UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Thermal studies at the Brantley Damsite on the Pecos River near Carlsbad, New Mexico

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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Background

In November of 1982, I was approached by Ray Larsen (now retired) of the U.S. Bureau of Reclamation concerning a temperature measurement program that had been in progress at the proposed Brantley damsite near Carlsbad, New Mexico. At Ray's request, I visited him in Denver where he, I, and Susan Oren (staff geologist, Brantley Project) examined the results of the temperature-logging program to date. There was considerable curvature, and there were irregular temperature changes in the temperature profiles, both evidence for vertical water movement. In some serial logs from individual wells, there were also apparent changes in temperature with time at various depths, suggesting a possible response to releases of water from McMillan dam upstream from the proposed site.

I pointed out to Ray and Susan that the results to date, although suggestive of vertical water movement in the formation, were ambiguous in that the water movement could be confined to the borehole itself considering that the annulus around the casing was gravel packed and provided a highly transmissive path in response to small head differences in the well. I suggested that we grout casing in a few representative wells, allow enough time for the temperature disturbance associated with the grout-emplacement to subside, then monitor the wells for several months in an effort to detect temperature changes in space and time that might be related to pervasive vertical water movement or lateral water movement in response to releases from McMillan Dam.

The experiment that evolved consisted of temperature measurements in seven grouted wells interspersed with nine ungrouted wells along a line roughly parallel to and downstream from the dam axis (Figure 1). Temperature logging was begun in January of 1983 and continued until February of 1984. Prior to releases of water from McMillan on March 25, 1983, we were able to establish a satisfactory background temperature gradient for most wells. Several sets of temperature logs were obtained in March and April of 1983 in an attempt to detect possible thermal effects of the releases. Thereafter, logs were repeated at intervals of approximately one month until February 1984.

I am grateful to Susan Oren, Ann Gilroy, Tony Herrell, and Jim Gates of USBR who obtained the temperature data and provided core samples. Robert Munroe and Gene Smith measured thermal conductivities, and Vaughn Marshall assisted with the preparation of figures. Art Lachenbruch reviewed a draft of the manuscript.

Results

A synoptic view of the latest temperature profiles from the grouted and ungrouted wells, respectively is given in Figures 2 and 3. Although the temperature profiles from the grouted wells are generally smoother than those from the ungrouted wells (compare Figures 2 and 3), there is substantial curvature in most profiles; its sense would suggest downward percolation of ground water if thermal conductivity were assumed to be constant. We collected 111 representative specimens from the grouted wells and measured their thermal conductivity. We found significant systematic variations of thermal conductivity with depth (Table 1). In particular, the lower member of the Permian Seven Rivers formation (within which most of the wells bottomed) is much less conductive of heat than the overlying Azotea member; this qualitatively explains the increasing temperature gradient with depth.

Formal calculations of heat flow (Table 1) revealed that, in general, increases in temperature gradient are compensated by decreases in thermal conductivity and vice versa. Component heat flows for contiguous depth intervals in individual wells generally agree with each other to within their combined uncertainties, the single exception being DH 143 (Table 1) where heat flow increases systematically below 61 meters.

Time-series for the grouted wells (Figures 4 through 10) indicate a progressive return to equilibrium from disturbances induced by a combination of lost circulation, lateral water flow, and the curing of the cement grout. The most dramatic example is OW-70 (Figure 9). In some cases, the ungrouted wells (Figures 11 through 19) show a conductive return to equilibrium, but most had been drilled and cased a sufficient time before this series of measurements began, to show no change in temperature with time. In particular, no response to the water released from McMillan Dam on March 25, 1983, was detected.

Comments

On the whole, the thermal data do not suggest pervasive downward seepage of water within the Seven Rivers Formation. To the extent that the seven grouted wells are representative of the floor of the proposed reservoir, the outlook for massive downward water movement is negative. For example, a formal one-dimensional analysis of DH 143 (which has the least internal consistency among component heat flows) would predict a maximum vertical seepage velocity under present hydraulic head conditions of about one foot per year (downwards). It is noteworthy that hydraulic conductivity measured in this well was very low, in contrast to DH 124 which has the most internally consistent component heat flows and has some cavernous sections with high measured hydraulic conductivities. The filling of the reservoir will raise the hydraulic head by several tens of feet and will tend to accentuate any existing potential for downward seepage. The present series of thermal data does not address this question.

For the most part, temperature profiles in the ungrouted wells are similar in shape to those from the grouted ones (cf Figures 2 and 3) with minor excursions most likely imposed by local water movements in the wells. The notable exceptions (Figure 3) are DH 231 (see also Figure 19) and DH 180 (Figure 11). The shape of the profile for DH 231 suggests lateral seepage of cool water (probably from the McMillan reservoir itself according to Bureau of Reclamation Staff). DH 180 is in a zone identified by USBR as one of potential "major leakage." It penetrates a zone of solution cavities between ~350 and 450 feet, a zone of severe temperature disturbance (Figure 11) whose character remained constant but the detail of which was changing slightly with time. This profile is certainly suggestive of lateral water movement, but the gradients above and below the cavernous zones appear conductive suggesting that the lateral flow is localized and that there is no significant vertical water movement. Also, the profile from OW-70, which is in the same "suspect" area has evolved from one not unlike DH-180 to one that seems primarily conductive since it was grouted (Figure 9). This, in turn, suggests that water channels at ~200 and 600 feet in OW-70 were not of great lateral extent and could be effectively sealed off by grouting.

I must emphasize that, while all the indications from heat-flow measurements are that pervasive vertical water seepage is not now occurring in the grouted wells (and probably not in the ungrouted ones either) we have not sampled the bulk of the reservoir floor. Changes in the piezometric surface due to filling of the reservoir could enhance any tendency that now exists for vertical seepage. Vertical seepage along discrete fractures or solution channels not sampled by our wells also cannot be ruled out.

Within a regional context, most heat-flow values are somewhat lower than the mean of about 40 mW m^{-2} established by Herrin and Clark (1956). The lowered mean heat flows (Table 1) could be attributed to water movement having a downward vertical component of velocity of a few millimeters per year in rocks below the depth of penetration of our test wells. Such flows probably would have no bearing on seepage from the reservoir.

Reference

Herrin, E., and Clark, S. P., Jr., 1956, Heat flow in west Texas and eastern New Mexico: Geophysics, v. 21, p. 1087-1099.

TABLE 1. Heat flow from grouted wells near the Brantley Dam Site, New Mexico

Hole designation	N. Lat.	W. Long.	Elev. m	Depth interval m	Temp. gradient °C km^{-1}	N*	<K>** $Wm^{-1} K^{-1}$	Heat flow mWm^{-2}
DH 124	32° 20.5'	104° 07.8'	982	24- 37	8.20±0.39	5	3.91±0.43	32±5
				37- 52	7.79±0.16	4	4.29±0.31	33±3
				52-110	6.16±0.06	6	5.26±0.13	32±1
				110-125	9.84±0.18	4	3.36±0.8	33±2
						Weighted mean		33±0.3
DH 143	32° 21.8'	104° 06.6'	1012	46- 61	4.80±0.15	5	4.75±0.30	23±2
				61- 70	9.42±0.8	4	1.75±0.28	16±4
				70-125	6.37±0.05	6	4.60±0.42	29±3
				125-143	11.42±0.28	6	2.78±0.70	32±9
						Weighted mean		27±3
DH 187	32° 20.3'	104° 09.1'	990	30- 64	7.81±0.11	6	3.98±0.61	31±5
				64-122	6.05±0.04	6	5.31±0.10	32±1
				122-168	8.70±0.09	6	3.82±0.30	33±3
						Weighted mean		32±0.5
DH 198	32° 20.3'	104° 08.0'	980	37- 98	7.08±0.04	5	4.92±0.27	35±2
				98-137	10.73±0.13	6	4.58±0.41	49±5
				137-146	18.41±0.88	6	1.96±0.27	36±7
						Weighted mean		40±5
DH 199	32° 20.3'	104° 08.3'	985	46-113	7.34±0.04	6	5.12±0.45	38±4
				113-152	9.15±0.17	6	4.77±0.41	44±5
				155-165	15.60±0.65	3	3.27±0.26	51±6
						Weighted mean		41±3
OW 70	32° 21.3'	104° 07.3'	1003	76-125	5.83±0.09	5	5.24±0.08	31±1
				128-198	14.08±0.18	10	2.81±0.45	40±7
						Weighted mean		36±4
DH 406	32° 18.0	104° 11.8'	1045	110-146	6.70±0.04	6	4.61±0.38	31±3

*Number of thermal conductivity specimens.
**Harmonic mean thermal conductivity ± standard error.

