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## SCALING OF GEOTHERMAL WELLS IN CERRO PRIETO FIELD

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## ABSTRACT

Scale incidence on production pipes of Cerro Prieto geothermal wells is a problem and occurs frequently, but has been diminished by selection of the main productive strata or using orifice restrictions at the wellhead discharge. This last technique made' in some new wells that have 120 bars pressure at wellhead. 150 wells have been drilled with the deepest exploration well being 4,300 m. The drilling for exploration and production wells continue at the present time. Around  $100 \times 10^6$  tons of water-steam mixture is extracted every year, 40% is separated steam which is used in three geothermoelectric power stations having a total of 620MW of installed capacity.

## INTRODUCTION

The Cerro Prieto geothermal field actually covers an area of 40 square kilometers. The wells cover approximately two thirds of this area and the evaporating pond the rest. More than 150 wells have been drilled in this field to depths ranging from 1,000 to 4,300 m. High temperature geothermal fluids flow through this liner and are conducted to the surface through the production casing (19 to 24 cm OD). 30 wells are used to supply the necessary steam to maintain full load at CP-1 power station with 180MW of installed capacity<sup>1</sup>, 27 wells for CP-II and 28 wells for CP-III with a 220MW of installed capacity each<sup>2</sup>.

The wellhead pressure under normal operation at the different wells varies from 9 bars to 103 bars, this last pressure because some of the wells have an orifice restriction. The separation and flashing pressures are 13 and 5.5 bars on the wells of CP-II and CP-III areas, and 8 bars on the wells of CP-1<sup>3</sup>.

The separated steam flow rate for normal operations varies from 25 t/h on some wells of CP-I to 120 t/h on wells of CP-II area. In some wells the maximum flow rate of separated steam during initial discharge reach 250 t/h<sup>4</sup>.

The bottom hole temperatures in most of the production wells are between 280 and 367°C, the highest being measured in CP-III area.

## BRINE CHEMISTRY

A typical chemical analysis of the separated brine extracted by the wells at CP-I is shown in Table I<sup>5</sup> and basic analysis of brine of CP-II is shown in Table II<sup>2</sup>.

Table I. Typical chemical analysis of brine\* from Cerro Prieto I wells area in mg/Kg

Na	8,300	Mn	0.6	F	2.4
K	2,210	Fe	1.5	Al	0.05
Ca	521	Br	17.7	Co	0.002
Mg	0.5	Cu	0.5	Ag	0.004
Li	27	Zn	0.01	SiO <sub>2</sub>	864
Rb	11	Cd	0.4	Cl	16,030
Cs	39	Pb	0.005	SO <sub>4</sub>	2
Sr	15	Bi	0.08	HCO <sub>3</sub>	44
B	9.4	As	1.5	----	----
Cr	0.5	I	0.6	pH	8.0

\* Separated water at atmospheric pressure.

Table II. Basic typical analysis of brine\* from CP-II and CP-III wells area in mg/Kg

Na	12,222	Mg	0.4	SO <sub>4</sub>	4
K	3,541	B	39	HCO <sub>3</sub>	56
Li	30	Cl	22,664		
Ca	475	SiO <sub>2</sub>	1,126		

\* Separated water at atmospheric pressure.

As can be seen in both cases, the following relationship can be established:

Cations:  $Na^+ > K^+ > Ca^{2+} > Mg^2$

Anions:  $Cl^- > HCO_3^- > SO_4^{2-}$

According to the geothermal water classification, the brine is of subterranean origin and formed under restricted circulation or stagnation. By means of isotopic analysis of the geothermal fluid it has been established that the water from the geothermal reservoir is mainly of meteoric origin and is derived from the Colorado River.

