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RESERVOIR FRACTURING IN THE GEYSERS HYDROTHERMAL SYSTEM: FACT OR FALLACY?

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ABSTRACT

Proper application of proven worldwide fracture determination analyses adequately aids in the detection and enhanced exploitation of reservoir fractures in The Geysers steam field. Obsolete, superficial ideas concerning fracturing in this resource have guided various malformed judgements of the actual elusive trends. Utilizing regional/local tectonics with theoretical rock mechanics and drilling statistics, offers the most favorable method of fracture comprehension. Exploitation philosophies should favor lateral drilling trends along local tensional components and under specific profound drainage/faulting manifestations to enhance high productivities. Drill core observations demonstrate various degrees of fracture filling, brecciation, strain responses, and rock fracture properties, giving the most favorable impression of subsurface reservoir conditions. Considerably more work utilizing current fracturing principles and geologic thought is required to adequately comprehend and economically exploit this huge complex resource.

INTRODUCTION

Reservoir fracturing in The Geysers field is often termed as debatable and elusive, yet need not be when appropriate current tectonic/hydrothermal studies are applied. Determination of reservoir fracture trends and location can be ascertained through application of methods by Stearns and Friedman (1972). Utilization of active regional and local stress fields, active fault and drainage trends, theoretical rock mechanics, drilling experiences, oriented drill cores, and borehole televiewer logging, definitely allow the geologist to determine and drill high permeability trends and zones. Many former and current interpretations of Geysers fracturing use obsolete, superficial geologic thought, which could be greatly enhanced through the utilization of correct tectonic principles that have proven to be very effective in defining reservoir fracturing in worldwide fluid energy systems for the last 35 years.

MEGATECTONICS

The Geysers regional tectonics are excellently portrayed by McLaughlin (1981, Figure 7), where the steam field lies within a wide shear zone bounded by the right lateral Maacama and Collayomi Fault zones (Figure 1). Former Franciscan imbricate thrust faults (McLaughlin, 1978, 1981) are assumed to be inactive and hydrothermally sealed for up to the last three million years (Hebein, 1985). The San Andreas system fault scheme of Moody and Hill (1956) and a regional strain ellipsoid (Wilcox, et al., 1973) can now be applied so as to comprehend the regional and local stress/strain patterns.

The drainage in Figure 1 represents segments of large, deep, near vertical faults and joints in the earth's crust. Regional/local shears probably traverse through the creeks. Enhanced tectonic strain induces profound erosion along active fault trends ("creekology").

LOCAL TECTONICS

The strain ellipsoid can be utilized to determine the local strains within the steam field (Figures 2 and 3). Refer to Thomas (1981, Plate V). Individual block rotations within the steam field allow for various positioning of the strain ellipsoid in different portions of the Geysers field. Figure 4 illustrates a typical shear model and how the Geysers drainage mimics potential fault trends.
Some steam field workers continue to profess the importance of old, imbricate thrust contacts (long inactive and sealed?) in reservoir permeability, yet the author downplays any importance and concentrates on current active tectonic stresses/strains. Numerous fluid injection tracer tests demonstrate reservoir radial flow out from the injection point with differing preferential pathlines over various times, suggesting a thoroughly fractured nonhomogeneous reservoir.

SPECIFIC DRILLING PHILOSOPHIES

Directional drilling beneath creeks in many parts of the steam field has demonstrated that profoundly enhanced reservoir permeability exists under such drainage (faulting and jointing) trends. The author proposes (Figure 4) a drilling scheme of deep lateral penetration parallel to the fields variable tensional components which should intersect more tension joints and synthetic/antithetic shears of various orders. Drilling under drainage through the shear or tensional component is also stressed whenever possible. Compressional trend and vertical drilling (Hebein, 1985) should be avoided. If reservoir rock blocks are indeed fractured, this method will enhance penetration of a maximum number of permeable zones. Statistically, most reservoir fractures (main metagraywacke, felsic intrusions, and sometimes the lithocap) should be near vertical and follow the three general directions on the regional strain ellipsoid.