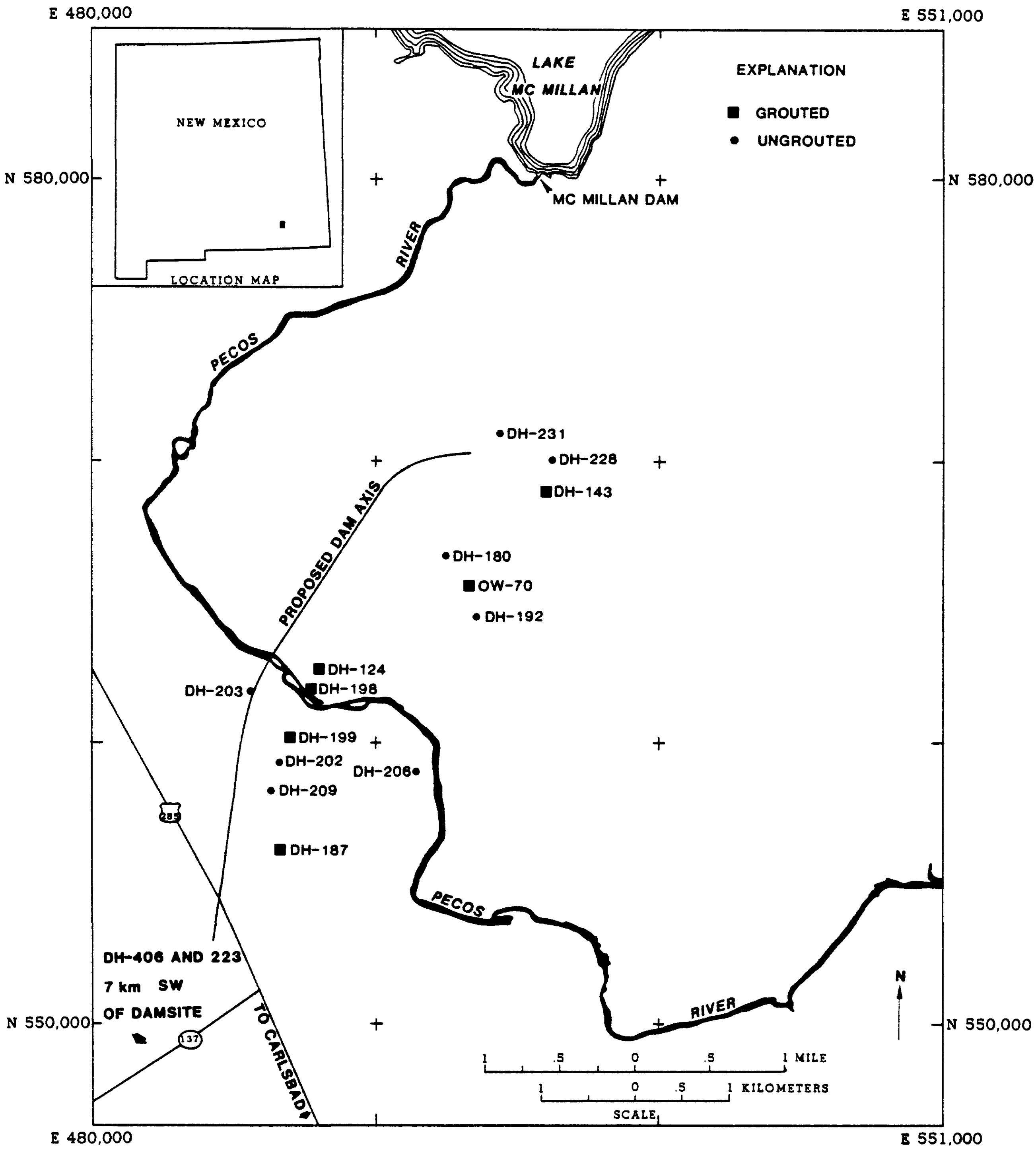
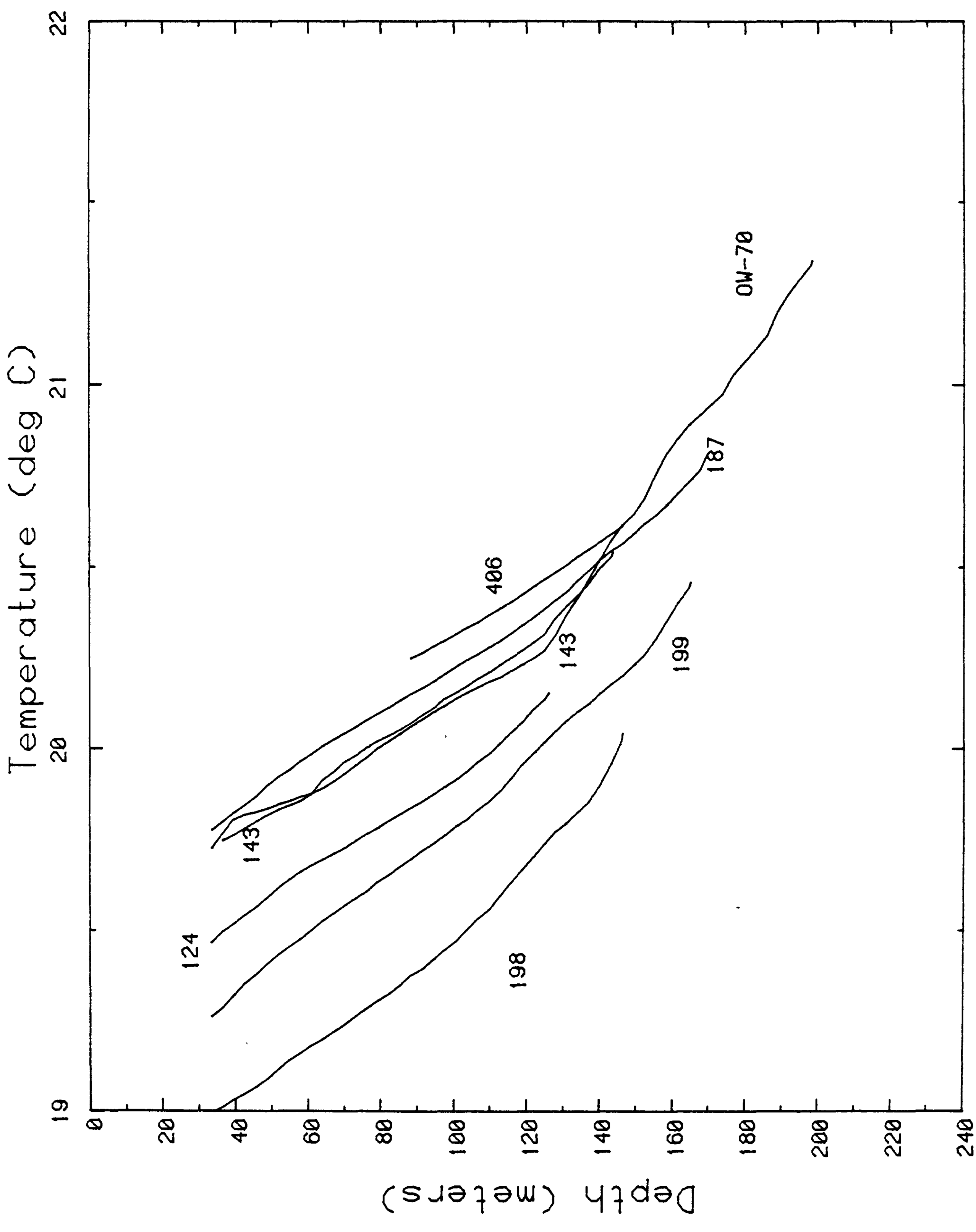
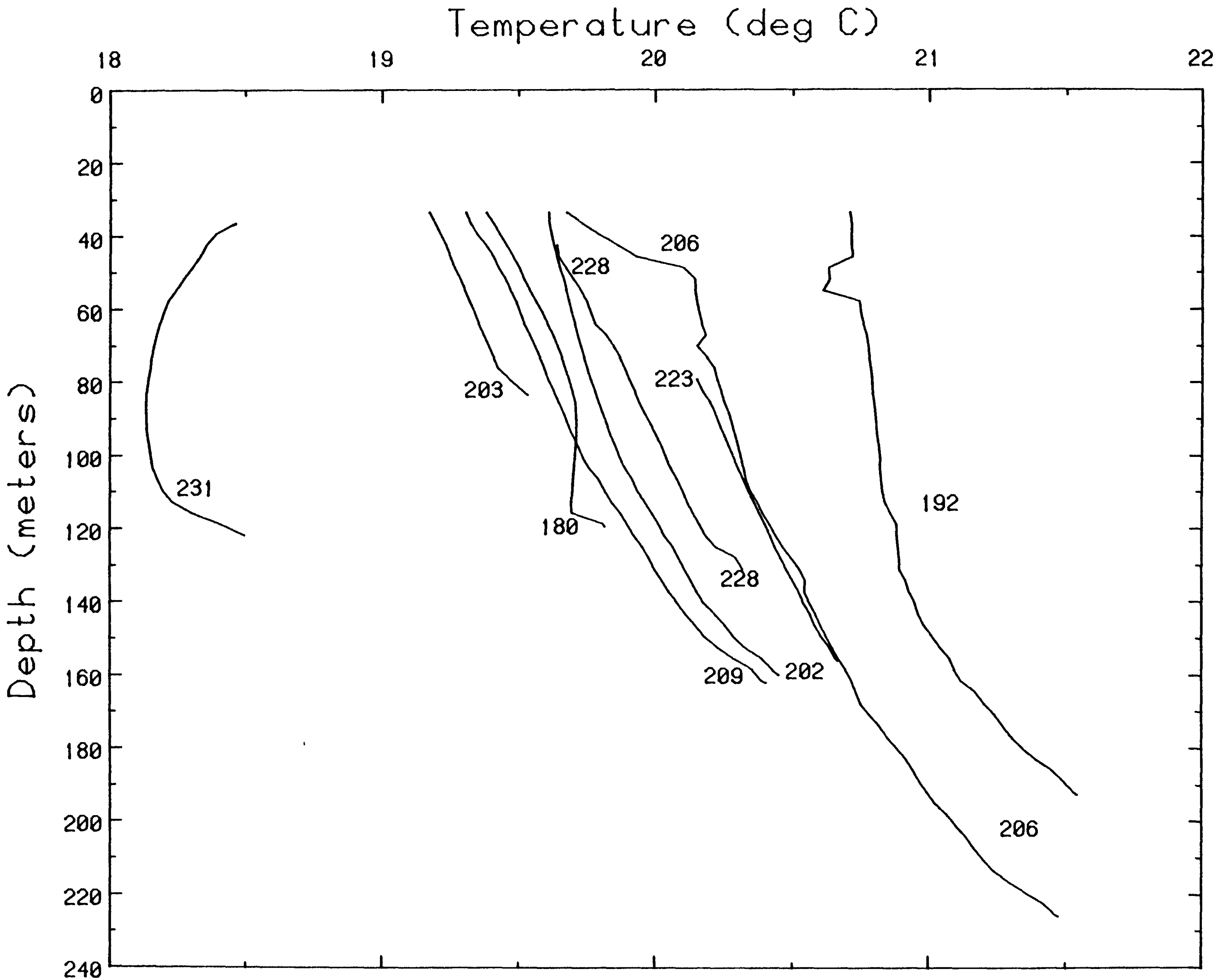


Figure 1. Locations of test wells used in this study relative to the dam axis and Pecos River.



Brantley Dam: Grouted Wells; February 1984.

Figure 2



Brantley Dam: Ungrouted Wells; February 1984.