The high concentration of dissolved solids in the brine is the result of water leaching and/or water-rock interaction at high temperatures on the

sedimentary rocks. The water rock interaction that occur take place over thousand of years and reach an equilibrium state with surrounding minerals (KCl, NaCl, etc.) or saturation with respect to some salts such as silica, bicarbonate, sulfide and sulfate salts, etc. The predominant rocks in the Cerro Prieto production strata are sandstone and shale. A chemical composition of sandstone core recovered from Cerro Prieto I well at 1,090 m. is shown in Table III.

Table III. Chemical composition of sandstone core recovered from CP-I well in mg/Kg.

Na	4,875	Mg	8,505	Cl	2,100
K	11,200	B	244	SiO <sub>2</sub>	266,000
Li	72	Fe	520		
Ca	28,000	Br	65		

The geothermal fluids also contain substantial amounts of dissolved gases mainly CO<sub>2</sub> and H<sub>2</sub>S and minor amounts of NH<sub>3</sub>, CH<sub>4</sub>, H<sub>2</sub>, etc. see Table IV. Some of these gases play an important role in the occurrence of scales.

Table IV. Gas content\* on separator steam from wells of CP-II and CP-III area in mg/Kg

CO <sub>2</sub>	11,674	NH <sub>3</sub>	81	Ar	5
H <sub>2</sub> S	688	N <sub>2</sub>	36	He	0.5
CH <sub>4</sub>	142	H <sub>2</sub>			

\* Median values for the samples analysed in 1987<sup>2</sup>

The high content of dissolved silica in the well brine is the result of dissolution of rock by water at the reservoir temperature. Experimental testing conducted in our laboratory with a sandstone core sample obtained from a well depth of 1,090 m and using geothermal brine (prior to the test, silica was removed from the brine). As expected, the concentration of silica in solution increases with temperature, and follows approximately the solubility curve obtained by other investigators and also are in agreement with the silica quantified on CP-I wells brine.

It has been possible to established that the fluid discharged by the Cerro Prieto wells is saturated with respect to silica at the temperature at which the brine is found in the reservoir.

In a similar manner, the brine is saturated with respect to carbonate and other minerals at the temperature of the brine.

**OCCURRENCE OF SCALE ON PRODUCTION WELLS PIPE.**

Mainly due to the saturation condition of some of the brine components, deposition of scale occurs inside the production pipe of the wells as the geothermal fluid undergoes physical changes on its way to the surface. The physical process by which scaling occurs is based on the fact that, when the high temperature water ascends through the produc-

tion casing and the pressure to which it is subjected is reduced, partial flashing occurs of the water into steam. The zone of the casing where this change of phase occurs depends on the original enthalpy of the fluids. Fig. 1 shows the relation between the enthalpy measured in each well and the depth at which the deposits were found. This condition is valid only for CP-I wells because only a single phase liquid was extracted from reservoir.

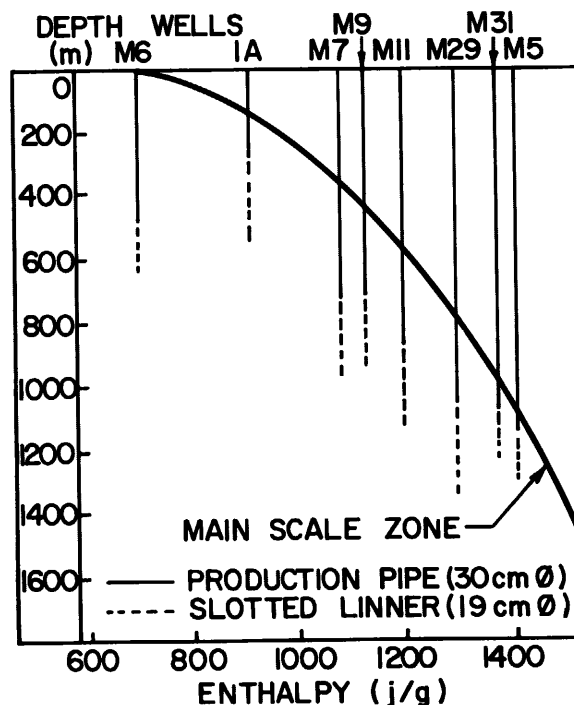


Fig. 1 Scale depth occurrence vs enthalpy on Cerro Prieto I wells.

