REFINED CONCEPTUAL MODELING AND A NEW RESOURCE ESTIMATE FOR THE SALTON SEA GEOTHERMAL FIELD, IMPERIAL VALLEY, CALIFORNIA

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ABSTRACT

Interim results of a new conceptual modeling effort for the Salton Sea geothermal field (SSGF), in the Salton Trough of southernmost California, show that this resource: (1) is hotter at depth (up to at least 389^{o}C at 2 km) than initially thought; (2) is probably driven by a still-cooling felsic intrusion rather than (or in addition to) the primitive mafic magmas previously invoked for this role; (3) may be just the most recent phase of hydrothermal activity initiated at this site as soon as the Trough began to form ~4 m.y. ago; (4) is thermally prograding; and (5) in spite of 30 years' production has yet to experience significant pressure declines.

Thick (up to 400 m) intervals of buried extrusive rhyolite are now known to be common in the central SSGF, where temperatures at depth are also the hottest. The considerable thicknesses of these concealed felsic volcanics and the lack of corresponding intermediate-composition igneous rocks imply coeval granitic magmas that probably originated by crustal melting rather than gabbroic magmatic differentiation. In the brine-saturated, Salton Trough sedimentary sequence, granitic plutons inevitably would engender convective hydrothermal systems. Results of preliminary numerical modeling of a system broadly similar to the one now active in the SSGF suggest that a still-cooling felsic igneous intrusion could underlie deep wells in the central part of the field by no more than a kilometer. The model results also indicate that static temperature profiles for selected Salton Sea wells could have taken 150,000 to 200,000 years to develop, far longer than the 20,000 years cited by previous investigators as the probable age of the field. The two viewpoints conceivably could be reconciled if the likely long hydrothermal history here were punctuated rather than prolonged. Configurations of the temperature profiles indicate that portions of the current Salton Sea hydrothermal system are still undergoing thermal expansion.

A newly consolidated, field-wide reservoir database for the SSGF has enabled us to re-assess the field's ultimate resource potential with an unprecedented level of detail and confidence. The new value, 2330 MW_e (30+ year lifetime assured) closely matches an

earlier estimate of 2500 MW_e (Elders, 1989). If this potential were fully developed, the SSGF might one day satisfy the household electrical-energy needs of a fourth the present population of the State of California.

INTRODUCTION

Because of their distinctive geologic setting and plate-tectonic significance, the Salton Trough and the SSGF (**Fig. 1**) have anchored a number of landmark scientific investigations (e.g., White *et al.*, 1963; Helgeson, 1968; Elders *et al.*, 1972; Elders, 1984; Lachenbruch *et al.*, 1985; Elders and Sass, 1988; Williams and McKibben, 1989). For years, however, scientific studies of the field were hampered by the reasonable proprietary concerns of neighboring geothermal companies exploring and developing the field. The field is now operated by a single company, CalEnergy Operating Corporation (CEOC). As a result, researchers are now permitted judicious access to previously confidential reservoir data and borehole samples.

The Energy & Geoscience Institute, University of Utah, is collaborating with CEOC to develop a refined conceptual model for the entire SSGF. The new model will advance basic understanding of the dynamics of incipient continental breakup, while providing new insight into the mechanisms by which high-temperature hydrothermal systems here and elsewhere in the region have arisen and evolved above asthenospheric-mantle-rooted, sediment-smothered spreading centers. The model will also help enable CEOC to develop, expand, and sustain the field with optimum efficiency, profitability, and environmental responsibility.

GEOLOGIC SETTING AND PRIOR INVESTIGATIONS

The Salton Trough, a major transtensional basin in southernmost California and northern Mexico (**Fig. 1**), is the structural and physiographic northern extension of the Gulf of California (Elders *et al.*, 1972; Elders, 1979; Lonsdale, 1989). The Gulf and the Trough straddle a continental rift separating the Pacific plate, to the west, from the North American Plate, on the east. Subsiding pull-apart basins above ocean-type spreading centers scattered along the length of the rift host vigorously active magma-hydrothermal systems. Two of these systems in the Trough, at Cerro Prieto and the SSGF, are among the world's largest and hottest.

The Trough began its existence in Oligocene to Miocene time as a coaxial but broader and shallower proto-rift, developed as a Basin-Range-style back-arc basin in response to subduction of the Farallon plate beneath the North American plate (Karig and Jensky, 1972; Herzig and Jacobs, 1994). Oligocene to Miocene basalts along the margins of the modern Trough attest to the lithospheric thinning, heating, and characteristic mafic-alkaline magmatism that accompanied the older rifting episode.

The modern Trough started to form at about 4 Ma (Elders *et al.*, 1972; Crowell, 1974; Lonsdale, 1989), as the proto-rift was further extended and ultimately ruptured to the asthenosphere to create a new and more landward margin between the Pacific and North American plates. The margin has evolved as a series of right-stepping, right-lateral transforms, linked at the oversteps by pull-apart basins (Elders *et al.*, 1972).

The Trough was filled as it subsided by sediments from the Colorado River, which constructed a transverse alluvial dam ("the delta") across the basin, impeding further marine incursions. Thereafter, frequent diversion of the River northward into the Trough rather than the Gulf supplied enormous volumes of water and sediment to the developing rift. As a result, the Trough is now filled by up to 6 km of fluid-saturated sandstone, siltstone, and mudstone (Merriam and Bandy, 1965; Muffler and Doe, 1968; Van de Kamp, 1973; Fuis and Kohler, 1984; Herzig *et al.*, 1988).

The nature of the basement in the Trough remains conjectural. Gravity and seismic data suggest that low-density sediments rest upon an intermediate-density basement extending to about 12 km depth. The intermediate basement, in turn, overlies a higher density layer extending to the base of the crust at about 23.5 km (Moore, 1973; Fuis and Kohler, 1984; Elders, 1984; Lachenbruch *et al.*, 1985; Elders *et al.*, 1997). This deep layer is inferred to be gabbro, added to the crust to compensate isostatically for the low-density sediments supplied from above. The intermediate crust permissibly could be: (1) hydrothermally metamorphosed Trough-fill sediments (Muffler and White, 1969); (2) pre-Trough continental crust, thinned and sparsely intruded by gabbro; or (3) some combination of these end-member alternatives.

