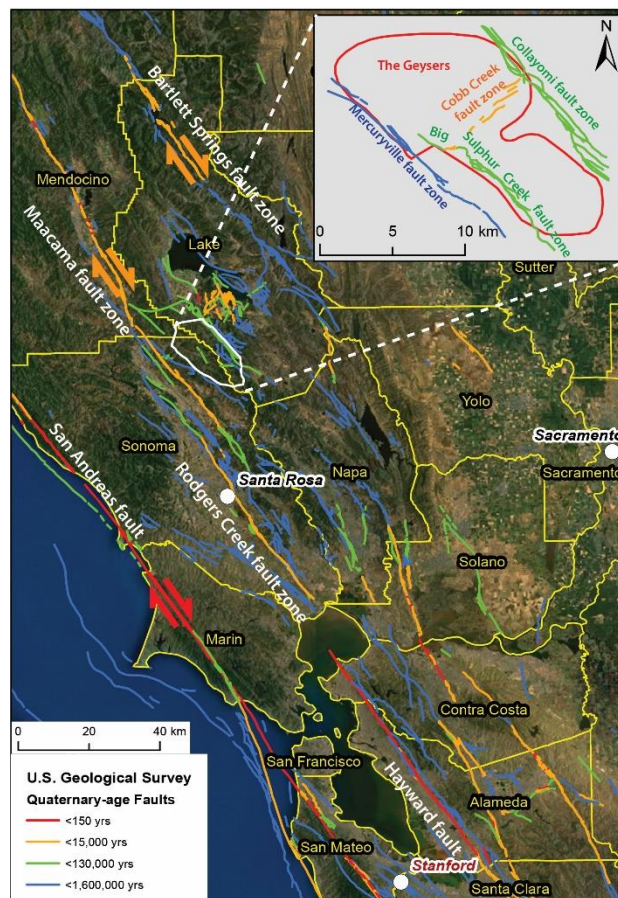


Figure 1. The Geysers mapping boundary (white) straddles the Lake-Sonoma county line (yellow) of northern California. The San Andreas Fault system of northern California and the major active dextral fault segments, the Hayward, Rodgers Creek, Maacama, and Bartlett Springs fault zones are labeled (from: USGS Quaternary faults database by Adams and Sawyer, 1999).

(Inset) Within the white mapping boundary, The Geysers steamfield (red outline) is bound by the inactive Mercuryville and Big Sulphur Creek fault zones on the southwest and by the inactive Collayomi fault zone to northeast, and divided by the Cobb Creek fault zone in the central portion of the steamfield (modified from Hartline et al., 2015).

2. GEOLOGIC SETTING

A brief review of northern California geology is necessary to provide background for the geologic setting of The Geysers, the largest known commercially-operating, vapor-dominated, geothermal system in the world. The Geysers is located in the Mayacmas Mountains of the northern California Coast Ranges approximately 120 km north of San Francisco, CA, USA (**Figure 1**).

2.1 Tectonics of the Western North American Margin

The bedrock geology at The Geysers is a complicated mélange of diverse terranes that were accreted to the western North American margin from ~160 Ma to 30 Ma during subduction of the Farallon plate. Accreted terranes from the Farallon plate were obducted, others subducted and exhumed. The complex Franciscan Assemblage – an accretionary terrane of the northern Coast Ranges and The Geysers – includes sedimentary and igneous rocks, which were intensely deformed and subsequently metamorphosed under high-pressure (0.85-1.0 GPa), low-temperature (200-350°C) conditions (Wayabayashi, 1992; Dumitru et al., 2010).

Concomitant with terrane accretion, the Farallon plate was subducted and consumed off the coast of California and the Baja Peninsula. In its place between the Mendocino and Rivera triple junctions to the north and south, respectively, the final convergence of these plates at ~30 Ma established a continental transform margin between the Pacific and North American plates and is manifested as the San Andreas Fault system of today. This major dextral, northwest-striking fault system sets the modern stage for stress and strain at The Geysers.

2.2 Regional Geology

2.2.1 Surface Geology

Geologic units of The Geysers are dominantly those of the Mesozoic Franciscan Assemblage of the Central Franciscan Belt with lesser quantities of Late Tertiary and Quaternary volcanic rocks (McLaughlin 1978, 1981; Hearn et al., 1981; Blake et al., 1988). In order of decreasing abundance these surface lithologies include: unmetamorphosed to moderately metamorphosed graywacke (i.e. poorly-sorted, coarse-grained sandstone with a clayey matrix, and interbedded argillite), greenstone, serpentinized peridotite and metamorphosed ultramafic rocks, extrusive volcanic rocks (e.g. rhyolite through basalt), radiolarian chert, and blueschist blocks (**Plate 1**). The Great Valley sequence of marine rocks resides outside and east of The Geysers steamfield. Establishing a precise stratigraphic column of Franciscan Assemblage sub-units is challenging given that lithologies (a) closely interfinger (i.e. outcrops of graywacke-matrix mélange), (b) are highly deformed (i.e. complexly faulted and folded), and (c) are concealed beneath landslide deposits and dense vegetation. Intense hydrothermal alteration is present above the axis of the underlying Quaternary granitic intrusion and in topographically low-lying thermal areas with active fumaroles and hot springs. Silica carbonate deposits define major veins that commonly contain mercury and hydrocarbons in an opaline matrix (Rytuba et al., 1994a; Sherlock, 2005).

