UNIVERSITY OF UTAH
RESEARCH INSTITUTE
UURI
EARTH SC
391 CHI
SALT LAKE
801

S Dak
well data

Ed Sammel
Water Resources Division
USGS
345 Middlefield Rd., MS 67
Menlo Park, CA 94025

Dear Ed:

Attached are the Petroleum Information data I promised to send you. Included are descriptions of 71 wells in South Dakota, which comprise all of our well temperatures in that state, and a few wells in south-central North Dakota.

Also attached are a format tabulation and formation codes to help you with the data listings.

I hope these attachments will be useful to you. Please call or write if you have any questions.

Sincerely,

Ross

Ross W. Whipple

RWW/smk

Encl.

cc: Mike Wright

PET. INFO. - SOUTH DAKOTA

WELLS WITH BHT'S BY COUNTY

COUNTY	No. WELLS WITH BHT'S
BUTTE	4
CORSON	7
CUSTER	1
DEWEY	3
FALL RIVER	9
HAAKON	4
HARDING	30
HUGHES	2
JACKSON	1
JONES	1
MELLETTE	1
PENNGTON	2
PERKINS	3
STANLEY	2
SULLY	1

TOTAL FOR STATE	71

①

SOUTH DAKOTA

		①	②	③	④	⑤	⑥	⑦	⑧	⑨
	1 PAGE	2 JONES	3 HAAKON	4 STANLEY	5 BUTTE	6 DEWEY	7 PERKINS	8 HARDING	9 CORSON	MELLETTE
005 1	846 ✓	1	1							
2	847 ✓		1	11						
3	848 ✓		11		1	1				
4	849 ✓				11	11				
5	850 ✓				1		111			
6	851 ✓							1111		
7	852 ✓							111	1	
8	853 ✓							111		
9	854 ✓							111	1	
10	855 ✓							11		
11	856 ✓								111	
12	857 ✓							111		
13	858 ✓							111		
14	859 ✓							11	1	
15	860 ✓							111		
16	861 ✓							111		
17	862							1	1	1
18		1 ✓	4 ✓	2 ✓	4 ✓	3 ✓	3 ✓	30 ✓	7 ✓	1 ✓
19										
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29										
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31										

SOUTH DAKOTA

	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	1 PAGE	2 HARDING	3 CORSON	4 MELLETTE	5 HUGHES	6 SULLY	7 JACKSON	8 PENNINGTON	9 CUSTER	FALL RIVER
1	863 ✓				11	1	1			
2	864 ✓							11	1	1
3	865 ✓									1111
4	866 ✓									1111
5					2 ✓	1	1 ✓	2 ✓	1 ✓	9 ✓
6										
7										
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31										

SOUTH DAKOTA

△ less than 1 km
○ More than 1 km OK

~~AMBIENT 45°F (7.2°C)~~

Y – YOUNGER THAN MADISON
O – OLDER

AMBIENT °F		1	2 Sec	3 T	4 R	5 DEPTH FT	6 °F	7 °F/1000	8 DEPTH (m)	9 °C		°C/km
47.4	1	1 Y	10	1N	29E	2636	123	29.6	803	50.6	▲	52 ✓
47.3	2	2 Y	18	3N	24E	1760	92	26.7	536	33.3	▲	46 ✓
47.3	3	3 Y	11	3N	27E	[illegible]	88	36.7	357	31.1	▲	63 ✓
47.3	4	Y				2738	129	30.6	834	53.9	▲	54 –
47.3	5	4 Y	10	4N	28E	[illegible]	83	30.5	380	28.3	▲	52 ✓
47.3	6	5 Y	11	5N	19E	1698	90	26.5	518	32.2	▲	46 ✓
47.3	7	6 ?	1	6N	21E	4042	142	24.0	1232	61.1	○	43 ✓
45.0	8	7 Y	29	6N	21E	2313	120	32.4	705	48.9	▲	59 ✓
45.9	9	8 Y	25	10N	6E	2590	92	NO	789	33.3	△	32 ✓
45.9	10	9 O	4	12N	22E	5010	130	NO	1527	54.4	○	30 ✓
45.9	11	10 O	4	12N	22E	5030	175	25.8	1533	79.4	●	47 ✓
45.0	12	11 O	29	13N	22E	5010	162	23.4	1527	72.2	○	43 ✓
	13	12 Y	16	14N	3E	3098	105	19.4	944	40.6	△	35 ✓
	14	13 Y	29	14N	4E	3208	117	22.4	978	47.2	△	41 ✓
	15	14 Y	14	14N	6E	3245	98	NO	989	36.7	△	30 ✓
	16	15 Y	20	14N	11E	3271	137	28.1	997	58.3	▲	51 ✓
	17	Y				4750	167	25.7	1448	75.0	●	47 ✓
45.0	18	16 O	24	14N	15E	6301	172	20.2	1920	77.8	○	37 ✓
	19	17 O	8	14N	16E	6315	170	19.8	1925	76.7	○	36 ✓
	20	18 Y	29	15N	2E	3302	117	21.8	1006	47.2	○	40 ✓
	21	19 ?	21	15N	5E	3900	167	31.3	1189	75.0	●	57 ✓
	22	20 Y	36	15N	6E	3368	128	24.6	1026	53.3	●	45 ✓
	23	21 Y	4	15N	7E	4150	163	28.4	1265	72.8	●	52 ✓
	24	22 Y	1	17N	1E	[illegible]	86	29.4	424	30.0	▲	54 ✓
44.1	25	23 O	11	17N	7E	8225	198	NO	2507	92.2	○	34 ✓
45.0	26	24 O	22	19N	7E	8273	180	NO	2522	82.2	○	30 ✓
[illegible]	27	25 Y	4	19N	25E	2577	96	19.8	785	35.6	△	36 ✓
	28	26 O	2	20N	4E	8454	208	19.3	2577	97.8	○	35 ✓
	29	27 O	10	20N	4E	8373	196	NO	2552	91.1	○	33 ✓
45.0	30	28 O	16	20N	5E	8375	200	NO	2553	93.3	○	34 ✓
	31	29 O	22	20N	5E	8298	222	21.3	2529	105.6	○	39 ✓

SOUTH DAKOTA - P2

OK ↓ ↓

		1	2 Sec	3 T	4 R	5 Depth (ft)	6 °F	7 °F/1000	8 Depth (m)	9 °C		°C/km
45.0	1	30 O	27	20N	5E	8352	210	19.8	2546	98.9	O	36 ✓
	2	31 O	20	20N	6E	8410	192	NO	2563	88.9	O	32 ✓
44.13	3	32 Y	32	20N	18E	5455	143	NO	1663	61.7	O	33 ✓
45.04	4	33 O	26	21N	2E	8565	184	NO	2611	84.4	O	30 ✓
45.03	5	34 Y	22	21N	3E	7134	181	NO	2174	82.8	O	34 ✓
44.16	6	35 Y	5	21N	21E	4876	170	25.6	1486	76.7	●	47 ✓
44.17	7	36 Y	12	21N	24E	1536	87	27.3	468	30.6	▲	51 ✓
44.18	8	37 Y	35	21N	26E	2568	92	NO	783	33.3	△	34 ✓
45.09	9	38 Y	21	22N	3E	6754	172	NO	2059	77.8	O	34 ✓
	10	39 O	24	22N	4E	8981	218	19.3	2737	103.3	O	35 ✓
	11	40 O	5	22N	5E	8875	216	19.3	2705	102.2	O	35 ✓
	12	41 O	5	22N	5E	9000	222	19.7	2743	105.6	O	36 ✓
	13	42 O	23	22N	5E	9097	220	19.2	2772	104.4	O	35 ✓
45.6	14	43 Y	27	22N	5E	7121	192	20.5	2170	88.9	O	38 ✓
	15	44 O	7	22N	6E	9004	190	NO	2744	87.8	O	29 ✓
41.1	16	45 O	36	22N	21E	6480	154	NO	1975	67.8	O	32 ✓
45.0	17	46 O	24	23N	3E	9092	250	22.5	2771	121.1	O	41 ✓
	18	47 O	31	23N	3E	8682	209	NO	2646	98.3	O	34 ✓
	19	48 O	19	23N	4E	9116	215	NO	2778	101.7	O	34 ✓
	20	49 O	22	23N	5E	9010	222	19.6	2746	105.6	O	3[illegible] ✓
45.0	21	50 O	30	23N	5E	9131	220	19.2	2783	104.4	O	35 ✓
	22	51 O	27	23N	6E	9152	219	NO	2790	103.5	O	34 ✓
	23	52 O	32	23N	6E	8852	225	20.3	2698	107.2	O	37 ✓
	24 ✓	53 O	19	23N	8E	9152	234	20.6	2790	112.2	O	38 ✓
41.1	25	✓ 54 Y	32	23N	27E	2688	89	NO	819	31.7	△	32 ✓
49.0	26	55 O	14	43N	29W	3130	164	38.0	954	73.3 ✓	▲	67 ✓
47.4	27	56 Y	1	111N	79W	1521	101	36.8	464	38.3	▲	64 ✓
47.4	28	57 Y	16	111N	79W	1522	82	24.3	464	27.8	△	41 ✓
47.4	29	58 Y	9	114N	77W	1525	101	36.7	465	38.3 ✓	▲	64 ✓
	30	59 ?	OMIT									
47.8	31	60 Y	10	4S	16E	1623	108	38.8	495	42.2 ✓	▲	68 ✓

SOUTH DAKOTA - p 3

OK ↓

	1	2 Sec	3 T	4 R	5 DEPTH FT.	6 °F	7 °F/1000	8 DEPTH (m)	9 °C	°C/km
47.8	61 Y	16	4S	16E	2611	128	31.8	796	53.3	▲ 60
48.5	62 Y	35	6S	2E	1200	90	37.3	368	32.2	▲ 63
"	63 Y	11	7S	1E	2071	78	15.9	631	25.6	△ 26
"	64 Y	22	7S	1E	2388	96	21.4	729	35.6	△ 36
"	65 Y	17	8S	3E	2030	98	26.1	619	36.7	▲ 44
"	66 Y	7	9S	2E	3091	108	20.4	942	42.2	△ 35
"	67 Y	20	11S	5E	2050	158	55.1	625	70.0	▲ 97
"	68 Y	22	11S	5E	2150	100	25.6	655	37.8	▲ 44
"	69 Y	3	12S	4E	1313	94	37.3	400	34.4	▲ 63
"	70 Y	16	12S	4E	1412	88	30.4	430	31.1	▲ 50
"	71 Y	5	12S	5E	2305	108	27.3	702	42.2	▲ 47

END SD

Change

△ less than 1 km

○ Greater than 1 km

Red ○ > 50°C/km

● > 45°C/km < 50°C/km

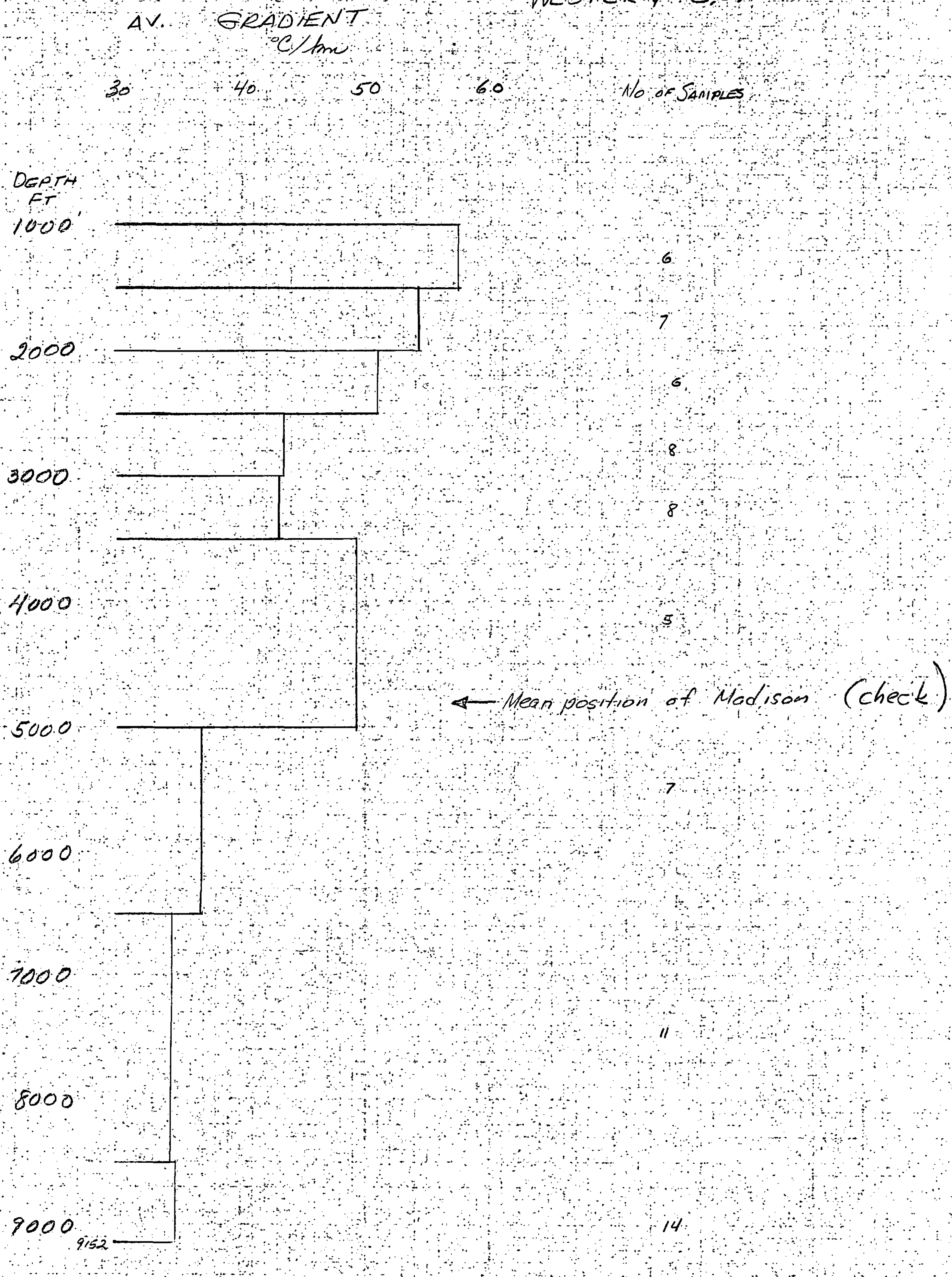
○ > 40°C/km < 45°C/km

○ > 35°C/km < 40°C/km

Blue ○ < 35°C/km

av good all holes = 42.4
all deep wells = 37.4
all shallow wells = 50.1

WESTERN S.D.


AV. GRADIENT
°C/km
30
40
50
60
No of Samples
Depth
Ft
1000'
2000
3000
4000
5000
6000
7000
8000
9000
9152
6
7
6
8
8
5
7
11
14
← Mean position of Madison (check)

SO. DAK.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33 N 164 W  93   36    10002                         048987791026792S 0489865810267881
                       10010 013 00607273 79400 8325060 900353NSSN             5927275
                       10021 TWP N 164   RGE W  93   SEC   36   055TH PRINCIPAL
                       101   NDAK BURKE      A  2061 FSL   736 FEL  NW NE SE D   D
                       102   WILHITE I J ETAL                      1 STATE
                       103    1947 KB                                 SHORT CREEK
                       104                                         API 33 013  00607 00
                       105   SPUD 08/09/1968 COMP 08/19/1968 ROTARY              D&A
                       107   DTD  5927                              FM/TD 353NSSN
                       40101 DST 01         5897- 5927 351MDSN                       003
                       40102 OVERLAPS 353MIDL  353NSSN
                       40131 FINAL OP  2H     IFP   57 FFP  134 BHT  172F
                       40201 DST 02         5864- 5894 351MDSN                       004
                       40231 FINAL OP  2H     IFP   96 FFP  121 BHT  174F

33 N 164 W  96   32    10002                         0489836910316689 0489834810316603
                       10010 023 00093273        1299050 911351MDSN            6340J66
                       10021 TWP N 164   RGE W  96   SEC   32   055TH PRINCIPAL
                       101   NDAK DIVIDE     A  820 FSL  1985 FEL     SW SE WF  WF
                       102   CALVERT DRLG & PROD                1-8 KNUDSON
                       103    1896 KB 1886 GR                          WILDCAT
                       104    1855 ES 1884 GR  P                   API 33-023- 00093 00
                       105   SPUD 10/15/1966 COMP 10/27/1966 ROTARY             D&A-OG
                       107   DTD  6249 LTD  6340                     FM/TD 351MDSN
                       40101 DST 01        6215- 6249 351MDSN                     S002
                       40110 GAS  TS IN  2H
                       40131 FINAL OP  3H     IFP   88 FFP  352 BHT  170F

40 N   1 E  29   10    10007                         0440542310061342 0440524910061280
                       10010 075 05054273        8880550 900109SOUX            2800867
                       10021 TWP N   1   RGE E  29   SEC   10   19BLACK HILLS
                       101   SDAK JONES      A   510 FSL  1889 FEL     SW SE WF  WF
                       102   TENNECO OIL                        1 HERMAN ESTATE
                       103    2071 KB 2060 GR                          WILDCAT
                       104    2331 ES 2023 GR  P                   API 40-075- 05054 00
                       105   SPUD 05/06/1966 COMP 05/13/1966 ROTARY              D&A
                       107   DTD  2800 LTD  2648                     FM/TD 109SOUX
                       40101 DST 01         1386- 1443 603GRNR               MISRUN 003
                       40201 DST 02         1390- 1443 603GRNR   1417                004
                       40231 FINAL OP  1H                FFP  373 BHT  86F
                       40301 DST 03         2619- 2653 419WALS                       005
                                                          2636
                       40302 OVERLAPS 109SOUX
                       40331 FINAL OP  1H                FFP 1359 BHT  123F

40 N   3 E  24   18    10002                         0442178110126780 0442169010126782
                       10010 055 20018273        9999550 901602FLRV            2533073
                       10021 TWP N   3   RGE E  24   SEC   18   19BLACK HILLS
                       101   SDAK HAAKON     A  1980 FSL   530 FEL     NE SE WF  WF   2
                       102   INVESTORS DRLG VENTURES            1 W R LEE
                       103    2178 KB 2170 GR                          WILDCAT
                       104    2212 DF 2204 GR P  LSE NO            API 40-055- 20018-00
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40 N   3 E  24   18    105   SPUD 01/05/1972 COMP 01/13/1972 ROTARY             D&A-G
                       107   DTD  2530 LTD  2533                     FM/TD 602FLFV
                       40101 DST 01         1720- 1800 609CRCS              MISRUN 002
                       40131                                       BHT   92F
                       40201 DST 02         2275- 2330 602OKOT                     S003
                       40231 FINAL OP  1H     IFP   99 FFP  100 BHT   94F

40 N   3 E  27   11    10002                         0442354310083398 0442332010083550
                       10010 117 05063273        8880550 900109SOUX            2804867
                       10021 TWP N   3   RGE E  27   SEC   11   19BLACK HILLS
                       101   SDAK STANLEY    A  1895 FNL  2075 FEL     SW NE WF  WF
                       102   TENNECO OIL                        1 HALL
                       103    1816 KB 1805 GR                          WILDCAT
                       104    1832 ES 1824 GR  P                   API 40-117- 05063 00
                       105   SPUD 05/19/1966 COMP 05/28/1966 ROTARY              D&A
                       107   DTD  2804 LTD  2800                     FM/TD 109SOUX
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40 N  3 E  24  18    105   SPUD 01/05/1972 COMP 01/13/1972 ROTARY            D&.-G
                     107   DTD  2530 LTD  2533                        FM/TD 602FLRV
                     40101 DST 01          1720- 1800 609CRCS  1760     MISRUN 002
                     40131                                      BHT   92F
                     40201 DST 02          2275- 2330 602DKOT  2303           S003
                     40231 FINAL OP  1H    IFP    99 FFP  100 BHT   94F

40 N  3 E  27  11    10002                          0442354310083398 0442332010083550
                     10010 117 05063273         8880550 900109SOUX          2804867
                     10021 TWP N   3   RGE E  27   SEC   11   19BLACK HILLS
                     101   SDAK STANLEY   A  1895 FNL  2075 FEL      SW NE WF  WF   3
                     102   TENNECO OIL                        1 HALL
                     103    1816 KB 1805 GR                          WILDCAT
                     104    1832 ES 1824 GR  P                  API 40-117- 05063 00
                     105   SPUD 05/19/1966 COMP 05/28/1966 ROTARY            D&A
                     107   DTD  2804 LTD  2800                        FM/TD 109SOUX
                     40101 DST 01          1158- 1182 603GRNR  1170              003
                     40131 FINAL OP  1H              FFP    87 BHT   88F  36.7
                     40201 DST 02          2598- 2630 419MNLS  2614              004
                     40210 WTR  TS IN     06M AT   2000 BWPD FRESH WTR   26
                     40231 FINAL OP  0H18M IFP 1310 FFP 1394 BHT  115F
                     40301 DST 03          2733- 2743 419DKLS  2738              005
                     40310 WTR  TS IN     07M AT   2000 BWPD FRESH WTR
                     40331 FINAL OP  0H10M IFP 1230 FFP 1433 BHT  129F

40 N  4 E  28  10    10002                          0443257810074341 0443239410074504
                     10010 117 05064273         8880550 900109SOUX          2733867
                     10021 TWP N   4   RGE E  28   SEC   10   19BLACK HILLS
                     101   SDAK STANLE    A   660 FNL   660 FWL      NW NW WF  WF   4
                     102   TENNECO OIL                        1 RANKIN TRUST
                     103    1848 KB 1837 GR                          WILDCAT
                     104    1837 ES 1829 GR  P                  API 40-117- 05064 00
                     105   SPUD 04/25/1966 COMP 05/04/1966 ROTARY            D&A
                     107   DTD  2733 LTD  2724                        FM/TD 109SOUX
                     40101 DST 01          1104- 1192 603GRNR           MISRUN 004
                     40201 DST 02          1181- 1310 603GRNR  1246              005
                     40231 FINAL OP  1H              FFP   211 BHT   83F
                     40301 DST 03          2695- 2733 351MDSN                    006
                     40302 OVERLAPS 109SOUX
                     40331 FINAL OP  1H              FFP 1503

40 N  5 E  19  11    10002                          0444136810178608 0444142210178650
                     10010 055 20004273         2641050 901602SKCK          2714J70
                     10021 TWP N   5   RGE E  19   SEC   11   19BLACK HILLS
                     101   SDAK HAAKON    A   660 FNL  1980 FEL    C NW NE WF  WF   5
                     102   EXETER OPLG ETAL                  11-2 STATE
                     103    2482 KB 2472 GR                          WILDCAT
                     104    2471 DF 2463 GR P  LSE NO           API 40-055- 20004-00
                     105   SPUD 10/01/1970 COMP 10/03/1970 ROTARY            D&A-G
                     107   DTD  2714                                  FM/TD 602SKCK
                     40101 DST 01          1697- 1800 603TPNR                    002
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40 N  5 E  19  11    40131 FINAL OP  1H    IFP    94 FFP  302 BHT   90F

40 N  6 E  21   1    10002                          0445043310153493 0445010510153481
                     10010 055 05055273         9999950 900203KC?V          4323966
                     10021 TWP N   6   RGE E  21   SEC    1   19BLACK HILLS
                     101   SDAK HAAKON    A   740 FSL   581 FWL      SW SW WF  WF
                     102   PLUM CREEK OIL DEV                 1 BE RY
                     103    1959 KB                                  WILDCAT
                     104                                        AP  40-055- 05055 00
                     105   SPUD 11/15/1965 COMP 12/20/1965 ROTARY            D&A
                     107   DTD  4323                                  FM/TD 203RDRV
                     40101 DST 01          4001- 4083 000UNKN                    0L2
                     40131 FINAL OP  1H    IFP    26 FFP    31 BHT  142F

40 N  6 E  21  29    10002                          0444459410161503 0444462310161499
                     10010 055 20008273         2641050 900602SKCK          2575J70
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33 N 163 W

33 N 163 W

33 N 163 W

33 N 163 W

33 N 163 W

33 N 163 W

33 N 163 W

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40 N  5 E 19 11   40131 FINAL OP  1H    IFP   94 FFP  302 BHT   90F

40 N  6 E 21  1   10002                         0445043310153493 0445010510153481
                  10010 055 05055273            9999950 900203RDRV          4323966
                  10021 TWP N   6   RGE E  21   SEC    1   19BLACK HILLS
                  101   SDAK HAAKON    A  740 FSL    581 FWL       SW SW WF   WF    6
                  102   PLUM CREEK OIL DEV                  1 BERRY
                  103    1959 KB                               WILDCAT
                  104                                     API 40-055- 05055 00
                  105   SPUD 11/15/1965 COMP 12/20/1965 ROTARY          D&A
                  107   DTD  4323                           FM/TD 203RDRV
                  40101 DST 01         4001- 4083 000UNKN  4042               002
                  40131 FINAL OP  1H    IFP   26 FFP   31 BHT  142F

40 N  6 E 21 29   10002                         0444459410161503 0444462310161499
                  10010 055 20008273            2641050 900602SKCK          2575J70
                  10021 TWP N   6   RGE E  21   SEC   29   19BLACK HILLS
                  101   SDAK HAAKON    A  660 FSL    660 FWL     C SW SW WF   WF    7
                  102   EXETER DRLG ETAL                 29-13 BIERWAGEN
                  103    2340 KB 2330 GR                       WILDCAT
                  104    1880 DF 1872 GR P  LSE NO        API 40-055- 20008-00
                  105   SPUD 09/24/1970 COMP 09/25/1970 ROTARY          D&A
                  107   DTD  2575                           FM/TD 602SKCK
                  40101 DST 01 STRD  2292- 2334 602MDDY  2313                 002
                  40131 FINAL OP  1H    IFP  782 FFP  818 BHT  120F

40 N 10 E  6 25   10002                         0447946010334147 0447941410334103
                  10010 019 20010273            9999950 900602DKOT          2900471
                  10021 TWP N  10   RGE E   6   SEC   25   19BLACK HILLS
                  101   SDAK BUTTE     A  660 FSL    660 FWL     C SW SW WF   WF    8
                  102   KOCH EXPLORATION                    1 RICHARDS-FEDERAL
                  103    2959 KB 2949 GR                       WILDCAT
                  104    2956 DF 2949 GR   P              API 40-019- 20010 00
                  105   SPUD 06/29/1969 COMP 07/02/1969 ROTARY          D&A
                  107   DTD  2900                           FM/TD 602DKOT
                  40101 DST 01         2553- 2626 602MDDY  2590               002
                  40131 FINAL OP  0H50M IFP   45 FFP   60 BHT   92F

40 N 12 E 22  4   10002                         0450319210144288 0450311610144353
                  10010 041 20005273            9999950 710203RDRV          5055472
                  10021 TWP N  12   RGE E  22   SEC    4   19BLACK HILLS
                  101   SDAK DEWEY     A  2345 FNL   660 FEL      SE NE WF   WF     9
                  102   INVESTORS DRLG VENTURES             3 HOLLOWAY
                  103    2357 KB 2347 GR                       WILDCAT
                  104    2347 DF 2339 GR P  LSE NO        API 40-041- 20005-00
                  105   SPUD 07/07/1971 COMP 08/07/1971 ROTARY          TA-O
                  107   DTD  5055                           FM/TD 203RDRV
                  40101 DST 01         4975- 5045 203RDRV  5010               002
                  40131 FINAL OP  2H    IFP   65 FFP  230 BHT  130F
                  40201 DST 02         5005- 5045 203RDRV              MISRUN 004
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40 N 12 E 22  4   10002                         0450285010145835 0450276010145794
                  10010 041 20009273 99999 9999960 710309DVNN            5078472
                  10021 TWP N  12   RGE E  22   SEC    4   19BLACK HILLS
                  101   SDAK DEWEY     A  3665 FNL   660 FWL      NW SW D   D
                  102   INVESTORS DRLG                   7 HOLLOWAY
                  103    2358 KB 2348 GR                       UNNAMED
                  104                                     API 40-041- 20009 00
                  105   SPUD 08/14/1970 COMP 01/07/1971 ROTARY          TA-O
                  107   DTD  5076 LTD  5078                 FM/TD 309DVNN
                  40101 DST 01         5006- 5066 203RDRV              MISRUN 003
                  40201 DST 02         5006- 5066 203RDRV                     S004
                  40210 WTR  TS IN  1H50M
                  40231 FINAL OP  2H    IFP 1162 FFP 2203 BHT  175F
                  50102 203RDRV  PERF      JET                5051- 5051      006

40 N 13 E 22 29   10002                         0450555810145230 0450547810145057
                  10010 041 20026273 [illegible]
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33 N 163 W
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33 N 163 W
33 N 163 W

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06/08/78                    P E T R O L E U M   I N F O R M A T I O N ,   C O R P                PAGE  849
                                                                       SUB FILE GEOTHERMAL LISTING

40 N  12 E  22    4     10002                          045028501014583 5 045027601014579 4
                        10010 041 20009273 99999 9999960 710309DVNN              5078472
                        10021 TWP N  13   RGE E  22   SEC    4   19BLACK HILLS
                        101   SDAK DEWEY      A  3665 FNL    660 FWL     NW SW D    D
                        102   INVESTORS DRLG                         7 HOLLOWAY
                        103    2358 KB 2348 GR                          UNNAMED
                        104                                        API 40-041- 20009 00
                        105   SPUD 08/14/1970 COMP 01/07/1971 ROTARY              TA-0
                        107   DTD  5076 LTD  5078                      FM/TD 309DVNN
                        40101 DST 01          5006- 5066 203RDRV              MISRUN 003
                        40201 DST 02          5006- 5066 203RDRV                    S004
                        40210 WTR  TS IN  1H50M
                        40231 FINAL OP  2H    IFP 1162 FFP 2203 BHT  175F
                        50102 203RDRV  PERF      JET                5051- 5051      00()

40 N  13 E  22   29     10002                          0450555810145230 0450547810145057
                        10010 041 20026273 9999910139411 110203RDRV 203RDRV  5020K75
                        10021 TWP N  13   RGE E  22   SEC   29   19BLACK HILLS
                        101   SDAK DEWEY      A   660 FSL  1980 FEL   C SW SE WO  DO
                        102   TUCK B-W                               1 LITTLE SKUNK
                        103    2288 KB 2277 GR                          UNNAMED
                        104    2293 DF 2285 GR P  LSE NO           API 40-041- 20026-00
                        105   SPUD 07/10/1975 COMP 11/19/1975 ROTARY               OIL
                        107   DTD  5020                                FM/TD 203RDRV
                        20102 203RDRV  PERF                        5001- 5020 GROSS 005
                        20150 WTR
                        40101 DST 01          5000- 5020 203RDRV                    S002
                        40131 FINAL OP  1H    IFP  477 FFP 2047 BHT  162F
                        50102 203RDRV  PERF               W/  4/FT  5001- 5020 GROSS 004

40 N  14 E   3   16     10002                          0451826010375496 0451829110375457
                        10010 019 20003273            8914050 900602SKCK          3154270
                        10021 TWP N  14   RGE E   3   SEC   16   19BLACK HILLS
                        101   SDAK BUTTE      A   658 FNL    661 FEL  NW NE NE WF   WF
                        102   TEXAS GAS EXPL ETAL                  1-16 STEVENSON-STATE
                        103    3127 KB 3117 GR                          WILDCAT
                        104    3118 DF 3110 GR P  LSE NO           API 40-019- 20003-00
                        105   SPUD 10/16/1968 COMP 10/19/1968 ROTARY               D&A
                        107   DTD  3144 LTD  3154                      FM/TD 602SKCK
                        40101 DST 01          3041- 3154 602NCSL                     002
                        40102 OVERLAPS 602SKCK
                        40131 FINAL OP  0H35M IFP  158 FFP  411 BHT  105F