OBSERVED DRILL CORE FRACTURING

Deep oriented drill cores from the Bottlerock area exhibit fresh vertical tension fractures in an en echelon fashion and correspond to surface drainage directional patterns immediately above the core point(s). Large rock fragments blown up from the Bottlerock reservoir (top) exhibit profound sericitic alteration (condensate sealing) with sheared slickensides cemented with realgar. Cores from the shallow Big Geysers area exhibit sub-vertical and vertical fractures filled with quartz-pyrite-epidote-chalcopyrite-sphalerite-galena veins, those in turn fractured and filled with quartz-adularia-argentite veins. Some sericitization exists in the rock matrix, suggesting a shallower hot spring chaotic fracturing environment. Ancient schistosity trends are sealed tight. Small fracture caverns are witnessed. Quartz flooding has enhanced the already highly brittle nature of the metagraywackes. Deep rock fragments blown up from the Bottlerock reservoir are very similar in nature to the aforementioned descriptions. Deeper Big Geysers cores exhibit vertical, enechelon, epidote-filled tension fractures, in turn shot through by crosscutting quartz-actinolite-chalcopyrite veins in systematic mega to mini-breccia fashion.

Cores from the Little Geysers exhibit profound quartz flooding and sealing of ancient schistosity trends. Fractures in three or more subvertical to vertical trends are flooded with quartz-actinolite-chalcopyrite veins. Sealing is profound. Felsic intrusive cores from the Little Geysers area are shot through by tourmaline veins (some small explosion breccia dikes), those in turn shot through by quartz veins, those in turn shot through with actinolite-quartz veins, those in turn shot through by sericitic alteration holes (perhaps due to steam cell sealing). High angle fracture trends run parallel to one another and also cut across some in a complex and chaotic fashion. Fracture caverns are witnessed.

CONCLUDING REMARKS

Considerably more work is required to adequately map fracture trends and enhancements in the Geysers steam field. The complexities of such a deep, large, completely faulted resource, coupled with varying personal interpretations of reservoir fracturing has lead to multi-lined avenues of geologic thought (some non-supportive) among the resource operators. Acceptance and use of appropriate tectonic fracturing principles aligned with wellfield observations and drilling experiences, offers the most favorable attitude for the exploitation of any fluid energy resource. Many obsolete and inadequate ideas concerning field fracturing must be dismissed in favor of new scientific approaches for the proper economic exploitation of steam permeability. The aforementioned discussion offers a realistic and incident-proven approach to solve the complexing problems of the Geysers reservoir(s).