2.2.2 Subsurface Geology

Surface lithologies at The Geysers are also found in well cuttings and core; however, at reservoir depths, two lithologies exist that are not present at the surface: hornfels and a Quaternary granitic intrusion, locally known as “the felsite” (more formally, the Geysers plutonic complex, GPC). The hornfels resulted from contact thermal metamorphism of graywacke lithologies overlying the deeper granitic intrusion. The Geysers reservoir would not exist if the intrusion of the GPC had not intruded and initiated the hydrothermal system (e.g., Hartline, et al., 2015).

The Geysers plutonic complex (GPC) is composed of microgranite porphyry, orthopyroxene-biotite granite, hornblende-pyroxene-biotite granodiorite, and leucocratic dikes (Hulen, 1995) with a mean age of ~1.18 Ma from U-Pb zircon. The GPC is temporally indistinguishable from, and geochemically similar to, the local dacites and rhyolites of the Cobb Mountain volcanic rocks in the Clear Lake volcanic field (several local flows between 1.15 to 1.00 Ma from combined $^{206}\text{Pb}/^{238}\text{U}$ zircon and $^{40}\text{Ar}/^{39}\text{Ar}$ sanidine) (Hearn et al., 1995; Hulen, 1995; Dalrymple et al., 1999; Schmitt et al., 2003a, 2003b). Concisely, Cobb Mountain volcanic rocks are the eruptive equivalents of the GPC, but not necessarily equivalent to the entire Clear Lake volcanic suite (e.g. Hulen and Nielson, 1996).

The GPC intruded along an elongated northwest-southeast axis (e.g., Hulen (1997), well-confined by northwest-striking faults to the southwest and northeast, as modeled in three-dimensions from well data using SKUA GOCAD software (see companion paper Hartline and others (2016), this workshop). The GPC slopes gently downwards to the northwest, whereas at its southeastern terminus there is a large, steep slope break (about 3500 ft of vertical relief). The peak of the intrusion is located in the southeastern edge of the steamfield, and gradually deepens toward the northwest and southeast margins, particularly in the northwest (i.e. Aidlin property) (Hartline et al., 2015) (**Figure 2**). This geometry is analogous to a subsurface mountain range oriented northwest-southeast with false summits and saddles.

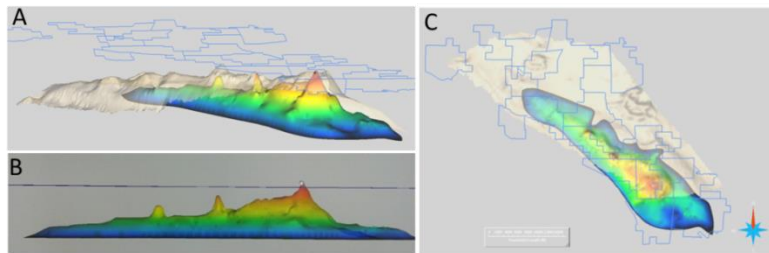


Figure 2. Geysers plutonic complex (GPC) (“felsite”) profile views from SKUA GOCAD model (Hartline et al., 2015). Color scale represents subsurface elevation of top of GPC (e.g. deeper blue through shallower red). Top of hornfels unit drapes over the GPC (transparent peach overlay). Blue polygons are lease boundaries projected onto mean sea level. Three views of GPC: a) looking north; b) looking northeast; and c) map view looking downward.

2.3 Regional Structure

Northern California hosts numerous major strike-slip faults east of the northern segment of the San Andreas Fault system (**Figure 1**). Of these major northwest-striking dextral faults, the Maacama fault zone resides nearest to The Geysers, less than 15 km southwest of the steamfield (Adams and Sawyer, 1999). Significant local fault zones within The Geysers associated with the Maacama fault zone include (from west to east): the Mercuryville, the Big Sulphur Creek, and the Collayomi fault zones. These northwest-striking fault zones exhibit dextral slip, help constrain the GPC location, and bound the steamfield reservoir to the southwest by the Mercuryville and Big Sulphur Creek fault zones and to the northeast by the Collayomi fault zone (**Figure 1**). The structural grain of The Geysers region is characterized by orthorhombic patterns of northwest- and northeast-striking faults. Significant well-developed, northwest-striking, dextral, strike-slip faults with fewer northwest-striking thrust faults are subparallel to major valleys, whereas northeast-striking faults cross-cut the landscape as subtle, discontinuous links among the northwest-striking faults. Notably, these ancillary, linking structures may provide favorable locations for geothermal fluid flow where critically-stressed and dilated, brittle damage zones formed in the pull-apart basin (i.e. right steps in right-lateral faults) (Oppenheimer 1986; Donnelly-Nolan et al., 1993; Faulds et al., 2011).

