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LOS AZUFRES : THE INITIAL RESPONSE OF A FRACTURED HYDROTHERMAL SYSTEM TO EXPLOITATION

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ABSTRACT

Los Azufres is the first mexican geothermal field that produces electricity from an intensely fractured volcanic hydrothermal system. A capacity of 90 MWe has been installed and the reservoir is being monitored to detect its early response to steam production. Field data, linked to reservoir engineering studies and empirical observations, provide a first draft of a quantitative, integrated conceptual field's model. Presented herein is a brief, general, updated survey of the Los Azufres reservoir, subject to a concentrate mass extraction. A resume of the actual reservoir characteristics compared with field's natural pre-production state is made. At local scales, some important chemical and thermodynamical parameters start to exhibit temporal trends. Global mass and energy balances with reinjection are developed for this system.

INTRODUCTION

The Los Azufres geothermal reservoir was discovered in 1972. It is a volcanic hydrothermal system intensely fractured and faulted located in the western part of the Mexican Neo-Volcanic Axis at an elevation of about 2800 masl. The field is sited in a sierra, some 400 meters above the surrounding valleys. Its total explored area (geology, geophysics, geochemistry) covers about 60 km^2 (Fig. 1). The first well Az-1 has been drilled successfully by the Comision Federal de Electricidad (CFE) in 1976. At the present time about 60 wells have been completed and a capacity of 90 MWe is installed. The wellheads elevation vary between 2700 and 3200 masl. Los Azufres is the first Mexican geothermal field that generates electricity from fluids saturating volcanic rocks and is the second in importance in Mexico, after Cerro Prieto. In spite of a large amount of available information, a careful analysis of pressure and temperature logs, non-condensible gases and production parameters showed, until 1987, that there were very few temporal trends in the data. This suggested that the hydrothermal system as a whole was still in a natural quasi-steady state and that the observed changes corresponded to very local effects in some of the wells connected to wellhead generators (Kruger et al, 1985; Suárez et al, 1986). Since November, 1988 the southern sector of Los Azufres is submited to a concentrate rate of mass extraction. At this stage of field development it is important to compare quantitatively the natural thermodynamic state of the reservoir and its initial response to an increasing rate of exploitation. This paper is a resume of observed behavior and it represents multidisciplinary studies in progress.

THE NATURAL STATE OF THE RESERVOIR

For the last 14 years a large amount of data has been gathered and a quantitative integrated conceptual model of the field is being developed based on data from mineralogical, geochemical, geophysical and reservoir engineering studies. The system consists of a complex andesitic layers series of different textures and rhyolites in the upper levels. The distribution of hydrothermal alteration minerals suggests a geometry for the field corresponding to a main reservoir at depth discharging ascending fluids through convective circulation volumes or cells. These cells are closely related to two highly fractured sub-systems which define two connected geothermal zones identified at Los Azufres: Maritaro in the north and Tejamaniles in the south, (Gutiérrez and Aumento 1982; De La Cruz 1984; Cathelineau et al 1985; Viggiano 1987). A central zone of high resistivity separates the northern and southern portions of the field. In this zone, at shallow levels, the hydrothermal alteration is very low; but deeper (below 1800 m.) there is a continuity in the alteration linking Maritaro with Tejamaniles. This is a preliminary proof of the existence of a deep aquifer underlying the total area of the reservoir. The field's abnormal geothermal gradient generates a broad, central dome structure which is deformed by hydrothermal alteration brought out by ascending fluids and creating two main zones of alteration and discharge. In Tejamaniles this circulation zone is narrow, bringing out fumaroles, boiling mud pools and steaming ground. These surface manifestations are scattered between the Agua Fria and Los Azufres faults (Fig. 2). There is no isotopic evidence of mixture of meteoric water or shallow groundwater with geothermal fluid, therefore a caprock must exist and the recharge, if any, may be lateral and deep.

Enthalpy and chemical data show that boiling occurs within the reservoir (Nieva et al 1983). The chemical composition of the feeding fluid is not the same in all the wells of the field, suggesting that there are different production sections at several levels. The CO_2 mass fraction in the produced fluids varies between 0.2 % (well Az-4, north) and 8.5 % (well Az-34, south) in vapor discharged at a separation pressure of 10 bar (Quijano et al 1987). The highest CO_2 content has been found in shallow wells with high steam quality, located near the Puentecillas fault. In this area there is a CO_2 concentration gradient, positive in W-E direction. Chemical data (Quijano et al 1987; Nieva et al 1987) show that the concentration of volatile components in the fluid such as CO_2 and deuterium decreases with depth, while concentration of non-volatile components such as oxigen-18 and chloride increases. Figure 3 shows the vertical distribution of mass fraction of CO_2 dissolved in liquid and vapor, as calculated bv Nieva (1987) from data of several Los Azufres wells. This distribution can be interpreted as resulting from upward flow and partial steam condensation with heat release. The same mechanism may explain the observed distortion of isothermal curves: the negative slope of the curve could correspond to a 'cold' path of falling liquid, while the positive slope could be the 'hot' path of ascending steam. This image agrees with

FIGURE No. 1 LOCATION OF LOS AZUFRES.

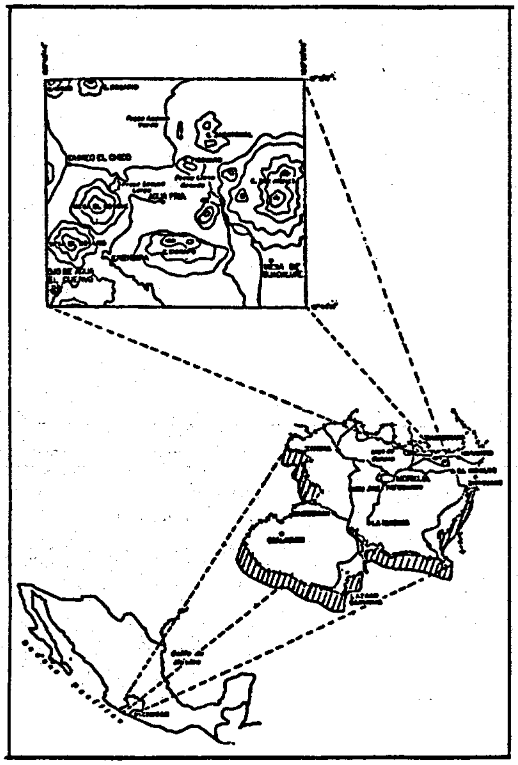
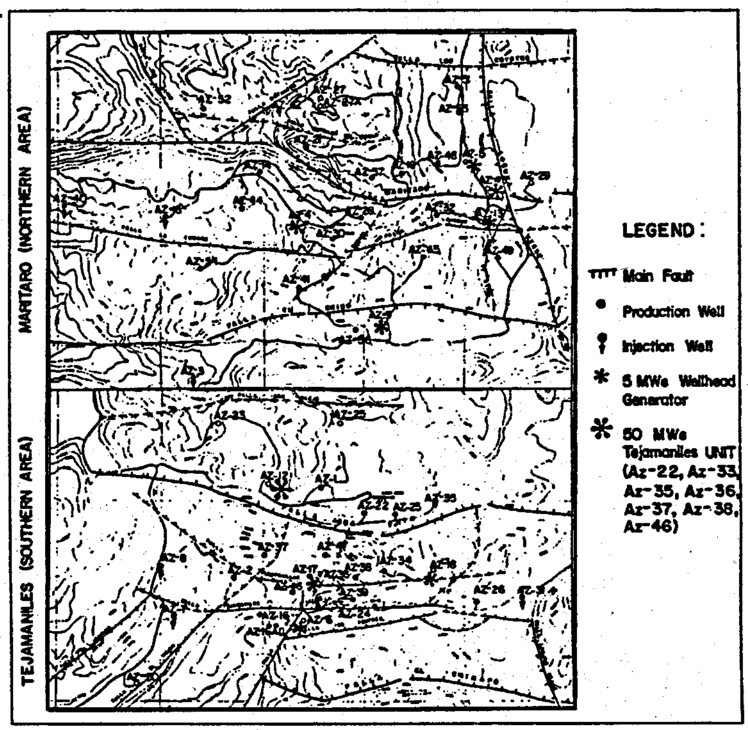


FIGURE No. 2 MAP OF THE "LOS AZUFRES" GEOTHERMAL FIELD



mineralogical models. Pressure and temperature profiles measured in several Maritaro and Tejamaniles wells, are exhibited in Figures 4 to 7. These profiles clearly show that between 1600 and 2250 masl the pressure and temperature gradients,in the southern sector, are small, indicating a nearly vaporstatic distribution of thermodynamic conditions. On the other hand, between 0 and 1550 masl the thermodynamic profiles correspond to boiling hydrostatic conditions. While in the northern subarea the temperature vertical profile seems to be more erratically distributed.