Heat sources for the high-temperature geothermal systems of the Salton Trough have traditionally been envisioned as gabbroic (e.g., Elders, 1984; Elders *et al.*, 1997). We will show later in this paper that in the upper crust of the SSGF, granitic heat sources not only cannot be ruled out, they are probably the most likely candidates.

Production fluids for the SSGF are brines (up to at least 30% total dissolved solids/TDS; e.g., Helgeson, 1968). The brines are believed to have originated largely though dissolution, during intermittent flooding of the Trough by the Colorado River, of saline residues left in the wake of evaporating lakes much like the modern Salton Sea and its immediate predecessor, Lake Cahuilla (Sykes, 1937; Elders, 1979; Rex, 1983; Osborn, 1989; McKibben and Hardie, 1997).

Williams and McKibben (1989) determined that the SSGF brines have a crude vertical salinity (and therefore density) zonation. Deeper brines, generally below depths of about 1000 m, are exclusively hypersaline (20-30 wt.% TDS). Shallower brines range in TDS down to a few per cent. The deeper and hotter fluids are also metalliferous (McKibben and Hardie, 1997), having precipitated sparse but widespread base-metal veinlets in the past (e.g., McKibben and Elders, 1985). At present, high-purity electrolytic zinc is being extracted from the brines by CEOC; the eventual annual yield of the metal is anticipated to reach 30,000 tons.

EXTENT AND CONFIGURATION OF THE SSGF HEAT ANOMALY

As one phase of our modeling effort, we have revised a map of the shallow thermal-gradient anomaly encompassing the SSGF. **Figure 2** documents the extensive borehole control on which the revision is based; the new map is shown as **Figure 3**. The general "boomerang" or "porkchop" shape of the anomaly has changed little from Newmark *et al*. (1988), but the newer drilling results show the feature to be more areally extensive (72.4 km^2). The revised map also reveals a more complex configuration of shallow "hot spots" within the anomaly.

FELSIC VOLCANISM AND THE NATURE OF THE HEAT SOURCE

We have alluded to the idea that granitic rather than gabbroic plutons could well be the immediate principal heat sources for the SSGF. The major reason for this contention is the unexpectedly large volume of buried extrusive rhyolite penetrated in central SSGF wells since 1997. Hulen and Pulka (2000) documented such rhyolites and associated phreatomagmatic tuffs up to several hundred meters thick and concealed beneath 1.6 km of Trough-fill sedimentary rocks in injection wells Smith IW-2 and Vulcan IW-8 (**Fig. 2**). Since then, a new high-temperature production well, Elmore-16 (**Fig. 2**) has penetrated, below a depth of 1.5 km, three separate rhyolite intervals with an aggregate thickness of 400 m.

The felsic melts that erupted to form the exposed rhyolite domes of the SSGF have been cited as the products of either crustal melting (Robinson *et al.*, 1976) or (on the basis of additional isotopic evidence) magmatic differentiation (Herzig and Jacobs, 1994). The latter interpretation is presently preferred, but the Salton domes are thin (30-150 m) and volumetrically modest features; all four volcanic centers probably aggregate less than 0.5 km^3. By contrast, the implied volume of the newly discovered buried rhyolites is much larger. These felsic volcanics are up to several hundred meters thick. Rhyolites of this thickness elsewhere commonly occur in flow-dome fields (e.g., at Coso, California; Duffield *et al.*, 1979) that may be up to several cubic kilometers in volume.

Even without pending isotopic confirmation, we feel confident in asserting that the newly discovered buried rhyolite bodies and the dome field(s) they imply in the central SSGF cannot have originated simply by differentiation from a mafic magmatic parent. If these felsic igneous rocks (and those yet undrilled) are as voluminous as indicated, then their origin as differentiates would seem to mandate a much larger volume of intermediate-composition magma and its crystallization products, for example andesite or granodiorite. No such rocks have been reported for the SSGF; only mafic and felsic varieties. In view of this distinctly bimodal igneous-rock suite, we suggest that crustal melting is a much more likely means of producing all or most of the rhyolite encountered at depth in the SSGF.

Smith and Shaw (1975) argue that young rhyolites can be excellent indicators of sizable, high-temperature geothermal systems. The reason is that the rhyolites are typically associated with large, initially viscous, slowly cooling granitic magma bodies, the optimum geothermal heat sources in continental geologic settings. We believe it very likely that such plutons have been and continue to be primary heat sources for the SSGF. A graphic portrayal of this scenario is offered as **Figure 4**.

An intriguing possibility for the central SSGF is that a large, hot, granitic intrusion might underlie the drilled portion of the field by no more than a kilometer, and perhaps much less than that value. One well here has a static temperature of 389^{o}C at a depth of only 2 km. Norton and Knight (1977), Norton (1982), and Norton and Taylor (1979) have shown through numerical modeling and geologic analysis that regardless of the composition, depth, or size of an igneous heat source, the 400^{o}C isotherm in an overlying convective hydrothermal system rarely extends more than a few hundred meters above the top of the pluton. For example, in the numerical hydrothermal system above the ~320 km^3 Skaergaard gabbro in Greenland, the 400^{o}C isotherm extends only about 0.8 km above the pluton at the system's thermal maximum (Norton and Taylor, 1979). Even above a hypothetical cooling felsic batholith, the 400^{o}C isotherm (with the exception of small salients) extends a maximum of about 1 km above the igneous body (Norton and Knight, 1977). A hypothetical granitic intrusion beneath the Salton Sea geothermal field would likely be orders of magnitude smaller than the above examples, perhaps more like the intrusions associated with porphyry copper deposits. Norton (1982) has shown that in porphyry systems, the 400^{o}C isotherm barely ascends above the pluton during the lifetime of the associated magmatic-hydrothermal system. From these analyses and the foregoing evidence, we predict that a 1-10 km^3, still-cooling felsic igneous heat source will be found just below presently drilled depths in the central part of the geothermal field.

