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EXPLORATION, DRILLING, AND DEVELOPMENT OPERATIONS IN THE BOTTLE ROCK AREA OF THE GEYSERS STEAM FIELD, WITH NEW GEOLOGIC INSIGHTS AND MODELS DEFINING RESERVOIR PARAMETERS.

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ABSTRACT

MCR Geothermal Corporation pioneered successful exploratory drilling the Bottle Rock area of the Geysers Steam Field in 1976. The wellfield is characterized by a deep reservoir with varied flowrates, temperatures, pressures, and steam chemistries being quite acceptable. More detailed reservoir engineering tests will follow as production commences.

Subsurface geology is comprised of a deep main graywacke rock(s) with overlying cap, condensation, and highly altered reservoir zones. Liquid reserves for steam production probably exist in the condensation zone fractures and alteration pores(?), and by physical adsorption in micropores along fracture surfaces, since interstitial porosities and the presence of a basal boiling brine have been ruled out.

The steam reservoir evolved from ancestral liquid-dominated hydrothermal systems and possesses an extremely viable fracture system comprised of tectonic rubble breccias. Essentially, the steam reservoir(s) are huge tectonic breccias superimposed on (mimicing) and now overlapping huge ancestral hydrothermal breccias. While earlier reservoir models utilized a boiling-brine and/or Raleigh-plume dispersion mode of existance and operation, geological data now suggests that the reservoir may be a system of verticle steam-filled fractures with a separate condensation zone held somewhat immobile along the top and flank boundaries of the fracture networks.

Local extensional tectonics have and continue to play a very important role in the formation and continuance of both the ancestral liquid and active vapor systems in the steam field. Accordingly so, drilling programs should be designed with tectonics in mind so as to maximize well deliverabilities.

The Francisco lease will supply steam to power a 55 MW powerplant presently under construction by the California Department of Water Resources.

INTRODUCTION

Figure 1 is a location map illustrating MCR's developments. Entex Petroleum, Inc., Houston, Texas is a partner in the current Francisco production venture.
MCR's stepout into the Bottle Rock area confirmed a boundary addition to the extremely large and prolific Geysers field. Public information on the characteristics of the field has been sparse. This presentation, however, should stimulate discussion of technical information regarding the Bottle Rock area and assist total steam field comprehension.

WELLFIELD CHARACTERISTICS - FRANCISCO LEASE

Area:	380 acres, 3 pad locations
Wells:	12 drilled to date, 1 used as injector, 2 not to be used.
Depths (drilled):	8606 to 10,586 feet.
Flowrates:	47,000 to 179,000 Lbs/Hr @ 125 psig; average 110,000 Lbs/Hr
Times:	generally 12 wks to drill, production casing at 6500'-6700'
Steam entries:	5 (minimum) to 21 (maximum) 6575'/6310' (TVD) to 10,560'/10,240' (TVD); range 2-3000 Lbs/Hr. to 90,000 Lbs/Hr.

Some wells are drier and show superheat at the wellhead, some discharge a wetter steam Initially, Francisco 1-5 was drilled to 8970 feet in 1976 and produced 108,000 Lbs/Hr steam @ 109 psig with 6" bore. MCR's minimum economic limit is 75,000 lbs/hr, although lower output wells would be connected to the gathering system.

Reservoir temperatures average 247°C/477°F and pressures range from 500-550 psig. These temperatures and pressures appear to exceed values given for other parts of the steam field (Cochran, 1979; Ramey, 1968; Lipman, et al., 1977). Temperatures and pressures tend to climb slightly as depth is increased within the reservoir. These variances from other reservoir values may indicate differing conditions in separate field cells or that the Francisco lease has very "virgin" conditions in the reservoir. Shut in wellhead pressures hold at 400-455 psig.

Steam chemistry is within field ranges and is highly acceptable. Table 1 is an analysis of condensate and non-condensables from a typical well.

TABLE 1

Arsenic	(ug/l)	< 10
Mercury (Total)	"	22
Iron	(mg/l)	0.63
Calcium	"	< 0.080
Boron	"	7.8
Chloride	"	5.0
Fluoride	"	< 0.10
Sulfate	"	2.6
Bicarbonate Alkalinity	"	170
Carbonate Alkalinity	"	0
Nitrate	"	0.49
Specific Conductance	(umhos)	430
ph		6.2
T.D.S.	(mg/l)	12
Suspended solids	"	< 2
Noncondensables	(ppm/wt)	4,300
Water vapor	"	996,000
Carbon dioxide	"	3,700
Sulfur (as H_2S)	"	219
Ammonia	"	64.6
Methane	"	104
Nitrogen	"	143
Hydrogen	"	75
Radon 222 (pico cur/l noncond.)		480

Rate: 121,000 LBS/Hr.
T°: 352°F

Transient well testing and tracer tests will follow in hope that general values for reservoir transmissivity and draw-down can be obtained. Inhomogenities in geologic structure (fracture framework) may also be implied through these tests.