A synthesis of petrophysical measurements performed in 24 drilling cores of 17 wells are presented in Table 1 (Contreras et al 1988). The reported properties are: total density of dry rock, effective porosity, absolute matrix permeability (Kabs,microdarcy), permeability estimated by pressure tests (Kpres,millidarcy), specific heat, thermal conductivity and difussivity. The vertical distribution of these properties (Figs. 8, 9 and 10) clearly show that porosity decreases exponentially with depth, while rock density and thermal conductivity increase quadratically with depth. In horizontal planes the same rock properties appear randomly distributed.

PREVIOUS STEADY STATE NUMERICAL STUDIES

Puentecillas, a main fault in Tejamaniles, has wells with the highest steam quality in the field. The measured pressure-temperature gradients are small, however steam, gas and heat are discharged at the field's surface. This mass and energy transport can be explained by a convective two-phase process (Pruess et al., 1987; Iglesias et al., 1986) in which heat is transported from depth by ascending steam and condensing at the top expelling upwards its internal energy; condensed liquid descends to the bottom and evaporates again. In order to understand the steady state behavior of the Los Azufres reservoir a number of numerical studies have been performed under a cooperative CFE-DOE agreement (Suárez et al., 1989). The main scope of that work was to numerically model a portion of the Puentecillas fault in Tejamaniles. Solutions were presented for a 'natural state' balanced liquid-vapor-CO_2 with heat injection and different boundary conditions: heat injection into a sealed system, heat and fluid (H_2O + CO_2) injection with discharge through small cracks and fractures in the caprock, heat and fluid injection without discharge.

The calculations were performed with MULKOM, for a water-carbon dioxide equation of state (Pruess 1988). Our results were as follows: The supply of heat diminishes the bottom fluid density. Buoyancy and gravity together originate an upward mass movement. The ascending fluid tends to expand loosing pressure and temperature by incrementing

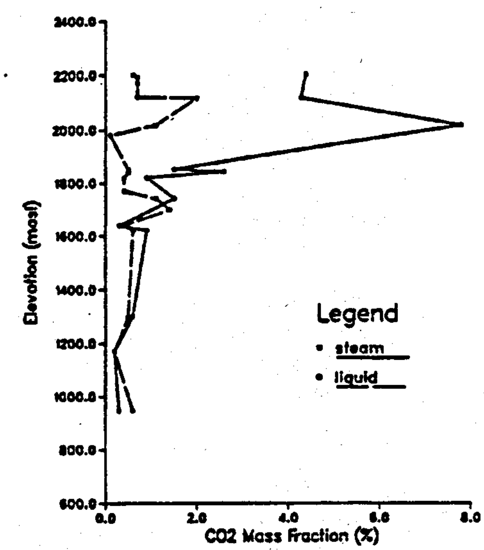


Figure 3. CO_2 (mass fraction) profile at Los Azufres.

FIGURE No.4 LOS AZUFRES, MARITARO
SPATIAL DISTRIBUTION OF PRESSURE
PROJECTED ALONG AZ-10 COORDINATES

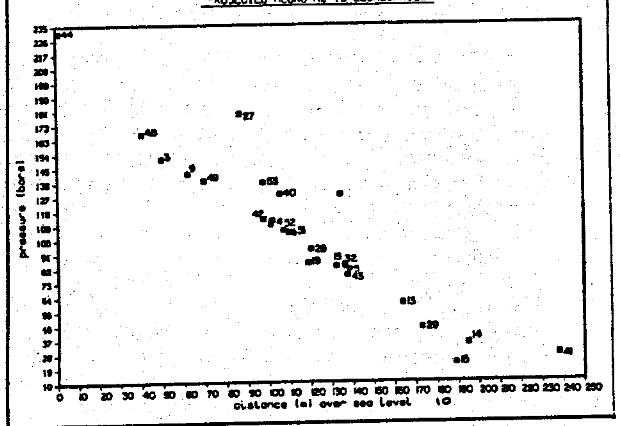


FIGURE No.5 LOS AZUFRES, MARITARO.
SPATIAL DISTRIBUTION OF TEMPERATURE
PROJECTED ALONG AZ-10 COORDINATES

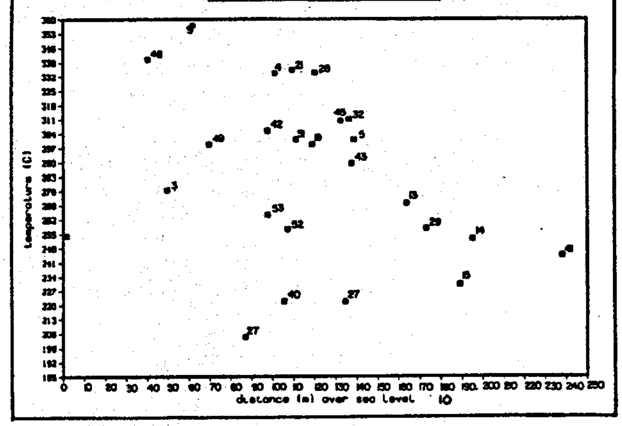


FIGURE No.6 LOS AZUFRES, TEJAMANILES.
SPATIAL DISTRIBUTION OF PRESSURE
PROJECTED ALONG AZ-10 COORDINATES

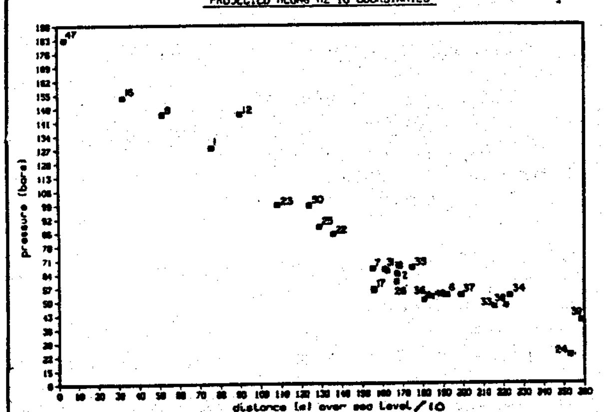
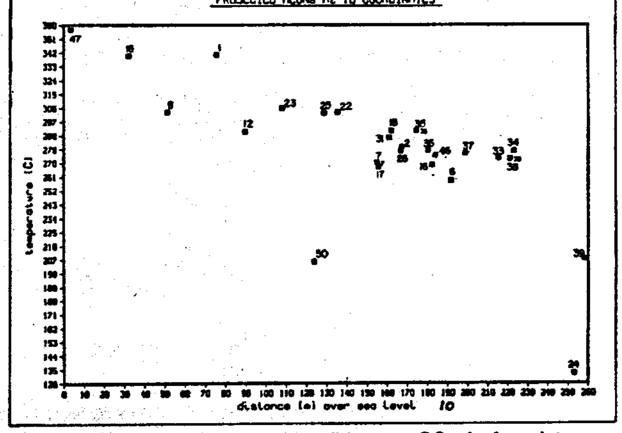


FIGURE No.7 LOS AZUFRES, TEJAMANILES.
SPATIAL DISTRIBUTION OF TEMPERATURE
PROJECTED ALONG AZ-10 COORDINATES



steam quality. In the middle of the fault steam saturation goes from 10% to 62%, keeping this value until the caprock; for a total pressure of 26.9 bar, a temperature of 213.3 C and a CO_2 partial pressure of 6.5 bar, steam condenses suddenly, delivering its latent heat of vaporisation which is transported by conduction through the remaining part of the caprock and to the atmosphere. This condensation zone corresponds to a rock matrix volume having different petrophysical properties. At the same time the condensed liquid moves downward under the action of gravity, descending to the bottom and

TABLE 1.- ROCK PARAMETERS IN LOS AZUFRES RESERVOIR

(Coordiates X, Y are relative to the Mercator coordinates of Well Az-E10 : X = 322,000.3, Y = 2,186,615.7, Z in masl.)