40 N  14 E   4   29     10002                          0451537910366843 0451538210366737
                        10010 019 20002273            8914050 900602SKCK          3241270
                        10021 TWP N  14   RGE E   4   SEC   29   19BLACK HILLS
                        101   SDAK BUTTE      A   659 FNL    660 FWL     NW NW WF   WF
                        102   TEXAS GAS EXPL ETAL                  1-29 DUNCAN-FEDERAL
                        103    3065 KB 3055 GR                          WILDCAT
                        104    3065 DF 3057 GR P  LSE NO           API 40-019- 20002-00
                        105   SPUD 10/05/1968 COMP 10/10/1968 ROTARY               D&A
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06/08/78                    P E T R O L E U M   I N F O R M A T I O N ,   C O R P                PAGE  850
                                                                       SUB FILE GEOTHERMAL LISTING

40 N  14 E   4   29     107   DTD  3241 LTD  3240                      FM/TD 602SKCK
                        40101 DST 01          3174- 3241 602NCSL                     017
                        40102 OVERLAPS 602SKCK
                        40131 FINAL OP  1H    IFP   47 FFP   94 BHT  117F

40 N  14 E   6   14     10002                          0451751710334654 0451751110334663
                        10010 019 20007273            9999950 900602FUSN             3644
                        10021 TWP N  14   RGE E   6   SEC   14   19BLACK HILLS
                        101   SDAK BUTTE      A  1980 FSL    660 FEL   C NE SE WF   WF
                        102   KOCH EXPLORATION                       1 OLSEN
                        103    2920 KB 2910 GR                          WILDCAT
                        104    2868 DF 2860 GR  P                  API 40-019- 20007 00
                        105   SPUD 06/17/1969 COMP 06/21/1969 ROTARY               D&A
                        107   DTD  3644                                FM/TD 602FUSN
                        40101 DST 01          3213- 3276 602MDDY                     002
                        40131 FINAL OP    20M IFP 1050 FFP 1110 BHT   98F
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40 N  14 E   4   29   107   DTD  3241 LTD  3240                     FM/TD 602SKCK
                      40101 DST 01          3174- 3241 602NCSL                017
                      40102 OVERLAPS 602SKCK
                      40131 FINAL OP  1H     IFP   47 FFP   94 BHT  117F

40 N  14 E   6   14   10002                          04517517103346S4 0451751110334663
                      10010 019 20007273          9999950 900602FUSN          3644
                      10021 TWP N  14   RGE E   6   SEC   14   19BLACK HILLS
                      101   SDAK BUTTE     A  1980 FSL   660 FEL   C NE SE WF  WF
                      102   KOCH EXPLORATION                      1 OLSEN
                      103    2920 KB 2910 GR                         WILDCAT
                      104    2868 DF 2860 GR  P                API 40-019- 20007 00
                      105   SPUD 06/17/1969 COMP 06/21/1969 ROTARY           D&A
                      107   DTD  3644                               FM/TD 602FUSN
                      40101 DST 01          3213- 3276 602MDDY                002
                      40131 FINAL OP       20M IFP 1050 FFP 1110 BHT   98F

40 N  14 E  11   20   10002                          0451565010280602 0451571810280593
                      10010 105 20006273          8900550 901419MNLS          5000K72
                      10021 TWP N  14   RGE E  11   SEC   20   19BLACK HILLS
                      101   SDAK PERKINS   A   660 FSL  1980 FWL   C SE SW WF  WF
                      102   TEXACO INC                            1 W R CRAWFORD
                      103    2599 KB 2588 GR                         WILDCAT
                      104               GR     LSE NO          API 40-105- 20006-00
                      105   SPUD 09/17/1971 COMP 09/30/1971 ROTARY           D&A-G
                      107   DTD  5000 LTD                           FM/TD 419MNLS
                      40101 DST 01          3240- 3301 602MDDY                S003
                      40131 FINAL OP      45M IFP 1104 FFP 1208 BHT  137F
                      40201 DST 02          4708- 4791 419MNLS                004
                      40231 FINAL OP  1H30M IFP  242 FFP  598 BHT  167F

40 N  14 E  15   24   10002                          0451599410222981 0451599410222911
                      10010 105 20011273          9999950 900203RDRV          6504376
                      10021 TWP N  14   RGE E  15   SEC   24   05STH PRINCIPAL
                      101   SDAK PERKINS   A  1980 FSL  1980 FEL   C NW SE WF  WF
                      102   SMOKEY OIL                       33-24 ACKERMAN-FEDERAL
                      103    2433 KB 2423 GR                         WILDCAT
                      104                                      API 40 105  20011 00
                      105   SPUD 11/27/1976 COMP 02/20/1976 ROTARY           D&A
                      107   DTD  6504 LTD  6503                     FM/TD 203RDRV
                      40101 DST 01          6290- 6311 203RDRV                002
                      40131 FINAL OP  2H     IFP 1860 FFP 2590 BHT  172F

40 N  14 E  16    8   10002                          0451878610218947 0451876510218923
                      10010       20010           9026050 900203RDRV          6454775
                      10021 TWP N  14   RGE E  16   SEC    8   19BLACK HILLS
                      101   SDAK PERKINS   A  1880 FSL  1995 FEL  SW NW SE WF  WF
                      102   TRUE OIL                         33-8 MILLER
                      103    2381 KB 2369 GR                         WILDCAT
                      104                                      API 40 105  20010 00
                      105   SPUD 06/14/1975 COMP 06/28/1975 ROTARY           D&A
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40 N  14 E  16    8   107   DTD  6448 LTD  6454                     FM/TD 203RDRV
                      40101 DST 01          6220- 6230 203RDRV                002
                      40131 FINAL OP  3H     IFP   34 FFP   54 BHT  158F
                      40201 DST 02          6290- 6340 203RDRV                003
                      40231 FINAL OP  1H     IFP 2043 FFP 2082 BHT  170F

40 N  15 E   2   29   10002                          0452331310390268 0452336010390287
                      10010 063 20017273          9120550 900553MRSN          3800869
                      10021 TWP N  15   RGE E   2   SEC   29   19BLACK HILLS
                      101   SDAK HARDING   A  1980 FSL  1980 FEL   C NW SE WF  WF
                      102   UNION OIL OF CALIFORNIA               1 USA-664
                      103    3548 KB 3536 GR                         WILDCAT
                      104    3475 DF 3467 GR P  LSE NO         API 40-063- 20017-00
                      105   SPUD 08/11/1969 COMP 08/17/1969 ROTARY           D&A
                      107   DTD  3800                               FM/TD 553MRSN
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40 N  14 E  16   8    107   DTD  6448 LTD  6454                      FM/TD 203RDRV
                      40101 DST 01         6220- 6230 203RDRV                  002
                      40131 FINAL OP  3H     IFP   34 FFP   54 BHT  158F
                      40201 DST 02         6290- 6340 203RDRV                  003
                      40231 FINAL OP  1H     IFP 2043 FFP 2082 BHT  170F

40 N  15 E   2  29    10002                          0452331310390268 0452336010390287
                      10010 063 20017273         9120550 900553MRSN            3800869
                      10021 TWP N  15   RGE E   2   SEC   29   198LACK HILLS
                      101   SDAK HARDING  A  1980 FSL  1980 FEL  C NW SE WF  WF
                      102   UNION OIL OF CALIFORNIA              1 USA-664
                      103    3548 KB 3536 GR                          WILDCAT
                      104    3475 DF 3467 GR P  LSE NO          API 40-063- 20017-00
                      105   SPUD 08/11/1969 COMP 08/17/1969 ROTARY             D&A
                      107   DTD  3800                              FM/TD 553MRSN
                      40101 DST 01         3275- 3328 602MDDY                  002
                      40102 OVERLAPS 602MDDY
                      40131 FINAL OP  1H     IFP    3 FFP  230 BHT  117F

40 N  15 E   5  21    10002                          0452437110352527 0452448310352497
                      10010 063 20006273         9999950 900602LKOT            3900068
                      10021 TWP N  15   RGE E   5   SEC   21   198LACK HILLS
                      101   SDAK HARDING  A   660 FSL   660 FWL  C SW SW WF  WF
                      102   CHRISTENSEN CHRIS ETAL               1 JUKER
                      103    3042 KB 3036 GR                          WILDCAT
                      104    3042 DF 3034 GR P  LSE NO          API 40-063- 20006-00
                      105   SPUD 08/12/1968 COMP 08/18/1968 ROTARY             D&A
                      107   DTD  3898 LTD  3900                    FM/TD 602LKOT
                      40231 FINAL OP  1H30M IFP  242 FFP  598 BHT  167F

40 N  15 E   6  36    10002                          0452147210333148 0452152910333116
                      10010 063 20016273         9120550 900553MRSN            3959969
                      10021 TWP N  15   RGE E   6   SEC   36   198LACK HILLS
                      101   SDAK HARDING  A   735 FSL  1980 FEL   SW SE WF  WF
                      102   UNION OIL OF CALIFORNIA              1 STATE-217
                      103    2975 KB 2966 GR                          WILDCAT
                      104    2985 DF 2977 GR P  LSE NO          API 40-063- 20016-00
                      105   SPUD 08/19/1969 COMP 08/24/1969 ROTARY             D&A
                      107              LTD  3959                   FM/TD 553MRSN
                      40101 DST 01         3343- 3393 602MDDY                  002
                      40102 OVERLAPS 602SKCK
                      40131 FINAL OP  1H     IFP  835 FFP 1115 BHT  128F

40 N  15 E   7   4    10002                          0452860210327029 0452861210326968
                      10010 063 20048273         8900550 900553MRSN            4250K72
                      10021 TWP N  15   RGE E   7   SEC    4   198LACK HILLS
                      101   SDAK HARDING  A   660 FSL  1980 FEL  C SW SE WF  WF
                      102   TEXACO INC                           1 W WHITE /NCT-1/
                      103    2963 KB 2952 GR                          WILDCAT
                      104                                       API 40 063  20048 00
                      105   SPUD 09/09/1971 COMP 09/13/1971 ROTARY             D&A
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40 N  15 E   7   4    107   DTD  4250                              FM/TD 553MRSN
                      40101 DST 01         3650- 3716 602MDDY                  002
                      40131 FINAL OP  1H30M IFP 1222 FFP 1267 BHT  130F
                      40201 DST 02         4110- 4190 602FLRV                  003
                      40231 FINAL OP  1H     IFP 1084 FFP 1354 BHT  163F

40 N  17 E   1   1    10002                          0454701610394358 0454708410394328
                      10010 063 20065273         5651350 901604SNNN            1533773
                      10021 TWP N  17   RGE E   1   SEC    1   198LACK HILLS
                      101   SDAK HARDING  A  1120 FNL  1980 FEL  S2 NW NE WF  WF
                      102   MONT-DAKOTA UTILITIES            31X-1 STATE
                      103    3553 KB 3548 GR                          WILDCAT
                      104                                       API 40 063  20065 00
                      105   SPUD 06/14/1973 COMP 06/22/1973 ROTARY           D&A-G
                      107   DTD  1533                              FM/TD 604SNNN
                      40101 DST 01         1328- 1455 604EGLE                 S002
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40 N  15 E   7    4    107   DTD  4250                                  FM/TD 553MRSN
                       40101 DST 01          3650- 3716 602MDDY  3683             002
                       40131 FINAL OP  1H30M IFP 1222 FFP 1267 BHT  130F
                       40201 DST 02          4110- 4190 602FLRV  4150             003
                       40231 FINAL OP  1H     IFP 1084 FFP 1354 BHT  163F

40 N  17 E   1    1    10002                          0454701610394358 0454708410394328
                       10010 063 20065273          5651350 901604SNNN           1533773
                       10021 TWP N  17   RGE E   1   SEC   :   19BLACK-HILLS
                       101   SDAK HARDING   A  1120 FNL  1980 FEL  S2 NW NE WF  WF  22
                       102   MONT-DAKOTA UTILITIES              31X-1 STATE
                       103    3553 KB 3548 GR                           WILDCAT
                       104                                        API 40 063  20065 00
                       105   SPUD 06/14/1973 COMP 06/22/1973 ROTARY              D&A-G
                       107   DTD  1533                                  FM/TD 604SNNN
                       40101 DST 01          1328- 1455 604EGLE  1392            S002
                       40131 FINAL OP  4H     IFP   64 FFP   74 BHT   86F
                       50102 604SNNN  OPENHOLE                    1501- 1519 GROSS 004

40 N  17 E   7   11    10002                          0454565510321915 0454576410321753
                       10010 063 20031273          9999950 90020JRDRV              8374
                       10021 TWP N  17   RGE E   7   SEC  11   19BLACK-HILLS        23
                       101   SDAK HARDING   A   660 FNL   660 FEL  C NE NE WF  WF
                       102   LADD PETROLEUM                      1 LAFLIN
                       103    3188 KB 3178 GR                           WILDCAT
                       104    3186 DF 3178 GR P  LSE NO           API 40-063- 20031-00
                       105   SPUD 01/10/1970 COMP 02/05/1970 ROTARY                D&A
                       107   DTD  8371 LTD  8374                        FM/TD 203RDRV
                       40101 DST 01          8200- 8250 203RDRV  8225             002
                       40131 FINAL OP  1H30M IFP  138 FFP  308 BHT  198F

40 N  19 E   7   22    10002                          0455981910325149 0455973710324878
                       10010 063 20115273          2940050 910203RDRV           8537177
                       10021 TWP N  19   RGE E   7   SEC  22   055TH PRINCIPAL
                       101   SDAK HARDING   A  1980 FNL  1980 FWL  C SE NW WF  WF  24
                       102   WEBB RESOURCES-CENEX             22-6 STATE
                       103    3050 KB 3040 GR                           WILDCAT
                       104    3050 DF 3040 GR P  LSE NO           API 40-063- 20115-00
                       105   SPUD 11/29/1976 COMP 12/22/1976 ROTARY              D&A-0
                       107   DTD  8535 LTD  8537                        FM/TD 203RDRV
                       40101 DST 01          8236- 8310 203RDRV  8273            S002
                       40102 OVERLAPS 259SLRN
                       40131 FINAL OP  2H     IFP  132 FFP  329 BHT  180F

40 N  19 E  25    4    10002                          0456331710104267 0456339110104133
                       10010 031 20008273          9999970 901559JRSC              2904
                       10021 TWP N  19   RGE E  25   SEC   4   19BLACK-HILLS
                       101   SDAK CORSON    A   660 FSL   660 FEL  C SE SE S    S  25
                       102   KOCH EXPLORATION                    1 RICHLER
                       103    2050 KB 2040 GR                           WILDCAT
                       104                                        API 40-031- 20008 00
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40 N  19 E  25    4    105   SPUD 06/07/1969 COMP 06/10/1969 ROTARY              D&A-G
                       107   DTD  2904                                  FM/TD 559JRSC
                       40101 DST 01          2541- 2612 602MDDY                  S002
                       40131 FINAL OP   20M IFP  901 FFP 1021 BHT   96F

40 N  20 E   4    2    10002                          0457220410360461 0457214010360329
                       10010 063 20090273  6000 7281061 110203RDRV 203RDRV  8652376
                       10021 TWP N  20   RGE E   4   SEC   2   055TH PRINCIPAL
                       101   SDAK HARDING   A   660 FSL   660 FWL  C SW SW D   DO
                       102   KOCH EXPL                         14-2A TILUS
                       103    3072 KB 3060 GR                           BUFFALO
                       104                                        API 40 063  20090 00
                       105   SPUD 07/17/1975 COMP 10/12/1975 ROTARY                OIL
                       107   DTD  8652               PB  8558           FM/TD 203RDRV
                       20102 203RDRV  PERF              W/  2/FT  8426- 8468 GROSS 006
                       20150 WTR
                       40101 DST 01          8421- 8487 203RDRV                  S003
                       40131 FINAL OP  3H     IFP  186 FFP  580 BHT  208F
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40 N  19 E  25   4    105   SPUD 06/07/1969 COMP 06/10/1969 ROTARY         D&A-G
                      107   DTD  2904                               FM/TD 559JRSC
                      40101 DST 01        2541- 2612 602MDDY   2577          S002
                      40131 FINAL OP      20M IFP  901 FFP 1021 BHT   96F

40 N  20 E   4   2    10002                     0457220410360461 0457214010360329
                      10010 063 20090273  600C 7281061 110203RDRV 203RDRV 8652376
                      10021 TWP N  20  RGE E   4   SEC   2   055TH PRINCIPAL
                      101   SDAK HARDING  A  660 FSL  660 FWL  C SW SW D  DO  26
                      102   KOCH EXPL                        14-2A TILUS
                      103    3072 KB 3060 GR                       (B)UFFALO
                      104                                    API 40 063  20090 00
                      105   SPUD 07/17/1975 COMP 10/12/1975 ROTARY          OIL
                      107   DTD  8652            PB  8558         FM/TD 203RDRV
                      20102 203RDRV  PERF           W/  2/FT  8426- 8468 GROSS 006
                      20150 WTR
                      40101 DST 01        8421- 8487 203RDRV   8454          S003
                      40131 FINAL OP  3H    IFP  186 FFP  580 BHT  208F
                      40201 DST 02        8570- 8652 203RDRV                  004
                      40231 FINAL OP  2H    IFP  312 FFP  891

40 N  20 E   4  10    10002                     0457144010361571 0457155710361357
                      10010 063 05121273  6000 9999961 110203RDRV 203RDRV 8420166
                      10021 TWP N  20  RGE E   4   SEC  10   19BLACK HILLS
                      101   SDAK HARDING  A 1980 FNL  2180 FEL   SW NE D  DO  27
                      102   PENNZOIL CO                      32-10A TILUS
                      103    3036 KB 3024 GR                        BUFFALO
                      104    3038 DF 3028 GR  P LSE NO     29 API 40-063- 05121 00
                      105   SPUD 11/21/1965 COMP 01/01/1966 ROTARY          OIL
                      107   DTD  8420                          FM/TD 203RDRV
                      20102 203RDRV  PERF           W/  4/FT  8375- 8376      007
                      40101 DST 01        8372- 8374 203RDRV   8373          S002
                      40131 FINAL OP  3H    IFP   33 FFP  429 BHT  196F
                      50102 203RDRV  PERF           W/  4/FT  8375- 8376      004
                      50202 203RDRV  PERF           W/  4/FT  8375- 8376      005
                      50302 203RDRV  PERF           W/  4/FT  8375- 8376      006

40 N  20 E   5  16    10002                     0456992610351297 0456988510351187
                      10010 063 20080273 45000 317055  110203RDRV 203RDRV 8653K77
                      10021 TWP N  20  RGE E   5   SEC  16   19BLACK HILLS
                      101   SDAK HARDING  A 2000 FNL  2050 FEL  SW SW NE WF  WFD  28
                      102   GULF OIL                         1 STATE CAVE HILLS
                      103             2923 GR                     JONES CREEK
                      104    2733 DF 2723     P              API 40 063  20080 00
                      105   SPUD 12/19/1974 COMP 04/08/1975 ROTARY          OIL
                      107   DTD  8653            PB  8452         FM/TD 203RDRV
                      111   CSG  5 1/2 @ 8651 W/  790                       06
                      20102 203RDRV  PERF     JET   W/  4/FT  8362- 8368      009
                      40101 DST 01        8350- 8400 203RDRV   8375          S004
                      40131 FINAL OP  2H    IFP  250 FFP  750 BHT  200F
                      50102 203RDRV  PERF           W/  4/FT  8503- 8509      007
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40 N  20 E   5  16    50202 203RDRV  PERF           W/  4/FT  8362- 8368      008

40 N  20 E   5  22    10002                     0456815410349554 0456828910349630
                      10010 063 20049273         2342950 911203RDRV       8500572
                      10021 TWP N  20  RGE E   5   SEC  22   19BLACK HILLS
                      101   SDAK HARDING  A 1980 FSL  2029 FWL     NE SW WF  WF
                      102   DEPCO INC                       23-22 FEDERAL-GRUSE
                      103    2926 KB 2914 GR                       WILDCAT
                      104    2727 DF 2718 GR P  LSE NO      API 40-063- 20049-00
                      105   SPUD 10/11/1971 COMP 11/09/1971 ROTARY         D&A-OG
                      107   DTD  8500 LTD  8491                 FM/TD 203RDRV
                      40101 DST 01        8289- 8306 203RDRV                 S002
                      40131 FINAL OP  0H30M IFP  291 FFP  367 BHT  222F
                      40201 DST 02        8345- 8383 203RDRV                 S003
                      40231 FINAL OP  1H    IFP   60 FFP   85 BHT  204F
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40 N  20 E   5   16   50202 203RDRV  PERF            W/ 4/FT  8362- 8368        008

40 N  20 E   5   22   10002                          045681541034955 045682891034963O
                      10010 063 20049273        2342950 911203RDRV             8500572
                      10021 TWP N  20   RGE E   5   SEC   22   19BLACK HILLS
                      101   SDAK HARDING  A  1980 FSL  2029 FWL      NE SW WF   WF
                      102   DEPCO INC                        23-22 FEDERAL-GRUSE
                      103    2926 KB 2914 GR                        WILDCAT
                      104    2727 DF 2718 GR P  LSE NO        API 40-063- 20049-00
                      105   SPUD 10/11/1971 COMP 11/09/1971 ROTARY             D&A-OG
                      107   DTD  8500 LTD  8491                      FM/TD 203RDRV
                      40101 DST 01          8289- 8306 203RDRV                   S002
                      40131 FINAL OP  0H30M IFP  291 FFP  367 BHT  222F
                      40201 DST 02          8345- 8383 203RDRV                   S003
                      40231 FINAL OP   1H    IFP   60 FFP   85 BHT  204F
                      40301 DST 03          3948- 3990 603GRNR            MISRUN 004
                      40401 DST 04          3948- 3992 603GRNR                   S005
                      40431 FINAL OP   1H    IFP 1323 FFP 1380

40 N  20 E   5   27   10002                          045667181034865 9045666241034866 4
                      10010 063 20139273 45000 2940060 910203RDRV              8567178
                      10021 TWP N  20   RGE E   5   SEC   27   055TH PRINCIPAL
                      101   SDAK HARDING  A  1980 FSL   660 FEL   C NE SE D    D
                      102   WEBB RESOURCES                   27-9 NIEMI
                      103    3002 KB 2989 GR                        JONES CREEK
                      104    2999 DF 2989     P              API 40 063  20139 00
                      105   SPUD 08/24/1977 COMP 09/17/1977 ROTARY             D&A-O
                      107   DTD  8567 LTD  8562                      FM/TD 203RDRV
                      40101 DST 01          8316- 8358 203RDRV                   S002
                      40131 FINAL OP   1H    IFP  258 FFP  344 BHT  200F-
                      40201 DST 02          8346- 8357 203RDRV                   S003
                      40231 FINAL OP   1H    IFP   87 FFP  197 BHT  210F

40 N  20 E   6   20   10002                          045685201034149 2045684291034131 0
                      10010 063 20113273        2940050 91020900VC             8639077
                      10021 TWP N  20   RGE E   6   SEC   20   055TH PRINCIPAL
                      101   SDAK HARDING  A  1980 FNL  2080 FWL      SE NW WF   WF
                      102   WEBB RESOURCES                   20-6 WEBB-CENEX-FEDERAL
                      103    2933 KB 2923 GR                        WILDCAT
                      104    2933 DF 2923     P              API 40 063  20113 00
                      105   SPUD 12/27/1976 COMP 01/20/1977 ROTARY             D&A-O
                      107   DTD  8636 LTD  8639                      FM/TD 2090DVC
                      40101 DST 01          8401- 8419 203RDRV                   S00?
                      40131 FINAL OP   2H    IFP  529 FFP 1363 BHT  192F

40 N  20 E  18   32   10002                          045655371019396 9045656651019400 4
                      10010 031 20014273        1652050 900202WNPG             7515171
                      10021 TWP N  20   RGE E  18   SEC   32   19BLACK HILLS
                      101   SDAK CORSON   A  1945 FNL   660 FWL   N2 SW NW WF   WF
                      102   CONSOLIDATED OIL & GAS             1 TRIBAL
                      103    2383 KB 2371 GR                        WILDCAT
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40 N  20 E  18   32   104    2381 DF 2371 GR  P              API 40-031- 20014 00
                      105   SPUD 10/23/1970 COMP 11/17/1970 ROTARY             D&A
                      107   DTD  7510 LTD  7515                      FM/TD 202WNPG
                      40101 DST 01          5420- 5490 352MSNC                    002
                      40131 FINAL OP   2H    IFP  410 FFP 1455 BHT  143F
                      40201 DST 02          6920- 6962 203RDRV                    003
                      40231 FINAL OP  3H 5M IFP  643 FFP 2687

40 N  21 E   2   26   10002                          045753821038339 5045765631038333 9
                      10010 063 20001273        5480050 900203RDRV             8600J67
                      10021 TWP N  21   RGE E   2   SEC   26   19BLACK HILLS
                      101   SDAK HARDING  A  1980 FSL   660 FEL      NE SE WF   WF
                      102   MIAMI OIL PRODUCERS              1 PAINTERS INC
                      103    3179 KB 3168 GR                        WILDCAT
                      104    3176 ES 3168 GR  P              API 40-063- 20001 00
                      105   SPUD 07/04/1967 COMP 09/02/1967 ROTARY             D&A
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40 N  20 E  18   32    104     2381 DF 2371 GR  P                 API 40-031- 20014 00
                       105    SPUD 10/23/1970 COMP 11/17/1970 ROTARY          D&A
                       107    DTD  7510 LTD  7515                        FM/TD 202WNPG
                       40101 DST 01          5420- 5490 352MSNC   5455              002
                       40131 FINAL OP  2H     IFP  410 FFP 1955 BHT  143F
                       40201 DST 02          6920- 6962 203RDRV                     003
                       40231 FINAL OP  3H 5M IFP  643 FFP 2687

40 N  21 E   2   26    10002                           045753821038339 5 045755631038333 9
                       10010 063 20001273         5480050 900203RDRV           8600J67
                       10021 TWP N  21   RGE E   2   SEC   26   19BLACK HILLS
                       101    SDAK HARDING  A  1980 FSL   660 FEL     NE SE WF  WF   33
                       102    MIAMI OIL PRODUCERS                 1 PAINTERS INC
                       103     3179 KB 3168 GR                       WILDCAT
                       104     3176 ES 3168 GR  P                 API 40-063- 20001 00
                       105    SPUD 07/04/1967 COMP 09/02/1967 ROTARY          D&A
                       107    DTD  3600                   8565 FM/TD 203RDRV
                       40101 DST 01          8550- 8580 203RDRV  CUSH  650 WTR     002
                       40131 FINAL OP  2H     IFP  303 FFP  677 BHT  184F

40 N  21 E   3   22    10002                           0457713210373543 0457734410373416
                       10010 063 05126273  6000 1371510 911203RDRV           8805369
                       10021 TWP N  21   RGE E   3   SEC   22   19BLACK HILLS
                       101    SDAK HARDING  A  1980 FNL  1980 FEL     SW NE WO  WO   34
                       102    CHAMPLIN PETROLEUM                  1 CLARKSON ESTATE
                       103     3280 KB                               BUFFALO
                       104     3288 ES 3280 GR  P                 API 40-063- 05126 00
                       105    SPUD 06/07/1968 COMP 12/31/1968 ROTARY          D&A-OG
                       107    DTD  8805            PB  8559          FM/TD 203RDRV
                       40101 DST 01          6840- 6910 353CRLS   6875               002
                       40131 FINAL OP  2H     IFP   67 FFP  378 BHT  168F  17.9
                       40201 DST 02          7110- 7158 352MSNC   7134               003
                       40231 FINAL OP  2H     IFP  771 FFP 1299 BHT  181F  19.0
                       40301 DST 03          7330- 7475 352MSNC                      004
                       40310 WTR  TS IN    30M                 MCW 7402
                       40331 FINAL OP  1H     IFP 1410 FFP 3232 BHT  183F  18.6
                       40401 DST 04          8505- 8555 203RDRV                     S005
                       40431 FINAL OP  1H     IFP   18 FFP  208 BHT  189F
                       40501 DST 05          8574- 8616 203RDRV                     S006
                       40531 FINAL OP  1H     IFP   41 FFP  144 BHT  188F
                       40601 DST 06          8648- 8720 203RDRV                      007
                       40631 FINAL OP  1H     IFP   23 FFP  848 BHT  190F
                       50102 203RDRV  PERF                       8572- 8576         009
                       50103 203RDRV  PERF                       8584- 8602         010
                       50202 203RDRV  PERF                       8572- 8602 GROSS   011
                       50302 203RDRV  PERF             W/  3/FT  8529- 8541         013
                       50402 203RDRV  PERF             W/  3/FT  8529- 8541         014
                       50502 203RDRV  PERF             W/  3/FT  8529- 8541         015
                       50602 203RDRV  PERF                       8529- 8541         016
                       50702 203RDRV  PERF                       8529- 8541         017
                       50802 203RDRV  PERF                       8529- 8541         018
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40 N  21 E   3   22    50902 203RDRV  PERF                       8529- 8541         019
                       51002 203RDRV  PERF                       8529- 8541         020
                       51102 203RDRV  PERF                       8529- 8541         021
                       51202 203RDRV  PERF                       8529- 8541         022
                       51302 203RDRV  PERF                       8529- 8541         023

40 N  21 E  21    5    10002                           0458161410154121 0458166210154161
                       10010 031 20018273         1270550 90115300WD           7400876
                       10021 TWP N  21   RGE E  21   SEC    5   055TH PRINCIPAL
                       101    SDAK CORSON   A  640 FNL  1980 FEL  N2 NW NE WF  WF
                       102    CHEVRON OIL                        13-5 BAILEY
                       103     2173 KB 2162 GR                       WILDCAT
                       104                                        API 40 031  20018 00
                       105    SPUD 06/24/1976 COMP 07/17/1976 ROTARY          D&A-G
                       107    DTD  7400                          FM/TD 15300WD
                       40101 DST 01          4867- 4885 352MSNC                     005
                       40131 FINAL OP  0H30M IFP  418 FFP  737 BHT  170F
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40 N  21 E   3  22   50902 203RDRV  PERF                          8529- 8541        019
                     51002 203RDRV  PERF                          8529- 8541        020
                     51102 203RDRV  PERF                          8529- 8541        021
                     51202 203RDRV  PERF                          8529- 8541        022
                     51302 203RDRV  PERF                          8529- 8541        023

40 N  21 E  21   5   10002                           045816141015412 1 0458166210154161
                     10010 031 20018273          1270550 9011530OWD              7400876
                     10021 TWP N  21  RGE E  21   SEC   5   055TH PRINCIPAL
                     101   SDAK CORSON   A   640 FNL  1980 FEL  N2 NW NE WF  WF
                     102   CHEVRON OIL                        13-5 BAILEY
                     103    2173 KB 2162 GR                        WILDCAT
                     104                                  API 40 031  20018 00
                     105   SPUD 06/24/1976 COMP 07/17/1976 ROTARY         D&A-G
                     107   DTD  7400                             FM/TD 15300WD
                     40101 DST 01          4867- 4885 352MSNC                   005
                     40131 FINAL OP  0H30M IFP  418 FFP  737 BHT  170F
                     40201 DST 02          6325- 6362 203RDRV                  S006
                     40231 FINAL OP  1H    IFP  569 FFP 1554 BHT  174F
                     40301 DST 03          6362- 6426 203RDRV                   007
                     40331 FINAL OP  0H45M IFP  502 FFP 1023 BHT  168F

40 N  21 E  24  12   10002                           0457912510108325 0457918010108253
                     10010 031 20004273          58[illegible] 901353MIDL         4040170
                     10021 TWP N  21  RGE E  24   SEC  12   19BLACK HILLS
                     101   SDAK CORSON   A   660 FSL   662 FEL    SE SE WF  WF
                     102   MURPHY OIL CAYMAN CORP            1 B STATE
                     103    1983 KB 1972 GR                        WILDCAT
                     104    1981 DF 1973 GR P  LSE NO       API 40-031- 20004-00
                     105   SPUD 06/06/1969 COMP 06/16/1969 ROTARY         D&A-G
                     107   DTD  4039 LTD  4040                  FM/TD 353MIDL
                     40101 DST 01          1521- 1551 603NBRR             MISRUN 002
                     40201 DST 1A          1521- 1551 603NBRR             MISRUN 003
                     40301 DST 1B          1521- 1551 603NBRR             MISRUN 004
                     40401 DST 1C          1521- 1551 603NBRR                   005
                     40431 FINAL OP  3H    IFP   15 FFP  525 BHT   87F