WELL AND SUBSURFACE GEOLOGY

Figure 2 represents a generalized geologic section of lease wells. McLaughlin (1981) and Thomas (1981) both define a "lithocap" above the steam reservoir. This cap is comprised of a massive Franciscan melange up to 6000-6700 feet in thickness under the Bottle Rock area.

The main graywacke's upper portions show Franciscan metamorphic alteration (calcite) and the mid to lower portions exhibit massive quaternary hydrothermal alteration. Alteration appears similar to accounts for other wells throughout the steam field (Lambert, 1976; Lockner et al., 1982); Sternfeld, 1981) with the exception that Bottle Rock wells encounter these conditions at much greater depth. MCR's wells encroach upon an apparent contact metamorphic zone (migmatites) at depth. In two wells, drilling encountered fine grained felsic volcanic dike rocks of dacitic to rhyolitic composition.

Coring of the main graywacke beneath the Francisco lease was above the reservoir section as was coring from other parts of the field (Lockner et al., 1982). The cores show excellent fresh enechelon, concentric fractures which probably relate to fresh fracturing associated with recent tectonic extension. This upper portion of the main graywacke is massively calcite veined, very dense, virtually non-porous (thin sectioned), and appreciably brittle. Petrographically, these rocks are albite-sericite-epidote-chlorite-quartz altered. This rock would make an excellent initially fractured reservoir rock in the ancestral liquid systems of the Geysers field. Interstratified argillites are dense, carbonaceous black, moderately calcite veined, and well sheared with glassy slickensides associated with actinolite/chlorite-like recrystallization. It is highly conceivable that these argillites (and other melange types) could hold steam bearing fractures if such fractures communicate with fractures in massive graywacke bodies.

A condensation zone (maximum three to five hundred feet thick)definitely exists above the steam reservoir (Fig. 2) and is probably found in some form in all other parts of the steam field. This zone is characterized by liquid saturated fractures and perhaps some pore saturation with specific rock alteration. The hydrothermal alteration process is probably phyllic (sericitic) alternation, where steam condensate alters and leaches rocks within the zone. Here, detrital and hydrothermal feldspars are altered to clay group (illite) minerals and zeolites, quartz is augmented, and realgar is viewed in traces. Steam and water entries are commonly encountered while drilling in this zone. The water usually dissipates after a day or two of drilling but in one instance a water entry was so large that the zone(s) required plugging off before air drilling could resume.

Ramey (1968) reported the presence of a water body (condensation zone) between the shallow upper and lower reservoirs in the Sulphur Bank area of the steam field. Several researchers (White et al., 1971; Truesdell and White, 1973; D'Amore and Truesdell, 1979) have speculated on the occurrence of this zone with MCR's drilling confirming its presence. Weres et al. (1977) reported the alteration of reservoir rocks with the formation of minute, sand-like particles (smectite?) in the pores of the graywacke encountered in wells in the Castle Rock Springs area of the Geysers field. This probably represents a condensation zone and is quite similar to MCR's findings.

Table 2 is an analysis of fluids (flashed to some unknown extent) from the condensation zone penetrated by a well. The well is the same one whose steam analysis is presented in Table 1.

TABLE 2

Potassium	(mg/l)	110
Calcium	"	96
Sodium	"	270
Iron	"	2.3
Arsenic	(ug/l)	320
Mercury	"	3.2
Chloride	(mg/l)	250
Sulfate	"	400
Sulfide (H_2S)	"	< 0.10
Silica	"	2.0
Bicarbonate Alkalinity	"	230
Total Carbon dioxide	"	170
Boron	"	14
Ammonia	"	< 0.20

The actual reservoir rocks are highly hydrothermally altered, non-porous in thin section and are probably composed of numerous diffusion microfractures and flow fractures. Petrographically, these rocks are albite-illite-smectite-chlorite-epidote-zeolite-quartz altered. Smectite pore fill has destroyed former residual interstitial porosity. The fracture model by Norton and Knapp (1977) is utilized for fracture porosity definition. Porosity estimates are speculative, if not near unobtainable because the reservoir has fracture porosity. Diffusion and residual porosity can be determined but flow porosity is destroyed during coring. Overall fracture porosity is probably less than 5%, both in the main reservoir and the condensation zone. Thermogenics (Caupuano, 1979) estimates overall reservoir fracture porosity at 1-3%, while Union Oil Co. (Lipman, et al., 1977) estimates a 3-7% interstitial porosity (irrelevant?) from cores probably retrieved above the reservoir section itself (Lockner et al., 1982). Residual porosity fluids are probably very limited and immobile, excluding the effects of any secondary surface adsorption in micropores.

