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20 December 1982

Mr. Dean Pilkington
AMAX Exploration, Inc.
1707 Cole Boulevard
Golden, Colorado 80401

Dear Dean:

This is a summary of the results of applying Teledyne Geotech's two-dimensional wave number filtering technique to the thermal gradient data at Alum, Nevada.

Twenty-one temperature-depth logs provided by AMAX comprise the data base. Thermal gradients were chosen from the logs from depth intervals encompassing 30 meters whenever possible. Terrain corrections were not applied to the data because there is relatively little variation in elevation over the prospect. A surface thermal gradient contour map (figure 1) was generated over a grid extending 9 km north-south, and 12 km east-west at an elevation of 5210 ft - the average well head elevation. Spacing between grid points was 1 km. The fit to the data was approximately 2.5%.

The two-dimensional wave number filtering technique was applied to three temperature gradient profiles. Profile A-A' (figure 2) intersects intermediate depth wells I1, I2, and passes near I3. Profile B-B' (figure 3) runs east-west through I2; profile C-C' (figure 4) runs north-south through I2. Estimates of subsurface temperatures were made at three locations, corresponding to the locations of the three intermediate depth wells (figures 5, 6, and 7). A surface temperature of 12°C and a background gradient of 50°C/km were assumed for the prospect (53.6°F, 2.74°F/100 ft).

The main conclusions drawn from the wave number filtering are:

At well location I2 (figure 6), the temperature estimates from the three intersecting profiles indicate a probable maximum temperature between 200 and 250°F (95-120°C). The depth of the rollover in the estimated temperature-depth profile is about 1500 ft (450 m). The temperature-depth profiles at well locations I1 (figure 5) and I3 (figure 7) are likely to be similar.

The two-dimensional wave number technique makes use of the information about depth to the source contained in the wave number spectrum of the surface thermal gradient data. It consists of three basic steps (Li et al, 1982). The first step is to parameterize a two-dimensional model of the earth into two sets of discrete line sources, located to allow a separation of the contributions from shallow and deep heat sources. The second step consists of solving for the model source strengths by minimizing the error, in a constrained least-squares sense, between the observed spectrum and the spectrum predicted by the model sources. The third step consists of constructing a filtered set of gradient data from the modeled deep source distribution. Alternatively, the model sources can be used to estimate subsurface temperatures. This latter technique was used to estimate the subsurface temperatures at locations I1, I2, and I3 (figure 1) which are the locations of the three intermediate-depth wells. This was done stepwise using a series of models. Each model contains two source layers that are separated in depth by 600 m (Swanberg and Li, 1982). The layers are shifted to greater depths with each model. The resulting deep source distribution from each model is used to estimate the temperature at a point mid-way between the two source layers.

Profiles A-A', B-B', and C-C' intersect at intermediate depth well I2. Deep source distributions from each profile were used to estimate temperatures at I2 (figure 6). From the range of values of the three estimates, it appears as if the maximum temperature may be 200 to 250°F (95-120°C) with the rollover occurring about 1500 to 2000 ft (450-600 m). The well may be isothermal below this depth.

Temperatures were estimated for intermediate depth wells I1 and I3 using deep sources distributions from profile A-A' (figures 5 and 7). Both temperature-depth profiles resemble the profile for I2 in that the maximum temperatures approach 200 to 250°F (95-120°C) before the rollover at a depth of approximately 2000 ft (600 m).

The surface gradient contour map (figure 1) shows an enlongated anomaly trending northwest-southeast. The elongation of the anomaly has been heavily influenced by thermal gradient data from well 17 in the northeast quadrant of the model, and to a lesser extent by wells 14 and 20 in the south. Profile A-A' parallels this trend. The temperature-depth profiles estimated from A-A' at I1, I2, and I3 using the wave number filtering process described above are similar in character. Temperatures increase smoothly with depth to about 2000 ft (600 m). Below this depth, temperatures begin to oscillate. Generally, however, the temperatures continue to increase at a gradient above background. This may indicate the existence of sources deeper than 2000 ft.

Profiles B-B' and C-C' intersect A-A' (and the trend of the anomaly) at location I2. Processing of these profiles yield temperature estimates which increase to about 200°F (95°C) at about 2000 ft (600 m), but then fall off sharply and consistently back to background. This suggests that there are no sources below 2000 ft which contribute to the surface thermal anomaly.

The linear trend of the anomaly could be viewed as a shallow thermal aquifer spreading along a northwest-southeast direction. If this is a viable model, the temperature-depth estimates at I2 from profiles B-B' and C-C' probably more accurately reflect the shallow nature of that aquifer than the estimates from profile A-A'.

The drilling of a few more shallow gradient boreholes in the northeast and southeast of the grid is suggested. These would be useful to further define the anomaly of the Alum prospect. The addition of these wells could increase the confidence of the subsurface estimates. Expanding the areal coverage to the west and north by adding more shallow boreholes will help clarify the trend of the gradient as it approaches background values.

References

Li, T. M. C., C. A. Swanberg, and J. F. Ferguson, 1982, A method for filtering hot spring noise from shallow temperature gradient data, in Transactions, vol. 6, pp. 137-140, Geothermal Resources Council.

Swanberg, C. A., and T. M. C. Li, 1982, Wave number filtering of thermal data from the Valles Caldera, New Mexico, in Transactions, vol. 6, pp. 181-184, Geothermal Resources Council.

As always, if there are any questions, please feel free to call us.

