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LOW TEMPERATURE GEOTHERMAL RESOURCE EVALUATION OF THE MOSES LAKE-RITZVILLE-CONNELL AREA, WASHINGTON

by

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The study area is located in portions of Adams, Grant, Lincoln, and Franklin counties of eastern Washington (figures 1 and 2). The area is representative of a complex stratigraphic and geohydrologic system within the basalt flows of the Columbia River Basalt Group. The regional piezometric surface and stratigraphic units dip towards the southwest (Luzier and Burt, 1974; Tanaka, 1979).

Fluid temperature data were collected by three different agencies. The Geological Engineering Section (WSU) at Washington State University, runs a continuous fluid temperature (FT) log as part of a complete suite of geophysical logs. The U.S. Geological Survey (USGS) runs a continous fluid FT log in conjunction with caliper and natural-gamma logs. Southern Methodist University (SMU) and the Washington State Department of Natural Resources, Division of Geology and Earth Resources (DNR), have cooperated in gathering FT data. The DNR-SMU data were collected by taking temperature measurements at 5 m intervals. Bottom-hole temperatures (BHT) and bottom-hole depths (BHD) of selected wells in the study area are given in table 2. Some of the BHT data in table 2 may vary from those previously reported by WSU. These discrepancies are the result of changes in the calibration method of the FT tool.

A technique developed by Biggane (1982) was used to determine the geothermal gradients within the area. A least squares linear regression analysis of the relationship between the BHT and BHD was used to determine the geothermal gradient of a given well data group (WDG). Well data groups were selected on the premises of geographic proximity, position within the regional groundwater flow system, land slope azimuth, and land slope dip (figure 2). Some data points have been excluded from the linear regression analysis on the basis of factors such as duplicate logging of the same hole, down-hole flow, holes not logged to total depth, and questionable FT tool responses.

