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HEAT AND MASS TRANSFER STUDIES OF THE EAST MESA ANOMALY*

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Heat and mass transfer due to convection in a two-dimensional model of the East Mesa geothermal system are presented in this paper. These results are an extension of those presented by Goyal and Kassoy (1977). Geological, geophysical, geochemical, and borehole logging data suggests the existence of four different zones in this anomaly. Basement, the deepest zone, is about 4 km from the surface (Combs and Hadley, 1977) and carries nearly vertical tensile fractures (Bailey, 1977). These fractures would increase the vertical permeability much more than the horizontal permeability. A clay-dominated zone overlies the basement and extends to about 1.9-2.2 km from the surface. The vertical permeability of the sediments in this zone is expected to be good near the fractures. The horizontal permeability is thought to be only moderate because of the presence of clay and dirty sands. Sands dominate the sedimentary zone from

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about 800-1900 meters depth. Both horizontal and vertical permeabilities in this zone are expected to be better than the underlying zone because of greater sand contents, continuity, and less compaction. The fourth zone, containing large amounts of clay, is represented by the upper 600 meters or so. The vertical permeability is probably very low in these sediments but the numerous shallow wells in them indicate that their horizontal permeability is good. The major source of fluid for Southern Imperial Valley brines is the underflow from the Colorado River. This water percolates gradually into sediments and/or fractured basement rock over an area considerably larger than the anomaly itself. Heated at depth by an as yet undefined source, the liquid can rise in the high permeability fractured fault zone, convecting energy toward the surface. When a horizontal aquifer is intersected (relatively large horizontal permeability), reservoir charging will occur.

A two-dimensional mathematical model of this system is shown in Figure 1. The Mesa fault is assumed to act as a conduit for the rising hot water (Combs and Hadley, 1977). Liquid rises in the reservoir section of the fault. The presence of clays in the cap suppresses the vertical transport there. Water pushed out of the fault by the overpressure associated with convection is assumed to flow horizontally in the aquifer. Spatially uniform temperature boundary conditions are imposed on the cold cap surface and at the hot bottom boundary of the reservoir. On the lateral boundary far from the fault (H'>>L'>>ye'), the temperature distribution is assumed to be controlled by vertical conduction. A quasi-analytic theory is developed for high Rayleigh number convection of a liquid in a rigid porous medium. In this approximation liquid rises up the fault and spreads into the near region of the reservoir adiabatically. The cooling effect of the cap in the reservoir is confined to a thin layer adjacent to the interface. The layer grows with distance from the fault. In the far field, full depth of the aquifer is cooled by the surface.

The following simplifying assumptions are made in the analysis:

(i) Flow is steady.

(ii) Physical properties such as coefficient of thermal expansion, specific heat, and medium thermal conductivity are assumed constant.

(iii) Fault medium is isotropic.

(iv) Fault and aquifer are homogeneous in the x-y plane.

(v) Vertical permeability in the aquifer is zero. The presence of shaly layers, associated with the interbedding, makes the vertical transport unimportant in the global sense.

(vi) The ratio (permeability/kinematic viscosity) is a constant. This is a qualitative representation of the decrease of kinematic viscosity with depth (associated with increasing temperature) and the corresponding decrease in permeability due to compaction. In actual situations precise compensation is not achieved.

Figures 2 and 3 show the near fault and far field temperatures in the aquifer and cap at different distances away from the fault. The nondimensional parameters used in these figures are defined as below:

z = actual vertical distance/reservoir depth (L')

y = horizontal distance/reservoir depth (L')

$\hat{y}$ = horizontal distance/reservoir length in y-direction (H')

ℓ = cap thickness/reservoir depth (L')

y_e = semi-fault width/reservoir depth (L')

d = an O(1) number

λ = thermal conductivity of the cap/thermal conductivity of the aquifer

M = actual mass flow rate/reference mass flow rate

T = actual temperature/reference temperature

τ = temperature difference across the reservoir/reference temperature

R = Rayleigh number = reference convection heat transfer/reference conduction heat transfer

It can be noted that the predicted temperatures in the near field (Figure 2) are quite like that for Mesa well 8-1, 44-7, and 48-7. Far field profiles as in Figure 3 can be related to those in 5-1, 31-1, and the Republic geothermal wells. Surface heat flux ratio (near fault/far field) can be obtained from the Comb's contours (Goyal, 1978) drawn for the East Mesa area. A similar ratio can also be obtained from the Figure 4 which is plotted for the temperature gradient at the surface vs. horizontal distance from the fault. A detailed analysis of this work and the effect of the various parameters is available in Goyal (1978).