Sincerely,

Todd M. C. Li

Peter R. Marvin

TMCL/PRM/cr

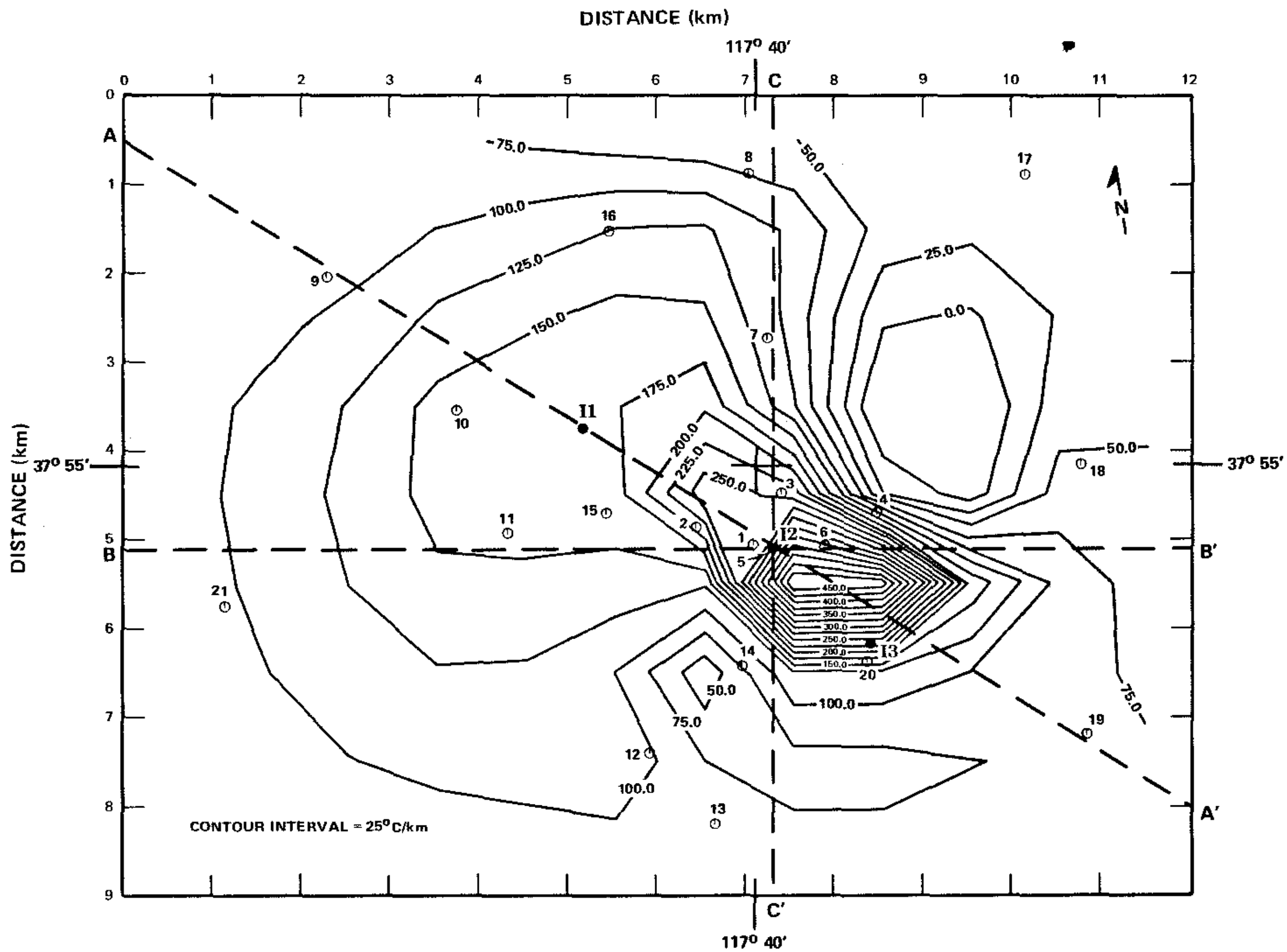


FIGURE 1. SURFACE GRADIENTS AT ALUM, NEVADA ELEVATION = 5012 FT, SURFACE FIT ≅ 2.5%.

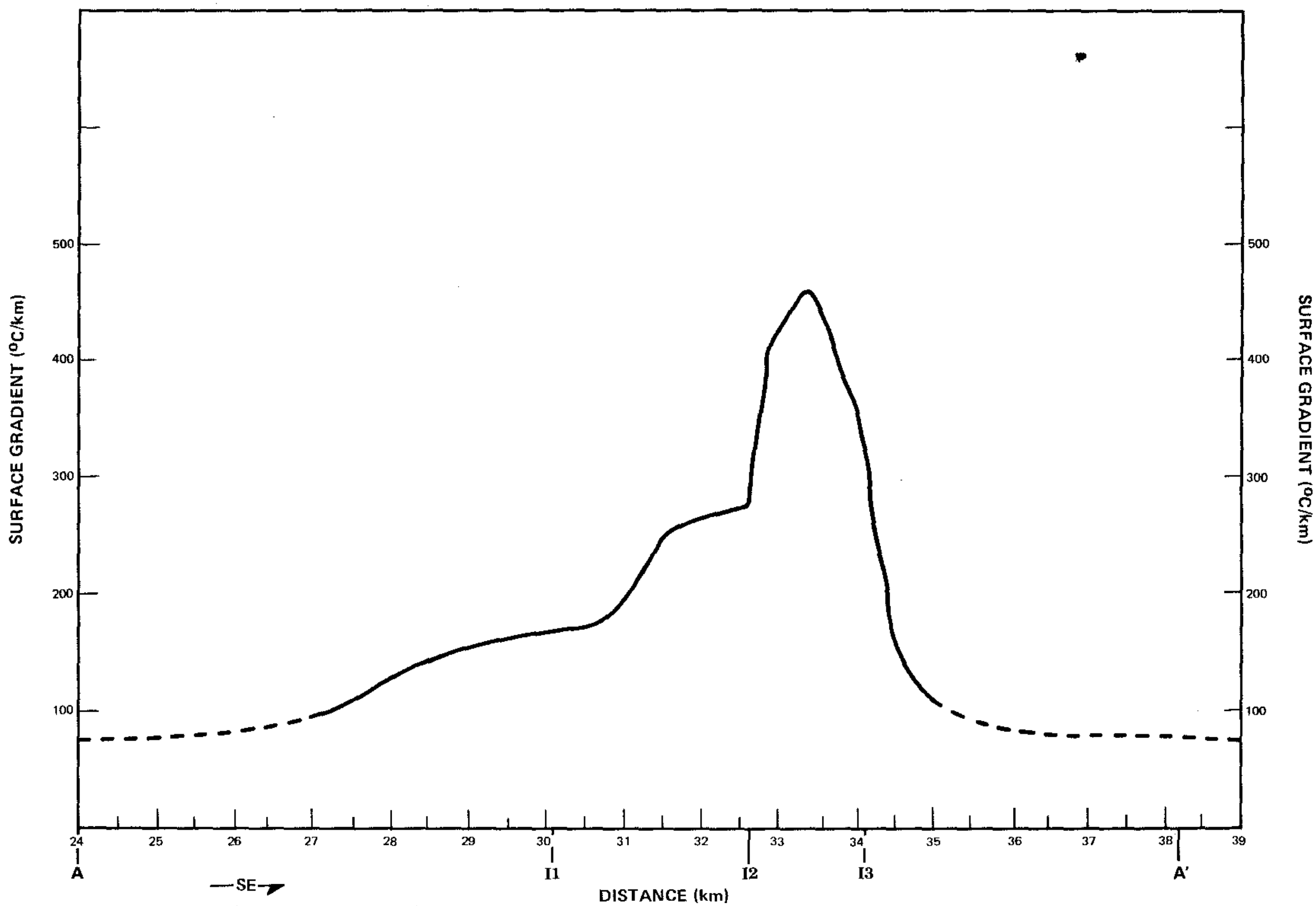


FIGURE 2. SURFACE GRADIENT PROFILE A-A' AT ALUM, NEVADA WITH LOCATIONS OF INTERMEDIATE DEPTH WELLS I1 AND I2. I3' IS THE LOCATION ON A-A' CLOSEST TO WELL I3.

