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Status of the Cerro Prieto Project

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As part of its program in geothermal energy (Table 1), funded by DOE/GHTD under the Reservoir Definition Program, Lawrence Berkeley Laboratory (LBL) has continued to carry out studies of the Cerro Prieto geothermal system (Figure 1) and has kept abreast of the latest developments at the field. The FY1984 effort has been significantly smaller than in previous years because of the lack of a formal agreement for continued technical cooperation between DOE and the Comisión Federal de Electricidad of Mexico (CFE), operator and manager of the Cerro Prieto field. The earlier agreement (Witherspoon et al., 1978) expired in July 1982; a new three-year agreement is expected to be signed before the end of 1984.

Recent LBL studies on Cerro Prieto have been restricted mainly to analyzing field data gathered earlier and to updating the models of this geothermal field on the basis of new well data and studies performed by CFE.

RECENT FIELD ACTIVITIES

In September 1984 one of the two 110-MW_e turbogenerators of power plant CPII was placed in operation, increasing the installed generating capacity at Cerro Prieto to 290 MW_e. The second 110-MW_e unit of CPII is planned to be added to the system in December 1984. The construction of power plant CPIII continued; it should be operational in mid-1985, bringing the total installed capacity at the field to 620 MW_e.

The drilling activity at Cerro Prieto continued at full pace. New production wells were drilled to replace older ones and to supply steam to the new power plants. Deep exploration wells were drilled to outline the boundaries of the thermal anomaly and to locate more precisely the hot fluid recharge area. Between April 1983 and September 1984 sixteen wells were completed (Figures 2 and 3; Table 2).

The wells of the E-series in the western part of the field tap the lower reservoir in that area, replacing or supplementing the fluid output of older, shallower wells. The completion and temperature profile of one of these wells is shown in Figure 4.

The 200-series wells drilled in the eastern part of the system are exploratory. Well M-203 is presently the deepest at Cerro Prieto, with a total depth of 3995 m. Data from these wells were used to make a map showing the depth to the 300°C isotherm (Figure 5). Some of the deep eastern wells were drilled under very difficult conditions. One example is well M-112, which encountered temperatures above 300°C from about 2000 m to its deepest point (3622 m) and met with numerous lost-circulation zones (Mañón, 1984). Figure 6 shows a typical completion and temperature profile for one of the wells in the east.

The rate of fluid production and the average enthalpy of the produced fluid have remained relatively constant since late 1982, varying between 4300 and 4700 tonnes/hour and between 1410 and 1450 kJ/kg, respectively (Figures 7 and 8). The rate of fluid production has increased since September 1984, when one of the new turbogenerators in power plant CPII came on line. Table 3 shows the total annual steam-brine production and electrical generation at Cerro Prieto since power production began in 1973.

In response to fluid extraction (with no brine reinjection), the pressure in the shallow western reservoir has been gradually dropping. This is indicated by changes in the water level in well M-6 (Figure 9), located west of the production region.

Table 4 shows the March 1984 production characteristics (determined from separator data) of wells supplying steam to power plant CPI; data obtained using James' (1970) lip pressure method are available for the wells that will supply fluids to the new power plants (Tables 5 and 6). Given in Tables 7 and 8 are the chemical characteristics of the fluids produced by some of the wells supplying steam to power plant CPI.

Apart from activities related to electrical power production, CFE has recently begun at Cerro Prieto a number of demonstration projects related to the direct use of geothermal fluids (Mañón, 1984). Among them are fish farming, greenhouse agriculture, absorption refrigeration, and mineral extraction.

CFE recently granted a license to a private company to utilize the geothermal waste heat for food production and industrial use. The Baja California State government and a private concern are working on an agreement to establish farms and industries that require low-cost process heat. A plant for extracting 100,000 tonnes/year of potassium chloride from the separated brines is being built west of the Cerro Prieto wellfield. Construction of the evaporation ponds for this plant is nearly complete (Mañón, 1984).

RECENT STUDIES

Over the past seven years great advances have been made toward understanding the Cerro Prieto system, both in its natural state and under exploitation. A large body of information is included in the numerous reports and papers published since 1977. Most of these are included in the proceedings of the four symposia held on Cerro Prieto (LBL, 1978 and 1981; CFE, 1979 and 1982), and many have recently been summarized in three review papers (Lippmann, 1983; Lippmann et al., 1984; Mañón, 1984). Discussed below are the findings of some later studies that were not included in these publications.

Work has continued on updating the hydrogeologic model for Cerro Prieto developed by Halfman et al. (1984a). Data obtained from recently completed wells confirm the soundness of that model. The depositional environments of the various sedimentary units found at the reservoir level were derived from the study of dipmeter logs. They were shown to correspond to a coastal system (Halfman et al., 1984b). Along a west-to-east line, one would find, in succession, longshore current, shoreline, and protected embayment deposits (Figure 10). By establishing the characteristics of the coastal environment of deposition of the sedimentary rocks forming the Cerro Prieto geothermal reservoir and its caprock, it was simple to explain the change in lithology and disappearance of different units. This new analysis should be useful for locating and designing the completion of new wells in the field.

The results of an extensive geologic study were reported by Cobo et al. (1984). On the basis of cuttings, cores, and wireline log data, they developed a geologic model of the Cerro Prieto field. Their model suggests that a major fracture and a set of radial faults might be the main conductors of geothermal fluids in the system. Some features of this model disagree with those of developed by Halfman et al.; efforts will be made to integrate features of both into a single hydrogeologic model of the field.

On the basis of whole rock analyses, Reed (1984), suggests that the Cerro Prieto volcano is derived from the partial melting of granitic basement rocks and not from differentiation of gabbroic intrusions. The small magma chamber associated with the volcano had insufficient volume to retain the heat to drive the present hydrothermal system. Reed contends that the volcanism and the current hydothermal activity are both the result of heat transferred to the crust by gabbroic intrusions.

On the basis of geochemical and reservoir engineering, Truesdell et al. (1984) conclude that the localized boiling occurring in the shallow western Cerro Prieto reservoir has produced excess steam and increased the enthalpy of the produced fluids. This boiling also caused mineral deposition around the wells, thereby decreasing the permeability and the fluid flow. In the shallow western reservoir the inflow of colder waters has limited the extent of aquifer boiling and permeability loss. However, according to these authors, such recharge might not occur in the deeper reservoir at Cerro Prieto, and injection of waste brine might be required to decrease boiling and prevent loss of production due to mineral precipitaion.

Wilt et al. (1984) continued their analysis of dipole-dipole resistivity data. The trend of increasing apparent resistivity associated with the shallow reservoir in the western part of Cerro Prieto was reversed in the period between Fall 1981 and Spring 1983. This change is interpreted to be caused by the collapse of boiling zones around the production wells due to a progressive cooling of the reservoir by the influx of cold recharge waters. On the other hand, in the eastern part of the field, the decrease in resistivity intensified, possibly as a result of the continuing influx of hotter, saline waters from depths greater than 3 km.

The analysis by Grannell et al. (1984) of gravity and leveling data obtained since 1978 at Cerro Prieto indicates that subsidence persists, possibly as a result of fluid production and partial recharge. Modeling of the gravity changes indicates a probable density increase, perhaps due to compaction within the reservoir.

Extensive reprocessing of the Cerro Prieto seismic reflection data (Blakeslee, 1984) has shown that the production region coincides with a zone of reflection attenuation and that a region of high-velocity events rimmed that zone. Blakeslee suggests that this concurrency may prove to be a valuable discriminant for locating geothermal reservoirs using seismic reflection.

Other recent papers have analyzed or summarized some of the reservoir engineering data collected on Cerro Prieto. A method to compute the bottomhole enthalpy in a well and its change with wellhead conditions has been developed by Hiriart and Sânchez (1984) and applied to Cerro Prieto well M-147. Iglesias et al. (1983) have described a method for using productivity curves to determine the reservoir pressure, mass productivity index, thermal power productivity index, and radius of influence of liquid-fed geothermal wells. They applied their method to a number of Cerro Prieto wells. The petrophysical properties of Cerro Prieto reservoir sandstones were discussed by Contreras et al. (1984) and summarized in a review paper.