For Cerro Prieto II and Cerro Prieto III the reservoir fluid is in two phases and hence wells produce steam-water mixtures. Therefore scale occurrence is not uniform and some wells follow an inverse of the curve of Cerro Prieto I wells (Fig.2)

Chemically, deposition occurs when the brine, originally saturated with respect to silica, carbonates, sulfides, etc. at the reservoir temperature become supersaturated as a portion of the water flashes into steam and the temperature of the brine is reduced by this change of phase. Also (for carbonates) the CO<sub>2</sub> originally present in the brine is transferred to the steam phase when boiling starts, the initial equilibrium is disturbed, and bicarbonates are precipitated as carbonates.

Silica and carbonate scale typically occur in the wells of CP-I area primarily because of the lower temperature reservoir than is present at CP-II and CP-III area, see Table 5 and Figs. 3 to 7.

Because higher reservoir temperatures at Cerro

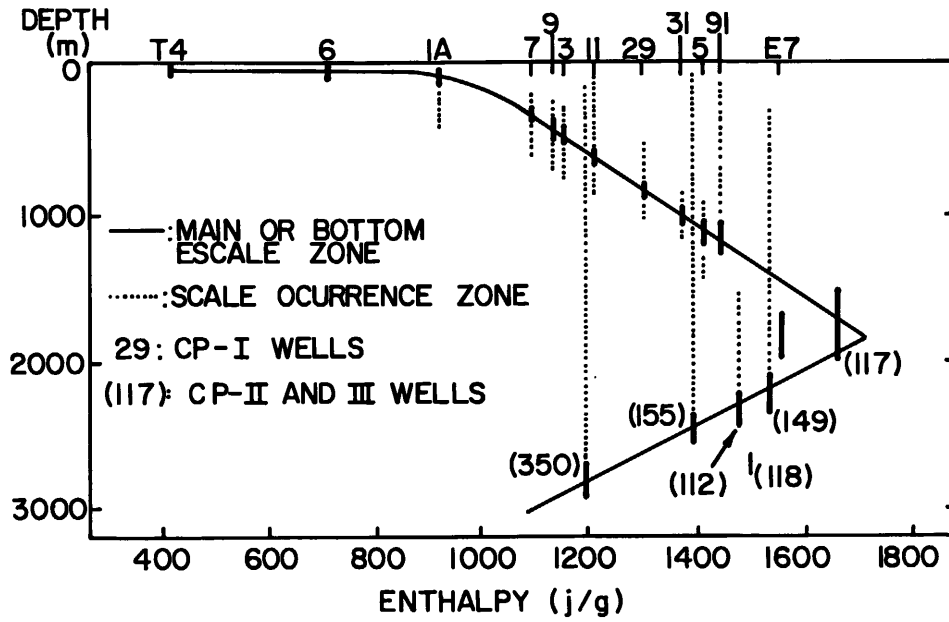


Fig. 2 Scale occurrence zone vs. enthalpy on CP-I , CP-II and CP-III wells.