AGE AND DURATION OF THE HYDROTHERMAL SYSTEM

Previously published estimates of the age of the Salton Sea geothermal system range from a few thousand years (Heizler and Harrison, 1991) to at least 100,000 years (Williams and McKibben, 1989). McKibben and Hardie (1997) suggest that this broad range of age estimates likely reflects a combination of (1) different viewpoints about the behavior (e.g., diffusion rates) of radiogenic elements in the dated minerals; and (2) a complex evolution with multiple thermal pulses. Results of our investigation to date support the latter interpretation, but suggest that even the most recent pulse may be more long-lived than previously imagined.

We now know that there are voluminous buried extrusive rhyolites as old as 700,000 years at drilled depths in the SSGF (Hulen and Pulka, 2000). These rhyolites imply coeval granitic intrusions, which, as we have argued, probably crystallized from crustal melts produced around or within deep, mantle-derived, gabbroic magma chambers (**Fig. 4**). On the basis of 3.7 m.y.-old basalt xenoliths in the Salton rhyolite domes (Herzig and Jacobs, 1994), these primitive gabbroic magmas (and derivative felsic crustal melts) have likely always been characteristic of the Salton Sea spreading center. The viscous felsic melts, intruded into the brine-saturated Salton Trough sediments, inevitably would have engendered high-temperature hydrothermal systems (Norton, 1984), indistinguishable from the one circulating in the SSGF today. From these arguments, it seems likely that high-temperature hydrothermal activity has been characteristic of this site since inception of the Salton Trough ~4 m.y. ago.

As a preliminary test of the long-duration hydrothermal hypothesis, one of us (Norton) has completed a simplified, 2-D, numerical hydrothermal-history model of a system broadly similar to the one now active in the SSGF. It is assumed for the model that a 4 X 4-km felsic pluton is emplaced beneath a 4 X 4-km mass of fluid-saturated siliciclastic sedimentary rock with porosity and permeability approximating that measured and geophysically inferred for the reservoir itself. For details of the methods, procedures, and assumptions employed for the modeling, the reader is referred to Norton (e.g., 1982, 1984) and Norton and Taylor (1979). A sequence of modeled temperature vs. depth curves (**Fig. 5A**) above the numerical cooling pluton suggest that static thermal profiles measured in selected production and injection wells (**Fig. 5B**) could take 150,000 to 200,000 years to develop.

On the basis of this preliminary modeling, and on the likely intrusion of gabbroic and derivative granitic plutons at this site for the last 4 m.y., we suggest that Kasameyer *et al.*'s (1988) numerically modeled age of 20,000 years for the system substantially underestimates the true age and full duration of hydrothermal activity. Our differing viewpoints conceivably could be resolved if, as suggested by Williams and McKibbern (1989), the long-lived hydrothermal activity has been intermittent rather than continuous. Still, the available evidence suggests that even the still-active thermal "pulse" would likely have been initiated more than 100,000 years ago.

THE ULTIMATE RESOURCE POTENTIAL OF THE SSGF

Previously published estimates of the long-term (30 yr) electric-power production potential of the SSGF span an order of magnitude (**Table 1**) and range from 2,500 MW_e (Elders, 1989) to 30,000 MW_e (Meidav and Howard, 1979). The estimates are based on the investigators' assessments of reservoir area, thickness, volume, temperature, porosity, permeability, fluid mass and replacement capacity, stored heat, heat recoverability, and heat-to-electricity conversion efficiency. There has been little consensus about these parameters, apart from their pointing to a very large geothermal resource.

The most recent of the SSGF resource-potential estimates – the 2500 MW_e of Elders (1989) – could well be the most realistic. Utilizing a wealth of new drilling and reservoir data acquired since that paper was published, we have re-appraised the resource from a different perspective and arrived at a similar value (**Table 1**; **Fig. 6**). Our approach, hitherto precluded by the proprietary concerns of multiple operators, is solidly based on 30 years' production history in all sectors of the field. We have simply extrapolated the well-established characteristics of this known resource to the rest of the Salton Sea heat anomaly.

We hasten to add that lending institutions may impose more rigorous requirements for resource appraisal than those that have guided our efforts in this regard. Nonetheless, it seems inescapable to us that this field, fully developed, has great potential to one day be the largest, hottest, and most productive in the world.

As we have shown, the SSGF occurs within a 72.4 km^2 thermal-gradient anomaly, constrained by more than 100 shallow boreholes and deep geothermal wells, within which gradients in the depth range 30-80 m exceed 200^{o}C/km. More than 90% of the deep wells completed to date within this anomaly have been actual or potential commercial producers (one or more sidetracks have sometimes been required to find the right combination of productive fractures and intergranular permeability; many wells proven productive have actually been utilized for injection). Some of these producers have immense thermal-fluid outputs; for example, Vonderahe-1, in the southwestern part of the field (**Fig. 2**), supports 45 MW_e of installed capacity by itself. Moreover, in the 30 years since inception of the field, the SSGF has yet to experience significant pressure declines. This fact implies not only copious natural recharge but also a successful re-injection strategy; it also means that the field can likely be sustained for decades (if not longer) to come.

Deep wells in the SSGF have been drilled to date almost entirely within the onshore portion of the shallow thermal-gradient anomaly (**Fig. 3**). The larger offshore, to the west and beneath the Salton Sea, is highly prospective but essentially untested by deep drilling. However, wells at the western edge of the onshore portion of the anomaly are as hot and prolific as those drilled anywhere else in the field. In fact, the hottest well (T_{max} = 389^{o}C) drilled to date is also one of the westernmost. In light of these facts, we can think of no good reason why the productive geothermal reservoir should terminate to the west simply because the rest of the heat anomaly in that direction is sublacustrine.