Figure 3

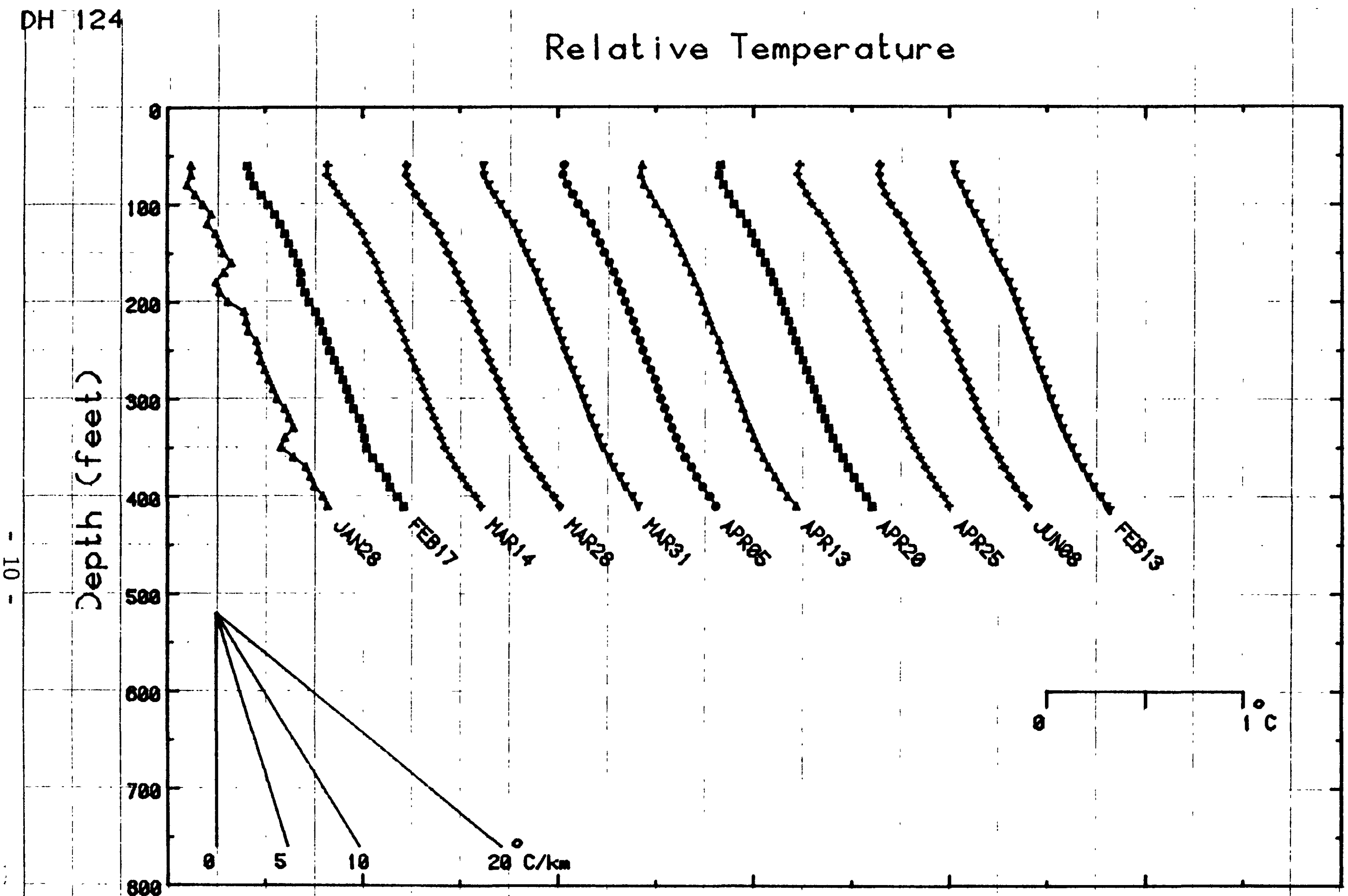


Figure 4. Temperature profiles (with arbitrary temperature origin) for DH 124 between January 28, 1983, and February 13, 1984.

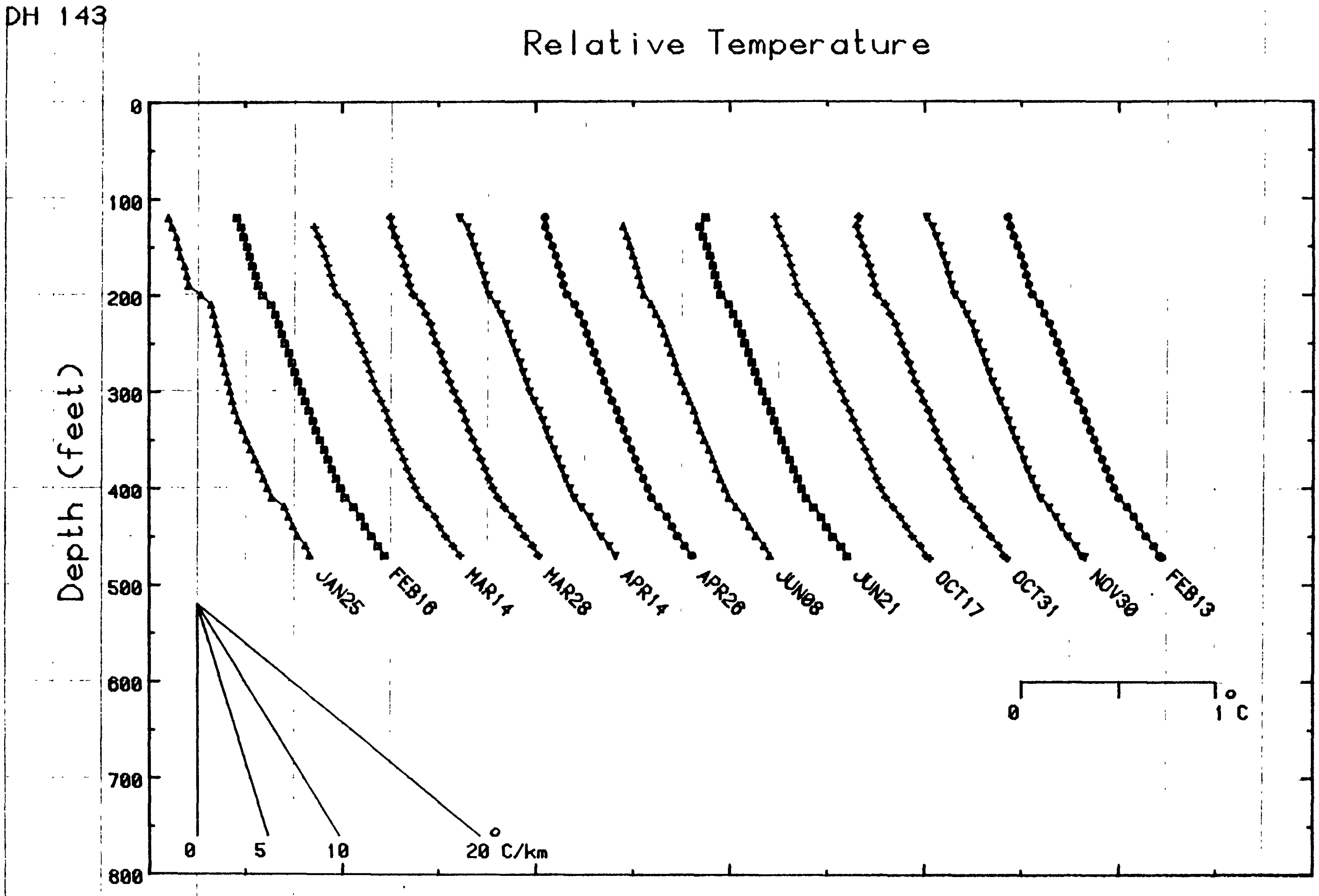


Figure 5. Temperature profiles (with arbitrary temperature origin) for DH 143 between January 25, 1983, and February 13, 1984.

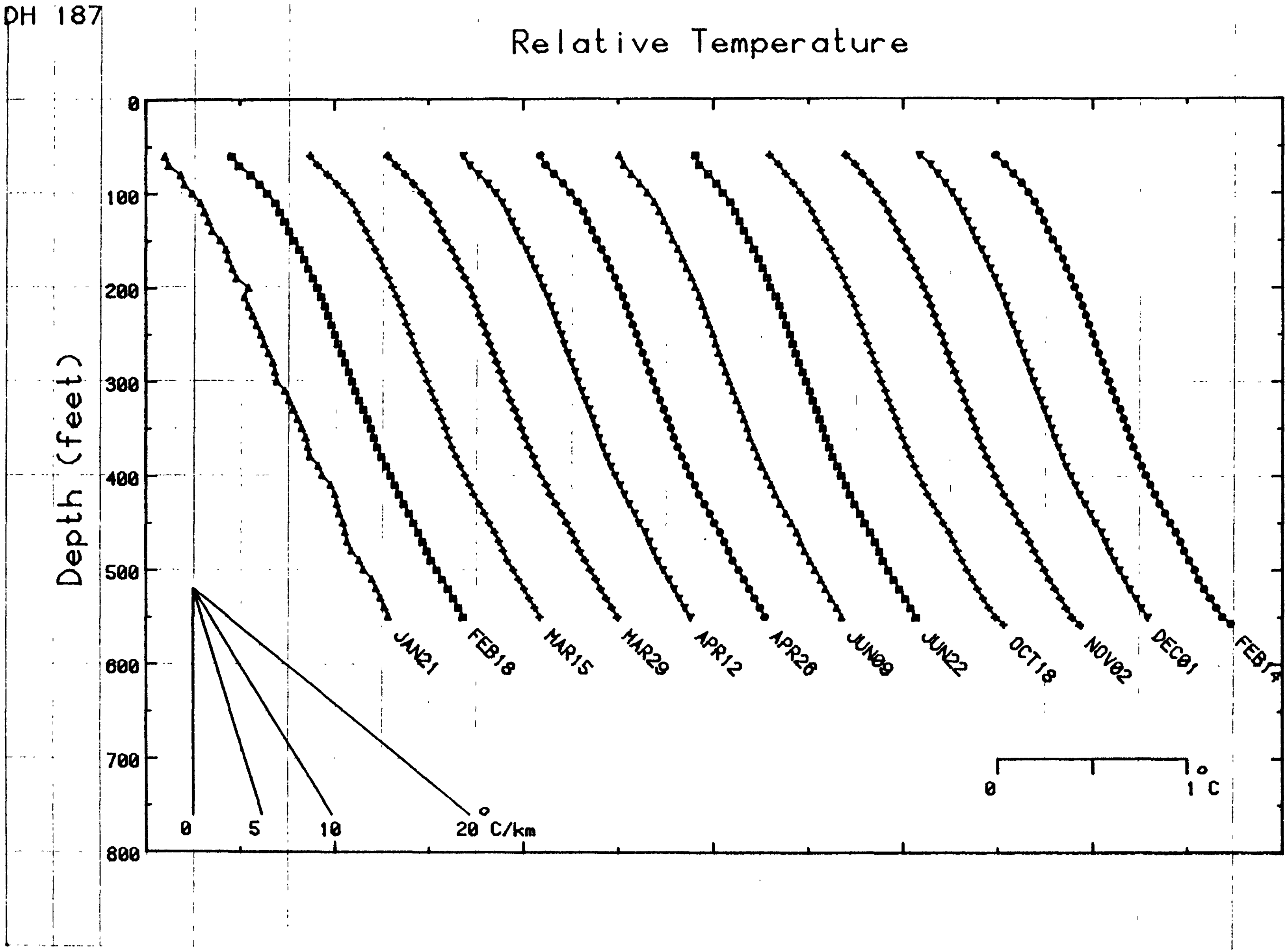


Figure 6. Temperature profiles (with arbitrary temperature origin) for DH 187 between January 21, 1983, and February 14, 1984.