WELL	X (m)	Y (m)	Z (m)	ROCK DENSITY (gr/cm³)	POROSITY (%)	KABS (mcd)	KPRES (md)	KTER (W/m/C)
Az-001	3613.6	2539.1	2856.5	2.72	2.6	1.0		
Az-003	1304.3	3998.5	2788.5	2.30	14.8	3.5		1.68
Az-003	1304.3	3998.5	2788.5	2.56	13.2	177.3	14.3	1.84
Az-003	1304.3	3998.5	2788.5	2.74	2.1	1.3		1.99
Az-004	2422.1	5612.9	2865.0	2.43	12.6	1.8		1.56
Az-005	3987.3	6206.9	2900.0	2.08	23.2	1.7		1.17
Az-005	3987.3	6206.9	2900.0	2.38	11.9	151.3		
Az-008	2023.9	1737.2	2797.0	2.59	7.8	123.5	42.3	2.34
Az-009	3209.6	4616.7	2941.0	2.66	2.6	2224.0		
Az-010	111.2	159.1	2654.0	2.66	4.7	1.3		
Az-019	3351.9	6103.6	2839.5	2.29	15.5	15.0		1.97
Az-020	1332.9	-1343.6	2500.0	2.26	13.1	1.8		1.58
Az-020	1332.9	-1343.6	2500.0	2.66	4.7	1.5		1.71
Az-022	4030.3	2262.9	2856.0	2.45	9.9	1.7	56.0	2.17
Az-025	3811.4	3169.8	2888.0	2.30	14.5	1.8		1.75
Az-026	5138.2	1404.9	2909.0	2.61	2.6	2.0		2.20
Az-026	5138.2	1404.9	2909.0	2.41	10.4	401.0	167.3	1.55
Az-029	4635.1	6016.0	2904.0	2.07	20.1	41.0		1.05
Az-029	4635.1	6016.0	2904.0	2.81	0.7	0.0		
Az-041	2369.5	4931.7	3004.5	2.36	16.3	1.3		
Az-046	3296.0	1480.8	2808.5	2.51	7.4	0.0	140.0	
Az-047	3673.0	1843.5	2883.8	2.76	2.1	2.0	(Az-36)	1.89
Az-048	3714.4	6199.0	2921.2	2.84	1.0	0.0		
Az-050	1793.1	552.4	2730.0	2.47	8.9	10.0		1.52

Thermal Diffusion = 0.0066 cm^2/seg (Well Az-19) at 250 °C and 80 bar
Rock Specific Heat = 0.278 Cal/gr/°C

boiling again. The non-condensible gas CO_2 is found to accumulate near the reservoir top and in the caprock. In this region temperature gradient is almost conductive. Binary diffusion tends to increase CO_2 partial pressure to some depth in the fault beneath the condensation zone.

THE UNSTEADY STATE OF THE FIELD

Since August 1982, five wellhead units (5 MWe each) were installed at Los Azufres, two in Maritaro and three in Tejamaniles (Fig. 2); in November 1988 a 50 MWe unit was installed in Tejamaniles. These plants have been in continuous operation with a total mass extraction indicated in Table 2. The present pressure and temperature profiles of the reservoir cannot be distinguished from the initial ones, shown in Figures 4 to 7. At this moment a series of P-T logs are being performed; some partial results do not show any particular change. The system as a whole, seems to be, from a thermodynamic point of view, in a quasi-steady state.

The geochemical behavior of this field is better understood by regarding both zones as separated entities. In the southern sector the wells Az-6, Az-16D and Az-17 have a rich history that shows an interesting chemical evolution. In this region there is a second group of wells (Az-2, 16, 33, 37 and 46) having less information because they are younger or poor productors. Data from both groups show that chlorides in liquid, Argon and Nitrogen in steam have been growing since June 1986; this effect probably has a close relation with the injection of fluids into the reservoir and with multiple evaporation of the injected water within the production zones. On the other hand, the molar ratio N_2/Ar has been decreasing with time reaching, in some cases, the same value as in the atmosphere (83.6). This is probably a consequence of the continuous injection of fluid into wells Az-7 and Az-8 (Table 3). The air mixed with the fluid could flow through the fractures and arrive to the production zone. This effect seems to extend radially to wells Az-16, 33, 37 and 46 having well Az-16D located in the center.

In the northern sector the wells Az-5 and Az-13 show a remarquable constant behavior; they have being producing almost continuously since 1982. Their N_2 content varies between 0.62 % and 0.48 % in weight. On the other hand, gas content has been slightly decreasing. Figures 13 to 24 synthesize these comportments. The production history of the field is summarized in Figures 25 to 57.

GEOTHERMAL RESERVOIR EVALUATION

Several preliminary evaluation studies have been done by CFE and by other organizations, but have not been published. The main purpose of those studies was to estimate the energy and mass capacity of the field and its longevity under exploitation. The general conclusion was that the reservoir may have the capacity to generate 110 MWe for 20 years.

RESERVOIR CHARACTERISTICS.- The porosity of the reservoir varies between 1% and 24%; the matrix permeability is very low (between 0 and 2 microdarcies), but some pressure tests have shown permeabilities up to 180 md. On the other hand, total lost circulation occur very often during drilling and related to fractured networks around the faults (Figs. 11 and 12). This indicates an extremely high permeability acting by a multiporosity mechanism. For example a drilled well presenting total lost circulation at 1500 m depth, its mud column (viscosity of 20 cp, density of 1.1 g/cm^3) exerts a bottom pressure gradient equal to 170 bar/m, producing a mud flow into the formation at a linear velocity of about 0.08 m/seg. This corresponds to an effective permeability of about 100 darcy. Los Azufres may be visualized as a discontinuous volume of fractured andesites, intersected by several high permeability faults, with very little permeability in the block matrix and fractured meshes around faults. The permeability is also very low at the top and bottom of the reservoir, but the system permits the communication to the surface by small open conduits (cracks) through the caprock, which is quasi-sealed.

VOLUMETRIC ANALYSIS

The calculation of the Los Azufres size is hypothetical because its real areal extent is unknown. But on the basis of

Figure 8. LOS AZUFRES POROSITY DISTRIBUTION

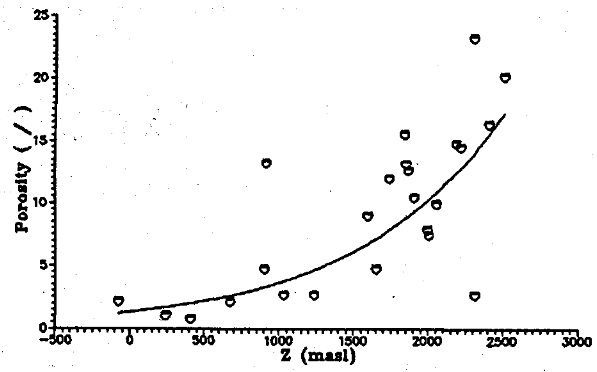


Figure 9. LOS AZUFRES ROCK DENSITY DISTRIBUTION

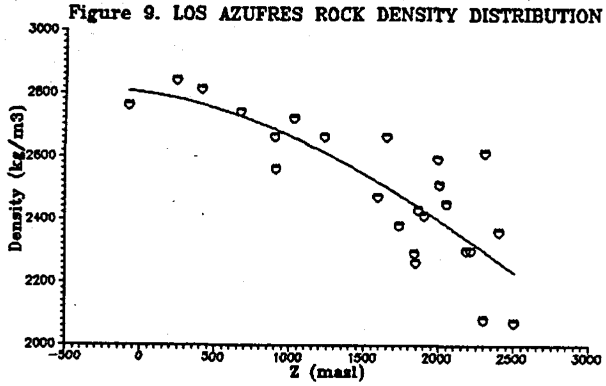


Figure 10. LOS AZUFRES THERMAL CONDUCTIVITY

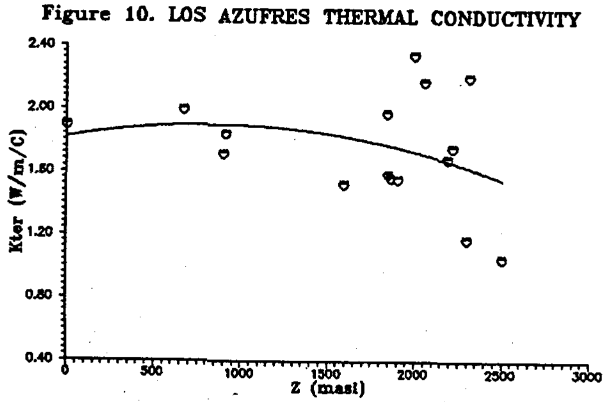


TABLE 2.- LOS AZUFRES PRODUCTION HISTORY.

PLANT	Qp (T/h)	PERIOD	TOTAL MASS EXTRACTED (T)
portable generators			
North	330	Aug. 82 - Dec. 89	21,423,600
South	180	Aug. 82 - Dec. 87	8,532,000
	270	Jan. 88 - Dec. 89	4,730,400
Tejamaniles Unit	665	Nov. 88 - Dec. 89	6,783,000

Qp(North) = 21,423,600 T, Qp(South) = 20,045,400, Qp(Total) = 41,469,000

TABLE 3.- LOS AZUFRES INJECTION HISTORY

FLUID FROM	TO WELL	Qi (T/h)	PERIOD	TOTAL MASS INJECTED (T)
NORTH				
Az- 5				
Az-13	Az-15	105	Aug. 82 - Mar. 84	1,524,600
Az-19		70	Apr. 84 - Aug. 87	2,091,600
Az-28	Az-15	30	Mar. 84 - Dec. 84	219,600
Az- 5				
Az-13	Az-40	100	Jul. 83 - Aug. 87	3,648,000
Prod. Tests		190	Sep. 87 - Dec. 89	3,876,000
Az- 9	Az-3	35	Feb. 88 - Dec. 89	588,000
SOUTH				
Az- 6				
Az-16D				
Az-17	Az- 7	134	Aug. 82 - Nov. 88	7,428,960
Prod. Tests				
Az-18	Az-31	60	Nov. 87 - Dec. 89	1,137,600
Az-22	Az- 8	80	Nov. 88 - Dec. 89	816,000
Az-33	Az- 7	15	Nov. 88 - Dec. 89	153,000
Az-46	Az- 7	30	Nov. 88 - Dec. 89	306,000
Cooling Tower	Az- 8	35	Nov. 88 - Dec. 89	357,000

Qi(North) = 11,947,800 T., Qi(South) = 10,198,560 T., Qi(Total) = 22,146,360 T.

