WATER ENTRY BELOW STEAM PRODUCTION: A CASE HISTORY AT THE GEYSERS

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Burmah Oil and Gas Company has drilled over twenty holes in the southeast portion of The Geysers steam field; to date only one has proved nonproductive. This report documents a case history unique to Burmah of a water entry below steam production.

History

A 12-1/4" hole was drilled to 3000' and 9-5/8" OD casing was cemented to the surface. Burmah then directionally drilled an 8-3/4" hole with air and encountered minor steam entries at 5120', 6335', and 6457', as shown on Fig. 1. No additional steam entries were found below these depths. Total steam flow measured less than 20,000 pounds per hour.

At 7580' an increase of air pressure on the stand pipe from 420 psig to 580 psig was noted. The well started making 128 barrels per hour of water having a temperature of 188-190°F measured at the surface. The partial chemical analysis of this water is listed on Fig. 2, Column 1. Air drilling continued to 7665' with no decrease in water production. Drill pipe was pulled out of the hole to 4363' and air circulated for four hours. The well produced only steam, no water. No temperature or pressure survey was run. The lack of water at 4363' indicates a water pressure of less than 1355 psig.

Since the hole produced a sub-commercial rate of steam, Burmah decided to plug the hole and directionally redrill the hole in a more westerly location. Steam entries were encountered at 4259', 4362', 5480', 5660', 5943', 6731', 6858', and 6980'. Fig. 1 shows the location of these steam entries. The hole produced approximately 120,000 pounds *of* steam per hour after the last steam entry. Again the hole produced water, but at a lower rate of approximately 80 barrels an hour. The analysis of this water is shown on Column 2 on Fig. 2. The water entry indicated by the increase of standpipe air pressure was at 7138'. No pressure or temperature survey was run. The hole was plugged with 43 sacks of cement. The drill pipe stuck while pulling out of the hole. The best estimate of the top *of* the plug is 6830' measured by the free point indicator on the stuck pipe. The stuck drill pipe was partially recovered to 6062'. Further recovery attempts proved unsuccessful.

After the drilling rig was released, the surface well head pressure stabilized at 484 psig. A static pressure and temperature survey stopped at 3515'. The survey indicated essentially saturated steam. At a later date the well, when first opened for a flow test, produced water along with steam. Column 3 *of* Fig. 2 lists the partial chemical analysis. Subsequent flows at higher rates produced saturated steam with no entrained water. The isochronal testing indicated a flow rate of 86,000 pounds of steam per hour. An analysis of the steam condensate produced at this flow rate is shown in Column 4 *of* Fig. 2.

Discussion

The chemical analyses of the two water entries are similar but not identical even given allowances for sampling and testing errors. The samples are dissimilar enough to preclude the positive conclusion that they are the same water. It is plausible that the two waters, though sharing a common origin, are located in separate fracture systems. Both water entries are in siliceous argillites.

The water produced on the first test (Column 3) indicates contamination from cement (pH and chloride) and also some evaporation of the deep water as inferred from the increased boron concentration. The analysis of the steam condensate is typical of steam condensate analyses of wells in the surrounding area. A physical chemistry analysis has not been attempted to determine if the chemical constitutents of the water and steam are in equilibria.

A review of the wells in the surrounding area shows this well to be bounded by commercial production 2100' to the north, 4000' to the west, 1100' to the south and 3700' to the east. None of these wells showed any indication of deep water entries. It should be noted, however, that none of these wells reached the equivalent vertical depth of the water entries in the original hole or redrill of the subject well. Other wells at greater distances always have been drilled to at least 700 vertical feet below the deepest water entry. The vertical and horizontal difference between the two water entries of 407' and 540', respectively, indicates a possible structural rather than an hydrological control of the water in this localized area. Because temperature and pressure surveys were not conducted while the holes were producing water, conclusions about steam-water communication and equilibrium are difficult.

Due to the physical condition of the hole (apparent sharp dog leg and pipe left in the hole), it is not possible to positively demonstrate by temperature and pressure surveys that the water has been shut off by the cement plug. However, it is certainly inferred indirectly by the quality of the steam produced during the well test. The loss of steam flow rate indicates also that at least the bottom two steam entries were effectively plugged.