Northeast-trending lineaments and northeast-trending alteration and ore zones are well-documented in the Geysers-Clear Lake region (Bailey, 1946; Yates et al., 1946; Ciancanelli, 1970a, 1970b; Rich and Steele, 1974; Goff et al., 1977; Hearn et al., 1976, 1988; Beall et al., 1989; Williamson 1990; Rytuba et al., 1994b; Walters et al., 1996). However, assessing the relationship of these structures with respect to geothermal productivity, permeable fracture zones, and hydraulic discontinuities was not a research focus during the development of The Geysers from the late 1960's into the early 1990's. Results from this study are beginning to shift that focus.

3. METHODS FOR ASSEMBLING THE COMPILATION MAP

Surface geologic mapping is one of the most cost effective methods in all phases of geothermal development from exploration to production to reservoir management. Geologic mapping involves the identification and distribution of rock types (i.e. lithologies) and their spatial and temporal relationships in an area of investigation. Over the course of decades, The Geysers geothermal field geology has been mapped extensively by numerous geologists, at all different scales, with varying levels of detail and with distinct lithologic units. Of a total thirty original legacy maps, twenty hand-drawn and mostly unpublished, paper maps of portions of the surface geology were digitized and compiled using ArcGIS software. The compilation process was time-consuming because a majority of these paper maps have irregular map scales (1:200 scale), or have irregular map dimensions (from 8 in. x 11 in. to 8 ft. x 5 ft.) (**Figure 3**). Of the twenty maps that were digitized, only eighteen were selected for the final compilation map because of considerable overlap among some maps.

