AN INTERFERENCE TEST IN ALFINA GEOTHERMAL FIELD (NORTHERN LATIUM, ITALY)

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A fina field is situated in central Italy near the Lake of Bolsena.[1] Its geo ogical-stratigraphical sequence is as follows:

a A thick (>500 m) Cretaceous-Eocene sedimentary series n flysch facies comprising mainly clays and marls. This flysch series forms the cap rock;

b. A Mesozoic sedimentary series, stratigraphically quite regular, of more than 400 m thickness, comprising mainly carbonates (1imestones, marly limestones and calcarenites). This series forms the geothermal aquifer, having a high permeability as a result of the presence of fractured zones.

Fig. 1 shows the location of the wells. Fig. 2 gives a cross-section of the reservoir along the A-A line shown in Fig. 1, using the geological data from wells 13, 1 BIS, 2 and 4 which lie almost on a straight line on the cross-section.

The field produces CO_2 in the highest part of the reservoir (wells ALF 1, ALF 1 BIS, ALF 13) while it produces water where the cap rock is lower (wells ALF2, ALF 4, ALF 5--Fig. 3). This fact, toget er with the various pressure and level measurement from all the wells, which wi 1 be discussed later, have led , to the schematic cross-section shown in Fig. 2 a gas cap lying over a water-table.

The temperatures found in the formations have a gradient of about 0.2°C/m in the cap rock down to the top of the reservo r; for about 400 m below that, the temperature increases slowly from 130 to 150°C.

ALF 1 BIS well produced CO_2 from the time of its explosion on 20 May 1974 to 8 September 1974 when it began carrying water. During this period the well was shut-in on various occasions to check the pressure behavior in the reservoir. At the same time the water level was recorded in ALF 2 well, which, although sterile, is in contact with the reservoir.

Pressure and Water Level Analysis

The graph shown in Fig. 4 gives the water-level versus time for ALF 2. We can see that each single production phase causes the level to decrease. The constant level seen in the control well (ALF 2) at the end of each production phase indicates that the system may be considered as a closed one at least for periods of some years. If a raph is drawn of the level decrease as a function of the quantity produced Fig. 5), then a proportional relationship appears.

By utilizing the pressure data in the gas cap and at a given depth beneath the water table in static conditions we can determine the location of the gas-water interface. It is initially 120 ± 5 m from the reservoir top.

The system is made up of water, rock and CO_2 in the gas phase and dissolved in water.

During production ALF 1 BIS produces gas, the gas and water pressures decrease, part of the CO_2 dissolved in water passes into the gas phase, the gas, water and rock expand as a consequence of the pressure decrease and the gas-water interface rises.

The rise in the interface was deduced from the fact that the gas pressure decrease was greater than that of the water.

At this point we might consider the variations in volume of the system as a result of the pressure decreases which, in their turn, are a result of the gas extraction.

The volume of gas extracted in average reservoir conditions can be expressed as

$$V_e = - \Delta p_w V_w (c_w + c_f) - \Delta p_g V_g (c_g + c_f) - \Delta p_g V_w A \qquad (1)$$

where c_w, c_f and c_g are the compressibility values of water, rock and gas respectively (atm^{-1}).

V_w and V_g are the volumes in reservoir conditions for the water and gas contents of our system (m^3).

V_e is the gas volume extracted in reservoir conditions (m^3).

Δp_w, Δp_g are the pressure variations of the liquid and gas phases (atm). A is the volume of the gas dissolved in water per unit of water volume (both in reservoir conditions) for a unit pressure rise ($atm^{-1} \frac{m^3\ CO_2}{m^3 H_2O}$)

Introducing the experimental values equation 1 becomes

$$a V_w + b V_g = V_e \qquad (2)$$

where both V_w and V_g are the unknown quantities.

We can find only a range of variations for the unknown gas and water volumes.

The maximum value for V_w is obtained for $V_g = 0$.

$$V_w \leq \frac{1}{a} V_e$$

The maximum gas value can be estimated letting $V_w = 0$.

$$V_g \leq \frac{1}{b} V_e$$

The drilling data for ALF 2 well and an estimation of the area permeated by water and gas have led us to suppose that

$$V_w \geq 6\, V_g \quad \text{and from (2)} \quad V_w \geq \frac{6}{6a + b}\, V_e\,, \quad V_g \leq \frac{1}{6a + b}\, V_e$$

Combining all the preceding inequalities we can define a possible range for V_w and V_g as:

$$\frac{6}{6a + b} \cdot V_e \leq V_w \leq \frac{1}{a}\, V_e \qquad 0 < V_g \leq \frac{1}{6a + b}\, V_e$$

The ratio between minimum and maximum values obtained for V_w is less than 2.