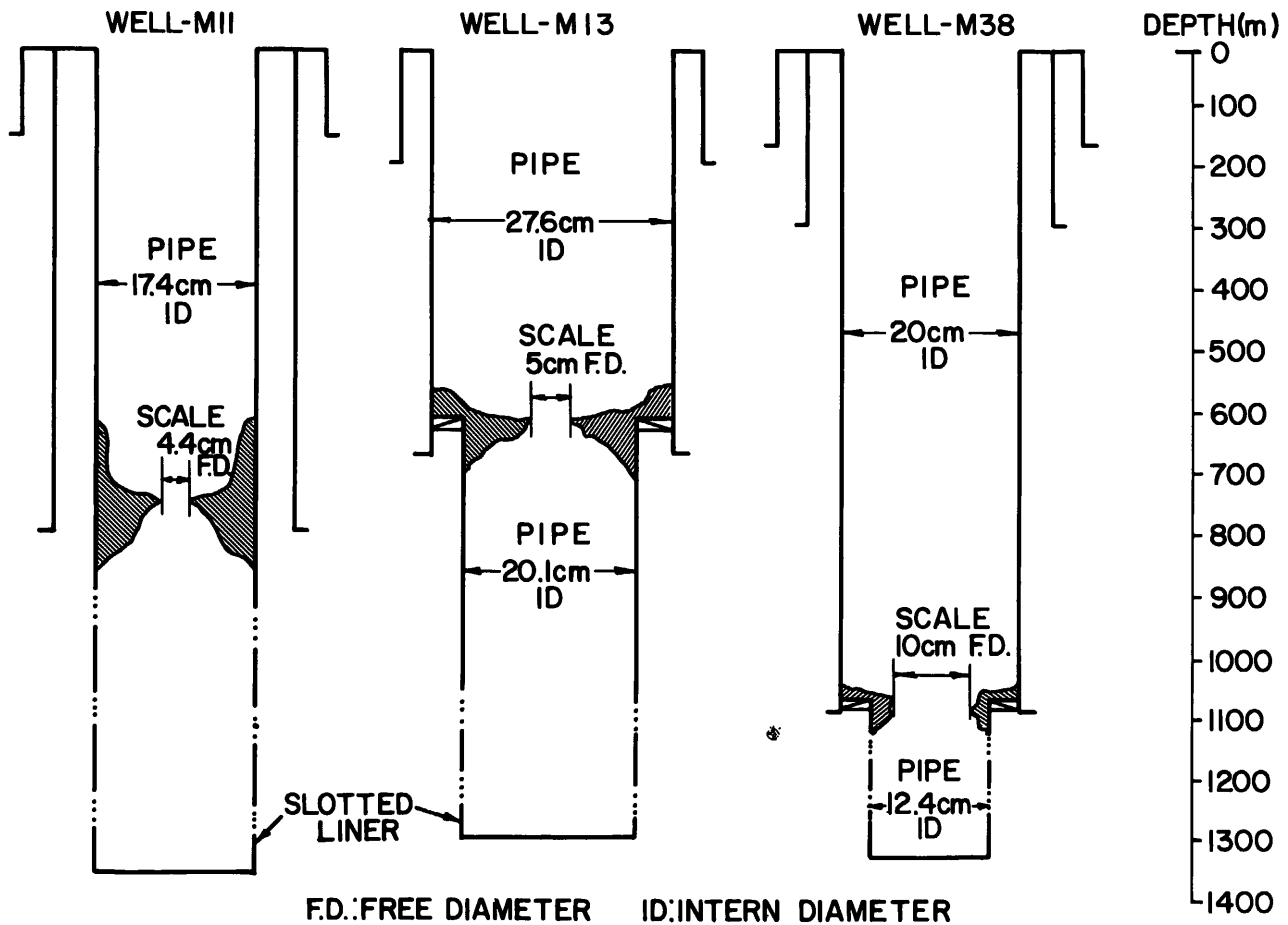


Fig. 3 Scale in production pipes of Cerro Prieto I wells.

Table 5. Chemical composition of scale in production pipes of CP-I wells.