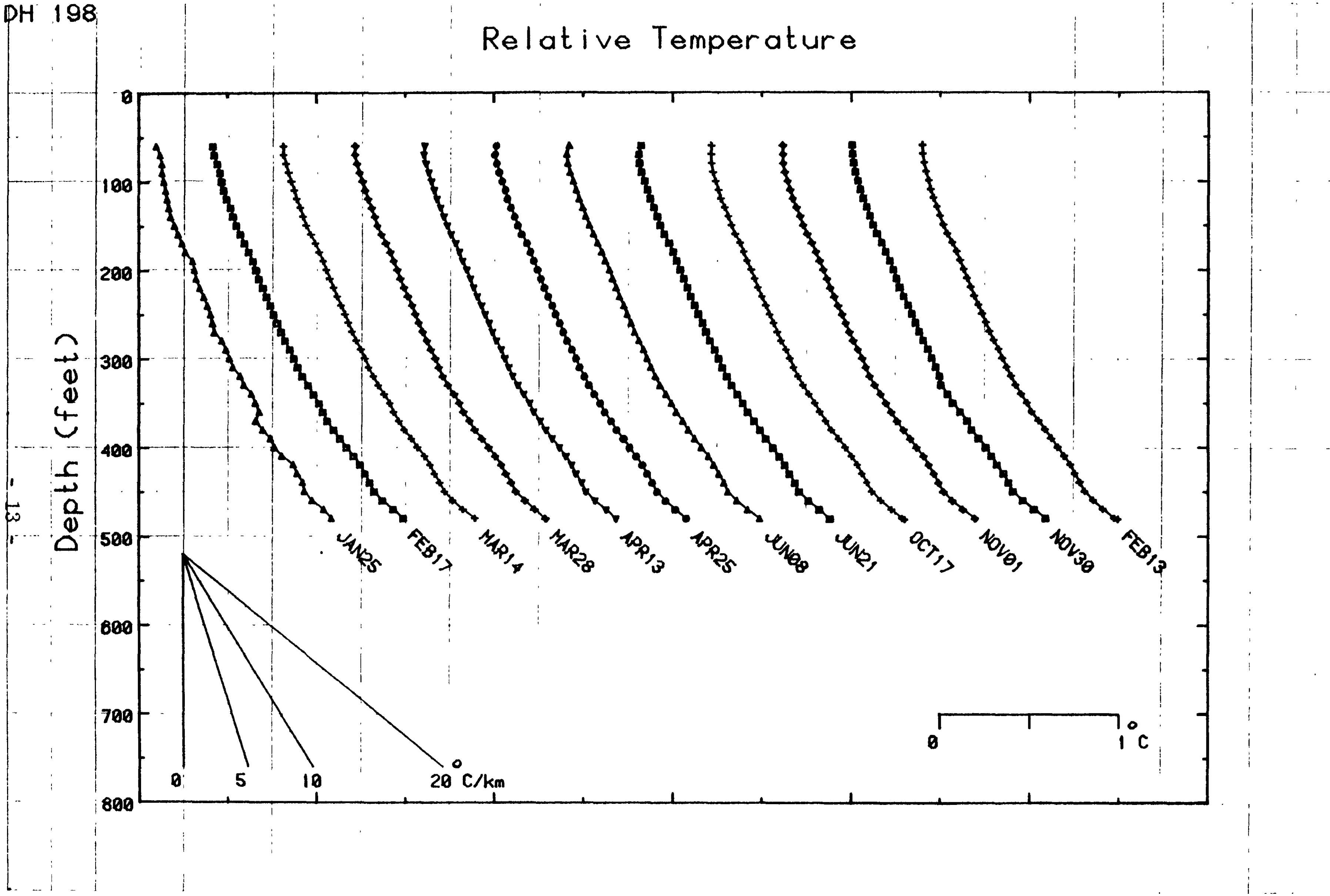


Figure 7. Temperature profiles (with arbitrary temperature origin) for DH 198 between January 25, 1983, and February 13, 1984.

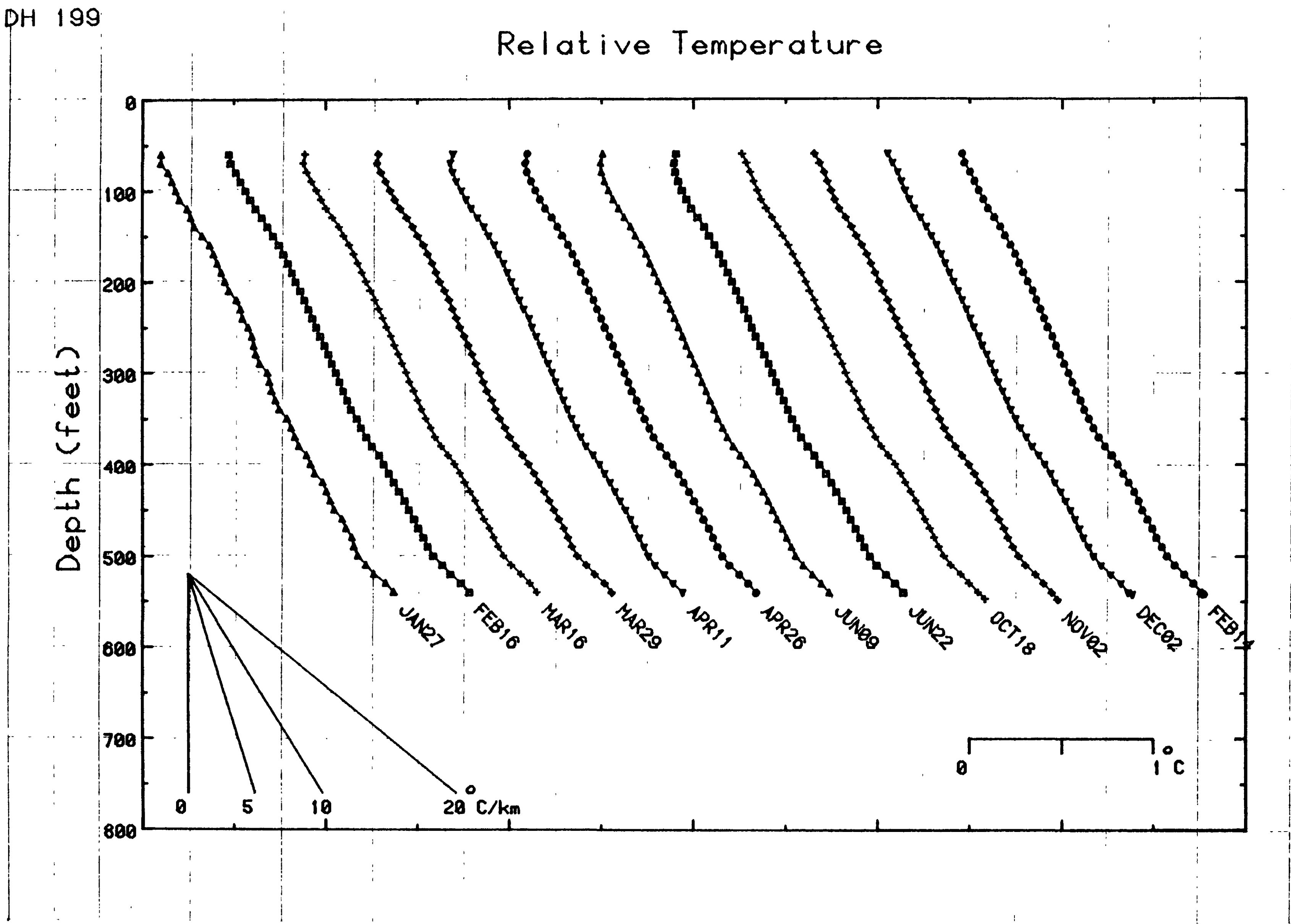


Figure 8. Temperature profiles (with arbitrary temperature origin) for DH 199 between January 27, 1983, and February 14, 1984.