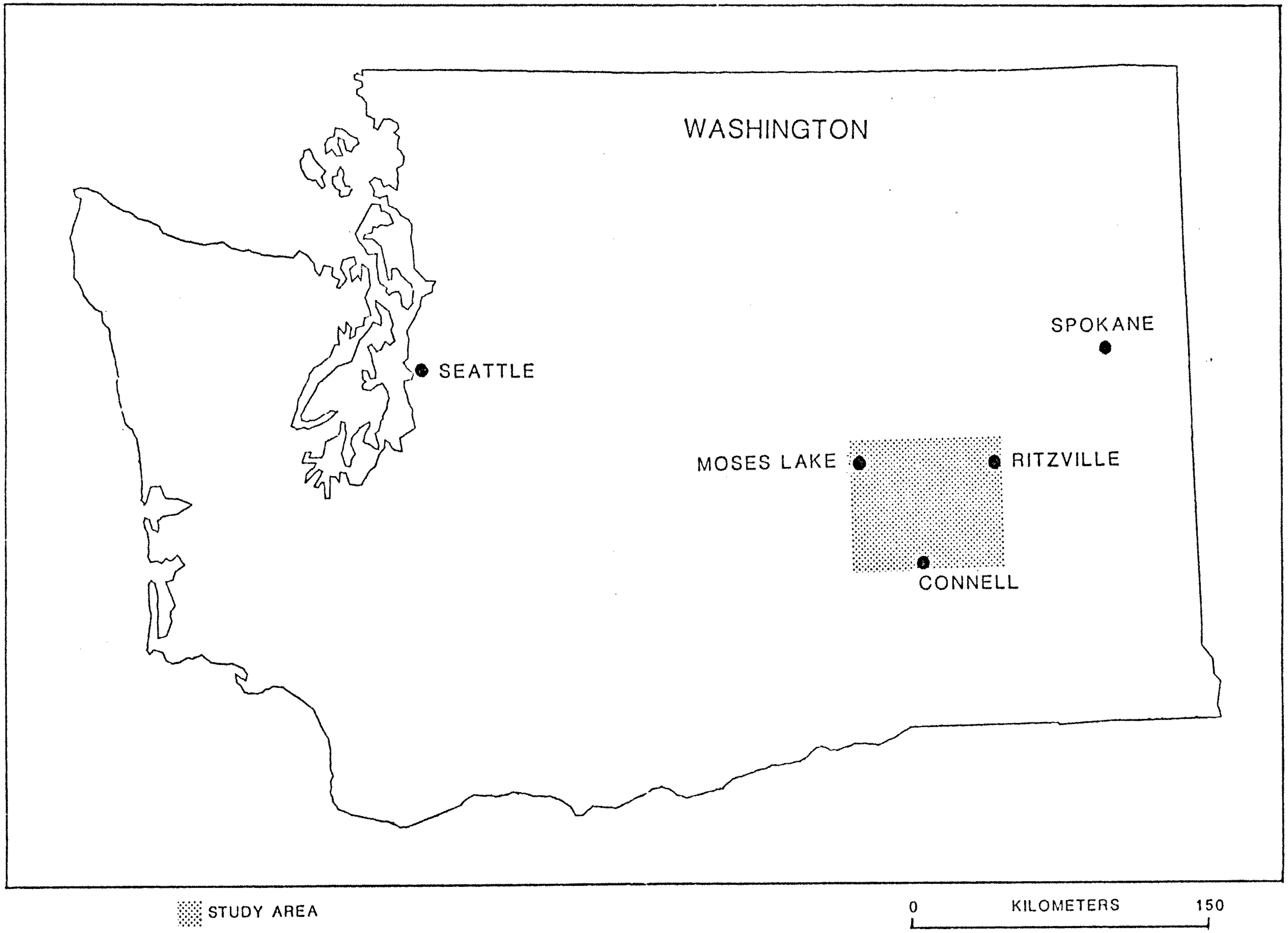

FIGURE 1 LOCATION OF THE STUDY AREA

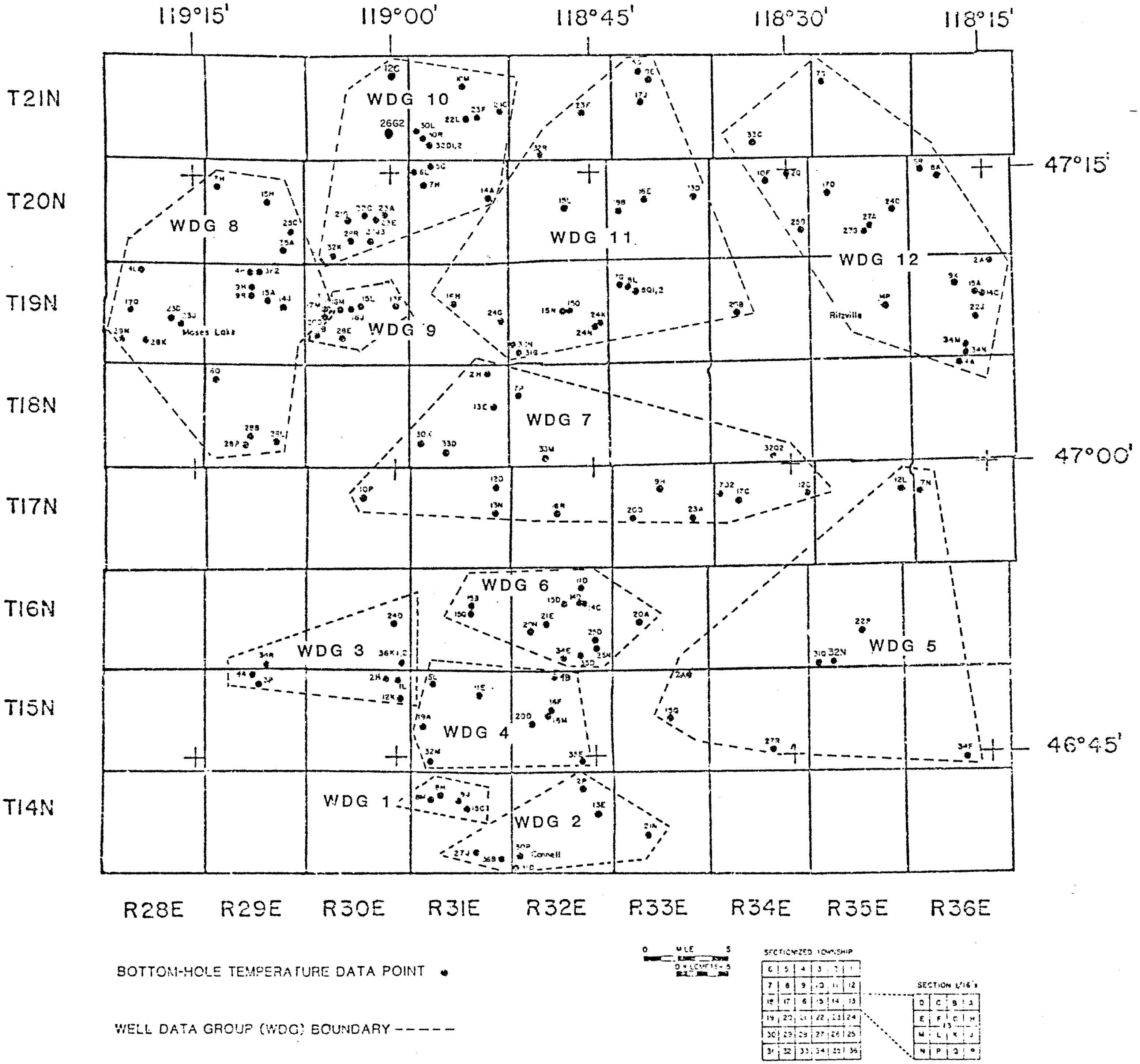

FIGURE 2 LOCATION OF BOTTOM-HOLE TEMPERATURE DATA

Table 2. — LOCATIONS, DESIGNATIONS, BOTTOM-HOLE TEMPERATURES, AND BOTTOM-HOLE DEPTHS OF SELECTED WELLS

Source	Location	Owner	Date	Elev. (m)	Depth (m)	BHT (°C)	WDG	Comments
1	14N/31E-08H1	Rathbun, Corrin	01/20/77	333.8	196.3	16.0	1	
1	14N/31E-08M1	Rathbun, Corrin	03/18/80	347.5	758.0	43.1	13	
1	14N/31E-09J1	Rathbun, Corrin, #3	07/11/79	342.9	332.2	22.2	1	
1	14N/31E-15C1	Kummer Farms	11/13/79	339.9	413.3	20.3	1-E	Downhole flow
5	14N/31E-27J1	Andrews, Clyde	04/29/71	387.1	207.3	25.2	2	
5	14N/31E-36B1	Connell City	04/20/71	275.6	84.1	15.5	2	
1	14N/32E-02P1	Hart, Frank	06/20/79	376.4	235.6	27.1	2	
1	14N/32E-13E1	Hart, Dick	11/10/71	386.2	232.2	23.7	2	
1	14N/32E-30P1	Connell City #7	06/18/76	265.2	252.4	17.8	2-E	Downhole flow
1	14N/32E-31D1	Connell City #6	01/20/72	259.4	302.3	29.0	2	
1	14N/33E-21N1	Heider, Walter	02/15/75	423.7	351.1	28.2	2	
1	15N/29E-03P1	Othello City #5	05/06/74	320.7	298.4	29.4	3	
1	15N/29E-04A1	Othello City #6	02/15/79	321.6	367.3	24.7	3-E	Downhole flow
1	15N/30E-01L1	Matthews, Clyde #1	12/11/74	387.7	216.6	6.4	3-E	Questionable FT data
1	15N/30E-02H1	Matthews, Clyde, #2	12/09/74	379.5	278.0	14.8	3-E	Reported depth 316.1m
1	15N/30E-12K1	Meldrin, Ted	02/12/76	382.5	408.7	17.8	3-E	Reported depth 420.3m
1	15N/31E-05L1	McKay, Ed	05/19/76	379.5	404.4	26.8	4	
5	15N/31E-11E1	Lyle Bros.	10/26/71	381.0	213.3	20.1	4-E	Duplicate logging
1	15N/31E-11E1	Lyle Enterprises #3	09/05/73	381.0	211.5	19.0	4	
1	15N/31E-19A1	Johnson, Arthur	05/11/75	378.6	341.7	27.6	4	
1	15N/31E-32M1	Kummer, Clarence, #4	03/20/80	344.4	364.5	26.0	1	
1	15N/32E-04B1	Damon, Don	11/09/71	381.0	266.2	21.9	4	
2	15N/32E-16F1	Stelger			179.8	20.0	4	
1	15N/32E-16M1	Hatton Test #1 (DNR)	01/11/78	381.0	335.6	15.2	4-E	Reported depth 457.2m
1	15N/32E-20D1	Hatton City #2	04/03/79	365.8	214.9	18.2	4	
1	15N/32E-35E1	Hart, Cyril	09/03/71	376.4	307.8	22.9	4	
1	15N/33E-02A1	Tompkins, Robert	05/24/72	452.6	252.1	24.9	5	
1	15N/33E-15Q1	Strohmaier, Albert	03/15/74	438.6	202.4	18.1	5	
1	15N/34E-27R1	Watson, Leroy	11/30/72	455.7	242.6	19.9	5	
1	15N/36E-34F1	Blauert, Fred	03/23/72	323.1	213.0	25.3	5	
1	16N/29E-34R1	Othello City #3	01/06/77	340.5	260.0	25.0	3	
1	16N/30E-24D1	Kliphardt, G. W.	03/14/72	426.7	219.8	26.1	3	

Table 2. — LOCATIONS, DESIGNATIONS, BOTTOM-HOLE TEMPERATURES, AND BOTTOM-HOLE DEPTHS OF SELECTED WELLS (Cont'd)

Source	Location	Owner	Date	Elev. (m)	Depth (m)	BHT (^oC)	WDG	Comments
5	16N/30E-36K1	DNR #2 (Mike Damon)	03/26/71	387.1	184.1	20.6	3	
1	16N/30E-36K1	Damon, Mike	03/09/71	384.1	209.7	20.2	3-E	Duplicate logging
1	16N/30E-36K2	Damon (DNR)	07/16/74	381.0	241.4	24.7	3	
5	16N/30E-36K2	DNR (Damon)		381.0	210.6	20.1	3-E	Duplicate logging
2	16N/31E-15*	Wholman	01/22/81		229.8	26.2	6	
1	16N/31E-15B1	Lyle, Rex	05/10/75	426.7	200.5	22.6	6	
1	16N/31E-15Q1	Lyle, Rex (South)	07/08/75	429.2	409.9	27.5	6	
1	16N/32E-11D1	Phillips, D. E., #12	05/07/74	446.5	310.0	28.2	6	
1	16N/32E-14C1	Beatrice House Well	05/05/74	429.8	154.5	21.1	6	
1	16N/32E-14D1	Phillips, D. E., #11	03/04/74	420.6	312.7	20.0	6-E	Reported depth 399.3m
1	16N/32E-15D1	Phillips, D. E., #17	03/10/75	455.7	439.5	34.0	6	
1	16N/32E-20N1	Phillips, R. V.	03/05/74	448.1	372.1	28.8	6	
1	16N/32E-21E1	Phillips, D. E., #10	01/19/72	460.3	282.5	26.9	6	
1	16N/32E-25D1	Phillips, D. E., #2	06/23/76	454.8	431.3	29.1	6	
1	16N/32E-25N1	Phillips, D. E., #16	03/08/75	402.3	381.9	31.4	6	
1	16N/32E-34E1	Phillips, D. E., C-34	09/13/78	424.6	772.6	41.4	13	
2	16N/32E-34E1	PhillipsA	04/09/81	424.6	370.0	24.0	6-E	Duplicate logging
1	16N/32E-35D1	Phillips, D. E., #9	08/03/72	448.7	272.2	24.2	6	
1	16N/33E-20A1	Phillips, J. Boyd	04/18/78	484.6	444.4	19.8	6-E	Reported depth 618.1m
4	16N/35E-22P1	Baumann Inc.	02/09/78		315.0	15.3	5	
1	16N/35E-31Q1	Baumann Farms	02/19/76	484.6	599.5	22.4	5	
5	16N/35E-32N1	Bauman, Richard	02/11/67	480.0	214.0	21.0	5	
1	17N/30E-10P1	Warden City #6	04/06/79	390.1	253.3	14.8	7	
1	17N/31E-12D1	Phillips, D. E., C-12	06/25/76	384.0	591.9	27.5	7	
1	17N/31E-13N1	Burgeson, Jim	02/12/76	365.8	230.7	16.6	7	
2	17N/32E-14*	DNRCRB	03/12/81		188.7	23.2	7-E	Duplicate logging
1	17N/32E-16R1	Kulm (DNR)	10/21/77	417.6	356.9	19.3	7	
5	17N/33E-09H1	Breit Brothers #3	04/21/67	399.9	89.3	12.9	7	
5	17N/33E-20D1	Breit Brothers #4	04/21/67	396.8	98.8	15.1	7	
1	17N/33E-23A1	Baumgard, Carl	09/26/72	506.0	202.4	16.9	7	
5	17N/34E-07D2	Lind Golf Course	03/22/71		204.5	13.9	7	
5	17N/34E-12Q1	Lind City	04/21/71		226.5	15.5	7	

Table 2. — LOCATIONS, DESIGNATIONS, BOTTOM-HOLE TEMPERATURES, AND BOTTOM-HOLE DEPTHS OF SELECTED WELLS (Cont'd)

Source	Location	Owner	Date	Elev. (m)	Depth (m)	BHT (°C)	WDG	Comments
5	17N/34E-17C1	Phillips, Chester	08/18/67	428.2	91.4	12.7	7	
1	17N/35E-12L1	Kison, Rachel	12/16/71	499.9	135.6	19.3	5	
1	17N/36E-07N1	Kautz, William B.	09/19/78	527.3	274.3	13.3	5	
1	18N/29E-06Q1	American Potato #2	01/23/75	355.1	204.8	21.7	8	
5	18N/29E-26L1	A&W Feedlot	03/04/71	341.4	91.1	14.7	8	
5	18N/29E-28B1	Landis Farms #6	04/02/71	355.1	97.5	16.7	8	
5	18N/29E-28P1	Landis Farms	04/02/71	341.4	61.0	15.0	8	
5	18N/31E-02H1	Hutterian Bretheren	03/05/71	371.8	122.5	13.0	7	
5	18N/31E-13E1	Franz, Victor	08/13/67	429.8	299.3	15.6	7	
1	18N/31E-30K1	Dyck, Leo	12/07/76	396.9	188.1	15.0	7	
1	18N/31E-33D1	Phillips, D. E., C-33	08/12/76	432.8	727.5	30.2	7	
5	18N/32E-07P1	Hutterian Bretheren	11/11/67	396.2	239.9	21.7	7	
3	18N/32E-33M1	Franz	11/15/81		319.0	19.2	7	
5	18N/34E-32Q2	WSU Exp. Sta.	02/13/67	498.3	184.7	16.2	7	
1	18N/36E-04A1	Heinemann, Don	02/19/76	539.2	281.0	16.3	12-E	Downhole flow
3	19N/28E-04L1	Moses Lake	08/25/81		221.5	19.3	8	
2	19N/28E-17Q1	Dunkin	01/12/81		163.7	15.9	8	
1	19N/28E-23D1	Moses Lake City #7	09/27/74	324.6	282.2	23.8	8	
1	19N/28E-23J1	Moses Lake City #5	09/28/74	358.1	210.3	17.7	8-E	Reported depth 289.5m
1	19N/28E-28K1	Moses Lake City #4	09/26/74	327.7	293.5	16.2	8-E	Reported depth 304.8m
5	19N/28E-28K4	Moses Lake #4	03/08/72	327.6	294.7	17.5	8-E	Duplicate logging
5	19N/28E-29M1	City of Westlake	05/19/71	323.1	141.7	19.8	8-E	Duplicate logging
1	19N/28E-29M1	Moses Lake City #31	03/04/75	321.6	140.2	20.6	8-E	Reported depth 210.3m
1	19N/29E-03F2	Fode, Roy, #2	01/16/76	413.6	322.2	29.0	8	
1	19N/29E-04H1	Shinn, Frank, #2	03/03/75	399.9	280.7	25.7	8	
1	19N/29E-09H1	Shinn, Frank, #1	01/30/73	395.6	175.3	14.1	8	
5	19N/29E-09H1	Shinn Irrigation	02/27/73	396.2	175.3	11.8	8-E	Duplicate logging
1	19N/29E-14J1	Jett-Aero #2	03/03/74	411.5	218.2	21.5	8	
1	19N/29E-15A1	Masto Farms	11/26/74	416.1	288.6	21.1	8	
5	19N/30E-13F1	American Potato	02/15/67	443.8	202.1	20.6	9	
1	19N/30E-15L1	Radach, Jerry	12/08/74	439.5	359.6	16.6	9	Downhole flow
1	19N/30E-16J1	Sparks, Dave, (East)	12/07/74	442.6	279.2	15.9	9	

Table 2. — LOCATIONS, DESIGNATIONS, BOTTOM-HOLE TEMPERATURES, AND BOTTOM-HOLE DEPTHS OF SELECTED WELLS (Cont'd)