Transient Analysis

The level transients in ALF 2 caused by two production periods from ALF 1 BIS were studied.

First of all, it must be noted that the common transient analysis assumptions were not valid.

1. Our reservoir is not homogeneous nor isotropic but fractured with an unknown permeability and porosity distribution.

2. Two completely separate phases are present: one phase is produced, but the pressure is controlled in the other. Reservoir compressibility and viscosity are unknown factors.

3. The producing well does not penetrate the reservoir and the flow pattern is almost certainly not radial.

4. The bottom and lateral boundaries are not known.

However, we tried transient analysis methods for homogeneous, isotropic medium and single phase fluid[2] as a first step and we hope that further discussion will help us to find more appropriate models.

A first glance shows that an early transient period was followed by typical pseudo steady-state.

The line source solution seems appropriate in the early period (≈50 hours) while the pseudo steady-state conditions are apparent after 100 hours, showing evidence of a closed boundary.

Dimensionless pressure p_D versus dimensionless time t_{DA} were generated for a rectangular reservoir with impermeable walls.

A good match (Fig. 6) was obtained for the rectangle shown in the map (Fig. 7) for the first production period.

The data for the second production period are not in agreement with those frm the first period. Therefore a good match is not possible with the same type curve.

A rise in the water table may be responsible for this discrepancy. The matchpoint gives the following values:

$$\frac{k}{\phi \mu c} = 0.7 \text{ m}^2/\text{sec}$$

$$\frac{hk}{\mu} = 3500 \text{ darcy-meter/cp}$$

References

1. R. Cataldi, M. Rendina, 1973, "Recent discovery of a new geothermal field in Italy: Alfina." Geothermics, Vol. 2, No. 3-4, pp. 106-116.

2. C. S. Matthews, D. G. Russel, "Pressure build-up and flow tests in wells." Society of Petroleum Engineers of AIME, 1967.

Nomenclature

A = volume of the gas dissolved in water per unit of water volume both in reservoir conditions) for a unit gas pressure rise (atm^{-1})

a = dimensionless constant

b = dimensionless constant

c = compressibility (atm^{-1})

c_f = effective compressibility of the formation. Relative change in pore volume per unit change in pressure (atm^{-1})

c_g = gas compressibility (atm^{-1})

c_w = water compressibility (atm^{-1})

h = formation thickness (m)

k = permeability (darcy)

p_D = dimensionless pressure drop

Δp_g = change in gas pressure due to gas extraction (atm)

Δp_w = change in water pressure at a certain depth due to gas extraction (atm)

t_{DA} = area-based dimensionless time

V_e = gas volume extracted measured in reservoir conditions (m^3)

V_g = gas volume in the reservoir (m^3) in reservoir conditions

V_w = water volume in the reservoir (m^3) in reservoir conditions

ϕ = porosity

μ = viscosity (cp)