40 N  21 E  26  35   10002                           0457444910086088 0457446710085903
                     10010 031 20007273          9999970 900559JRSC              2935
                     10021 TWP N  21  RGE E  26   SEC  35   19BLACK HILLS
                     101   SDAK CORSON   A   660 FNL  1980 FEL   C NW NE S    S
                     102   KOCH EXPLORATION                  1 SCHOTT-KNUDSON
                     103    2100 KB 2090 GR                        WILDCAT
                     104    2098 DF 2090 GR P  LSE NO       API 40-031- 20007-00
                     105   SPUD 06/03/1969 COMP 06/06/1969 ROTARY         D&A
                     107   DTD  2935                            FM/TD 559JRSC
                     40101 DST 01          2544- 2593 602MDJY                   002
                     40131 FINAL OP    20M IFP  955 FFP 1044 BHT   92F

40 N  22 E   3  21   10002                           0458583910376610 0458593810376573
                     10010 063 20030273          1652050 911203RDRV              9057270
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40 N  22 E   3  21   10021 TWP N  22  RGE E   3   SEC  21   19BLACK HILLS
                     101   SDAK HARDING  A  1980 FNL   660 FWL   C SW NW WF  WF
                     102   CONSOLIDATED OIL & GAS         1-21 FEDERAL
                     103    3249 KB 3237 GR                        WILDCAT
                     104    3245 DF 3237 GR P  LSE NO       API 40-063- 20030-00
                     105   SPUD 12/04/1969 COMP 01/22/1970 ROTARY         D&A-OG
                     107   DTD  9057 LTD  9056                 FM/TD 203RDRV
                     40101 DST 01          6711- 6797 353KBBY                   002
                     40131 FINAL OP  2H    IFP  818 FFP 2333 BHT  172F
                     40201 DST 02          7020- 7100 353CRLS                   003
                     40231 FINAL OP  1H30M IFP 1020 FFP 2917 BHT  165F
                     40301 DST 03          8685- 8729 203RDRV                  S004
                     40331 FINAL OP  3H    IFP  128 FFP  434 BHT  180F
                     40401 DST 04          8767- 8797 203RDRV                  S005
                     40431 FINAL OP  3H    IFP   64 FFP  297 BHT  195F
                     50102 203RDRV  OPENHOLE                      8676- 9057        006
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40 N  22 E   3   21   10021 TWP N  22   RGE E   3   SEC   21   19BLACK HILLS
                      101   SDAK HARDING  A  1980 FNL   660 FWL  C SW NW WF  WF   38
                      102   CONSOLIDATED OIL & GAS          1-21 FEDERAL
                      103    3249 KB 3237 GR                     WILDCAT
                      104    3245 DF 3237 GR P  LSE NO      API 40-063- 20030-00
                      105   SPUD 12/04/1969 COMP 01/22/1970 ROTARY          D&A-OG
                      107   DTD  9057 LTD  9056                  FM/TD 203RDRV
                      40101 DST 01        6711- 6797 353KBBY                  002
                      40131 FINAL OP  2H    IFP  818 FFP 2333 BHT  172F
                      40201 DST 02        7020- 7100 353CRLS  7060            003
                      40231 FINAL OP  1H30M IFP 1020 FFP 2917 BHT  165F
                      40301 DST 03        8685- 8729 203RDRV                 S004
                      40331 FINAL OP  3H    IFP  128 FFP  434 BHT  180F
                      40401 DST 04        8767- 8797 203RDRV                 S005
                      40431 FINAL OP  3H    IFP   64 FFP  297 BHT  195F
                      50102 203RDRV  OPENHOLE                 8676- 9057      006

40 N  22 E   4   24   10002                      04585874103574l7 0458572510357400
                      10010 063 20082273 99999 2342951 110203RDRV 203RDRV  9210475
                      10021 TWP N  22   RGE E   4   SEC   24   19BLACK HILLS
                      101   SDAK HARDING  A  1830 FNL  2030 FWL  NE SE NW WF  WFD  39
                      102   DEPCO INC                       22-24 TRAVERS
                      103              3204 GR                    UNNAMED
                      104    3214 DF 3205 GR P  LSE NO      API 40-063- 20082-00
                      105   SPUD 11/10/1974 COMP 04/04/1975 ROTARY            OIL
                      107   DTD  9210                            FM/TD 203RDRV
                      20102 203RDRV  PERF            W/  2/FT  8948- 8956     007
                      20150 WTR
                      40101 DST 01        8911- 9050 203RDRV  8981           S003
                      40131              45M IFP  444 FFP  571 BHT  218F
                      50102 203RDRV  PERF            W/  2/FT  9074- 9080     005
                      50202 203RDRV  PERF            W/  2/FT  8948- 8956     006

40 N  22 E   5    5   10002                      0459051610352698 0459060310352484
                      10010 063 20053273         2342950 911203RDRV          9137272
                      10021 TWP N  22   RGE E   5   SEC    5   19BLACK HILLS
                      101   SDAK HARDING  A   700 FNL  1320 FEL  S2 N2 NE WF  WF   40
                      102   DEPCO INC                       41-5 JANVRIN
                      103    2977 KB 2966 GR                     WILDCAT
                      104                                   API 40-063- 20053 00
                      105   SPUD 12/22/1971 COMP 01/27/1972 ROTARY          D&A-OG
                      107   DTD  9137                            FM/TD 203RDRV
                      40101 DST 01        8858- 8892 203RDRV  8875           S003
                      40131 FINAL OP  2H    IFP   63 FFP   99 BHT  216F
                      40201 DST 02        9021- 9039 203RDRV                 S004
                      40231 FINAL OP  0H45M IFP 1915 FFP 2851
                      40301 DST 03        8986- 9013 203RDRV  9000           S005
                      40331 FINAL OP  1H    IFP  368 FFP  476 BHT  226F
                      40401 DST 04        8913- 8974 203RDRV                  006
                      40431 FINAL OP  1H    IFP   36 FFP   98
                      40501 DST 05        8900- 8964 203RDRV          MISRUN 007
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40 N  22 E   5    5   10002                      0459062710353546 0459049910353351
                      10010 063 20086273 85000 5025011 110203RDRV 203RDRV  9106075
                      10021 TWP N  22   RGE E   5   SEC    5   19BLACK HILLS
                      101   SDAK HARDING  A   500 FNL  1800 FWL  NW NE NW WO  WOE
                      102   LUFF KENNETH ETAL               1-5 JANVRIN
                      103              2985 GR                    TRAVERS RANCH
                      104    2997 DF 2987 GR P  LSE NO      API 40-063- 20086-00
                      105   SPUD 04/17/1975 COMP 08/28/1975 ROTARY            OIL
                      107   DTD  9106                            FM/TD 203RDRV
                      20102 203RDRV  PERF            W/  2/FT  9004- 9014     009
                      40101 DST 01        8903- 8971 203RDRV          MISRUN 002
                      40201 DST 02        8903- 8971 203RDRV                  003
                      40231 FINAL OP  1H30M IFP   98 FFP   98 BHT  212F
                      40301 DST 03        8968- 9002 203RDRV                 S004
                      40331 FINAL OP  2H    IFP  134 FFP  223 BHT  220F
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40 N  22 E   5   5    10002                           04590627103535+6 04590499103533351
                      10010 063 20086273 85000 5025011 110203RDRV 203RDRV  9106075
                      10021 TWP N  22   RGE E   5   SEC   5   19BLACK HILLS          41
                      101   SDAK HARDING  A   500 FNL  1800 FWL  NW NE NW WO  WOE
                      102   LUFF KENNETH ETAL                1-5 JANURTN
                      103             2985 GR                    TRAVERS RANCH
                      104    2997 DF 2987 GR P  LSE NO         API 40-063- 20086-00
                      105   SPUD 04/10/1975 COMP 08/28/1975 ROTARY              OIL
                      107   DTD  9106                            FM/TD 203RDRV
                      20102 203RDRV  PERF               W/  2/FT  9004- 9014      009
                      40101 DST 01          8903- 8971 203RDRV           MISRUN 002
                      40201 DST 02          8903- 8971 203RDRV                  003
                      40231 FINAL OP  1H30M IFP   98 FFP   98 BHT  212F
                      40301 DST 03          8968- 9002 203RDRV  8985           S004
                      40331 FINAL OP  2H    IFP  134 FFP  223 BHT  220F 19.47
                      40401 DST 04                                   MISRUN 005
                      40501 DST 05          8972- 9020 203RDRV                 S006
                      40531 FINAL OP  2H
                      40601 DST 06          8972- 9028 203RDRV  9000           S007
                      40610 GAS  TS IN  1H45M
                      40631 FINAL OP  2H    IFP  223 FFP  617 BHT  222F 19.6

40 N  22 E   5  23    10002                           04585972103466645 04585779103466644
                      10010 063 20102273 88000 666501  911203RDRV               9200277
                      10021 TWP N  22   RGE E   5   SEC   23   055TH PRINCIPAL       42
                      101   SDAK HARDING   A  1600 FNL  1980 FEL  N2 SW NE WO  WO
                      102   PET INC                          1-23 FEIST
                      103              3068 GR                   YELLOW HAIR
                      104                                    API 40 063  20102 00
                      105   SPUD 08/06/1976 COMP 09/04/1976 ROTARY           D&A-OG
                      107   DTD  9200                            FM/TD 203RDRV
                      40101 DST 01          8926- 8966 203RDRV                 S002
                      40131 FINAL OP  2H    IFP  441 FFP 1657 BHT  215F
                      40201 DST 02          9066- 9128 203RDRV  9097            003
                      40231 FINAL OP  2H    IFP  420 FFP 1699 BHT  220F

40 N  22 E   5  27    10002                           04584257103448171 04584238103448130
                      10010 063 20043273 99999 9999951 110203RDRV 203RDRV  9140073
                      10021 TWP N  22   RGE E   5   SEC   27   19BLACK HILLS         43
                      101   SDAK HARDING  A  2540 FNL   500 FEL  SE SE NE WF  WFD
                      102   DEPCO INC                        42-27 FEDERAL
                      103    3202 KB 3190 GR                     UNNAMED
                      104                                    API 40 063  20043 00
                      105   SPUD 12/15/1970 COMP 02/14/1971 ROTARY              OIL
                      107   DTD  9130 LTD  9140 PB  9109         FM/TD 203RDRV
                      20102 203RDRV  PERF      JET   W/  4/FT  8909- 9070 GROSS 008
                      40101 DST 01          7087- 7155 353CRLS  7121           S002
                      40131 FINAL OP  2H    IFP  139 FFP  696 BHT  192F
                      40201 DST 02          8876- 8912 203RDRV                 S003
                      40231 FINAL OP  2H 3M IFP  139 FFP  185 BHT  210F
                      40301 DST 03          9018- 9082 203RDRV                 S005
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40 N  22 E  5   27    40331 FINAL OP  2H     IFP  150 FFP  201 BHT  210F
                      50102 203RDRV  PERF      JET  W/  4/FT  8909- 9070 GROSS 007
                      50150 WTR

40 N  22 E  6    7    10002                         045889341034337 7 045889141034327 7
                      10010 063 20073273        5025050 910203RDRV            9100K73
                      10021 TWP N  22   RGE E   6   SEC   7   19BLACK HILLS
                      101   SDAK HARDING   A  1240 FNL  1300 FWL  SE NW NW WF  WF   [44]
                      102   LUFF KENNETH D ETAL            1-7 KALISTAK
                      103    2924 KB 2911 GR                   WILDCAT
                      104    2921 DF 2911 GR P  LSE NO      API 40-063- 20073-00
                      105   SPUD 11/04/1973 COMP 12/04/1973 ROTARY           D&A-O
                      107   DTD  9100                         FM/TD 203RDRV
                      40101 DST 01         8820- 8950 203SNMN   [8885]        002
                      40131 FINAL OP  0H30M IFP   72 FFP  120 BHT  182F [15.4]
                      40201 DST 02         8970- 9038 203SNMN                 003
                      40202 OVERLAPS 203RDRV                [9004]
                      40231 FINAL OP  1H30M IFP  701 FFP 1837 BHT  190F

40 N  22 E 21   36    10002                         045820481014645 6 045820831014657 6
                      10010 031 05056273        8325050 911203RDRV            6680966
                      10021 TWP N  22   RGE E  21   SEC  36   19BLACK HILLS
                      101   SDAK CORSON    A   660 FSL  1980 FWL     SE SW WF  WF   [45]
                      102   WILHITE , J                      1 STATE
                      103    2226 KB 2215 GR                   WILDCAT
                      104    2247 DF 2238 GR  P             API 40-031- 05056 00
                      105   SPUD 08/23/1965 COMP 11/01/1965 ROTARY           D&A-OG
                      107               LTD  6680             FM/TD 203RDRV
                      40101 DST 01         6464- 6495 203RDRV                S003
                      40131 FINAL OP  2H     IFP  104 FFP 1587 BHT  154F
                      40201 DST 02         6518- 6535 203RDRV                 004
                      40231 FINAL OP  1H30M IFP   83 FFP  208 BHT  154F

40 N  23 E  3   24    10002                         045941341036874 0 045940131036871 0
                      10010 063 20099273 99999 6665010 911203RDRV            9187776
                      10021 TWP N  23   RGE E   3   SEC  24   19BLACK HILLS
                      101   SDAK HARDING  *                         NE SE WO  D   [46]
                      102   PETROLEUM INC                    1 STATE
                      103    3068 KB 3057 GR                   UNNAMED
                      104    3066 DF 3056 GR P  LSE NO      API 40-063- 20099-00
                      105   SPUD 06/09/1976 COMP 07/11/1976 ROTARY           D&A-OG
                      107   DTD  9120 LTD  9187               FM/TD 203RDRV
                      40101 DST 01         7344- 7374 352MSNC   [7359]        002
                      40131 FINAL OP  2H     IFP  320 FFP  545 BHT  210F [22.4]
                      40201 DST 02         8942- 8972 203RDRV   [8957]       S003
                      40231 FINAL OP  2H     IFP  200 FFP  427 BHT  222F
                      40301 DST 03         9074- 9130 203RDRV                S004
                      40331 FINAL OP  2H     IFP  949 FFP 3074
                      40401 DST 04 STRD    9088- 9115 203RDRV          MISRUN 005
                      40501 DST 05 STRD    9070- 9114 203RDRV   [9092]       S006
                      40531 FINAL OP  2H     IFP  265 FFP 1665 BHT  250F [22.5]
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40 N  23 E  3   31    10002                         045919681037919 4 045918261037923 4
                      10010 063 20091273        3466050 900203RDRV            8897K75
                      10021 TWP N  23   RGE E   3   SEC  31   19BLACK HILLS
                      101   SDAK HARDING   A   660 FNL   660 FEL   C NE NE WF  WF
                      102   HELMERICH & PAYNE              1-31 MILLER-FEDERAL
                      103             3093 GR                  WILDCAT
                      104                                   API 40 063  20091 00
                      105   SPUD 10/29/1975 COMP 11/30/1975 ROTARY           D&A
                      107               LTD  8897             FM/TD 203RDRV
                      40101 DST 01         8669- 8695 203RDRV                 002
                      40131 FINAL OP  1H     IFP   62 FFP  291 BHT  209F

40 N  23 E  4   19    10002                         045940231036756 045938801036760 0
                      10010 063 20144273 50000 666501  110203RDRV 203RDRV  9246J77
                      10021 TWP N  23   RGE E   4   SEC  19   05STH PRINCIPAL
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33 N 164

40 N 1

40 N 3

40 N 3

40 N 3

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40 N  23 E   3   31    10002                          0459196810379194 0459182610379234
                       10010 063 20091273          3466050 900203RDRV          8897K75
                       10021 TWP N  23  RGE E   3   SEC   31   198LACK-HILLS
                       101   SDAK HARDING  A   660 FNL   660 FEL  C NE NE WF  WF      47
                       102   HELMERTCH & PAYNE                 1-31 MILLER-FEDERAL
                       103             3093 GR                       WILDCAT
                       104                                     API 40 063  20091 00
                       105   SPUD 10/29/1975 COMP 11/30/1975 ROTARY             D&A
                       107             LTD  8897                    FM/TD 203RDRV
                       40101 DST 01          8669- 8695 203RDRV    8687          002
                       40131 FINAL OP  1H    IFP   62 FFP  291 BHT  209F

40 N  23 E   4   19    10002                          0459402310367564 0459388010367600
                       10010 063 20144273 50000 666501  110203RDRV 203RDRV  9246J77
                       10021 TWP N  23  RGE E   4   SEC   19   055TH PRINCIPAL
                       101   SDAK HARDING  A  1600 FSL  2400 FEL  SW NW SE WO  WOE    48
                       102   PET INC                          1-F ARITHSON
                       103    3079 KB 3065 GR                       S MEDICNE PLE HLL
                       104    3075 DF 3065 GR P  LSE NO        API 40-063- 20144-00
                       105   SPUD 09/08/1977 COMP 11/03/1977 ROTARY             OIL
                       107   DTD  9240 LTD  9246                    FM/TD 203RDRV
                       20102 203RDRV  PERF                      9122- 9130         005
                       20141              @ 9446FT        BHT 192F
                       40101 DST 01          8950- 8978 203RDRV    8964         S002
                       40110 GAS  TS IN  1H50M                  /NO GAUGE/
                       40131 FINAL OP  2H    IFF  290 FFP  517 BHT  210F
                       40201 DST 02          9090- 9142 203RDRV    9116         S003
                       40210 GAS  TS IN  1H52M                  /NO GAUGE/
                       40231 FINAL OP  2H    IFP  387 FFP 1082 BHT  215F

40 N  23 E   5   22    10002                          0459437210348220 0459427910348164
                       10010 063 200?4273 99999 2342951 110203RDRV 203RDRV  9230973
                       10021 TWP N  23  RGE E   5   SEC   22   198LACK-HILLS
                       101   SDAK HARDING  A   660 FNL   660 FEL  C NE NE WF  WFD     49
                       102   HANOVER PLANNING                 41-22 OTTERNESS
                       103    2956 KB 2942 GR                        UNNAMED
                       104    2968 DF 2958 GR P  LSE NO        API 40-063- 20064-00
                       105   SPUD 05/06/1973 COMP 08/27/1973 ROTARY             OIL
                       107   DTD  9230                              FM/TD 203RDRV
                       20102 203RDRV  PERF              W/  2/FT  8970- 9150 GROSS 015
                       40101 DST 01          8945- 9075 203RDRV    9010         S002
                       40131 FINAL OP  1H15M IFP  135 FFP  234 BHT  222F 19.64
                       40201 DST 02          9080- 9170 203RDRV    9125         S003
                       40210 GAS  TS IN   40M                   NOT GAUGED
                       40231 FINAL OP  0H55M IFP  172 FFP  247 BHT  224F 19.61
                       50102 203RDRV  PERF       JET    W/  2/FT  8970- 8974       008
                       50202 203RDRV  PERF       JET    W/  2/FT  9038- 9050 GROSS 009
                       50302 203RDRV  PERF       JET    W/  2/FT  9094- 9150 GROSS 010
                       50402 203RDRV  PERF       JET    W/  2/FT  8970- 9150 GROSS 011
                       50502 203RDRV  PERF                        8970- 9150 GROSS 012
                       50602 203RDRV  PERF                        8970- 9150 GROSS 013
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40 N  23 E   5   22    50702 203RDRV  PERF                        8970- 9150 GROSS 014

40 N  23 E   5   30    10002                          0459302210354447 0459291910354359
                       10010 063 20126273 60000 2940010 911203RDRV            9200178
                       10021 TWP N  23   RGE E   5   SEC   30   055TH PRINCIPAL
                       101   SDAK HARDING   A  1800 FNL   660 FEL  N2 SE NE WO  D
                       102   WEBB RESOURCES                  30-8 NJOS-JANVRIN
                       103    3048 KB 3038 GR                       STATE LINE
                       104                                     API 40 063  20126 00
                       105   SPUD 06/03/1977 COMP 06/14/1977 ROTARY           D&A-OG
                       107   DTD  9200 LTD  9191                    FM/TD 203RDRV
                       40101 DST 01          8986- 8998 203RDRV                S002
                       40131 FINAL OP  1H    IFP   86 FFP  125 BHT  215F
                       40201 DST 02          9104- 9158 203RDRV                S003
                       40231 FINAL OP  1H    IFP  353 FFP  355 BHT  220F
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40 N  23 E   5  22    50702 203RDRV  PERF                       8970- 9150 GROSS 014

40 N  23 E   5  30    10002                       0459302210354447 0459291910354359
                      10010 063 20126273 60000 2940010 911203RDRV             9200178
                      10021 TWP N  23   RGE E   5   SEC   30   055TH PRINCIPAL
                      101   SDAK HARDING  A  1800 FNL   660 FEL  N2 SE NE WO  D
                      102   WEBB RESOURCES                    30-8 NJOS-JANURIN
                      103    3048 KB 3038 GR                           STATE LINE
                      104                                    API 40 063  20126 00
                      105   SPUD 06/03/1977 COMP 06/14/1977 ROTARY            D&A-OG
                      107   DTD  9200 LTD  9191                     FM/TD 203RDRV
                      40101 DST 01          8986- 8998 203RDRV                   S002
                      40131 FINAL OP  1H     IFP   86 FFP  125 BHT  215F
                      40201 DST 02          9104- 9158 203RDRV                   S003
                      40231 FINAL OP  1H     IFP  353 FFP  355 BHT  220F

40 N  23 E   6  27    10002                       0459285610336328 0459266810336052
                      10010 063 20084273 99999 5025051 110203RDRV 203RDRV  9270775
                      10021 TWP N  23   RGE E   6   SEC   27   19BLACK HILLS
                      101   SDAK HARDING  A  2640 FNL  1950 FEL     E2 C WF  WFO
                      102   LUFF KENNETH ETAL                 1-27 MILLER
                      103    2907 KB 2895 GR                           UNNAMED
                      104    2904 DF 2895 GR P  LSE NO       API 40-063- 20084-00
                      105   SPUD 01/22/1975 COMP 04/29/1975 ROTARY              OIL
                      107   DTD  9270                               FM/TD 203RDRV
                      20102 203RDRV  PERF                       8986- 9213 GROSS 012
                      20150 WTR
                      40101 DST 01          8380- 9050 203RDRV                   S002
                      40102 OVERLAPS 203GNTN
                      40131 FINAL OP  2H     IFP  160 FFP  472 BHT  215F
                      40201 DST 02          9066- 9120 203RDRV                   S003
                      40210 GAS  TS IN  1H28M                  6 IN INTERMITTENT
                      40231 FINAL OP  2H     IFP  198 FFP  415 BHT  217F WK BL INCR
                      40301 DST 03          9125- 9175 203RDRV            MISRUN 004
                      40331                                     BHT  217F
                      40401 DST 04          9125- 9175 203RDRV            MISRUN 005
                      40501 DST005          9130- 9175 203RDRV                   S006
                      40531 FINAL OP  2H     IFP  214 FFP  406 BHT  219F
                      50102 203RDRV  PERF      JET      W/  2/FT  9166- 9213 GROSS 008
                      50202 203RDRV  PERF               W/  2/FT  8986- 9028 GROSS 009
                      50302 203RDRV  PERF               W/  2/FT  9086- 9101        010
                      50402 203RDRV  PERF               W/  2/FT  9109- 9110        011

40 N  23 E   6  32    10002                       0459107210341078 0459088810340796
                      10010 063 20145273 40001 502505  110         203RDRV  9110J77
                      10021 TWP N  23   RGE E   6   SEC   32   19BLACK HILLS
                      101   SDAK HARDING  A  1320 FSL   2375 FWL    E2 SW WF  WOE
                      102   LUFF KENNETH                      1-32 SWANSON
                      103    2880 KB 2866 GR                      HARDING SPRINGS E
                      104                                    API 40 063  20145 00
                      105   SPUD 08/25/1977 COMP 10/14/1977 ROTARY              OIL
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40 N  23 E   6  32    107   DTD  9110          PB  9060
                      20102 203RDRV  PERF              W/  2/FT  8858- 9018 GROSS 006
                      40101 DST 01          8818- 8886 203RDRV                   S002
                      40102 OVERLAPS 203SNMN
                      40110 GAS  TS IN  0H19M                   /NO GAUGE/
                      40131 FINAL OP  2H     IFP  279 FFP  415 BHT  225F
                      40201 DST 02          8904- 8962 203RDRV                   S003
                      40231 FINAL OP  2H     IFP  193 FFP  293 BHT  214F
                      40301 DST 03          8968- 9070 203RDRV                   S004
                      40331 FINAL OP  2H     IFP  216 FFP  465 BHT  225F

40 N  23 E   8  19    10002                       0459375110318037 0459362910318138
                      10010 063 20097273       10235550 911203RDRV           9436676
                      10021 TWP N  23   RGE E   8   SEC   19   055TH PRINCIPAL
                      101   SDAK HARDING  A  660 FSL  1926 FWL  W2 SE SW WF  WF
                      102   SMOKEY OIL                        24-19 GRUBER
                      103    2812 KB 2800 GR                           WILDCAT
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40 N 6 E
40 N 6 E
40 N 10 E
40 N 12 E

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40 N 12 E 2

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40 N  23 E   6   32   107   DTD  9110             PB  9060
                      20102 203RDRV  PERF             W/  2/FT  8858- 9018 GROSS 006
                      40101 DST 01          8818- 8886 203RDRV                S002
                      40102 OVERLAPS 203SNMN
                      40110 GAS  TS IN  OH19M                     /NO GAUGE/
                      40131 FINAL OP  2H     IFP  279 FFP  415 BHT  225F
                      40201 DST 02          8904- 8962 203RDRV                S003
                      40231 FINAL OP  2H     IFP  193 FFP  293 BHT  214F
                      40301 DST 03          8968- 9070 203RDRV                S004
                      40331 FINAL OP  2H     IFP  216 FFP  465 BHT  225F

40 N  23 E   8   19   10002                    045937511031803 7 045936291031813 8
                      10010 063 20097273        10235550 911203RDRV          9436676
                      10021 TWP N  23   RGE E   8   SEC   19   055TH PRINCIPAL
                      101   SDAK HARDING   A   660 FSL  1926 FWL  W2 SE SW WF  WF
                      102   SMOKEY OIL                       24-19 GRUBER
                      103    2812 KB 2800 GR                          WILDCAT
                      104    2810 DF 2800 GR P  LSE NO          API 40-063- 20097-00
                      105   SPUD 04/13/1976 COMP 05/25/1976 ROTARY             D&A-OG
                      107   DTD  9436                               FM/TD 203RDRV
                      40101 DST 01          9124- 9180 203RDRV                S002
                      40131 FINAL OP  2H     IFP  463 FFF  654 BHT  234F
                      40201 DST 02          9221- 9266 203RDRV                 003
                      40231 FINAL OP  2H     IFP  469 FFP  856 BHT  224F

40 N  23 E  27   32   10002                    045907261007992 7 045892581007982 1
                      10010 031 20006273        9999970 500559JRSC            3050
                      10021 TWP N  23   RGE E  27   SEC   32   19BLACK HILLS
                      101   SDAK CORSON    A   660 FSL  1980 FEL  C SW SE S  S
                      102   KOCH EXPLORATION                   1 STATE
                      103    2149 KB 2139 GR                          WILDCAT
                      104                                      API 40-031- 20006 00
                      105   SPUD 05/28/1969 COMP 05/31/1969 ROTARY              D&A
                      107   DTD  3050                               FM/TD 559JRSC
                      40101 DST 01          2660- 2717 602MDDY                 002
                      40131 FINAL OP     20M IFP  925 FFP 1044 BHT   89F

40 N  43 W  29   14   10002                    043706661007412 2 043706521007413 4
                      10010 095 05000359        317055019001O9PCMB           3196066
                      10021 TWP N  43   RGE W  29   SEC   14   066TH PRINCIPAL
                      101   SDAK MELLETTE 1A  1320 FNL  1520 FWL   E2 NW WFX WF
                      102   GULF OIL                       1 RUSSELL OLSON
                      103              1812 GR                        WILDCAT
                      104    1825 KB 1812 GR  P LSE NO          API 40-095- 05000-00
                      105   SPUD 09/21/1965 COMP 09/24/1965 ROTARY  RECOMPL D&AW
                      107   DTD  3196 LTD  3193 PB  3164 OTD  3196 FM/TD 109PCMB
                      40101 DST 01          3126- 3133 202WNPG                 001
                      40131 FINAL OP  1H10M IFP  342 FFP  355 BHT  164F
                      50102 202WNPG  PERF      JET  W/  4/FT  3146- 3146       003
                      50202 202WNPG  PERF      JET  W/  4/FT  3147- 3147       004
                      50302 202WNPG  PERF      JET  W/  4/FT  3157- 3157       005
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40 N  43 W  29   14   50402 202WNPG  PERF      JET  W/  4/FT  3163- 3163       006

40 N 111 W  79    1   10002                    044444251002837 4 044442701002834 3
                      10010 065 20002273         150070 901602DKOT           1667K75
                      10021 TWP N 111   RGE W  79   SEC   1   055TH PRINCIPAL
                      101   SDAK HUGHES    A  1510 FSL  1510 FWL  SW NE SW S   S
                      102   ANSCHUTZ CORP                     1 JONES
                      103    1807 KB 1799 GR                          WILDCAT
                      104    1811 DF 1803 GR P  LSE NO          API 40-065- 20002-00
                      105   SPUD 09/25/1975 COMP 09/29/1974 ROTARY              D&A-G
                      107   DTD  1667                               FM/TD 602DKOT
                      40101 DST 01          1514- 1528 602DKOT                S002
                      40131 FINAL OP  1H     IFP  631 FFP  631 BHT  101F
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40 N 12 E
40 N 13 E
40 N 14 E
40 N 14 E
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40 N 14 E

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40 N  43 W  29  14    50402 202WNPG  PERF      JET   W/  4/FT  3163- 3163        006

40 N 111 W  79   1    10002                         0444442510028374 0444427010028343
                      10010 065 20002273            150070 901602DKOT            1667K75
                      10021 TWP N 111   RGE W  79   SEC   1    055TH PRINCIPAL
                      101   SDAK HUGHES    A  1510 FSL  1510 FWL  SW NE SW S    S
                      102   ANSCHUTZ CORP                          1 JONES
                      103    1807 KB 1799 GR                         WILDCAT
                      104    1811 DF 1803 GR P  LSE NO          API 40-065- 20002-00
                      105   SPUD 09/25/1975 COMP 09/29/1974 ROTARY             D&A-G
                      107   DTD  1667                              FM/TD 602DKOT
                      40101 DST 01          1514- 1528 602DKOT                  S002
                      40131 FINAL OP  1H     IFP  631 FFP  631 BHT  151F

40 N 111 W  79  16    10002                         0444155410334331 0444140210034387
                      10010 065 20003273            150070 900602DKOT            1651K75
                      10021 TWP N 111   RGE W  79   SEC  16    055TH PRINCIPAL
                      101   SDAK HUGHES    A  1510 FSL  1510 FWL  SW NE SW S    S
                      102   ANSCHUTZ CORP                          1 STATE
                      103    1827 KB 1819 GR                         WILDCAT
                      104    1827 DF 1819 GR P  LSE NO          API 40-065- 20003-00
                      105   SPUD 09/20/1974 COMP 09/25/1974 ROTARY             D&A
                      107   DTD  1651                              FM/TD 602DKOT
                      40101 DST 01          1514- 1530 602DKOT                   002
                      40131 FINAL OP  1H     IFP  605 FFP  605 BHT   82F