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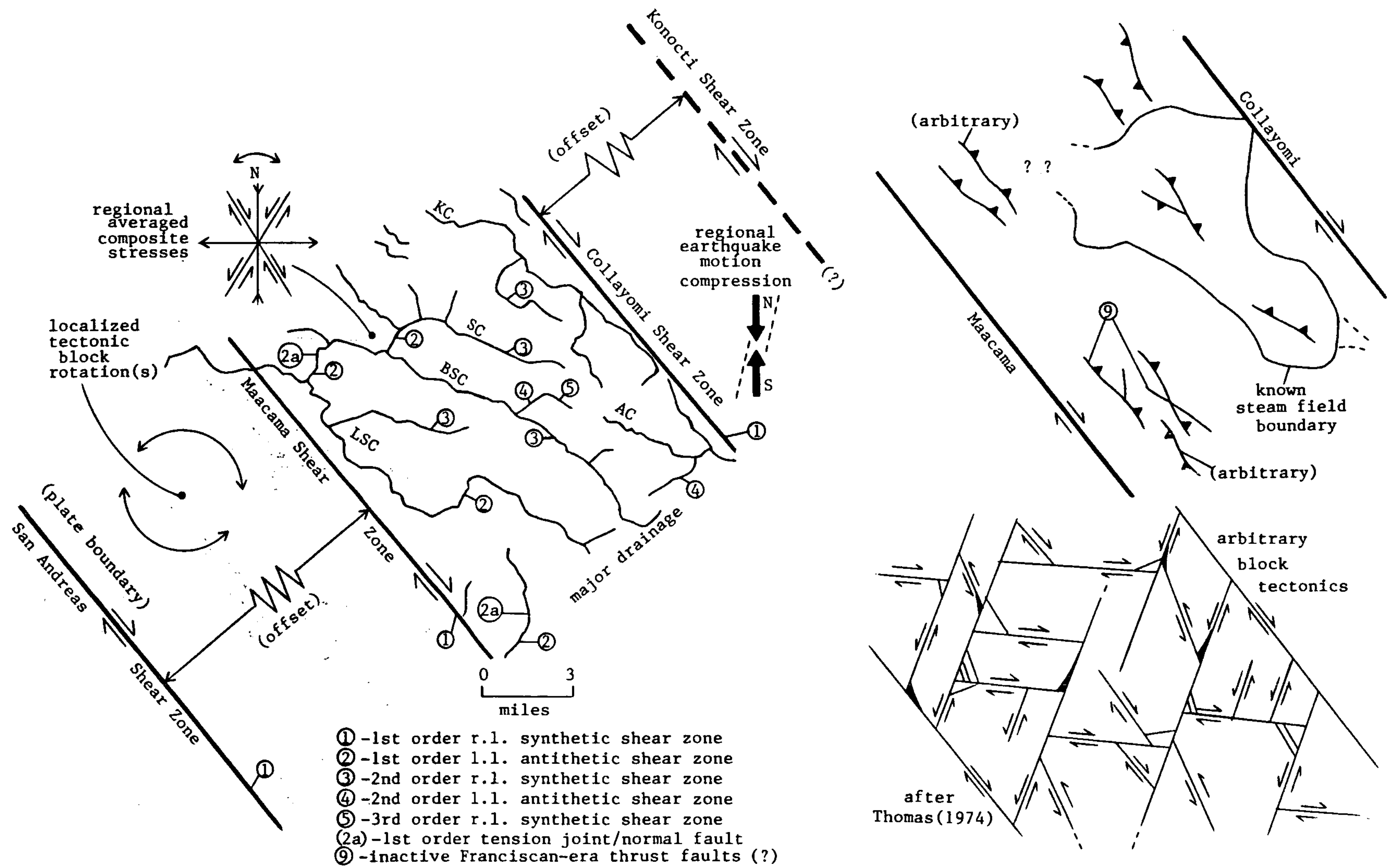


Figure 1. A conceptual illustration depicting the regional stresses and strains about the Geysers Steam Field, modified in part after McLaughlin(1981,figure 7). Specific drainage trends are probably localized prolifications of shears that traverse across the entire fieldwide drainage patterns. The fault type guide generally follows the nomenclature of Moody and Hill(1956). Here, most drainage segments appear to follow the San Andreas fault classification scheme. Tension jointing can occur as block boundaries or as interblock fractures. All trends follow the strains on the regional strain ellipsoid.