Source	Location	Owner	Date	Elev. (m)	Depth (m)	BHT (°C)	WDG	Comments
1	19N/30E-16M1	Sparks, Dave, (West)	12/06/74	438.9	289.2	18.8	9	
1	19N/30E-17M1	Schmidt, Reuben	11/01/72	432.8	224.6	21.9	8	
5	19N/30E-20D1	Jett Aero	03/11/73	419.4	306.9	13.5	8-E	Duplicate logging
1	19N/30E-20D1	Jett-Aero #1	02/01/73	435.0	311.8	25.8	8	
5	19N/30E-28E1	Prior, C.	06/26/73		210.9	11.6	9-E	Duplicate logging
1	19N/30E-28E1	Basin Produce	02/16/72	420.0	211.8	18.5	9	
5	19N/30E-30B1	Schaffer, Paul	11/09/67	415.7	292.0	18.3	9	
5	19N/31E-16H1	Kagele, Jacob	02/15/68	429.8	167.6	16.1	11	
5	19N/31E-24G1	Kagele, Norman	04/14/67	451.1	190.5	17.8	11	
1	19N/31E-24G1	Kagele, Norman	02/15/72	449.0	164.6	20.0	11-E	Reported depth 192.6m
5	19N/32E-15N1	Shannon	11/16/67	504.7	213.3	18.2	11	
5	19N/32E-15Q1	Shannon	11/08/67	505.3	134.1	17.2	11	
5	19N/32E-24K1	Shannon	12/29/69	519.6	216.1	16.8	11-E	Duplicate logging
1	19N/32E-24K1	S & K Farms	01/02/73	530.4	242.9	20.8	11	
1	19N/32E-24N1	J & M Farms	08/07/75	510.2	694.9	32.5	13	
5	19N/32E-30N1	Kagele, Norman	02/17/68	434.3	165.2	21.1	11	
5	19N/32E-31G1	Gering, Howard	04/19/67	438.3	156.0	16.2	11	
5	19N/33E-07G1	Sackmann, Howard	12/07/67	539.5	185.3	15.2	11	
5	19N/33E-08L2	Hoefel, Arthur	01/04/68	545.6	139.3	14.0	11	
1	19N/33E-08Q1	Hoefel, Paul	12/15/75	561.4	231.3	20.7	11	
1	19N/33E-08Q2	Hoefel, Paul, #2	01/18/75	556.3	745.2	42.3	13	
2	19N/34E-20B1	Kagele	12/11/80	566.0	189.9	17.5	12-E	Duplicate logging
1	19N/34E-20B1	Kagele, Melvin	01/14/75	566.0	341.7	19.7	12	
5	19N/35E-14P1	Ritzville #8	10/27/71	548.6	222.5	17.6	12	
5	19N/36E-02A1	Krause, Norman	02/13/67	566.9	92.6	12.4	12	
1	19N/36E-09K1	Gering, Gale	03/20/78	566.9	229.2	21.1	12	
2	19N/36E-14C1	Gering	12/11/80		210.0	14.4	12	
1	19N/36E-15A1	Gering, Gale	11/20/75	580.6	380.4	19.7	12	
1	19N/36E-22J1	Templin, Del	01/24/75	568.2	197.8	16.2	12	
1	19N/36E-34M1	Heinemann, Don	04/09/73	539.2	136.5	18.9	12	
1	19N/36E-34N1	Heinemann, Don, #2	06/05/73	539.2	102.4	20.8	12	
1	20N/29E-07H1	Cole, E. B.	05/13/75	94.7	214.9	21.0	8	

Table 2. — LOCATIONS, DESIGNATIONS, BOTTOM-HOLE TEMPERATURES, AND BOTTOM-HOLE DEPTHS OF SELECTED WELLS (Cont'd)

Source	Location	Owner	Date	Elev. (m)	Depth (m)	BHT (°C)	WDG	Comments
1	20N/29E-15H1	Cole, Ivan	01/31/73	416.1	158.2	14.3	8	
1	20N/29E-25C1	Reinke Farms	01/21/76	433.4	405.7	26.3	8	Reported depth 413.0m
1	20N/29E-35A1	Powers, Tom	05/12/75	408.4	292.6	26.6	8	
5	20N/30E-21G1	Claassen, Clint	05/30/67	474.9	322.8	25.3	10-E	Duplicate logging
1	20N/30E-21G1	Claassen, Clint	12/28/77	475.5	469.7	28.7	10	
5	20N/30E-22C1	Spics, Herb	01/28/71	485.8	123.7	15.8	10	
5	20N/30E-23A1	Franz, Herb	02/14/73	500.2	219.4	19.3	10-E	Duplicate logging
1	20N/30E-23A1	Franz, Herb, #2	02/13/73	500.2	218.5	21.9	10	
5	20N/30E-23E1	Franz, Herb	03/30/72	484.6	337.1	34.9	10-E	Duplicate logging
1	20N/30E-23E1	Franz, Herb, #1	03/22/72	484.0	335.9	26.6	10	
5	20N/30E-27J3	Jantz, Joe	02/06/67	484.6	176.8	15.3	10	
5	20N/30E-28R1	Jantz, Joe	04/20/72	466.3	181.3	28.6	10-E	Duplicate logging
1	20N/30E-28R1	Stucky, J. Jantz	04/12/72	464.8	178.3	20.3	10	
1	20N/30E-32K1	Neibaur/West	02/13/76	445.0	382.5	21.1	10-E	Reported depth 399.3m
1	20N/31E-05C1	Kissler, Merlin	01/06/72	501.4	172.5	19.0	10	
5	20N/31E-06L1	Frick, Fred	11/05/67	484.9	187.1	16.0	10	
5	20N/31E-07H1	Frick, David	05/14/71	481.6	158.8	13.8	10	
5	20N/31E-14A1	Krell, Miller	03/04/71	456.6	132.0	13.6	10	
5	20N/32E-15L1	Ragust, W. C.	04/27/67	521.8	237.7	14.8	11	
5	20N/33E-13D1	Schoonover, Otto	02/29/68	527.3	155.1	18.2	11	
5	20N/33E-16E1	USGS Odessa Test	04/05/71	509.0	228.0	15.9	11	
1	20N/33E-16E1	Odessa Test (DOE)	03/04/71	507.5	225.5	14.5	11-E	Duplicate logging
1	20N/33E-19B1	Schorzman, Ray	08/29/74	541.0	238.0	19.5	11	
1	20N/34E-02Q1	Weber, John	04/11/72	594.4	201.5	21.0	12	
5	20N/34E-10F1	Weizel, Leroy	02/15/72	585.2	237.7	17.8	12-E	Duplicate logging
1	20N/34E-10F1	Weizel, Leroy	03/06/72	583.7	236.8	18.3	12	
5	20N/34E-25G1	Ott, Richard	02/16/68	573.0	189.3	13.3	12	
5	20N/35E-17D1	Hardung, Lavine	03/02/68	604.1	232.5	20.9	12	
1	20N/35E-17D1	Hardung, Lavine	09/04/71	604.1	227.1	15.3	12-E	Duplicate logging
1	20N/35E-24D1	Ahern, Cliff	05/04/74	592.8	157.0	20.6	12	
1	20N/35E-27A1	Kagele, Richard	01/07/77	611.1	364.8	15.6	12-E	Reported depth 384.0m
5	20N/35E-27G1	Kagele, Richard	08/12/67	591.3	242.0	13.7	12	

Table 2. — LOCATIONS, DESIGNATIONS, BOTTOM-HOLE TEMPERATURES, AND BOTTOM-HOLE DEPTHS OF SELECTED WELLS (Cont'd)

Source	Location	Owner	Date	Elev. (m)	Depth (m)	BHT (°C)	WDG	Comments
5	20N/36E-06R1	Curtis, Ed	02/27/68	584.3	135.9	14.2	12	
1	20N/36E-08A1	Curtis, Bill	04/21/69	581.9	144.8	13.7	12	
5	21N/30E-12C1	Beck	02/19/68		231.0	13.3	10	
5	21N/30E-26G2	Schell, Harvey	11/12/67	499.9	171.0	21.4	10	
1	21N/31E-10M1	Basalt Explorer #1	06/14/72	490.7	1340.1	64.5	13	
4	21N/31E-10M1	DABE-1	08/31/61	490.7	1249.7	57.5	13-E	Duplicate logging
5	21N/31E-22L1	Bates, Don, #2	04/17/67	514.5	233.8	19.8	10	
1	21N/31E-22L1	Bates, Don, #2	09/23/76	533.4	477.9	17.8	10-E	Duplicate logging
5	21N/31E-23F1	Walter, Wayne	12/22/67	540.1	226.8	16.7	10	
5	21N/31E-23F1	Schafer, Jerry	12/13/73	552.3	292.9	21.0	10	
5	21N/31E-24C1	Schibel, Don	02/07/71	536.4	193.8	20.6	10	
1	21N/31E-30L1	Kissler, Bob	03/20/73	512.1	143.2	15.9	10	
1	21N/31E-30R1	Kissler, Bob	03/19/73	502.0	263.3	23.8	10	
5	21N/31E-30R1	Kissler, Fred	12/20/67	502.0	236.5	17.1	10-E	Duplicate logging
1	21N/31E-32D1	Kissler, Fred	02/14/72	508.7	209.4	19.6	10	
1	21N/31E-32D2	Kissler, Bob	04/03/77	509.0	365.7	18.9	10	
1	21N/32E-23F1	Schafer, Jerry	02/01/72	552.3	297.2	23.8	11	
5	21N/32E-32R1	Fink, Al	02/08/67	527.9	192.6	17.2	11	
5	21N/33E-05Q1	Odessa #2	05/12/71	472.1	75.6	10.9	11	
1	21N/33E-09E1	Odessa City	11/22/77	490.7	201.2	14.5	11	
5	21N/33E-17J1	Ramm, Emil	12/21/67	543.7	207.3	18.2	11	
5	21N/34E-33C1	Hardung, Joe	04/24/67	585.8	270.6	17.2	11-E	Duplicate logging
1	21N/34E-33C1	Hardung, Joe	03/09/69	585.2	241.7	24.7	12	
5	21N/35E-07G1	Iverson, Bill	11/20/66	612.0	134.7	15.6	12	

*Location unknown

Source:
1) Washington State University, Geological Engineering.
2) Kane, John R., Washington State Department of Natural Resources Division of Geology and Earth Resources, Olympia, WA.
3) Barker, Washington State Department of Natural Resources Divisoin of Geology and Earth Resources, Olympia, WA.
4) Blackwell, David D., 1979, Heat Flow and Geothermal gradient Measurements in in Washington to 1979 and Temperature-Depth Data Collected During 1979. Washington Department of Natural Resources Division of Geology and Earth Resources Olympia Washington.
5) U.S. Geological Survey (USGS) Tacoma, Washington, Unpublished logs.

Data points which have excluded are followed by an "E" in figures 3 through 15 and in the table 2. The results of the analysis are given in table 1 and figures 3 through 15.

Table 1

WDG	Projected Surface Temperature		Gradient
1	7.1°C	+	47.9°C/Km
2	13.0 C	+	49.9 C/Km
3	9.4 C	+	65.3 C/Km
4	9.1 C	+	49.1 C/Km
5	------------	------	------------
6	17.1 C	+	31.9 C/Km
7	10.4 C	+	26.8 C/Km
8	10.8 C	+	45.0 C/Km
9	------------	------	------------
10	11.3 C	+	35.0 C/Km
11	9.7 C	+	40.1 C/Km
12	13.4 C	+	21.9 C/Km
13	13.4 C	+	38.1 C/Km

WDG's 1 through 4 indicate the highest gradients and are most promising for further investigation into the use of low-temperature goethermal resources. A qualitative assessment can be made of each WDG by comparing the number of scattered data points to the number of data points which lie on the calculated gradient.

It would be misleading to calculate a geothermal gradient for WDG 5. The sparse distribution of data over a large area is primarily responsible. The inconsistency of data in Figure 7 (WDG 5) implies that several potential WDG's exist over the area, but there are not enough data to support their delineation.