The results of numerical modeling studies of the field (Ayuso et al., 1984) suggest that the planned 620-MW_e generating capacity could be maintained through the year 1998. These studies are still in progress.

FINAL REMARKS

The joint U.S.-Mexican studies on Cerro Prieto (and Los Azufres) are expected to intensify once the new DOE/CFE agreement on geothermal energy is signed. This agreement includes cooperative activities in Geology and Hydrogeology, Geophysics, Geochemistry, Reservoir Engineering, Reinjection, Subsidence and Induced Seismicity, Geochemical Engineering and Materials, Energy Conversion Technology, and Information Exchange. Soon we hope to be able to report on the new results obtained under this international cooperative effort.

ACKNOWLEDGEMENT

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REFERENCES

Ayuso, M. A., Márquez, R., Esquer, C. A., and Negrin, G., 1984. Modeling studies in the Cerro Prieto Geothermal Field. Geothermal Resources Council Transactions, v. 8, p. 175-181.

Blakeslee, S., 1984. Seismic discrimination of a geothermal field: Cerro Prieto. Geothermal Resources Council Transactions, v. 8, p. 183-188.

Cobo, J. M., Cobo, F. J., and Bermejo, F. J., 1984. Geological model of the geothermal field at Cerro Prieto, Baja California. Geothermal Resources Council Transactions, v. 8, p. 189-192.

Comisión Federal de Electricidad, 1979. Proceedings, Second Symposium on the Cerro Prieto Geothermal Field, Baja California, Mexico, October 17-19, 1979. Mexicali, Comisión Federal de Electridad.

Comisión Federal de Electricidad, 1982. Proceedings, Fourth Symposium on the Cerro Prieto Geothermal Field, Baja Califonria, Mexico, October 10-12, 1982. Mexicali, Comisión Federal de Electricidad, in preparation.

Contreras, E. A., Iglesias, E. R., and Bermejo. F., 1984. Geothermal Resources Council Transactions, v. 8, p. 193-202.

Grannell, R. B., Zhou, H. W., and Wyman, R. M., 1984. Modeling of repetitive gravity observations at Cerro Prieto geothermal field. Geothermal Resources Council Transactions, v. 8, p. 203-206.

Halfman, S. E., Lippmann, M. J., Zelwer, R., and Howard, J. H., 1984a. Geological interpretation of geothermal fluid movement in Cerro Prieto field, Baja California, Mexico. American Association of Petroleum Geologists Bulletin, v. 68, p. 18-30.

Halfman, S. E., Lippmann, M. J., and Gilreath, J. A., 1984b. Cerro Prieto case history: Use of wireline logs to characterize a geothermal reservoir. Presented at 1984 California Regional Meeting of the Society of Petroleum Engineers, Long Beach, California, April 11-13, 1984, SPE-12739.

Hiriart, G., and Sánchez, E., 1984. Thermodynamic considerations about the well M-147 at Cerro Prieto. Geothermal Resources Council Transactions, v. 8, p. 207-210.

Iglesias, E., Arellano, V., and Molinar, R., 1983. A method to recover useful geothermal-reservoir parameters from production characteristic curves. (2) Hot water reservoirs. Proceedings, Ninth Workshop on Geothermal Reservoir Engineering, Stanford Geothermal Program Report SGP-TR-74, p. 291-297.

James, R., 1970. Factors controlling borehole performance. Proceedings, United Nations Symposium on the Development and Use of Geothermal Resources. Geothermics, special issue, v. 2, p. 1502-1515.

Lawrence Berkeley Laboratory, 1978. Proceedings, First Symposium on the Cerro Prieto Geothermal Field, Baja California, Mexico, September 20-22, 1978. Lawrence Berkeley Laboratory Report LBL-7098.

Lawrence Berkeley Laboratory, 1981. Proceedings, Third Symposium on the Cerro Prieto Geothermal Field, Baja California, Mexico, March 24-26, 1981. Lawrence Berkeley Laboratory Report LBL-11967.

Lippmann, M. J., 1983. Overview of Cerro Prieto studies. Geothermics, v. 12, no. 4, p. 267-289.

Lippmann, M. J., Goldstein, N. E., Halfman, S. E, and Witherspoon, P. A., 1984. Exploration and development of the Cerro Prieto geothermal field. Journal of Petroleum Technology, v. 36, p. 1579-1591.

Mañón, A., 1984. Recent activities at Cerro Prieto. Geothermal Resources Council Transactions, v. 8, p. 211-216.

Reed, M., J., 1984. Relationship between volcanism and hydrothermal activity at Cerro Prieto, Mexico. Geothermal Resources Council Transactions, v. 8, p. 217-221.

Truesdell, A. H., D'Amore, F., and Nieva, D., 1984. The effects of localized aquifer boiling on fluid production at Cerro Prieto. Geothermal Resources Council Transactions, v. 8, p. 223-229.

Wilt, M., Goldstein, N. E., and Sasaki, Y., 1984. Long-term dipole-dipole resistivity monitoring at the Cerro Prieto geothermal field. Geothermal Resources Council Transactions, v. 8, p. 235-240.

Witherspoon, P. A., Alonso, H., Lippmann, M. J., Mañón, A., and Wollenberg, H. A., 1978. Mexican-American cooperative program at the Cerro Prieto geothermal field. Lawrence Berkeley Laboratory Report LBL-7095.

Table 1. Geothermal Projects Earth Sciences Division Lawrence Berkeley Laboratory FY1984 and 1985.

Well-test analysis
- Single/multiple wells,
- Injection/production tests

Relative permeability laboratory experiments and field data analysis

Modeling reservoir behavior
- Natural state
- Under exploitation
- Temporal and spatial variations in concentrations of noncondensible gases

Study optimization of heat extraction

Modeling migration of injected fluids in fractured/porous rocks

Development of modeling capabilities for transport of heat, mass, and chemical species in rock masses
- Porous/fractured media
- Saturated/unsaturated media
- One/two phases
- Single/multi- component fluids
- Fluid/rock interactions

Fault and fracture mapping
- Numerical and scale modeling of electrical/EM methods
- Evaluation of vertical seismic profiling and cross-hole seismic tomography

Development of surface and downhole instrumentation

Well-log analysis

Multidisciplinary field case studies
- Klamath Falls (Oregon)
- Cerro Prieto/Los Azufres (Mexico)
- Salton Sea – SSSDP (California)
- Heber (California)
- Cascades (California, Oregon, Washington)
- Krafla (Iceland)

Magma energy development (assistance to SNL)
- Geological and geophysical evaluation of probable sites