40 N 114 W  77   9    10002                         0446964010011559 0446988610011654
                      10010 119 20001273            150070 900602DKOT            1637K75
                      10021 TWP N 114   RGE W  77   SEC   9    055TH PRINCIPAL
                      101   SDAK SULLY     A  1510 FSL  1510 FWL  SW NE SW S    S
                      102   ANSCHUTZ CORP                          1 KOONTZ
                      103    1854 KB 1846 GR                         WILDCAT
                      104    1858 DF 1850 GR P  LSE NO          API 40-119- 20001-00
                      105   SPUD 09/30/1975 COMP 10/03/1974 ROTARY             D&A
                      107   DTD  1637                              FM/TD 602DKOT
                      40101 DST 01          1515- 1534 602DKOT                   002
                      40131 FINAL OP  1H     IFP  598 FFP  598 BHT  101F

40 S   1 E  18  28    10002                         0439275110197847 0439267410197752
                      10010 071 20003273           3321650 900203RDRV            4871577
                      10021 TWP S   1   RGE E  18   SEC  28    055TH PRINCIPAL
                      101   SDAK JACKSON   A  1980 FSL   410 FWL  W2 NW SW WF   WF
                      102   HANAGAN PETROLEUM                      1 JACKSON-FEDERAL
                      103    2604 KB 2593 GR                         WILDCAT
                      104                                       API 40 071  20003 00
                      105   SPUD 10/14/1976 COMP 11/08/1976 ROTARY             D&A
                      107   DTD  4871                              FM/TD 203RDRV
                      40101 DST 01                                        MISRUN 002
                      40131                                        BHT  110F

40 S   4 E  16  10    10002                         0437139510218046 0437139510217997
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40 S   4 E  16  10    10010 103 20006273         9999950 900109PCMB          4829770
                      10021 TWP S   4   RGE E  16   SEC  10   19BLACK HILLS
                      101   SDAK PENNGTON  A  1980 FNL   660 FEL   C SE NE WF  WF
                      102   ??ELESS DRLG                      10-8 FEDERAL
                      103    2458 KB 2447 GR                        WILDCAT
                      104    2455 DF 2447 GR P  LSE NO        API 40-103- 20006-00
                      105   SPUD 05/26/1970 COMP 06/17/1970 ROTARY            D&A
                      107   DTD  4829 LTD  4803                  FM/TD 109PCMB
                      40101 DST 01          1575- 1670 603GRNR                  002
                      40131 FINAL OP  OH4EM IFP  448 FFP  553 BHT  108F
                      40201 DST 02          2030- 2125 602MDDY           MISRUN 003
                      40301 DST 2A          2030- 2125 602MDDY                  004
                      40331 FINAL OP  OH10M IFP  818 FFP  818 BHT  119F

40 S   4 E  16  16    10002                        0436996010221024 0436996410220988
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40 N 14 E

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40 N 15 E

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40 S   4 E  16   10    10010 103 20006273        9999950 900109PCMB         4829770
                       10021 TWP S   4   RGE E  16   SEC   10   198LACK HILLS
                       101   SDAK PENNGTON  A  1980 FNL   660 FEL  C SE NE WF   WF
                       102   WHELESS DRLG                    10-8 FEDERAL
                       103    2458 KB 2447 GR                       WILDCAT
                       104    2455 DF 2447 GR P  LSE NO        API 40-103- 20006-00
                       105   SPUD 05/26/1970 COMP 06/17/1970 ROTARY            D&A
                       107   DTD  4829 LTD  4803                   FM/TD 109PCMB
                       40101 DST 01          1575- 1670 603GRNR                 002
                       40131 FINAL OP  OH45M IFP  448 FFP  553 BHT  108F
                       40201 DST 02          2030- 2125 602MDDY            MISRUN 003
                       40301 DST 2A          2030- 2125 602MDDY                 004
                       40331 FINAL OP  OH10M IFP  818 FFP  818 BHT  119F

40 S   4 E  16   16    10002                        0436996010221024 0436996410220988
                       10010 103 20001273        9999950 900553MRSN         2702770
                       10021 TWP S   4   RGE E  16   SEC   16   198LACK HILLS
                       101   SDAK PENNGTON  A  1980 FNL  1980 FWL  C SE NW WF   WF
                       102   WHELESS DRILLING                16-5 STATE
                       103    2455 KB 2450 GR                       WILDCAT
                       104                                     API 40-103- 20001 00
                       105   SPUD 11/23/1969 COMP 12/07/1969 ROTARY            D&A
                       107   DTD  2690 LTD  2702                   FM/TD 553MRSN
                       40101 DST 01          2595- 2626 602FLRV                 002
                       40131 FINAL OP  OH30M           FFP  111 BHT  128F

40 S   6 E   2   35    10002                        0434794910384427 0434801910384443
                       10010 033 00414126        9999950 911404HYDN         1340370
                       10021 TWP S   6   RGE E   2   SEC   35   055TH PRINCIPAL
                       101   SDAK CUSTER    A   647 FSL  2208 FEL   SW SE WF   WF
                       102   SOUTH DAKOTA OIL DEV               1 HEY
                       103    4060 KB 4056 GR                       WILDCAT
                       104                                     API 40-033- 00414 00
                       105   SPUD 06/13/1966 COMP 10/01/1966 ROTARY            D&A-OG
                       107   DTD  1340                             FM/TD 404HYDN
                       40101 DST 01          1193- 1219 451CASS                S002
                       40131 FINAL OP  1H    IFP   34 FFP  145 BHT   90F
                       50102 451CASS  PERF            W/  2/FT  1190- 1248 GROSS 004

40 S   7 E   1   11    10002                        0434502210396292 0434491210396310
                       10010 047 20071126       10503350 900419MNLS         2250277
                       10021 TWP S   7   RGE E   1   SEC   11   055TH PRINCIPAL
                       101   SDAK FALL RV   A   660 FSL  2217 FEL  N2 SW SE WF   WF
                       102   AQUARTUS RESOURCES             34-11 PETERSON
                       103    3689 KB 3679 GR                       WILDCAT
                       104    3687 DF 3679 GR P  LSE NO        API 40-047- 20071-00
                       105   SPUD 12/09/1976 COMP 12/22/1976 ROTARY            D&A
                       107   DTD  2250 LTD  2248                   FM/TD 419MNLS
                       40101 DST 01          2060- 2082 405LEO 1                002
                       40102 OVERLAPS 405LEO 2
                       40131 FINAL OP  1H    IFP  593 FFP  882 BHT   78F
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40 S   7 E   1   22    10002                        0434290610399258 0434291110399191
                       10010 047 20045126        6603150 911405LEO          2545K70
                       10021 TWP S   7   RGE E   1   SEC   22   055TH PRINCIPAL
                       101   SDAK FALL RV   A  1980 FNL   660 FWL   C SW NW WF   WF
                       102   PETRO-LEWIS CORP                5-22 PETERSON
                       103    3542 KB 3534 GR                       WILDCAT
                       104    3544 DF 3536 GR P  LSE NO        API 40-047- 20045-00
                       105   SPUD 11/17/1970 COMP 11/27/1970 ROTARY            D&A-OG
                       107   DTD  2545                             FM/TD 405LEO
                       40101 DST 01          2381- 2395 405LEO                 S002
                       40131 FINAL OP  OH45M IFP   30 FFP   75 BHT   96F

40 S   8 E   3   17    10002                        0433524510378941 0433529010378834
                       10010 047 20003126        2940050 900405LEO 3        2271670
                       10021 TWP S   8   RGE E   3   SEC   17   055TH PRINCIPAL
                       101   SDAK FALL RV   A  1980 FSL  1800 FWL    NE SW WF   WF
                       102   GARY SAMUEL [illegible]
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06/08/78

40 N 14 E

40 N 15 E

40 N 15 E

40 N 15 E

40 N 15 E

06/08/78

40 N 15 E

40 N 17 E

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40 S   7 E   1   22   10002                               0434290610399258 0434291110399191
                      10010 047 20045126           6603150 911405LEO                2545K70
                      10021 THP S   7    RGE E   1   SEC   22   055TH PRINCIPAL
                      101   SDAK FALL RV   A  1980 FNL   660 FWL   C SW NW WF  WF   64
                      102   PETRO-LEWIS CORP                   5-22 PETERSON
                      103    3542 KB 3534 GR                          WILDCAT
                      104    3544 DF 3536 GR P  LSE NO         API 40-047- 20045-00
                      105   SPUD 11/17/1970 COMP 11/27/1970 ROTARY               D&A-OG
                      107   DTD  2545                               FM/TD 405LEO
                      40101 DST 01          2381- 2395 405LEO  2388            S002
                      40131 FINAL OP  0H45M IFP   30 FFP   75 BHT   96F

40 S   8 E   3   17   10002                               0433524510378941 0433529010378934
                      10010 047 20003126           2940050 900405LEO 3              2271570
                      10021 THP S   8    RGE E   3   SEC   17   055TH PRINCIPAL
                      101   SDAK FALL RV   A  1980 FSL  1800 FWL   NE SW WF  WF   65
                      102   GARY SAMUEL                      17-11 CLEVELAND QUARRIES
                      103    3596 KB 3589 GR                          WILDCAT
                      104    3597 DF 3539 GR  P                API 40-047- 20003 00
                      105   SPUD 07/22/1968 COMP 08/02/1968 ROTARY               D&A
                      107   DTD  2270 LTD  2271                     FM/TD 405LEO 3
                      40101 DST 01          2023- 2037 405LEO  2030             002
                      40131 FINAL OP  1H    IFP  196 FFP  606 BHT   98F
                      40201 DST 02          2215- 2270 405LEO                   003
                      40231 FINAL OP  1H    IFP  196 FFP  606

40 S   9 E   2    7   10002                               0432882810392839 0432886310392871
                      10010 047 20047126           6603150 900405LEO 2              3250K70
                      10021 THP S   9    RGE E   2   SEC    7   055TH PRINCIPAL
                      101   SDAK FALL RV   A   420 FNL  1960 FWL  NW NE NW WF  WF   66
                      102   PETRO-LEWIS CORP                   3-7 TROTTER-FEDERAL
                      103    3885 KB 3877 GR                          WILDCAT
                      104                                      API 40-047- 20047 00
                      105   SPUD 12/07/1970 COMP 12/18/1970 ROTARY               D&A
                      107   DTD  3250                               FM/TD 405LEO 2
                      40101 DST 01          3080- 3101 405LEO 2  3091           002
                      40131 FINAL OP  1H    IFP  534 FFP 1177 BHT  108F

40 S  11 E   5   20   10002                               0430807610354481 0430798810354498
                      10010 047 20055126           2940050 900602SKCK               2288073
                      10021 THP S  11    RGE E   5   SEC   20   055TH PRINCIPAL
                      101   SDAK FALL RV   A  2100 FNL   500 FEL  SE SE NE WF  WF   67
                      102   WEBB RESOURCES                     20-8 STATE
                      103    3652 KB 3647 GR                          WILDCAT
                      104                                      API 40 047  20055 00
                      105   SPUD 12/31/1971 COMP 01/14/1972 ROTARY               D&A
                      107   DTD  2275 LTD  2288                     FM/TD 602SKCK
                      40101 DST 01          2021- 2078 602MWRY  2050            002
                      40131 FINAL OP  0H30M         FFP  311 BHT  158F

40 S  11 E   5   22   10002                               0430847810352066 0430839310352117
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40 S  11 E   5   22   10010 047 20053126           2940050 900602MWRY               2351073
                      10021 THP S  11    RGE E   5   SEC   22   055TH PRINCIPAL
                      101   SDAK FALL RV   A   660 FNL   660 FWL   C NW NW WF  WF
                      102   WEBB RESOURCES                     22-4 STATE
                      103    3668 KB 3663 GR                          WILDCAT
                      104                                      API 40 047  20053 00
                      105   SPUD 10/19/1971 COMP 10/22/1971 ROTARY               D&A
                      107   DTD  2351 LTD  2348                     FM/TD 602MWRY
                      40101 DST 01          2119- 2180 602MWRY                  002
                      40131 FINAL OP  0H10M         FFP  373 BHT  100F

40 S  12 E   4    3   10002                               0430412010363333 0430402610363364
                      10010 047 20033126           9999950 900602FLRV               1956J69
                      10021 THP S  12    RGE E   4   SEC    3   055TH PRINCIPAL
                      101   SDAK FALL RV   A   660 FNL  1980 FWL   C NE NW WF  WF
                      102   ECHO OIL ETAL                      1-3 FEDERAL-INDIAN CO
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40 S  11 E   5   22     10010 047 20053126        2940050 900602MWRY            2351073
                        10021 TWP S  11   RGE E    5   SEC   22   055TH PRINCIPAL
                        101   SDAK FALL RV   A   660 FNL   660 FWL  C NW NW WF  WF   68
                        102   WEBB RESOURCES                   22-4 STATE
                        103    3668 KB 3663 GR                          WILDCAT
                        104                                          API 40 047  20053 00
                        105   SPUD 10/19/1971 COMP 10/22/1971 ROTARY              D&A
                        107   DTD  2351 LTD  2348                    FM/TD 602MWRY
                        40101 DST 01          2119- 2180 602MWRY   2150              002
                        40131 FINAL OP  OH1CM             FFP  373 BHT  100F

40 S  12 E   4    3     10002                          04304120103633333 04304026103633364
                        10010 047 20033126        9999950 900602FLRV            1956J69
                        10021 TWP S  12   RGE E    4   SEC    3   055TH PRINCIPAL
                        101   SDAK FALL RV   A   660 FNL  1980 FWL  C NE NW WF  WF   69
                        102   ECHO OIL ETAL                   1-3 FEDERAL-INDIAN CR
                        103    3618 KB 3612 GR                          WILDCAT
                        104    3620 DF 3612 GR P  LSE NO          API 40-047- 20033-00
                        105   SPUD 10/22/1969 COMP 10/26/1969 ROTARY              D&A
                        107   DTD  1956                              FM/TD 602FLRV
                        40101 DST 01          1268- 1358 602MDDY   1313              002
                        40131 FINAL OP  1H    IFP   88 FFF  238 BHT   94F

40 S  12 E   4   16     10002                          0430028110364725 0430013610364893
                        10010 047 20010126        2940050 900501SPRF            2619
                        10021 TWP S  12   RGE E    4   SEC   16   055TH PRINCIPAL
                        101   SDAK FALL RV   A   660 FSL  1980 FEL  C SW SE WF  WF   70
                        102   GARY SAM                        16-15 STATE-GARY
                        103    3620 KB 3615 GR                          WILDCAT
                        104    3623 DF 3615 GR  P                 API 40-047- 20010 00
                        105   SPUD 03/21/1969 COMP 04/07/1969 ROTARY              D&A
                        107   DTD  2619 LTD  2615                    FM/TD 501SPRF
                        40101 DST 01          1365- 1458 603GRNR   1412      MISRUN 002
                        40102 OVERLAPS 602NCSL
                        40131 FINAL OP    30M IFP   52 FFF   93 BHT   88F
                        40201 DST 02          1365- 1458 603GRNR             MISRUN 003
                        40202 OVERLAPS 602NCSL
                        40231 FINAL OP    30M IFP   92 FFP   92

40 S  12 E   5    5     10002                          0430339410355446 0430329610355587
                        10010 047 20051126        2940050 901609CRCS            2369073
                        10021 TWP S  12   RGE E    5   SEC    5   055TH PRINCIPAL
                        101   SDAK FALL RV   A  1980 FSL  1980 FWL  C NE SW WF  WF   71
                        102   WEBB RESOURCES                  5-11 FEDERAL
                        103    3784 KB 3779 GR                          WILDCAT
                        104                                          API 40 047  20051 00
                        105   SPUD 09/10/1971 COMP 09/16/1971 ROTARY              D&A-G
                        107   DTD  2367 LTD  2369                    FM/TD 609CRCS
                        40101 DST 01          2292- 2317 602MWRY   2305             S002
                        40131 FINAL OP  OH30M             FFP  411 BHT  108F
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43 N   1 E   1   15     10002                          0404887610986136 0404878710986115
                        10010 047 30228243        1410350 911609CRCS            7175J77
                        10021 TWP N   1   RGE E    1   SEC   15   27SALT LAKE
                        101   UTAH UINTAH    A   712 FNL   754 FEL  SW NE NE WF  WF
                        102   ASHER AMERICAN INC                 1 ASHERN ROOSEVELT
                        103    5953 KB 5942 GR                          WILDCAT
                        104                                          API 43 047  30228 00
                        105   SPUD 08/22/1976 COMP 09/30/1976 ROTARY              D&A-OG
                        107   DTD  7175                              FM/TD 609CRCS
                        40101 DST 01          6787- 6860 652WSTC             MISRUN 002
                        40201 DST 02          6787- 6860 652WSTC                   S003
                        40210 GAS  TS IN    16M                  /NO GAUGE/
                        40211 GAS  TS IN    05M AT     31 MCFD /31.4/
                        40212 GAS  TS IN    30M AT     23 MCFD /23.3/
                        40213 GAS  TS IN    45M AT     19 MCFD
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06/08/78
40 N 19 E
40 N 20 E
40 N 20 E
40 N 20 E

06/08/78
40 N 20 E
40 N 20 E

South Dakota

LEMMON QUAD

PI REF. #	WELL NAME	COMPANY/OPERATOR NAME	TYPES OF LOGS RUN	COUNTY	LOCATION LATITUDE/LONGITUDE T R SEC	TOTAL DEPTH LOGGED (FT)
K6778X	598-0088	Forest Service	GR-N	Perkins	45.851°/102.718° T22N R11E S23	350
K6778Z	606-0077	Forest Service	GR-N	Perkins	45.940°/102.715° T23N R11E S23	305
K6778W	596-0031	Forest Service	GR-N	Perkins	45.885°/102.795° T22N R11E S8	300
K6777Y	591-0073	Forest Service	GR-N	Perkins	45.724°/102.193° T20N R16E S6	308
K6778S	595-0058	Forest Service	GR-N	Perkins	45.810°/102.100° T21N R16E S2	298
[illegible]77Z	592-0074	Forest Service	GR-N	Perkins	45.686°/102.164° T20N R16E S21	341
[illegible]777X	591-0079	Forest Service	GR-N	Perkins	45.716°/102.233° T20N R15E S11	381
K6776X	579-0089	Forest Service	GR-N	Perkins	45.571°/102.574° T19N R13E S31	458
K6776W	577-0094	Forest Service	GR-N	Perkins	45.643°/102.503° T19N R13E S3	273
K6776Z	577-0098	Forest Service	GR-N	Perkins	45.693°/102.511° T20N R13E S15	618
K6777S	577-012	Forest Service	GR-N	Perkins	45.668°/102.532° T20N R13E S28	375
K6777W	590-0063	Forest Service	GR-N	Perkins	45.728°/102.383° T20N R14E S3	385
K6779S	599-0082	Forest Service	GR-N	Perkins	45.923°/102.558° T23N R13E S30	337
K6778Y	594-0090	Forest Service	GR-N	Perkins	45.837°/102.372° T22N R14E S27	357
K6776Y	Johnson Water Well	Johnson	GR-N	Perkins	45.626°/102.390° T19N R14E S10	477

Resistance RS, Resistivity-R, Gamma Ray-GR, Neutron-N, Density-Den, Temperature-T, Caliper-C[illegible]

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PI REF. #	WELL NAME	COMPANY/OPERATOR NAME	TYPES OF LOGS RUN	COUNTY	LATITUDE/... T R SEC	
		AUSTIN QUAD				
G7199A	#2 Tillie Juergen	Burns Petroleum	GR-N	Fayette	30°/97° 03.75'	5000
		CORPUS CHRISTI QUAD				
G7199D	2 H.J. Mosser	Texas Energy Exploration	GR-N	Jim Wells	27°54.56'/97°57.50'	5334
		CRYSTAL CITY QUAD				
G7199C	#2 Smith	Tipperary Oil & Gas	GR-N	Frio	28° 41'/98° 23.20'	5010
		SAN ANTONIO QUAD				
G7199E	#1 Patillo Higgins Jr.	Holloway Oil Co.	GR-N	Wilson	29° 16.70'/98°02'	2660
		SEQUIN QUAD				
G7199B	#3 Robin B. Unit	T.D. Coffman	GR-N	Fayette	29°45.25'/97°07.85'	5000

Resistance RS, Resistivity R, Gamma Ray GR, Neutron N, Density Den, Temperature T, Caliper Cal, Spectral Gamma - KUT, Self Potential - SP

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Rev 8 1 80

GRAND JUNCTI...
WELL LOGS OF NURE...

The Grand Junction, Colorado, Office, U.S. Depar...
placed on open file 118 well logs obtained fro...
...hich is part of the National Uranium Resourc...
...ilable for perusal only at the Technical ...
...obtained between January 1 and Ma...
...ctric - SP, single point resis...
...utron/neutron; gamma/gamma...
...uranium, and thorium)...
...very well.
...open file pe...
...logging...
...log...

TEXAS EL PASO COUNTY PHILLIPS PET 2000 fnl 3000 fel of sec.	1 Hueco Tanks API 42-141-30096	6-Blk1-PSL-sur WILDCAT GW

2000 test. (11-5-80). Abandoned location.

TX1-122581

Petroleum Information. CORPORATION

 Form No. 611

Vicinity of Philip
Haakon County, S. Dakota

AREA
SD
Haakon
Biblio.

(ESL) Aldophson, D.G., LeRoux, E.F., 1968, Temperature variations of deep flowing wells in S. Dakota: USGS PP 600 D, p D60-62.

(IC) Casda, D.J., 1975, A Study of the Radium Content of the Groundwaters in Western S. Dak w/ Emphasis on the Madison (Pahasapa) Limestone: Ph.D Dissertation, S. Dak School of Mines & Technology, 58p.

(ESL) Davis, R.W, Dyer, C.F., Powell, J.F., 1961, Progress rept on wells penetrating artesian aquifers in S. Dakota: USGS, WSP 1534.

(?) Freeman R., Meier, R., 1978, Potential Appl. of Madison Fm. Waters for Community Heatings: Johns Hopkins U, Applied Physics Lab, QM-78-042

(??) Gries, John P., 1971, Groundwater Potential of the Pahasapa Limestone, S. Dak Acad. Sci. Proc., vol 50, pp 61-65.

(ESL) Gries, John P, 1977, Geothermal Applications on the Madison (Pahasapa) Aquifer System in S. Dakota: S. Dak. Sch of Mines & Tech, Final Rept Oct 1, 1976 - Sept 30, 1977

(IL) Hopkins, W.B & Petri, L.R. 1963 Geol of G.W. Res. of Lake Dakota Plain Area S.D. USGS WSP 1539T pp27+28

(IL) Jordan, W.H., Rothrock, E.P., 1940, A magnetic survey of central S. Dakota: S. Dak. Geol. Survey, Rept. of Invest # 37, 35p.

(ESL) Konikow, L.F., 1976, Prel. Digital Model of Groundwater Flow in the Madison Gp., Powder River Basin + Adj. Areas, Wy., Mt., S. Dak, N. Dak, + Nebraska: USGS, Water Resources Invest. 63-75

(IL MAD.) Latkovich, V., 1960, The Piezometric Surface of the Pre-Charles Mississippian Limestone, S. Dakota: S. Dak Sch. M+T, Bachelor's thesis.

(GV) Lum, Daniels, 1961, Gravity measurements east of the Black Hills and along a line from Rapid City to Sioux Falls, S. Dakota: S. Dak Geol Survey, Rept. Inv. 88, 26p.

(ESL) Muffler, L.J.P., 1978, Asst. of Geothermal Resources of the U.S. - 1978: USGS, Circ. 790, pp 92-93, 131.

(GM) Petsch, B.C., 1967, Magnetometer map of South Dakota: S. Dak. Geol. Survey, Mineral Inv. Resource Map No. 4.

Maps:

Dunc has:

1) S.D. Geol Survey #4., Major Physiographic divisions of S.D

2) " " " #1, Geol. map (8½"x11"), 1964

3) Schoon, Robert A.) SDD[illegible] Gen. stratigraphic column: S.Dak. Geol. Survey #6

4) USGS, 1963, Base map of S. Dakota (1:1,000,000) ✓ (in ESL

Topo quads (O.O) ✓Philip Gunction ✓Kadoka NE

7.5'

- ✓Philip (1953)
- ✓Philip SE (1953)
- ✓Powell (1954)

REFERENCE LIST

Vicinity of Philip Haakon County, So. Dakota

ESL Adolphson, D. G., and LeRoux, E. F., 1968, Temperature variations of deep flowing wells in So. Dakota: USGS Professional Paper 600-0; p. D60-62.

ESL Carda, D. J., 1975, A study of the groundwaters in western So. Dakota with emphasis on the Madison (Pahasapa) Limestone; Ph.D. Dissertation, So. Dakota School of Mines and Technology., 58 p.

ESL Davis, R. W., Dyer, C. F., and Powell, J. F., 1961, Progress report on wells penetrating artesian aquifers in So. Dakota; USGS Water Supply Paper 1534.

ESL EG&G, 1979, Direct heat application program summary, presented at the GRC Annual Meeting, Sept. 1979, pp. 21-23.

ESL Freeman, R., and Meier, R., 1978, Potential application of Madison Formation waters for community heatings; John Hopkins Applied Physics Lab., QM-78-042.

MARRIOTT Gries, J. P., 1971, Groundwater potential of the Pahasapa Limestone; So. Dakota Academy of Science Proceedings, v. 50, pp. 61-65.

ESL Gries, J. P., 1977, Geothermal applications on the Madison (Pahasapa) aquifer system in So. Dakota; So. Dakota School of Mines and Technology; Final Report, Oct. 1, 1976-Sept. 30, 1977.

ESL Hopkins, W. B., and Petrie, L. R., 1963, Geology of groundwater resources of Lake Dakota Plain Area, So. Dakota: USGS Water Supply Paper 1539T, pp. 27-28.

ESL Jordan, W. H., and Rothrock, E. P., 1940, A magnetic survey of central So. Dakota; So. Dakota Geological Survey Report of Investigations #37, 35 p.

ESL Konikau, C. F., 1976, Preliminary digital model of groundwater in the Madison group, Powder River Basin and adjacent areas, WY, MT, S. DAK, and N. DAK and Nebraska: USGS, Water Resources Investigation 63-75.

ESL Latkovich, V., 1960, The piezometric surface of the Pre-Charles Mississippian Limestone, S. Dakota: So. Dakota School of Mines and Technology., Bachelor's Thesis.

ESL Lum, D., 1961, Gravity measurements east of the Black Hills and along a line from Rapid City to Sioux Falls, So. Dakota: So. Dakota Geol. Survey, Rept. Inv. #88, 26 p.

ESL Muffler, L. J. P., 1978, Assessment of geothermal resources of the U. S.-1978, USGS Circular 790, pp. 92-93, 131.

ESL Petsch, B. C., 1967, Magnetometer map of So. Dakota: So. Dakota Geol. Survey Mineral Investigation Resource Map #4.

ESL Rahn, P. H., and Gries, J. P., 1973, Large springs in the Black Hills, So. Dakota and Wyoming: So. Dakota Geol. Survey, Report of Investigation No. 107. SER/SDGS RI-107

SL Sandburg, C. A., 1962, Geology of the Willisten Basin, No. Dakota, Montana, and So. Dakota, with reference to subsurface disposal of radioactive wastes: USGS Rept. TEI-809, OFR.

SL Schoon, R. A., 1970, Results from drill stem tests of oil wells in So. Dakota drilled before July 1, 1970; So. Dakota Geol. Survey Circ. 41.

SL Schoon, R. A., 1971, Geology and hydrology of the Dakota Formation in So. Dakota: So. Dakota Geol. Survey Report of Investigation no. 104.

ESL Schoon, R. A., and McGregor, D. J., 1974, Geothermal potentials in So. Dakota So. Dakota Geol. Survey, Report of Invest. no. 110, 76 p.

ESL Searight, W. F., 1937, Lithologic stratigraphy of the Pierre Formation of the Missouri Valley in So. Dakota; So. Dakota Geol. Survey Report of Invest. no. 27.

ESL Shurr, G. W., 1979, Upper Cretaceous Tectonic activity on lineaments in western So. Dakota: USGS OF Rept. 79-1374.

ESL South Dakota Soil Conservation Service, Haakon County Conservation District, 1974, Resource Planning and Development-Long Range Program, Revised-Philip, So. Dakota.

PARRLOTT or ILL Steece, F. V., 1961, Preliminary map of the Precambrian surface: So. Dakota Survey, Mineral Invest. Resource Map no. 2.

SL Swenson, F. A., 1968, New theory of recharge to the artesian basin of the Dakota: Geological Society of America Bull., v. 79, pp. 163-182.

AREA SD Gthm Poten

GEOTHERMAL POTENTIALS IN SOUTH DAKOTA

Robert A. Schoon and Duncan J. McGregor

For a geothermal reservoir to exist, there must be a heat source, a suitable reservoir rock above the heat source, water in the rock to transmit heat in the form of hot water or steam, and usually a cap rock above the geothermal reservoir rock to prevent rapid dissipation of heat. This last requirement does not appear to be absolutely necessary in that Allen and Day (1927) measured temperatures of 101.5°C (214.7°F) at a depth of 3 feet at Steamboat Fumarole in the geyser area of California. In this area there is no apparent cap rock (McDonald, 1972, p. 342).

In areas of active geothermal production, all have some like similarities in that they are found in regions of geologically young mountains, usually associated with active or past volcanic activity or where existence of faults are the rule rather than the exception. This is not to say, however, that every area meeting the above criteria overlies geothermal reservoirs. The relationship between any of the geographic or geologic variable is not all that clear cut. For examples, at Larderello the nearest volcanic rock lies 15 miles to the north and the Hawaiian volcanic areas seem to possess only minimal potentials for geothermal energy. In South Dakota the Homestake Gold Mine has a rather low thermal gradient in that at a depth of 6800 feet the temperature is only 122°F (personal communication, Mr Olin Hart, Chief Geologist, Homestake Mining Company). This is in a structurally deformed area that exhibits evidence of nearby Tertiary volcanic activity but has some of the lowest geothermal gradients in the State.

SOURCES OF HEAT

Sources of heat to create geothermal reservoirs involve much speculation but there appears to be general concurrence that the reservoir rock must have a direct relationship to a cooling igneous mass. According to McNitt (1963, p. 37) those areas throughout the world where geothermal energy is used are all located in regions where Cenozoic volcanism has occurred. This indicates that a direct relationship exists between thermal areas and processes of volcanism and magmatic intrusions. However, there is not complete agreement on this point. Levorsen (1967, p. 423) deals with aspects of the causes of the phenomenon by stating, *"The source of heat of the upper few miles of the earth's crust may be in the outward flow of heat from the central core of the earth, in the presence of igneous magmas that are cooling, in the disintegration of radioactive elements, or in the heat of subcrustal thermal convection currents. Lesser amounts of heat include the frictional heat formed during diastrophism . . . and exothermal chemical reactions that take place within permeable reservoir rock, both of which sources, if present, are temporary and local in their effects."* Levorsen previously suggested (p. 419) that in some cases change in geothermal gradient is best explained by a change in thermal conductivity of the rocks.

It is a known fact that temperature increases with depth in bore holes and that the rate of temperature increases or the thermal gradient varies considerably from place to place. There are a number of ways to formulate the phenomenon of the geothermal gradient, perhaps the most common is given by:

$$G = \frac{T - tF}{D}$$

where G = geothermal gradient, T = formation temperature (°F), tF - mean annual temperature (°F), and D = depth in hundreds of feet. The formula is self-explanatory and is the same as that used in computing the thermal gradients found in this report with only minor variations.

In this report the mean annual temperature was considered to be a constant 45°F over the entire State. Also, the annual mean temperature affects subsurface temperature down to a depth of 60 feet. Because of this, in computation of thermal gradients, the depth of the well was considered as 60 feet less than factual to account for the influence of the annual mean temperature. The effect of these deviations is minimal and for practical purposes corresponds to the above mentioned formula.