Ancestral hydrothermal veining comprised of quartz-epidote-feldspar is abundant in brecciated zones with this mineralization also found in disseminated veins and interstitial pores somewhat removed from the massive breccias. Sporatic, continuous occurrences of these massive hydrothermal brecciations and mineralizations strongly suggest the penetration of ancestral liquid dominated conduits as wells are laterally directionally drilled. The quartz-epidote alterations still remain the best indicator of upcoming steam entries although minor steam occurrences can occur in relatively clean rock, even in the calcite-rich rock near the top of the reservoir graywacke. Analysis of cuttings from other wells in the field (Sternfeld, 1981) show similar traits to Bottle Rock well cuttings. Frye (1976) discusses the importance of silica content in enhancing reservoir rocks with respect to steam occurrence in Aminoil's production area.

Ocasionally, semi-massive, very argillite-rich units within the main graywacke are penetrated. A dramatic loss of quaternary hydrothermal alteration and steam potential is usually witnessed. The argillites can become very clay-like or schistose and flakey, causing major sloughing problems. If sloughing is too severe, wellbores may collapse inward and raise considerable havoc while air drilling. Encountering such bodies at greater depths had actually prohibited the continuance of air drilling in one instance.

RESERVES

Where are the liquid reserves in the Geysers reservoir(s)? The condensation zone probably has substantial liquid reserves in place in both diffusion and flow fracture porosity. Fractures in the condensation zone should communicate with reservoir fractures intersected by the wellbores. Capillarity condensation (Hsieh and Ramey, 1983) may be responsible for holding fluids in the fractures of the condensation zone whereby the hydrostatic head of fluids in these fracture systems is less than underlying reservoir pressure, thus enabling such fluids to stay relatively in place. Since clay minerals (illite) found as traces to 15% of total rock volume in the condensation zone are hygroscopic, small reserves may be found in these altered pore spaces. Weres et al. (1977) inferred that these pore voids are responsible for overall reservoir fluid storage, but the author suggests that this potential storage medium only pertains to the condensation zone.

Since the physical surface adsorption of liquids into heated rocks has been demonstrated in the laboratory (Hsieh and Ramey, 1983), it can be assumed that this phenomena does exist along reservoir fractures. Liquids in micropores along fracture pathlines may contribute to reserves for steam formation, those liquids probably being a major reserve source. Of course, steam already in place in fractures is also part of the total reserves.

The suggestions that the reservoir rocks are a "cracked sponge" (Weres et al., 1977) or that substantial matrix porosity/permeability (mobile liquid saturation) exists

(Pruess and Narasimhan, 1981), should be dismissed. The reservoir rocks are virtually interstitially filled with solids. Determination of potential steam reserves may be very difficult if not unrealistic in a fractured, gas-drive reservoir where reserve porosity parameters are only implied and geologic inhomogenities are apparent throughout the reservoir.

The presence of a basal boiling brine overlain by an isothermal vapor zone such as is commonly found in near-surface fumarolic/hot spring-type geothermal regimes has been suggested as a major source of steam in large vapor systems such as the Geysers (White et al., 1971, Truesdell and White, 1973; D'Amore and Truesdell, 1979). Since no basal boiling water table has ever been found at the Geysers and other geologic features offer modes for potential storage of liquid reserves, this concept is deemed superficial and should not be utilized until direct supportive evidence is offered by field operators.

DEVELOPMENT OF LIQUID AND VAPOR SYSTEMS

The vapor system within the Geysers field was once a very prolific liquid system, therefore one must look upon the reservoir in terms of its past functions so as to more fully comprehend its present functions. Several successive liquid hydrothermal stages or phases (Lambert, 1976) did exist in at least several parts of the steam field.

Continual extensional tectonics over the last two to three million years in the Geysers region (McLaughlin, 1981) is probably responsible for all past and present igneous hydrothermal activity in this region. Thomas (1981) reports that felsic igneous intrusives occur under many of the anomaly crests within the steam field. It is highly plausible that intrusive masses (stock-like) underlie many key areas of the steam field and were directly responsible for the driving of ancestral convective liquid systems in separate or twinned locations in the Geysers field. Liquid system development probably evolved just as the active Wairakei and Broadlands systems (Grindley and Browne, 1975) now function with Rayleigh plume dispersion (Henley, 1973; Elder, 1981) as an acceptable mode of fluid circulation. MCR's drilling experiences provide evidence that the current vapor system is a direct result of a deep massive ancestral liquid system. One major contributing factor to system development was that the initial reservoir graywackes were already dense and brittle (low tensile strength) which offered an excellent host rock for fracture systems to develop within.