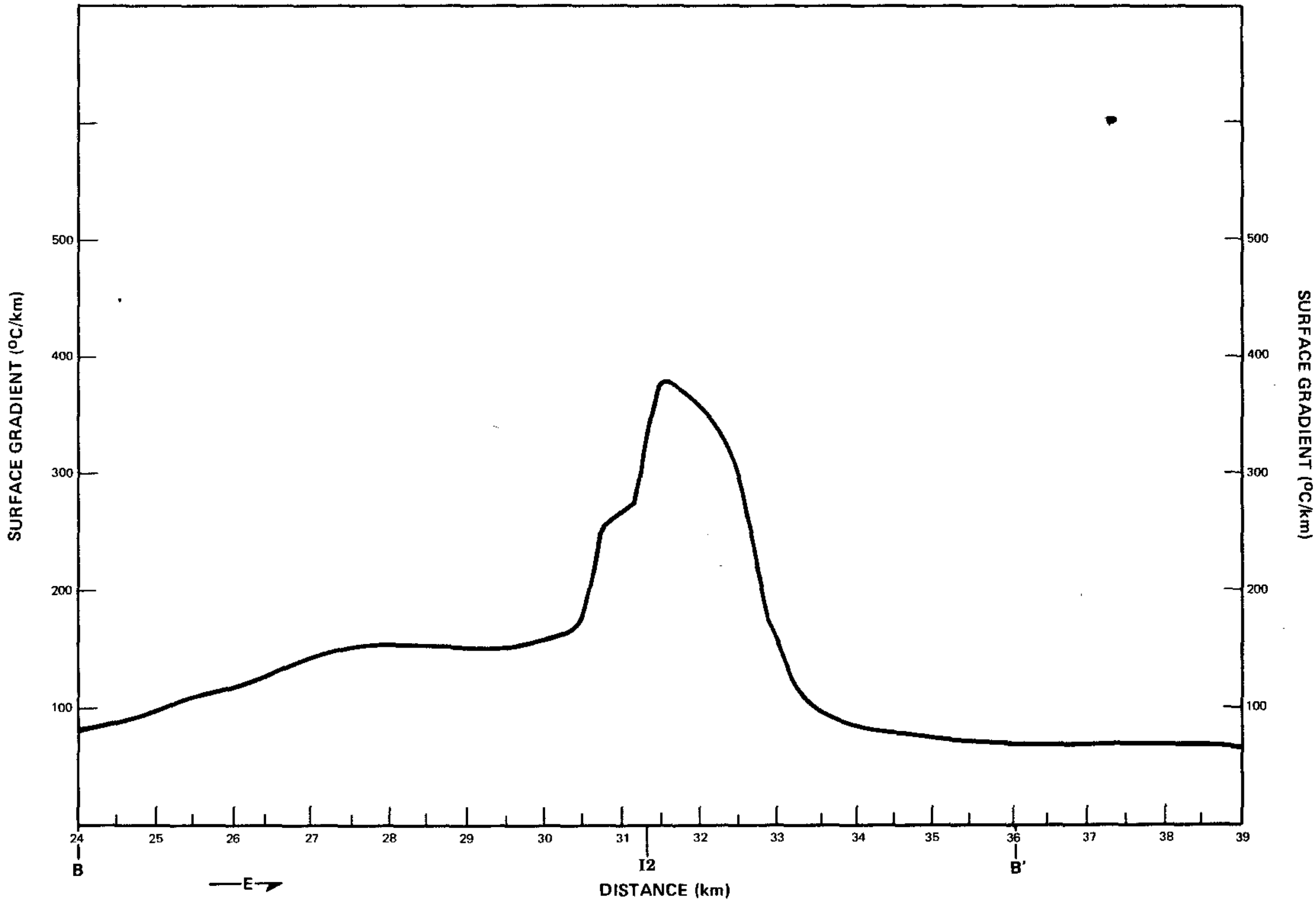


FIGURE 3. SURFACE GRADIENT PROFILE B-B' AT ALUM, NEVADA WITH LOCATION OF INTERMEDIATE DEPTH WELL I2

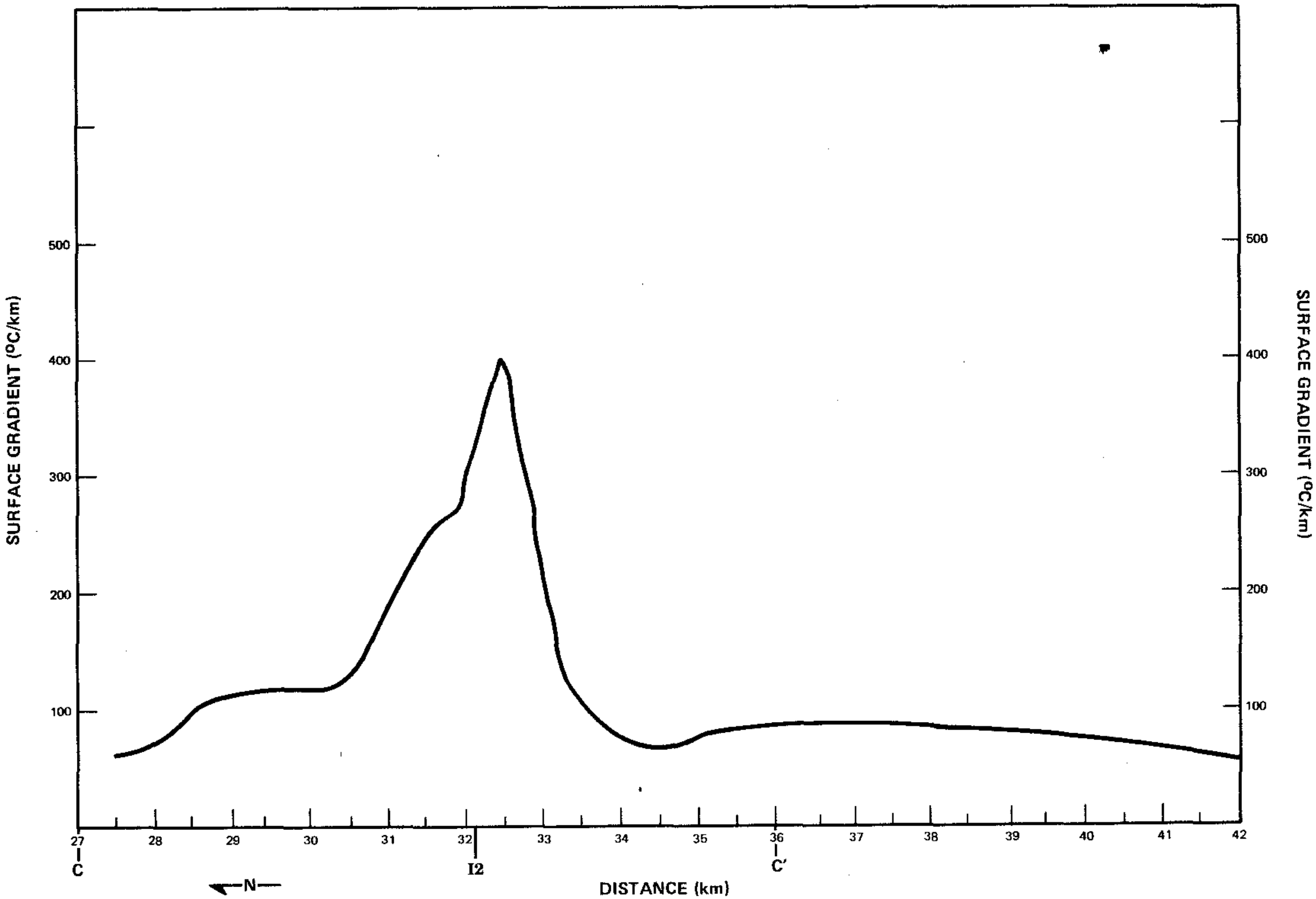


FIGURE 4. SURFACE GRADIENT PROFILE C-C' AT ALUM, NEVADA WITH LOCATION OF INTERMEDIATE DEPTH WELL I2.