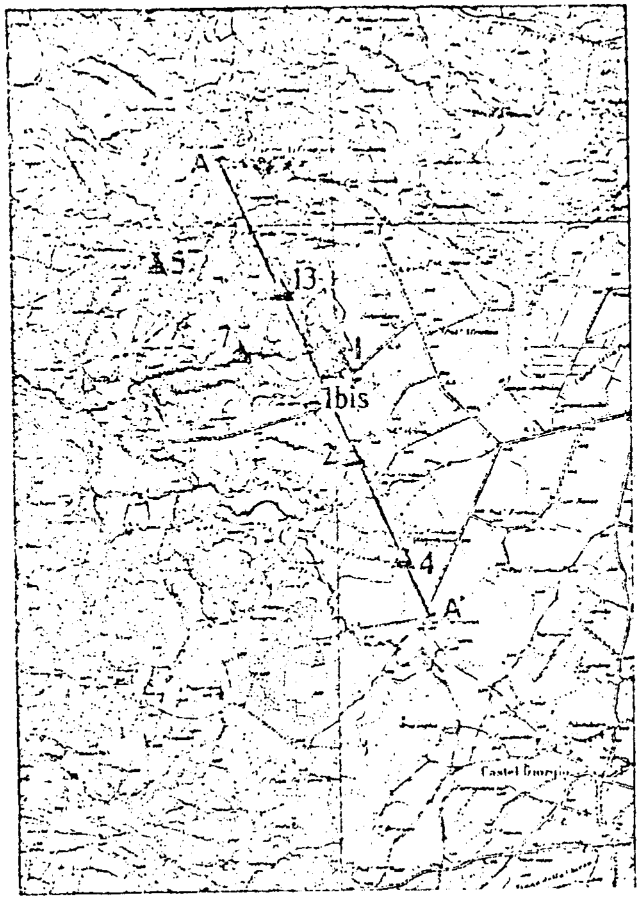

Fig.1 — LOCATION OF THE WELLS IN ALFINA REGION

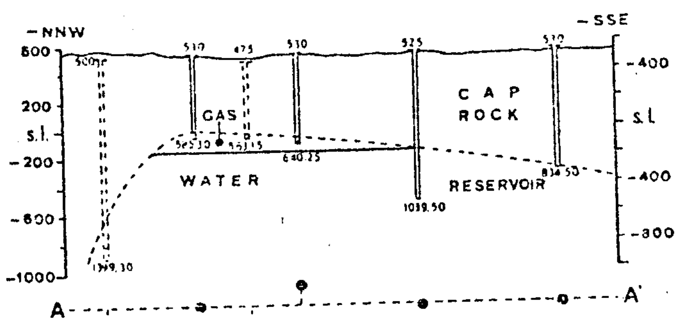

Fig. 2 – GEOLOGICAL CROSS SECTION

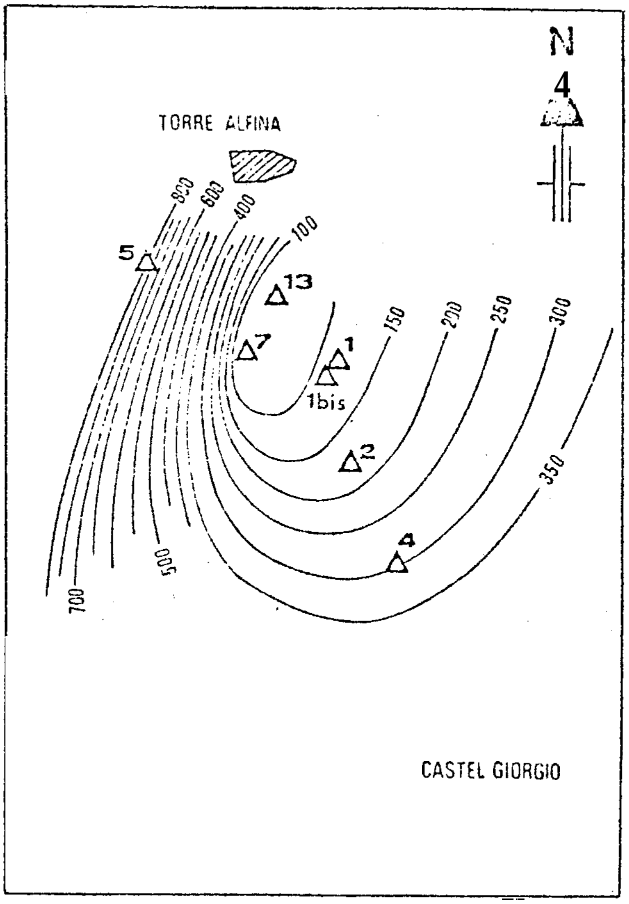

Fig 3 - CONTOUR LINES OF THE RESERVOIR TOP

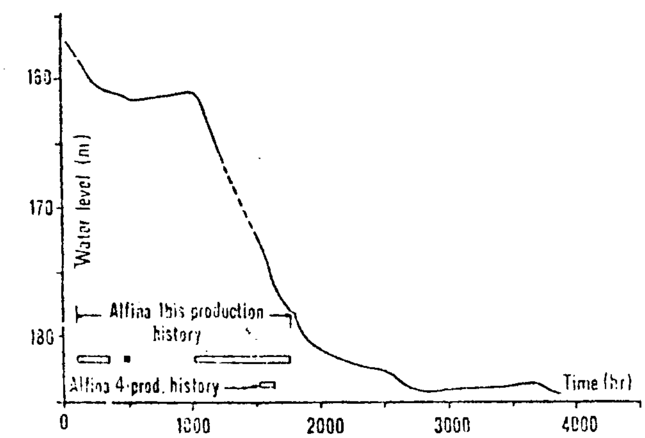

FIG.4-WATER LEVEL IN.ALF2 WELL Vs TIME