Tectonic extension and intense heat flow will continue as the liquid system now becomes quite mature, seals itself and becomes a candidate for vapor-domination. A good qualitative scenario for the evolution of a vapor system is given by Pruess and Truesdell (1980). As the system boils down and more vaporous conditions start to prevail on the top, the lower body liquid portions may themselves reseal, refracture, brecciate by steam explosions and hydraulic fracturing, and again reseal such as happened in intermediate depth systems such as those at Wairakei and Broadlands (Grindley and Browne, 1975). A previously boiling environment represented by deposition of minerals such as adularia, etc. (Ellis and Mahon, 1977) is encountered by drilling in MCR's wells and other parts of the field (Sternfeld, 1981; Lockner et al., 1982). Continual boil down must have occurred in the reservoir(s) since former hydrostatic pressures would have then been too high to allow for the boiling of a mildly saline single-phase liquid at appreciable depths. However, the author strongly disagrees (discussion forthcoming) with Sternfeld's rendition of successive boil-down levels involving imbricate thrust zones.

FRACTURE MODELS

Fracture properties are the key factors determining how the Geysers reservoir(s) respond. McLaughlin (1981, Figs. 8,9) presented models using near verticle fracturing stemming from extensional tectonics, which should be quite accurate. Thermogenics, Inc. (Caupuano, 1979), Shell Oil Co. (Hite and Fehlberg, 1976), and Union Oil Co. (Lipman et al., 1977) prefer a near verticle orientation for reservoir fractures or perhaps fractures just above the reservoir. MCR's drill core and drilling experiences strongly suggest that reservoir fractures are near-verticle. The author believes the idea of high volume near-verticle steam filled fractures in the Geysers reservoir(s) (Ramey and Gringarten, 1975) is quite realistic. H.J. Ramey stated (Kennedy, 1974), that numerous well tests in the Geysers field showed evidence of tremendous verticle fractures intersecting the wellbores. The pressure-time data suggests "cavernous" bodies exist in parts of the steam field. MCR's deep drilling experiences adequately confirms those speculations.

Drilling occasionally encounters drill breaks of say six inches to a foot of sudden drop. These breaks are usually associated with steam entries but sometimes yield little or no steam. Wellbores have penetrated what appears to be massive cavernous fractures, (rubble breccias) with very large steam entries coming forth from breaks of 5 or 6 feet in a minute or two. Massive ancestral hydrothermal brecciation is an excellent indicator. As tectonic extention continues, fractures will grow wider instead of veinfilling as in the ancestral liquid system, whereas steam is a relatively poor solvent and mineralizer with respect to the mineralizing effectiveness of hot water. As large fractures grow, steam-bearing conduits could penetrate into relatively unaltered rock, as is seen in several instances while drilling.

RESERVOIR MODELS

Early models (White et al., 1971; Truesdell and White, 1973) of steam reservoirs (the Geysers) depicted a basal boiling brine feeding steam filled fractures and an overlying condensation zone. D'Amore and Truesdell (1979) and Thomas (1981) utilized a Rayleigh condensation model based almost entirely on geochemical parameters. Thomas' data strongly suggests the presence of several higher level core-type reservoir anomalies within the steam field. Many anomalies probably have top-bounded closure, being asymetrically similar to a dome and/or plunging anticlinal form. While the D'Amore and Truesdell model is an excellent geochemical critique, it uses superficial geologic thought. The author strongly disagrees with the ideas of dissolution of a detrital and hydrothermal quartz-rich reservoir rock (perhaps a bit of dissolution in the condensation zone) and movement of steam and/or condensate through subhorizontal lateral fractures networks (Thomas, 1981). Figure 3 depicts a conception of reservoir (cell) anomalies according to MCR's data and other privileged data.

Rayleigh plume models may not necessarily be realistic or accurate in modeling a steam/gas drive reservoir. If the idea of a basal boiling brine is dismissed, the steam reservoir(s) may be no more than an essentially isobaric/isothermal saturated steam convection cell overlain by a condensation zone formed by the contact of very hot steam with a cooler cap rock. The accumulated condensate probably flows outward somewhat to form huge saturated bodies on the outmost flanks of the reservoir. This may account for the dirtier steam chemistry found in outer flank wells, due to the increased size and increased non-condensable gas volume of the condensation zone. As the hydrostatic head of the condensation zone becomes greater than the reservoir pressure, a small amount of condensate may dribble down into reservoir fractures and become vaporized, that is in an unexploited system. Water entries encountered by Aminoil (Frye 1976) while laterally drilling may emanate from large condensate bodies on the outermost flanks of a particular anomaly.

Whereas flank wells possess lower deliverabilities are wetter, and probably penetrate a larger condensation zone, potential liquid reserves for those wells may be higher with decline rates possibly being less severe.

