

SUMMARY OF 1976 GEOTHERMAL DRILLING – WESTERN UNITED STATES

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In 1976 there were 52 wells and 13 deep observation holes drilled to explore for and develop geothermal resources in the States of California, Idaho, Nevada, Oregon, and Utah. This was an increase of 27% over the total number of locations drilled in 1975. Of the 52 wells drilled during 1976, 39 (75%) are now considered to have successfully found at least potentially commercial quantities of steam or hot water, 8 are otherwise suspended, and 5 were abandoned. Two new fields were discovered, in the Imperial Valley and Nevada, and four important extensions to production were made at The Geysers.

Table 1 summarizes the drilling activity by States and Table 2 by Operator. Included are all wells spudded during calendar year 1976. The total footage drilled was 437,752 feet, which represents an increase of 82,609 feet (23%) over the total footage drilled in 1975. As in 1975, the three operators most active in 1976 were Union, Aminoil, and Republic Geothermal, based on footage drilled.

CALIFORNIA

There was a significant increase in geothermal drilling in the Imperial Valley during 1976 (Figure 1).

At Westmorland, Republic Geothermal drilled the "Landers" #2 to 7507 feet, discovering a new geothermal field southwest of the Salton Sea (Niland) KGRA field. The new field discovery was soon confirmed by the successful drilling and completion of three deep step-out wells: the "Dearborn" #1 (8000 feet), "Landers" #1 (7705 feet), and "Kalin Farms" #1 (8490 feet). Maximum recorded temperatures were approximately 500°F., and short-term flow rates exceeded 40,000 B/D. Republic then drilled the "Dearborn" #2 (4564 feet) and "Landers" #3 (4650 feet) wells in a successful attempt to evaluate and produce from an intermediate-depth commercial reservoir. Long-term flow tests are now being conducted to further delineate the thermal, chemical, and flow parameters of the six Republic wells now drilled in the Westmorland field.

Union Oil completed two wells in the Brawley area, the "Kruger" #1 (6793 feet) and "Jiminez" #1 (9618 feet). Both were successful, which brings the total number of potential commercial wells in the Brawley area to five. Union is now also conducting long-term testing in conjunction with power plant design.

At East Mesa, Magma drilled on federal KGRA land immediately south of the Bureau of Reclamation wells. The two new wells, Magma "US" #44-7 (7328 feet) and Magma "US" #48-7 (7523 feet), were both successfully tested with bottom hole temperatures exceeding 370°F. Meanwhile, at the Heber field, Chevron drilled the "GTW" #5 (7089 feet) as a deep observation hole and Union drilled three observation holes and two production wells, the "Thomson" #1 (7132 feet) and "Thomson" #2 (9701 feet). The two Union wells are reported to be commercial, extending confirmed production to the south and southwest.

At The Geysers field in Northern California, a series of development and extension wells were being drilled (Figure 2). Of the 16 development wells drilled, Union completed 13 in the Main Geysers area to supply PG&E Units 1-12 and Pacific Energy (now Thermogenics, Inc., a division of Hughes Aircraft Corp.) added one for use in Unit 15, a 55 mw. plant now under construction. The Shell "U.S. Geothermal" #C-5 and the recompleted Aminoil "CA-1862" #37-21 were successful development wells drilled further to the south.

Six wells were drilled in attempts to make generally modest extensions to the known productive limits of The Geysers field. The McCulloch "Francisco" #1-5 (8970 feet) obtained 75,000 #/hr. of dry steam at a location one mile north of previously proven production, and the Union "Phelps" #1 (8317 feet), also drilled in Lake County, was apparently successful at an extension site one mile northeast of developed production. Commercial extension wells were also completed at significant step-out distances of up to three miles to the northwest by Aminoil with the "Wildhorse" #5 (9327 feet) and "Aidlin" #1 (8629 feet).