% (w)	W e l l								
	1A	M7	M9	M10	M11	M11	M29	M29	M39
SiO <sub>2</sub>	0	6.0	12.5	19.5	60.5	12.5	0.52	25.63	18.43
CaCO <sub>3</sub>	94.6	68.8	75.5	75.7	30.2	80.3	94.07	60.00	76.55
MgCO <sub>3</sub>	4.2	21.3	-	3.2	-	3.2	-	4.15	-
FeS	-	0.7	9.5	1.6	5.4	2.1	0.071	9.78	1.37
NaCl	1.1	-	0.8	-	0.8	0.37	0.08	0.27	0.15
KCl	-	-	-	-	-	0.23	-	-	-
CaCl <sub>2</sub>	-	4.0	-	-	-	0.44	-	-	-
Mn	-	-	-	-	-	0.69	-	-	-
Cu	-	-	-	-	-	0.01	-	-	-
Zn	-	-	-	-	-	0.16	-	-	-
Au	-	-	-	-	-	0.0001	-	-	-
Ag	-	-	-	-	-	0.0061	-	-	-
Depth	5m	230m	750m	1080m	25m	720m	694m	1030m	1140m
date	Feb69	Jul68	Jul75	Nov68	Jan68	Jun68	Nov75	Dec79	Sep75

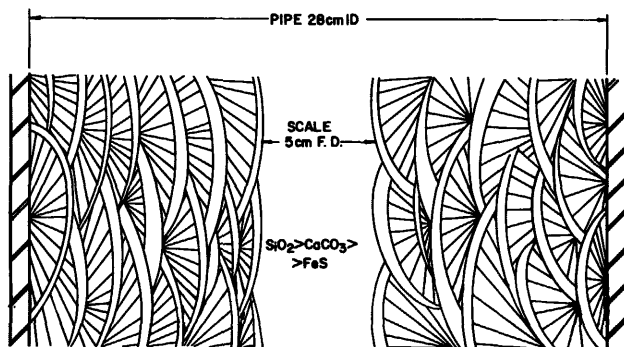


Fig. 4 Chemical deposition detail on well M13 at 591 m depth.

Prieto T† and Cerro Prieto III areas, silica and sulfide scale is more frequently found. See Table 6 and Fig. 8. In this figure are shown the possible compounds of iron and copper formed on the pipe wells.

The metallic sulfides (Fe, Pb, Cu, etc.) have a very low solubility<sup>6</sup> in proportion directly to the temperature. For which small temperature variations cause instantaneous deposition. Normally these type of scales occurs in well pipes, including the slotted liner and reservoir strata causing heavy damage to latter.

In general scaling problems in the production pipe are more or less severe, depending on the zone where scale is produced and the depth of this zone.

If for instance, the deposit is formed in the upper portion of the production pipe (Fig. 3), reaming of the well recovers the well output. If however, the deposit is formed in the slotted liner, fluid flow is restricted and the outside part of the slots can't be cleaned by reaming (Fig. 5 well M34).

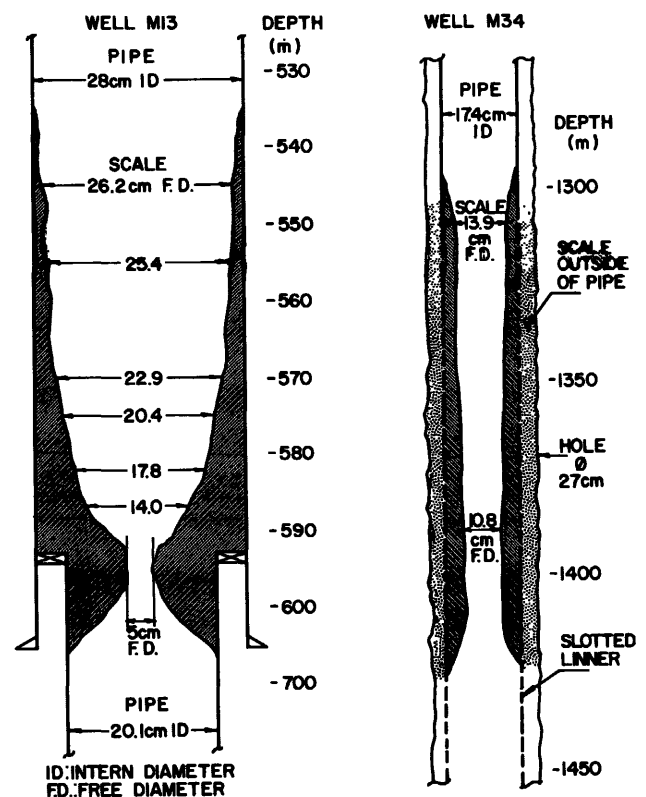


Fig. 5 Details of scale on wells M13 and M34.