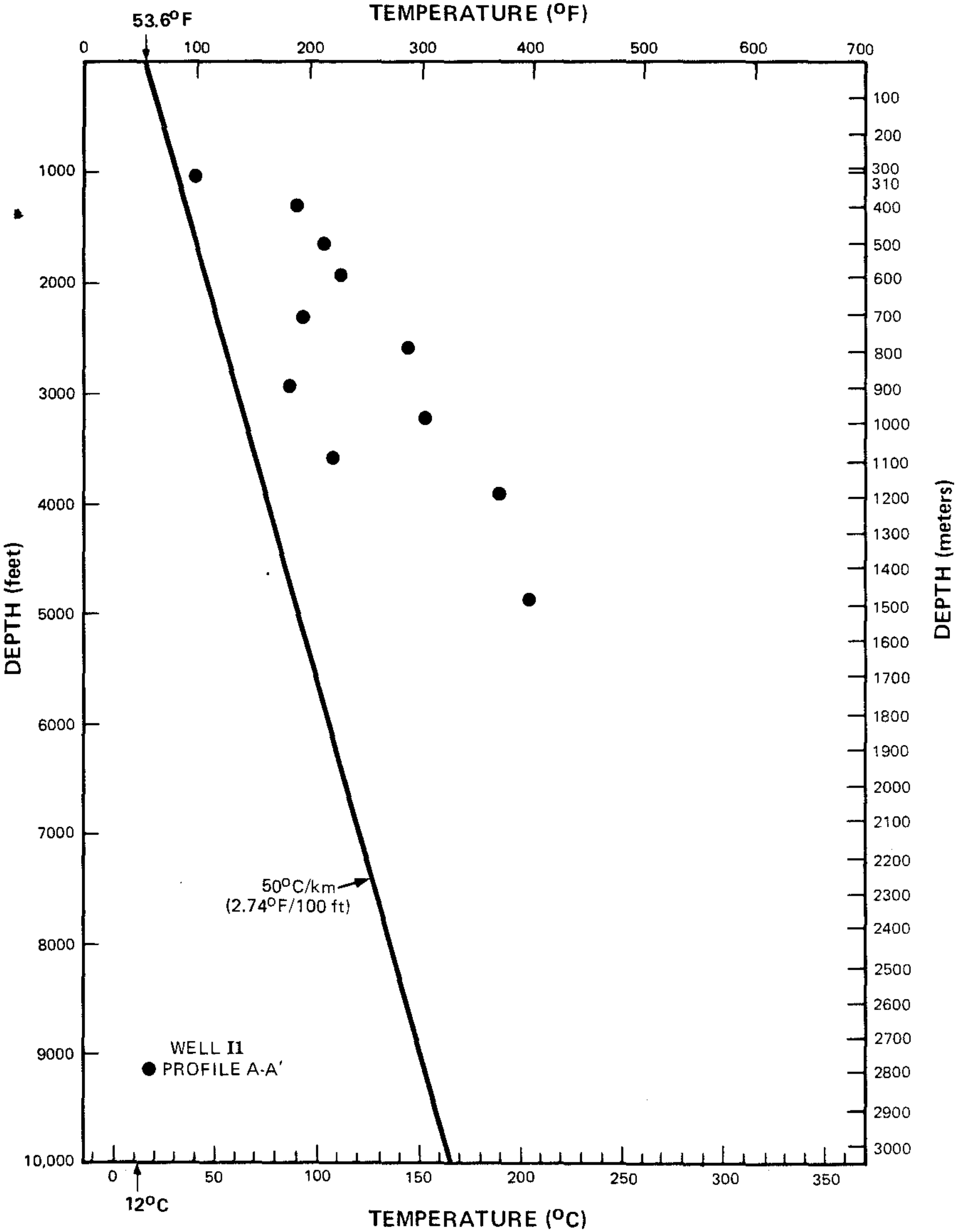


FIGURE 5. ESTIMATED SUBSURFACE TEMPERATURES AT INTERMEDIATE DEPTH WELL I1, WHICH IS LOCATED ON PROFILE A-A', ALUM, NEVADA

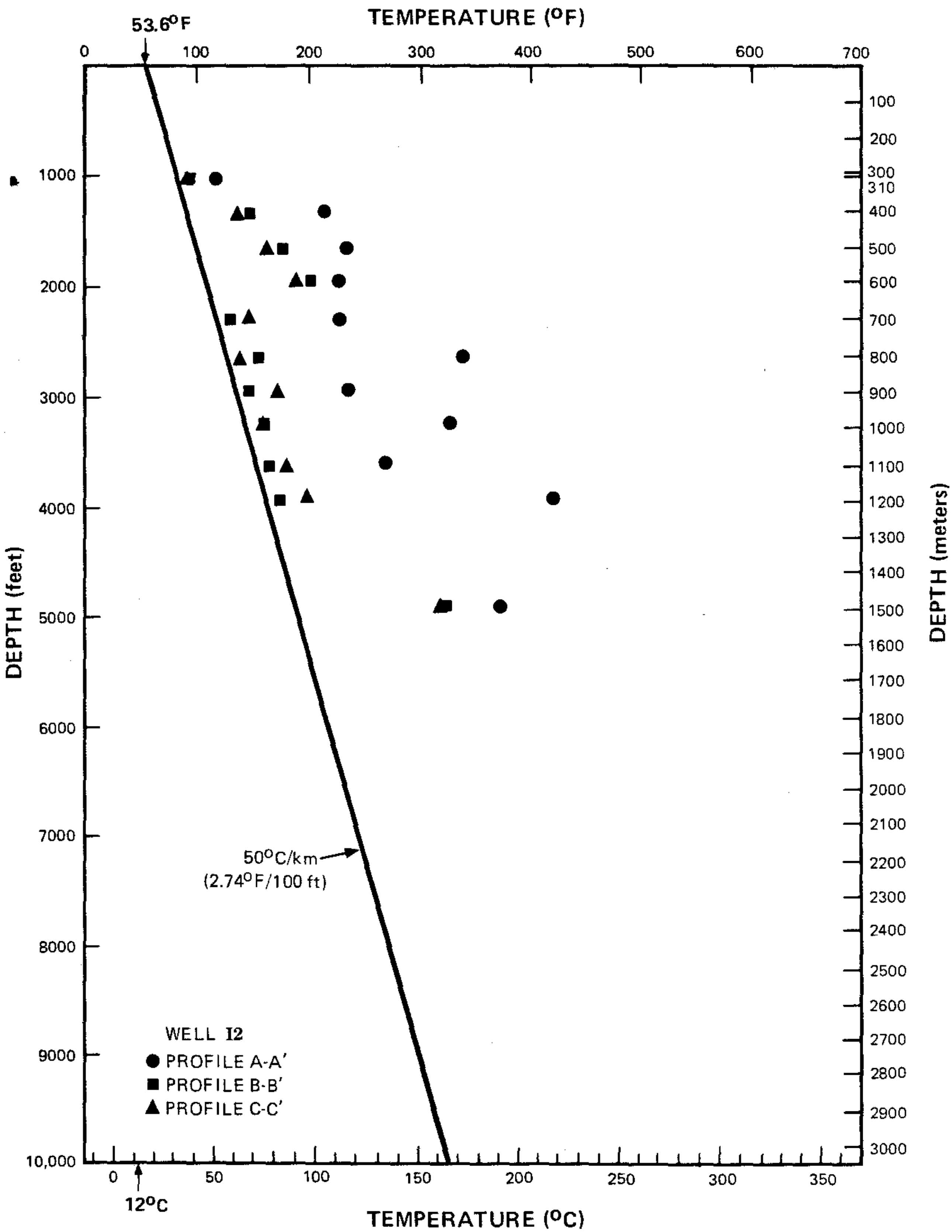


FIGURE 6. ESTIMATED SUBSURFACE TEMPERATUES AT INTERMEDIATE DEPTH WELL I2, WHICH IS LOCATED AT THE INTERSECTION OF PROFILES A-A′, B-B′, AND C-C′, ALUM, NEVADA