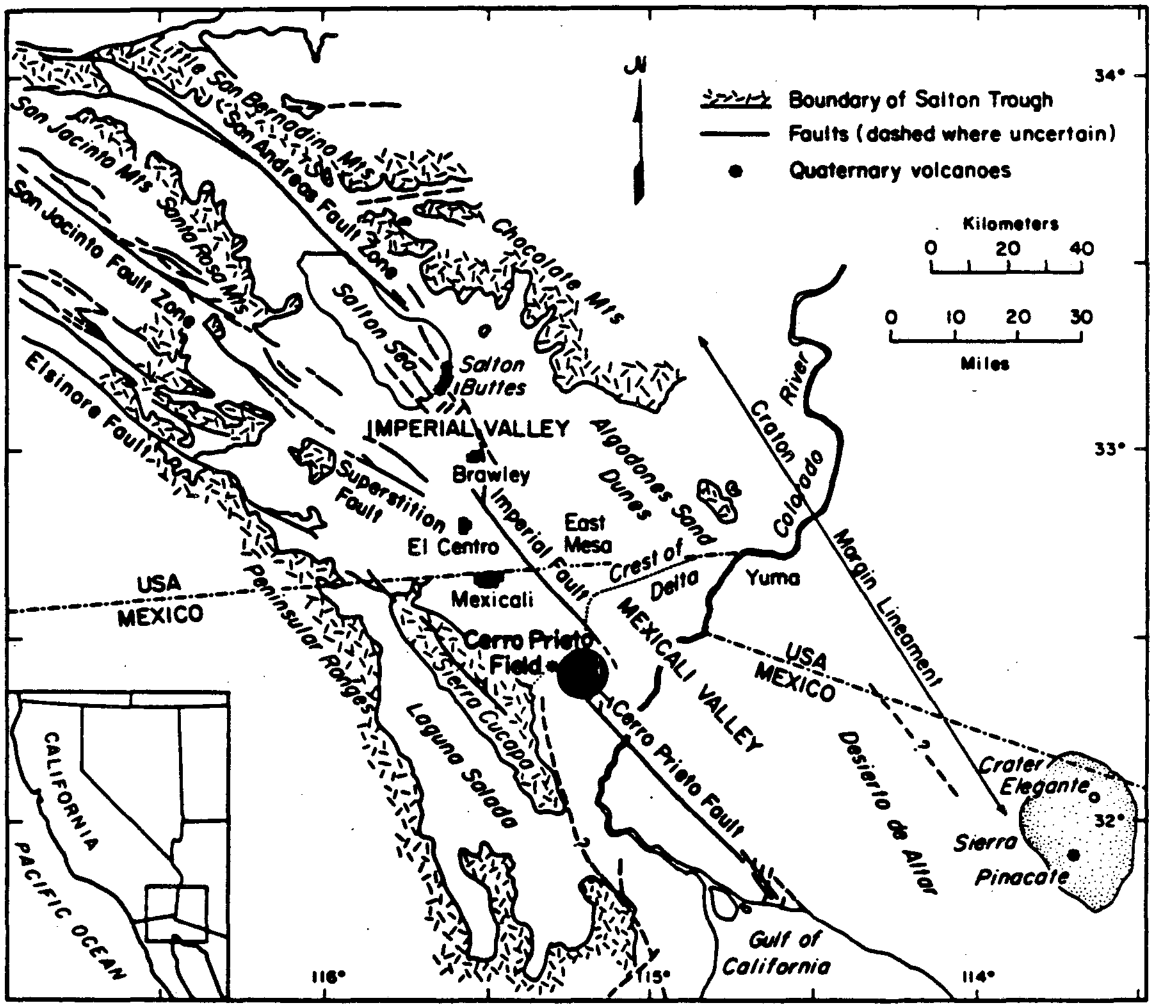

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Figure 1. Regional geology of the Salton Trough and location of the Cerro Prieto field.

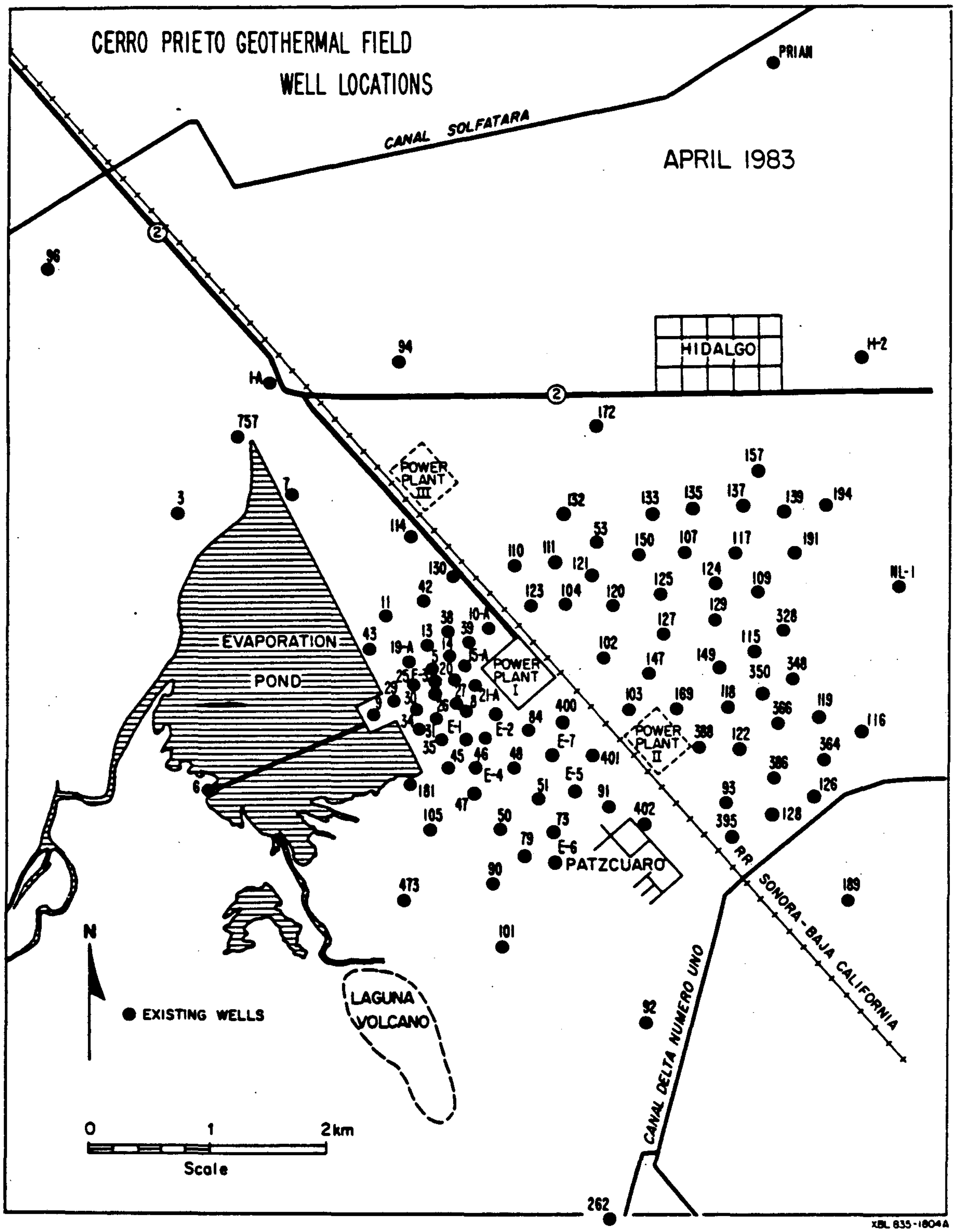

Figure 2. Location of wells in the Cerro Prieto field by April 1983.