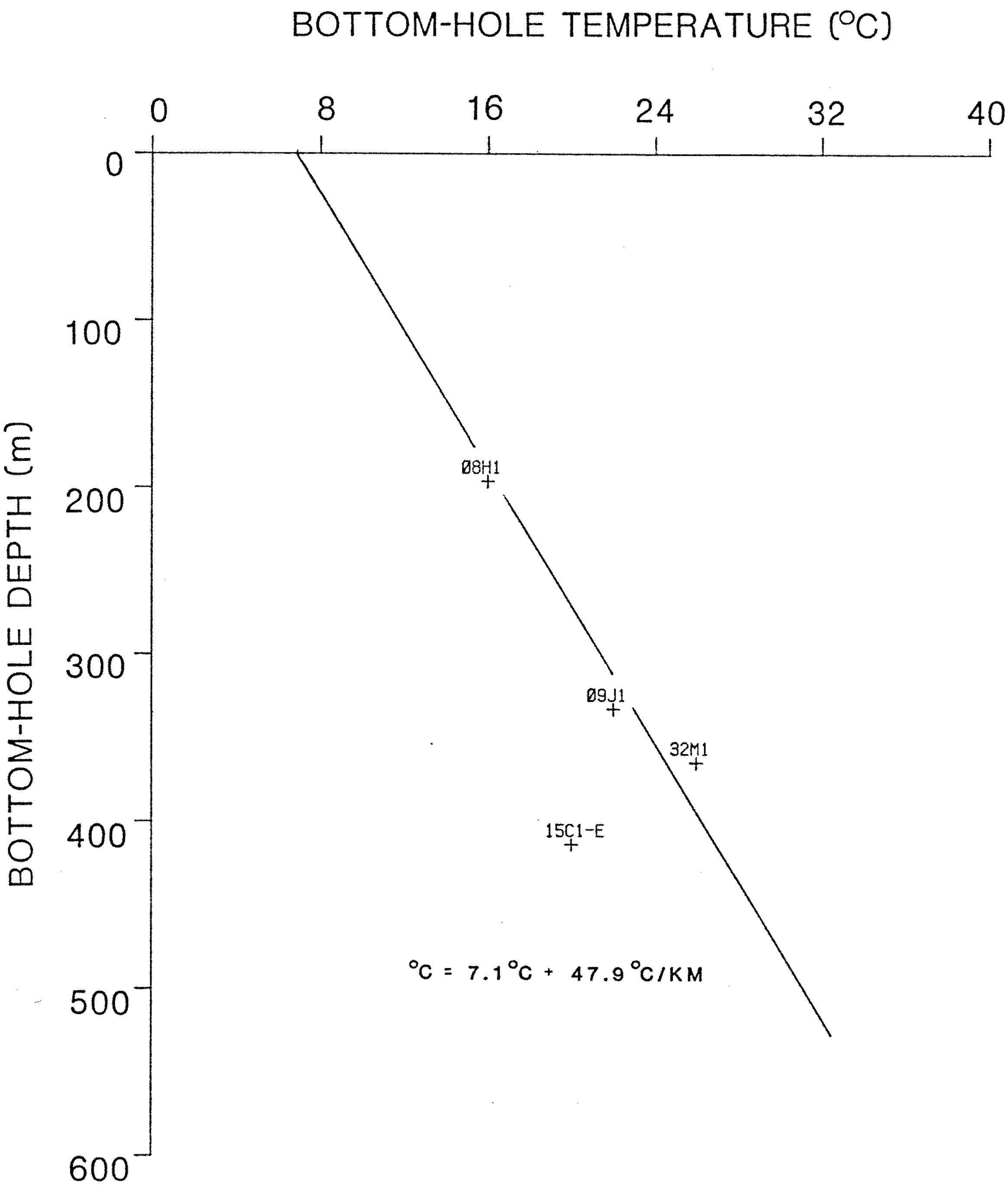

FIGURE 3 PLOT OF BOTTOM-HOLE TEMPERATURE VS. BOTTOM-HOLE DEPTH FOR WELL DATA GROUP 1

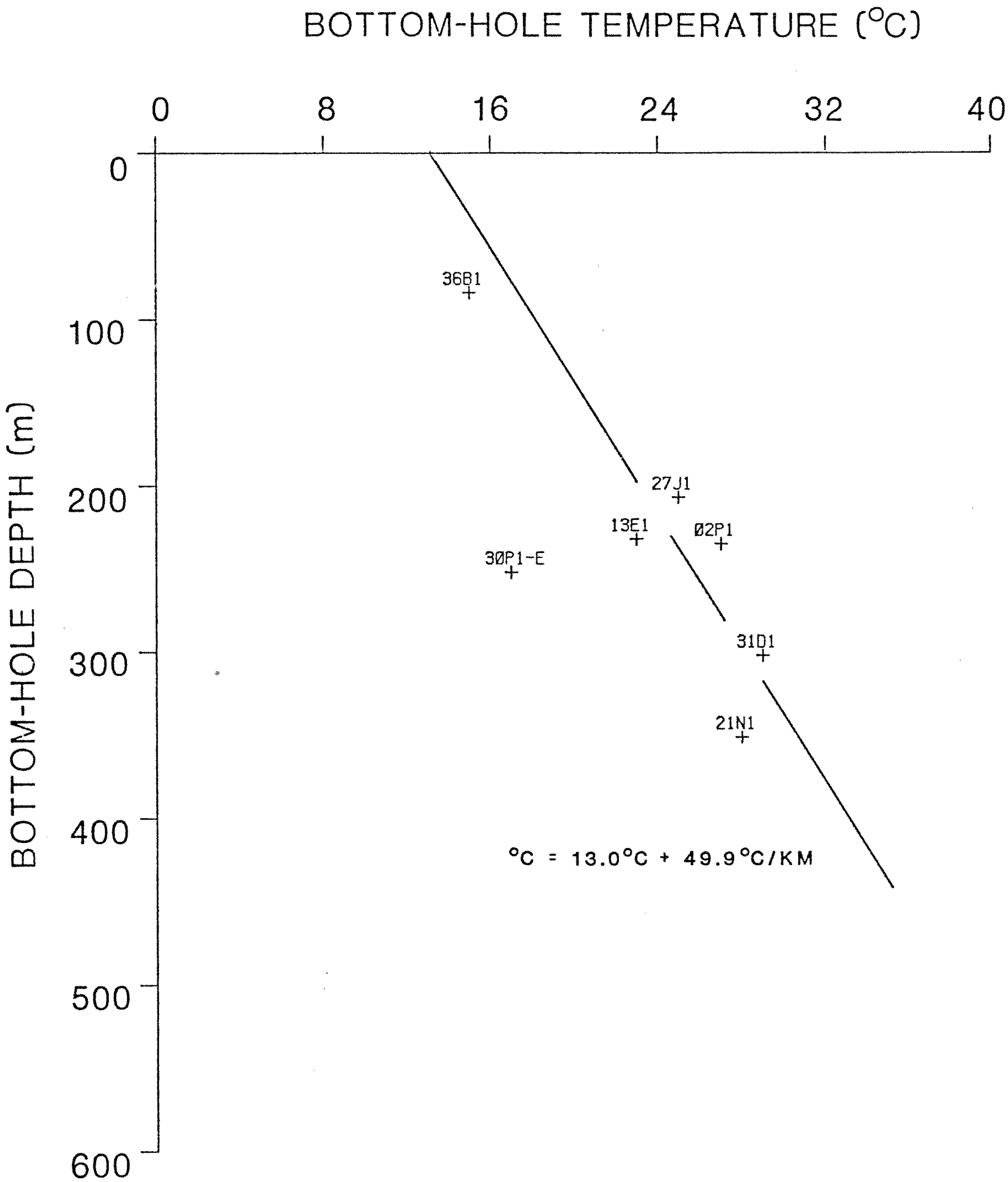

FIGURE 4 PLOT OF BOTTOM-HOLE TEMPERATURE VS. BOTTOM-HOLE DEPTH FOR WELL DATA GROUP 2

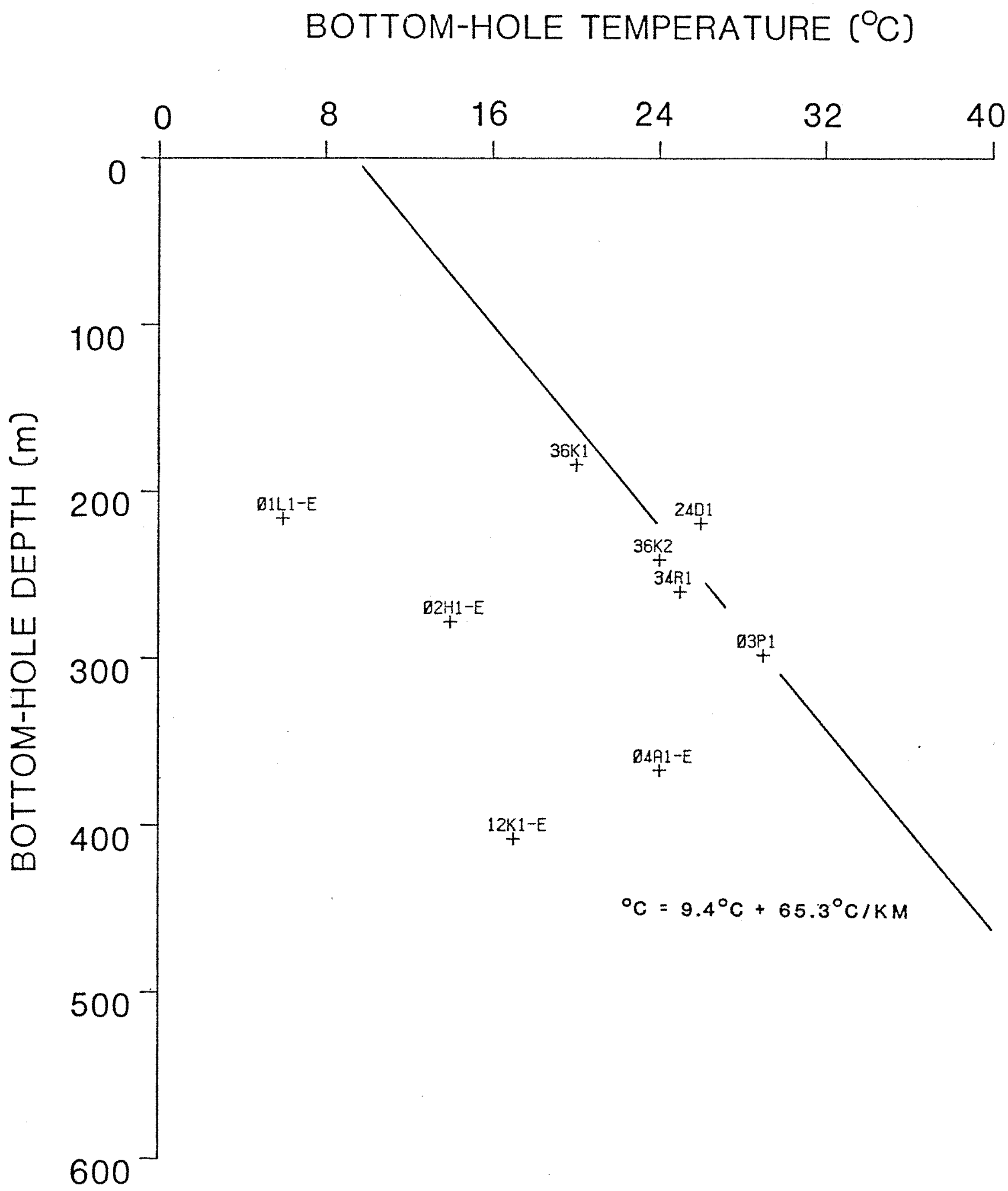