Only 14.4% of the areal extent of the shallow thermal anomaly has been extensively development drilled (the area supporting the field's current 335 MW_e capacity; **Fig. 6**). Another 24.2% has been sufficiently tested by strategically placed, deep and commercially producible geothermal wells to be considered proven resource. Assuming that this 24.2% of the anomaly will be as productive as the 14.4% already developed, it will be capable of supporting another 565 MW_e of installed capacity. This brings the total onshore resource – producing plus proven but undeveloped – to 900 MW_e.

The much larger offshore portion of the thermal anomaly is otherwise unlikely to differ much from its onshore counterpart. Given the stratigraphic monotony of this part of the Salton Trough, it is doubtful that the geologic framework beneath the Salton Sea is substantially different than that beneath the onshore SSGF. In other words, there is good reason to assume that the offshore part of the thermal anomaly will be underlain by a geothermal resource similar to and as productive as the SSGF on land.

The offshore part of the thermal anomaly constitutes 61.4% of its full areal extent. If the 38.6% of the thermal anomaly onshore is underlain by a 900 MW_e resource, then the offshore sector, in proportion, should support an additional 1430 MW_e, for a grand total of 2330 MW_e (**Fig. 6**).

It is conventionally stated that 1 MW_e is sufficient to supply the electrical-energy needs of 1000 standard households, or about 4000 people. By this measure, the SSGF, if developed to its full 2330 MW_e potential, could supply electricity for 9,300,000 individuals, or about a fourth of California's present population.

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FIGURE CAPTIONS

Figure 1. Location and tectonic map of the Salton trough (***ST***) and its high-temperature geothermal systems relative to the southeastern terminus of the San Andreas transform fault zone (***SA***) and the tip of the Gulf of California. Geothermal fields (not all currently producing abbreviated as follows: ***BD*** – Border; ***BR*** – Brawley; ***EB*** – East Brawley; ***EM*** – East Mesa; ***GL*** – Glamis; ***HB*** – Heber; ***MA*** – Mesa de Andrade; ***MS*** – Mesa de San Luis; ***SS*** – Salton Sea; ***TU*** – Tulecheck; ***WM*** – Westmoreland; Large arrows show modern relative motion of tectonic plates. Note location of SS and CP fields withing two prominent pull-apart zones, which also host the Trough's only exposed Quaternary volcanoes. Synthesized and redrawn from Elders *et al.* (1982); Lachenbruch *et al.* (1985); and Elders and Sass (1988).

Figure 2. Borehole control for an updated shallow thermal-gradient map of the Salton Sea geothermal field and vicinity (**Fig. 3**).

Figure 3. The Salton Sea shallow thermal-gradient anomaly, based on data available through June 2002. Revised and updated from Newmark et al. (1988). ***MI*** – Mullet Island; ***OB*** – Obsidian Butte; ***RH*** – Rock Hill; ***RI*** – Red Island.

Figure 4. Conceptual lithostratigraphic and hydrologic section through the eastern Salton trough and the Salton Sea pull-apart zone. Synthesized and modified from Moore (1973); Fuis and Kohler, 1984; Elders *et al.* (1984); Lachenbruch *et al.* (1985); and Elders and Sass (1988), with configuration of the young deep gabbro pluton (gb_2) adapted from Norton et al. (1984).

Figure 5. Comparison of computed temperature-depth (T-z) profiles for a highly simplified, generic numerical magma-hydrothermal system (***A***) with measured, static T-z profiles for Salton Sea geothermal wells Smith IW-2 and State 2-14 (***B***). The 2-D numerical system is generated by a 4 X 4 km felsic pluton, instantaneously emplaced at a temperature of 900^{o}C beneath a 4 X 4 km *lithocap* (the rock volume above the pluton) with a permeability of 0.25 millidarcies from pluton top to ground surface. Note that in the numerical system, concave-up thermal profiles, similar to the one measured for Smith IW-2, occur only when the system is thermally prograding. Preliminary modeling completed by D.L. Norton utilizing FLOW 6 software.

Figure 6. Map showing estimated ultimate conventional resource potential for the Salton Sea geothermal field as of July 2002.

TABLE CAPTION

Table 1. Published estimates of the ultimate electric-power-production potential of the Salton Sea geothermal field.