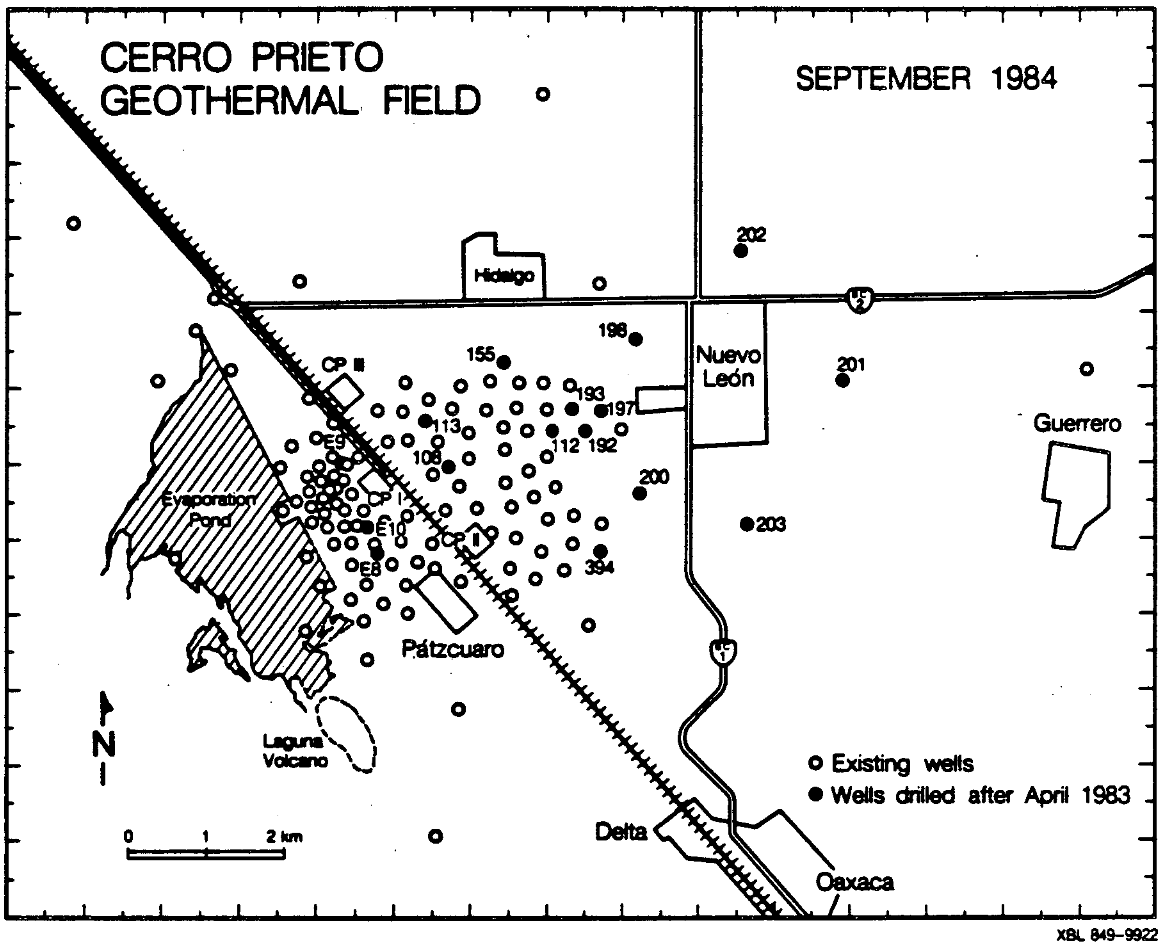

Figure 3. Location of wells drilled between April 1983 and September 1984 (from Mañón, 1984).

Table 2. Wells Completed at Cerro Prieto Between April 1983 and September 1984.

Well	Total Depth (m)	Open Intervals (m)
E-8	1796	1513-1794
E-9	1714	1479-1702
E-10	1814	1515-1807
M-108	2211	1896-2211
M-112	3622	2409-2801 & 3370-3622
M-113	2041	1771-2040
M-155	2526	2358-2525
M-192	2906	2596-2906
M-193	2226	1924-2226
M-197	2790	2578-2786
M-198	2797	2494-2622
M-200	2841	2482-2834
M-201	3610	OBSTRUCTED
M-202	3987	3712-3987
M-203	3995	3537-3993
T-394	3019	2684-3013

Note: Data from F. J. Bermejo and C. A. Esquer, personal communications, 1984.

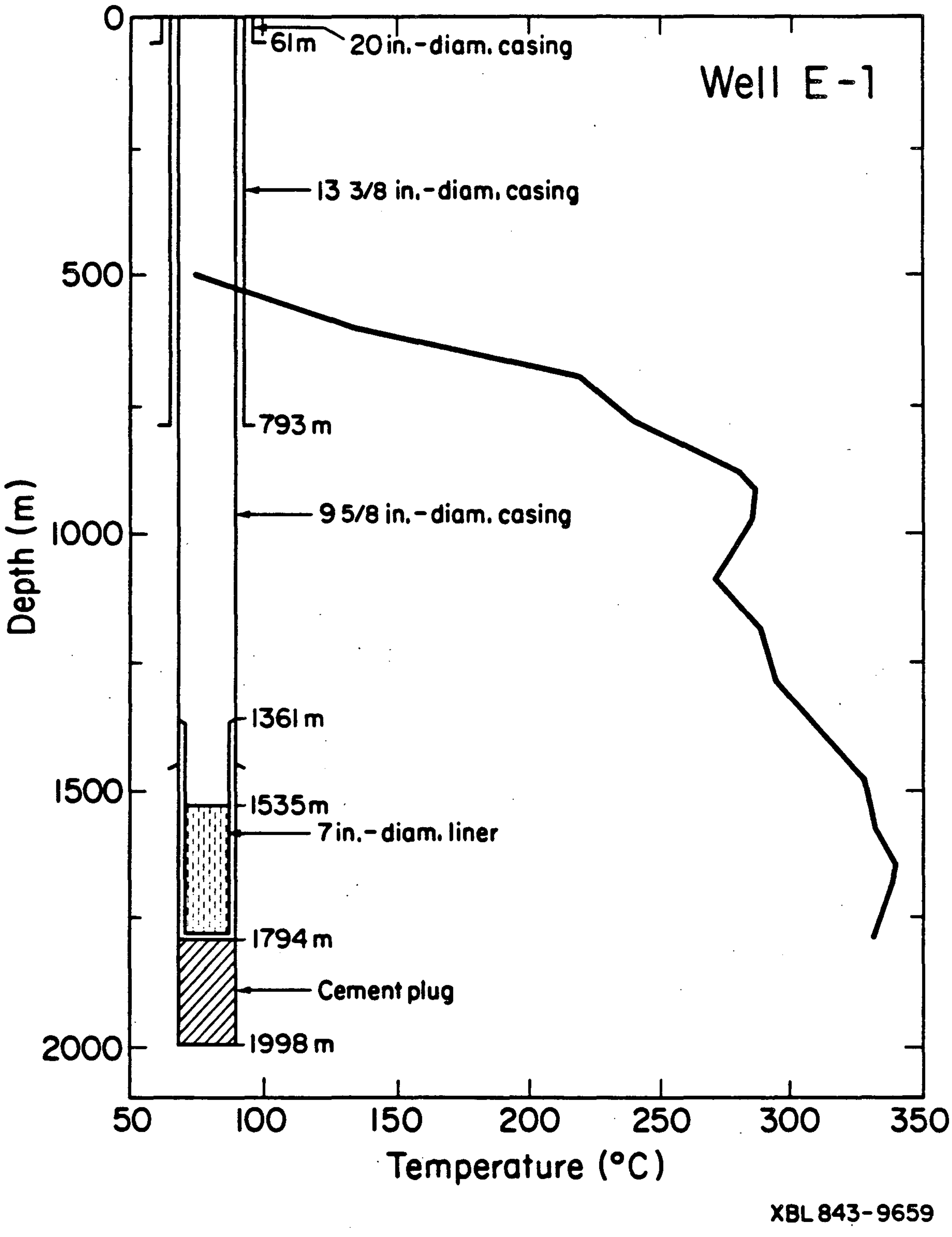

Figure 4. Completion and temperature profile for well E-1 (from F.J. Bermejo, personal communication, 1984).