FIGURE 5 PLOT OF BOTTOM-HOLE TEMPERATURE VS. BOTTOM-HOLE DEPTH FOR WELL DATA GROUP 3

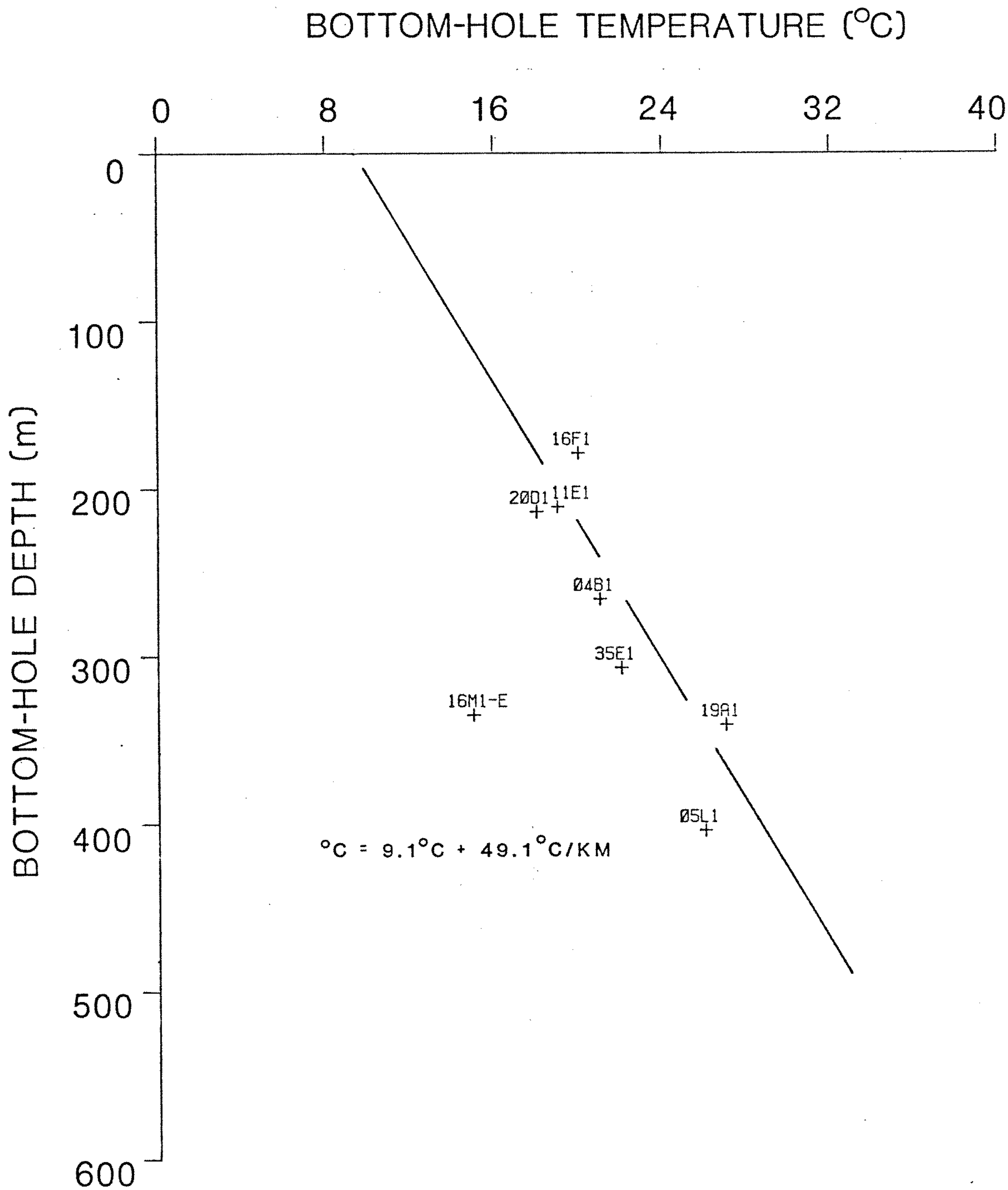

FIGURE 6 PLOT OF BOTTOM-HOLE TEMPERATURE VS. BOTTOM-HOLE DEPTH FOR WELL DATA GROUP 4

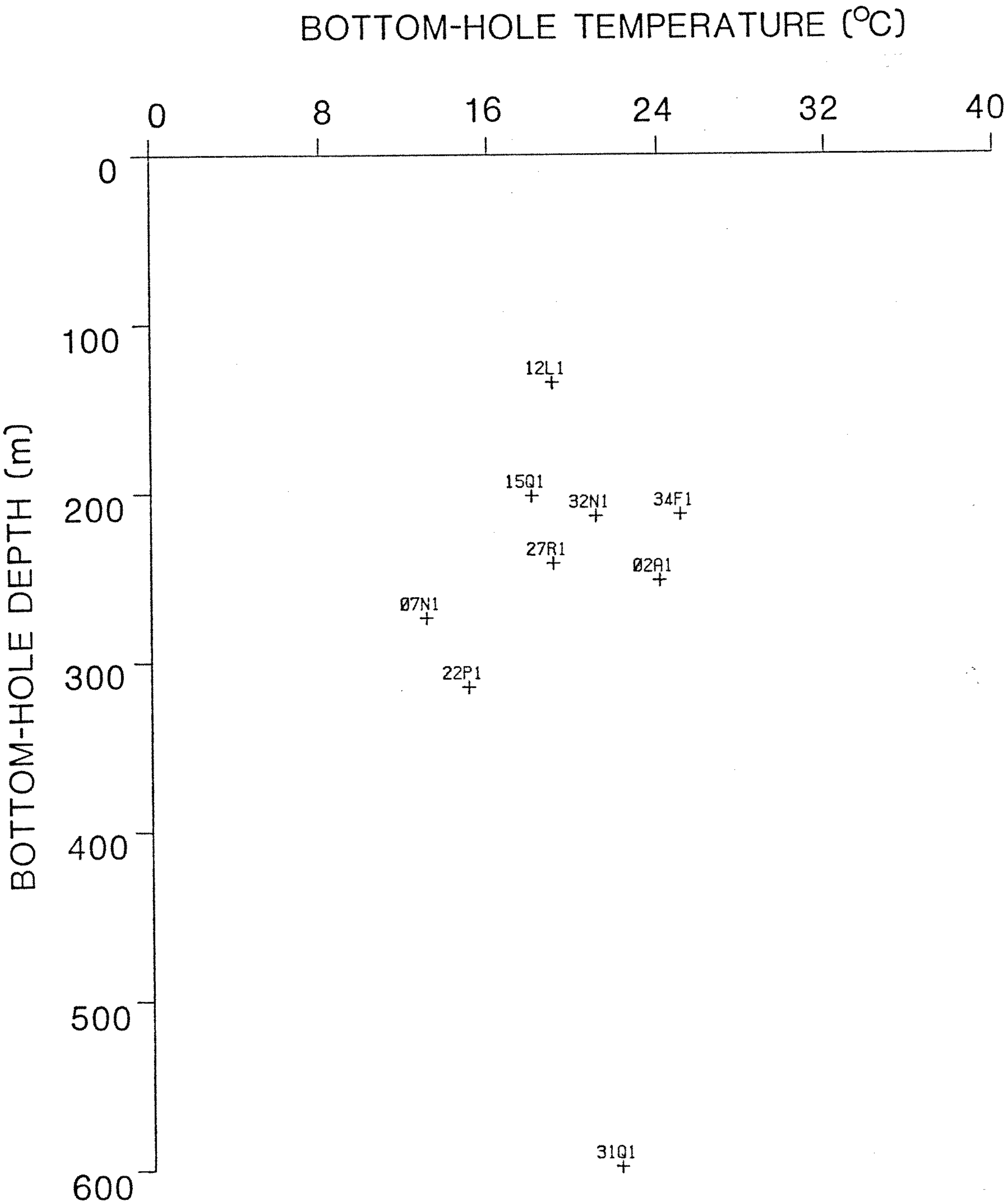

FIGURE 7 PLOT OF BOTTOM-HOLE TEMPERATURE VS. BOTTOM-HOLE DEPTH FOR WELL DATA GROUP 5