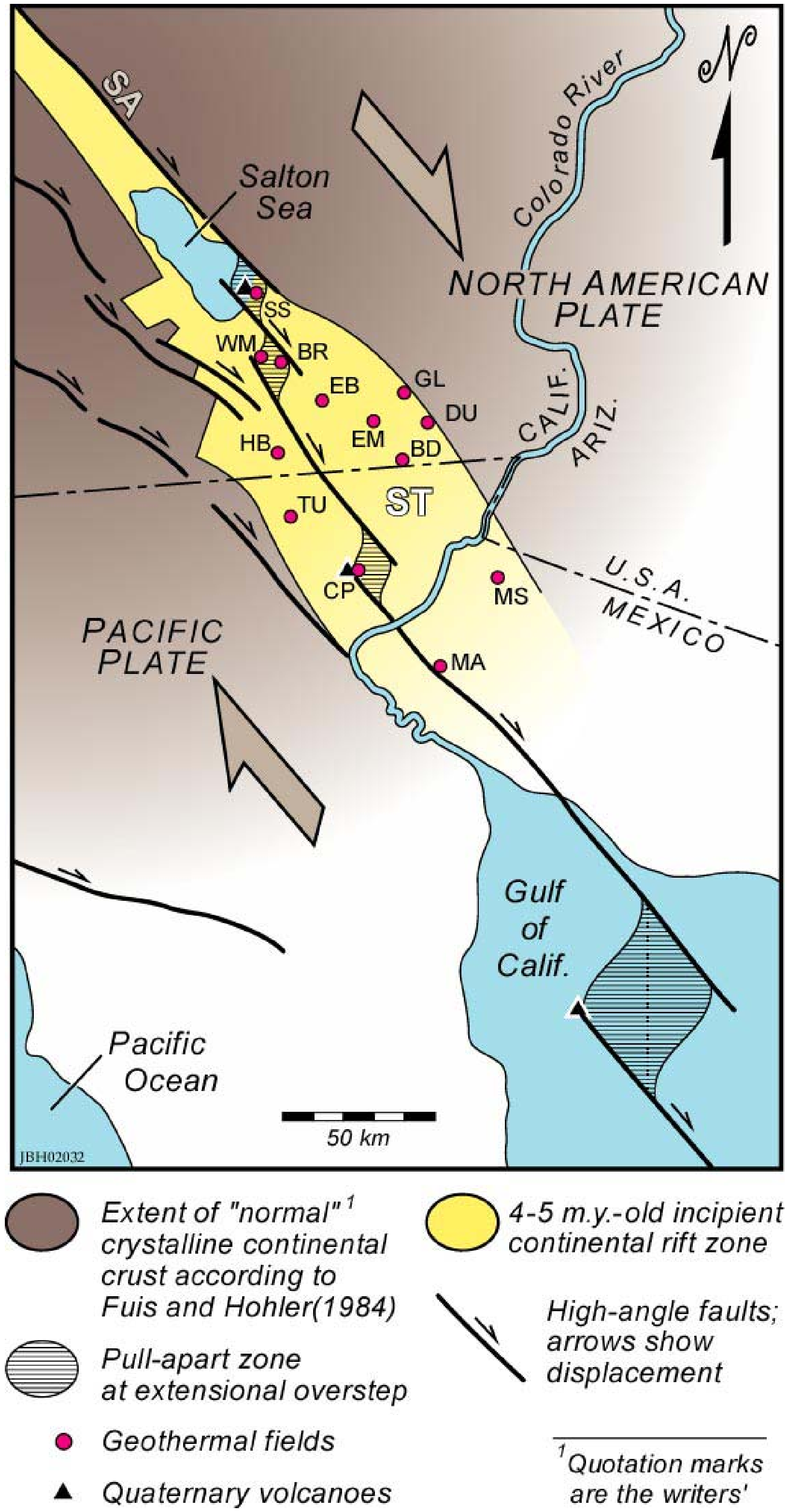
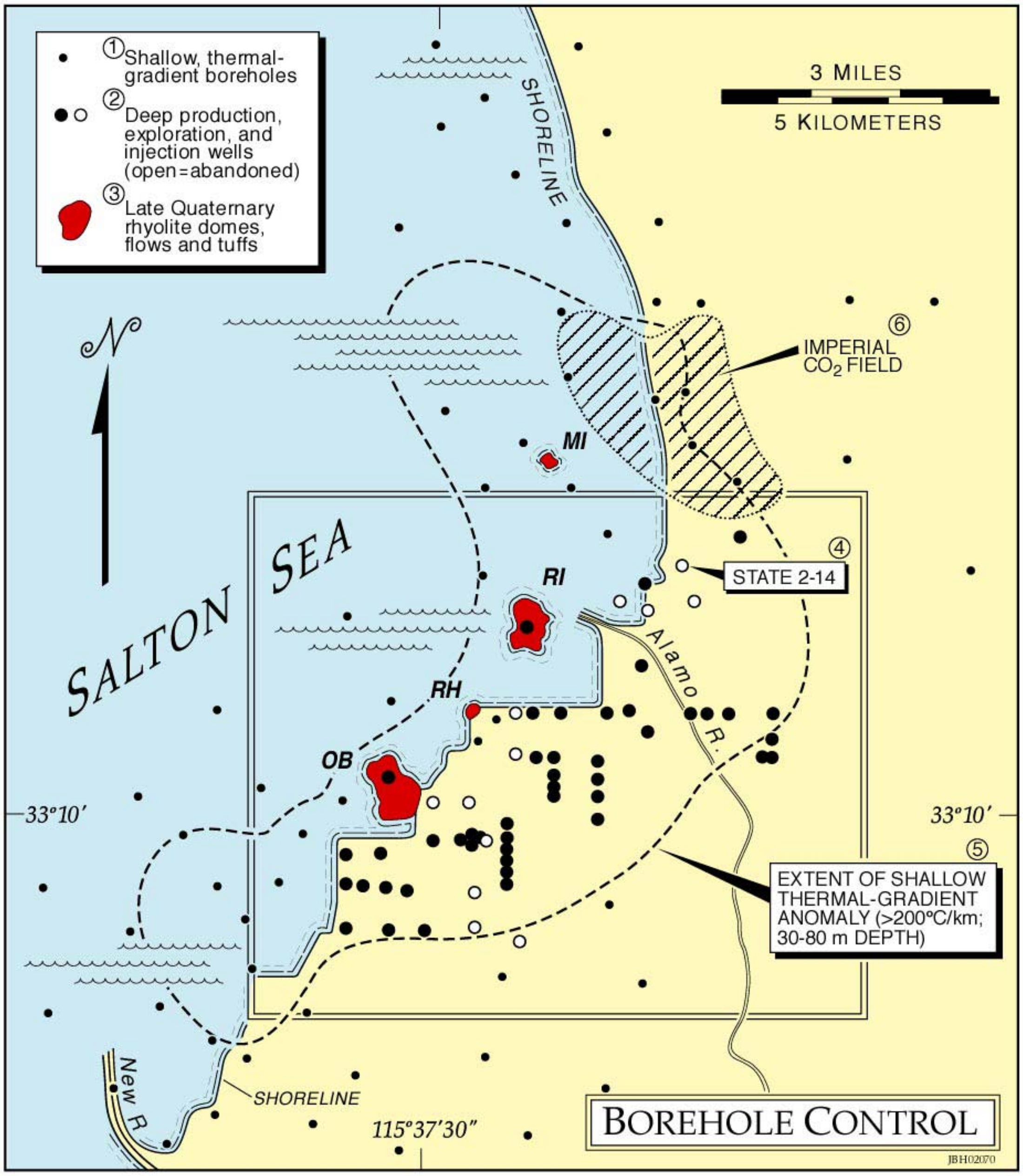