Mr. O. M. Phillips (1968, p. 138) states, *"Gradients as small as 1°C per 140 m are measured in some locations and as large as 1°C per 10 m in others, but in spite of this, the average over many such drillings in many countries of the world is very close to 1°C per 30 m."* If the foregoing is converted into degrees Fahrenheit and feet we find that some localities have geothermal gradients as low as .36°F/100 feet, some as high as 5.1°F/100 feet, with the average world geothermal gradient of 1.7°F/100 feet.

Schuster (1973) reports the average worldwide geothermal gradient is 87°F per mile (1.6°F/100 feet). At this gradient the boiling point of water would be reached at a depth of about 2 miles. Any area having a geothermal gradient several times that of the worldwide average certainly warrants investigation as a potential geothermal area.

A casual inspection of the isogradient map of the State (fig. 1) reveals that large areas have geothermal gradients considerably higher than the world average.

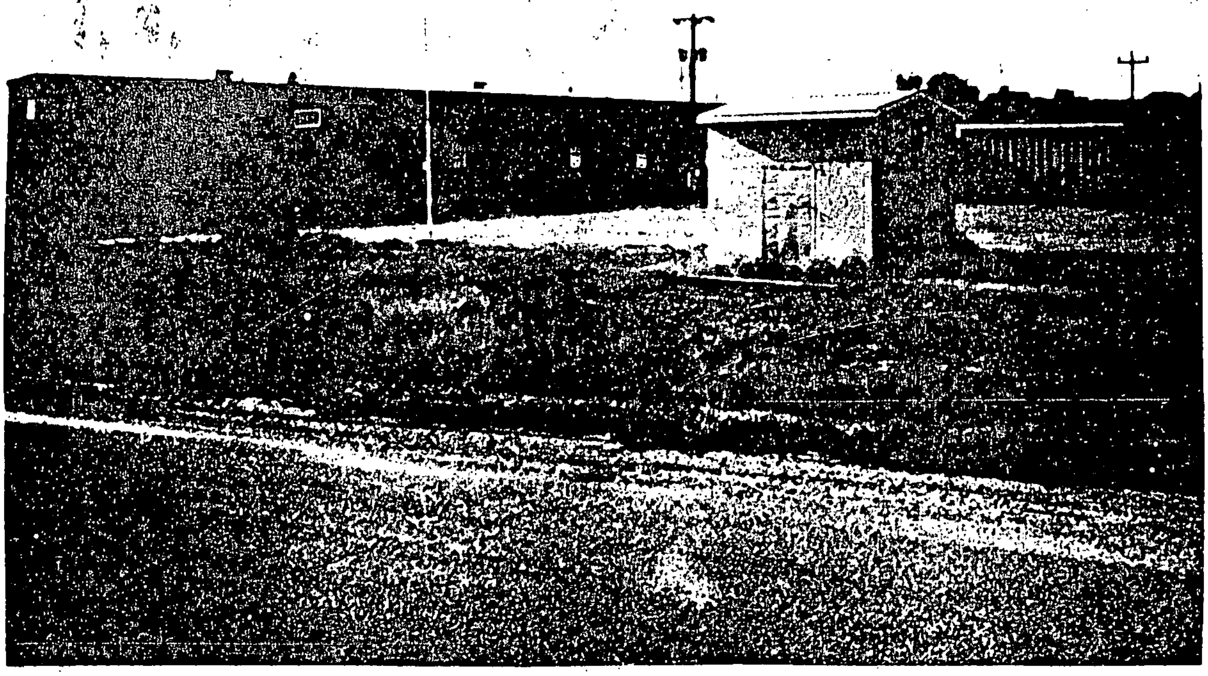


Figure 2. Photograph of the municipal well at Midland, S. D. The small building in the foreground houses the Midland city well. Hot water from this well heats the gymnasium in left background and the classroom building in right background.

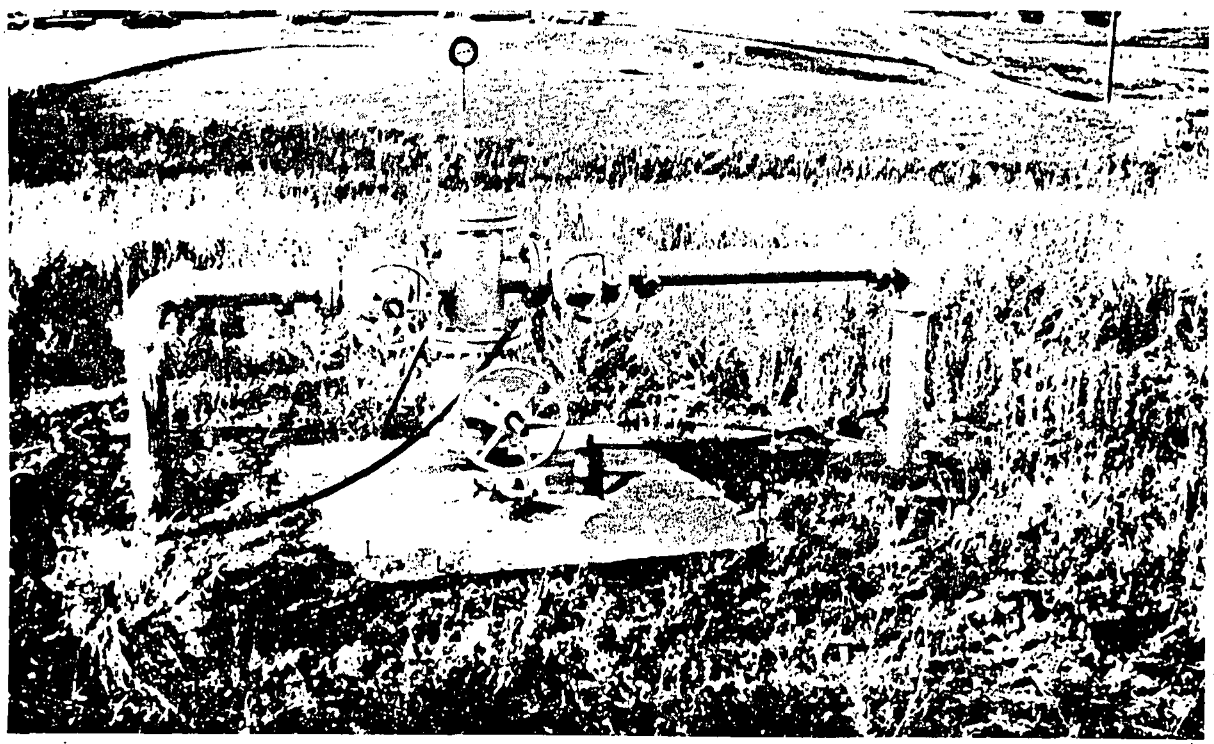


Figure 3. Photograph of the municipal well at Philip, S. D. The well yields water at a temperature of 158° Fahrenheit.

In northern Gregory County the 7°F/100 feet isogradient is present. Theoretically, this isogradient indicates that if one were to drill a hole 2400 feet deep, the temperature at the bottom of the hole (if the annual mean temperature is taken to be 45°F) would be approximately 212°F, the boiling point of water under atmospheric pressure. If this same hole were continued to a depth of 27,600 feet, the temperature should be about 1976°F, equivalent to the temperature of molten lava being ejected from an active volcano.

POSSIBLE CAUSES OF HIGH GEOTHERMAL GRADIENTS IN SOUTH DAKOTA

The study of geothermics is in its infancy, but much attention currently is being focused on the subject. In part this is because our nation is faced with a heating oil and natural gas shortage and additional heating sources are being sought. Then also, the exploration geologist has always been intrigued by the "anomaly" or the departure from the norm. From previous pages it is known that geothermal anomalies do exist in South Dakota. The cause of the hot artesian wells in South Dakota is speculation at this time. However, mechanics or conditions suggested by previous authors are given brief consideration.

Inspection of the Vertical Intensity Magnetic Map of South Dakota (Petsch, 1967) reveals a marked change in the general configuration of the contours. This change occurs in an area a few miles west of, and parallel to, the Missouri River. Many scientists contend that magnetic maps reflect structural trends or Precambrian rock types and younger magmatic intrusives. In South Dakota the magnetic map (fig. 9) is believed to be a reflection of basement rock types and/or structural trends and may mark a boundary of Precambrian Provinces. In North Dakota Laird (1964) separated these rock types into the Peace River, Superior, and Churchill Provinces of the Canadian Shield area. Similar to North Dakota, much of the structure and sedimentation in South Dakota may be governed by relative movements of two blocks or provinces of the shield area. Any relative movement between these two blocks would generate heat and create fracture zones which are two main requisites for an exploitable heat or power source. If this interpretation, based on the magnetic map, is correct then the logical area to search for geothermal energy is near the boundary of the Peace River and Superior Provinces. This boundary drawn by Laird in North Dakota has been projected through South Dakota and appears as figure 10 of this report.

Unstable areas are often accompanied by volcanic activity and hot thermal waters. It has been shown that the thermal gradient in south-central South Dakota is higher than the national average; however, it is more difficult to establish volcanic activity in the area during or subsequent to Precambrian time. Data concerning Precambrian rocks are limited, but Steece (1961) indicates that extrusive rocks are present in northwestern Hyde County. This extrusive is approximately 40 miles east of the inferred boundary of the Peace River-Superior rock masses, which is a rather extreme distance to postulate for a lava flow. This extrusive rock does strongly suggest the existence of an unstable area during, or subsequent to, Precambrian Time.

A comparison of the isogradient map with the gravity map of the State is less striking. The gravity map of South Dakota is quite generalized but in the area of Murdo (see fig. 11) a negative anomaly of -110 milligals is present in Jones, Mellette, and small portions of northwestern Tripp and southwestern Lyman Counties. Lum (1961, p. 6) in his gravity traverse of the State recognized this negative regional anomaly just east of Murdo, but he also (p. 7) discovered the existence of a broad positive anomaly of 11 milligals superimposed on the regional gravity minimum. He speculated this 11 milligal positive anomaly (fig. 12, this report) is possibly related to the Stanley County magnetic high. The authors do not disagree with Lum but also recognize that the positive anomaly could be a reflection of a post-Precambrian volcanic intrusive body. If this is the case the thermal gradient should be higher than that of the surrounding area. From observation of the isograident map it is apparent that some of the highest recorded temperatures in the State are present near the gravity anomaly east of Murdo. This area may be an early target in the event of future exploration.

An additional reason for singling out the area is to show the reader a difference of 11 milligals does exist between two surveys. If differences such as this do occur on a state-wide basis, the interpretation of the gravity map of the entire State could vary greatly and very conceivably agree quite closely with the magnetometer map in suggesting that the boundary of the Peace River-Superior Provinces exists in South Dakota. If the gravity map does indicate the Peace River-Superior Provinces then the boundary probably occurs along the -70 milligal contour which roughly follows the course of the Missouri River (see figs. 10 and 11).

According to McNitt (1963, p. 41) gravity and magnetic surveys do not appear to be particularly helpful in locating production fissures within structural depressions. He does note that detailed land magnetic surveys reveal magnetic lows over thermal areas due to hydrothermal alteration of magnetite to pyrite. In south-central South Dakota, Petsch (1967) shows two rather extensive magnetic

SOUTH DAKOTA

lows situated in eastern Mellette and Todd Counties and in northern Gregory and southern Brule Counties. Lum (1961, p. 6 and 7) notes that the broad positive gravity anomaly just east of Murdo may be a reflection of basement rock that is more mafic in character than the surrounding basement rock. This gravity anomaly lies just to the north of the magnetic low in eastern Mellette and Todd Counties. Lum's gravity traverse passed to the north of the magnetic anomaly of northern Gregory and southern Brule Counties. However, Lum (p. 5) does state *"a large positive anomaly of 15 milligals is located immediately west of Chamberlain. This anomaly is too large to be caused by either basement topography or by structure in the sedimentary rocks. Therefore, it is probably caused largely by a density contrast in the basement rocks."* The proximity of this gravity anomaly to the magnetic low in southern Brule County warrants additional study.

From Levorsen (p. 11, this report) it is stated that heat is evolved from the disintegration of radioactive elements. If such a source is present near the area of Midland, the source must be in rocks of Precambrian Age, because Gamma-Ray logs of sedimentary rocks in the area exhibit no intervals of extraordinarily high gamma activity. However, there is no evidence, such as cores of Precambrian rocks with which to lend credence to the preceding statement. On the other hand, Koenigsberger (1910) states that in the locality richest in radium, the pitchblende deposit in Joachimstal, the temperature gradients are normal. At this time the heating effect that radioactive decay has upon thermal gradients is problematical.

Any evolutionary process that produced structure in South Dakota would no doubt generate heat. Due to the masking effect of the Pierre Shale in the central and south-central part of the State, no structural evidence of sufficient intensity to generate a great amount of heat has been recognized in the area of higher thermal gradients. However, earthquakes are results of structural adjustments. Inspection of the earthquake locations in South Dakota (fig. 13 and table 2) suggests that structural adjustments are occurring in the vicinity where high thermal gradients are present. Heck and Eppley (1958, p. 39) reported an earthquake on May 9, 1906, in eastern Washabaugh County that was noted all along the Niobrara Valley from Rushmore (Nebraska) to Valentine (Nebraska). This quake was felt over an area of 7,000 to 8,000 square miles. The preceding authors also reported an earthquake occurring on July 23, 1946, at Wessington, South Dakota. This quake was generally felt from Pierre to DeSmet eastward and northward to Redfield, South Dakota. Agnew and Tullis (1962) report the occurrence of an earthquake 6 miles west of Pierre that had its focus at a depth of 10 miles. This report of the earthquake near Pierre is interesting in that the depth of origin or focus was located at a depth of 10 miles or 52,800 feet. From the isogradient map (fig. 1) the thermal gradient is at a rate of approximately 3.5°F/per 100 feet of depth. Multiplying the thermal gradient by the depth in hundreds of feet (3.5°F x 528) the temperature at the focus of the quake is projected to be 1848°F. This compares quite closely with the temperature of molten lava (1976°F). Thus, if the geothermal gradient is correct, and if this gradient is projected downward to a depth of 10 miles it is readily apparent that the temperature of the rocks is sufficient to cause these rocks to be in a plastic state and to yield to structural adjustment by flow rather than by rupture with subsequent shock. Perhaps a knowledge of the geothermal gradient of an area may enable one to accurately forecast the focus of earthquakes in any given area.

At any rate, the foregoing examples do not constitute a complete history of earthquakes in South Dakota, but do indicate that the State is not a totally stable area. These structural adjustments may be, in part, a cause of the warm artesian waters.

Another type of heating mechanism which may be the cause of the hot spots in South Dakota is that produced by convection cell currents existing in the mantle. Figure 14 shows the possible correlation between the stages of an orogenic cycle and a hypothetical convection current cycle. If convection currents were responsible for creating the energy that elevated the Black Hills area, the general fall-out of data becomes simple to explain. For instance, in stage 2 of figure 14, cooler temperatures exist below mountainous areas than in surrounding plains areas which is the reverse of what one would expect if high temperatures were evolved from structural deformation. Data in appendix I and plotted on the isogradient map indicate that the thermal gradients are indeed lower in the Black Hills area than in the plains area in south-central South Dakota. Stage 2 of figure 14 may also lend credence to the high geothermal gradient in northern Gregory County as being a true gradient and not a result of migrating hot water as discussed in the following paragraphs.

Closely related to the stages of orogenic cycle and the hypothetical convection current cycle illustrated by Bullard (see fig. 14, this report) is the idealized cross-sectional view of a geothermal reservoir (fig. 15, this report) illustrated by Schuster (1973). The illustration by Schuster shows a smaller convection cell with the currents flowing counter to the illustration in figure 14. This type of smaller convection cells may in practice be superimposed on a convection cycle such as illustrated in figure 14. Due to the masking of structures in South Dakota by glacial drift and Upper Cretaceous Shales, faults such as illustrated in figure 15 are not known to occur outside of the Black Hills area. However, it is possible

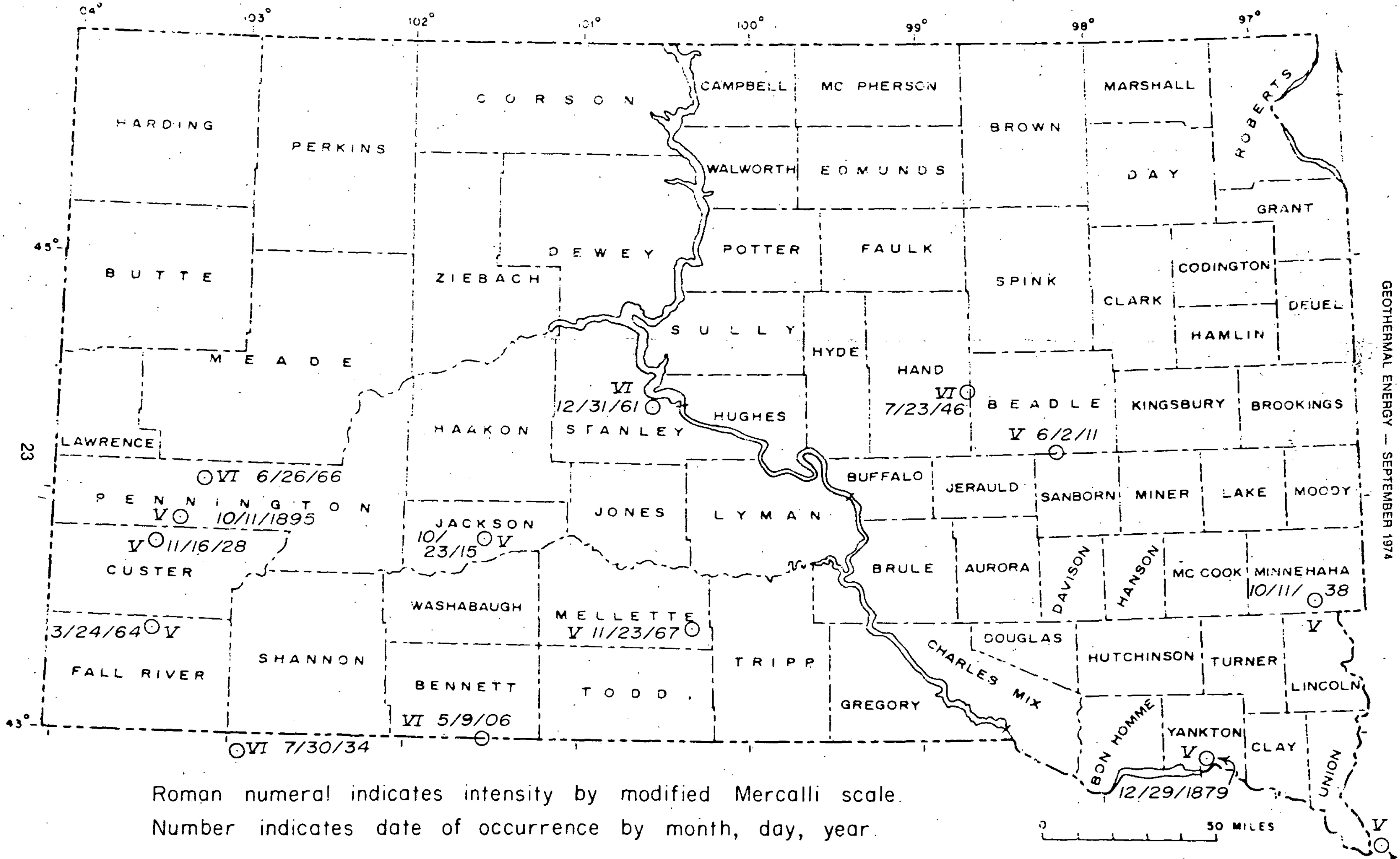


Figure 13 Approximate location of epicenters of earthquakes in South Dakota.

that differences in geothermal gradients in small areas are clues to the discovery of such structures."

As previously mentioned it is surprising that the periphery of the Black Hills, an area of deformation, does not exhibit as high geothermal gradients as the area in the eastern south-central part of the State which in the opinion of most geologists has been a relatively stable area throughout geologic time. The preceding discussion of convection currents in the mantle appears a logical explanation of the high geothermal gradients in the eastern south-central part of the State.

It is apparent from Schoon (1971; fig. 16, this report) that the 7°F isogradient is suspiciously near the area where the Madison-Red River recharge to the Dakota Formation takes place. If the two do in fact coincide then it is logical to assume that the water from the Madison-Red River is heated by a thermal gradient of 3°F/100 feet a distance of 20 miles to the west of the recharge area and upon rising to the Dakota Formation increases the thermal gradient of the area that is characterized by the 7°F thermal gradient.

The majority of geologic opinion holds that water movement is generally from west to east in sedimentary rocks in the southern half of South Dakota. Therefore, it is logical to search for a source of heat in a westward direction from the Kucera No. 1 Bartels Oil Test (SW SE section 23, Township 100 North, Range 77 West). From the isogradient map (fig. 1) of the State there is another large area with a 5°F thermal gradient which surrounds the 6°F and 7°F gradients and it logically follows that this area should be discussed further. This area is located in northwestern Tripp County and northeastern Mellette County For instance, at the Kucera No. 1 Bartels Oil Test (for location, see fig. 17) the thermal gradient is 3 1°F, approximately 28 miles to the east the thermal gradient is 7°F At the location of the Kucera No. 1 Bartels Oil Test the bottom-hole temperature was 117°F at a depth of 2387 feet. If it is assumed the water from near the bottom of the test is transferred to the area of high thermal gradient with no heat loss, and using the average depth of 1100 feet in the wells located in the area of high thermal gradient, the new assumed thermal gradient would be 7°F/100 feet. If the foregoing assumptions are true then perhaps the effect of circulating water on the thermal gradient should also be added to Levorsen's list of heat sources that contribute to thermal gradients.

The weak point of the foregoing assumption is, why should the temperature remain relatively constant between the Kucera No. 1 Bartels Oil Test and the area of the high thermal gradient and suddenly cool from the area of the high thermal gradient in an eastward direction? It is possible the area of recharge of the Madison-Red River interval to the Dakota Formation is quite restricted areally and as this warmer water enters the Dakota Formation and fans out in all directions the effect of warm waters soon becomes negligible.

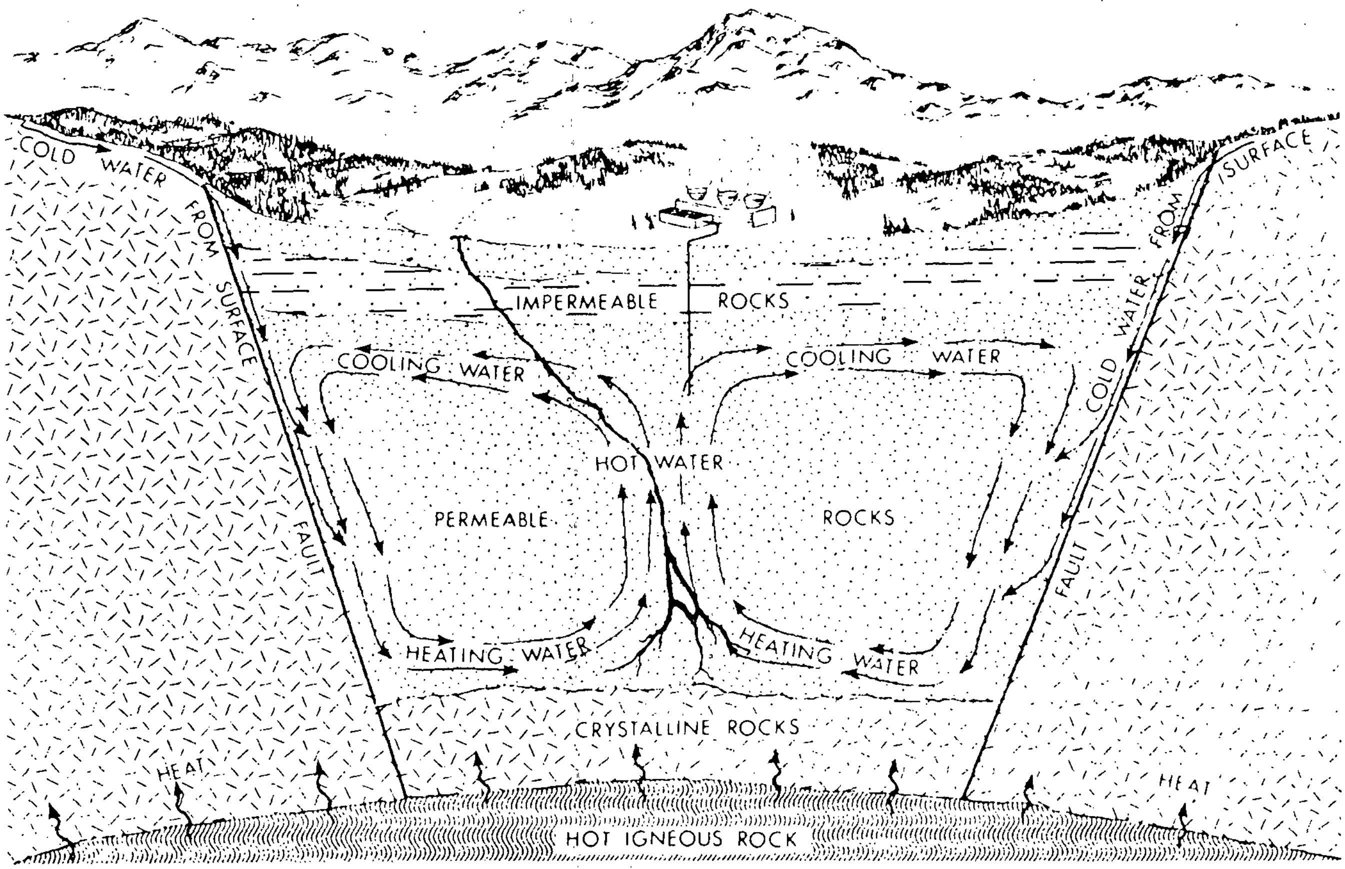
According to Heald (1930, p. 4) some students of earth temperatures feel that variations in these temperatures are in large part due to another means of circulating ground water. This school of thought believes that as the sediments pack down, water is squeezed out of the clays and shales and enters porous sandstones and limestones. The water thus released moves updip through these porous beds until it finally escapes where the beds crop out at the surface. Thus, waters deeply buried in a syncline would move updip and result in the temperatures in the updip areas being somewhat higher at a given depth below the surface of the ground than in the lower limbs of the syncline from which the water originated. Although this has been observed in Oklahoma and the regional picture seemed to support the conception, Heald noted that measurements of individual oil fields and individual wells seem to refute this theory.

Examination of the isogradient map of South Dakota tends to convince the observer that the theory is not at work in the State. For example, the axis of the Williston Basin passes through central Jackson and central Perkins Counties. If the theory were at work in the State the isogradient contours would be steeper on the west side of the axis of the Williston Basin than on the east side because the flanks of the basin are steeper on the west than on the east. Thus, the hotter fluids should migrate faster to the west. A cursory review of figure 1 shows the reverse to be true.

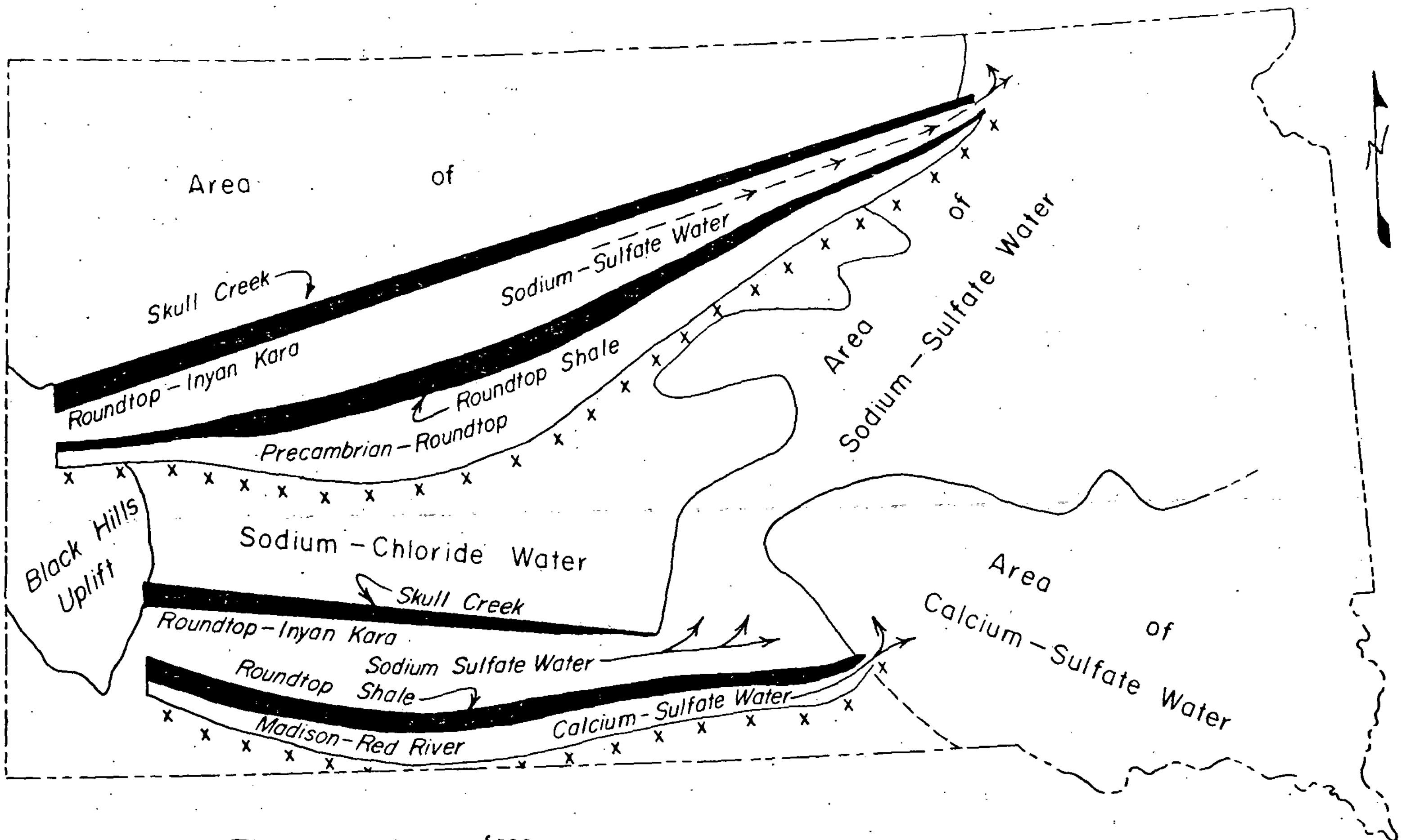
Unfortunately the data in the area of this high thermal gradient come from water wells which have not been logged. Thus, reliable data points upon which to base a structure are not numerous. About all that can be stated is that the possibility does exist. If a structure exists, the western end of the structure may be located in section 2, Township 4 South, Range 28 East. At this point, the sea level elevation of the top of the Minnelusa is -290 feet (see fig. 17). A well immediately to the south has the Minnelusa at -440 feet and another well approximately 7 miles to the northeast the Minnelusa is at 415 feet below sea level. However, there are two reasons against postulating structure on this data: (1) the Minnelusa has been quite severely eroded in this area, and (2) the structure, if present at all, is more subdued on the Precambrian surface.

In view of the aforementioned possibilities it is not possible with present data to identify the cause of the high geothermal gradients that exist in east

Figure 15. Cross section of northern California's geothermal electrical generating plant. (from Schuster, 1973.)



Idealized cross-sectional view of a geothermal reservoir. Hot igneous rocks at depth supply heat to the water-filled reservoir rock above. The hot water is less dense and rises until the impermeable cap rock is reached. If fissures are present in the cap rock, part of the geothermal fluid may escape and form hot springs or fumaroles at the surface. When the water reaches the area of the cap rock, it begins to move outward, cool, and become more dense. The greater density or weight causes the cooler water to move downward and be recycled, along with recharge water that might enter the reservoir along faults or fractures. A power plant is shown, drawing steam and/or hot water from the upper part of the reservoir.



x x x x x Precambrian surface

Aquiclude

Skull Creek denotes base of Dakota Formation

Figure 16. Schematic drawing illustrating the proximity of recharge to the Dakota Formation to the area of high geothermal gradient shown in Figure 1. (after Schoon, 1971)

south-central South Dakota. Perhaps the theory involving convection currents originating at depth is most plausible.