STATE	REGION	AREA	OPERATOR	WELLS	PROD.	SUSP.	ABD.	OBS.	FOOTAGE	
Calif.	Imperial Valley	Westmorland	Republic Geothermal	6	6	0	0	0	40,916	
		Brawley	Union	2	2	0	0	0	16,411	
		East Mesa	Magma Power	2	2	0	0	0	14,851	
		Heber	Union	5	2	0	0	3	29,633	
			Chevron	1	0	0	0	1	7,089	
			Union	14	14	0	0	0	122,675	
	The Geysers	Main Geysers	Aminoil		2	2	0	0	0	20,967
			Pacific Energy		1	1	0	0	0	10,550
			McCulloch		1	1	0	0	0	10,153
			Castle Rock	Aminoil	3	1	2	0	0	21,963
				Shell	1	1	0	0	0	5,626
				Aminoil	1	0	1	0	0	11,561
		Middletown	Chevron		1	0	1	0	0	9,232
			Shell		1	0	0	1	0	8,250
				Shell	1	0	0	1	0	10,431
			Cloverdale	Shell	1	0	0	1	0	10,431
			Mt. Konocti	Magma Power	1	0	1	0	0	6,660
			Calistoga	AMAX	3	0	0	0	3	5,868
Mono Co.	Long Valley	Republic Geothermal	1	0	1	0	0	6,920		
	Inyo Co.	Coso Hot Springs	Battelle Pac.NW Lab.	1	0	0	0	1	1,352	
Nevada	Churchill County	Desert Peak	Phillips	2	2	0	0	0	7,342	
		Stillwater	Union	3	0	0	0	3	11,654	
Oregon	Lander Co.	Beowawe	Chevron	1	0	1	0	0	5,680	
		Klamath Hills	Thermal Power	1	0	0	1	0	5,842	
Idaho	Cassia Co.	Raft River	Idaho Nat.Eng.Lab.	2	2	0	0	0	8,991	
		Boise	Idaho Nat.Eng.Lab.	2	0	0	0	2	3,188	
Utah	Beaver Co.	Roosevelt	Phillips	1	1	0	0	0	7,513	
			Thermal Power	2	2	0	0	0	7,362	
	Millard Co.	Cove Fort	Union	1	0	0	1	0	1,151	
	Iron Co.	Beryl Junction	McCulloch	2	0	1	1	0	17,921	

TABLE #1. SUMMARY BY STATES, 1976 GEOTHERMAL DRILLING, WESTERN U. S.

Earlier in the year Aminoil had unfortunately been less successful in adding production in the southeast part of the field where the "Davies Estates" #2 (8231 feet) and #3 (10,240 feet) reportedly both found adequate temperatures but insufficient steam flow.

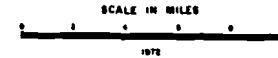
The five exploratory wildcat wells drilled at distances further from known production at The Geysers do not appear as yet to have found commercial production (Figure 3). The Magma "Watson" #1, located on the south flank of Mt. Konocti, was suspended at 5437 feet with mechanical hole problems. The Shell "Hilary Farms" #1 (6500 feet) and "Bounsall" #1 (8250 feet) were both abandoned, having found insufficient temperatures at the depths drilled. Chevron has suspended the "Dry Creek" #1 at 8597 feet awaiting further evaluation, and Aminoil suspended the "B-J" #1 after having drilled to 10,228 feet. Nearby, in Napa County, Amax drilled three tempera-

ture observation holes.