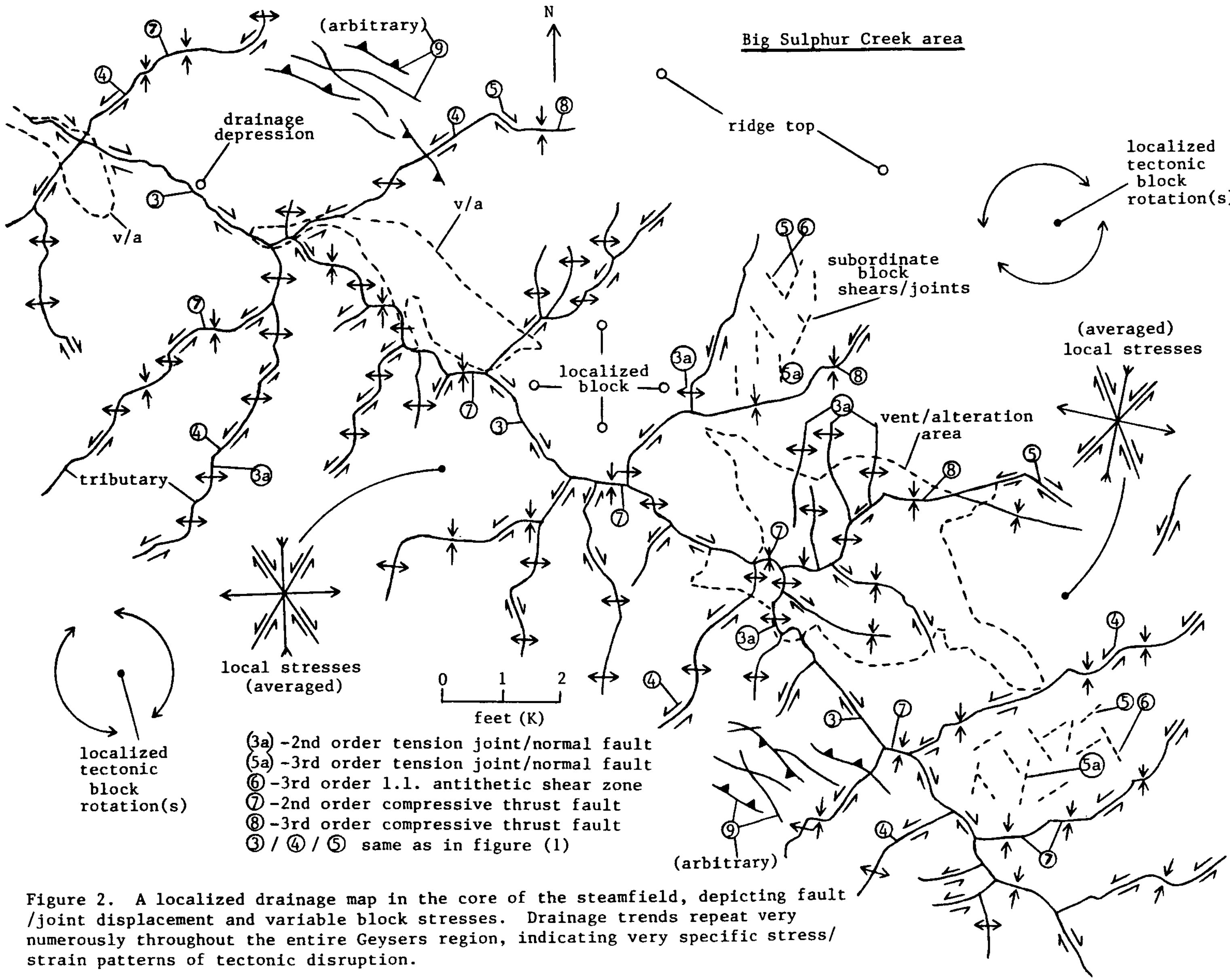