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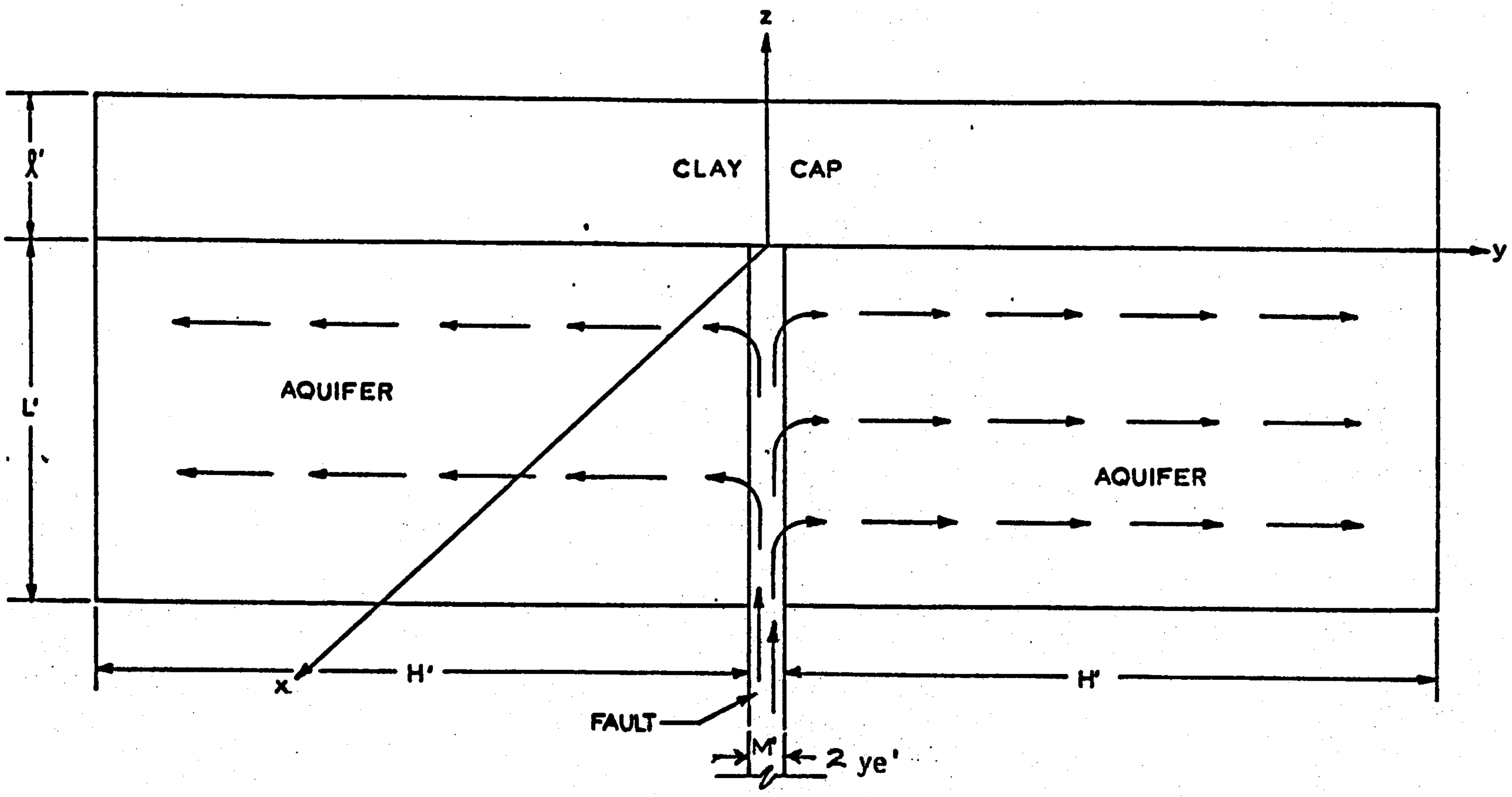
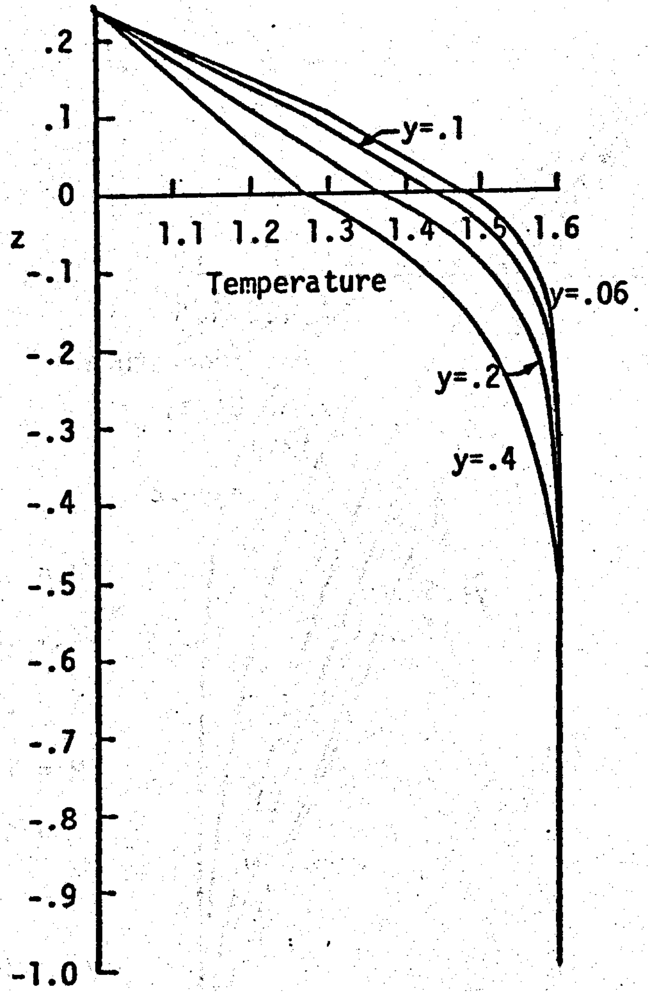