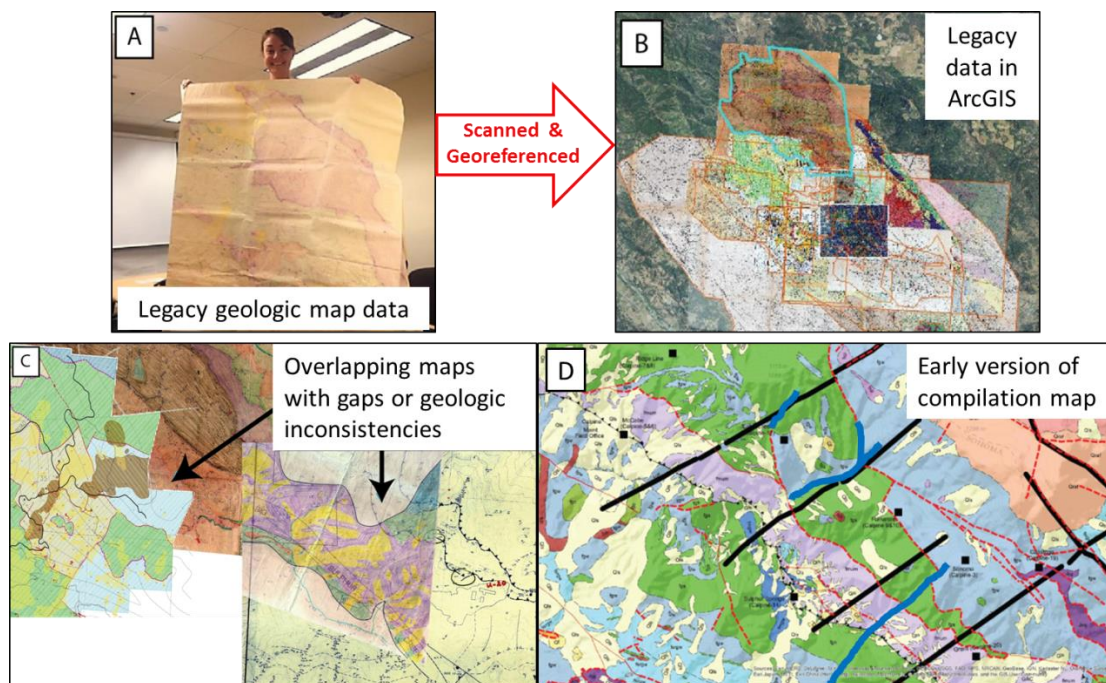


Figure 3. Flow chart of compilation map construction. A) Paper geologic maps like the one shown (Clayton et al., 1984) are irregularly sized and hand-drawn, and must be scanned and georeferenced in ArcGIS. B) ArcGIS image of 20 legacy maps that were digitized and used for the final compilation geologic map. C) Some maps overlap and have different geology at the same location. Two areas on two pairs of overlapping maps (arrows) require field checking to confirm observations at the surface. D) Close-up of an early version of fully digitized ArcGIS compilation geologic map showing digitized surface linework and standardized lithologic units – graywacke (blue), metamorphosed ultramafic rocks (lavender purple), greenstone (green), Cobb Mountain volcanic rocks (orange), chert (brown), and landslides (yellow). Other symbols include power plants (squares), subsurface faults (black), surface faults from legacy maps (red), and newly mapped surface faults (blue, Forson 2014). Refer to Plate 1 for detailed symbol legend and lithology key.

The laborious process of digitizing and assembling the final compilation surface geology map involved several steps (Figure 3). The following steps were required:

- 1) Scanning each geologic map;
- 2) Importing and georeferencing each map image into ArcGIS;
- 3) Designing and organizing an ArcGIS geodatabase to contain all editable, digital spatial data from each map;
- 4) Digitally tracing and symbolizing all spatial data from each map (spatial data include linework such as contacts and faults as well as structural symbols such as bedding and fault attitudes);
- 5) Reconciling any discrepancies among contacts, faults, and lithologies across legacy map boundaries with field checks, and then updating the geodatabase accordingly; and
- 6) Standardizing lithologic unit names and descriptions from each surface map into a schema that conforms with units observed in the subsurface from near-surface well log descriptions.

Finally, the fully-assembled compilation geologic map (Figure 5, Plate 1) is used by The Geysers production staff where it can be integrated into the 3D geologic model and used in conjunction with existing infrastructure and engineering maps.

Recently, two mapping updates amended the compilation map, bringing the total number of maps used to twenty. These mapping updates addressed areas with coverage gaps from the original legacy data and areas with other geologic uncertainties. These areas were the focus of mapping efforts for geoscience summer interns at The Geysers in 2014 and 2015

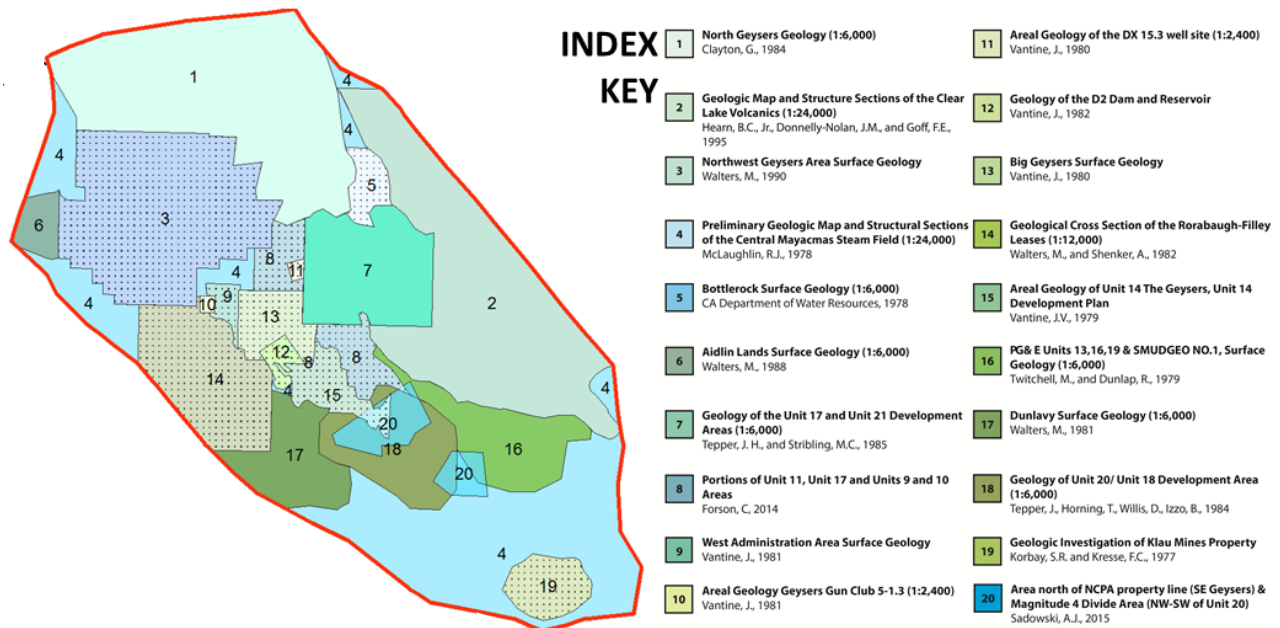


Figure 4. Index map for legacy maps of geologic source data used in The Geysers compilation map and geodatabase.