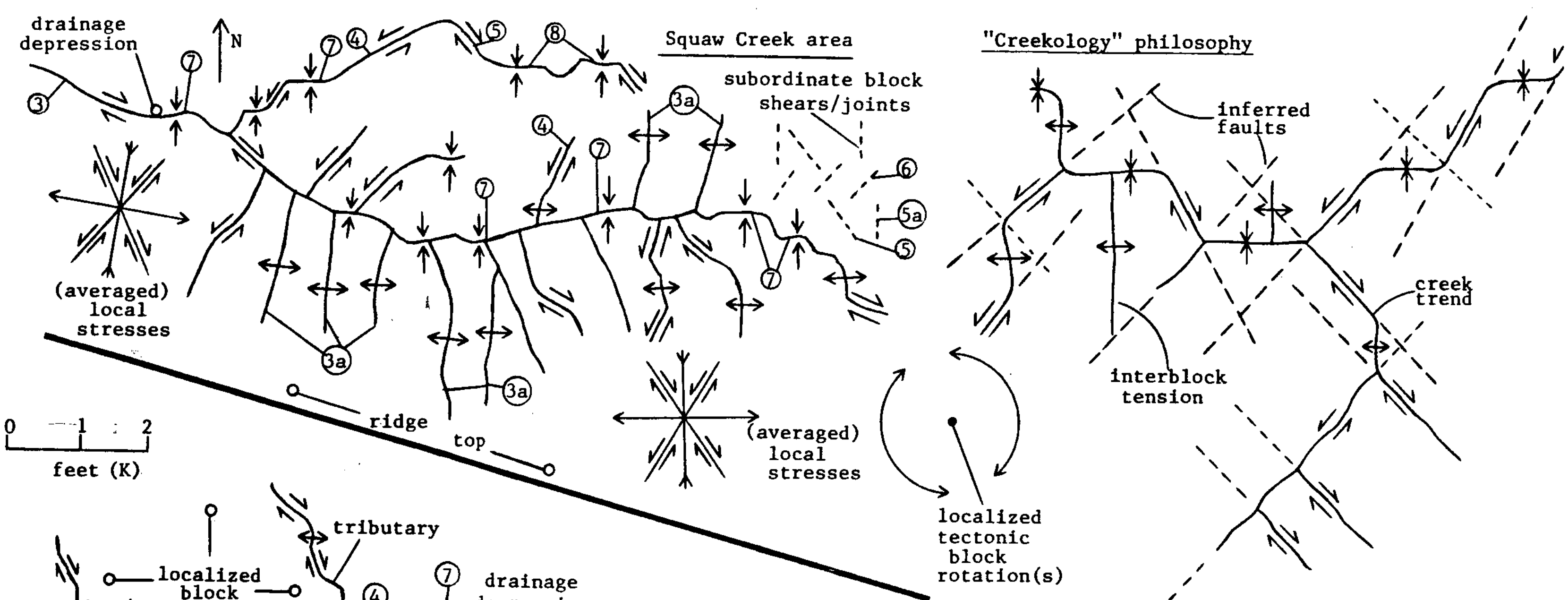