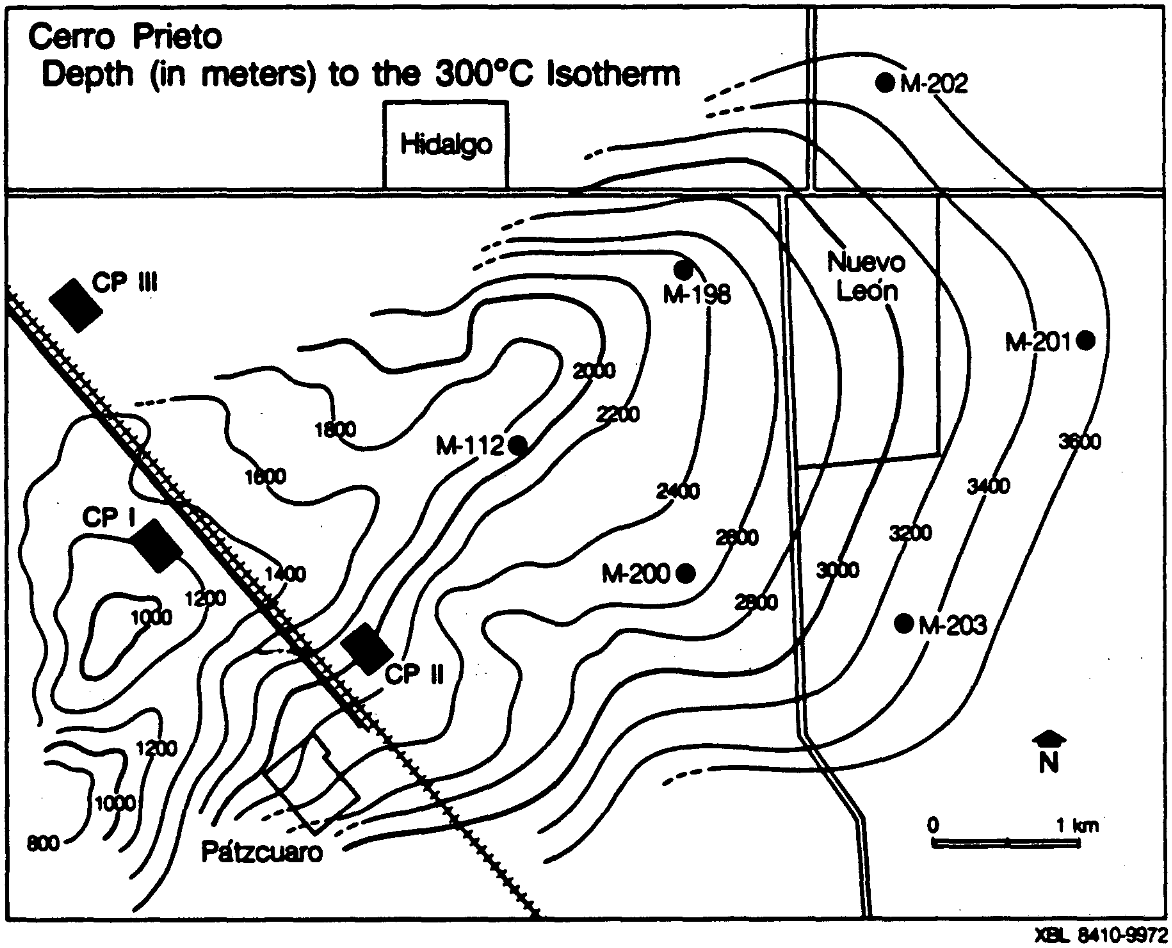

Figure 5. Depth to the 300°C isotherm (from Mañón, 1984).

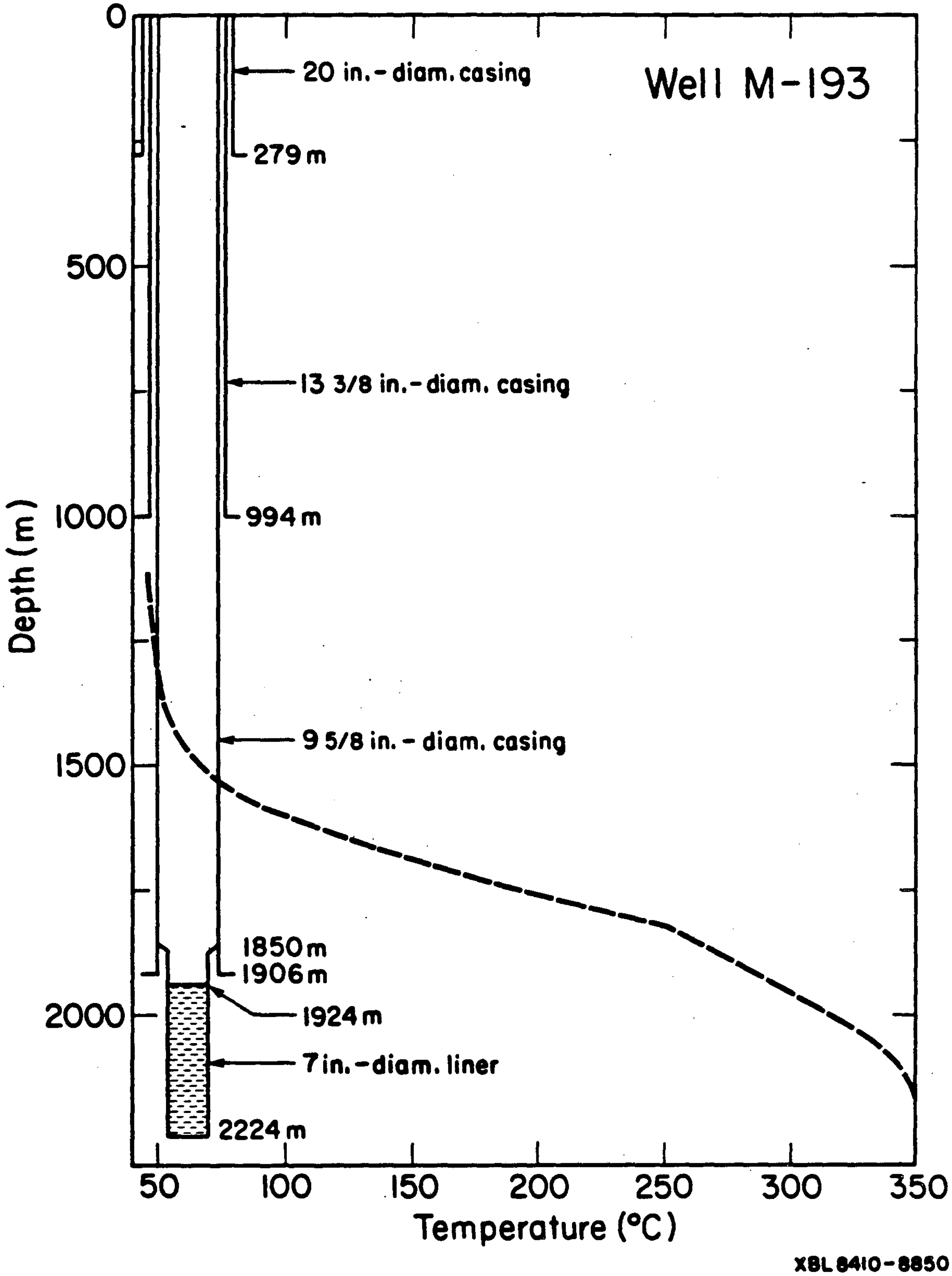

Figure 6. **Completion and temperature profile for well M-193 (from F.J. Bermejo, personal communication, 1984).**