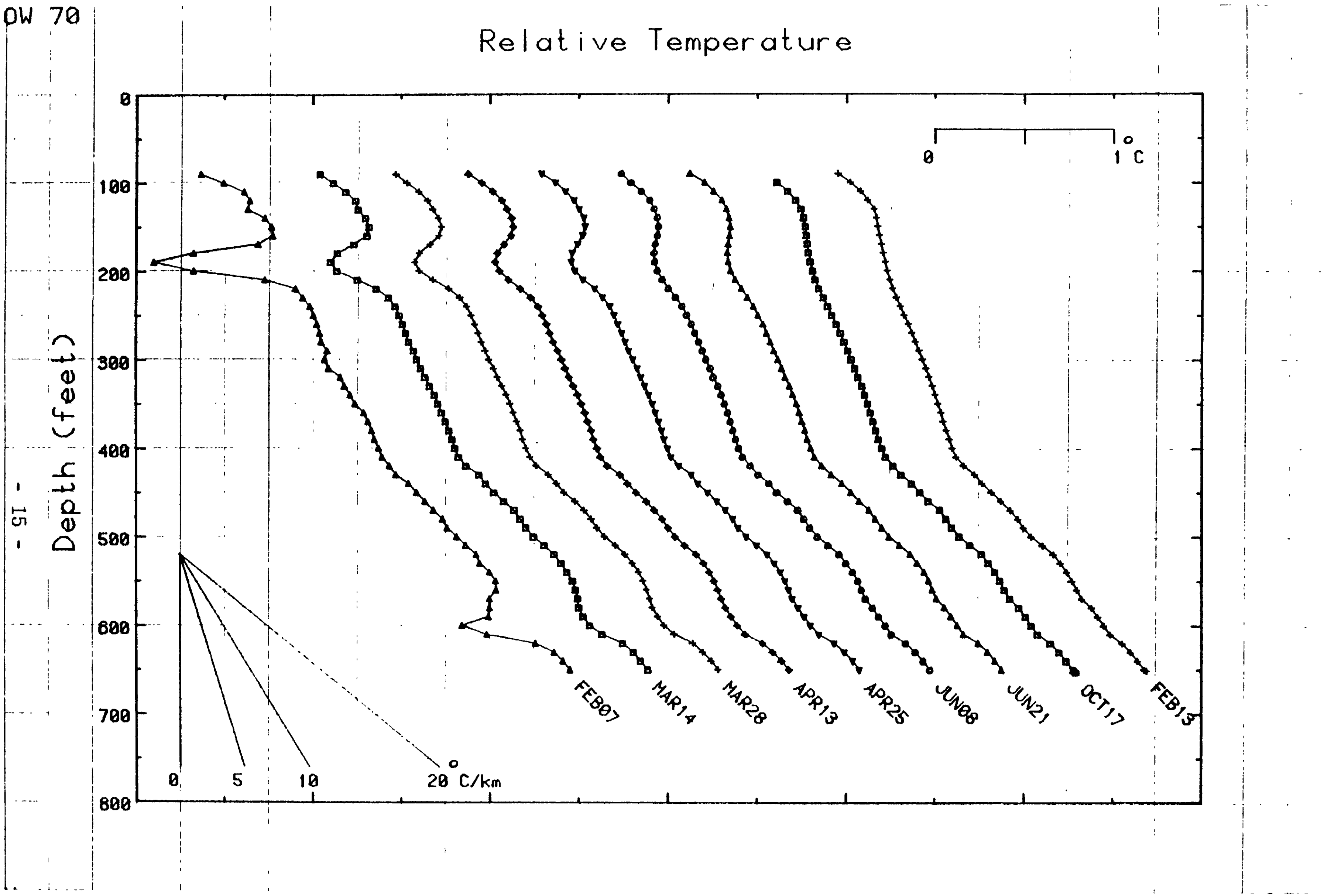


Figure 9. Temperature profiles (with arbitrary temperature origin) for OW 70 between February 7, 1983, and February 13, 1984.

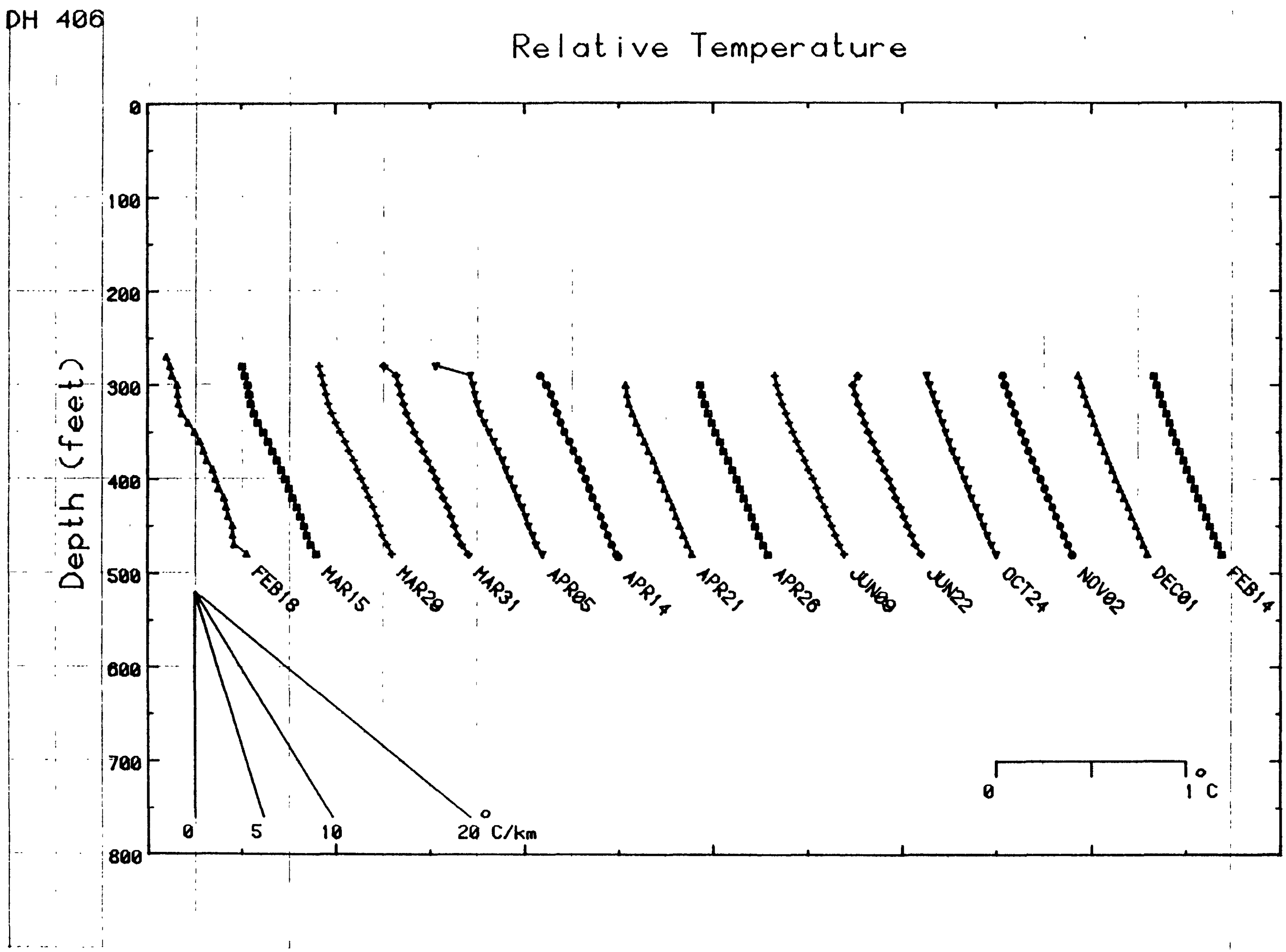


Figure 10. Temperature profiles (with arbitrary temperature origin) for DH 406 between February 18, 1983, and February 14, 1984.

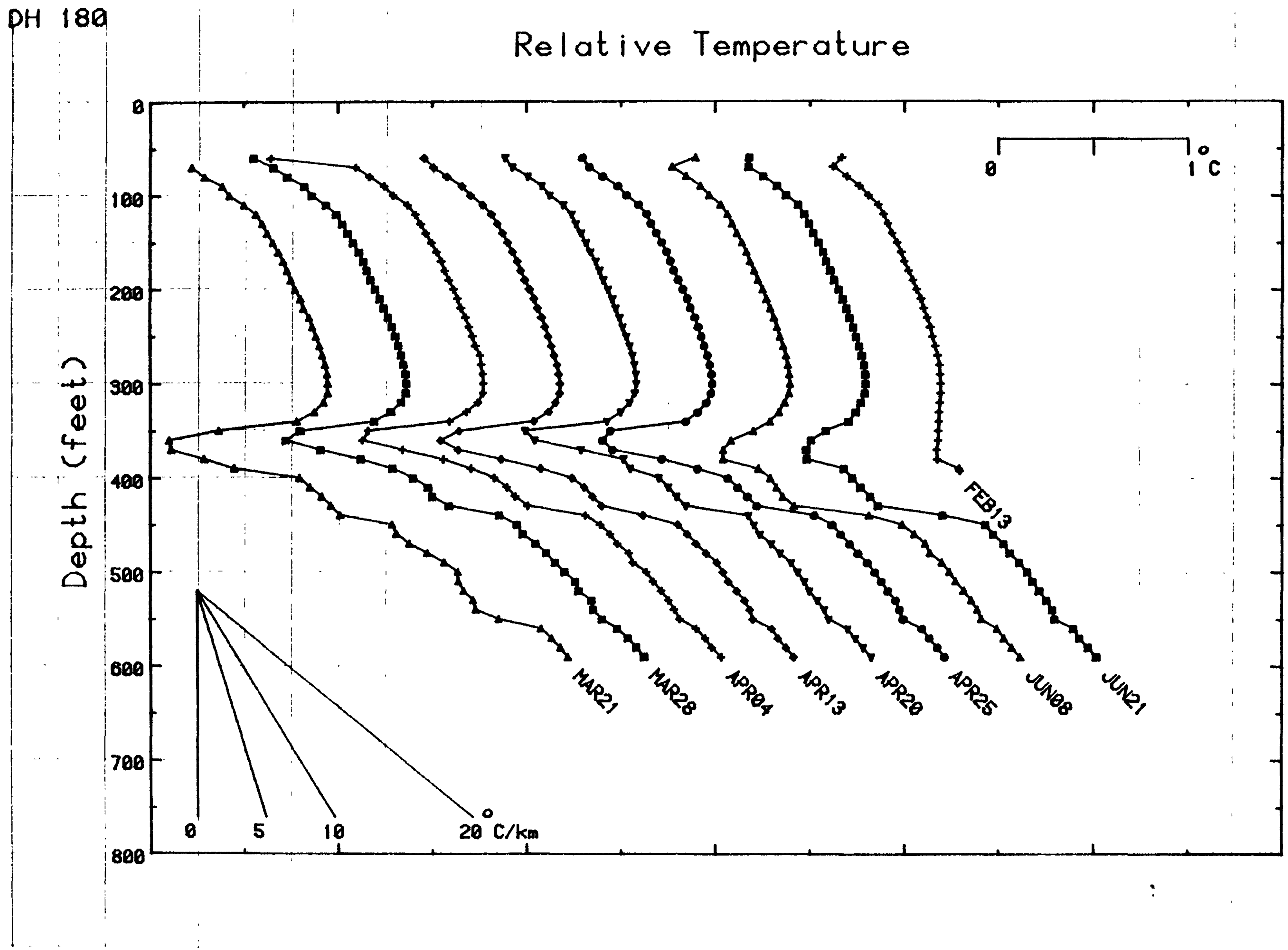


Figure 11. Temperature profiles (with arbitrary temperature origin) for DH 180 between March 21, 1983, and February 13, 1984.