Figure 2. A localized drainage map in the core of the steamfield, depicting fault /joint displacement and variable block stresses. Drainage trends repeat very numerously throughout the entire Geysers region, indicating very specific stress/ strain patterns of tectonic disruption.



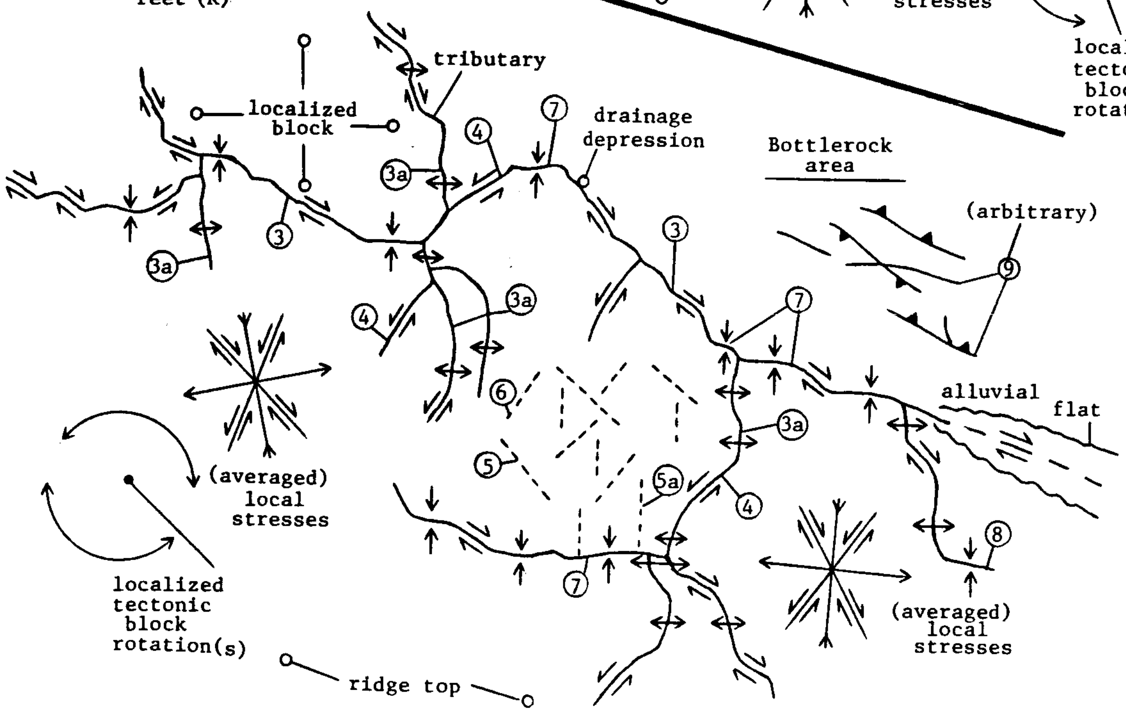
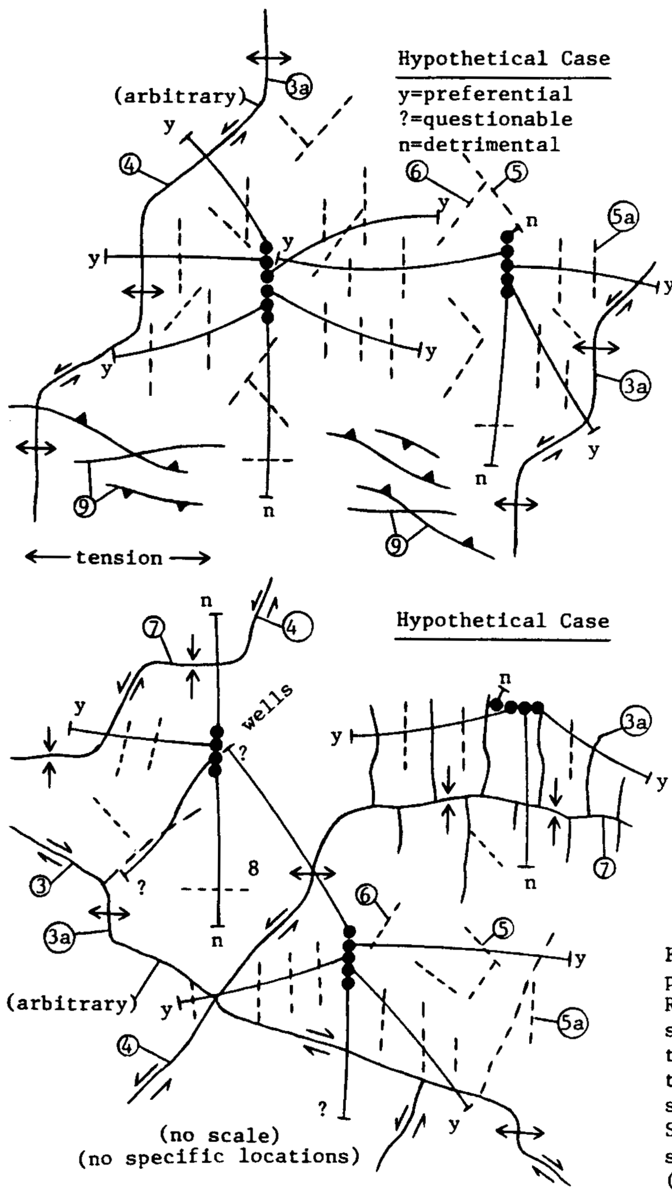


Figure 3. A localized drainage map in less profoundly fractured area of the steamfield. Intersections of specific proposed shears and tension joints(drainage) are found to provide enhanced reservoir fracture(near vertical) permeability when laterally drilled at depth. Drainage clustering may equate to profound subsurface tectonic disruption. In the lower illustration, blocks between drainage mains may be much less fractured than the mains, yet are economically viable when exploited in correct fashion.