Figure 11. TEJAMANILES PERMEABILITY DISTRIBUTION

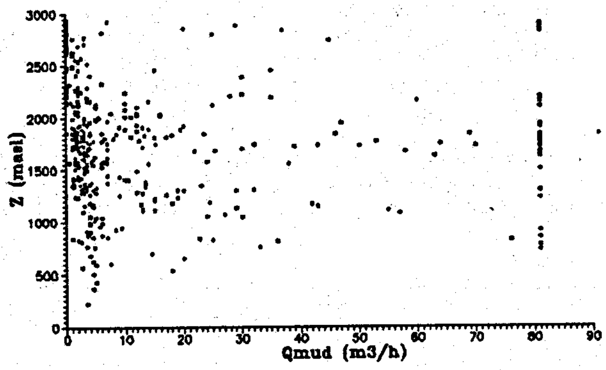
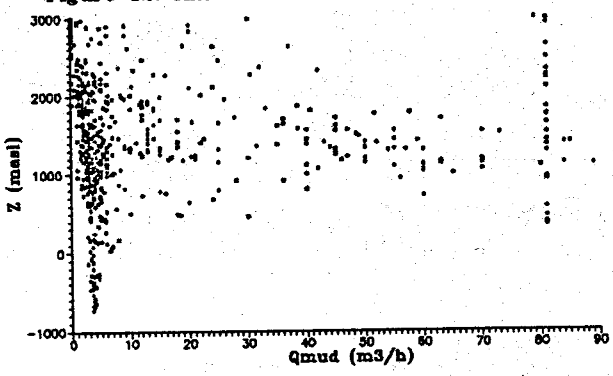


Figure 12. MARITARO PERMEABILITY DISTRIBUTION



geological and geophysical data, we have designed a simple geothermal model for this reservoir in order to estimate its reserves. Mineralogical and geophysical models suggest that the reservoir vertical extension goes from 500 masl to 2600 masl; on this basis, some years ago the mass and energy capacities of both sectors were computed (Suárez and Jaimes 1985; Suárez 1986), first by volumetric models and second with a two-phase, tridimensional simulator (Pruess, 1988). The results were as follows:

TEJAMANILES EVALUATION. The Tejamaniles sector contains initially about 930 million tons of fluid; it has an area equal to 11.5 Km^2 and a thickness of 1.8 Km. This rock-fluid volume contains 2.E16 KJ of thermal energy, 5 % belonging to the fluid.

MARITARO EVALUATION. Having an area of 20 Km^2 and a thickness equal to 2.1 Km, the Maritaro sector contains about 1822 million tons of water and 3.4 E16 KJ of internal energy, 7.6 % belonging to the fluid.

MASS BALANCE. From Tables 2 and 3 we obtain:

Maritaro:
Qp - Qi = 9,475,800 = 0.5 % of the fluid mass in place.

Tejamaniles:
Qp - Qi = 9,846,840 = 1.1 % of the fluid mass in place.

SUMMARY AND CONCLUSIONS

We have presented a simplified but general survey of the Los Azufres geothermal field. Geochemical and mineralogical models, linked with field observations and previous numerical models provide the draft of a preliminary conceptual model for the hydrothermal system. This can be visualized as formed by a deep main aquifer embedded in fractured porous rock of igneous origin. A deeper central dome structure, located under the reservoir, has been formed by magmatic circulation, conducting heat through volcanic intrusions, and originating the reservoir. There is a co-existence of vapor-dominated and liquid-dominated heat pipe conditions at different depths.

The initial response of the field to exploitation is primarily reflected by geochemical changes. The production history of both sectors show only small local alterations; this demonstrates that the system as a whole seems to be in a quasi-steady state.

ACKNOWLEDGEMENTS

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REFERENCES.

CATHELINEAU M., OLIVER R., NIEVA D., GARFIAS A.,1985. 'Mineralogy and distribution of Hydrothermal Mineral Zones in Los Azufres (Mexico) Geothermal Field'. Geothermics, Vol. 14 No.1, pp. 49-57.

CONTRERAS E.,DOMINGUEZ B.,IGLESIAS E.,GARCIA A.,HUITRON R., 1988. 'Compendio de Resultados de Mediciones Petrofisicas en Nucleos de Perforacion del Campo Geotermico de Los Azufres,Mich.', Geotermia-Revista Mexicana de Geoenergia, Vol.4 No.2, pp. 79-105.

DE LA CRUZ V.,1984. 'Modelo Geotermico Conceptual del Campo de LosAzufres,Mich.'. Dpt. Exploracion-CFE, Internal Report GG1184.

GUTIERREZ N.,AUMENTO F. 1982.'The Los Azufres (Mich.,Mexico) Geothermal Field'. 26th Inter. Geological Congress, J. Hydrology 56, pp.137-162.

IGLESIAS E.,ARELLANO V.,ORTIZ J. (1986). 'Natural Vertical Flow in the Los Azufres, Mexico, Geothermal Reservoir'. 11th Workshop on Geoth. Res. Engineering, Proceedings (pp.237_243), Stanford University.

KRUGER P.,SEMPRINI L.,VERMA S.,BARRAGAN R.,MOLINAR R.,ARAGON A., ORTIZ J., MIRANDA C.,GARFIAS A.,GALLARDO M., 1985. 'Initial Chemical and Reservoir Conditions at Los Azufres Wellhead Power Plant Startup'. 10th Workshop on Geothermal Reservoir Engineering, Stanford Ca., pp. 219-226.

NIEVA D.,QUIJANO J.,GARFIAS A.,BARRAGAN R.,LAREDO F.,1983.'Heterogeneity of the Liquid Phase, and Vapor Separation in Los Azufres (Mexico) Geothermal Reservoir'. 9th Workshop on Geothermal Reservoir Engineering, Stanford Ca. pp. 253-260.

NIEVA D.,VERMA M.,SANTOYO E.,BARRAGAN R.,PORTUGAL E.,ORTIZ,J.,QUIJANO J. 1987. 'Estructura Hidrologica del Yacimiento de Los Azufres'. International Symposium on Development and Exploitation of Geothermal Resources. Cuernavaca, Mor., Proceedings, pp. 202-213.

PRUESS K.,CELATI R.,CALORE C.,CAPPETTI G., 1987. 'On Fluid and Heat Transfer in Deep Zones of Vapor-Dominated Geothermal Reservoirs'. 12thWorkshop on Geothermal Reservoir Engineering, Stanford

PRUESS K., 1988. 'SHAFT, MULKOM, THOUGH: A Set of Numerical Simulators for Multiphase Fluid and Heat Flow.' Geotermia-Revista Mexicana de Geoenergia, Vol.4, No.1, pp. 185-202.

QUIJANO J.,GALLARDO M.,LAREDO F., TELLO M.,PEREZ E.,MORENO J., 1987.'Modelo Geoquimico de los Fluidos del Campo Geotermico de Los Azufres,Mich.'. Dpto. Exploracion-CFE, Internal Report 6-87.

SUAREZ C.,JAIMES G. 1985. 'Ingenieria Basica y Evaluacion Preliminar del Sector Tejamaniles (50 MW)'.,Cap. VI del Anteproyecto Tejamaniles, Dpt. Evaluacion-CFE, Internal Report 1385-026.

SUAREZ C., 1986. 'Ingenieria Basica y Evaluacion Preliminar del Sector Maritaro (90 MW)'. Cap. II del Anteproyecto Maritaro, Dpt. Evaluacion-CFE, Internal Report 1386-024.

SUAREZ C.,ESTRADA R.,PRECIADO A.,HERNANDEZ J., 1986. 'Comportamiento de Pozos de Los Azufres Durante la Operacion de Cinco Turbogeneradores Moviles. Periodo: Octubre 1982-Julio 1986.' Dpto. Evaluacion-CFE, Internal Report 1386-016.

SUAREZ C.,PRUESS K.,LIPPMANN M., 1989. 'Preliminary Modeling Studies on Los Azufres Geothermal Field: Free Convection in Tejamaniles'. Symposium in the Field of Geothermal Energy. Agreement between U.S. Dept. of Energy and CFE of Mexico (CONF-8904129), April 1989, San Diego, Ca., pp.161-184.

VIGGIANO C., 1987. 'Regimen de Flujo en Base a Mineralogia Autigenica en el Campo Geotermico de Los Azufres,Mich.', Geotermia Vol. 3, No. 3, pp. 191-213.