Farther west, in the area of the Black Hills, the thermal gradient is consistently quite low. However, the reader is advised that the condition may be true only at comparatively shallow depths. From the isogradient map it is clear that there is virtually no data in the crystalline area of the Black Hills. Also, the number of wells that penetrate to the Precambrian rocks in the periphery of the Hills are few. These two facts in conjunction with the belief of numerous geologists that outcrops of younger sedimentary rocks take on significant quantities of surface runoff may explain the lower than expected thermal gradient. If the conjectured recharge of warm water from the Madison-Red River interval in Gregory County is responsible for an increased thermal gradient in that area then, conversely, cool water in the form of surface runoff could lower the thermal gradient in the area of the Black Hills.

OTHER APPLICATIONS

In the search for oil, Levorsen (1967, p. 423) states that the crests of anticlines appear to have a small but measurable increase in thermal gradients in relation to the flanks of these same anticlines. Data points on known structures in South Dakota are not sufficient to confirm Levorsen's statements. The thermal gradients appear quite uniform in deeper portions of the Williston Basin. However, if Levorsen's statement holds true in South Dakota, undue attention should not be given to areas with contours at the expense of large areas with no contours. Because of the selection of the designated contour intervals it is quite possible that small areas within contour intervals exhibit greater variations than that suggested by wide spaced contour intervals. For this reason all data points in appendix I are plotted in areas that are considered to have oil potential.

Increased temperature lowers the viscosity (resistance to flow) of liquids. With this in mind the isogradient map may be instrumental in locating migration paths of oil.

In northwestern Haakon, northeastern Pennington, and southeastern Meade Counties, there is an area with a geothermal gradient in excess of 3°F/100 feet (fig. 1). Immediately to the west, in an updip direction, the geothermal gradient is 2°F or less per 100 feet. Although the variation is not great it is sufficient to give a 5000-foot oil test a temperature differential of 50°F (195°F - 145°F). From Levorsen (1964, fig. 5-33; fig. 18, this report) an accumulation of 32 API gravity oil subjected to a change in temperature from 90°F to 140°F could decrease in viscosity from 75 to 50 Saybolt Universal seconds.

California Edison And Geo-Energy Sign Steam-Purchase Pact

By a WALL STREET JOURNAL *Staff Reporter*

ROSEMEAD, Calif.—Southern California Edison Co. said it signed a contract with Geo-Energy Systems Inc., Los Angeles, to purchase geothermal steam upon the successful completion of a test geothermal well program in California's Imperial Valley.

According to the agreement, the utility would build a 55,000-kilowatt generating facility at the well site upon successful sustained production of a specified minimum amount and quality of steam required for economical electricity generation. Depending upon additional sustained production of steam, the company would build subsequent generating units, it said.

Geo-Energy, under terms of the agreement, must complete a test well within seven months to verify the technology to be utilized and the geology of the Imperial Valley area selected—five miles south of the Salton Sea. Additional wells will be produced to verify adequate reserves, Southern California Edison said.

Geo-Energy will be using a system called the Van Huisen Downhole Heat Exchanger, a patented heat-transfer system that is designed to extract heat from geothermal reservoirs without bringing any of the underground materials to the surface, the utility said. Allen T. Van Huisen, who invented the process, is the director of research and development for Geo-Energy, a Southern California Edison spokesman said.

Southern California Edison said it couldn't estimate the price of the steam to be purchased or the cost of the generating facility at this time. Geo-Energy officials couldn't be reached for comment.

This will be the third geothermal project for Southern California Edison, which is seeking steam elsewhere in the Imperial Valley and in Northern California.

Given the right combination of viscosity, pressure, and permeability this temperature variation could conceivably halt migration. Because permeability is affected inversely with the viscosity, and temperature increases result in a decrease in viscosity the possibility of geothermal trapping mechanisms are very apparent. Perhaps additional study may find that some so-called permeability traps are in reality thermal traps or viscosity traps.

CONCLUSION

The cause of high geothermal gradients in South Dakota is not fully understood. Dutcher et al. (1972, p. 25) gives criteria for distinguishing between conduction and convection by saying that a rule of thumb is, if the gradient is uniform, thus permitting an extrapolation to a reasonable mean surface temperature, heat flow is assigned to conduction. Whereas, if high temperatures with small gradients extrapolate to high surface temperatures, heat flow is attributed to convection. Whether this rule of thumb holds true in an area of extensively water flushed formations at depth is not known.

In the area of the 7°F isogradient the Precambrian surface is approximately at sea level, or depending upon drilling site, at a depth of 1500 to 2000 feet. If a test hole were continued a few hundred feet into the Precambrian rocks a temperature log could be run to determine whether or not the high geothermal gradient continues below the Cretaceous sands. If the geothermal gradient decreases, one could assume a false geothermal gradient is caused by hot water moving into the area from another area. On the other hand, if the geothermal gradient is continuous, a geothermal reservoir suitable for generating power might be present at a depth of 7800 feet.

Burnham and Stewart (1971) report that an ideal power site should have rock temperatures above 600°F at depths ranging from 6,000 to 10,000 feet, large quantities of surface water and an area remote from population centers. Using these criteria as requirements for a power site, the nearby Lake Francis Case and the rural nature of the area satisfy two requirements and there is left only one questionable requirement. This is determination of a completely reliable measurement of the geothermal gradient.

One possible requisite not mentioned in the preceding paragraph is the existence of a permeable interval at sufficient depth to insure a means to utilize high temperatures. Many wells drilled to and in Precambrian rock in South Dakota fail to yield water. However, if the change of the character of the contours on the magnetic and gravity maps of South Dakota represent the Peace River-Superior Provinces, it is quite possible that fractured Precambrian rocks are present in the area.

In view of the projected fuel shortage faced by our nation, the area of high geothermal gradients should be researched as a potential power supply. Along the same line more attention should be given by exploration geologists to the possible effects that subsurface changes in temperatures have on the migration and accumulation of oil.

Perhaps there are other areas in South Dakota with high geothermal gradients. These may in time be discovered by carrying out an extensive drilling program. However, a drilling program is a relatively expensive means of exploration. In south-central South Dakota including the area of Shannon, Washabaugh, Bennett, Mellette, and Todd Counties, there is a scarcity of data. The fact that all geothermal data points plotted in this area (with one exception) are higher than the world-wide average, suggests that this rather large area merits further study.

REFERENCES CITED

Agnew, A. F., and Tullis, E. L., 1962, Pierre earthquake of 1961: S. Dak. Acad. Sci. Proc., XLI, v. 41, 1962, p. 57-58

Allen, E. T., and Day, A. L., 1927, Steam wells and other thermal activity at the geysers, California: Carnegie Institute of Washington, Publication 466

Bullard, F. M., 1971, Volcanoes, in history, in theory, in eruption: University of Texas Press, 1971, 441 p.

Burnham, J. B., and Stewart, D. H., 1970, The economics of plowshare geothermal power: *in* Symposium on engineering with nuclear explosives — Am. Nuclear Soc. and U.S. Atomic Energy Comm., Las Vegas, Nev. 1970 Proc., v. 2, Springfield, Va., Clearinghouse Federal Sci. and Tech. Inf., p. 1376-1383, illus., 1970

Dutcher, L. C., Hardt, W. F., and Moyle, Jr. W. R., 1972, Preliminary appraisal of ground water in storage with reference to geothermal resources in the Imperial Valley area, California: U.S. Geol. Survey Circ. 649, 57 p.

Federal Register, 1973, Geothermal resources: Bur. of Land Management and Geol. Survey, v. 38, no. 140, pt. II

Heald, K. C., 1930, The study of earth temperatures in oil fields on anticlinal structure: Am. Petroleum Inst. Bull. 205, (Oct. 1930), p. 4

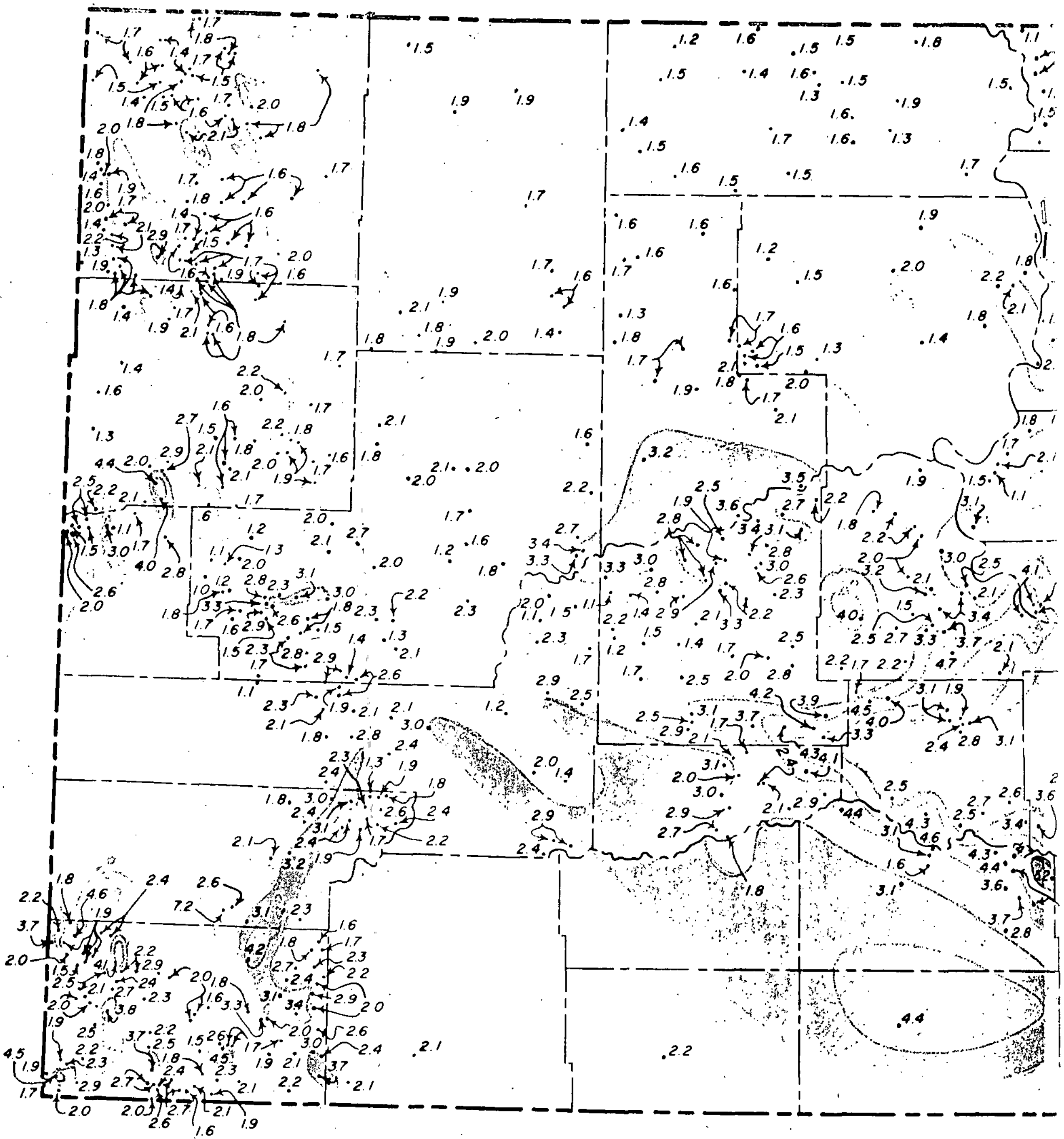
Heck, N. H., and Eppley, R. A., 1958, Earthquake history of the United States: U.S. Dept. of Commerce, U.S. Coast and Geodetic Survey, pt. I, 80 p.

Koenigsberger, J., and Muhlberg, M., 1910, On the measurements of the increase of temperatures in boreholes . . .: Trans. Inst. Min. Eng., v. 39 (June 2, 1910), 28 p.

Laird, W. M., 1964, Résumé of the stratigraphy and structure of North Dakota: Third Internat. Williston Basin Symposium, 1964, p. 39-44

Levorsen, A. I., 1967, Geology of petroleum, 2nd. Ed., W. H. Freeman and Company, San Francisco and London, 724 p.
Loehwing, D. A., 1973, Nature's teakettle, geothermal power is getting up a head of steam: Barron's National Business and Financial Weekly, Dow Jones & Co., Inc. Pub., August 13, 1973
Lum, Daniel, 1961, Gravity measurements east of the Black Hills and along a line from Rapid City to Sioux Falls, South Dakota: S. Dak. Geol. Survey Rept. Inv. 88, 26 p.
McNitt, J. R., 1963, Exploration and development of geothermal power in California: Cal. Division of Mines and Geology, Special Report 75, 45 p.
Macdonald, G. A., 1972, Volcanoes: Prentice-Hall, Inc., Englewood Cliffs, N. J., 510 p.
Muffler, L. J. P., 1973, Geothermal resources: *in* United States Mineral Resources, U.S. Geol. Survey Prof. Paper 820, p. 251-261
Petroleum Information, v. 47, no. 2, January 3, 19
Petsch, B. C., 1967, Magnetometer map of South Dakota: S. Dak. Geol. Survey, Mineral Inv. Resource Map no. 4
Phillips, O. M., 1968, The heart of the earth: Freeman, Cooper and Company, San Francisco, 236 p.
Schoon, R. A., 1971, Geology and hydrology of the Dakota Formation in South Dakota: S. Dak. Geol. Survey Rept. Inv. 104, 55 p.
Schuster, E. J., 1973, The search for hot rocks, geothermal exploration, Northwest: Reprint no. 11, Pacific Research, May 1973, Dept. of Nat. Resources, Division of Mines and Geology, 4 p.
Steece, F. V., 1961, Preliminary map of the Precambrian surface: S. Dak. Geol. Survey, Mineral Inv. Resource Map no. 2
Summers, W. K., 1968, Geothermics, New Mexico's untapped resources: N. Mex. Bur. of Mines and Mineral Resources, Circ. 98, 9 p.
Water Well Journal, 1974, Geothermal steam is private property: Water Well Journal, v. XXVIII, no. 2, February
Woollard, G. P., and Joesting, H. R., 1964, Bouguer gravity anomaly map of the United States (exclusive of Alaska and Hawaii): U.S. Geol. Survey Special Map

Copies of Report of Investigations No. 110 may be obtained from South Dakota Geological Survey, Dept. of Natural Resource Development, Vermillion, South Dakota.



LEGEND

Areas indicating geothermal gradients of less than 3° F. per 100

Areas indicating geothermal gradients ranging from 3° F. to 5° F

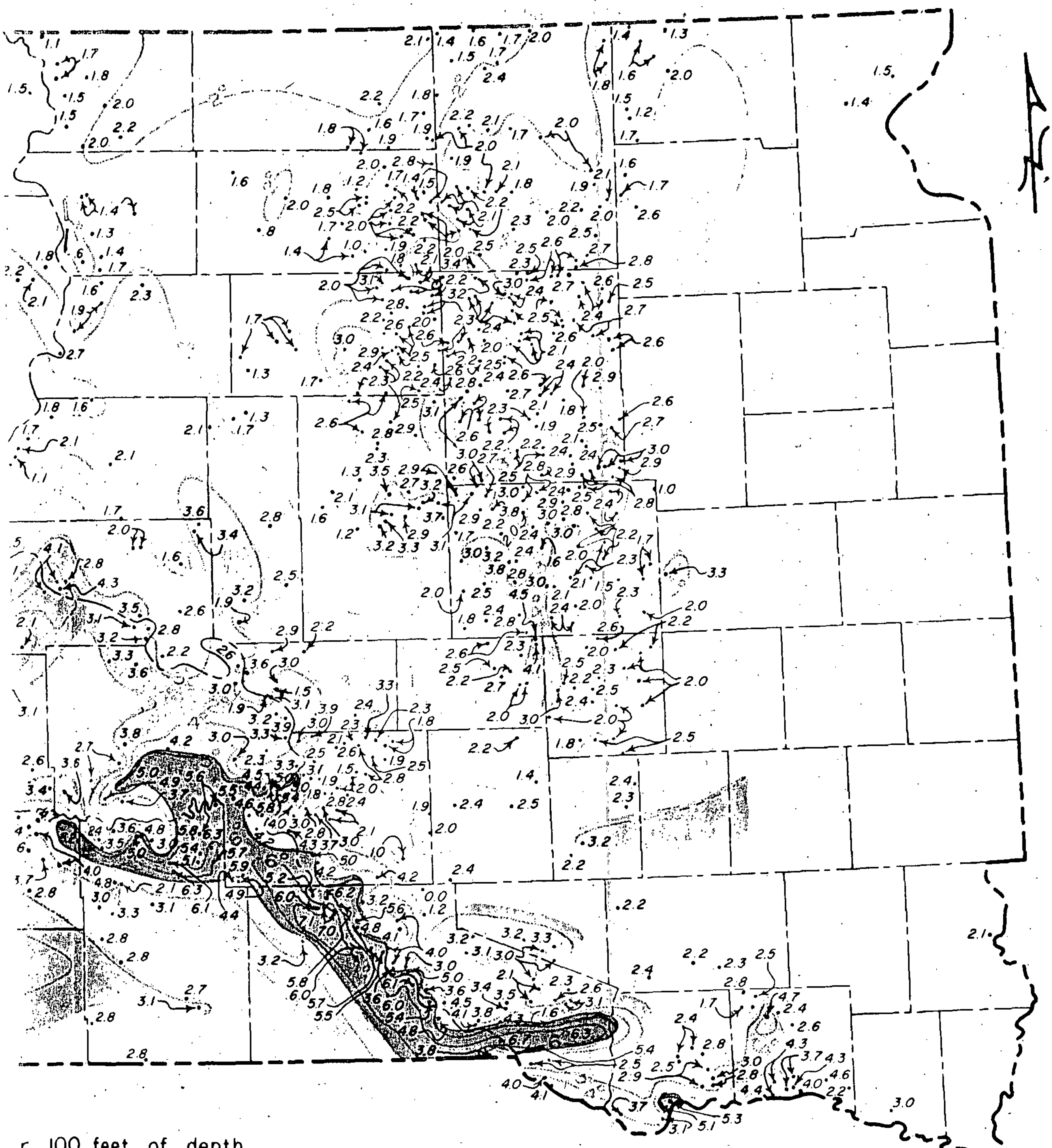
Areas indicating geothermal gradiants in excess of 5° F. per 100

3.0. Numbers adjacent to data points indicate geothermal gradient i

Isogradient intervals at 2°, 3°, 4°, 5°, 6°, and 7° per 100 feet

For county names see back of this map.

Figure 1. Isogradient map of South Dakota.



r 100 feet of depth.

5° F per 100 feet of depth.

r 100 feet of depth.

ient in °F per 100 feet of depth.

feet of depth.

10 0 10 20 30 40 50 miles

SCALE

AREA
SD
Kyle
Gthm

QM-78-226

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DRAFT

GEOTHERMAL ENERGY DEVELOPMENT BY THE OGLALA SIOUX AT KYLE, SOUTH DAKOTA

R. C. Eberhart
R. A. Freeman

April, 1978

DRAFT

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SUMMARY

A preliminary study has been completed which assesses the feasibility of developing the geothermal resources of the Madison formation for the community of Kyle, South Dakota, located on the Pine Ridge Indian Reservation. The key question considered is whether geothermal space heating can be cost-competitive with conventional space heating systems in the Kyle area. To answer this question, a cost model for a community geothermal space heating system was developed for Kyle, and used to compare costs of using geothermal energy with costs of using fuel oil and propane.

The design analysis assumes that 125 homes in the Kyle area are converted so that each can use geothermal energy for space heating. The analysis also assumes that the new high school planned for Kyle is heated by geothermal energy.

The result of the analysis is that geothermal space heating does appear to be cost-competitive with conventional space heating systems. In fact, substantial monetary savings are projected, whether or not a reinjection well is required, provided only that the geothermal resource exists in a form similar to that which has been assumed.

Moreover, the installation of a geothermal space-heating system would result in other important benefits for the Oglala Sioux:

1) The redirection of money back into the reservation,
2) New jobs,
3) A move toward energy self-sufficiency for the tribe, and
4) The availability of large additional amounts of energy (in addition to that used for space heating) for other purposes, such as greenhouses and fish hatcheries.

The analysis which has been performed has led to several recommendations:

1) The potential economic and social advantages of developing geothermal energy resources in the Kyle area are extremely significant, and it is urged that this development be given serious consideration.

2) It is recommended that a feasibility study, similar to that carried out for this report, be completed for the Wanblee, S. D., area.
3) It is recommended that the design of standardized heat exchangers, suitable for either solar or geothermal applications in BIA and HUD Native American housing throughout the United States, be pursued as soon as possible.
4) It is recommended that the utilization of low-grade heat from the discharge of the primary side of the central heat exchanger and the utilization of off-peak energy from the transmission/distribution system at Kyle be studied in detail.
5) It is recommended that, as a part of any effort to determine the magnitude and temperature of the Madison waters near Kyle for use as a geothermal resource, close attention be paid to the determination of water quality. If the water quality is sufficiently high, consideration can be given to using water from the geothermal well for drinking water and/or for irrigation.

I. INTRODUCTION

A large percentage of the western half of South Dakota appears to be underlain by a geothermal energy resource. This resource, an aquifer known as the Madison Limestone Formation (the Madison) varies in temperature, water quality, depth and thickness from place to place.

The Madison contains vast amounts of hot water at temperatures between 120°F and 160°F (49°C and 71°C). Much of the water is potable and has been used by some communities and individuals for many years. A few isolated projects exist or are underway to employ the waters for space heating. These projects, however, will use only a small fraction of the energy resource.

The geology of the Madison is reasonably well known and this knowledge is being advanced further by studies now being carried out. Thus it can be stated that the waters of the Madison represent a major geothermal resource that is available, today, to the people of western South Dakota. Furthermore, no new technology is required to tap this energy source, and so it is possible to develop it in a relatively short time.

It is especially significant that approximately one-third of the land over the Madison Formation in South Dakota lies within the boundaries of Indian reservations. Although the exact areal extent of the formation is unknown, all or portions of up to six Sioux Indian Reservations lie over the Madison.

The lifestyles, beliefs, dependence upon high priced energy sources, and economic plight of the Indian people all contribute to make the development of geothermal resources on Indian land in South Dakota a unique opportunity. The close involvement of various federal agencies such as the BIA and EDA in tribal affairs, and the tribal governmental structure which exists, contribute to make the institutional mechanisms of geothermal development on Sioux lands unique. And the current disputes relative to sovereignty of Sioux Indian people, particularly with respect to water and mineral rights, serve to make the potential problems which surround the possible development of Madison Formation geothermal resources unique.

This report is intended to examine, in a preliminary way, some possibilities which exist for the utilization of geothermal resources by the Sioux people. The outline of a plan is presented for resource utilization at Kyle, South Dakota, a town on the Pine Ridge Reservation of the Oglala Sioux.

The outline is not meant to be all inclusive; not all information needed to prepare a detailed plan for geothermal resource utilization at Kyle has been assembled. Likewise, this preliminary plan is not meant to be exclusive; Kyle is not the only location on Sioux land in South Dakota where geothermal development is possible.

The material in this report should be interpreted only as representing possible options for those who wish to consider geothermal energy for local applications. Since certain resource data are still being investigated, this report must be considered as preliminary. Comments and suggestions are actively solicited.

II. CHARACTERISTICS OF THE GEOTHERMAL RESOURCE

The Madison is a well-known aquifer that underlies portions of South Dakota, North Dakota, Montana and Wyoming. In South Dakota it extends beneath the western half of the state. The entire aquifer covers an area of about 25,000 square miles and stores an estimated one billion acre-feet of water. The water temperatures are considered "moderate", ranging from about 120°F to 160°F (or 49°C to 71°C). Although its exact extent is unknown, it is believed that the Madison underlies most of the northern and western portions of the Pine Ridge Indian Reservation. The Black Hills, Big Horn and Laramie Mountains are believed to recharge the Madison aquifer at the rate of 150,000 acre-feet per year.

The estimated age of the Madison waters is between 15,000 and 30,000 years. They reside in a limestone formation averaging 400 feet in thickness, at depths ranging from 3,000 to 6,000 feet in South Dakota. The porosity of the formation averages 8 per cent; the transmissivity is estimated to be 0.013 ft^2/sec and the storage coefficient is estimated to range from 0.0001 to 0.00025 (South Dakota School of Mines Report, "The Geothermal Applications on the Madison Aquifer System (Pahasapa) in South Dakota", 1976).

The ability of the aquifer to transmit water is quantitatively described by its transmissivity. Transmissivity is the rate at which water passes through a unit width of the aquifer under a unit hydraulic gradient (Lohman and others, 1972). The storage coefficient is a dimensionless number that is the ratio of the volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the hydraulic head (pressure) (Lohman and others, 1972).

The southern region of the Madison, including the area around the Pine Ridge Reservation, contains water that is generally potable and with dissolved solids of 1000 to 3000 ppm. To the north the water becomes more saline, less potable. Dissolved solids may be as high as 20,000 ppm near the border with North Dakota, and this presents problems in the direct use of the water.

Detailed discussions of the Madison's geology and its geothermal potential are available in a series of publications by the South Dakota Geologic Survey (of particular interest is the Report of Investigations No. 110) and by the South Dakota School of Mines and Technology in its report: "Geothermal Potential of the Madison (Pakasapa) Limestone, 1976."

Some information relative to the geothermal potential of the Madison in the vicinity of the Pine Ridge Reservation is contained in a listing of potential geothermal resources done by the Bureau of Indian Affairs (BIA) for The Department of Energy (DOE). Page 166 of the listing, which contains information relative to Pine Ridge, is attached as Appendix A. The information from Appendix A related to Pine Ridge is summarized in Table I.

TABLE I

PARTIAL LIST OF POTENTIAL GEOTHERMAL RESOURCES IN THE VICINITY OF THE PINE RIDGE INDIAN RESERVATION*

Name	Location Longitude	Location Latitude	Type	Temperature (Degrees F)	Flow (GPM)
Hot Spring	103°23.2'	43°33.7'	Spring	81	5000
Hot Brook	103°31.2'	43°33.7'	Spring	90	50
Cascade Spring	103°34.4'	43°23.4'	Spring	68	7200
Buffalo Gap Spring	103°12.0'	43°39.4'	Spring	?	?

* Taken from a listing prepared in 1977 for DOE by the BIA

As can be seen from Table I, only four warm springs are listed. Since all potential resources within 60 miles of the reservation, including oil wells, are supposed to be included in the listing, it is obviously incomplete. For example, the towns of Midland and Edgemont, both within 60 miles of the reservation, currently use geothermal energy. In addition, four oil wells in the immediate vicinity of the reservation have yielded geothermal-related data. (These wells are discussed later in this report).

Although the Madison can be used for space heating and other applications in South Dakota much more widely than it is today, several important factors must be better known before extensive geothermal development can be shown practicable and economic. These factors, listed below, require the collection of data relating to the Madison, itself, and other aquifers that may interact with the Madison.

1. The heat source and its life expectancy.

   It is considered probable that the thermal properties of the Madison waters will remain relatively constant. However, the exact nature of the source of heat that raises the water's temperature above that found at equal depths in other regions of the United States in not known yet. If the source is a concentration of trace radioactive elements in the Precambrian granite which covers the Madison Formation, as has been suggested, the natural diminution of water temperature is expected to be very slow, measured in tens of thousands of years. The USGS/WR Madison Study, in progress, should resolve the question of heat source and better predict the expected life of the Madison as a geothermal resource.

2. Madison parameters

   Physical factors that affect the ability to withdraw water and the drilling for water are well known in some areas, but not for the parts of the Madison which underlie the Pine Ridge Reservation. These factors include the aquifer's thickness, porosity, permeability, potentiometric head (artesian pressure), temperature, depth below ground level and the thickness of Precambrian base rocks that must be penetrated to reach the Madison's hot waters. USGS/WR work and planned work of the School of Mines should help to develop these data. Additional assistance is planned through the resource engineering program of the Division of Geothermal Energy of the Department of Energy.

3. Effects of substantial withdrawal

Extensive use of the water can affect the aquifer's thermal properties, quality of water and artesian pressure. In turn, such changes would affect the annual cost of a heating system by demanding higher flows, more rapid cleaning or replacement of components, and possible installation of additional pumps. Current USGS/WR work is developing a detailed and quantitative model of the hydrology in the Madison aquifer and other aquifers that can effect its flow. The area of particular interest is currently the Powder River Basin because of the Wyoming proposal to use Madison water to move coal via a slurry pipe line. DOE is negotiating to have the study extended so that proposed Madison usage in the South Dakota area would be included.

4. Thermodynamic model of aquifer

A local (western South Dakota) model of the aquifer needs to be developed so that various rates of withdrawal and locations of withdrawal can be examined with respect to cooling the aquifer, well to well artesian effects, or the need to reinject water after use. The USGS model should be carefully examined to see if it would be adequate, or if it needs to be modified for purposes of utilization in the Pine Ridge Reservation area.

To estimate the total geothermal potential of the Madison for community space heating (or other purposes where the assumptions apply) in western South Dakota the following assumptions are considered: the average water temperature is 140°F, water is withdrawn at the natural recharge rate of 150,000 acre-feet/year, and the load rejection temperature (water temperature at the end of the process) is 100°F. On this basis, the quantity of energy available is 16×10^{12} BTU, or the equivalent of 2.7 million barrels of oil, per year.

The above calculation, while providing a very rough estimate of total geothermal potential in western South Dakota, does not provide a particularly useful estimate for the amount of geothermal energy potential on the Pine Ridge Reservation. Several factors contribute to make the situation on much of Pine Ridge significantly more attractive than much of the surrounding area of western South Dakota.

One factor arises from the end uses to which the geothermal energy may be applied. An increased emphasis by the Sioux people on uses such as fish hatcheries, hydroponics and greenhouses would mean that the average load rejection temperature would probably be less than 100°F, resulting in more energy being recovered from a given volume of water. For example, the water temperature after using it for the space heating of homes, then for heating a greenhouse, might be 70°F, resulting in 240 BTU's per gallon more energy being recovered than if the load rejection temperature is 100°F, as above.

Another factor arises from an examination of geothermal gradient data for the Pine Ridge area. The geothermal gradient is defined as the increase of temperature per unit depth below the earth's surface. Its average value in the United States is about 1.4 or 1.5 degress Farenheit per 100 feet of depth. (That is, if a 1000-foot hole is drilled, the bottom-hole temperature will be, on the average, 14 or 15 degrees warmer than the temperature near the surface). Areas with geothermal gradients of 1.8 - 2.0°F/100 ft. are often considered as areas of potential geothermal resource. Areas with a gradient of over 2.0°F/100 ft. are almost always considered as promising geothermal resource areas. (The Ocean City, Maryland, area with a gradient of 2.1°F/100 ft, is considered as one of the most promising areas in the Eastern United States).

A series of geothermal gradient maps for the United States was published in 1976 by the American Association of Petroleum Geologists. A portion of one of the maps, with the boundaries of the Pine Ridge Reservation and the location of Kyle and Wanblee added, is reproduced as Plate I. It is clearly evident from Plate I that the geothermal gradient for almost all (over 90 percent) of the reservation is over two degrees Farenheit per 100 feet. Even more significant is the fact that a large area in the north-eastern part of the reservation (and part of the Rosebud Reservation, to the east), including Kyle, apparently has a geothermal gradient of at least 2.4 degrees F per 100 feet.