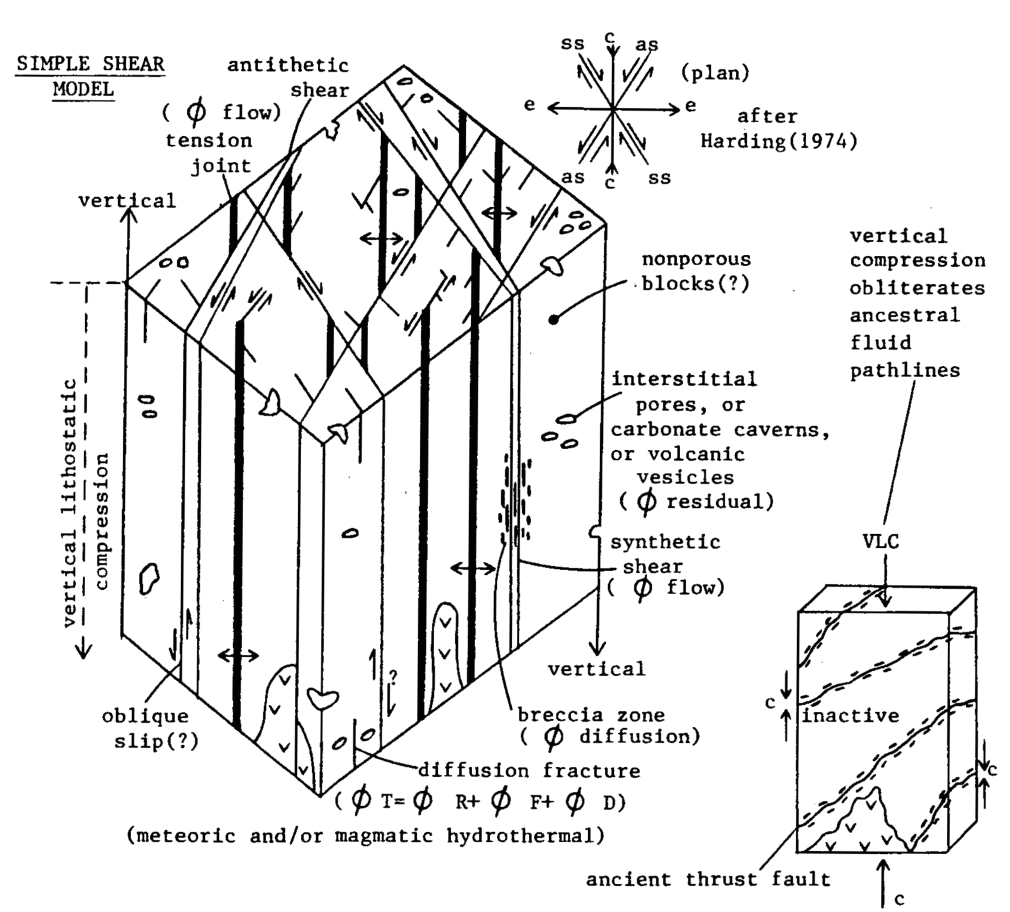


Figure 4. A proposed fieldwide drilling scheme, so as to enhance the number and permeability of near vertcal fractures penetrated by laterally deviated wellbores. Reservoir permeability will run in three general directions, determined by the local stresses and rock mechanics. The block model is applicable to the current state of the steamfield. Vertical lithostatic compression would obliterate ancient imbricate thrust faults(Franciscan stratigraphy) while ancestral hydrothermal mineralization should have sealed the compressed fault paths pervasively. The right-lateral San Andreas stresses/strains about the steamfield are incompatable with the relic subductive imbricate thrust fault fracturing that has long since ceased to exist. (Hebein, 1985).