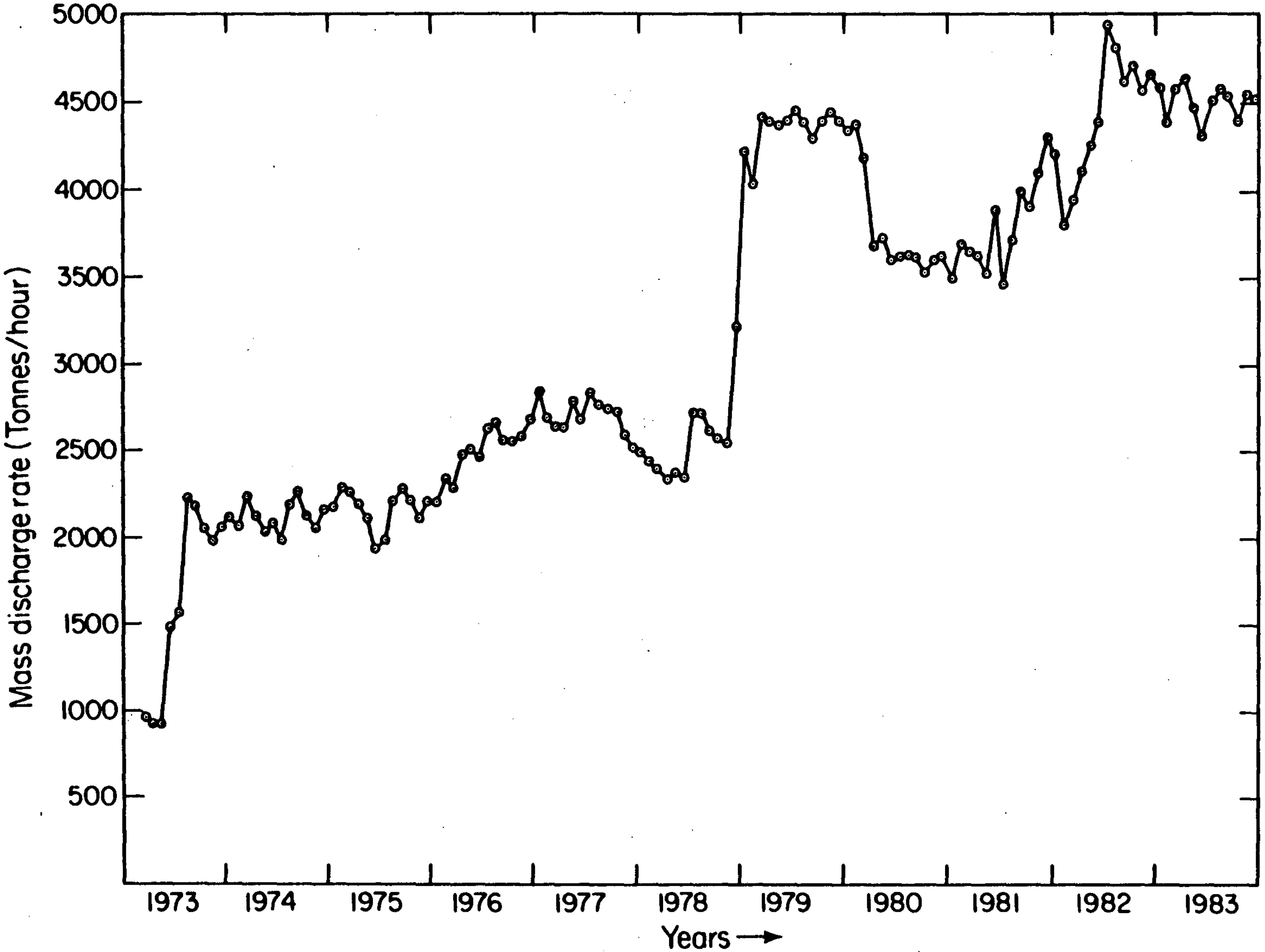

Figure 7. Mass production rate at Cerro Prieto (data from F.J. Bermejo, personal communication, 1984).

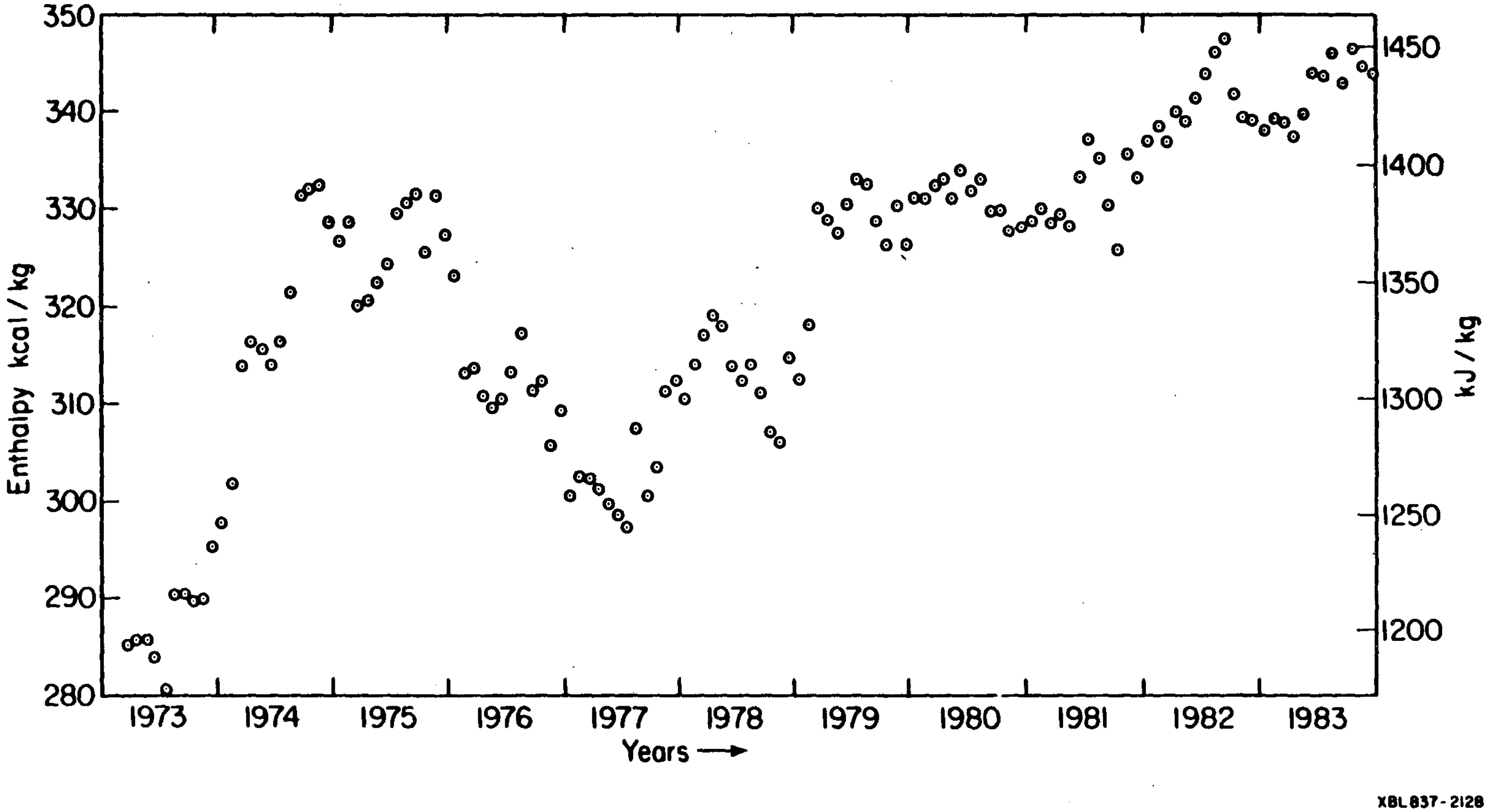

Figure 8. Average enthalpy of the fluids produced at Cerro Prieto (data from F.J. Bermejo, personal communication, 1984).