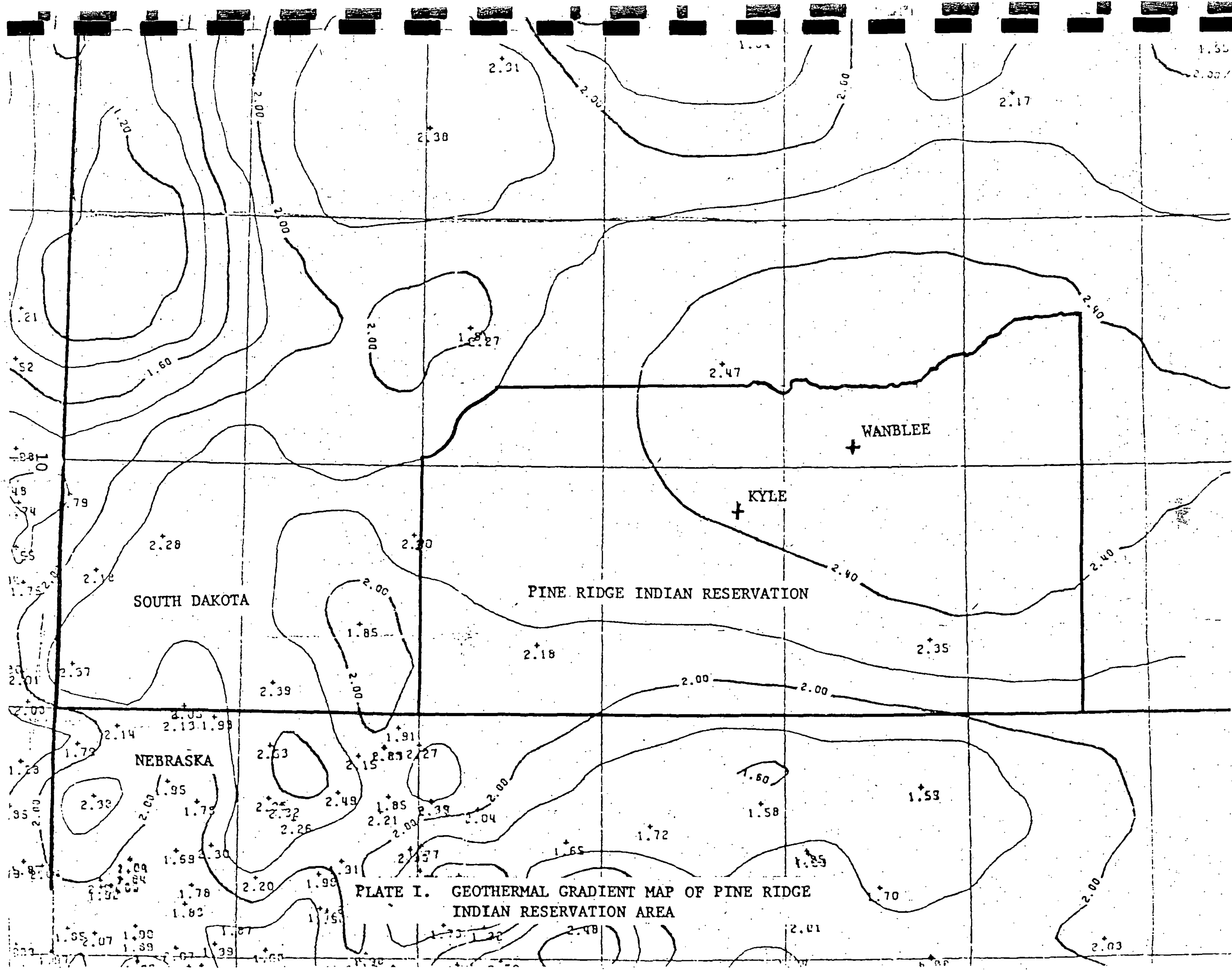

PLATE I. GEOTHERMAL GRADIENT MAP OF PINE RIDGE INDIAN RESERVATION AREA

In fact, as can be seen from the map from which Plate I was taken, this is the largest area in the southern two-thirds of South Dakota and the northern one-half of Nebraska with a gradient of 2.4 or higher.

The existence of these relatively high geothermal gradients on the Pine Ridge Reservation is supported by data from four oil wells which have been drilled on, or in the immediate vicinity of, the reservation. The locations of these wells, with gradients of 2.47, 2.35, 2.30 and 2.18, are shown on Plate I.

Using a gradient range of 2.35 - 2.45 degrees F per 100 feet, and a depth range of 3500 - 3800 feet, the resulting water temperature range which might be expected in the Kyle area is 147 - 158 degrees F.

III. PROPOSED GEOTHERMAL APPLICATION OF THE MADISON AQUIFER AT KYLE

INTRODUCTION

The sections above have defined the Madison aquifer as a geothermal resource that is already being used for space heating and which has the potential for much broader application in the Pine Ridge area.

In addition, geothermal energy is a clean source with few environmental disadvantages and, since it is located on the reservation, its use could reduce the problems that accompany the almost complete dependence on imported fuels: shortages, distribution and increasing prices.

Therefore, it is suggested that the Oglala Sioux, possibly in conjunction with assistance from federal agencies, consider developing local systems that tap the Madison and use the energy of the hot waters for heating homes and other buildings.

The key question in considering this proposed conversion is whether or not a community area can afford the costs. Unless the monthly costs (capital, amortization, maintenance, etc.) to a household (or other user) can be less than current and projected costs of conventional fuel systems, the household (or other user) cannot be expected to be interested in converting to geothermal.

To answer this question, a cost model for a community geothermal space heating system was developed for western South Dakota and used to show, in terms of town population, where the system is cost competitive with fossil fuels (Ref. 1). This model was then modified to more clearly reflect the conditions which exist on the Pine Ridge Reservation near Kyle, South Dakota, and used to make a similar cost comparison with fossil fuels for the Kyle community.

The design analysis which follows assumes that 125 homes in the Kyle community are converted so that each can utilize geothermal energy for space heating. Ninety of these houses are assumed to be currently designed to burn propane; 35 to burn oil. The analysis also assumes that the new high school planned for Kyle is heated by geothermal energy.

The system design parameters, as well as most of the design and cost calculations, are in Appendix B. The calculations are considered to be conservative. For example, it is assumed that the geothermal well yields water with a temperature of only 147°F, the lowest temperature expected; and that the well is drilled to a depth of 3800 feet, the greatest depth expected.

ESTIMATED COSTS FOR OIL AND PROPANE

Current Average Heating Fuel Cost for Homes in Kyle, S. D.

Assuming an average heating load of 1.725×10^8 Btu/year for a house in Kyle, the monthly average (over the entire year) is 14.4×10^6 Btu/mo (see Appendix B). Using a cost for propane of \$.39/gallon (\$4.24/10^6 Btu), and a cost for heating oil of \$.45/gallon (\$3.26/10^6 Btu), the average cost of heating a home in Kyle with propane is \$733 per year (\$61/mo.); with oil is \$563 per year (\$47/mo.). Table II summarizes the estimated current cost of heating the 125 homes in Kyle which are being considered for conversion to geothermal energy. As can be seen, the total estimated average yearly fuel cost is \$85,675.

TABLE II

ESTIMATED YEARLY RESIDENTIAL COSTS

Existing System

	One Home	No. of Homes	Total Yearly for Fuel Type
Oil Heat	\$563	35	\$19,705
Propane	\$733	90	\$65,970
		TOTAL	\$85,675

Projected Heating Cost for New High School (Oil Heat)

Making cost calculations (and comparisons) for a heating system for the new high school is difficult. For the purpose of this report, however, it is assumed that the cost of the system to transfer and distribute heat from a central location to individual rooms in the school is the same regardless of whether the heat is obtained from an oil-fired boiler or a geothermal resource.

The three factors which then enter into a cost comparison for the school are:

1) The cost of an oil-fired boiler for the school;
2) The school's share of the cost of a geothermal well/ distribution system; and
3) The cost of fuel oil to fire an oil-fired boiler.

Assuming an average heating load of 13 x 10^9 Btu/year for the new high school, the monthly average (over the entire year) is 1.1 x 10^9 Btu/month (see Appendix B). Using a cost for heating oil of $.41/gallon ($2.97/10^6 Btu), the average cost for fuel of heating the new high school would be $38,610/year, or $3217/month. (This price reflects the lower price of fuel oil to the school than the $.45/gallon charged to homeowners). In addition, the amortization of the $50K oil boiler results in a yearly cost of $7,500, or $625/month. The total cost, for purposes of this report, then, is estimated to be about $46,110 per year or $3,842 per month. (Note that the cost of the heat distribution system within the school has not been included, and is assumed to be the same as a distribution system for geothermal energy.)

DESCRIPTION OF GEOTHERMAL COMMUNITY HEATING SYSTEM FOR KYLE

Introduction

The geothermal space heating system is divided, for cost modeling purposes, into five main components:

(1) geothermal well,
(2) central heat exchanger facility,
(3) two-way transmission from central heat exchanger to community,
(4) reinjection well and transmission from central heat exchanger to reinjection well, and
(5) community distribution system (two-way pipeline, residence hookup and conversion of home heating system).

The Supply Well (and reinjection if required)

Based on current prices the cost of drilling, casing and enclosing a 7" diameter well drilled 3800' into the Madison formation was estimated by

Francis-Meador-Gellhaus, Inc. to be about $155,000. This figure is used to calculate total community costs for Kyle in the example below. Such a well is assumed to be artesian and have a flow rate of 933 gpm.

The Central Heat Exchanger

A central heat exchanger is used to transfer heat from the well to a secondary, closed-loop system containing treated water and thus, increase the overall system reliability. A stainless steel, plate-type heat exchanger with removable covers permitting ready access for periodic inspection and cleaning was selected. This type is considered to be extremely reliable and so a backup exchanger is not considered to be required.

To allow for growth it is assumed that the central exchanger for Kyle is designed with approximately ten percent excess capacity.

Town Distribution System for Kyle

The required cross-sectional area of the transmission pipe line is directly proportional to the population it supplies. Similarly, the cost per mile of installed pipe line varies linearly with the cross-sectional area of the pipe. This relationship is shown in Figure 1 for the closed-loop, two-way distribution line and in Figure 2 for the one-way line to a reinjection well, which might be considered desirable or required.

It follows, then, that pipe-line costs are directly proportional to the population served and costs per house can be determined.

The costs of transmission and distribution lines are based on the use of cement-asbestos pipe, on-site installation of 1" foam insulation for the feed line, burying the pipe 5' deep and compacting the refill soil only where the line crosses roads.

Individual Connections to Municipal System

Residential hook-up charges and conversion, including the local heat exchanger using the closed-loop heating fluid, are fixed costs per household.

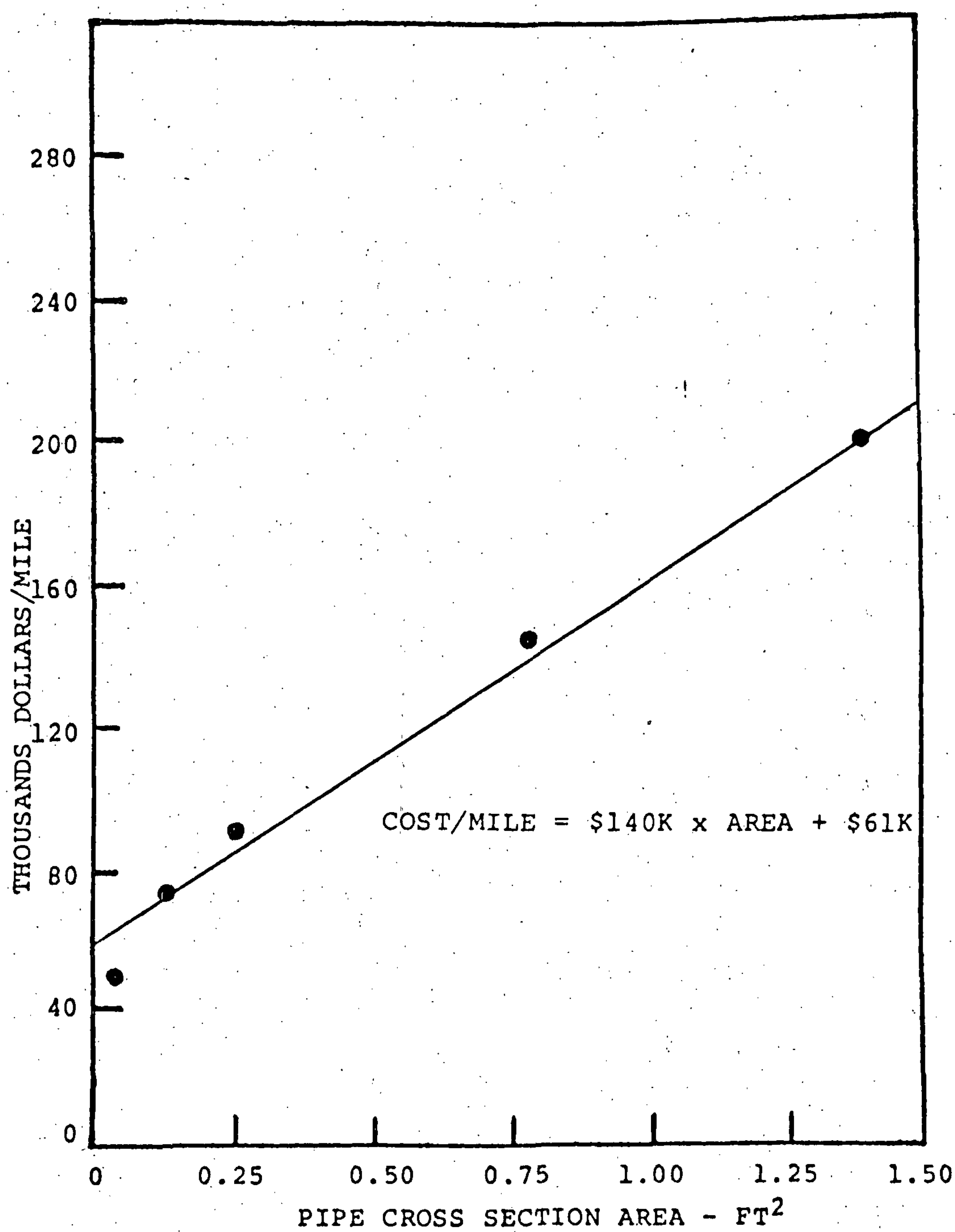

FIGURE 1
DOUBLE TRANSMISSION PIPELINE COSTS IN WESTERN SOUTH DAKOTA, ONLY FEED LINE INSULATED

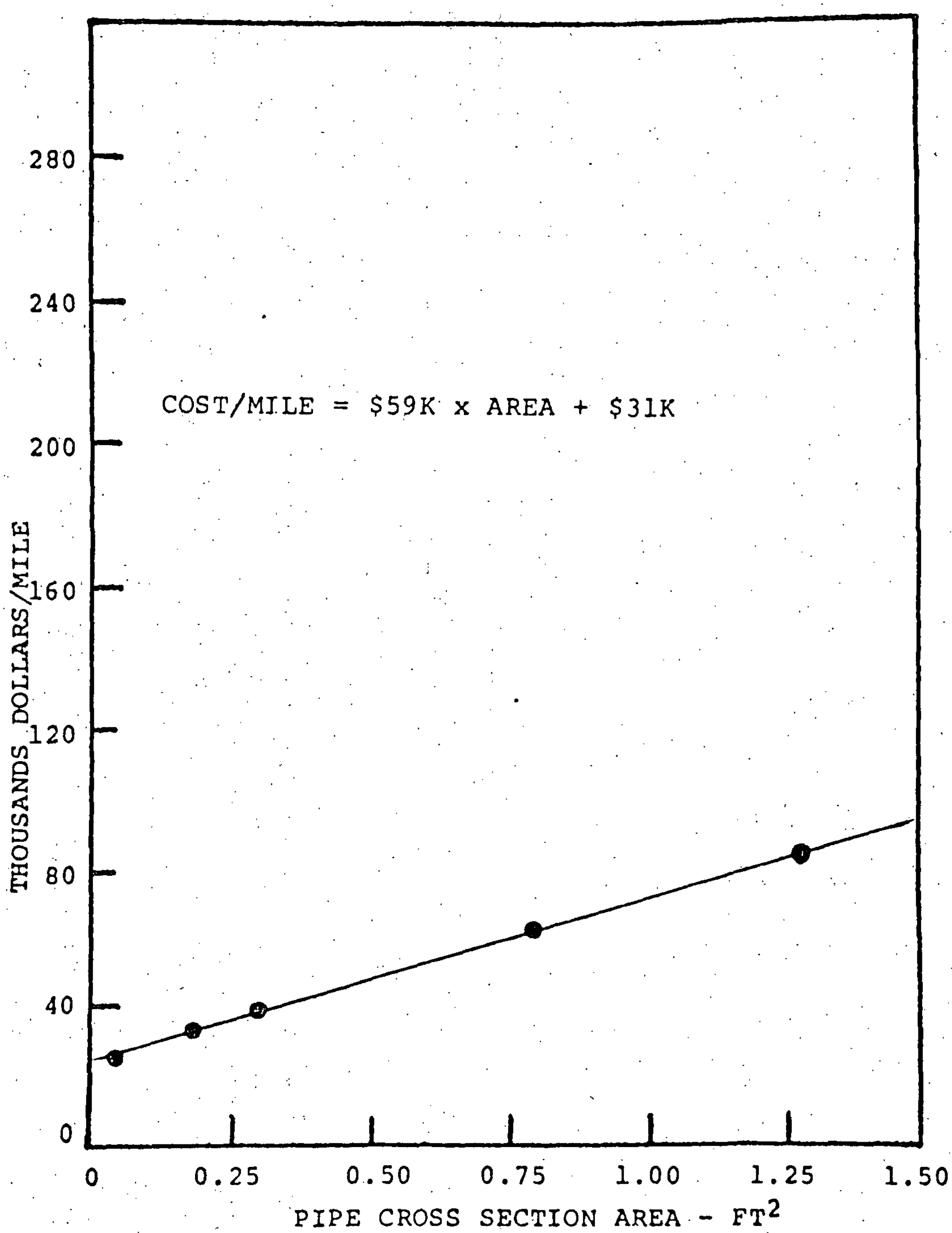

FIGURE 2
SINGLE TRANSMISSION PIPELINE COSTS IN WESTERN SOUTH DAKOTA
(FOR REINJECTION)

COST MODEL CALCULATIONS FOR KYLE

Introduction

Figure 3 illustrates the total costs for Kyle, S. D., with the production well one mile from town and one reinjection well located one mile from the production well. (Whether or not a reinjection well is required has not been determined.)

Energy Demands

The design requirements, both peak heating and average seasonal demands, were determined for weather conditions existing in western South Dakota and the type of housing in Kyle (see Appendix B). The peak heating demand was estimated to be 11.89×10^6 BTU/hr for 125 homes and the new high school. The distribution system consists of a six-inch main pipe and six three-inch feeder lines. Houses were assumed to be uniformly distributed through the town area for estimating the required pipe lengths. Homes were considered to be converted from a conventional forced-air system by installation of a heat exchanger.

COST MODEL RESULTS FOR KYLE

Using the estimated component costs, monthly costs for a geothermal heating system were calculated.

In these calculations it is assumed that the 125 homes to be converted have forced-air systems. (Conversion from oil or propane fired, forced-air furnaces, is relatively inexpensive since existing ducts can be used for hot air distribution.)

The conversion cost includes bringing the hot water into the house, the home heat exchanger, inserting the heat exchanger into the distribution ducting, thermostat and wiring for automatic control.

The monthly costs, assumed to be 15 percent per year, include capital amortization, maintenance, and services.

Table III, then, provides an answer to the question, "Can Kyle, South Dakota, consider geothermal space heating to be cost-competitive with conventional space heating systems?" The answer is yes, whether or not reinjection is required, providing only that the geothermal resource exists in a form similar to that which has been assumed.

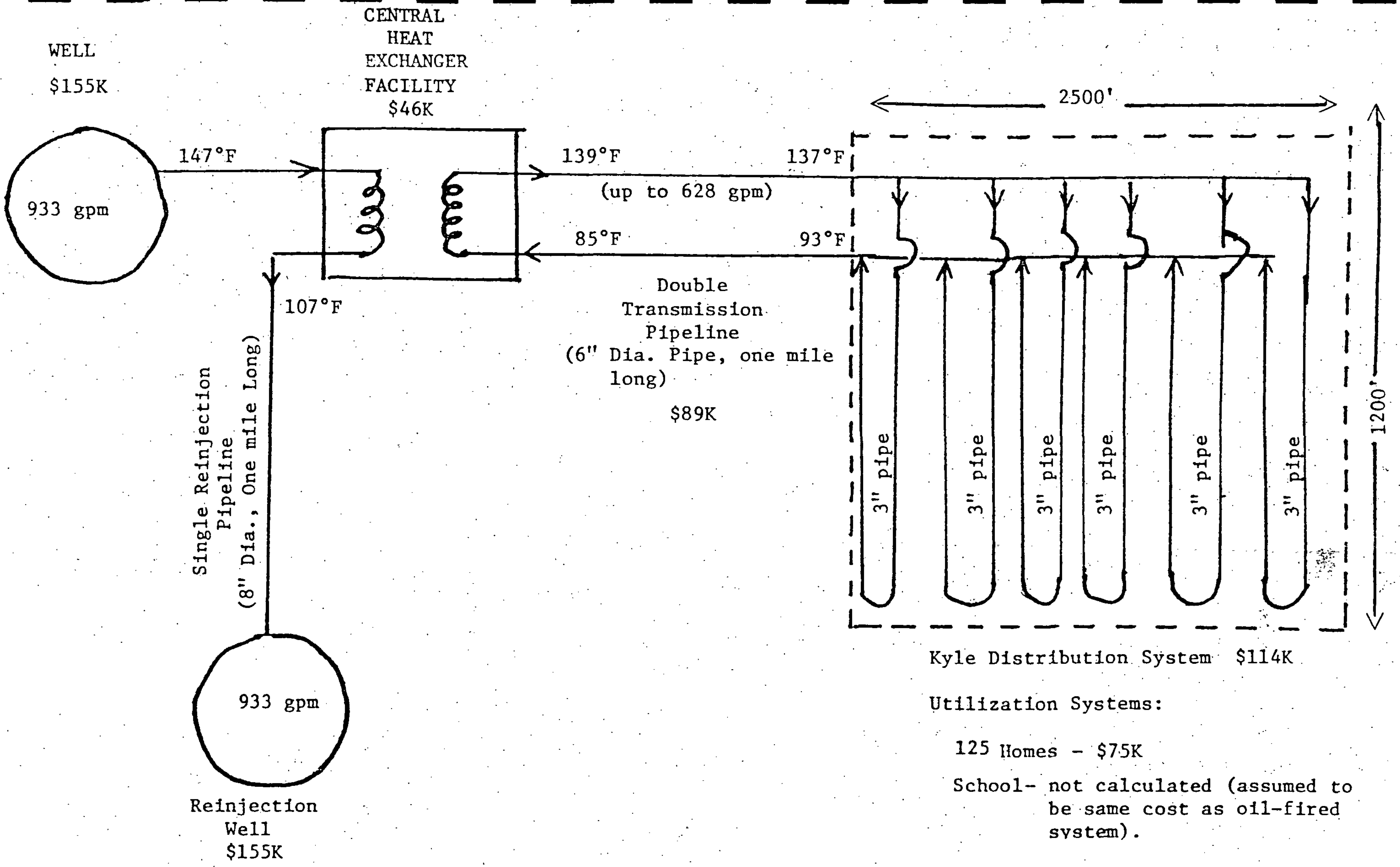

FIGURE 3. Kyle, South Dakota, Madison Geothermal
Spacing Heating System

Moreover, the installation of a geothermal space-heating system would result in other important benefits for the Oglala Sioux:

1) The redirection of money back into the reservation
2) New jobs
3) A move toward energy self-sufficiency for the tribe, and
4) The availability of large additional amounts of energy (in addition to that used for space heating) for other purposes, such as greenhouses and fish hatcheries.

TABLE III

SUMMARY OF ESTIMATED YEARLY COSTS

	125 Homes	New High School	TOTAL	Yearly Savings
Propane/Oil	$85.7K	$46.1K	$131.8K	-0-
Geothermal with Reinjection	$68.1K	$34.8K	$102.9K	$28.9K
Geothermal without Reinjection	$48.8K	$23.0K	$ 71.8K	$60.0K

It is anticipated that the energy would be sold by a public utility type of organization which is owned by the tribe. Thus, revenues received (or at least a portion of them) will remain on the reservation. This is in marked contrast to the current cash flow off the reservation for fuel oil and propane.

It is anticipated that most (if not all) of the labor required to install the transmission and distribution systems, the hook-ups, and the heat exchangers, would be done by Oglala Sioux people. This would result in perhaps 10-15 jobs (rough estimate) being created for the period of time it takes to get the system on-line (perhaps two years). In addition, it is anticipated that perhaps 3-5 full-time long-term jobs will be created (for example, maintenance persons, and bookkeepers).

It is anticipated that a large amount of additional heat energy will be available at minimal cost for additional applications. The discharge temperature of the central heat exchanger is designed to be 107°F. Assuming that energy is extracted such that the water temperature is lowered from 107°F to 87°F, an additional 8.9 million BTU's per hour will be available from the well side of the central heat exchanger. In addition, during most days, the transmission and distribution systems will be working at considerably less than peak design capacity. Significant energy (several million BTU's per hour) would therefore be available for uses which might be considered to be "interruptable", i.e., could be disconnected from the geothermal source for a few days or a few weeks each year.

Underscoring the job and cash flow advantages described above is the potential for saving significant amounts of oil and propane. Conversion to geothermal energy in Kyle could result in a yearly savings of about 138,000 gallons of oil (43,800 in homes; 94,200 in schools) and 169,000 gallons of propane.

In summary, the potential economic and social advantages of developing geothermal energy resources in the Kyle area are extremely significant, and it is urged that this development be given serious consideration.

IV. OTHER IMPLICATIONS OF GEOTHERMAL DEVELOPMENT AT KYLE

INTRODUCTION

The positive nature of the results of this study suggest several other projects which appear quite promising. Four of the most promising are discussed below.

UTILIZATION OF GEOTHERMAL ENERGY AT WANBLEE

As can be seen from Plate I, Wanblee is situated almost in the center of the highest geothermal gradient contour on the Pine Ridge Reservation. It is possible that a geothermal gradient as high as 2.5°F per 100' exists, which would result in water temperatures of about 153 - 160°F at depths of 3500-3800 feet. The population of the Wanblee area (about 500) may be sufficient to support the development of geothermal resources. It is recommended that a feasibility study, similar to that carried out in this report, be completed for the Wanblee area.

DESIGN OF HEAT EXCHANGERS

The heat exchangers which are designed for use at Kyle may have a much wider potential application than just at Kyle. Indeed, the potential application may be nation-wide.

The heat exchangers are being designed for Native American housing built by HUD and the BIA, and are designed for an inlet water temperature of about 140°F. Thousands of BIA and HUD houses exist on Indian Reservations all over the United States; thousands more planned or under construction. The design inlet temperature of about 140°F is appropriate for many potential geothermal resources, and it is expected that a number of other tribes, mainly in the West and Southwest, could utilize the heat exchanger design in developing their geothermal resources.

Possibly even more significant, however, is the fact that most solar-thermal flat plate collectors have outlet water temperatures of about 140°F. It would therefore seem possible to utilize the same basic heat exchanger design for all solar installations on BIA and HUD Native American Housing.

It would seem that a relatively large industry, hopefully organized and run with Native American labor, could be established to manufacture these heat exchangers. It is recommended that the design of standardized heat exchangers be pursued as soon as possible.

UTILIZATION OF LOW-GRADE HEAT

As was outlined earlier in this report, it is anticipated that a large amount of "low-grade" heat energy will be available at Kyle, at very minimal cost, for additional applications. The design discharge temperature of the central heat exchanger is 107°F.

Temperatures as low as 60°F are useful for fish hatcheries and greenhouses. Assuming only that energy is recovered such that the water temperature is lowered from 107°F to 87°F, an additional 8.9 million BTU's per hour will be available from the well side of the central heat exchanger; lowering the temperature to 77°F would make 13.4 million BTU's available.

In addition, during most days, the transmission and distribution systems will be working at considerably less than peak design capacity. Significant amounts of energy (several million BTU's per hour) would therefore be available for uses which might be considered to be "interruptable", i.e. could be disconnected from the geothermal source for a few days or a few weeks each year. Such interruptable customers could either supplement the geothermal source with conventional sources, such as electricity and fuel oil, or shut down completely during the coldest periods of the year. It is recommended that the utilization of low-grade heat from the discharge of the central heat exchanger and the utilization of off-peak energy from the transmission/distribution system be studied in detail.

UTILIZATION OF DISCHARGE WATER

Although the quality of the Madison water in the Kyle area is unknown, its quality in other communties in southwestern South Dakota is relatively high. This relatively high quality might make it possible to use the water from the geothermal well (before or after extraction of low-grade heat) for drinking water and/or for irrigation. The design flow of 933 gpm in the well would mean that up to 1.3

million gallons per day could be available for these (or other) uses. It is recommended that, as a part of any effort to determine the magnitude and temperature of the Madison waters near Kyle for use as a geothermal resource, close attention be paid to the determination of the water quality.

V. FINANCING GEOTHERMAL PROJECTS

As discussed, previously, the Madison geothermal resource is known to exist and known to be readily available in specific locations. However, for the broad utilization of the Madison, more precise reservoir and well data are needed in many areas. Department of Energy assistance in obtaining these data is available in PRDA's and PON's which are defined and discussed below.

In areas where the resource availability is proven, communities must obtain financing for the conversion project. Total project costs for conversion to geothermal energy space heating for 125 homes and a high school in the Kyle area, for example, would be approximately 500K-700K dollars. Various federal departments offer assistance in the grant, loan, and loan guarantee areas and some of the more promising possibilities are discussed below:

A. Department of Energy

1. Grant and Cost Sharing Programs

The DOE provides grants and participates in cost sharing programs for geothermal projects in the private sector. This is done through two vehicles: The Program Research and Development Announcement (PRDA) and the Program Opportunity Notice (PON).

a. PRDA

Each such announcement solicits proposals for studies and analyses that will lead to new and improved technology for extracting and utilizing energy from geothermal resources. PRDA's are issued from the department's San Francisco Operations office and can provide total funding for approved projects or sharing of costs when a proposer could benefit independently from participation in a project. State, municipal or non-commercial applicants are chosen on a competititve basis.

b. PON

This type of notice solicits proposals for geothermal field experiments and applications that will demonstrate adequacy of the reservoir as well as provide technical and economic data, and address legal, environmental and institutional issues for assessing the practicability of further resource usage. PON's are issued from the department's San Francisco Operations office. Applicants are selected competitively and projects are funded through federal and local cost sharing.

Of twenty-two proposals submitted in reponse to a 1977 PON eight were selected, four in South Dakota. These were to the School of Mines and Technology for heating ranch buildings and agriculture uses; to the community of Box Elder for heating the Douglas School complex; to the Haakon School District for heating school buildings in Phillip; and to the St. Mary's Hospital in Pierre for space heating the hospital and neighboring business structures

2) Loan Guaranty Program

This program is intended to assist lenders in the private sector by guarantying them against loss of principal or interest on loans made for evaluating economic potential of geothermal reservoirs, for research and development in the technology of extracting and utilizing resources, for obtaining rights in resources, and for developing, constructing and operating geothermal energy producing facilities.

The San Francisco office is responsible for supplying information on the program and for analyzing guaranty applications from South Dakota. (Mailing address: Department of Energy, Geothermal Loan Guaranty Program Office, San Francisco Operations Office, 1333 Broadway, Oakland, California, 94612, Telephone: (415) 273-7151).

B. Department of Housing and Urban Development

Title 1 Community Development Block Grants are currently available in at least three areas, two of which appear to be applicable to the Kyle, South Dakota, area.

1. Small Cities Grants

The first type of grant is the Small Cities Grant, which is a discretionary grant limited to non-SMSA areas. (An SMSA is a Standard Metropolitan Statistical Area, of which there are none on the Pine Ridge Reservation). These grants are awarded on a scoring system which includes factors such as the need for the project and the types of impacts on various types of people. It appears that the Kyle area is eligible for this type of grant.