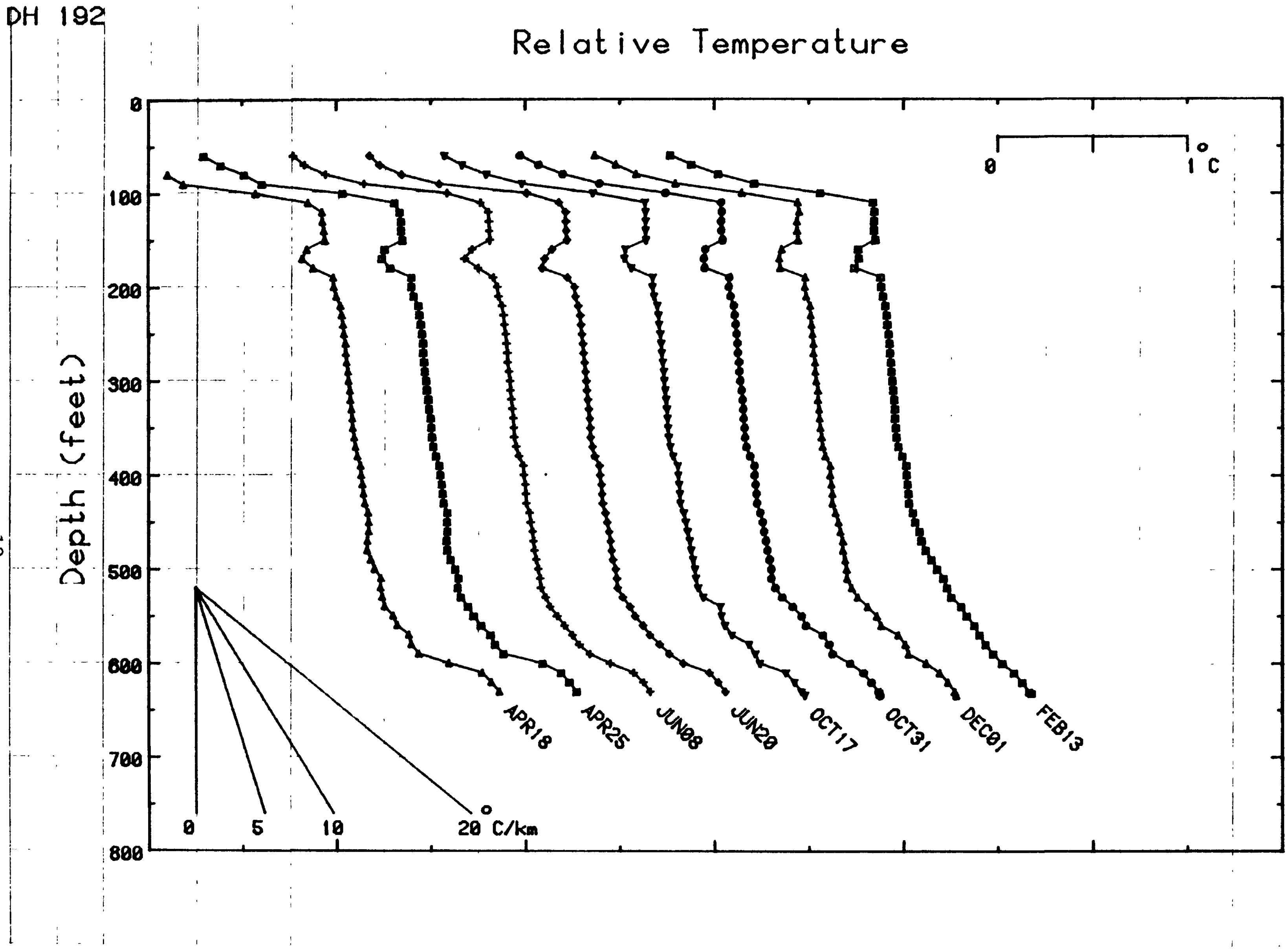


Figure 12. Temperature profiles (with arbitrary temperature origin) for DH 192 between April 18, 1983, and February 13, 1984.

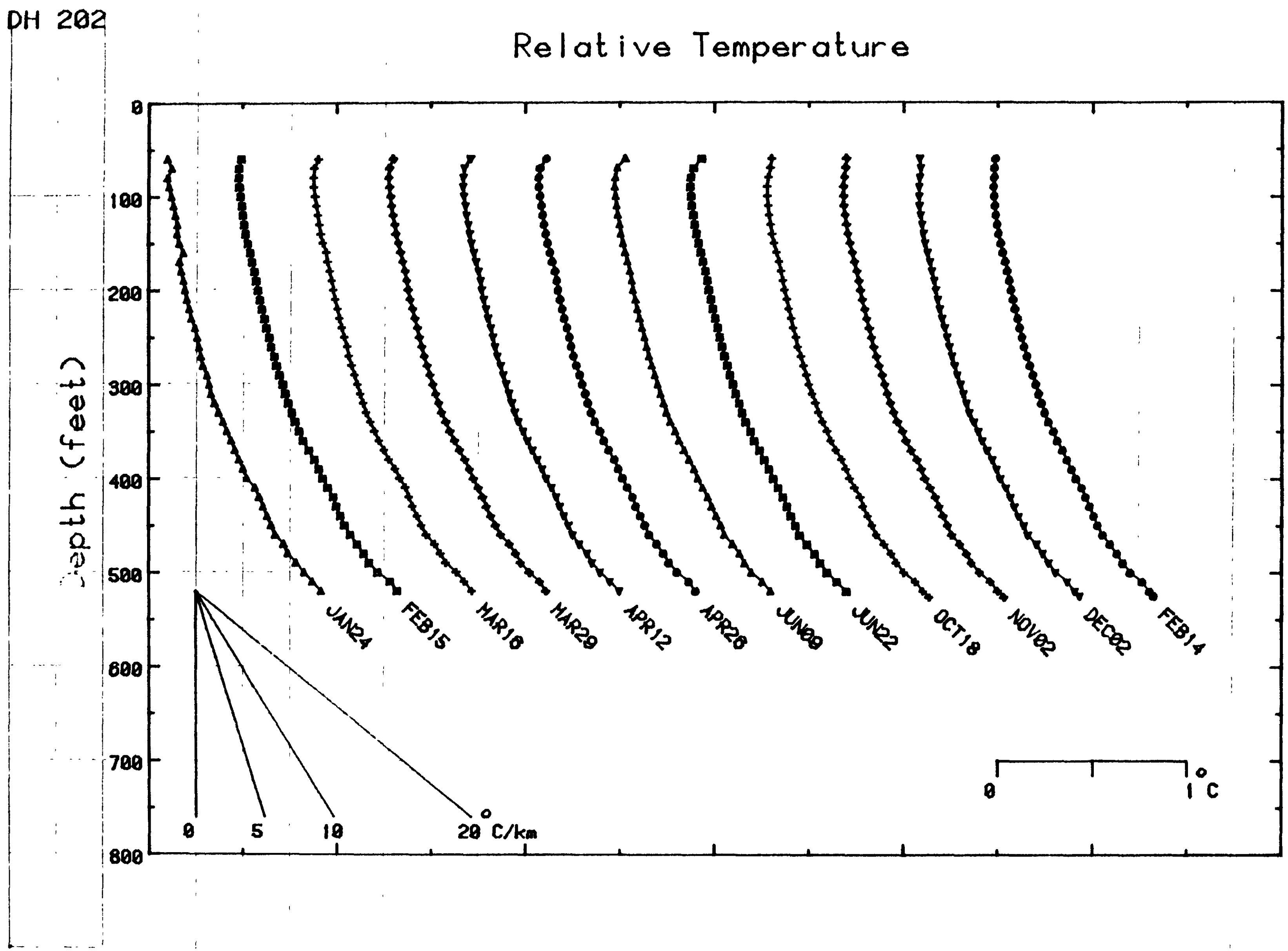


Figure 13. Temperature profiles (with arbitrary temperature origin) for DH 202 between January 24, 1983, and February 14, 1984.

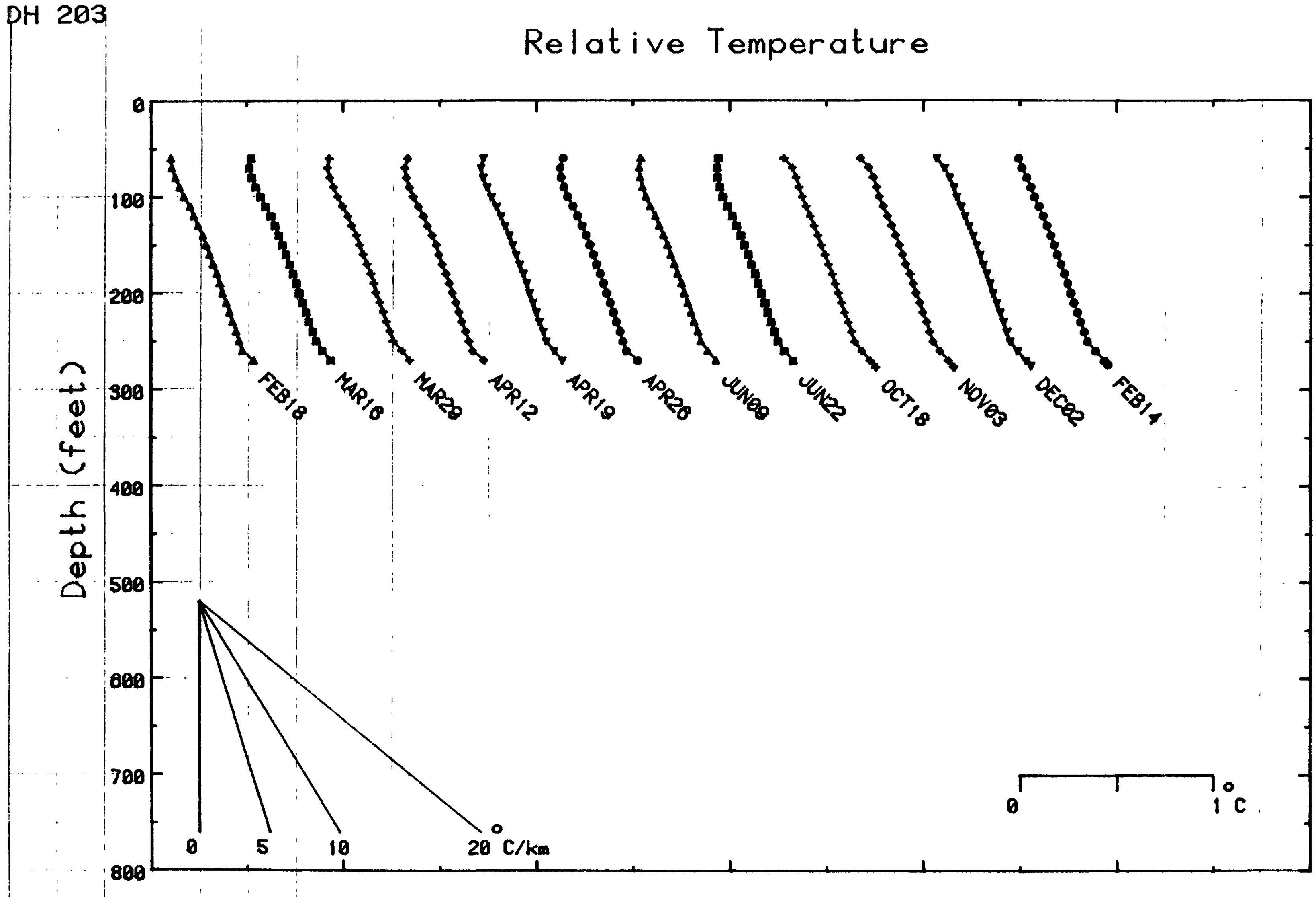


Figure 14. Temperature profiles (with arbitrary temperature origin) for DH 203 between February 18, 1983, and February 14, 1984.