The areas that crest the various field anomalies are known (public and privileged data) to harbor well deliverabilities in the 300,000+ Lbs/Hr class from very shallow wells (4,000 - 5,000 feet) with production coming beneath a thin lithocap from say 2 or 3 very large steam entries. Such wells decline in flowrate at much faster rates than do outer flank wells. It is proposed that these cores are huge tectonic breccia chimneys and that the Geysers reservoir(s) is basically a huge steam and condensate filled tectonic breccia(s) superimposed upon (mimicing) and now overlapping a huge ancestral hydrothermal breccia(s). The field anomaly cores may have been the highly altered or mineralized cores of a former liquid "mushroom" plume such as presently exists at Wairakei. These cores can fracture to more prolific degrees because of either locally enhanced tectonics (minimum principal stress) and/or a greater reduction in tensile strength due to enhanced mineralization. The core of the Squaw Creek anomaly is probably such an area with very high productivity, while MCR's leases represent the middle portions of the flank. In comparison, data from Shell Oil Co. (Cochran, 1979) and public drilling records strongly infers that Shell's leases occupy the core and steep flanks of such a field anomaly.

The Geysers field is probably composed of numerous reservoirs (cells) that are separated by relatively impermeable rock. There may be some minor cross flow between individual cells. Pressure mapping and tracer tests can identify such trends. MCR will initially consider the Francisco Lease area to be part of the Squaw Creek (Unit 17 and/or 11) cell(s) until pressure monitoring indicates otherwise.

How deep does the reservoir fracture system penetrate? With no significant evidence of a bottom, it can be confidently assumed that the reservoir will cease at some depth(s) determined by a localized dramatic change in the physical nature (tensile strength) of the rocks or a reduction in extensional tectonics (minimum principle stress). Encountering a contact metamorphic zone and/or felsic intrusive basement at depth may indicate a lithologic change substantial enough to no longer allow propogation of permeable fractures.

GENERAL GEYSERS FIELD TECTONICS

McLaughlin (1981, Figures 7 and 8) demonstrates the probable results of extentional forces in the Geysers Field area agreeing well with the shear strain ellipsoid of Crowell and Ramirez (1979) and the visible lineaments and topographic drainage throughout the field. Accordingly so, drilling programs should be designed with tectonics in mind.

The idea of sub-horizontal partings existing in the steam reservoir(s) (McLaughlin, 1981, Figure 8) may only apply to the very shallow tops of anomalies such as the Big Geysers anomaly where verticle lithostatic pressures are low. However, the contributory effects in deeper reservoirs (below 2000 - 3000 feet) is probably nil. As the tight top of the main graywacke is penetrated, permeability in the reservoir section quickly opens up, the only conclusion to be offered is that fractures pinch in going upward into the lithocap as is suggested by McLaughlin (1981, Figure 11). Primary horizontal extension in the form of large fractures and tectonic caverns are certain while secondary permeability in the form of hairline fractures is less certain but must exist. The secondary permeability may develop along synthetic and antithetic shear planes. Block faulting seen in cross section (Thomas, 1981), occurring along the strikes of recent shear planes, may also indicate enhanced secondary permeability pathlines. Gulati et al. (1978) suggest through tritium injection surveys, that injected fluids disperse radially in a Geysers reservoir from an injection point. This phenomena implied that there is lateral permeability along more than one pathline. Varying quantitative recovery values imply that permeabilities and pathline lengths/attitudes vary in different directions. Semprini and Kruger (1980) present evidence that suggests physical processes (structured features) control radon tracer flow through a Geysers Field reservoir. Geologically speaking, the Geysers reservoir(s) must therefore not be homogeneously fractured.

Several earlier ideas by various authors concerning permeability pathlines within the steam reservoir(s) are most likely obsolete. The idea of reservoir fracture permeability pathlines following old imbricate/subduction related thrust faults is poorly conceived. These faults are of mesozoic and tertiary age and are undoubtedly gouge gangue-sealed by former (tertiary and quaternary) mineralization, judging by what is seen in graywacke core rocks that have been altered by former events of hydrothermal metamorphism. Speculations of dipping soft, unfractured graywacke layers (slabs) sandwiched in between alternating hard fractured layers are also unsound. Quaternary age shear and extensional tectonics that vertically penetrate all graywacke grades should be thought of as the prominent factor in reservoir formation. Drilling experiences show that steam entries can occur in all three graywacke grades of former regional metamorphism.

DRILLING METHODOLOGY

What are the real benefits of directional drilling in the Geysers field? Most wells are probably drilled directionally for two reasons, one to minimize well pad locations in rought terrain and the other to penetrate more fracture systems through lateral penetration.

MCR's approach is to drill across inferred primary extensional permeability trends (verticle fractures) utilizing deep lateral penetration. Whereas near-verticle extensional fractures should form perpendicular to the extensional component (minimum principle stress), drilling should be oriented parallel to that stress. Drilling wells to the northwest or southeast has been highly successful with the northwest direction preferred because deviation control is much better. Drilling elsewhere usually results in very poor wells. Drilling should never proceed vertically, with the steam field offering good examples of deep verticle wells completed dry, and then turned into prolific producers when they were plugged back and sidetracked laterally.