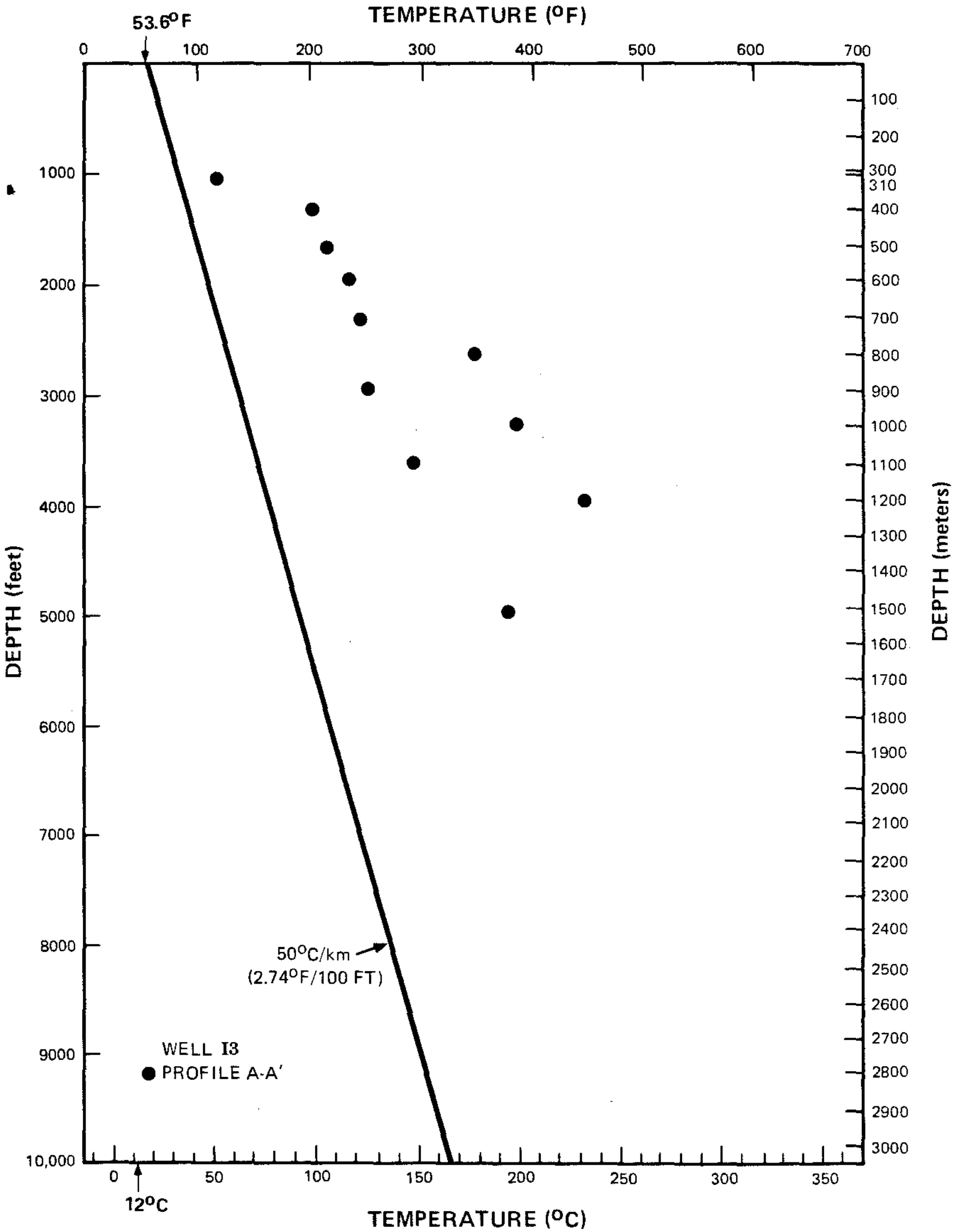


FIGURE 7. ESTIMATED SUBSURFACE TEMPERATURES AT LOCATION I3' ON PROFILE A-A', ALUM, NEVADA, WHICH IS NEAR INTERMEDIATE DEPTH WELL I3.

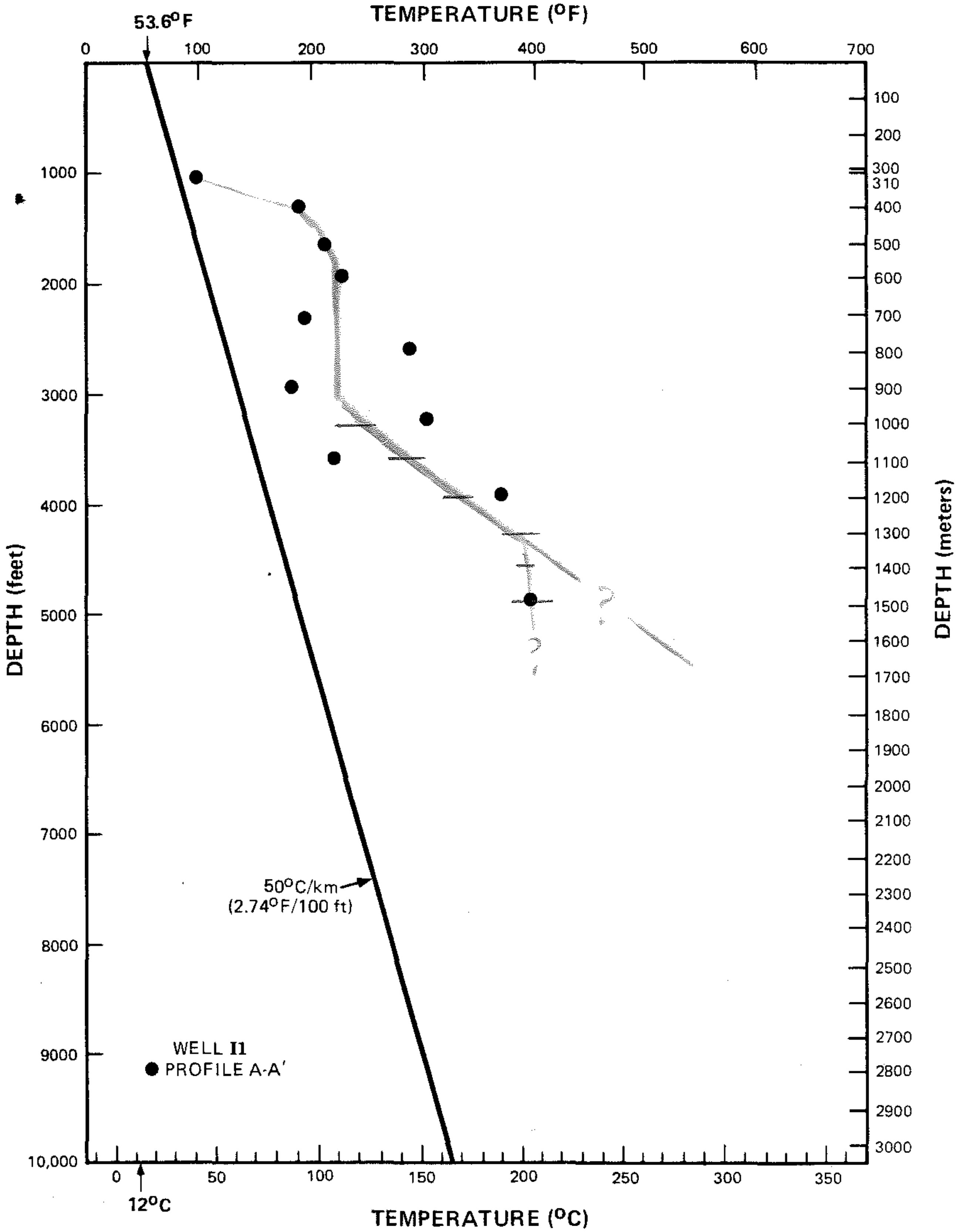


FIGURE 5. ESTIMATED SUBSURFACE TEMPERATURES AT INTERMEDIATE DEPTH WELL I1, WHICH IS LOCATED ON PROFILE A-A', ALUM, NEVADA