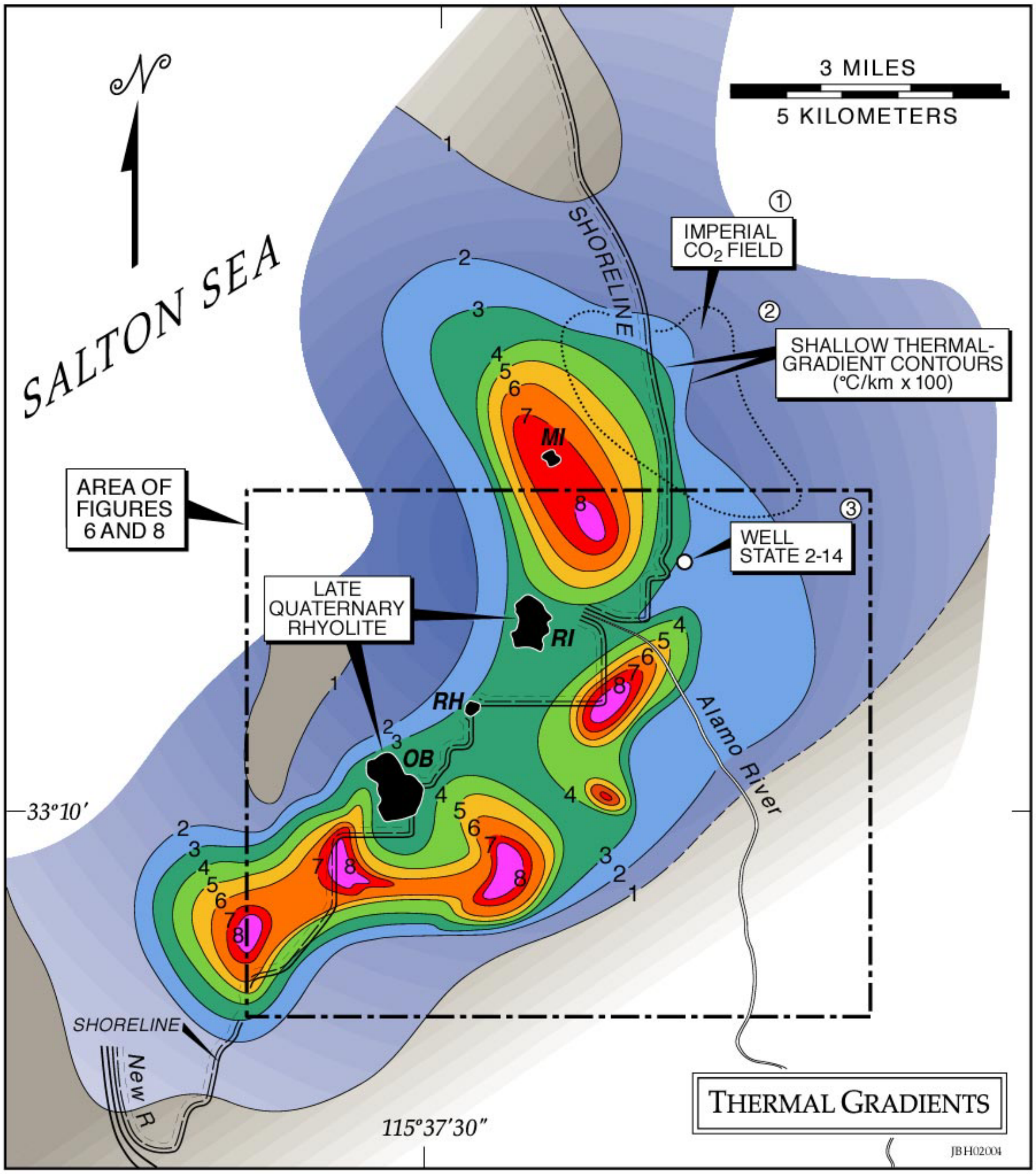