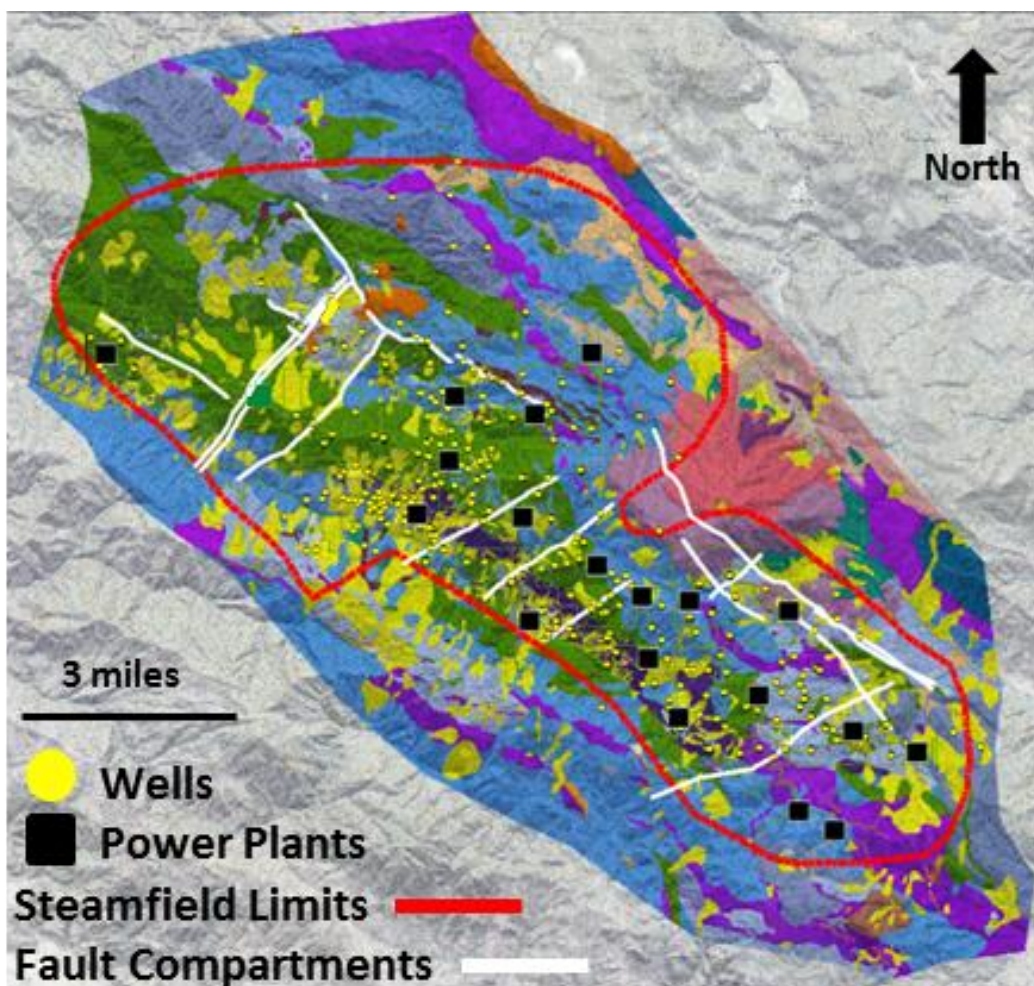


Figure 5. Simplified version of compilation surface geologic map of The Geysers (see Plate 1 for detailed version). Generalized surface geology includes: graywackes (blue and blue-gray), serpentinized peridotite and metamorphosed ultramafic rocks (purple), greenstone (green), Cobb Mountain volcanic rocks (orange), landslides (yellow), and Great Valley marine sequence (dark green). Steamfield (red) compartmentalized by subsurface faults (white) with limited surface expression. Refer to Plate 1 for detailed map, lithology color key, and unit descriptions.

4. RESULTS FROM COMPILATION MAP

Completion of the 2014 compilation shows broad geologic patterns (**Figure 5, Plate 1**). Lithologic units and dextral faults, both northwest-striking, dominate The Geysers steamfield terrane and are consistent with the regional topography and structural geology of the San Andreas terrane, where continuous, northwest-striking dextral faults are most common, followed by discontinuous, northeast-striking faults and shear zones. The northeast Geysers differs lithologically from the southeast Geysers as divided by the Cobb Creek fault zone in the central Geysers area (Nielson and Nash, 1996) (**Figure 1, inset**). Greenstone units predominate in the northwest, whereas graywacke predominates in the southeast. Ultramafic rocks are more common in the southeast than the northwest Geysers; and southeastern ultramafic rocks are coarser-grain serpentinized peridotite (unit Jos on the geologic map in Figure 2 and Plate 1) than the sparse finer-grain metamorphosed ultramafic rocks (unit MUM on the geologic map in Figure 2 and Plate 1) of the central-northwest Geysers.