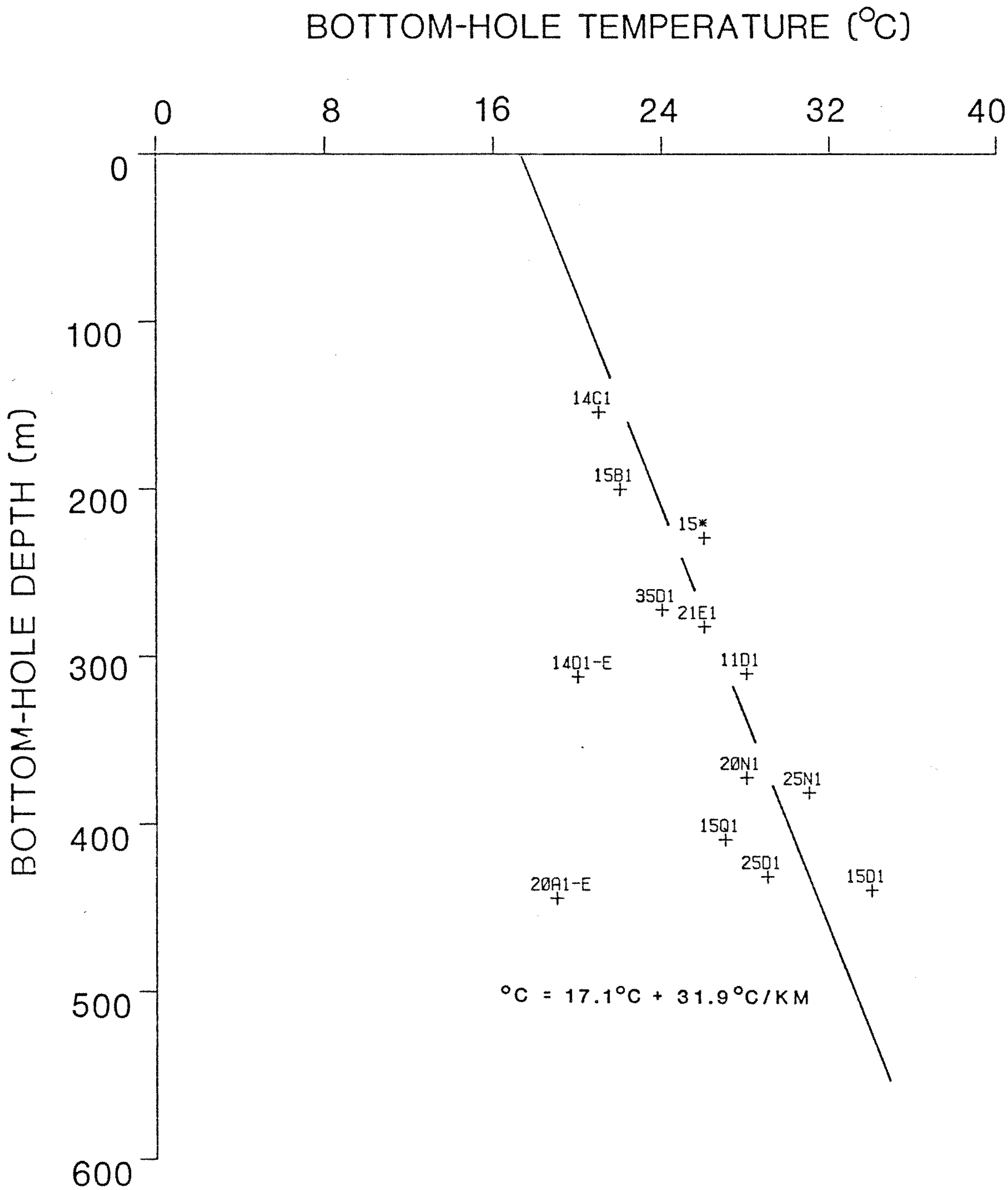

FIGURE 8 PLOT OF BOTTOM-HOLE TEMPERATURE VS. BOTTOM-HOLE DEPTH FOR WELL DATA GROUP 6

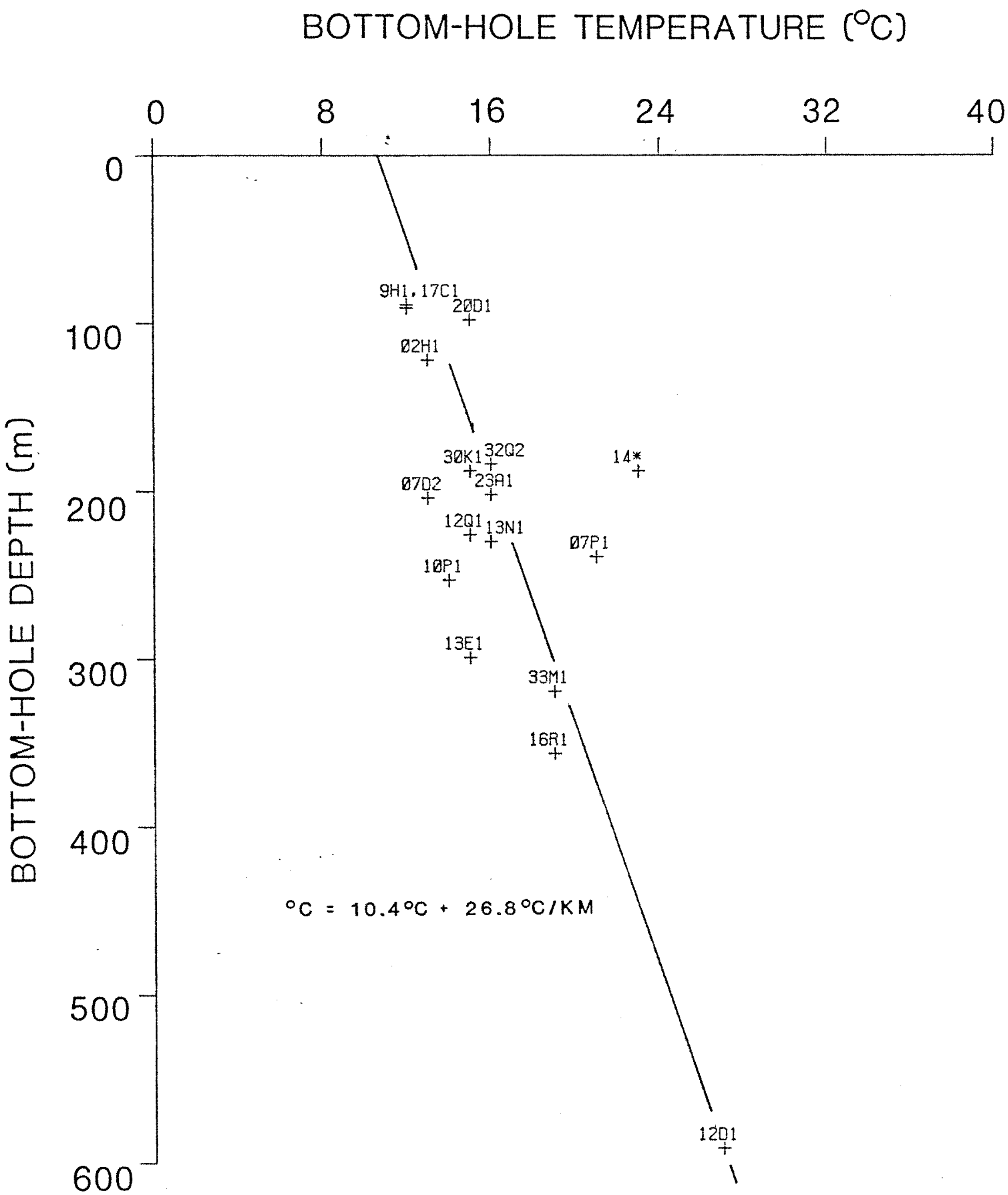

FIGURE 9 PLOT OF BOTTOM-HOLE TEMPERATURE VS. BOTTOM-HOLE DEPTH FOR WELL DATA GROUP 7

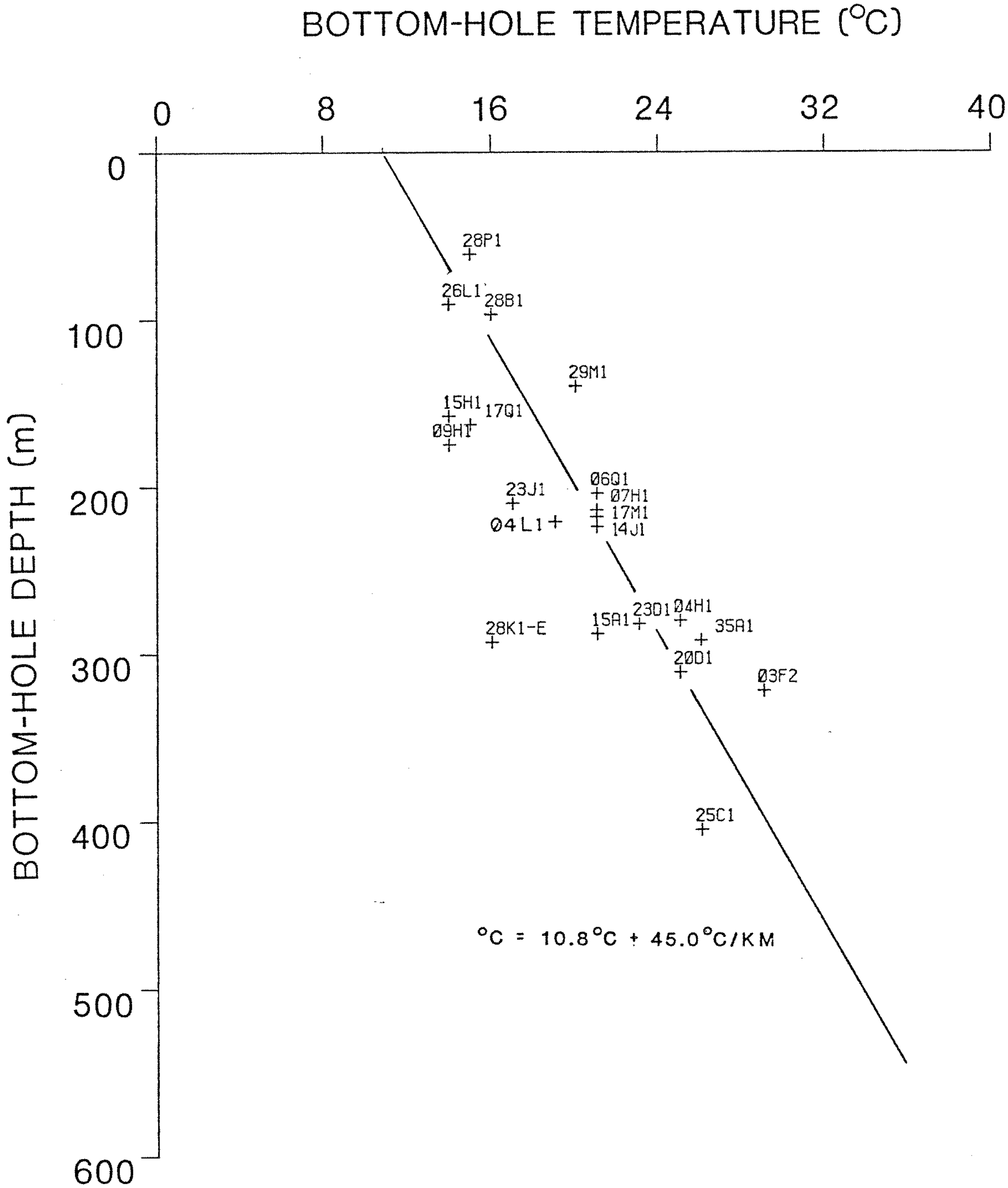

FIGURE 10 PLOT OF BOTTOM-HOLE TEMPERATURE VS.