FIGURE No.13. CHLORIDES IN WELL Az - 5

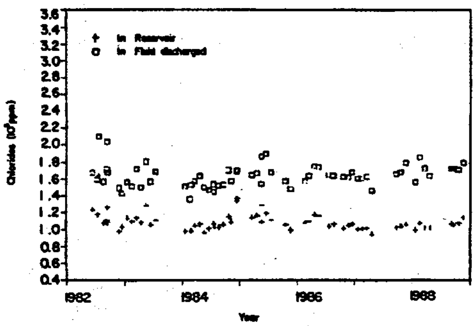

FIGURE No.14. CHLORIDES IN WELL Az - 13

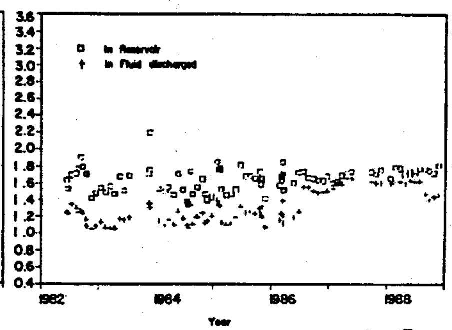

FIGURE No.15. CHLORIDES IN WELL Az - 16D

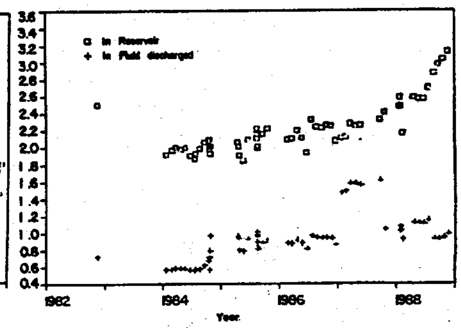

FIGURE No.16. GAS CONTENT WELL Az - 5

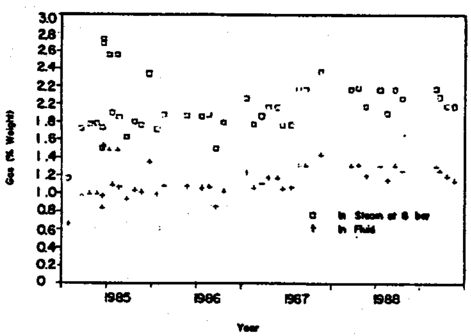

FIGURE No.17. GAS CONTENT. WELL Az - 13

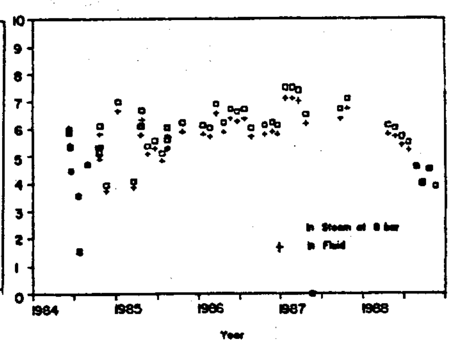

FIGURE No.18. GAS CONTENT. WELL Az - 6

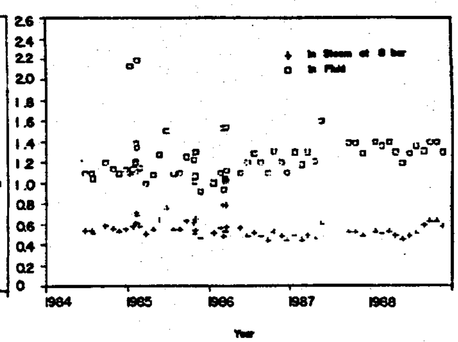

FIGURE No.19. GAS CONTENT WELL Az - 16D

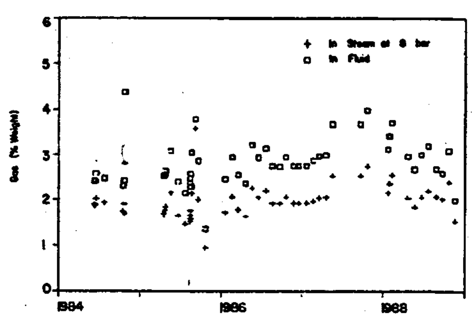

FIGURE No. 20. GAS CONTENT. WELL Az - 17

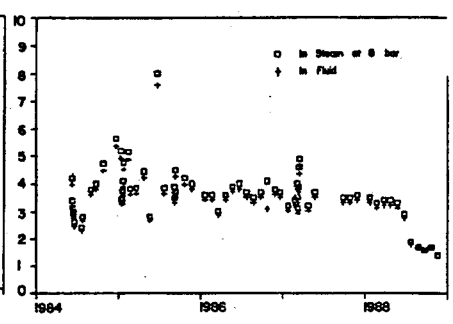

FIGURE No.21 EVOLUTION OF N_2/Ar

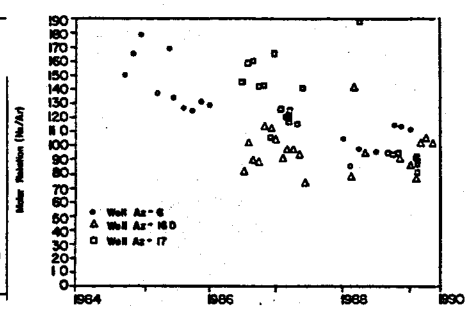

FIGURE No.22. NITROGEN EVOLUTION. WELL Az - 6