Geologic field work during the summer of 2014 and 2015 in the southeast and central Geysers areas assessed the distribution of rock units and combined observations of outcrop characteristics to update the compilation geologic map and geodatabase. Most notably, this new mapping revealed previously unrecognized north-northeast-striking surface faults associated with subsurface structures. Two significant northeast-striking surface faults were identified from surface geologic mapping and align with previously identified subsurface structures. These are given informal names – the “Felsite fault” and “Magnitude 4 Divide” shear zone – and each represent important structural features within the steamfield reservoir. The surface geology compilation map was essential for identifying the surface expressions these structural features across the steamfield.

4.1 Felsite fault

In the southeast Geysers, the surface expression of a significant subsurface structure was identified. The Felsite fault of the southeast Geysers is a northeast-striking, steeply southeast-dipping fault that accommodates normal slip. The Felsite fault apparently drops the

GPC (or “felsite”) down to the southeast in the subsurface and separates greenstone and graywacke at the surface. It partially separates the NCPA production area at the southeast end of The Geysers from the Calpine Corporation production area. Two features – one at the surface and one at the subsurface – are associated with the Felsite fault. East-southeast of its surface trace, a major east-west oriented silica carbonate vein crops out between serpentinized peridotite and graywacke near a minor fault intersection (**Figure 6**). At depth, a shallow reservoir resides in the hanging wall of the Felsite fault at 1000 to 1700 feet above mean sea level (**Figure 6**). Directly above the highest contour of the shallow reservoir is the outcrop of silica carbonate deposit. An unexposed breccia zone in the hanging wall of the Felsite fault presumably joins the shallow reservoir and silica carbonate deposits. Additionally, both very shallow steam entries and loss circulation zones (LCZs) define the shallow reservoir.