BOTTOM-HOLE DEPTH FOR WELL DATA GROUP 8

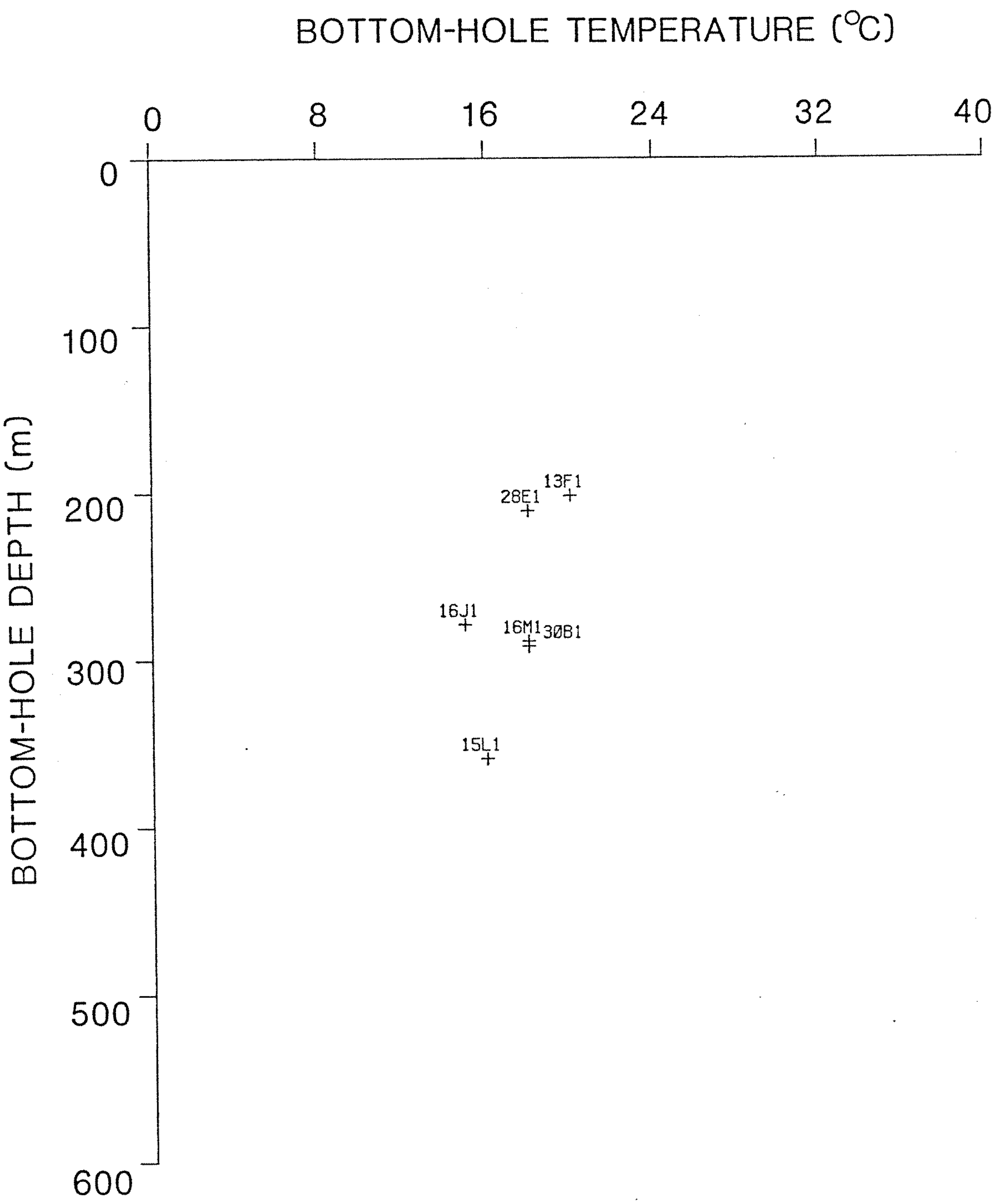

FIGURE 11 PLOT OF BOTTOM-HOLE TEMPERATURE VS. BOTTOM-HOLE DEPTH FOR WELL DATA GROUP 9

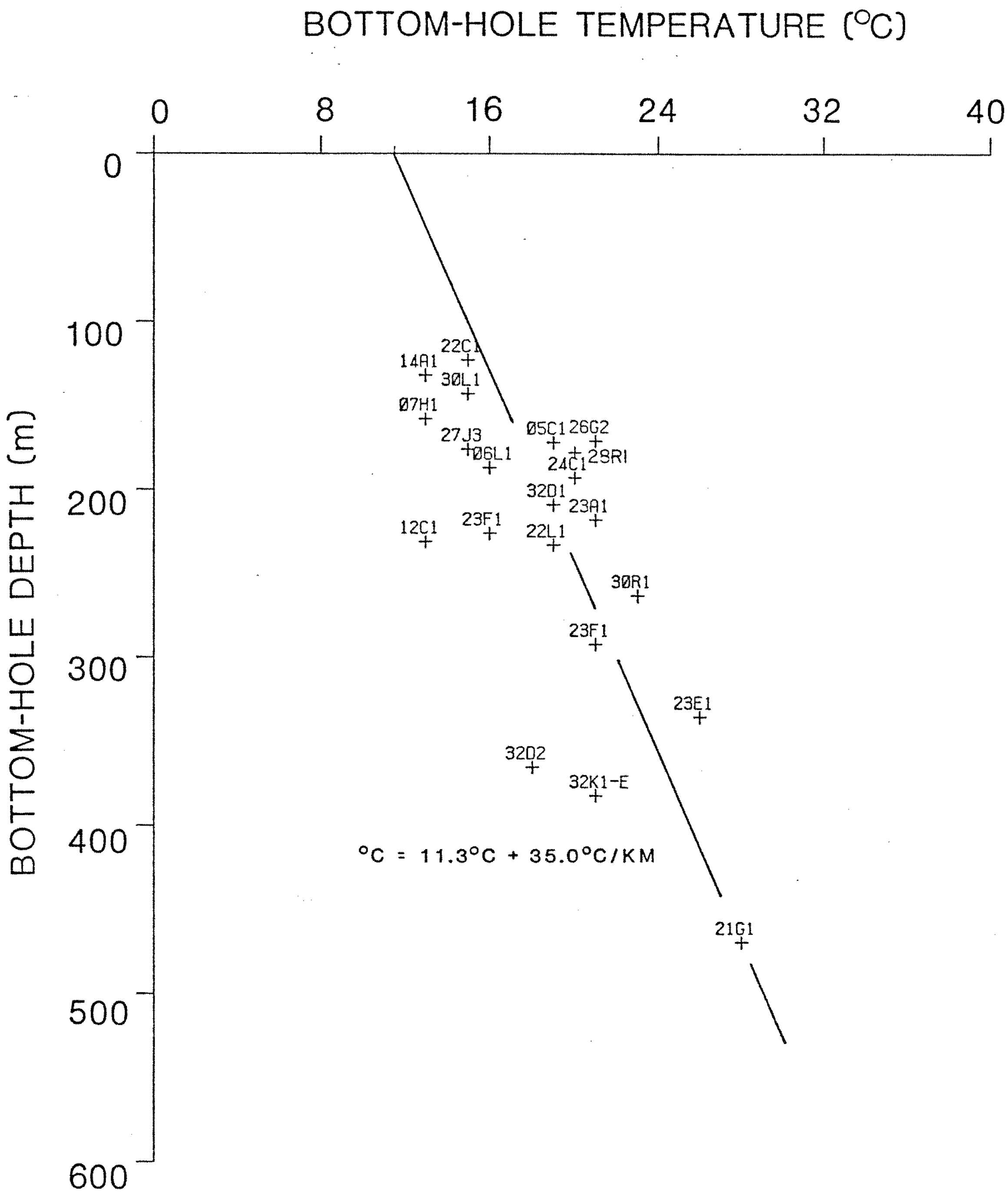

FIGURE 12 PLOT OF BOTTOM-HOLE TEMPERATURE VS. BOTTOM-HOLE DEPTH FOR WELL DATA GROUP 10

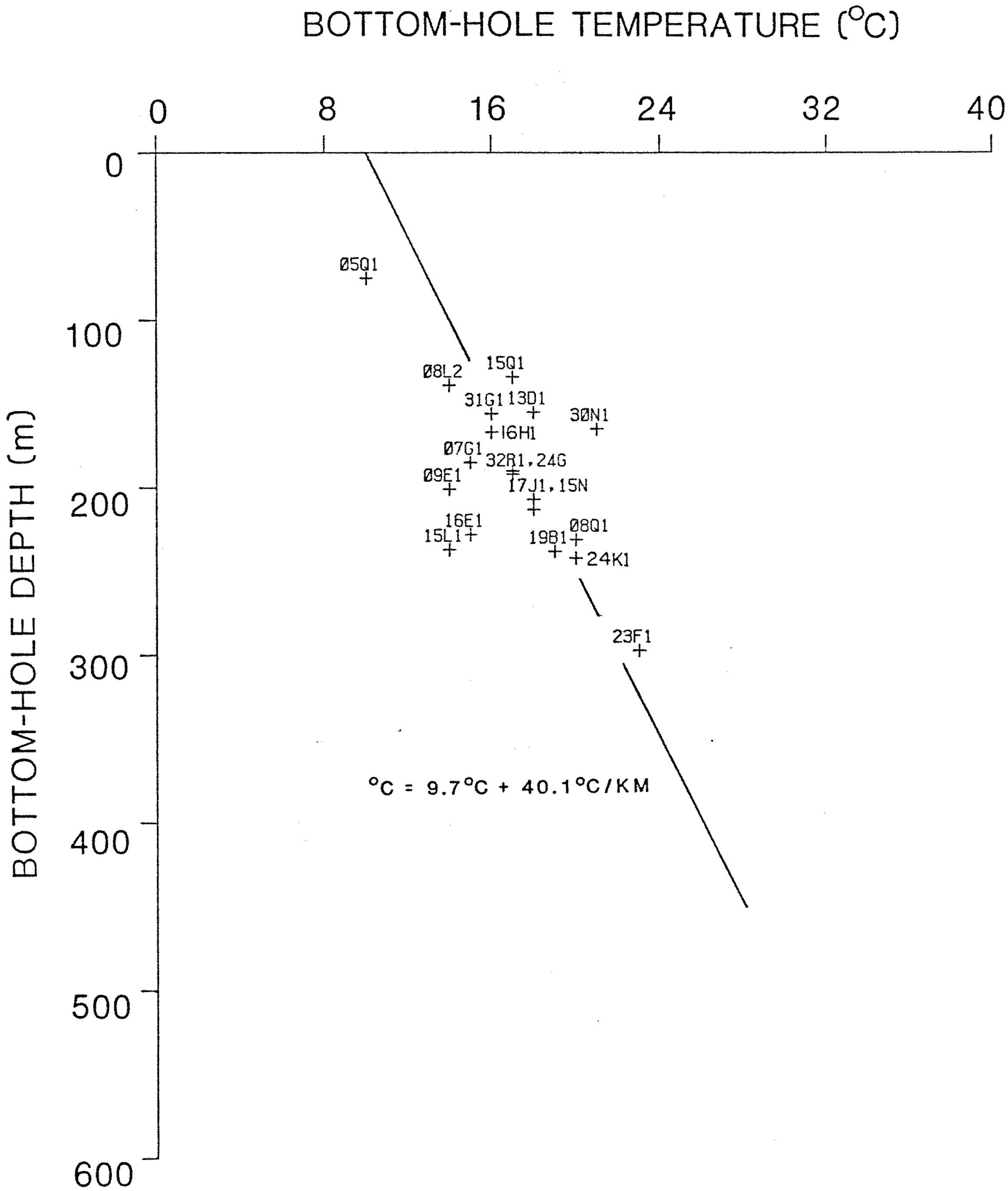

FIGURE 13 PLOT OF BOTTOM-HOLE TEMPERATURE VS. BOTTOM-HOLE DEPTH FOR WELL DATA GROUP 11

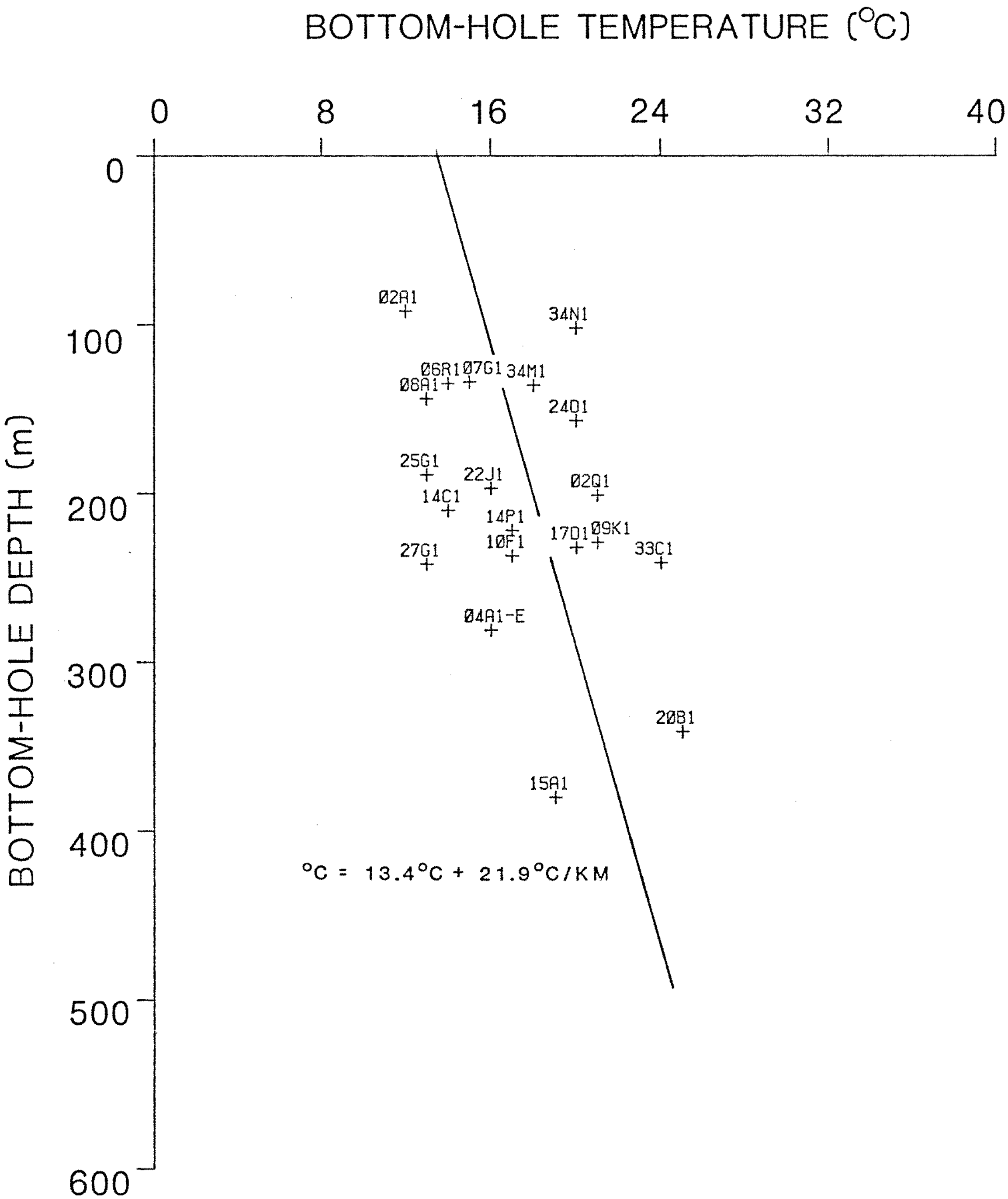

FIGURE 14 PLOT OF BOTTOM-HOLE TEMPERATURE VS. BOTTOM-HOLE DEPTH FOR WELL DATA GROUP 12

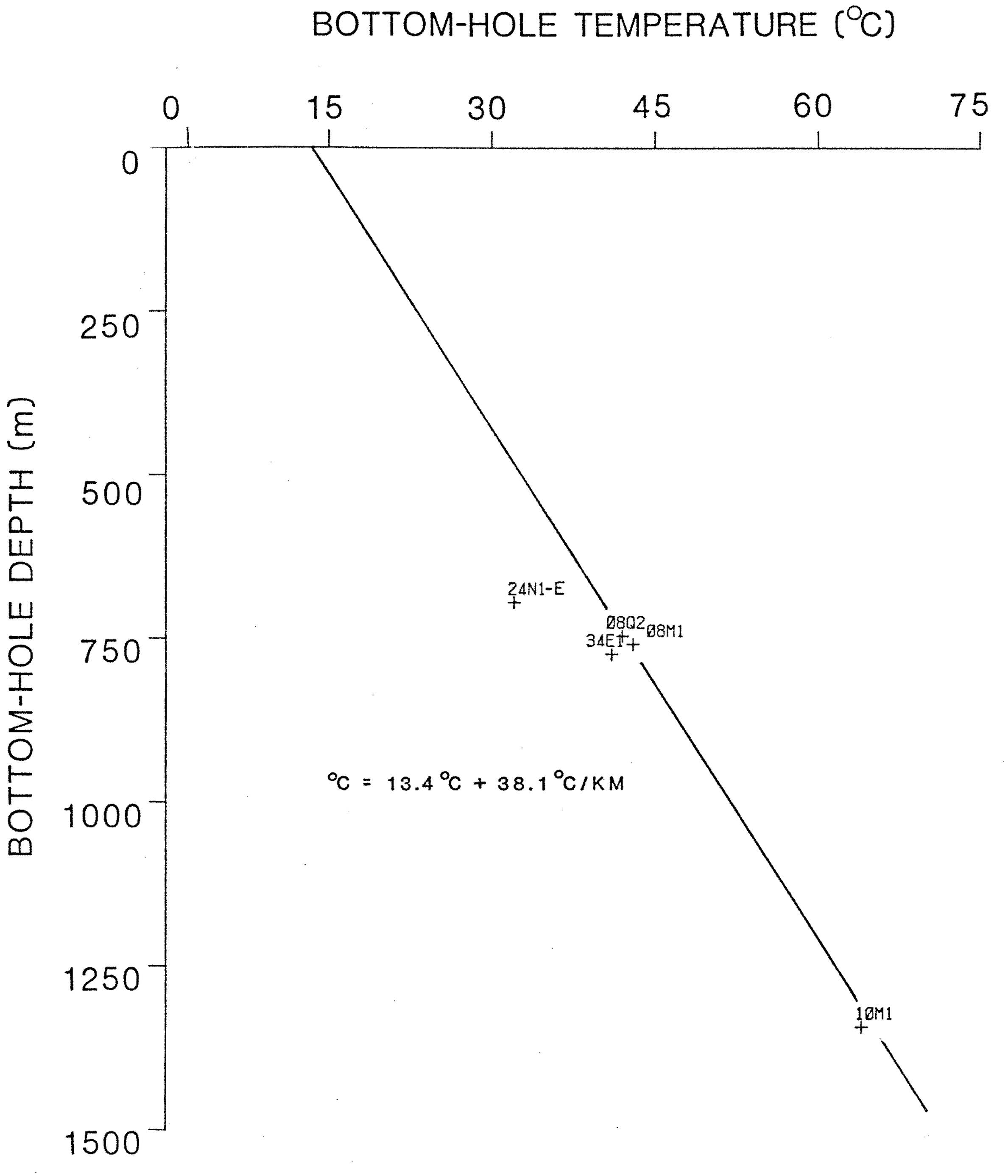

FIGURE 15 PLOT OF BOTTOM-HOLE TEMPERATURE VS. BOTTOM-HOLE DEPTH FOR DEEP WELL DATA GROUP 13

It is likely there exists a slight difference in tool response between reporting agencies, which would account for the scattered data points in the BHT vs. BHD plots (figures 3 through 15). Several other controls may introduce error into the results. A well which has recently been pumped yields a higher BHT, and associated geothermal gradient because of a substantial vertical flow component and the subsequent upwelling of warmer water. Heat generated by the drilling process itself may significantly increase the BHT. Static water levels within the study area vary as much as 25 m annually (Luzier and others, 1968). This annual fluctuation is a manifestation of intensive pumpage during the irrigation season. Cyclic pumpage creates a non-steady state ground water flow system. The non-steady redistribution of head potential is assumed to be associated with a non-steady redistribution of convective heat potential.

In 1968, nearly 7,000 acre feet were pumped from T 16N., R. 32E. which includes most of WDG 6 (Luzier and Burt, 1974). WDG 6, in the future, may shed some light on the relationship between excessive ground water withdrawal and its effects on the geothermal gradient in a given flow system.

Intensive pumpage, compounded with local recharge from Lind Coulee, are possible explanations for the low geothermal gradient in WDG 7. In figure 9 (WDG 7), the distribution of data about the calculated geothermal gradient indicates the actual gradient may vary from that which is reported.

The Moses Lake area (WDG 8) shows a favorable gradient for utilizing warmer water from depth. Scatter in the BHT vs. BHD plot (figure 10) may be a result of cyclic pumping.