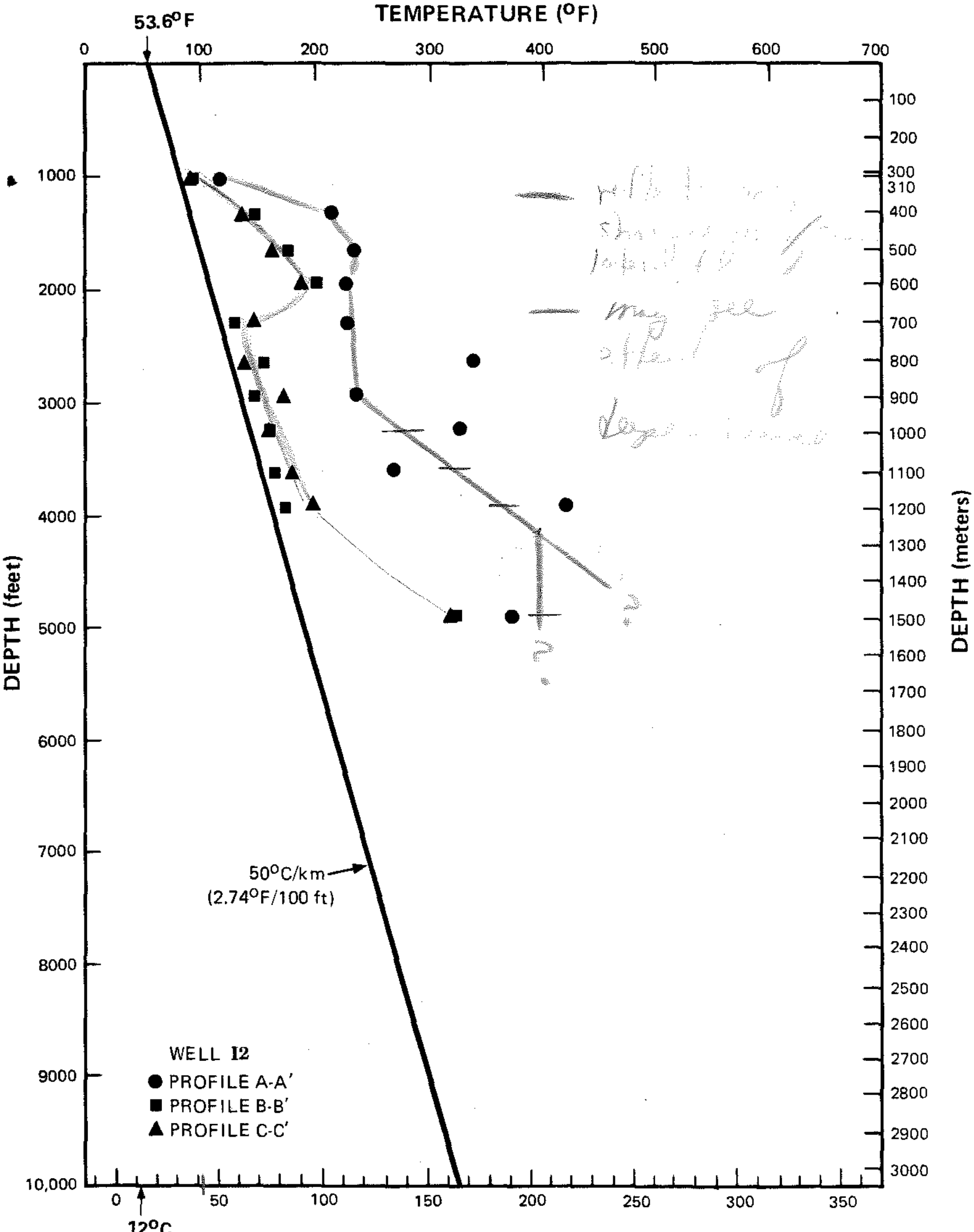


FIGURE 6. ESTIMATED SUBSURFACE TEMPERATUES AT INTERMEDIATE DEPTH WELL I2, WHICH IS LOCATED AT THE INTERSECTION OF PROFILES A-A′, B-B′, AND C-C′, ALUM, NEVADA