2. Urban Development Action Grants

The second grant type is the Urban Development Action Grant, which is a one-year grant available to non-SMSA's. This type of grant is appropriate when private investment money is also available. Kyle would appear to be eligible for this grant type.

3. Entitlement Grant

The third grant type is the Entitlement Grant, which is available only to SMSA's. This is a formula grant, based upon factors such as population and income levels. Kyle does not appear to be eligible for this type of grant.

An application for a grant by the Oglala Sioux will, of course, be in competition with other applications within the HUD Region (Region 8 for South Dakota). A major consideration in awarding grants is the inclusion of low-incoming housing. The Oglala Sioux Housing Authority is currently involved in, and aware of, a number of HUD-sponsored programs.

REFERENCES

1. R. A. Freeman and R. F. Meier, "Potential Application of Madison Formation Waters for Community Heating - South Dakota", APL/JHU April 1978.

POINT OR AREA COORDINATES LONG	LAT	LONG	LAT	NAME/OWNER/LOC	NOTES	ORG	ST	TYPE	TEMP DEG-C	FLOW (GPM)	WELL DEPTH (FT)	MISC	
101. 16.00	46. 6.36	101. 11.40	45. 26.57	STANDING ROCK		BIA	SD	FIR					
101. 11.40	46. 10.71	101. 6.00	45. 26.57	STANDING ROCK		BIA	SD	FIR					
101. 6.00	46. 15.86	101. 0.00	45. 26.57	STANDING ROCK		BIA	SD	FIR					
101. 0.00	46. 19.28	100. 54.00	45. 26.57	STANDING ROCK		BIA	SD	FIR					
100. 54.00	46. 21.43	100. 34.80	45. 26.57	STANDING ROCK		BIA	SD	FIR					
100. 34.80	45. 59.28	100. 27.00	45. 26.57	STANDING ROCK		BIA	SD	FIR					
100. 27.00	45. 49.29	100. 40.00	45. 38.57	STANDING ROCK		BIA	SD	FIR					
102. 0.00	43. 36.43	102. 54.00	43. 0.00	PINE RIDGE		BIA	SD	FIR					
103. 23.20	43. 33.70	0.	0.00	0. 0.00 HOT SPR			SD	SPRING	27.	5000.	0.	1	19.1
103. 31.20	43. 33.70	0.	0.00	0. 0.00 HOT BROOK			SD	SPRING	32.	50.	0.	2	25.5
103. 34.40	43. 23.40	0.	0.00	0. 0.00 CASCADE SPR			SD	SPRING	20.	7200.	0.	3	32.0
103. 12.00	43. 39.40	0.	0.00	0. 0.00 BUFFALO GAP SPR			SD	SPRING	0.	0.	0.	4	10.4
102. 54.00	43. 40.71	102. 9.60	43. 0.00	PINE RIDGE		BIA	SD	FIR					
103. 23.20	43. 33.70	0.	0.00	0. 0.00 HOT SPR			SD	SPRING	27.	5000.	0.	1	25.1
103. 31.20	43. 33.70	0.	0.00	0. 0.00 HOT BROOK			SD	SPRING	32.	50.	0.	2	31.3
103. 34.40	43. 23.40	0.	0.00	0. 0.00 CASCADE SPR			SD	SPRING	20.	7200.	0.	3	35.8
103. 12.00	43. 39.40	0.	0.00	0. 0.00 BUFFALO GAP SPR			SD	SPRING	0.	0.	0.	4	14.7
102. 9.60	43. 41.57	101. 39.00	43. 0.00	PINE RIDGE		BIA	SD	FIR					
103. 12.00	43. 39.40	0.	0.00	0. 0.00 BUFFALO GAP SPR			SD	SPRING	0.	0.	0.	4	50.6
101. 39.00	43. 45.00	101. 25.80	43. 0.00	PINE RIDGE		BIA	SD	FIR					
101. 25.80	43. 47.14	101. 12.00	43. 0.00	PINE RIDGE		BIA	SD	FIR					
102. 0.00	45. 26.57	101. 47.40	44. 30.00	CHEYENNE RIVER		BIA	SD	FIR					
101. 47.40	45. 26.57	101. 30.00	44. 34.29	CHEYENNE RIVER		BIA	SD	FIR					

APPENDIX A

SYSTEM DESIGN PARAMETERS FOR SPACE HEATING OF OGLALA SIOUX HOMES AND NEW HIGH SCHOOL AT KYLE, SOUTH DAKOTA

Average Volume per House (ft^3)	7700
Heat Loss Factor (Btu/hr, ft^3)	7.7
Based upon: 70°F inside design temp. -20°F outside design temp. Assume roof insulation	
Peak Heat Load per Home (Btu/hr)	5.93×10^4
Residential System Peak Design Size (Btu/hr)(125 homes)	7.41×10^6
Estimated Volume of New School (ft^3)	640,000
Heat Loss Factor (Btu/hr, ft^3)	7.0
Based upon: 70°F inside design temp. -20°F outside design temp. Assume roof and wall insulation	
New High School Peak Heat Load (&Peak Design Size) (Btu/hr)	4.48×10^6
Total Kyle System (125 homes & new high school) Peak Design Size (Btu/hr)	11.89×10^6
Well Flow Rate (gpm)	933 gpm
Well Temperature (°F)	147°F
Well Depth (ft)	3800'

Assume 6" Main Dist. Pipe: 0.20 ft^2 area

If v = 7 ft/sec in pipe, then 1.4 cfs is flow

84 cfm = 628 gpm = 5024 lb/min in central heat exchanger output

Assume Δt at homes/school of 137° - 93° = 44°F

Then heat avail = 221,056 Btu/min = 13.26×10^6 Btu/hr. AVAIL

And peak flow/home = 2.8 gpm

In secondary of main heat exchanger:

Assume 628 gpm, Δt = 54°F; then heat = 16.28×10^6 Btu/hr

In primary:

Assume 90% efficient main heat exchanger, then heat in = 17.90×10^6 Btu/hr.

Assume Δt_{in} for main heat exchanger = 50°F, flow = 933 gpm in well.

Assume main heat exchanger is sized for full load (with respect to well and distribution system) to allow for future growth:

Central Heat Exchanger Sizing

$$\text{Area}(m^2) = \frac{\theta}{K\Delta t_m}$$

where θ = peak heat load, Kcal/hr
(0.252 Kcal/Btu)

$k = 3050$ Kcal/m^2,h,°C

$\Delta t_m = 8.4°C$

$$\theta = (16.28 \times 10^6 \frac{BTU}{hr})(0.252 \frac{Kcal}{BTU}) = 4.10 \times 10^6 \frac{Kcal}{hr}$$

$$\text{Area} = \frac{4.10 \times 10^6}{3050 \times 8.4} = 160m^2$$

Cost = $(160m^2)(\$150/m^2)$ = $24,000
7,000 Installation
15,000 Building

$46,000 TOTAL for central heat exchanger facility

Distribution, Hookup and Conversion Costs for Residential part of Kyle, S.D.

Distribution

7200 ft (1.70 mi) 3" (.05 ft^2) pipe, 2-way, insulate 1-way = $72K (~$10/ft)
2500 ft (0.47 mi) 6" (0.2 ft^2) pipe, 2-way, insulate 1 way = 42K
$114K Total

Hookup

$210 per house for hookup in Philadelphia District Heating with 50' connection length - Brookhaven National Lab. Study - Science v. 195, p951

Use: $250 per house x 125 houses =$31K

Conversion

(Assume forced-air heat exists now)

Heating coil = $270/home

8hr. installation @ $10/hr = $80

Heating coil and installation = $350/house x 125 houses = $44K

AVERAGE ANNUAL HEATING DEMAND
FOR HOUSES AND NEW HIGH SCHOOL
IN KYLE, SOUTH DAKOTA

Heating season: 287 days (6888 hrs).

Average heating season outside temperature: 32.8°F (use 32°F)

Design outside temperature: -20°F

Average heating season inside temperature: 70°F

Using $H = \frac{24hD(T_i - T_a)}{(T_i - T_o)}$;

H = annual heating requirements
h = hourly design peak heat load
T_i = inside temperature (70°F)
T_a = average outside temperature (32°F)
T_o = outside design temperature (-20°F)
D = number of days in heating season

For each house, on the average,

$$H = \frac{24(5.93 \times 10^4)287(70-32)}{70-(-20)}$$

$= 1.725 \times 10^8$ BTU/year average for each house

$= 14.4 \times 10^6$ BTU/month average for each house

For the new high school

$$H = \frac{24(4.48 \times 10^6)\ 287(70-32)}{70-(-20)}$$

$= 13.0 \times 10^9$ BTU/year (average)

$= 1.1 \times 10^9$ BTU/month (average)

TOTAL GEOTHERMAL SYSTEM COST
FOR KYLE, S.D. (without reinjection)

Well	\$155K
Central heat exchanger facility	46K
Double transmission pipeline	89K
Kyle distribution system	114K
SUBTOTAL	\$404K for well and distribution system

Based upon relative sizes of peak heat loads (7.41×10^6 Btu/hr for homes, 4.48×10^6 Btu/hr for new high school) assign 62% of the \$404K to homes and 38% to the new high school.

Residential System

\$250K	well/distribution
75K	hookup & conversion for 125 homes
\$325K	TOTAL RESIDENTIAL COST
\$48.8K	15% yearly cost
\$390	per year per house (average)
\$ 33	per month per house (average)

System for New High School

\$154K	well/distribution
\$ 23K	15% yearly cost
\$1,920	per month (average) (does not include distribution system inside school, which is assumed to cost the same as one for oil heat).

TOTAL GEOTHERMAL SYSTEM COST FOR KYLE, S.D. (with reinjection)

Well	$155K
Reinjection well	155K
Reinjection pipeline	52K
Central heat exchanger facility	46K
Double transmission pipeline	89K
Kyle distribution system	114K
SUBTOTAL	$611K for wells and distribution/reinjection system

Based upon relative sizes of peak heat loads (7.41×10^6 Btu/hr for homes, 4.48×10^6 Btu/hr for new high school) assign 62% of the $611K to homes and 38% to the new high school.

Residential System

$379K well/distribution/reinjection
75K hookup & conversion for 125 homes
$454K TOTAL RESIDENTIAL COST
$ 68.1K 15% yearly cost

$545 per year per house (average)
$ 45 per month per house (average)

System for New High School

$232K well/distribution/reinjection
34.8K 15% yearly cost
$2,902 per month (average) (does not include distribution system inside school, which is assumed to cost the same as one for oil heat)

3-21-77

S Dak
1977 proposal
Johns Hopki

PROPOSAL FOR GEOTHERMAL RESEARCH

Robert Schoon and Duncan McGregor undertook a study of the geothermal potential in South Dakota. This study culminated by publication of Report of Investigations No. 110 of the South Dakota Geological Survey. Since publication several inquiries have been made as to the validity of the high geothermal gradient (see pp. 17 to 25, and fig. 1 of Report of Investigations No. 110, enclosed). This question cannot be concretely answered using current data.

Thus, the primary objective of this proposal is to determine the reliability of the geothermal gradients as illustrated in figure 1 of Report of Investigations No. 110. In other words, does the geothermal gradient continue as high in the Precambrian rocks as in the overlying sedimentary rocks. If the gradient is continuous, temperatures equal to the boiling point of water could be encountered at the relatively shallow depth of 2,500 feet. Basically, this submittal requests financial aid in the drilling of a geothermal test well to a depth of 2,500 feet to determine if the geothermal gradient is true.

The foregoing constitutes stage 1 of this submittal and cost estimates include only those relative to stage 1. If stage 1 is successful, i.e., finds the geothermal gradient true as illustrated in figure 1 of Report of Investigations No. 110, the project will have been successful and completed at the end of stage 1 and the heating mechanism can be assumed as either due to convection currents within the earth's interior or to radioactive decay in Precambrian rocks.

Perchance the test well proves the gradient to be false, i.e., due to preheated, circulating ground water derived from the west, a stage 2 submittal will be made at a later date. This stage 2 proposal will have as its primary objective the location of the heat source that causes abnormally high temperature of ground water underlying an area of 14,000 square miles. From Report of Investigations No. 110, if the high geothermal gradient existing in Gregory, Lyman, and Tripp Counties is false, then the geothermal gradient is due to circulating ground water and the heat source is located basinward in southern Haakon, Jackson, and Washabaugh Counties. However, implementation of stage 2 is directly dependent on the findings of the stage 1 program.

A stage 3 of this proposal might have as its objective the drilling of a geothermal production well. However, this stage 3 is also premature because it hinges on the outcome of stages 1 and 2.

The projected implementation of this proposal is June 1, 1975. Drilling and testing procedures should be completed no later than September 15, 1975. A completed technical report is envisioned as ready for final editing within four months of cessation of drilling and testing programs.

Hopkins, W.B.; Petrie, L.R., 1963 - Geol Survey - W.S.P. 1539T

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the entire area are of Recent age, but, in general, are composed of weathered and reworked Pleistocene deposits. Their total volume probably is no more than one one-hundredth as great as that of the glacial deposits.

The thickness of the unconsolidated Quaternary deposits ranges from a featheredge around the periphery of bedrock exposures to more than 256 feet in the Lords Lake buried channel a few miles southwest of Aberdeen. Available logs of holes drilled to bedrock indicate that the average thickness of the deposits is 76 feet.

About 30 percent of the wells shown on plate 1 tap the Quaternary deposits. However, not all these wells are sources of water supply, many being used only for observation of water-level fluctuations or not used at all. Unlike the wells tapping the Dakota sandstone, these wells do not flow.

GROUND WATER

Except for the very few wells that tap Cretaceous rocks other than the Dakota sandstone, all wells in the Lake Dakota plain area either tap the Dakota or the glacial deposits. Because the two aquifers differ in so many respects, they are discussed separately in this report.

WATER IN THE DAKOTA SANDSTONE

The presence of an artesian aquifer beneath the James River lowland was known at least 10 years before South Dakota became a State. A well at Aberdeen, 1,066 feet deep and drilled in 1881, was among the first in South Dakota to tap this aquifer. Hundreds of deep wells had been drilled by 1920, and while still new most of them had a strong flow. The availability of such an ample supply of ground water without the need for pumping equipment prompted early writers to describe the James River lowland as a "Garden of Eden."

RECHARGE

Because the Dakota sandstone in this area is overlain by a thick succession of beds that are practically impervious to water, the places where water enters the formation obviously are outside the area. Also, because water in the Dakota in this area is under sufficient pressure to flow from wells, the places where water enters the formation must be at a higher altitude. Hydrologists long have recognized that the water in the formation throughout the James River lowland is not of local origin and generally have agreed that the formation is recharged principally where it crops out in the vicinity of the Black Hills in western South Dakota. However, G. A. LaRocque and J. R. Jones, of the Geological Survey, who made a hydrologic study of the the unit as originally proposed, believe that only a small part of the recharge enters the Dakota where it is exposed and much, if not most, of the recharge is from formations that underlie the Dakota in the western part of the State but crop out at a higher altitude. These underlying formations, notably the Pahasapa limestone and Minnelusa sandstone, receive much greater recharge than does the Dakota from streams crossing their outcrop in the Black Hills region (Brown, 1944, p. 1), and, because they thin eastward to a knife edge west of the James River lowland, the water in them percolates under pressure into the overlying Dakota. LaRocque and Jones believe also that the Dakota may be recharged by downward movement of water in the large area where the hydrostatic pressure in the Dakota is less than enough to raise the water in wells to the top of the zone of saturation in overlying rocks.

MOVEMENT

According to Darton (1909, p. 60–61), the hydraulic gradient (and, therefore, the direction of percolation) of water in the Dakota is generally eastward throughout South Dakota. The rate of eastward percolation toward the James River lowland in T. 129 N. (the southernmost east-west row of townships in North Dakota) was estimated by Meinzer and Hard (1925, p. 90) to be 400 to 500 gpm (gallons per minute), and this estimate probably is equally applicable to each east-west row of townships in the Lake Dakota plain area. The average rate of discharge from the Dakota that could be maintained indefinitely without a regional diminution of hydrostatic pressure would be equal to the rate of eastward percolation across the west boundary of the area of withdrawal.

If the casing of a flowing well tapping the Dakota were to be extended upward to a level that flow no longer occurred, the water level in the casing would coincide approximately with the piezometric, or pressure-indicating, surface of the water in the Dakota at that point. Because some wells tap only one water-bearing stratum and some tap two, three, or possibly more, the water level in the extended casing of one well would not necessarily represent precisely the same piezometric surface as the water level in another well. However, they probably would differ in such a small amount, all other factors being equal, that in this report the water in the Dakota is considered to have only one piezometric surface. This imaginary surface is continuous with the water level in nonflowing wells that tap the Dakota outside the report area, provided the failure to flow is not due to plugging of the well screen or escape of water from the well into rocks overlying the Dakota. Because maps showing the configuration of the piezometric surface, prepared by Erickson (1954, 1955), show that a trough in that surface coincides with the James River lowland and that the

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TEMPERATURE VARIATIONS OF DEEP FLOWING WELLS IN SOUTH DAKOTA

By D. G. ADOLPHSON and E. F. LeROUX, Rapid City, S. Dak., Huron, S. Dak.

Work done in cooperation with the South Dakota Water Resources Commission

Abstract.—Measurements from about 200 deep artesian wells in South Dakota indicate that temperature differences in water flowing from wells of similar construction are related to the depth of wells and volume of discharge. Geothermal gradients at wells in the Dakota Sandstone east of the Missouri River range from 0.7°C per 100 feet in the southeast and 1.1°C per 100 feet in the northeast to 1.6°C per 100 feet along the Missouri River. Immediately west of the river, geothermal gradients average 1.5°C per 100 feet. In a "hot water belt" farther west, average geothermal gradients of 2.2°C per 100 feet may be due to deep high-temperature recharge to the Dakota Sandstone. Relatively low geothermal gradients in pre-Cretaceous rocks in the Black Hills may be due, in part, to rapid downward movement of recharging water in very porous formations.

Artesian aquifers tapped by thousands of flowing and nonflowing wells underlie much of South Dakota. Wells have been developed in both the pre-Cretaceous and Cretaceous Systems.

Temperatures of water flowing from about 200 wells of similar construction have been found to be related to the depth of the well and the volume of discharge. For large volumes of discharge, the temperature of the water discharging at the surface is very nearly that of the water in the producing formation. For wells of low flow, the temperature of the discharging water has been cooled during the relatively slow movement of water up the casing and is not as representative of formation temperature. For example, in 1960 a well in western South Dakota, drilled to a depth of 2,225 feet in the Minnelusa Sandstone, flowed 75 gallons per minute at a temperature of 39°C (Celsius). By 1962 the flow had decreased to 24 gpm and the temperature to 36°C. In 1965 the flow was 7 gpm and the temperature 32°C, and in 1967 the flow was 3 gpm and the temperature 27°C.

The southeastern, northeastern, and western areas of the State, shown on figure 1, designate units within which water-temperature variations with depth and volume of discharge from flowing wells are characteristically similar. Temperature plots indicate that temperatures for flows of less than 20 gpm are not representative of formation temperatures. Lines in the graphs, computed by the least-squares method, show that most of the plots for small flows fall between 13° and 17°C, regardless of the depth of the well, whereas for wells flowing more than 20 gpm there is an increase in the temperature of water with increase in depth of wells.

SOUTHEASTERN AREA

Depth of well, temperature of water, and relative volume of discharge for 67 flowing wells that yield water from the Dakota Sandstone in the southeastern area are shown in figure 2. The measured temperatures of water discharged by flowing wells in the area ranged from 11°C for a well 200 feet deep, in Hutchinson County in the center of the area, to 24°C for a well

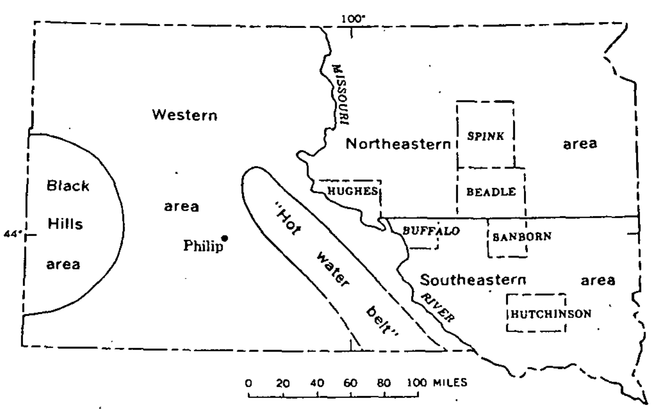

FIGURE 1.—Index map of South Dakota, showing approximate location of "hot water belt" and areas of similar geothermal gradients in the Dakota Sandstone.

U.S. GEOL. SURVEY PROF. PAPER 600-D, PAGES D60-D62

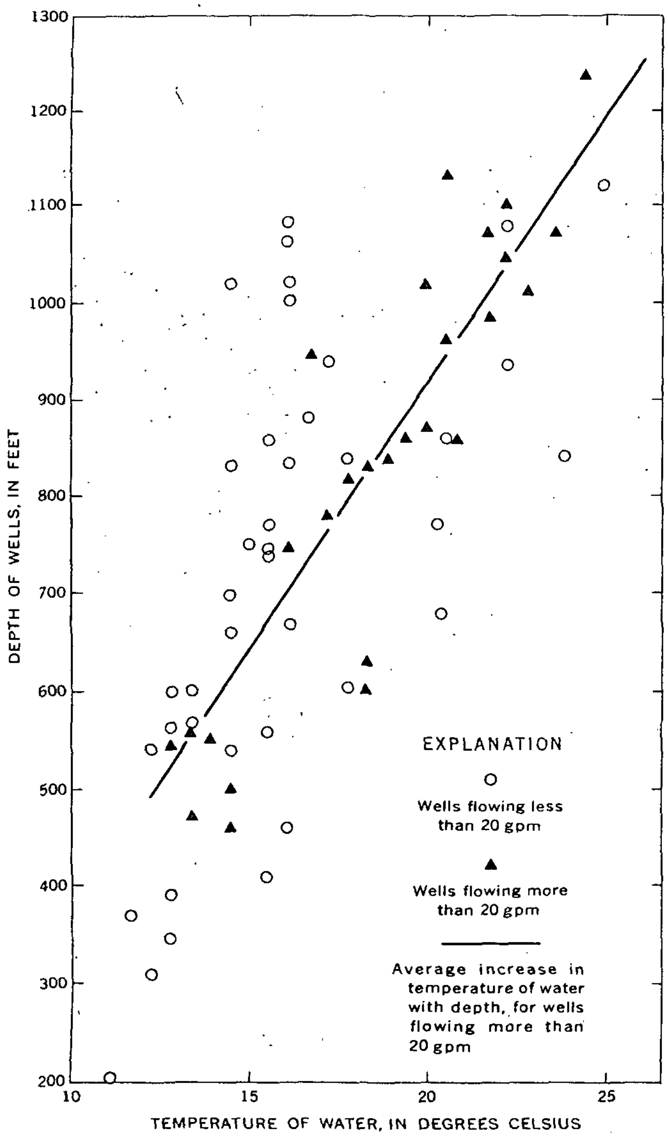

FIGURE 2.—Variations in water temperature with depth of well and volume of discharge for flowing wells in the Dakota Sandstone in southeastern South Dakota.

1,240 feet deep, in Buffalo County near the Missouri River. The average geothermal gradient in the southeastern area is 0.7°C per 100 feet.

NORTHEASTERN AREA

The 31 wells in the Dakota Sandstone represented by temperature and depth plots on figure 3 range in depth from 530 to 1,450 feet. Water temperatures range from 11° to 34°C. The water temperatures and geothermal gradients decrease eastward from the Missouri River. Temperatures as high as 34°C, and geothermal gradients of about 1.6°C per 100 feet are recorded for wells in Hughes and Buffalo Counties along the Missouri River. Farther east in Spink, Beadle, and Sanborn Counties, temperatures average about 20°C and geothermal gradients about 1.1°C per 100 feet.

WESTERN AREA

In the area immediately to the west of the Missouri River, known depths of wells flowing more than 20 gpm from the Dakota Sandstone range from 720 to 1,500 feet, and water temperatures range from 21° to 33°C (fig. 4, group *B*). Geothermal gradients at 22 wells average 1.5°C per 100 feet. Farther west there is a "hot water belt" (fig. 1) where well depths range from 1,180 to 1,830 feet and water temperatures from 36° to 54°C (fig. 4, group *A*). Geothermal gradients at 14 wells average 2.2°C per 100 ft. This "hot water belt" is in an area in which many of the deeper pre-Cretaceous formations are wedging out (Sandberg, 1962) and may be recharging the Dakota Sandstone (Hopkins and

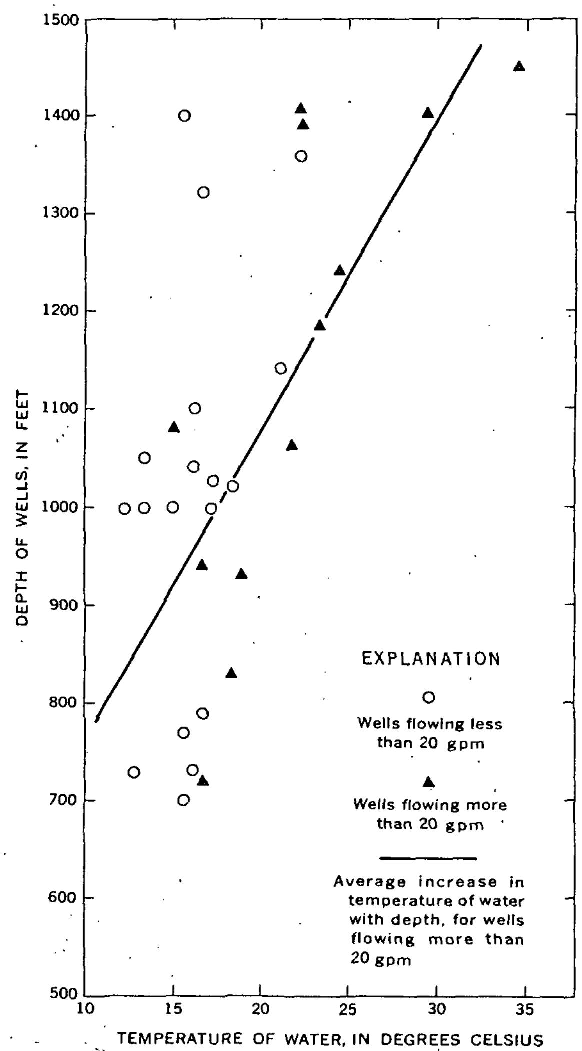

FIGURE 3.—Variations in water temperature with depth of well and volume of discharge for flowing wells in the Dakota Sandstone in northeastern South Dakota.

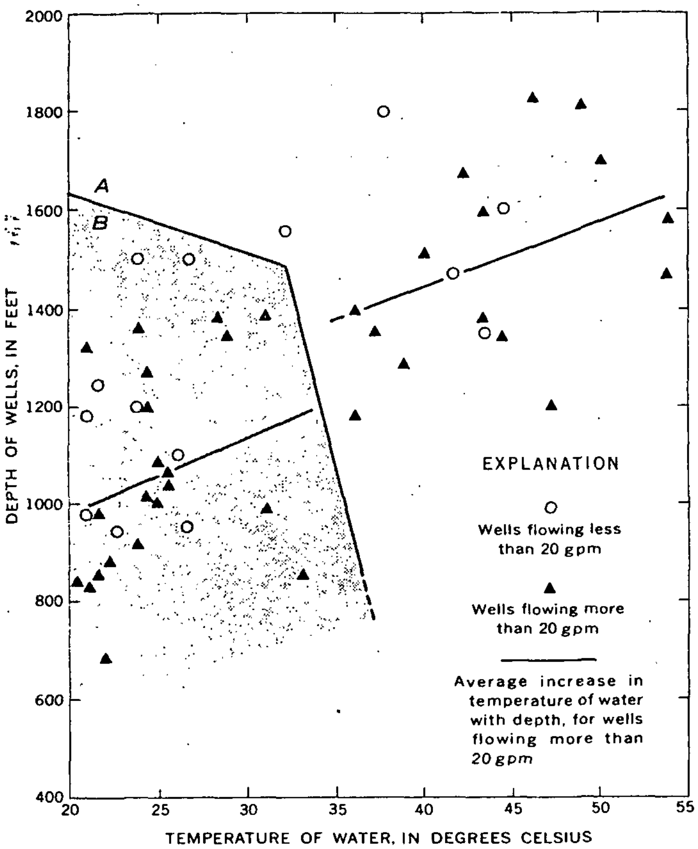

FIGURE 4.—Variations in water temperature with depth and volume of discharge for flowing wells in the Dakota Sandstone in western South Dakota. *A*, wells in "hot water belt;" *B* (shaded), other wells.

Petri, 1963) with high-temperature water. The municipal well at Philip, which is west of the "hot water belt," was drilled to a depth of 4,010 feet and produces 400 gpm from the pre-Cretaceous Madison Group at a temperature of 67°C.

BLACK HILLS AREA

Table 1 summarizes the water-temperature data for wells in the Black Hills area. The mean annual temperature in the area is about 8°C. Wells tap aquifers in the Pahasapa Limestone, Minnelusa Sandstone, Opeche Formation, Minnekahta Limestone, and the Spearfish Formation. Records are available for 42 wells ranging in depth from 300 feet near the outcrops to 4,900 feet 36 miles east of the outcrop area. Although the water temperatures range from 11° to 67°C, water temperatures of 26 wells ranging in depth from 300 to 1,300 feet are below 16°C.

The relatively low temperatures and geothermal gradients in the Black Hills area may be due to the

TABLE 1.—*Summary of water-temperature data for wells in the Black Hills area, South Dakota*

Principal source	Well depth range (ft)	Temperature range (°C)	Average geothermal gradient (°C per 100 ft)
Spearfish Formation	400–560	11–17	1.3
Minnekahta Limestone	360–680	11–22	.9
Opeche Formation	640–1,310	12–16	.7
Minnelusa Formation	300–4,900	11–60	.7
Pahasapa Limestone	460–4,110	11–67	1.0
Average of 42 wells			0.9

rapid downward movement of recharging waters in very porous formations such as the Pahasapa Limestone. Or, it may be that, for many wells, a meaningful temperature gradient cannot be calculated because they are uncased holes which allow mixing of water from several aquifers (Cox, 1962).

CONCLUSIONS

Temperatures of water flowing from deep artesian wells are related to the depth of the well and the volume of discharge.

In South Dakota, temperatures and geothermal gradients at wells in the Dakota Sandstone generally decrease eastward from a "hot water belt" west of the Missouri River. The abnormally high geothermal gradients (Levorsen, 1958, p. 401) in the western area may be due to deep high-temperature recharge to the Dakota Sandstone. Throughout most of the eastern part of the State, where temperature gradients are more nearly normal, the Dakota Sandstone rests on crystalline basement rock and is not recharged from below.

The relatively low geothermal gradients computed for the Black Hills area may be due, in part, to rapid downward movement of recharging water in very porous formations.

REFERENCES

Cox, Earl, 1962, Preliminary report on the artesian water supplies from the Minnelusa and Pahasapa aquifers in the Spearfish-Belle Fourche area: South Dakota State Geol. Survey Spec. Rept. 19, p. 11.

Hopkins, W. B., and Petri, L. R., 1963, Geology and ground-water resources of the Lake Dakota plain area, South Dakota: U.S. Geol. Survey Water-Supply Paper 1539–T, p. 27–28.

Levorsen, A. I., 1958, Geology of petroleum: San Francisco, W. H. Freeman and Co., 703 p.

Sandberg, C. A., 1962, Geology of the Williston basin, North Dakota, Montana, and South Dakota, with reference to subsurface disposal of radioactive wastes: U.S. Geol. Survey Rept. TEI–809, open-file rept. 148 p.