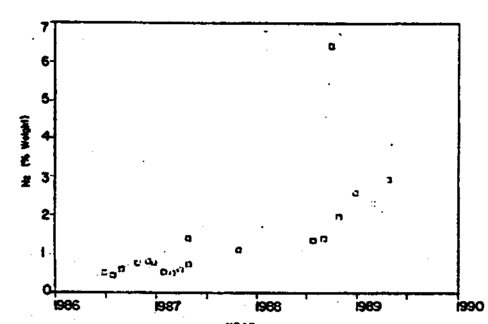

FIGURE No.23. EVOLUTION OF NITROGEN WELL Az - 16D

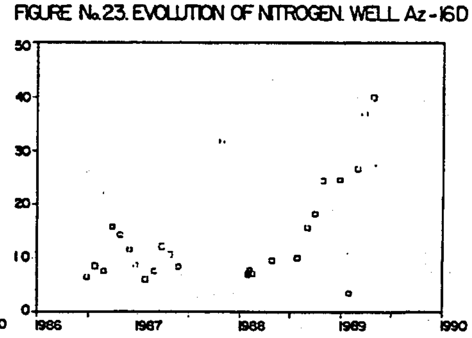

FIGURE No.24. EVOLUTION OF NITROGEN WELL Az - 17

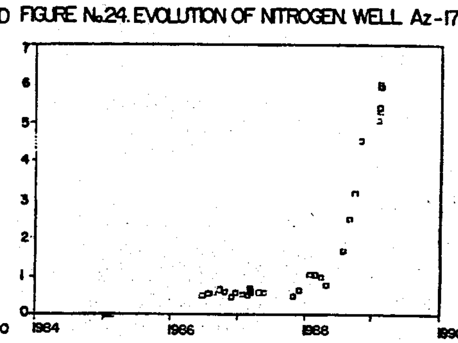

Figure 25. WELL AZ-5

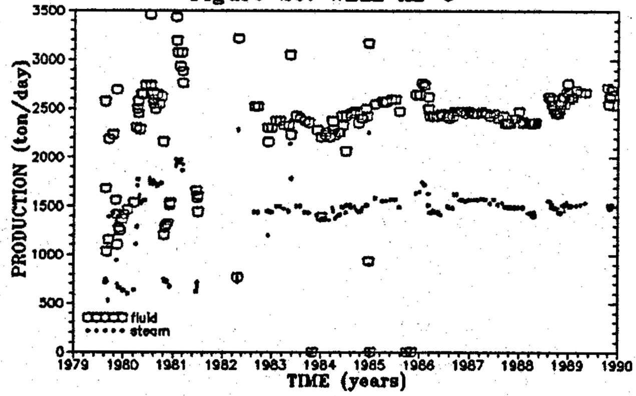

Figure 26. WELL AZ-6

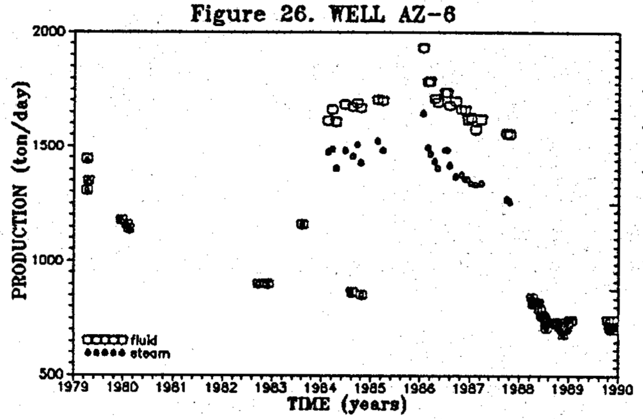

Figure 27. WELL AZ-13

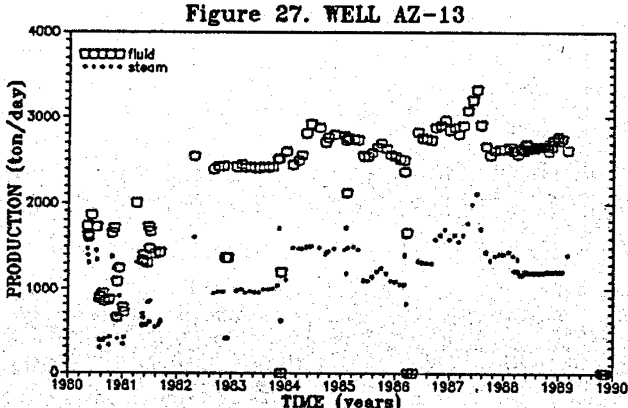

Figure 28. WELL AZ-16AD

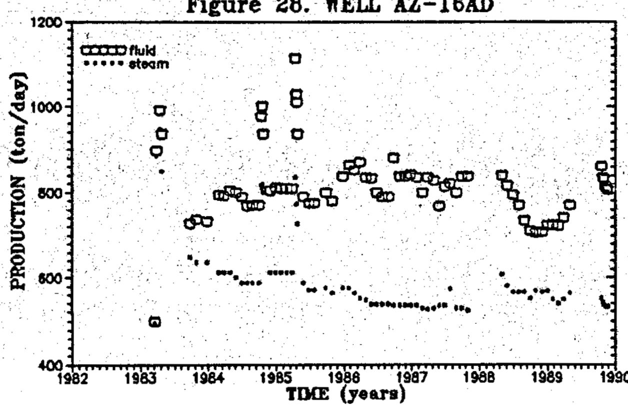

Figure 29. WELL AZ-17

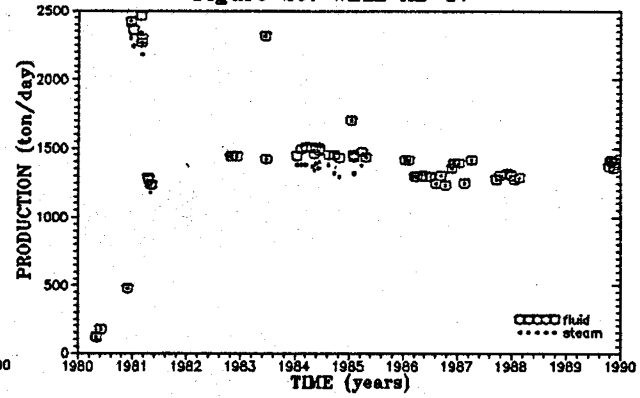

Figure 30. WELL AZ-22

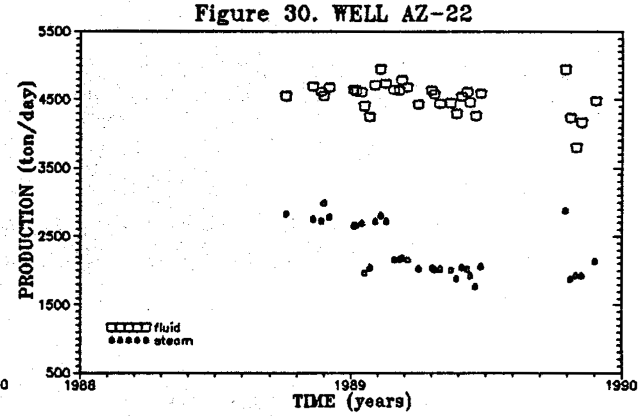

Figure 31. WELL AZ-33

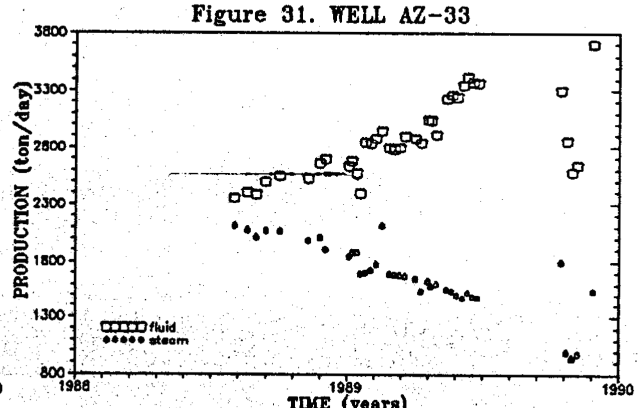

Figure 32. WELL AZ-34

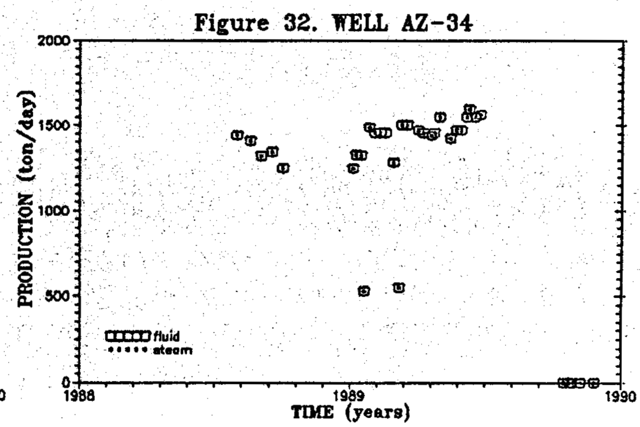