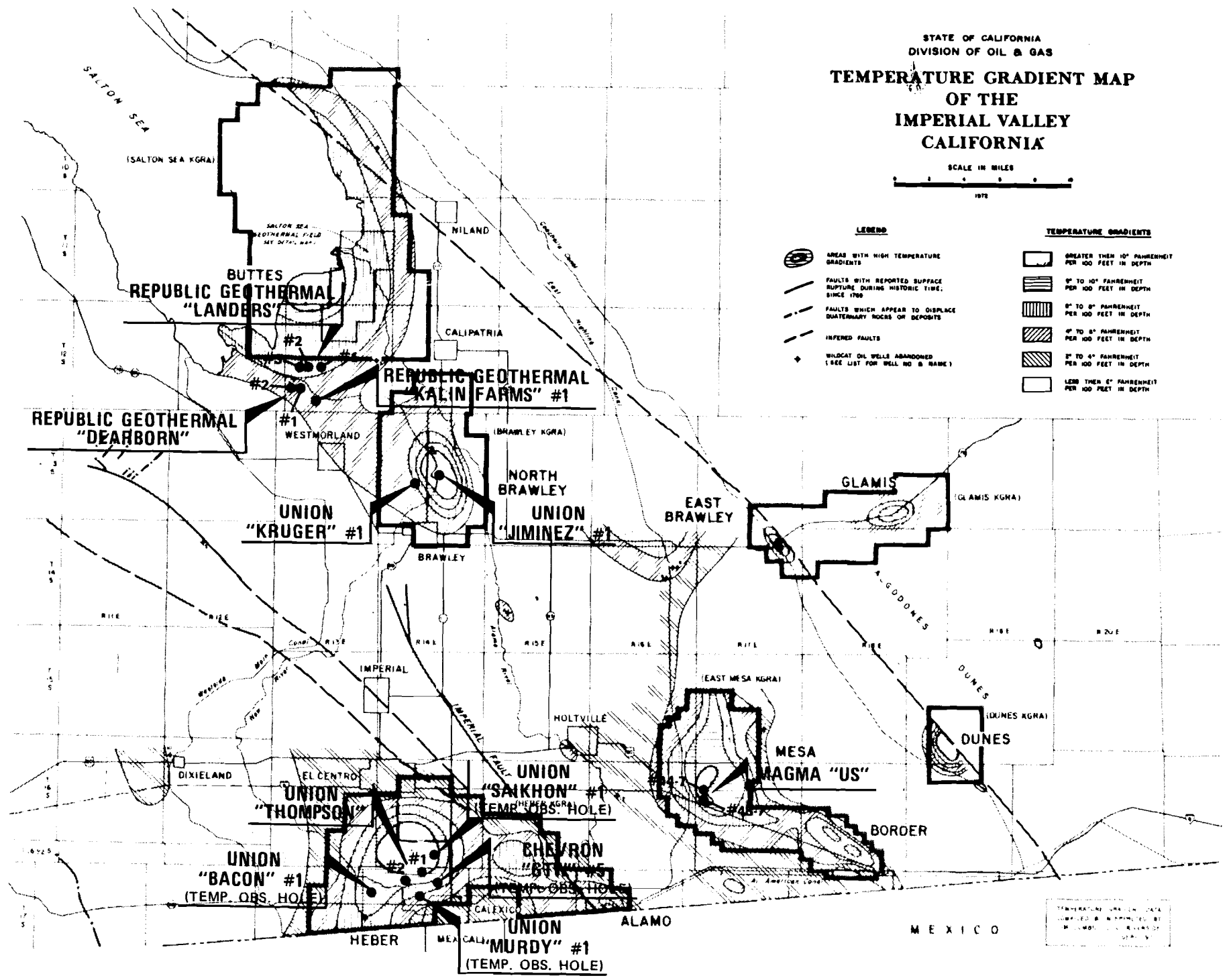
Along the Sierran front of eastern California is the Long Valley Caldera (Figure 4). The area has recently been the site of extensive USGS geothermal resource investigations, and in spring of 1976 Republic Geothermal drilled the "Long Valley" #66-29 to 6920 feet as the first deep test well within the caldera. Bottom-hole temperatures were disappointingly low, less than 200°F., and the outlook for the eastern part of the caldera now appears severely limited.

About 120 miles south of Long Valley is the Coso Hot Springs area. Battelle Pacific Northwest Laboratory, operating under an ERDA contract, continuously cored the "BDSH" #1 observation hole to 1352 feet in granitic basement as part of a continuing evaluation of the hot dry rock potential suspected to exist under the Naval Weapons Center. At a depth of 1000 feet the hole had a reported temperature of at least 300°F.

STATE OF CALIFORNIA
DIVISION OF OIL & GAS
**TEMPERATURE GRADIENT MAP
OF THE
IMPERIAL VALLEY
CALIFORNIA**



- LEGEND**
- AREA WITH HIGH TEMPERATURE GRADIENTS
 - FAULTS WITH REPORTED SURFACE RUPTURE DURING HISTORIC TIME, SINCE 1700
 - FAULTS WHICH APPEAR TO DISPLACE QUATERNARY ROCKS OR DEPOSITS
 - INFERRED FAULTS
 - WILDCAT OIL WELLS ABANDONED (SEE LIST FOR WELL NO. & NAME)
- TEMPERATURE GRADIENTS**
- GREATER THAN 10° FAHRENHEIT PER 100 FEET IN DEPTH
 - 8° TO 10° FAHRENHEIT PER 100 FEET IN DEPTH
 - 6° TO 8° FAHRENHEIT PER 100 FEET IN DEPTH
 - 4° TO 6° FAHRENHEIT PER 100 FEET IN DEPTH
 - 2° TO 4° FAHRENHEIT PER 100 FEET IN DEPTH
 - LESS THAN 2° FAHRENHEIT PER 100 FEET IN DEPTH