Figure 1. Mathematical Model of the East Mesa Geothermal System.



d = .32

ℓ = .24

λ = .7

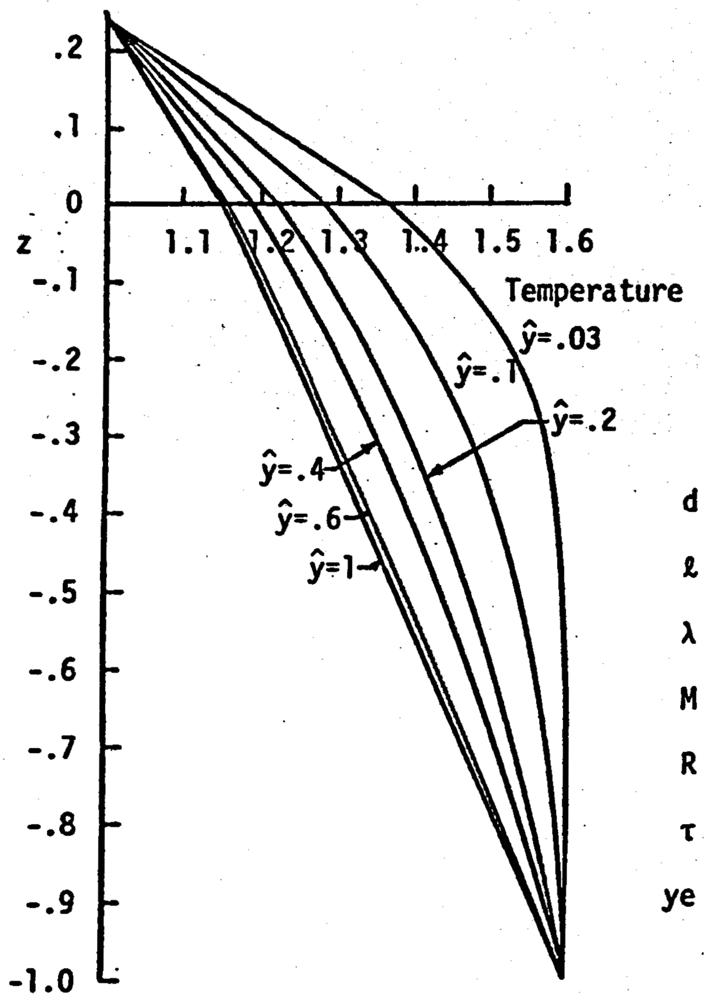
M = 1

R = 338

τ = .6

ye = .034

Figure 2. Near Fault Temperatures in the Aquifer and the Cap for Different Values of y