Figure 33. WELL AZ-35

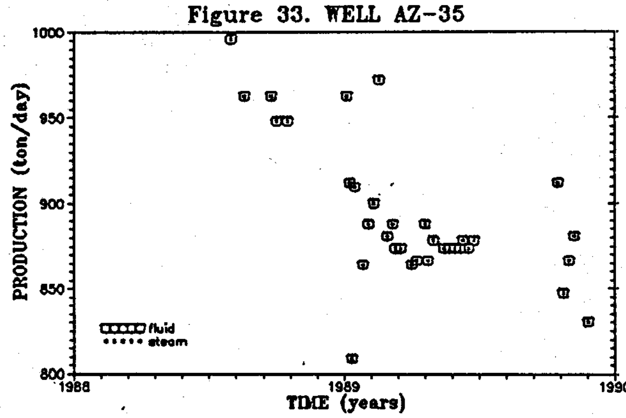

Figure 37. WELL AZ-5

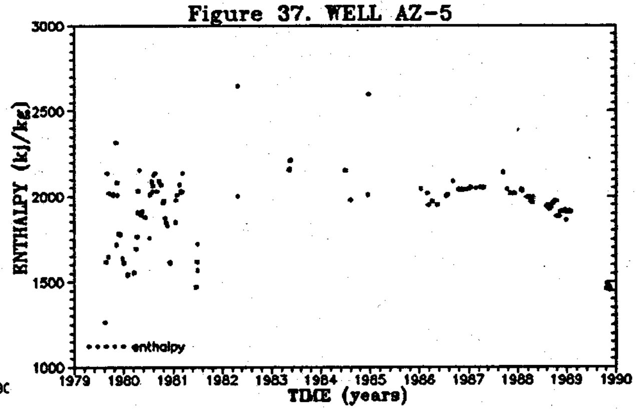

Figure 34. WELL AZ-36

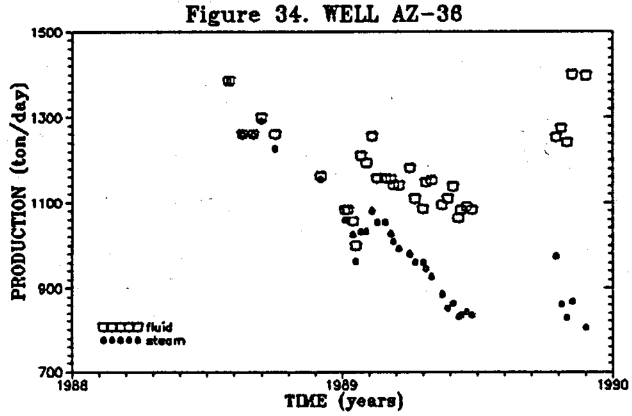

Figure 38. WELL AZ-6

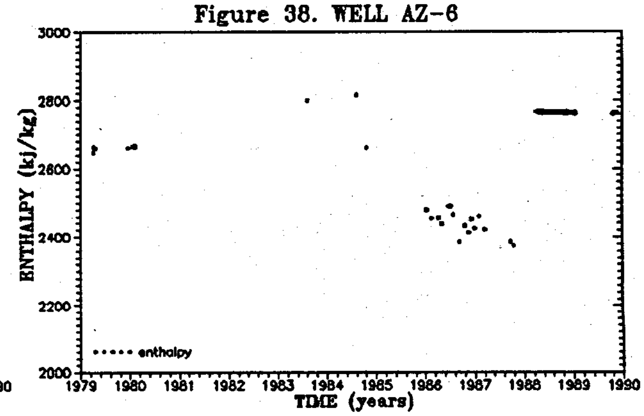

Figure 35. WELL AZ-37

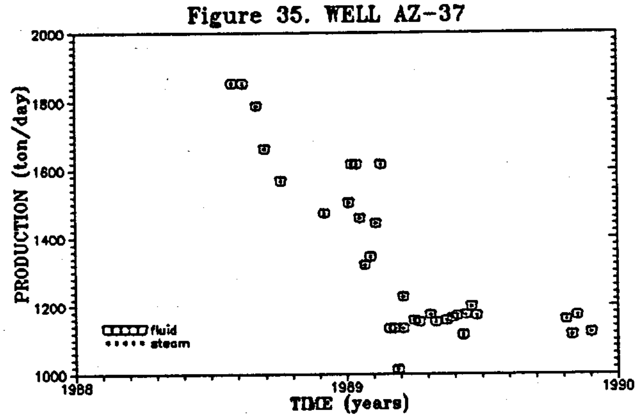

Figure 39. WELL AZ-13

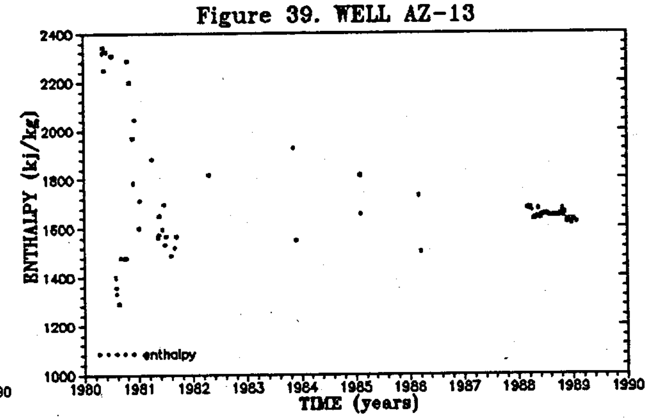

Figure 36. WELL AZ-38

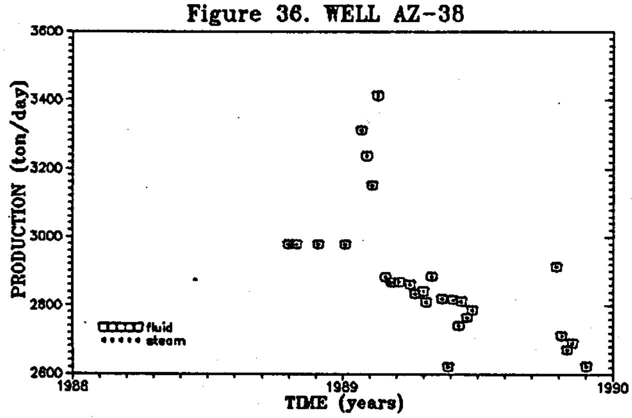

Figure 40. WELL AZ-16AD

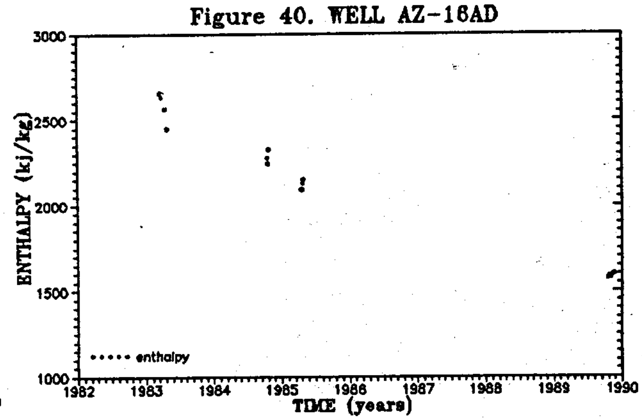

Figure 41. WELL AZ-17

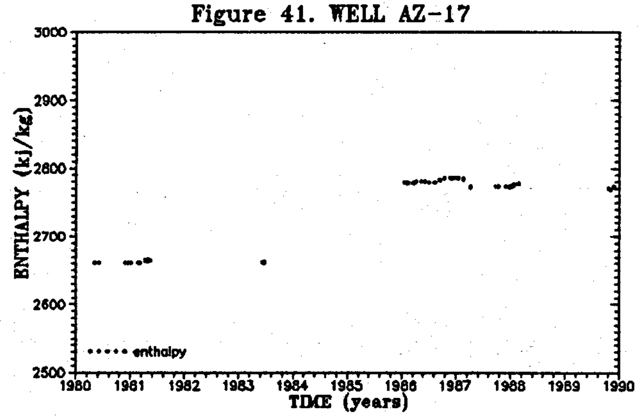

Figure 45. WELL AZ-35

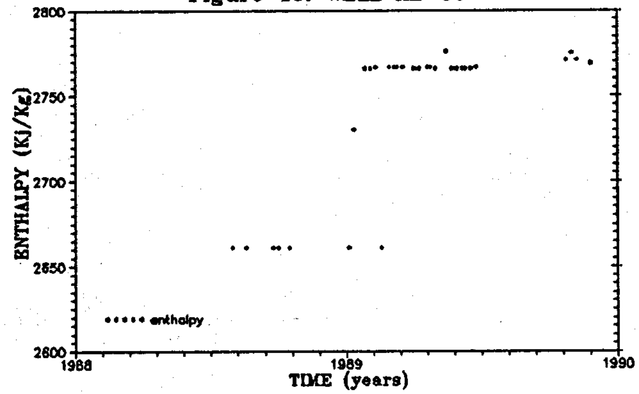

Figure 42. WELL AZ-22

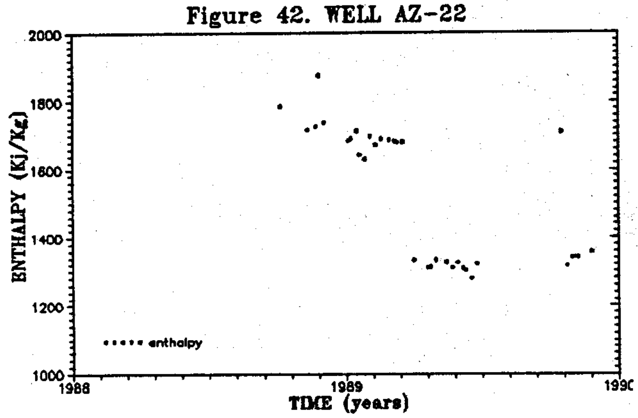

Figure 46. WELL AZ-36

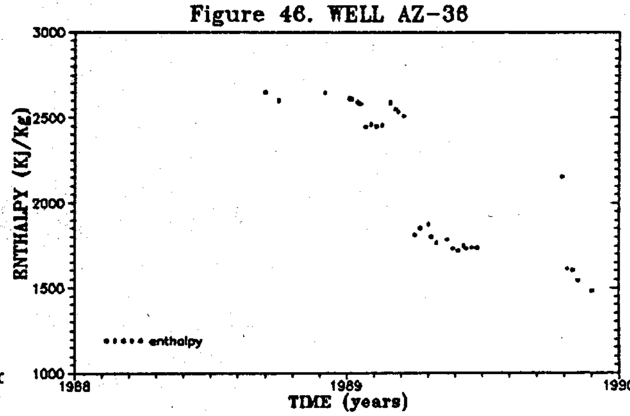