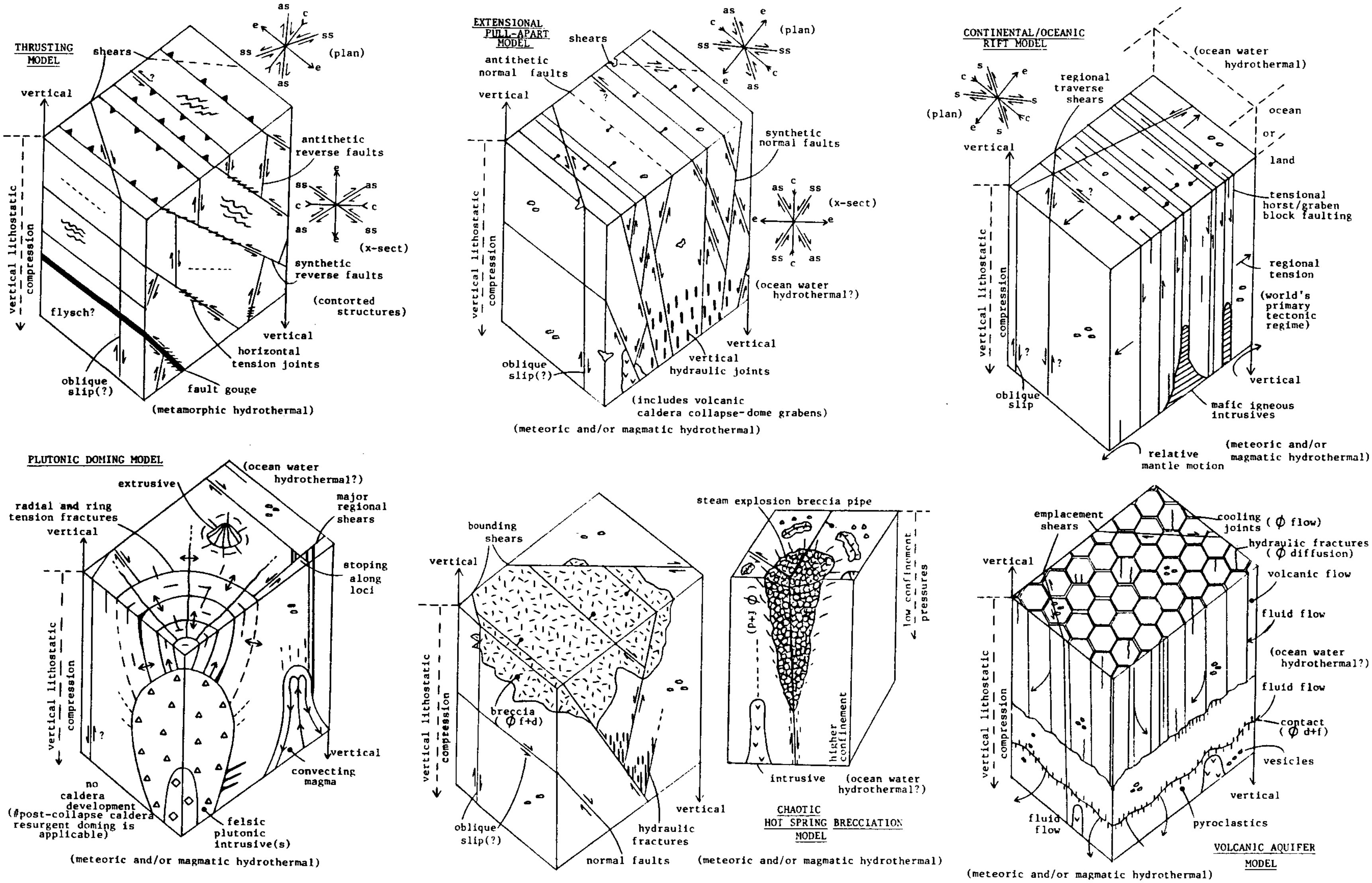


Figure 5. The ancient Geysers Franciscan complex was once a thrusting environment; presently inactive and hydrothermally sealed. This regime should not be confused with other types of tectonic regimes, applicable to other worldwide hydrothermal systems, active and fossil. An idealized collapsed and resurgent caldera model(Yellowstone?) could possess several of the above model tectonic systems. Geopressured environments(lithostatic confinement pressures) are not represented in any of the models. Other tectonic/fracture model(s) may exist.