TEMPERATURE GRADIENT DATA
OBTAINED & ANALYZED BY
M. WOODRUFF, DIVISION OF
OIL & GAS

Figure 10-1976 Geothermal Wells, Imperial Valley, California

Figure 1 - 1976 Geothermal Wells, Imperial Valley, California

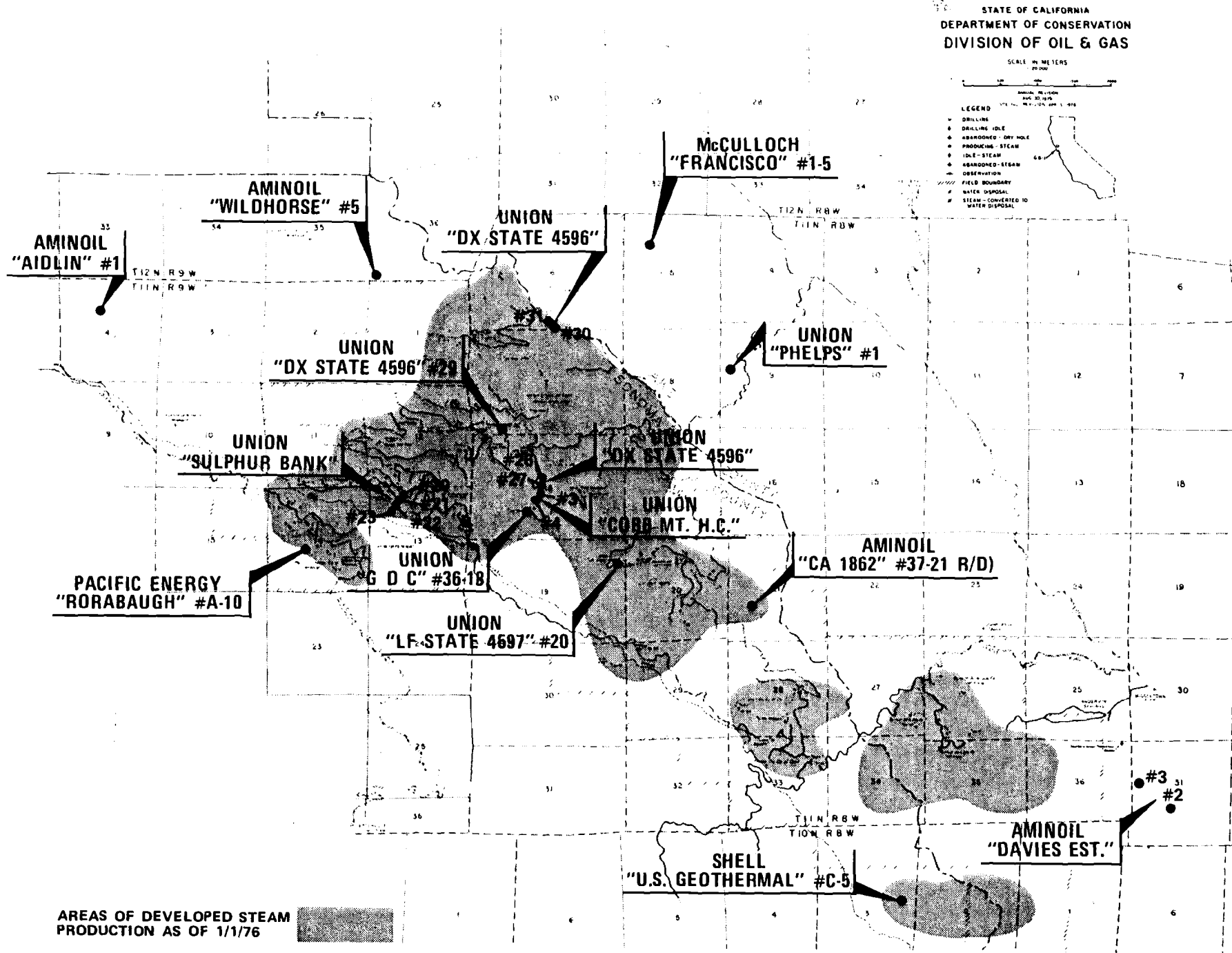


Figure 2, 1976 Geothermal Wells, The Geysers Field, California

NEVADA

In 1974 Phillips drilled the "Deserk Peak" #29-1 to a depth of 7662 feet at a location 5 miles southeast of Brady Hot Springs in Churchill County. After evaluation, Phillips returned in the fall of 1976 to drill the "Deserk Peak" #21-1 (4150 feet). This well is considered a commercial new field discovery, and the #21-2 confirmation well that immediately followed is reported to have a maximum temperature of 390°F. at a 3192 foot T.D. Additional drill sites are now being permitted. Twenty miles further southeast, Union was drilling three deep observation holes in the Stillwater area to depths of 2672 feet-5532 feet. A nearby 4237 foot well drilled in 1964 had a maximum temperature of 265°F. Elsewhere in Nevada, the "Rossi" #21-19 (5680 feet), was drilled and temporarily suspended by Chevron at Beowawe. The location is less than one mile southeast of their "Ginn" #1-13 drilled to 9563 feet in 1974.

OREGON

The one geothermal well drilled in 1976 was the Thermal Power "O'Connor Ranch" #1, located 12 miles south of Klamath Falls in the vicinity of shallow holes with 200°F. water at less than 300'. The "O'Connor" #1 was abandoned at 5842 feet after an unsuccessful attempt to recover lost drill pipe in the well.

IDAHO