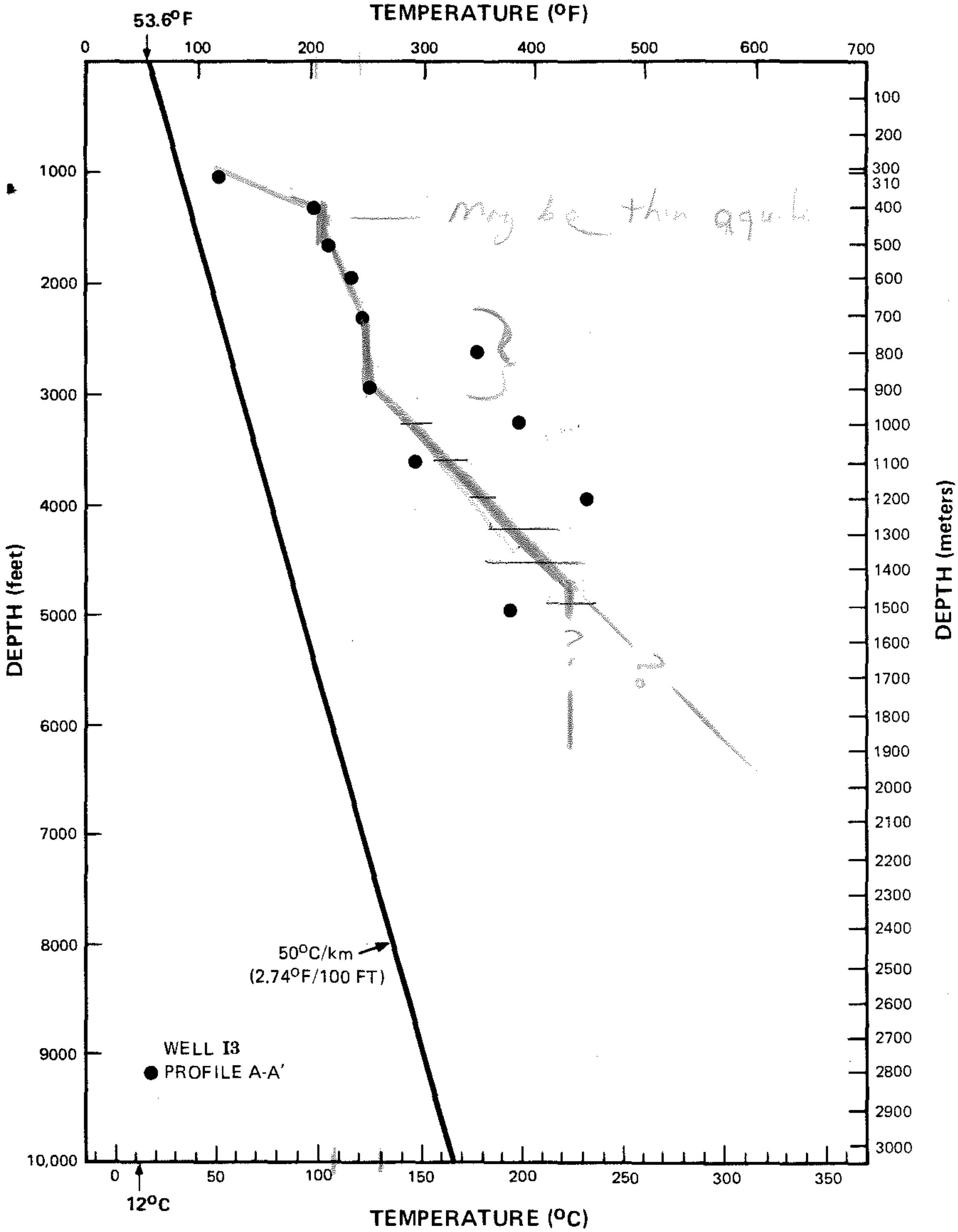
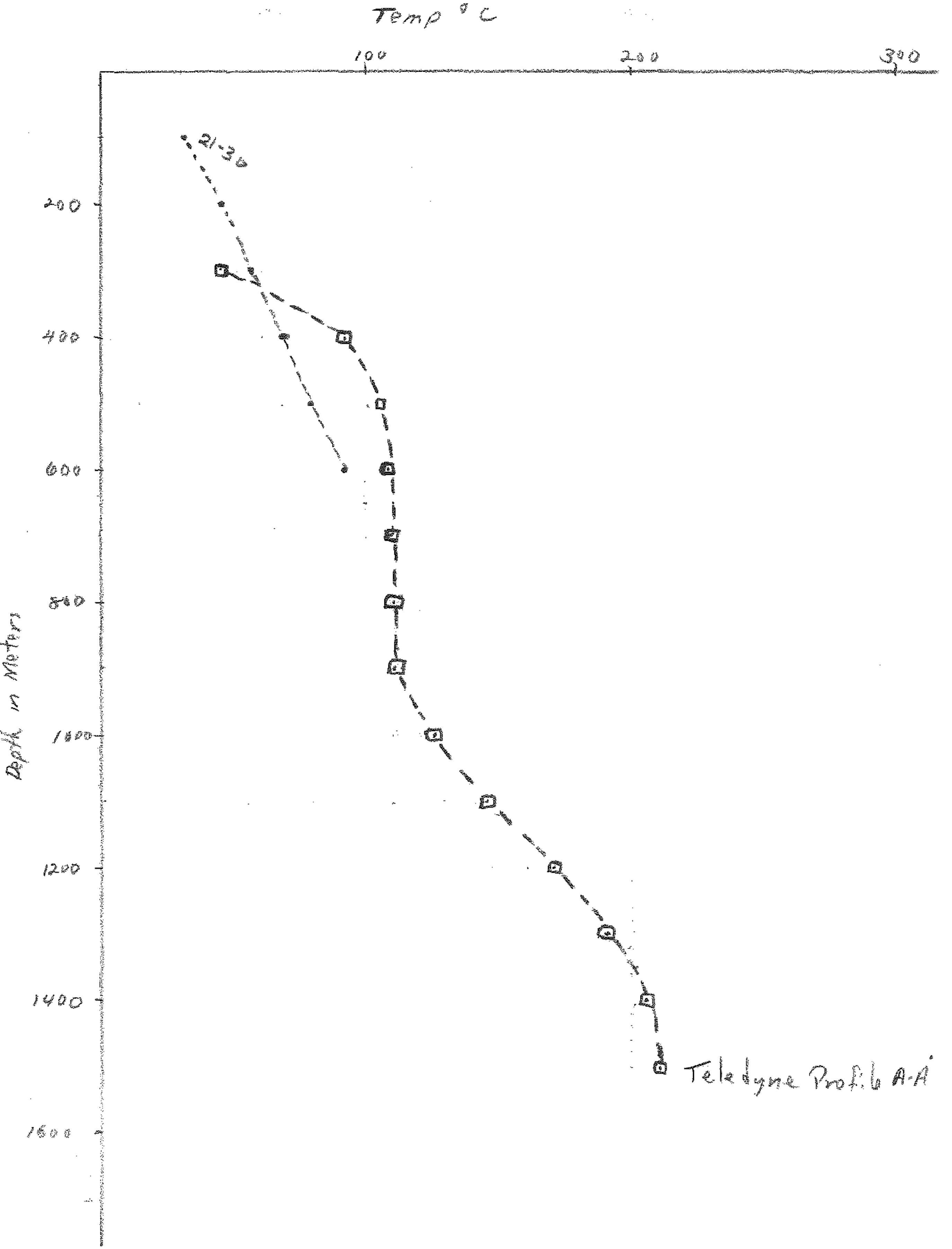
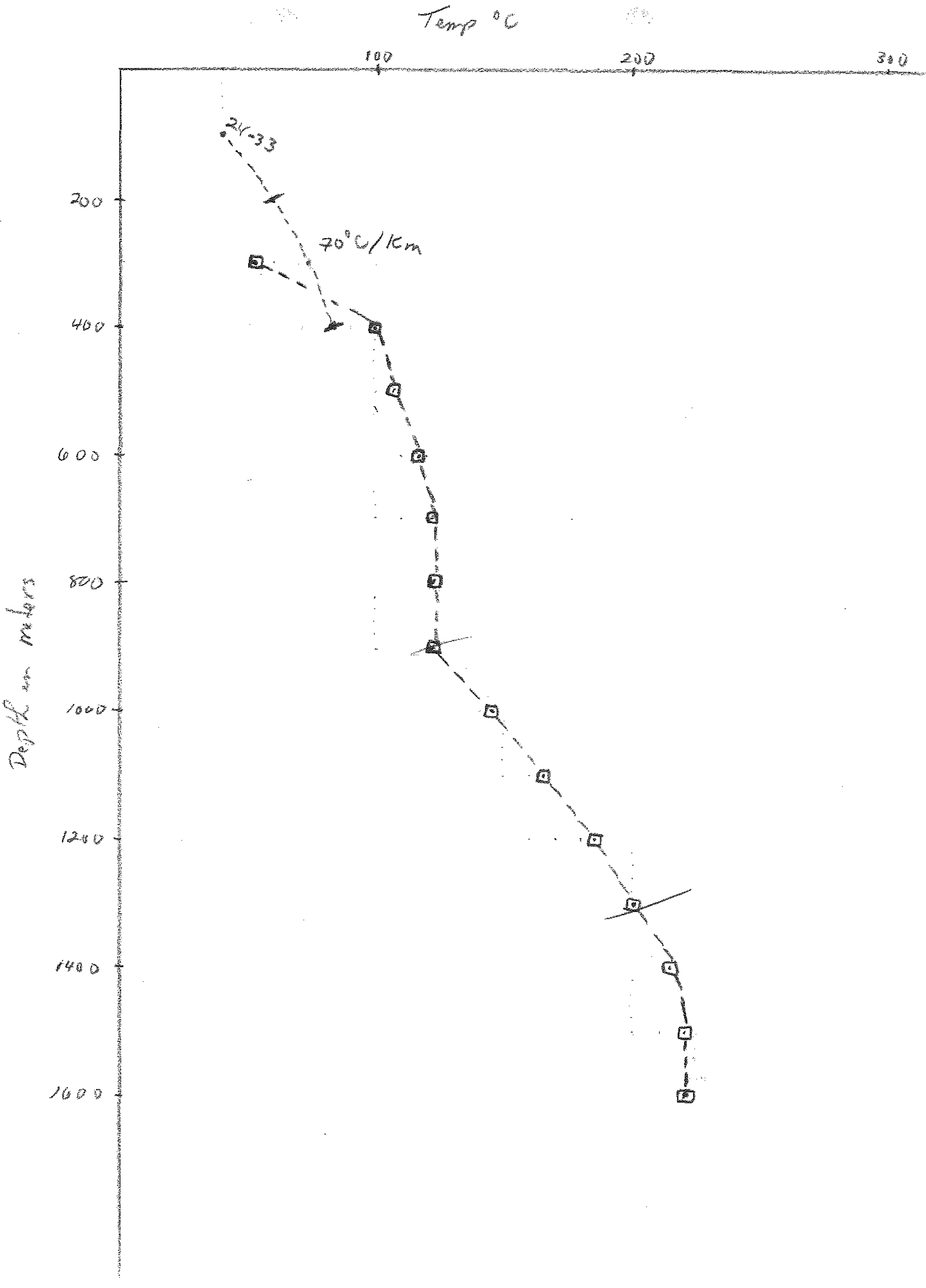
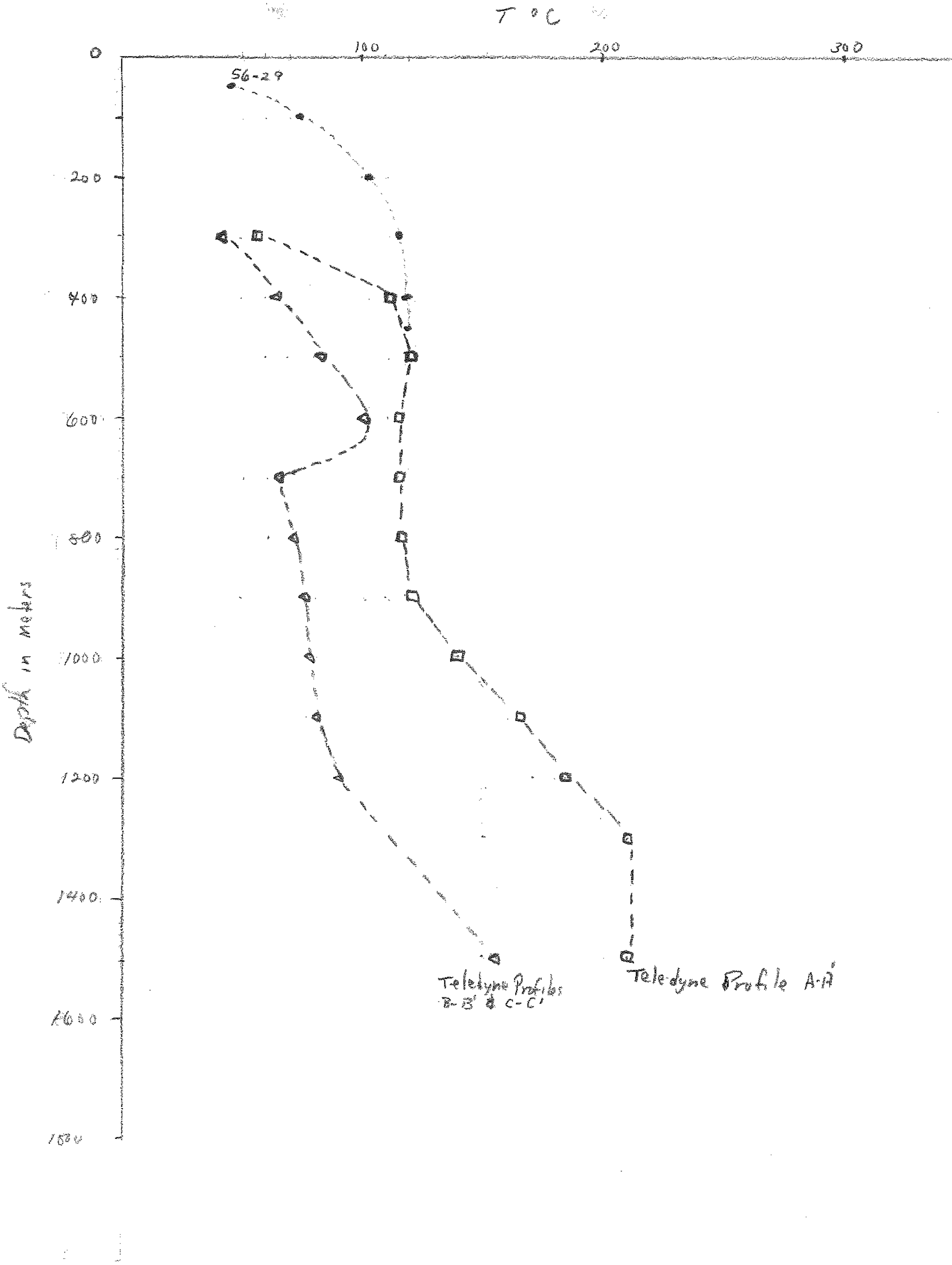


FIGURE 7. ESTIMATED SUBSURFACE TEMPERATURES AT LOCATION I3' ON PROFILE A-A', ALUM, NEVADA, WHICH IS NEAR INTERMEDIATE DEPTH WELL I3.