A reasonable geothermal gradient could not be fit to the data within WDG 9. The location coincides with anomalies in the piezometric surface. 8,000 acre feet were pumped from T. 19N., R. 30E. during the year of 1968 (Luzier and Burt, 1974). Intensive pumpage and recharge from the East Low Canal have been cited as possible explanations for this piezometric anomaly (Lobdell and Brown, 1977). The apparent low geothermal gradient in figure 11 (WDG 9) could be the result of this activity.

WDG's in the northern portion of the study area (WDG 10 through WDG 12) display favorable geothermal gradients. It should be noted that there are substantial static water level declines within these areas.

WDG 13 (figure 15) consists of those wells within the study area which are greater than 600 m in depth. The gradient, at 38.1°C/Km, is relatively low, below the average for the region. Biggane (1982) had noted that deeper wells in his study area showed a lower than average geothermal gradient, and suggested that this lower gradient may be attributed to a change in thermal conductivity at depth. For this study, however, 4 of the 5 wells which comprise WDG 13 fall within low gradient well data groups defined by shallower wells (i.e., groups 6, 10, and 11). The other well occurs in the relatively high gradient area WDG 1, which also has a very low projected surface temperature. The gradient as determined by that average projected temperature and the BHT is 47.5°C/Km, close to the average for WDG 1.

The deep wells within this study area therefore, seem to reflect the average gradients for the well data groups. They may not be representative of the regional gradient because they are located in low gradient well data groups.

Any one of the WDG's is a candidate for low-temperature geothermal development, provided a well is properly constructed. It would be unwise to select a low-temperature geothermal site without obtaining temperature logs from all of the wells in the nearby vicinity and analyzing them in great detail.

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Brown, J. C., 1978, Discussion of geology and ground-water hydrology of the Columbia Plateau, with specific analysis of the Horse Heaven, Sagebrush Flat, and Odessa-Lind areas, Washington: Washington State Univ., College of Engineering, Research Report 78/15-23, Pullman, Washington.

Lobdell, G. T., and Brown, J. C., 1977, Geophysical investigations of Washington's ground-water resources, annual report 1976/1977: Washington State Univ., College of Engineering, Research Report 77/15-76, Pullman, Washington.

Luzier, J. E., and Burt, R. J., 1974, Hydrology of basalt aquifers and depletion of ground-water in east-central Washington: Washington State Dept. of Ecology, Water-Supply Bulletin 33, Olympa, Washington.

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