$d = .32$

$\ell = .24$

$\lambda = .7$

$M = 1$

$R = 338$

$\tau = .6$

$ye = .034$

Figure 3. Temperature in the Aquifer and the Clay Cap at Different Locations away from the Fault

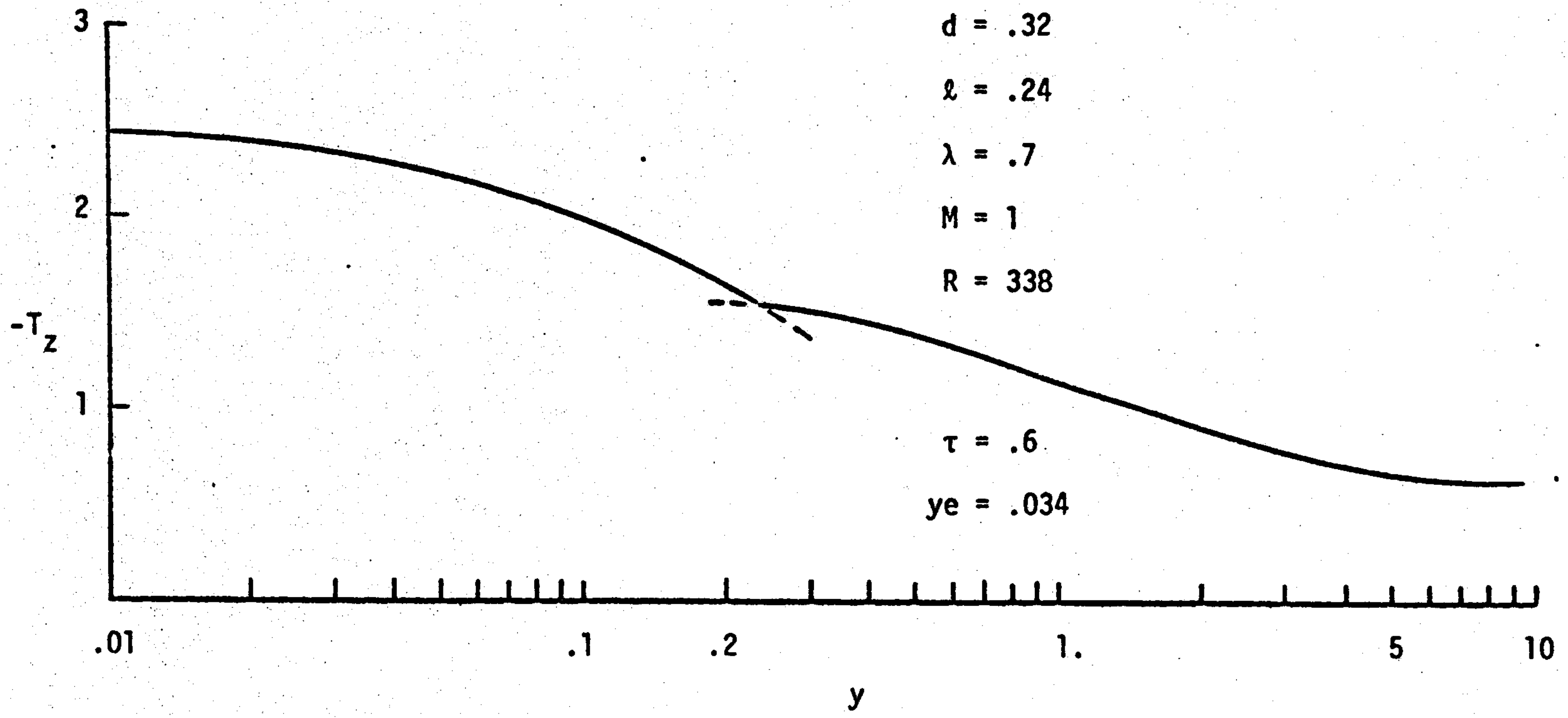


Figure 4. Surface Temperature Gradients vs. Length of the Aquifer