SA
Salton Sea
Colorado River
N
NORTH AMERICAN PLATE
SS
WM
BR
EB
GL
DU
EM
BD
HB
CALIF.
ARIZ.
TU
ST
CP
MS
U.S.A.
MEXICO
PACIFIC PLATE
MA
Gulf of Calif.
Pacific Ocean
50 km
JBH02032
Extent of "normal"[1] crystalline continental crust according to Fuis and Hohler(1984)
4-5 m.y.-old incipient continental rift zone
High-angle faults; arrows show displacement
Pull-apart zone at extensional overstep
Geothermal fields
Quaternary volcanoes
[1]Quotation marks are the writers'

Figure 1.



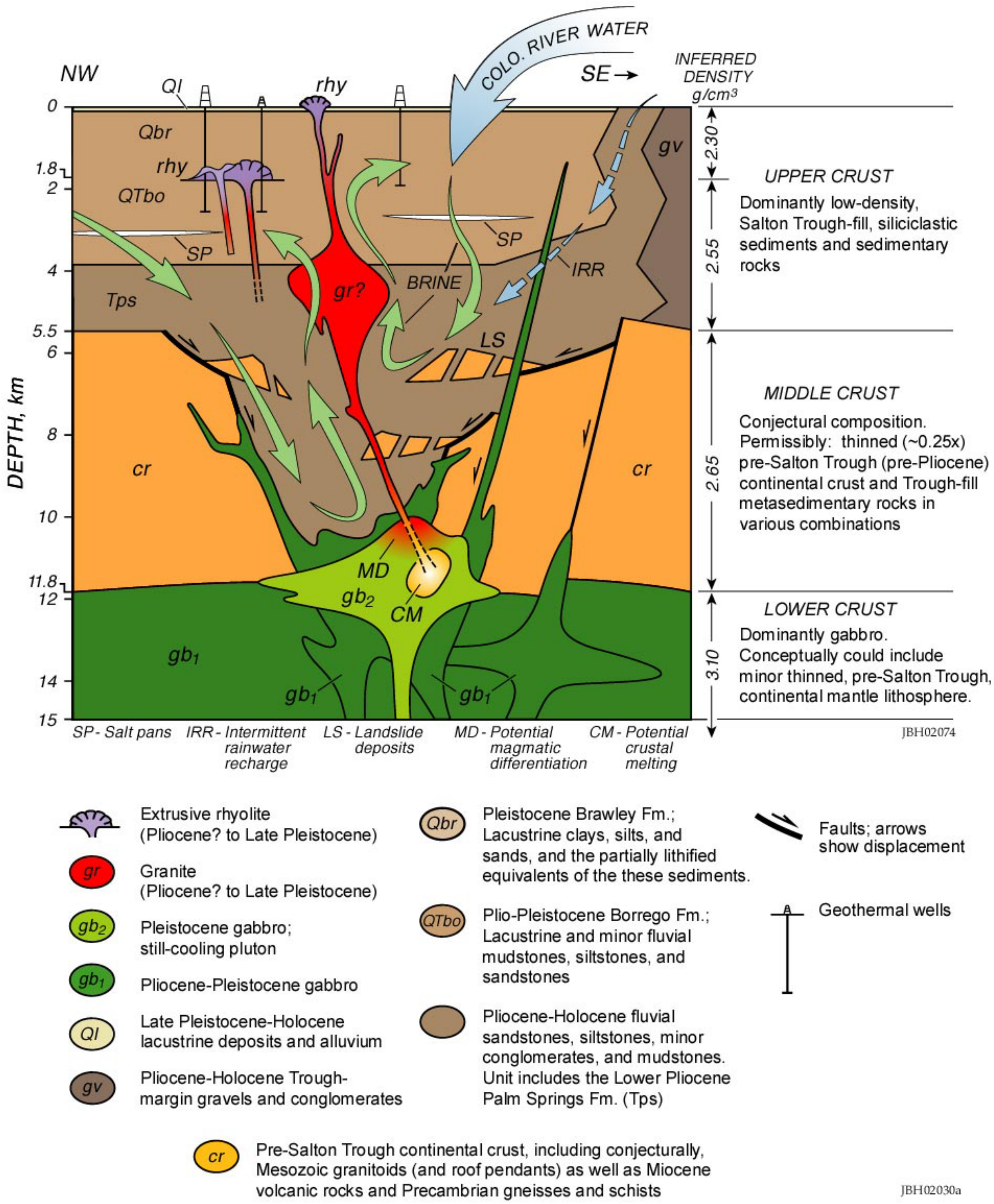
① From Newmark et al. (1988)
② Mostly Magma Energy, CalEnergy, and Unocal
③ Robinson et al. (1976)
④ Salton Sea Scientific Drilling Project (Elders and Sass, 1988)
⑤ Modified and updated from Newmark et al. (1988)
⑥ Rook and Williams (1942); Muffler and White (1968)

Figure 2.



① Rook and Williams, 1942; Muffler and White, 1968
② 30-80m depth; this document; modified and updated from Newmark et al. (1988)
③ Salton Sea Scientific Drilling Project (Elders and Sass, 1988)

Figure 3.



NW
SE →
COLO. RIVER WATER
INFERRED DENSITY g/cm³
Ql
rhy
Qbr
rhy
QTbo
SP
Tps
gr?
BRINE
SP
IRR
gv
LS
cr
cr
MD
gb₂
CM
gb₁
gb₁
gb₁
DEPTH, km
0
1.8
2
4
5.5
6
8
10
11.8
12
14
15
2.30
2.55
2.65
3.10
UPPER CRUST
Dominantly low-density, Salton Trough-fill, siliciclastic sediments and sedimentary rocks
MIDDLE CRUST
Conjectural composition. Permissibly: thinned (~0.25x) pre-Salton Trough (pre-Pliocene) continental crust and Trough-fill metasedimentary rocks in various combinations
LOWER CRUST
Dominantly gabbro. Conceptually could include minor thinned, pre-Salton Trough, continental mantle lithosphere.
SP - Salt pans
IRR - Intermittent rainwater recharge
LS - Landslide deposits
MD - Potential magmatic differentiation
CM - Potential crustal melting
JBH02074
Extrusive rhyolite (Pliocene? to Late Pleistocene)
gr Granite (Pliocene? to Late Pleistocene)
gb₂ Pleistocene gabbro; still-cooling pluton
gb₁ Pliocene-Pleistocene gabbro
Ql Late Pleistocene-Holocene lacustrine deposits and alluvium
gv Pliocene-Holocene Trough-margin gravels and conglomerates
Qbr Pleistocene Brawley Fm.; Lacustrine clays, silts, and sands, and the partially lithified equivalents of the these sediments.
QTbo Plio-Pleistocene Borrego Fm.; Lacustrine and minor fluvial mudstones, siltstones, and sandstones
Pliocene-Holocene fluvial sandstones, siltstones, minor conglomerates, and mudstones. Unit includes the Lower Pliocene Palm Springs Fm. (Tps)
Faults; arrows show displacement
Geothermal wells
cr Pre-Salton Trough continental crust, including conjecturally, Mesozoic granitoids (and roof pendants) as well as Miocene volcanic rocks and Precambrian gneisses and schists
JBH02030a

Figure 4.