The Idaho National Engineering Laboratory (INEL) continued exploration drilling in the Raft River Basin. The "RRGE" #2, originally drilled in 1975, was deepened from 5988 feet to 6543 feet, and the "RRGE" #3 was drilled in "birdfoot" fashion, meaning the original hole (5853 feet) and two directionally deviated lower redrills to 5532 feet and 5935 feet are all open to completion. The #3 well flows 800 gpm of 297°F. water. INEL also drilled two deep observation holes to 1222 feet and 1283 feet near Boise to help define the shallow intermediate-temperature geothermal resources of that area.

UTAH

Three additional development wells were successfully completed in the Roosevelt KGRA, site of a significant new field discovery in 1975. Phillips drilled #25-15 (7513 feet), their seventh geothermal well and sixth producer in that field. On nearby State leases within the same KGRA, Thermal Power completed the "Utah State" #14-2 (6108 feet) and #72-16 (1254 feet). Well #72-16, located near the controlling surface fault, hit steam at 300 feet, 700 feet and 1200 feet. Preliminary tests of #72-16 demonstrate a wellhead pressure of 355 psig and a temperature of 432°F. The indicated total mass flow rate is about 1 million #/hour.

OPERATOR	WELLS DRILLED	PRODU-CIBLE	SUS-PENDED	ABAN-DONED	OBSER-VATION	TOTAL FOOTAGE DRILLED
Union	25	18	0	1	6	181,524
Aminoil	6	3	3	0	0	54,491
Republic Geothermal	7	6	1	0	0	47,836
McCulloch	3	1	1	1	0	28,074
Shell	3	1	0	2	0	24,307
Chevron	3	0	2	0	1	22,001
Magma	3	2	1	0	0	21,511
Phillips	3	3	0	0	0	14,855
Thermal Power	3	2	0	1	0	13,204
Idaho Nat. Eng. Lab.	4	2	0	0	2	12,179
Pacific Energy	1	1	0	0	0	10,550
Amax	3	0	0	0	3	5,868
Battelle Pac. NW Lab.	1	0	0	0	1	1,352
TOTALS:	65	39	8	5	13	437,752

TABLE #2, SUMMARY BY OPERATOR, 1976 GEOHERMAL DRILLING, WESTERN U.S.