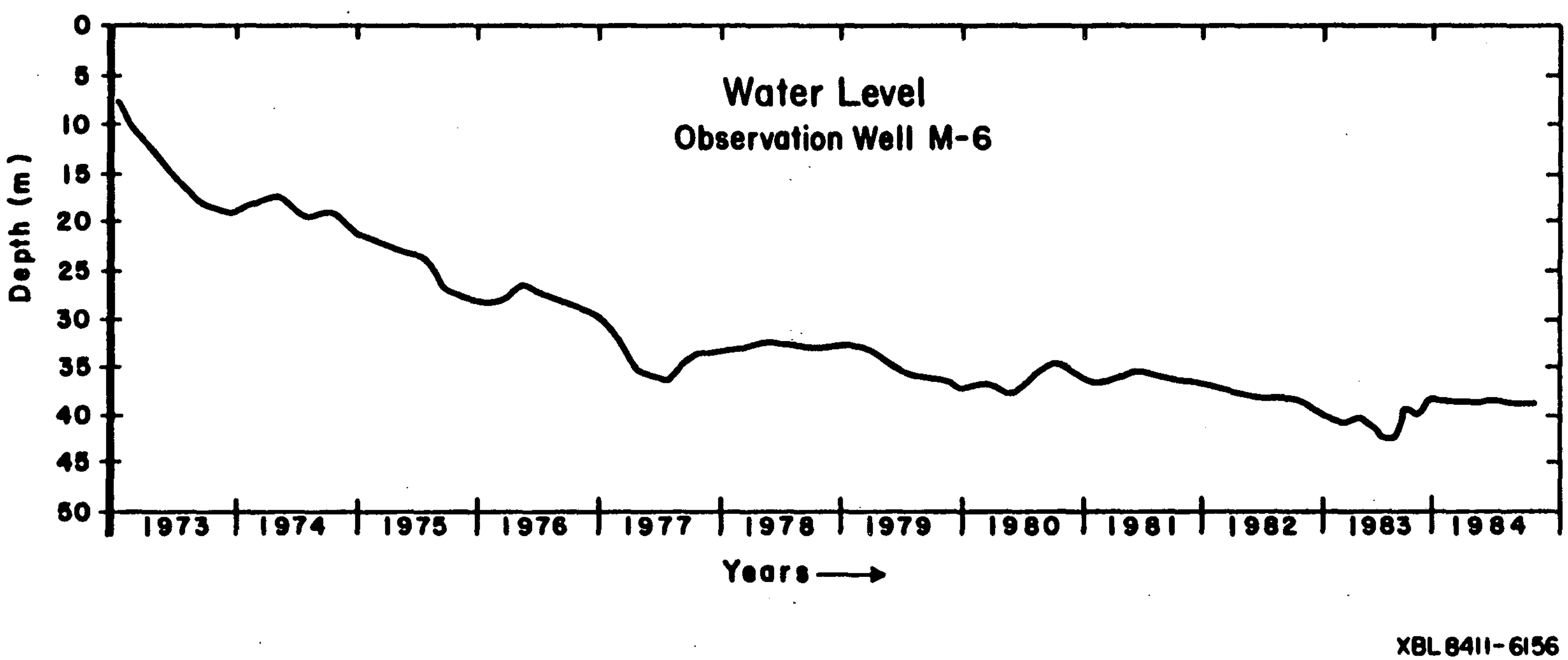

Figure 9. **Change of water level in Cerro Prieto well M-6 (from F.J. Bermejo, personal communication, 1984).**

Table 3. Annual Output at Cerro Prieto Geothermal Field.

Year	Steam-brine mixture production (tonnes x 10^6)	Electrical generation (GWh)	Specific fluid consumption (tonnes/MWh)
1973	10.2	193	52.8
1974	18.7	463	40.4
1975	19.1	518	36.9
1976	22.1	579	38.2
1977	23.8	592	40.2
1978	22.0	598	36.8
1979	38.2	953	40.1
1980	33.1	915	36.2
1981	33.0	954	34.6
1982	38.7	1263	30.6
1983	39.5	1220	32.4
	298.4	8248	

Note: Data from Mañón (1984).

Table 4. Wells Supplying Steam to Power Plant Cerro Prieto I (March 1984).

Well	Total Depth (m)	Separator Pressure $(kg/cm^2)g$	Steam Flow Rate (tonnes/h)	Brine Flow Rate (tonnes/h)	Fluid Enthalpy (kJ/kg)
E-2	1946	7.2	41.2	67.0	1501
E-3 M-20	1950 1386	7.0	41.6	132.1	1209
E-4	1767	8.6	76.2	77.2	1755
E-5	1970	8.3	56.6	111.5	1428
E-6	3098	7.7	46.2	101.2	1371
E-7	2122	8.7	90.8	138.7	1553
M-10A	1803	8.9	73.0	71.6	1776
M-11	1395	7.0	15.8	43.9	1262
M-14	1296	6.9	21.1	72.9	1175
M-19A	1448	7.2	54.0	126.0	1335
M-21A	1300	6.7	13.6	20.2	1542
M-25	1399	7.6	38.3	95.6	1314
M-26	1271	6.8	18.9	59.7	1206
M-29	1309	7.0	16.1	59.8	1151
M-30	1499	6.9	36.8	104.8	1248
M-35	1301	7.1	40.5	120.6	1234
M-42	1326	7.2	40.9	142.9	1178
M-43	1695	6.9	16.6	57.2	1177
M-45	1397	7.7	16.6	13.7	1838
M-47	1729	7.5	46.8	82.7	1466
M-50	1256	8.0	61.5	159.3	1305
M-51	1599	8.1	72.6	152.8	1396
M-73	1885	7.7	57.5	120.8	1391
M-79	1813	8.2	61.5	107.5	1403
M-84	1696	8.4	83.4	27.8	2266
M-90	1385	7.6	31.3	92.7	1253
M-91	2299	7.6	59.3	95.5	1512
M-102	1996	7.4	19.7	2.2	2563
M-103	2015	7.9	44.3	31.3	1929
M-104	1725	7.6	16.5	25.8	1525
M-105	1680	8.1	35.5	74.4	1396
M-114	1696	7.6	27.1	90.7	1199
M-120	2101	8.3	53.3	48.8	1804
M-130	1696	7.4	37.3	90.4	1322
M-169	2396	8.3	40.7	90.6	1374
			1503.1	2909.9	

Note: Data from F. J. Bermejo, personal communication, 1984.

Table 5. Cerro Prieto II Well Production Data (March 1984).

Well	Total Depth (m)	Wellhead Pressure $(kg/cm^2)g$	Mass Flow Rate (tonnes/h)	Fluid Enthalpy (kJ/kg)
M-93	2561	7	266	1334
M-115	2603	5	187	1404
M-116	3041	14	477	1400
M-118	2664	15	550	1502
M-119	2956	37	473	1431
M-122	2822	36	377	1555
M-124	2436	49	517	1574
M-127	2504	13	232	1478
M-128	3012	11	452	1418
M-147	1908	47	546	1833
M-149	2395	13	229	1538
M-169	2396	12	350	1515
T-328	2695	7	224	1562
T-348	2895	11	438	1595
T-350	3117	14	461	1510
T-364	2926	15	512	1427
T-366	2981	20	520	1515
T-386	2657	8	245	1436
T-388	2570	23	448	1495
T-395	2775	14	401	1334
T-400	2445	49	449	1651

Note: Mass flow rates and fluid enthalpies were measured using James' (1970) lip pressure method. Data from F. J. Bermejo, personal communication, 1984.

Table 6. Cerro Prieto III Well Production Data (March 1984).

Well	Total Depth (m)	Wellhead Pressure $(kg/cm^2)g$	Mass Flow Rate (tonnes/h)	Fluid Enthalpy (kJ/kg)
M-109	2396	35	451	1574
M-110	1996	15	521	1449
M-117	2495	14	512	1683
M-120	2101	11	272	1737
M-125	2315	13	454	1570
M-133	2450	11	346	1590
M-137	2504	16	494	1555
M-139	2494	16	500	1694
M-150	2104	10	164	2043
M-157	2621	11	390	1700
M-191	2499	17	539	1677

Note: Mass flow rates and fluid enthalpies were measured using James' (1970) lip pressure method. Data from F. J. Bermejo, personal communication, 1984.

Table 7. Chemical Composition of Separated Brine at Cerro Prieto.