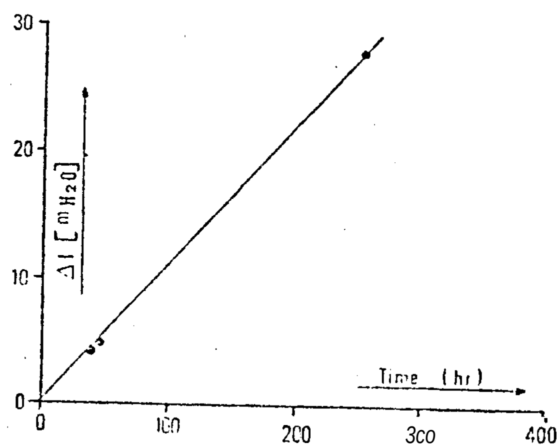

FIG. 5 -- DRAWDOWN IN ALF2 WELL Vs ALF1bis CUMULATIVE PRODUCTION

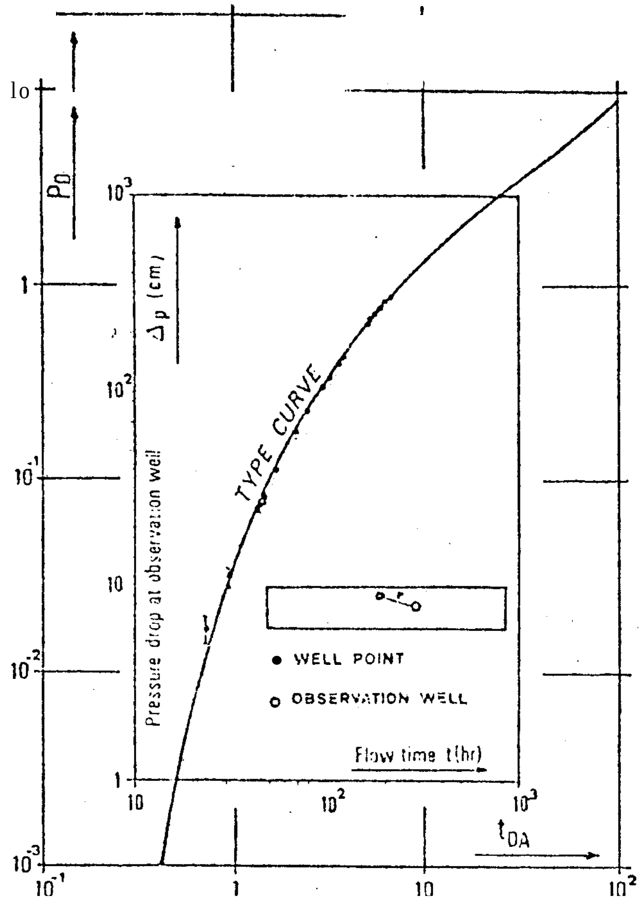

Fig.6 Type curve match lor the closed rectangle considered

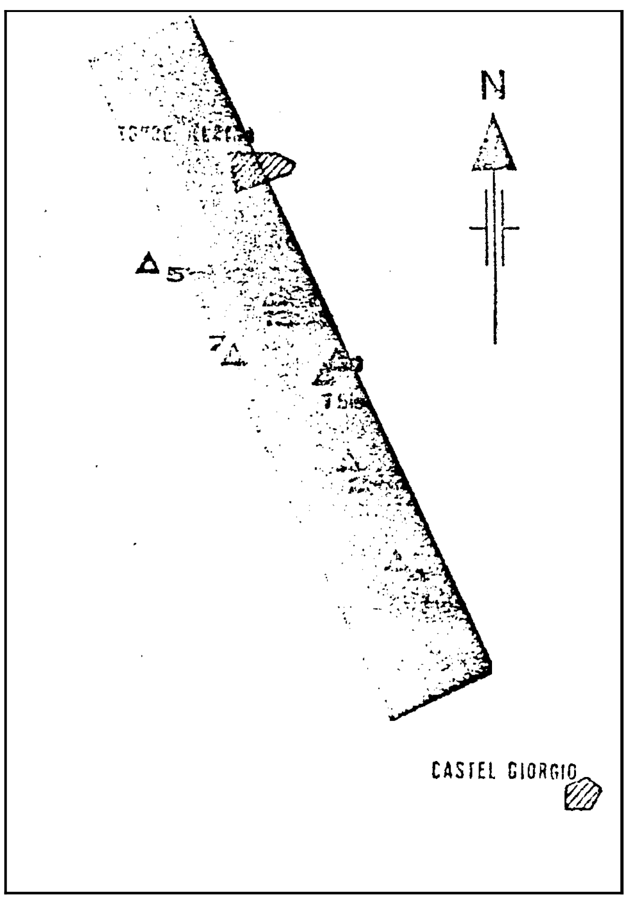

FIG.7– GEOMETRIC SHAPE CONSIDERED FOR THE RESERVOIR