Scale also occurs in the surrounding ground (in the production strata) scaling it completely or diminishing its permeability with no means of cleaning it. To prevent this scale occurrence, orifice restrictions are currently installed on the wellheads, which maintain higher pressures in the

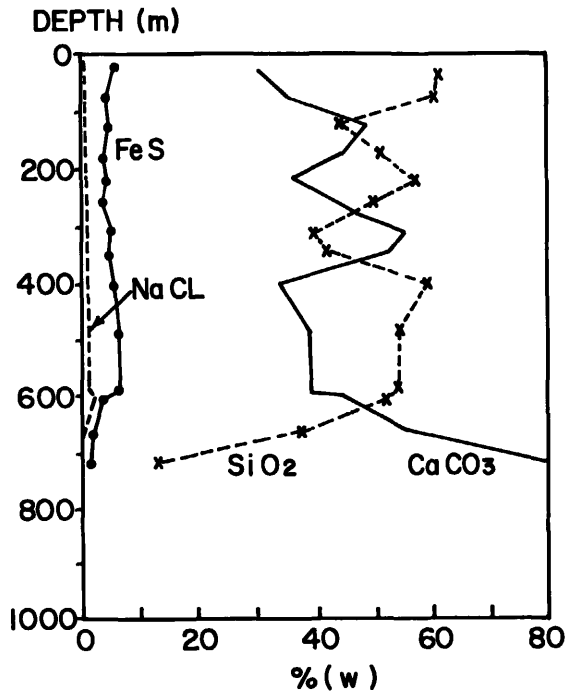


Fig. 6 Chemical variation deposits vs depth on well M-11

well and diminish the scale formation.

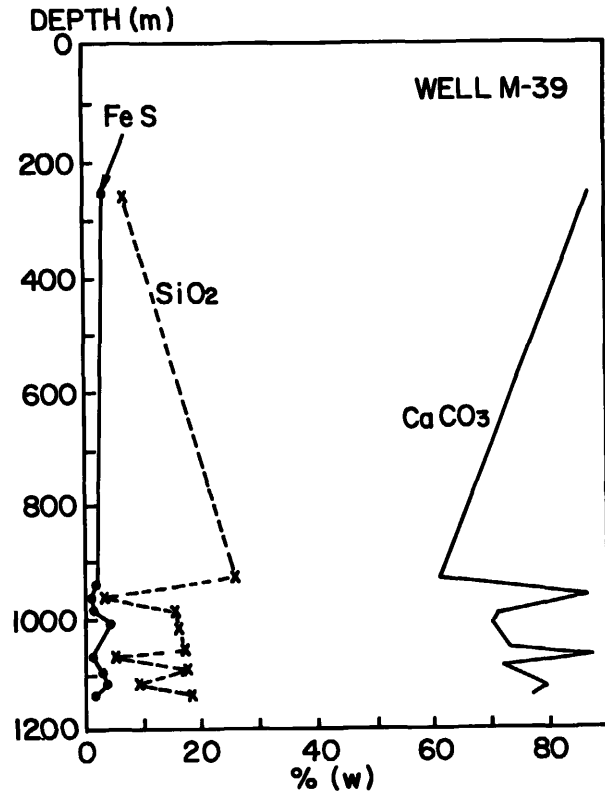


Fig. 7 Chemical variation deposits vs depth on well M-39

Table 6. Chemical composition of scale in production pipes of CP-II and CP-III wells area.