Well	Date	Wellhead pressure $(kg/cm^2)g$	Separation pressure $(kg/cm^2)g$	Brine production (tonnes/h)	Steam/gas production (tonnes/h)	pH	Components (in mg/l, under laboratory conditions) Na	K	Li	Ca	Cl	HCO_3	TDS	SiO_2
E-4	4/24/84	56.2	8.5	57.7	67.1	6.6	10972	3066	29	414	20299	49	36435	1002
E-6	4/24/84	12.0	8.4	108.4	45.7	7.2	10909	2959	29	509	20316	80	37138	1094
E-7	4/25/84	68.8	9.5	148.2	90.1	7.0	12319	3449	33	489	23274	47	41624	1266
M-10A	4/17/84	64.5	9.0	69.5	66.6	6.2	9856	2912	31	373	18582	76	33300	1183
M-14	4/17/84	30.6	7.3	68.3	21.1	6.8	4679	804	12	241	8335	127	14779	693
M-21A	4/23/84	7.7	7.5	19.3	13.2	7.2	5761	1263	16	256	10232	117	18414	838
M-35	4/23/84	8.8	7.7	123.4	39.1	8.1	4227	782	10	158	7503	71	13413	706
M-51	4/25/84	16.9	8.1	148.2	73.1	7.1	6100	1477	16	201	10795	100	19039	927
M-84	4/27/84	8.8	8.4	23.4	80.7	7.0	10485	2958	29	470	19797	63	35463	925
M-90	4/24/84	7.7	7.6	102.5	30.4	7.6	4562	926	12	158	7886	76	14309	708
M-91	4/27/84	9.8	7.8	85.5	57.0	7.1	10021	2704	27	373	18547	71	34003	1308
M-103	4/25/84	8.8	8.1	80.7	41.7	6.9	6104	1405	15	191	10795	92	19445	1069
M-105	4/24/84	9.1	8.6	69.4	36.7	7.3	9742	2279	25	531	17798	49	32095	938
M-114	4/30/84	7.6	7.5	92.3	24.5	7.8	7110	1357	17	432	13281	72	23270	718
M-120	4/26/84	17.9	9.5	39.7	48.0	6.7	10151	2946	30	382	18815	51	33762	1112
M-169	4/26/84	64.7	8.1	70.7	31.7	7.1	11552	3164	29	491	21462	57	39725	1266

Note: Data from F. J. Bermejo, personal communication, 1984.

Table 8. Chemical Composition of Separated Steam at Cerro Prieto.

Well	Date	Wellhead pressure $(kg/cm^2)g$	Separation pressure $(kg/cm^2)g$	Brine production (tonnes/h)	Steam/gas production (tonnes/h)	Components (wt%)								
						H_2O	CO_2	H_2S $\times 10^{-2}$	CH_4 $\times 10^{-2}$	NH_3 $\times 10^{-3}$	H_2 $\times 10^{-3}$	N_2 $\times 10^{-3}$	Ar $\times 10^{-4}$	He $\times 10^{-6}$
M-21A	5/12/82	19.0	6.4	105.7	41.1	98.13	1.75	8.1	1.8	10.3	3.3	3.7	1.3	0.0
M-31	5/19/82	7.0	6.5	24.0	9.7	98.62	1.29	6.3	1.8	8.0	3.2	4.7	1.2	1.7
M-51	5/25/82	9.0	7.7	178.5	83.3	98.37	1.52	6.9	2.2	7.6	4.1	7.0	1.8	4.2
M-104	4/2/82	8.1	7.1	25.5	38.4	96.61	3.19	13.6	4.6	8.0	11.6	6.4	1.5	0.0
M-105	5/25/82	9.2	8.2	76.9	51.2	99.17	0.77	3.9	1.5	4.1	2.8	5.8	1.5	3.4
M-120	4/13/82	36.9	8.8	118.0	95.1	98.20	1.68	8.1	1.9	12.4	4.1	4.3	1.1	6.0
E-3	4/27/82	31.5	6.7	125.3	34.5	98.20	1.66	7.9	1.3	14.2	4.0	4.8	1.2	4.3

Note: Data from F. J. Bermejo, personal communication, 1983.

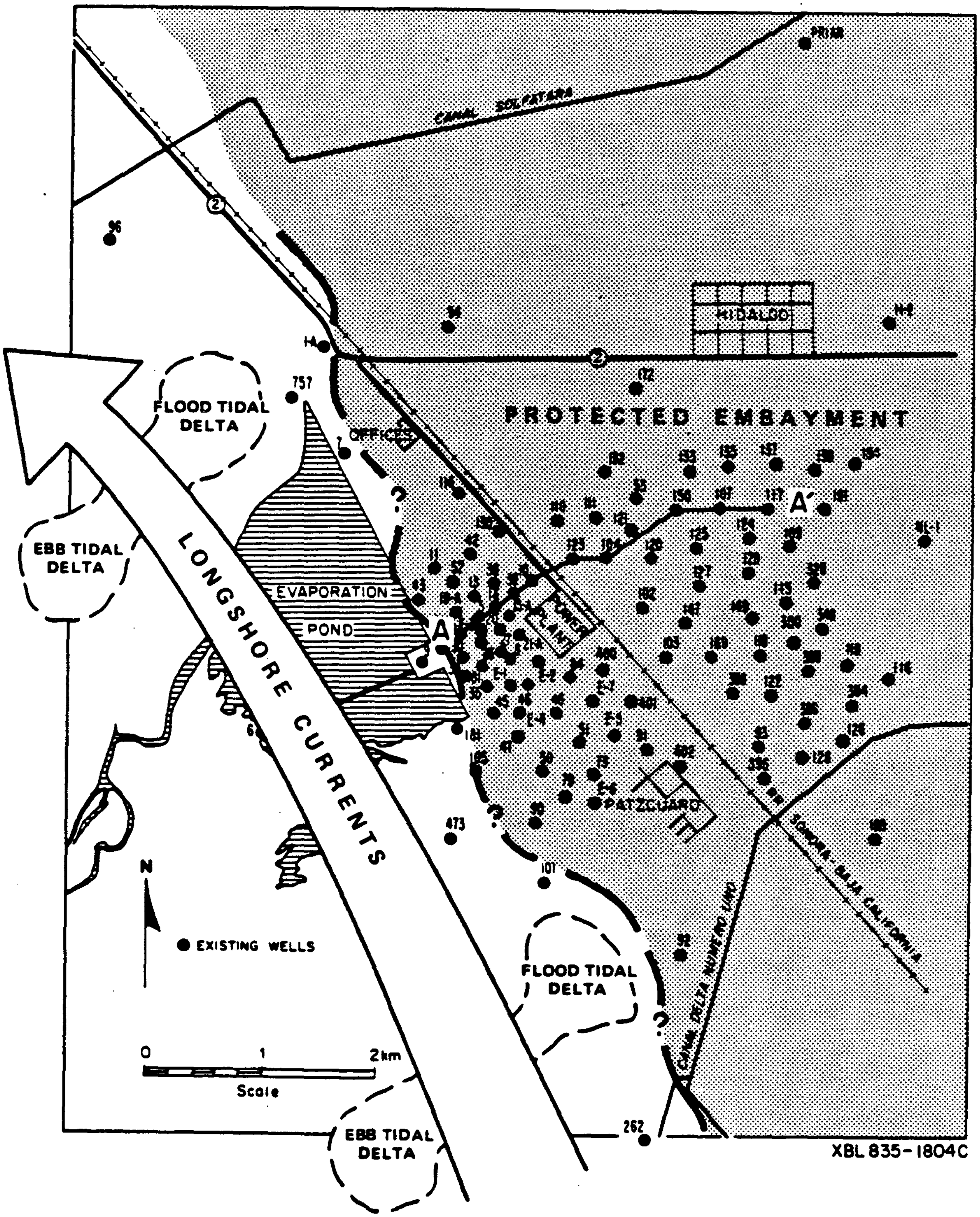

Figure 10. **Schematic paleoenvironmental map of the deeper part of the Cerro Prieto section (from Halfman et al., 1984b).**

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