Figure 43. WELL AZ-33

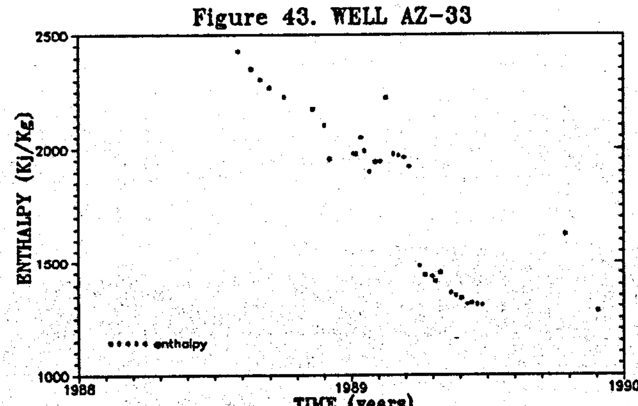

Figure 47. WELL AZ-37

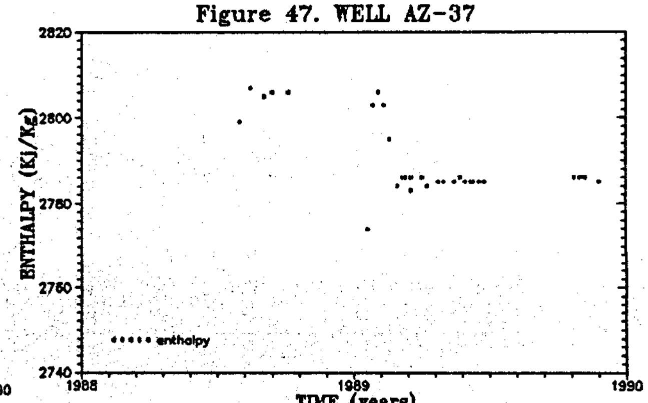

Figure 44. WELL AZ-34

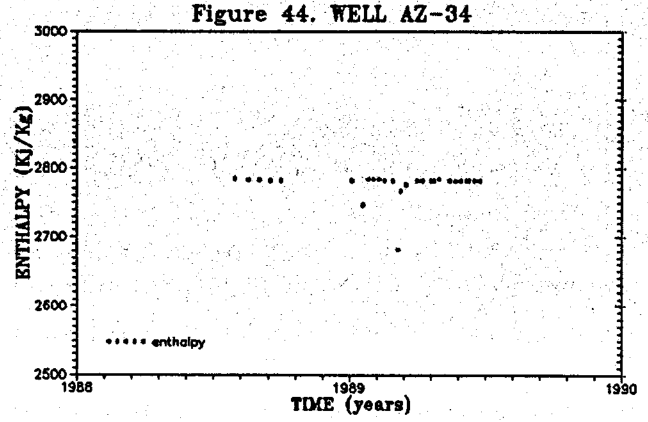

Figure 48. WELL AZ-38

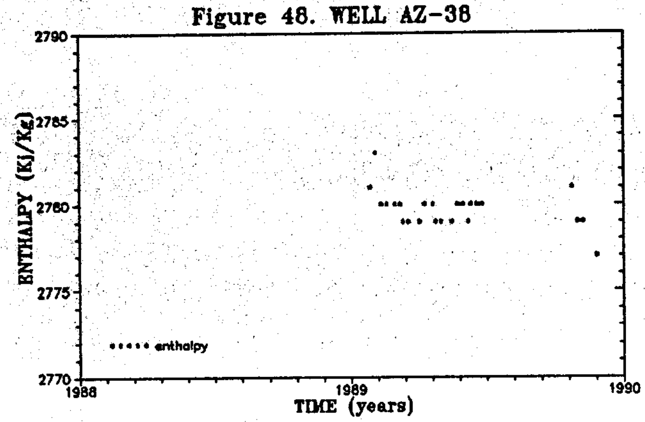

Figure 49. WELL AZ-5

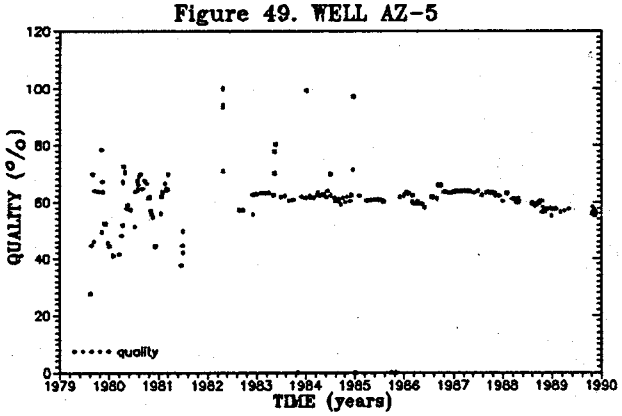

Figure 53. WELL AZ-17

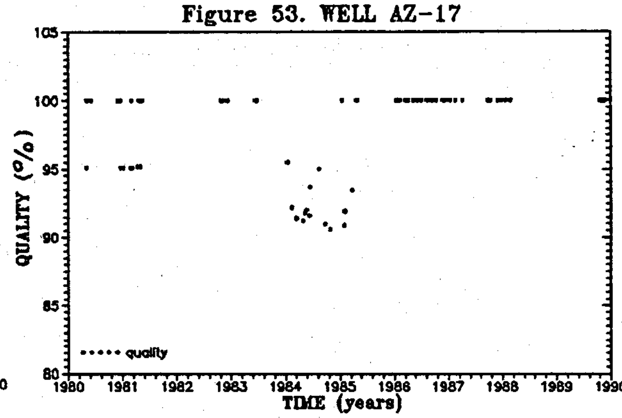

Figure 50. WELL AZ-6

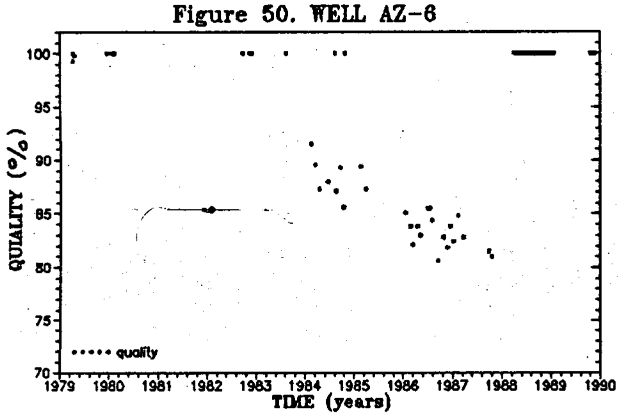

Figure 54. WELL AZ-22

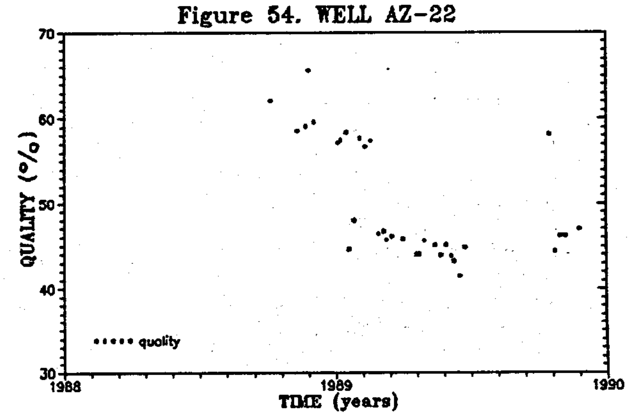

Figure 51. WELL AZ-13

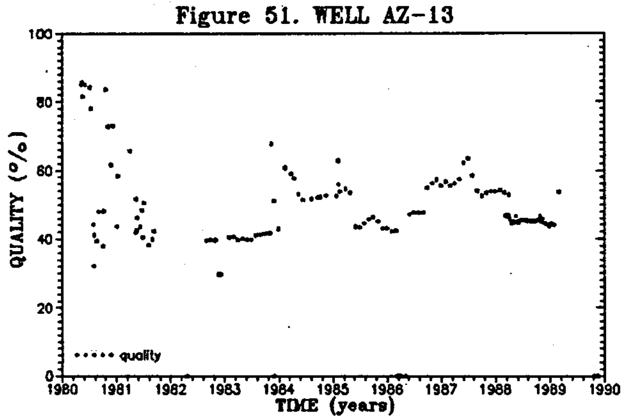

Figure 56. WELLS AZ-34,AZ-35,AZ-37,AZ-38

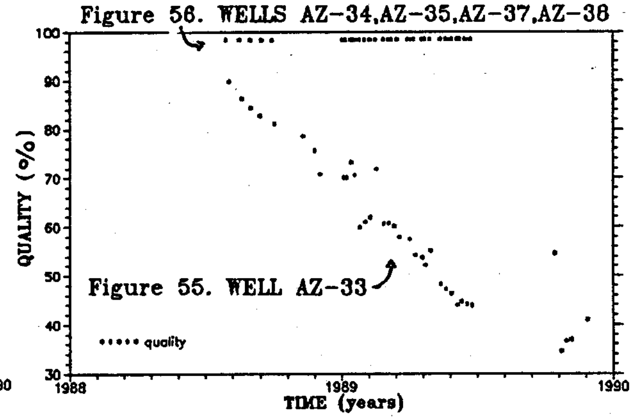

Figure 52. WELL AZ-16AD

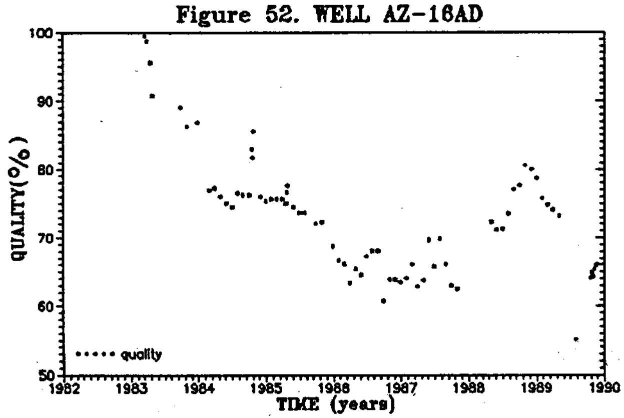

Figura 57. WELL AZ-36