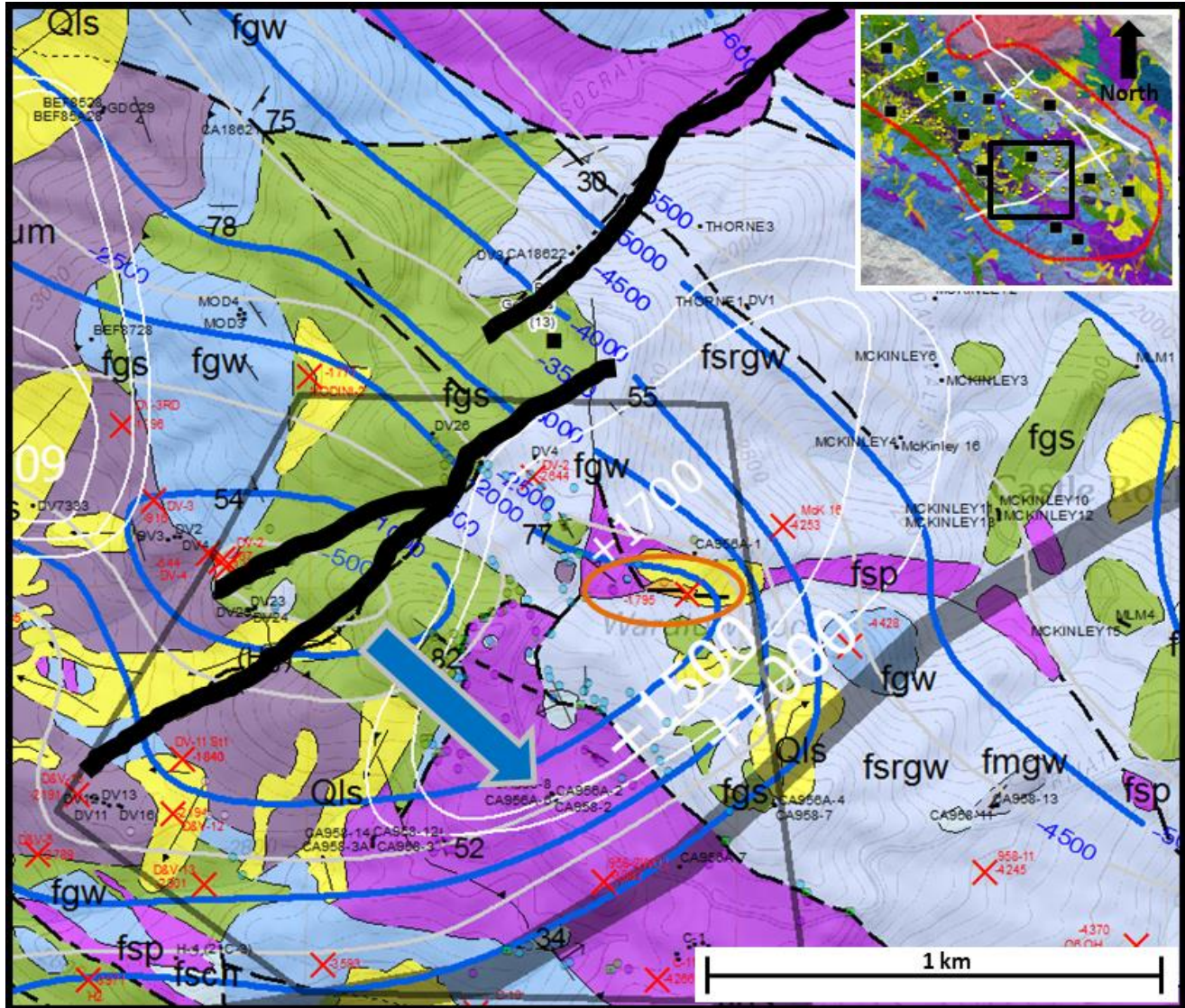


Figure 6. Felsite fault of southeast Geysers. (inset) Location of Felsite fault area of the southeast Geysers area (black box). (main) Southeast-dipping, Felsite fault (thick black line) with subsurface trace (semi-transparent black). GPC intrusion (blue and gray contours) defined by control points from wells (red Xs) show a precipitous drop of intrusion depth to the southeast (blue arrow points in direction of decreasing GPC elevation). Between the surface and subsurface traces of the Felsite fault, the silica carbonate deposit (orange unit within orange oval) resides above the shallow reservoir (white contours). All contours are relative to mean sea level. Other symbols include: power plant (square, Big Geysers - Unit 13), labeled wells (black dots), lithologic contacts (thin solid lines, dashed where approximate) faults (thick solid lines, dashed where approximate), teeth where thrust), mapping area (thin polygon), and mapping waypoints (dots colored to observed lithology). Refer to Plate 1 for detailed symbol legend and lithology key.

4.2 Magnitude 4 Divide Shear Zone

Originally postulated by Beall and Wright (2010), and defined with additional subsurface seismicity analyses by Hartline and others (2015) (**Figure 7**), the Magnitude 4 Divide shear zone is located south-southwest of Unit 3 (Sonoma) and west of Unit 20 (Grant) in the central-southeast portion of The Geysers (**Figure 7**). The Magnitude 4 Divide shear zone gets its name from observations by Beall and

Wright (2010) that show earthquakes of magnitudes 4.0 to 4.7 occur primarily northwest of the divide, whereas magnitude 4 events are uncommon southeast of the divide.

Surface geologic mapping identified the Magnitude 4 Divide shear zone by careful observation of lithologic contacts and subtle features, such as: geomorphologic features, hydrothermal alteration and replacement areas, and outcrop textures. Faceted spurs (i.e. southeast-facing flat irons), captured drainages, and elevated drainages (i.e. drainages subparallel to and above the main drainage to Big Sulphur Creek), represent large geomorphologic features visible from aircraft and aerial photographs that provide insight to subtly-expressed surficial faults and shear zones. The subtler features include hydrothermal alteration and replacement outcrops that exhibit advanced argillic grade alteration (i.e. white clays) and intensely silicified outcrops, which align along the northeast-striking structure. Outcrop features show cataclastic textures with poorly developed gouge (e.g. breccia zones with quartz textures indicating open space filling), common blueschist knockers (i.e. tectonism is necessary to exhume these high density blocks from metamorphic depths), and kinematic indicators (e.g. Riedel shears exhibiting very steeply southeast-dipping with normal-oblique slip). These features were observed in a traverse upstream along Big Sulphur Creek and areas north and south of central part of the shear zone associated with the Magnitude 4 Divide.