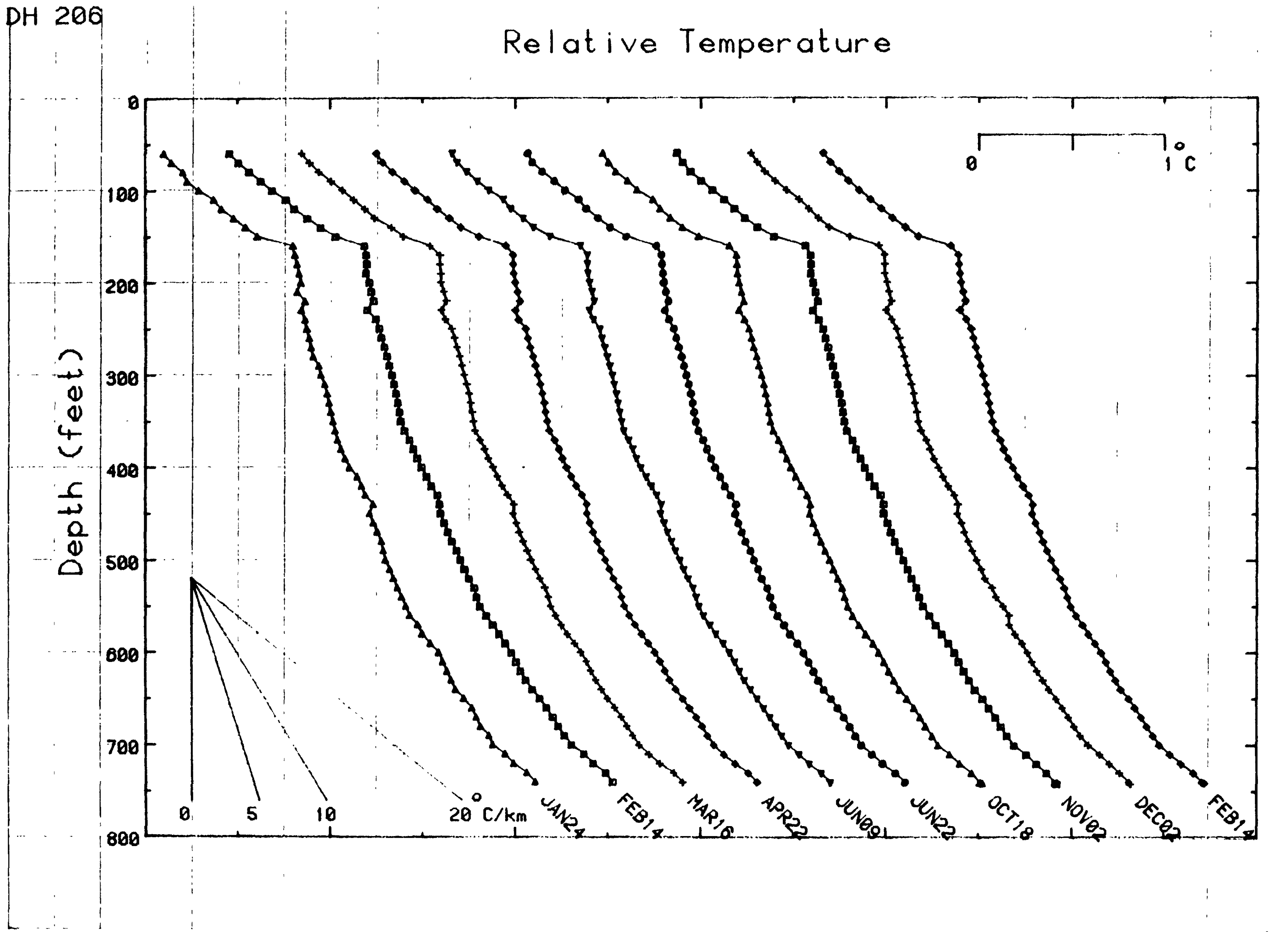


Figure 15. Temperature profiles (with arbitrary temperature origin) for DH 206 between January 24, 1983, and February 14, 1984.

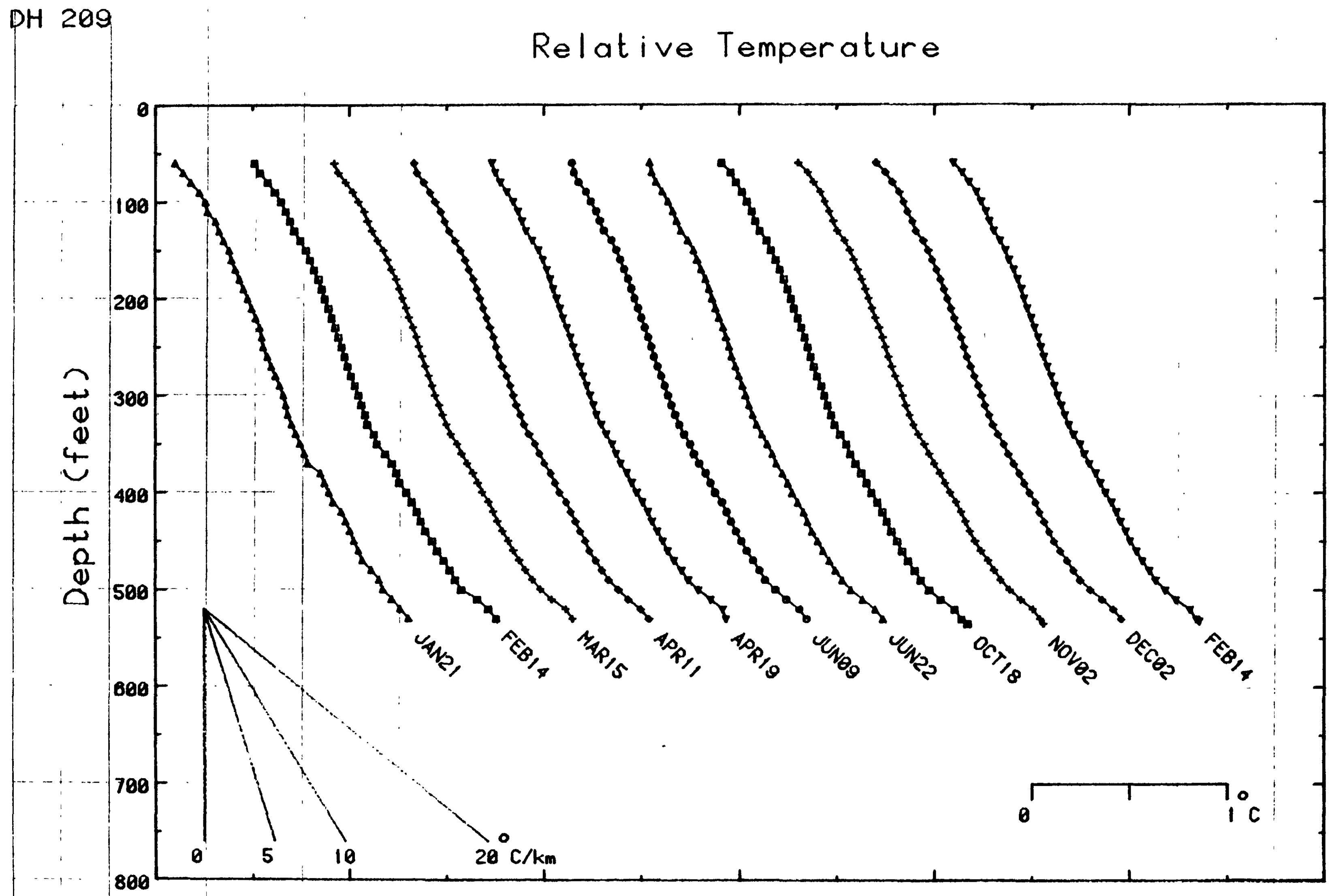


Figure 16. Temperature profiles (with arbitrary temperature origin) for DH 209 between January 21, 1983, and February 14, 1984.