Some may argue that wells can be fanned out in any direction, becoming adequate producers, thus contradicting the approach suggested here. This may be factual in rare isolated areas where tectonics forces deviate from the normal or in the core areas of the field's anomalies where fracturing is more pervasive and permeable. However, the extensional component philosophy is still considered to be the most appropriate within the steam field.

When is the time to set production casing and proceed to air drill into the reservoir? First, the top of the main graywacke must be identified. Then, evidence of the condensation zone along with drilling mud temperatures and bottoms up mud temperatures must be utilized in deciding where to set production casing. The use of elaborate temperature logging is not actually required.

CONCLUDING REMARKS

Aside from MCR's current area of interest two other wells (Figure 1) were drilled in other parts of the Geysers area. Both wells were subsequently plugged and abandoned and the leases released after varying and interesting results. Newfield 1-33 was drilled from the eastern side of the Collayomi Fault Zone, through the fault and massive ophiolite, then into reservoir rocks consisting of a silicified melange type. This well penetrated to 8985 feet and produced about 30,000 Lbs/Hr of steam, thus revealing that some vestige of the steam reservoir exists all the way over to the fault zone. Tellyer 1-24 was drilled to 12,194 feet in deep massive graywackes and encountered numerous water, steam, and gas entries but was unable to sustain any degree of production.

Condensed steam will be reinjected at rates up to 750 gallons per minute through one well placed deep into the reservoir. Depletion wells will be drilled from existing pads as steam declines warrant. Approximately 1,100,000 Lbs/Hr of steam will be initially available to the powerplant in order to combat initial declines.

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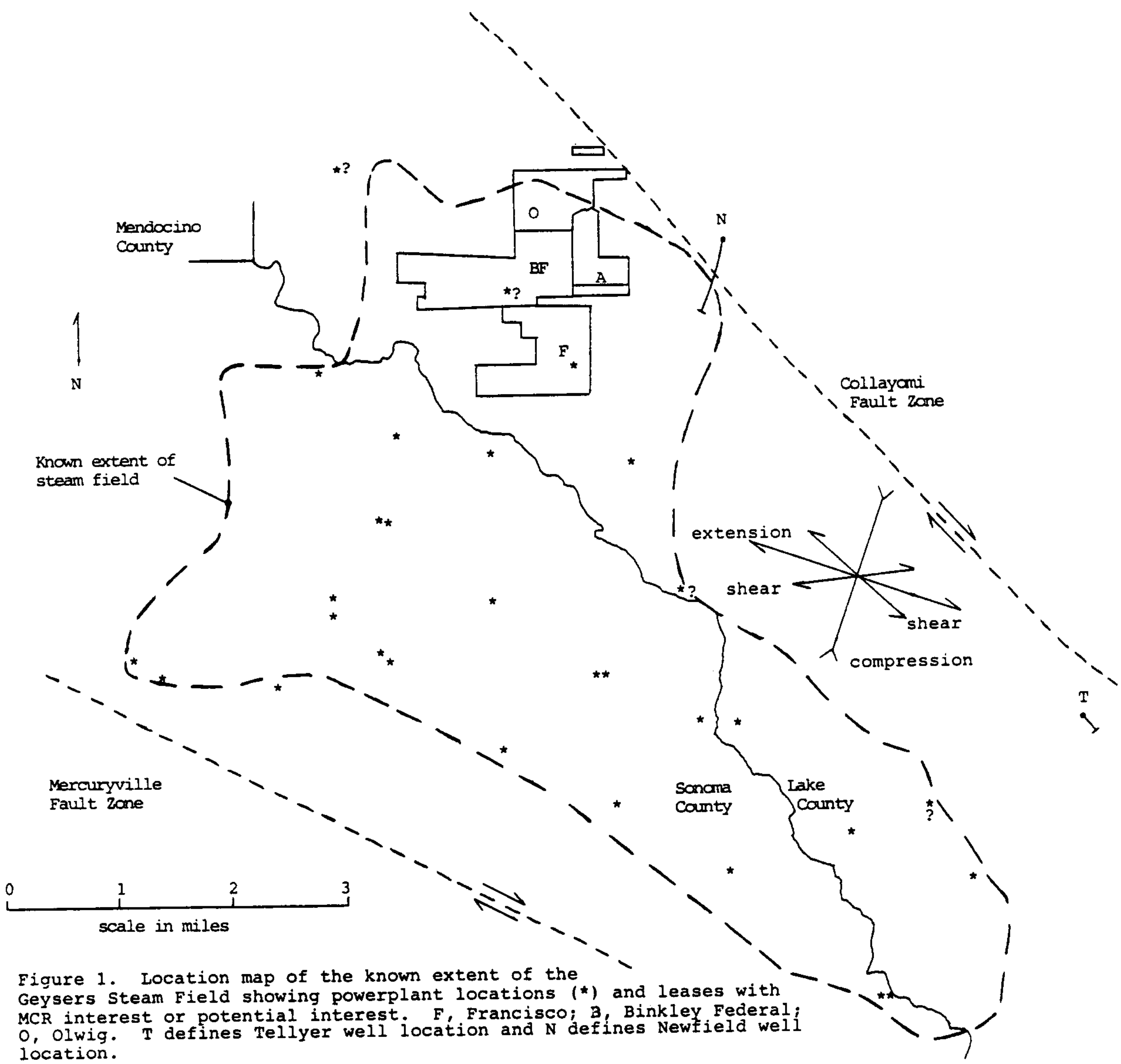