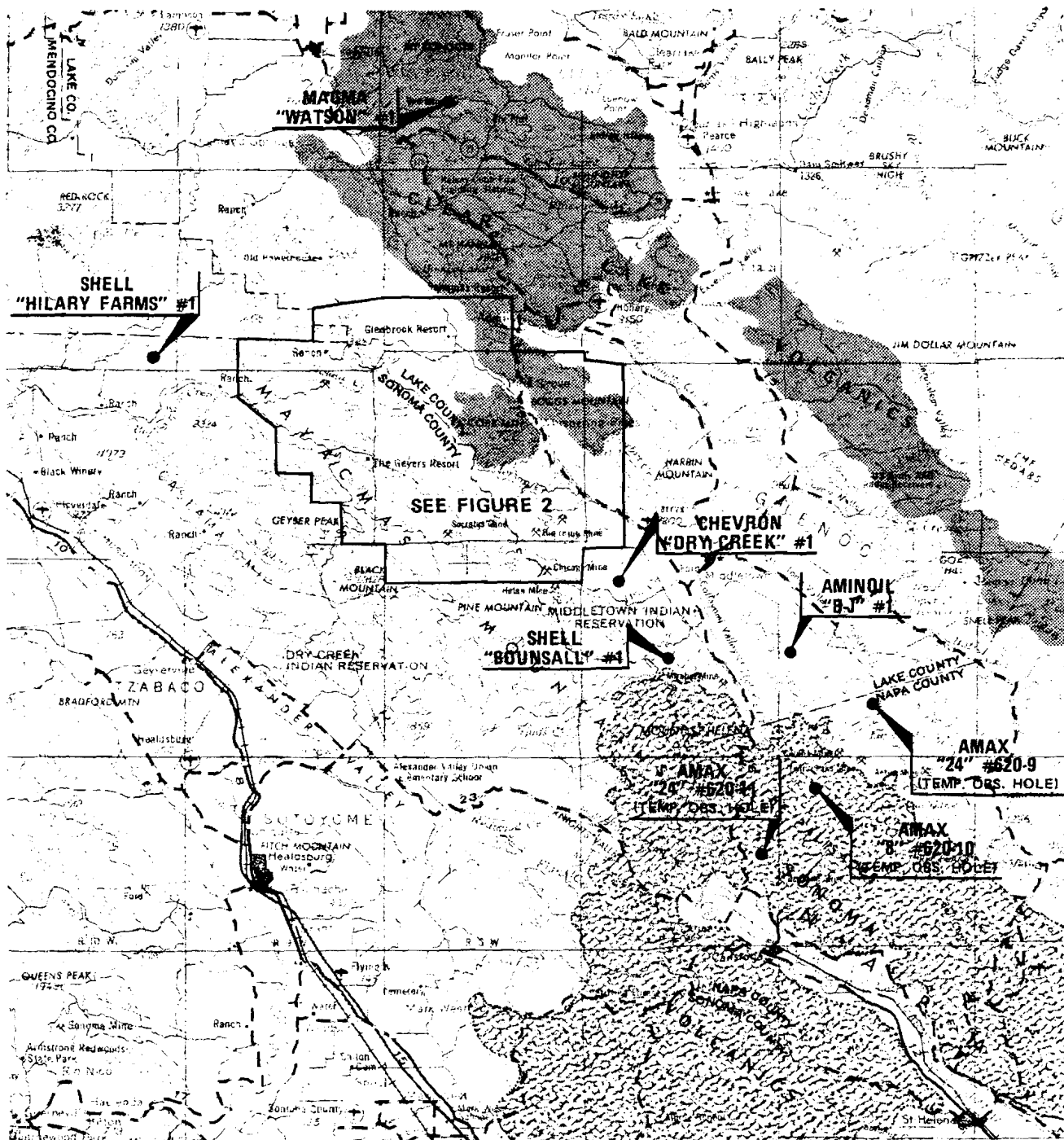


Figure 3, 1976 Geothermal Wells, The Geysers Region, California

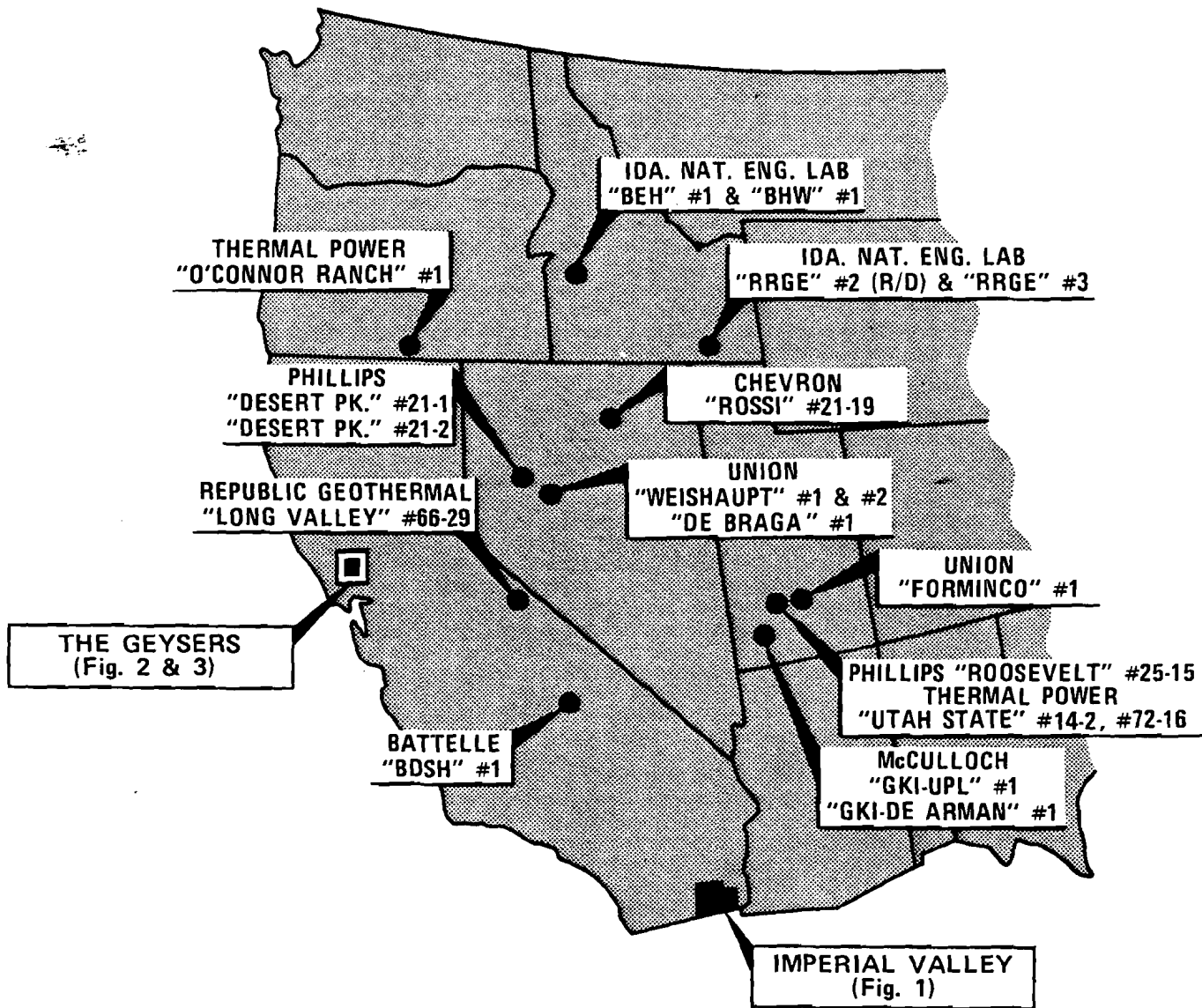


Figure 4, 1976 Geothermal Wells, Western United States

Union drilled the "Forminco" #1 at Cove Fort, about 18 miles east of Roosevelt. The well was finally aborted at 1151 feet and abandoned after having fought significant lost circulation and hydrogen sulphide problems. McCulloch drilled two wells to the south near Beryl Junction. The first was abandoned at 4986 feet and the "De Arman" #1 has been suspended indefinitely after reaching a total depth of 12,295 feet.

In summary, the geothermal industry demonstrated in 1976 a moderately increased drilling effort that achieved a healthy mix of development, production step-out, and exploratory wild-cat wells in both proven and unproven provinces. The indicated success of 75% of the total deep

wells drilled is still extremely high, especially considering nine unproven areas were explored. Hopefully this success ratio will remain high as exploration and drilling technologies evolve and improve.

Dr. Smith, Vice President-Exploration, received his education as a geologist at Middlebury College and Indiana University. After spending a decade as an explorationist with Standard Oil Company of California, he has been with Republic Geothermal for the past two years. Mr. Isselhardt received a M.A. (geology) at U.C. Berkeley and was active with Union Oil geothermal operations for five years before coming to Republic in 1976. Mr. Matlick, an exploration geologist-geochemist, joined Republic in 1975 after completing his M.S. in geology at Arizona State University.