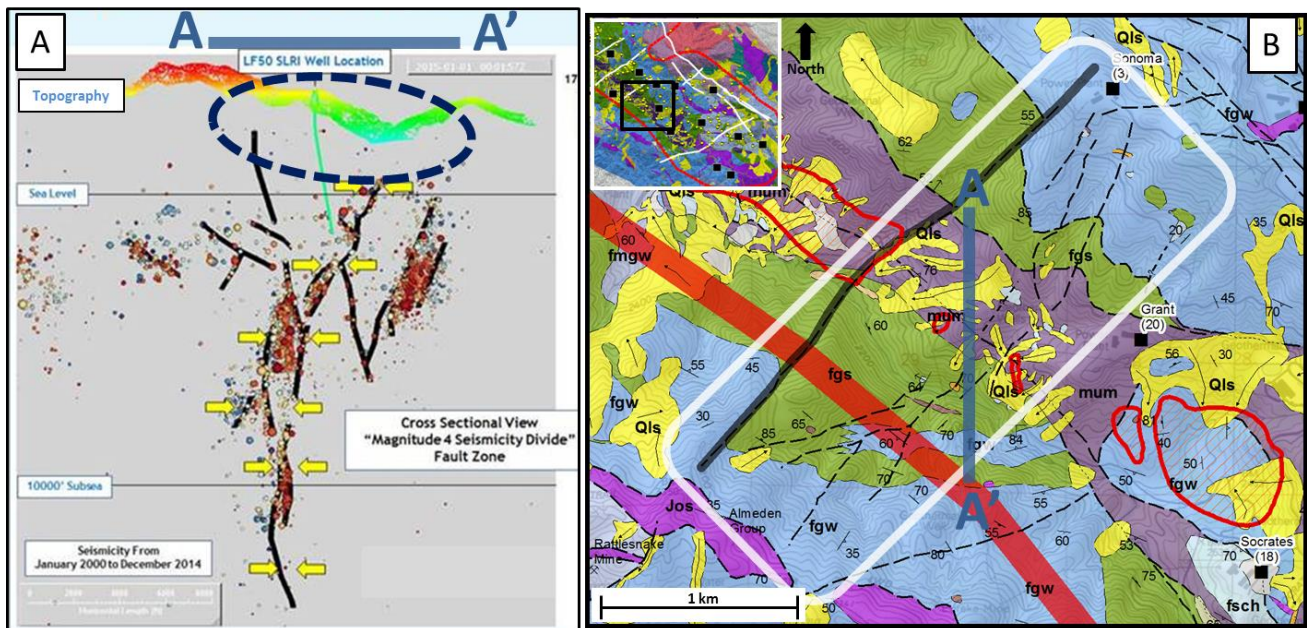


Figure 7. Magnitude 4 Divide shear zone in cross-section and map view. (A) Profile view of Magnitude 4 Divide shear zone. Seismicity associated with the Magnitude 4 Divide shear zone from January 2000 to December 2014 along a northwest-southeast cross section (A-A') (Hartline et al., 2016, this workshop). Yellow arrows constrain seismic events (red and blue dots) between discontinuous fault planes (black lines) with uncertainty in the shallow subsurface (dashed oval).

(B) Map view of Magnitude 4 Divide shear zone of central Geysers. (inset) Location of Magnitude 4 Divide shear zone area in central Geysers north (black box). (main) Magnitude 4 Divide shear zone is a set of northeast-striking, vertical to steeply northwest-dipping, discontinuous faults (within white box). Location of blue cross section line (A-A') is approximate. Other symbols include: power plants with unit number (square), thermal areas with hot springs, fumaroles, and/or alteration (red hachured areas), subsurface discontinuity (thick gray semi-transparent line), southwest steamfield limit (thick red line), lithologic contacts (thin solid lines, dashed where approximate), faults (thick solid lines, dashed where approximate). Refer to Plate 1 for detailed symbol legend and lithology key.

5. CONCLUSIONS

Surface geologic mapping is one of the most cost effective methods in all phases of geothermal energy development from exploration to reservoir management. As of 2014-2015, The Geysers has a centralized geodatabase with geologic linework for lithologic contacts, faults, and geologic units. The detailed compilation covers the entire geothermal production area and is a first for the area.

Faults and shear zones play a major role in the “ground preparation” of both hydrothermal ore deposits and geothermal systems. Recent surface mapping coupled with subsurface structural analysis demonstrate that the northeast-striking Felsite fault and Magnitude 4 Divide shear zone both play significant roles in the reservoir architecture of The Geysers. Hydrothermal and metamorphic processes at depth, combined with understanding the surface lithologies, aid in the identification of such structures, which is critical to constraining reservoir parameters such as the location of hydrogeologic discontinuities and conduits for fluid flow. These discontinuities compartmentalize the geothermal reservoir and require further attention to understand their significance with respect to production and

injection. Additionally, such structures have been identified at depth, but are not identified at the surface, thus, calling for future mapping to confirm their locations.

The surface geologic map compilation, together with existing geologic well logs that constrain the subsurface stratigraphy, provide detailed surface constraints for a robust 3D geologic model. (See companion paper of Hartline and others (2016), this workshop for additional details on 3D modeling and subsurface geology). By integrating the surface and subsurface data, geologists can understand why certain reservoir compartments are more productive than others. As the understanding of Geysers geology evolves, geologists can refine observations and interpretations to build a more precise geologic model that will facilitate better geothermal resource management.

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