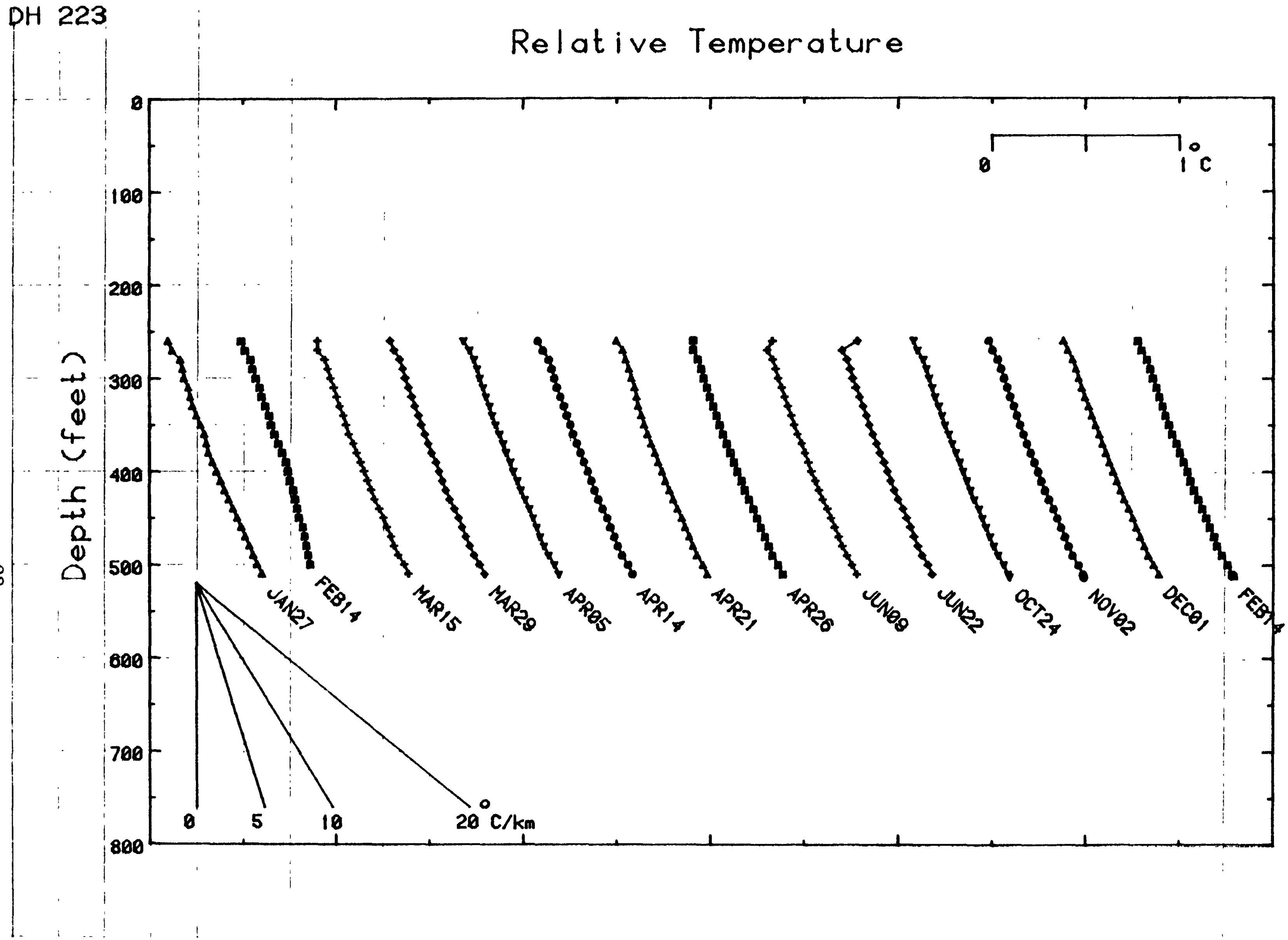


Figure 17. Temperature profiles (with arbitrary temperature origin) for DH 223 between January 27, 1983, and February 14, 1984.

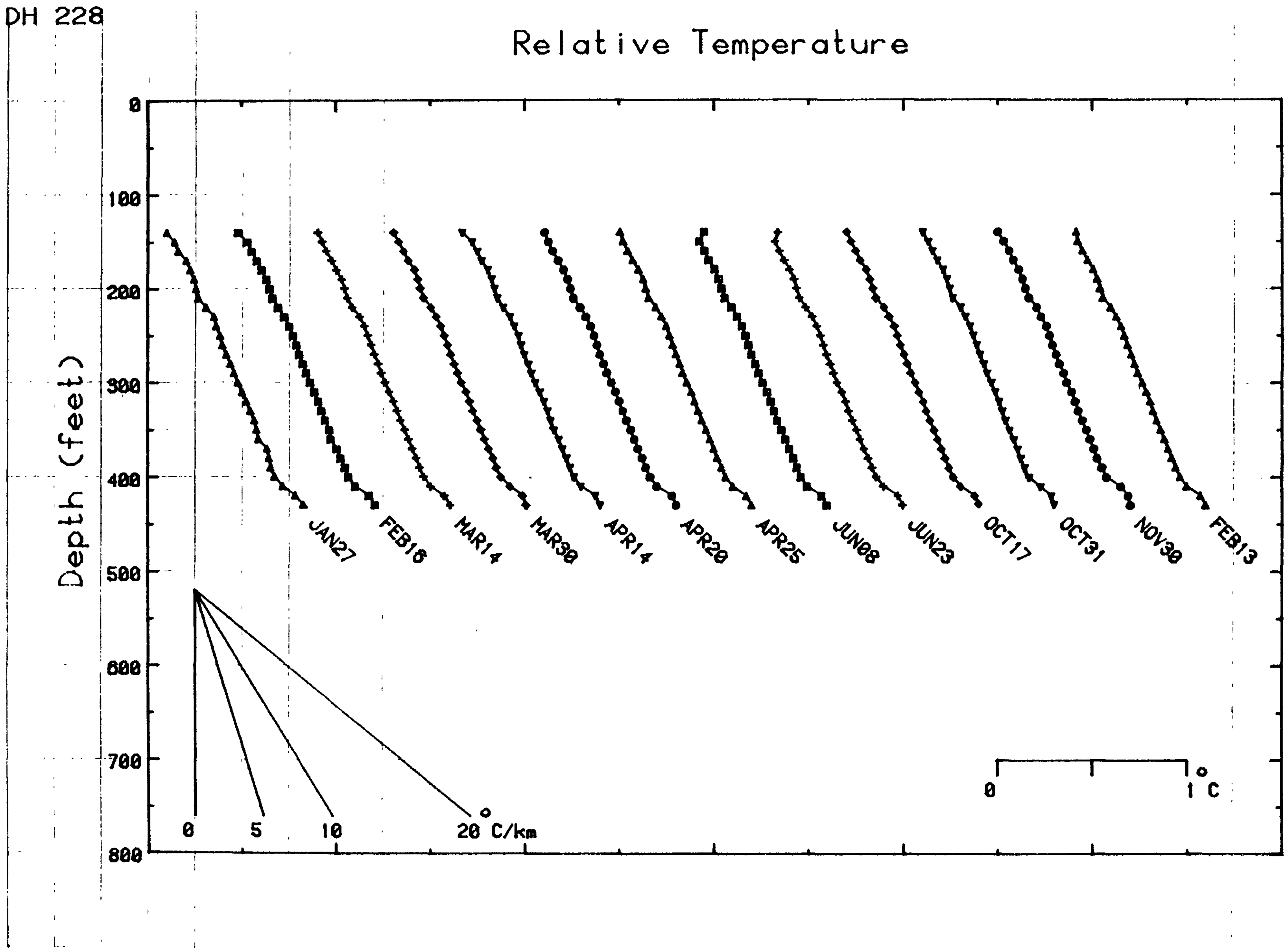


Figure 18. Temperature profiles (with arbitrary temperature origin) for DH 228 between January 27, 1983, and February 13, 1984.

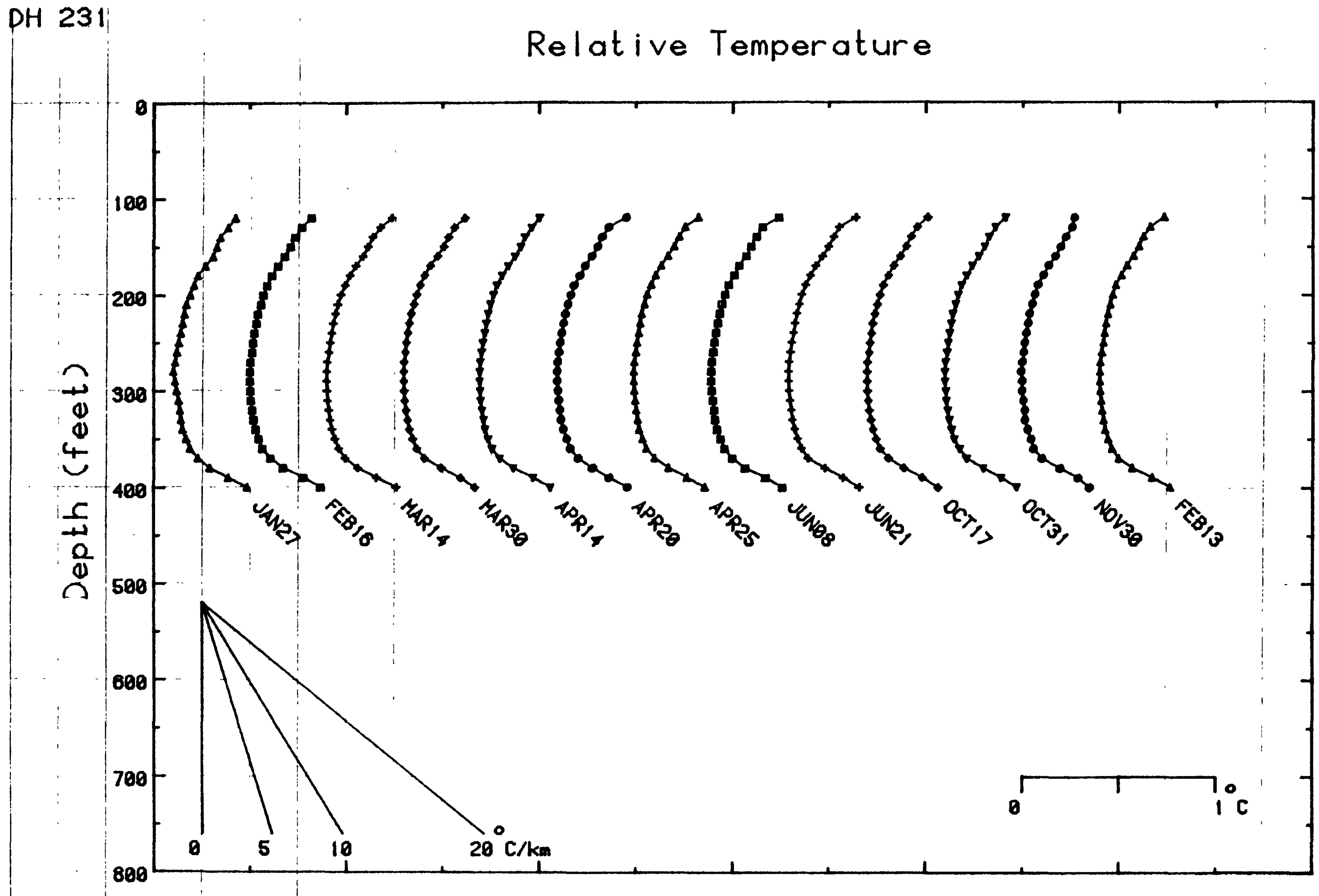


Figure 19. Temperature profiles (with arbitrary temperature origin) for DH 231 between January 27, 1983, and February 13, 1984.