Figure 1. Location map of the known extent of the Geysers Steam Field showing powerplant locations (*) and leases with MCR interest or potential interest. F, Francisco; 3, Binkley Federal; O, Olwig. T defines Tellyer well location and N defines Newfield well location.

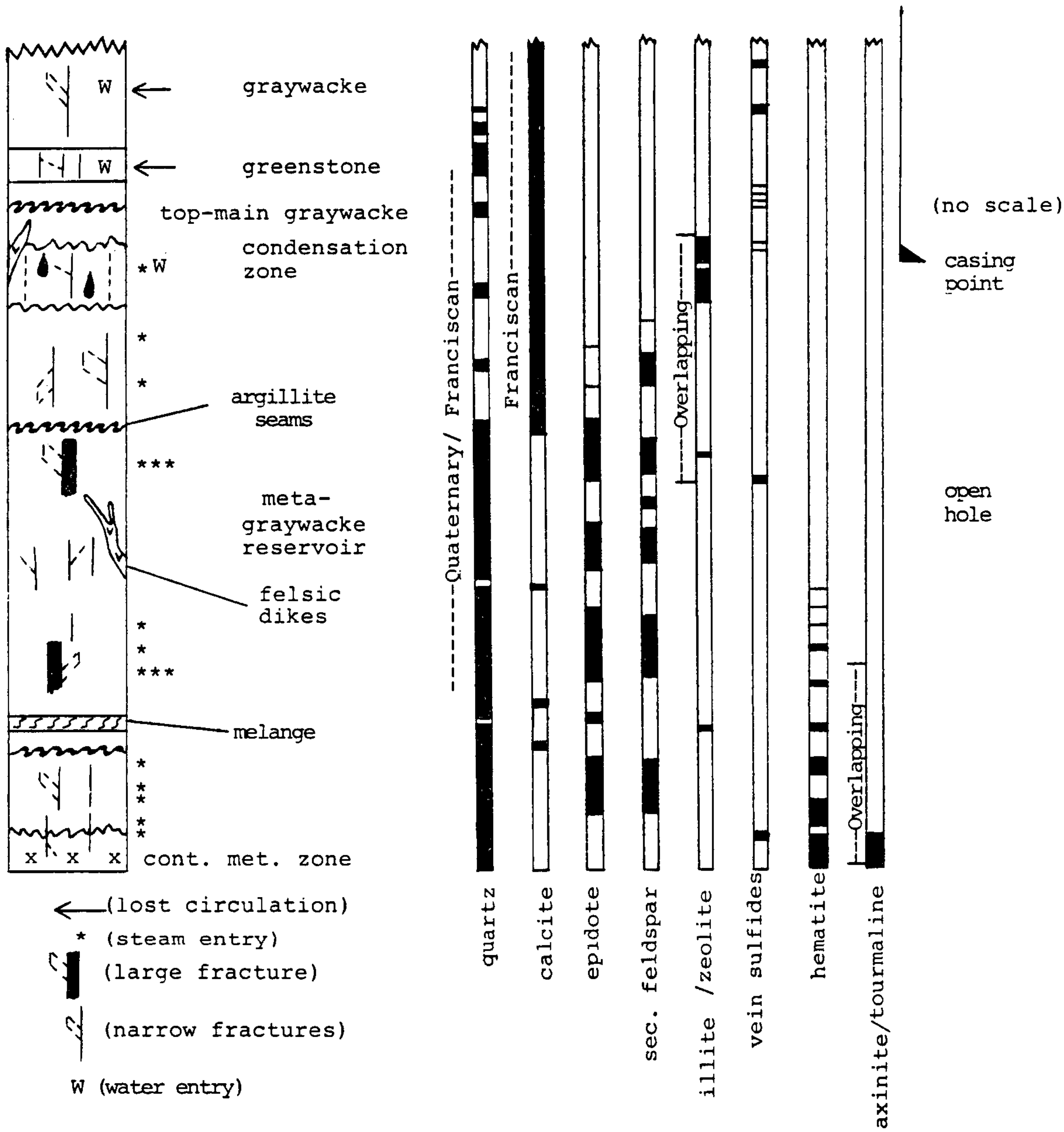

Figure 2. Generalized lithologic section and mineralogical zoning of a typical Francisco lease well, showing permeable traits.