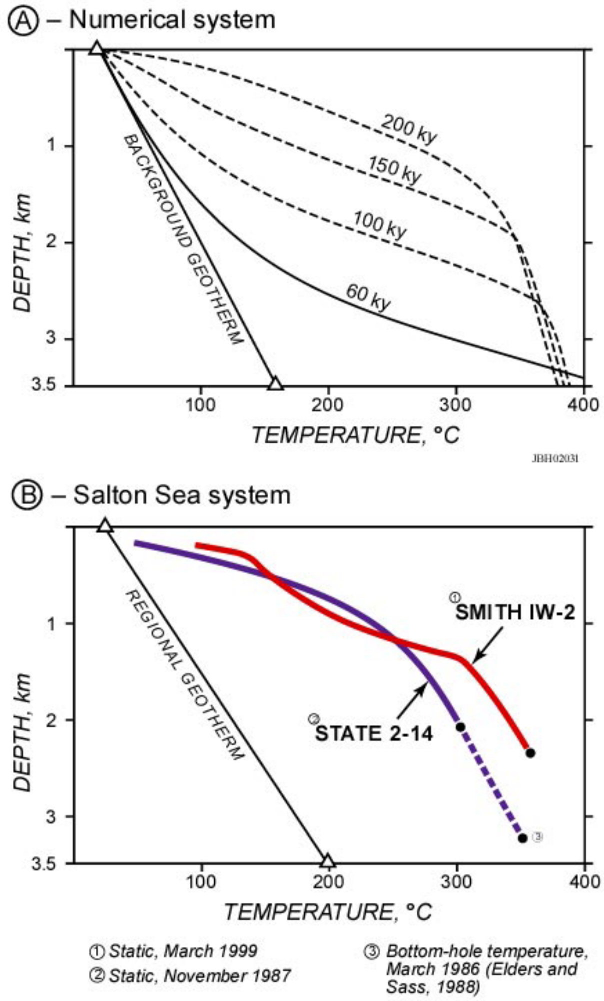


Figure 5.

MWe for at least 30 years	Reference
17,500	*Biehler and Lee, 1977*
1,300 to 8,700	*Younker and Kasameyer, 1978*
3,400	*Brook et al., 1979*
30,000	*Meidav and Howard, 1979*
2,500	*Elders, 1989*
2,330	*This paper*

JBH02056

Table 1.

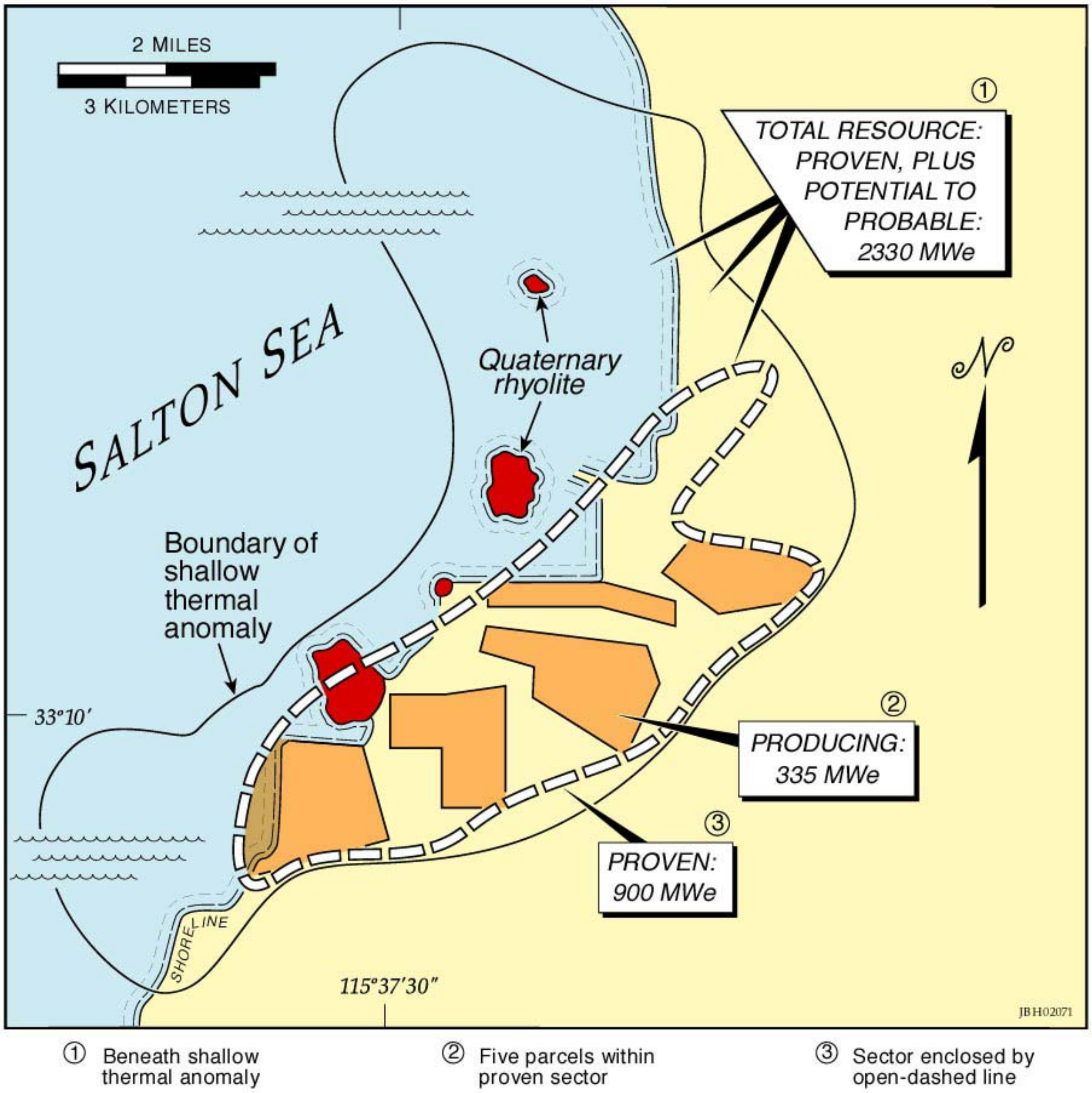

2 MILES
3 KILOMETERS
①
TOTAL RESOURCE:
PROVEN, PLUS
POTENTIAL TO
PROBABLE:
2330 MWe
SALTON SEA
Quaternary
rhyolite
Boundary of
shallow
thermal
anomaly
33°10′
②
PRODUCING:
335 MWe
③
PROVEN:
900 MWe
SHORELINE
115°37′30″
JBH02071
① Beneath shallow thermal anomaly
② Five parcels within proven sector
③ Sector enclosed by open-dashed line

Figure 6.