% (w)	W e l l s											
	E7	M91	M101	M117	M149		M155		M202		M350	
					NM	M	NM	NM	NM	M	NM	M
SiO <sub>2</sub>	62.5	59.3	82.5	44.0	56.3	0	62.9	16.4	33.8	3.3	25.8	7.7
Ca	0.9	0.5	0.4	7.4	0.7	0.6	0.6	0.3	16.4	4.2	0.3	0.2
Mg	0.5	0.04	0.1	1.7	0.5	0.3	0.3	1.1	0.9	0.5	0.5	0.1
Fe	8.0	5.7	1.5	4.7	5.6	53.8	4.5	28.2	4.8	61.2	25.0	6.2
S <sup>2-</sup>	19.9	3.0	0.4	0.2	2.7	14.8	2.0	18.2	0.4	7.5	23.0	29.8
Na	0.8	2.0	0.5	0.1	0.1	0.1	0.7	0.6	0.3	0.03	0.4	0.1
K	0.1	1.0	0.2	0.8	0.1	0.1	0.5	0.1	0.3	0.07	0.2	0.1
Cu	nd	nd	0.2	nd	nd	nd	0.3	9.1	nd	nd	9.5	2.3
Pb	nd	nd	0.5	nd	nd	nd	0.3	6.0	nd	nd	5.7	24.2
Depth	1762m	1002m	1337m	1978m	1095m	2360m	60m	2230m	3590m	3542m	90m	2240m
Date	Aug87	Jul86	Jan88	Apr85	Feb85		Dec87		Apr85		Dec87	

NM: non magnetic powder

M: Magnetic powder sample

nd: not determ.

CONCLUSION

Scaling in the production pipes of wells and in the reservoir strata has caused problems and restricted the integral use of the geothermal fluids. However it has been possible until now to prevent partially

the occurrence of scaling in production pipes using orifice control at the wellheads and by reaming the scale when it occurs. Using these techniques, the wells and of the geothermoelectric power stations has been continuous since inauguration of the first units in April 1973. In the

DEPTH (m x 100)

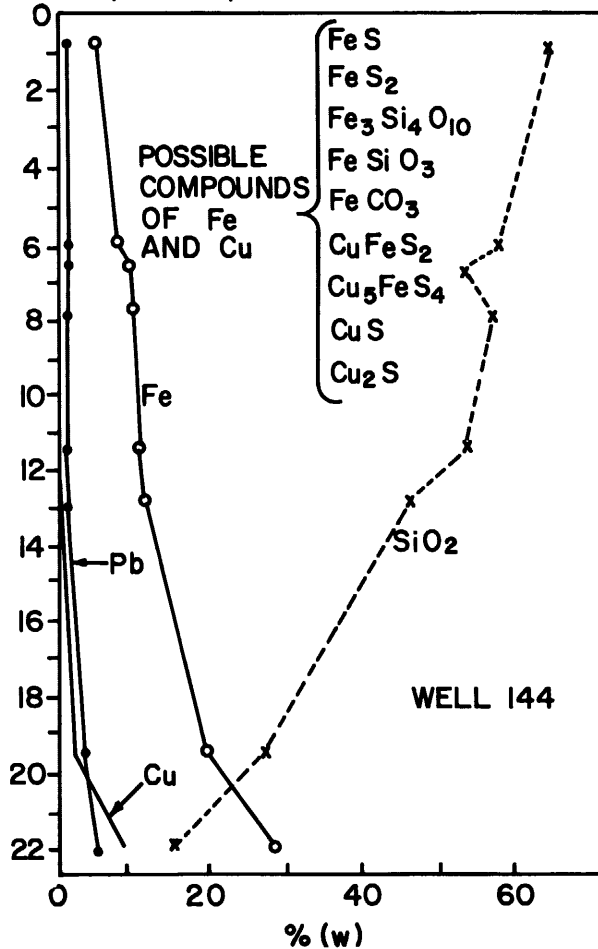


Fig. 8 Scale composition SiO<sub>2</sub>, Fe, Cu and Pb vs depth in well M144 of Cerro Prieto II.

future we hope to use better preventive systems that will make the exploitation of high enthalpy water-dominant geothermal reservoirs much easier.

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