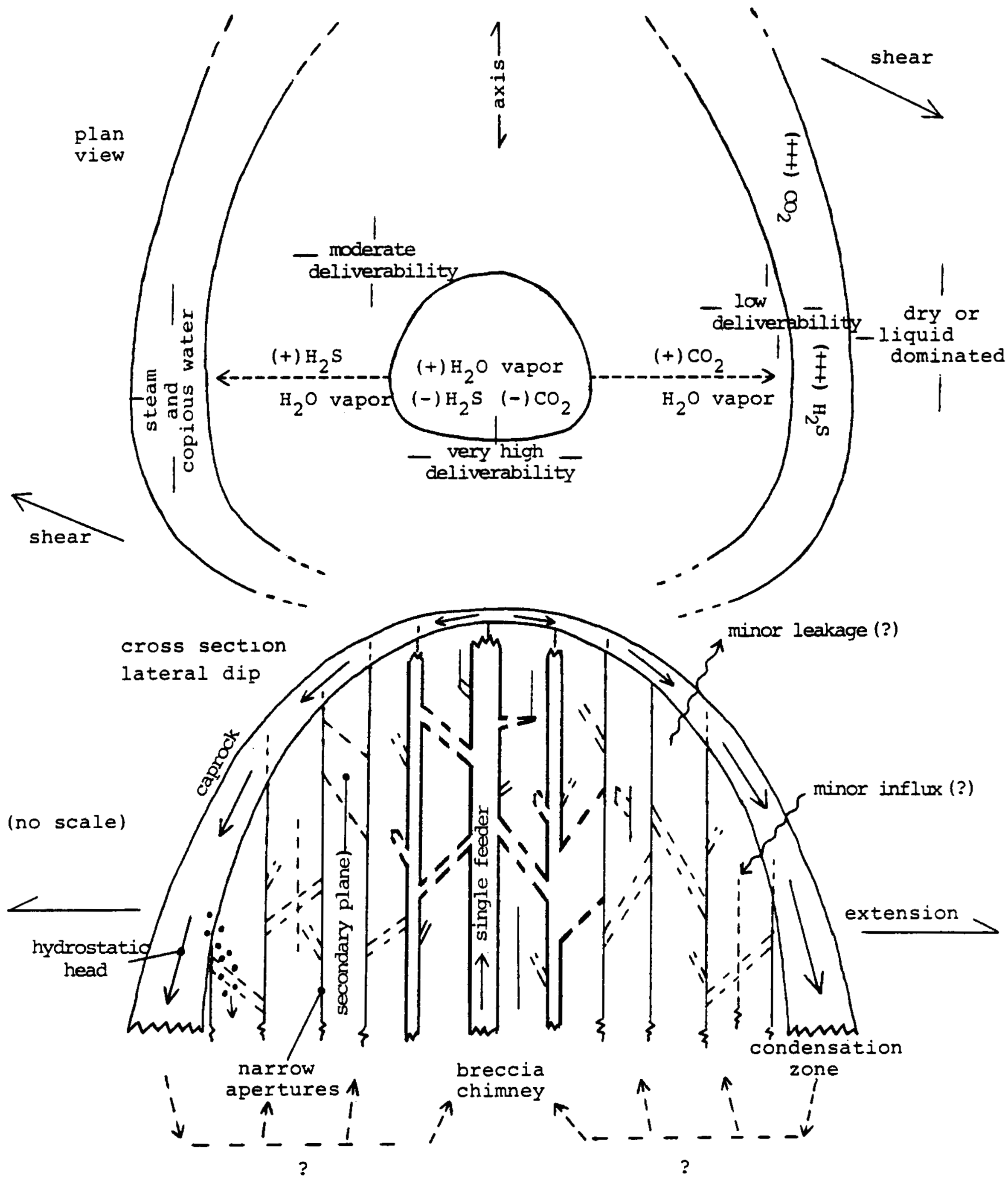

Figure 3. Illustration defining a conceptual view across the lateral dip of Geysers reservoir(s). A huge breccia chimney is developed in the core with variances in steam (probably condensate also) chemistry throughout the system. The presence of a basal boiling brine is questionable. Changes in permeability may relate to differing structural stresses/strains across any field anomaly. This is two-dimensional. As the fringe of the cell is approached, the effects of a massive condensation zone and the eventual end of the reservoir are shown.