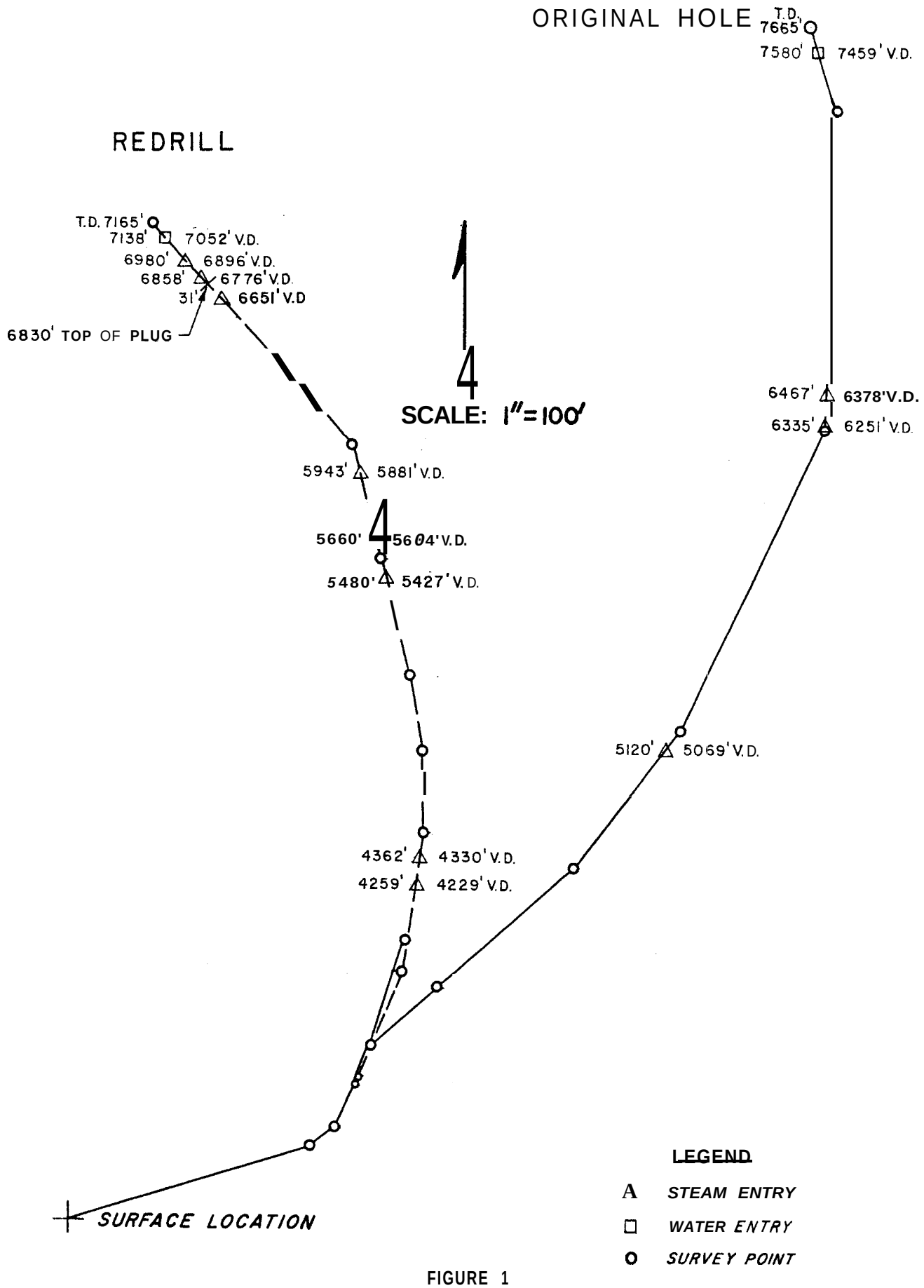
ORIGINAL HOLE
T.D. 7665'
7580' 7459' V.D.
REDRILL
T.D. 7165'
7138' 7052' V.D.
6980' 6896' V.D.
6858' 6776' V.D.
31' 6651' V.D
6830' TOP OF PLUG
SCALE: 1"=100'
6467' 6378' V.D.
6335' 6251' V.D.
5943' 5881' V.D.
5660' 5604' V.D.
5480' 5427' V.D.
5120' 5069' V.D.
4362' 4330' V.D.
4259' 4229' V.D.
SURFACE LOCATION
LEGEND
A STEAM ENTRY
WATER ENTRY
SURVEY POINT

FIGURE 1

CHEMICAL ANALYSES

	1	2	3	4
pH	5.3	5.1	8.4	5.7
Specific Conductance µmhos/cm @ 25°C	650.0	1000.0		
Calcium, mg/l	<10.0	10.0		<.1
Magnesium, mg/l		37.0		.005
Ammonia, mg/l		43.1		25.2
Sodium, mg/l	146.0	117.0		<.1
Iron, mg/l				1.0
Boron, mg/l	82.8	24.1	142.0	2.4
Potassium, mg/l	110.0	86.0		<.01
Aluminum, mg/l		<.02		c.1
Mercury, µg/l		54.0	1.5	2.4
Sulfate, mg/l		414.0		10.0
Chloride, mg/l	41.0	10.0	26.0	2.0
Fluoride, mg/l		8.0		<.01
Bicarbonate, mg/l		12.2		80.0
Nitrate, mg/l		2.2		15. 5
Silica, mg/l		400.0		1.2
Sulfide, mg/l				100.0

1. Water entry of original hole.
2. Water entry of redrill.
3. Water produced on initial well flow.
4. Steam condensate at 85,000 pounds per hour flow rate.

FIGURE 2