Temp °C
100
200
300
Depth in Meters
200
400
600
800
1000
1200
1400
1600
21-30
Teledyne Profile A-A'


Temp °C
100
200
300
Depth in meters
200
400
600
800
1000
1200
1400
1600
24-33
70°C/Km



T °C
0
100
200
300
56-29
200
400
600
800
1000
1200
1400
1600
1800
Depth in Meters
Teletyne Profiles B-B' & C-C'
Tele-dyne Profile A-A'

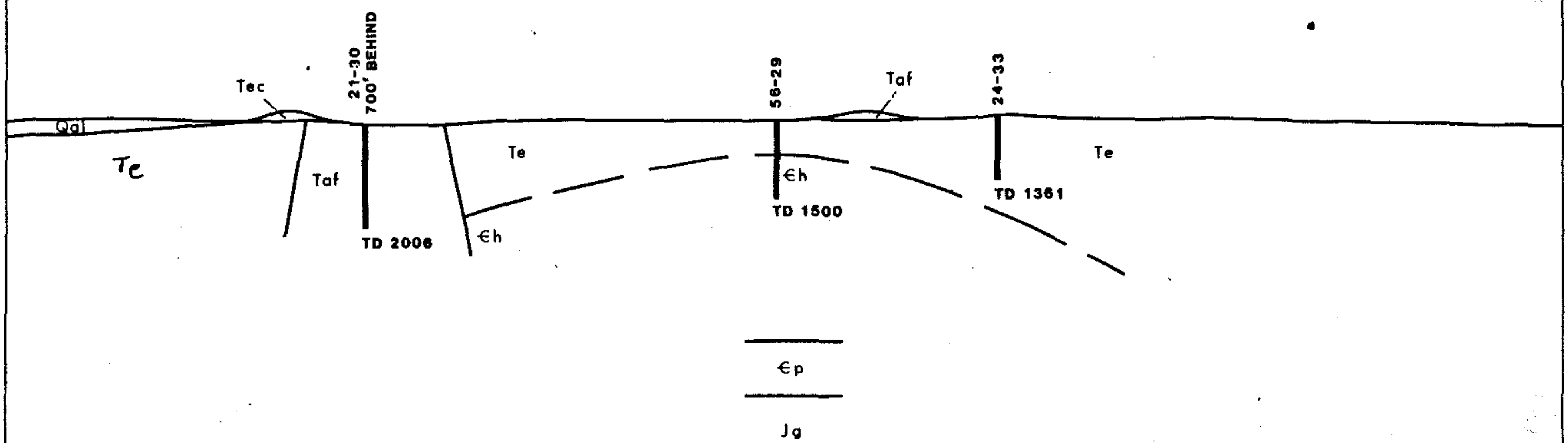
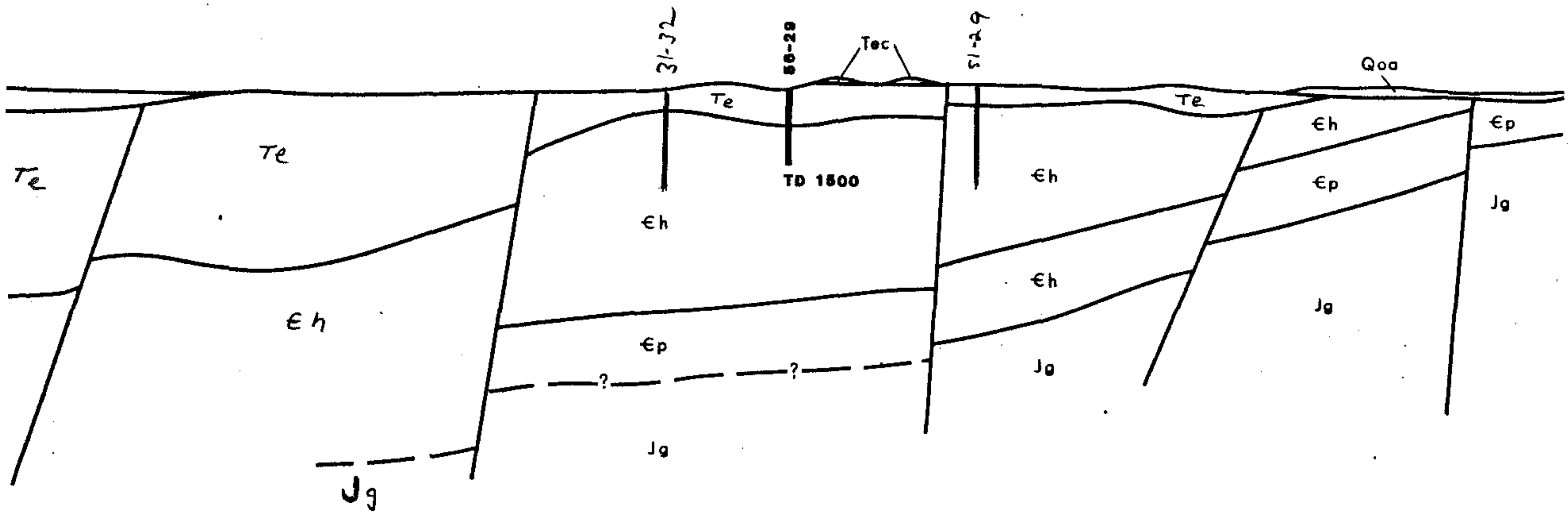
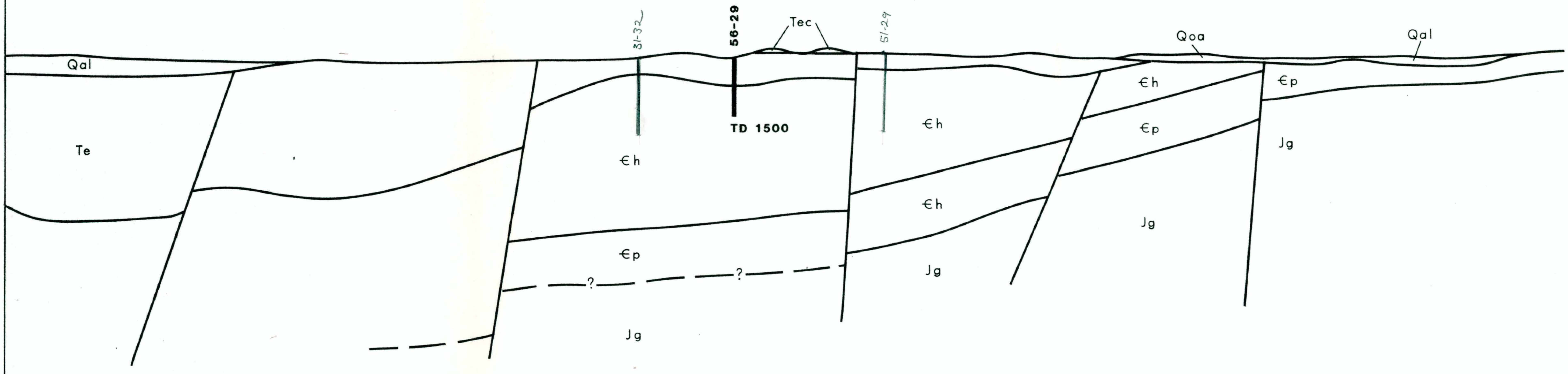


Figure 5

NORTHWEST-SOUTHWEST CROSS-SECTION THROUGH 21-30, 56-29 & 24-33

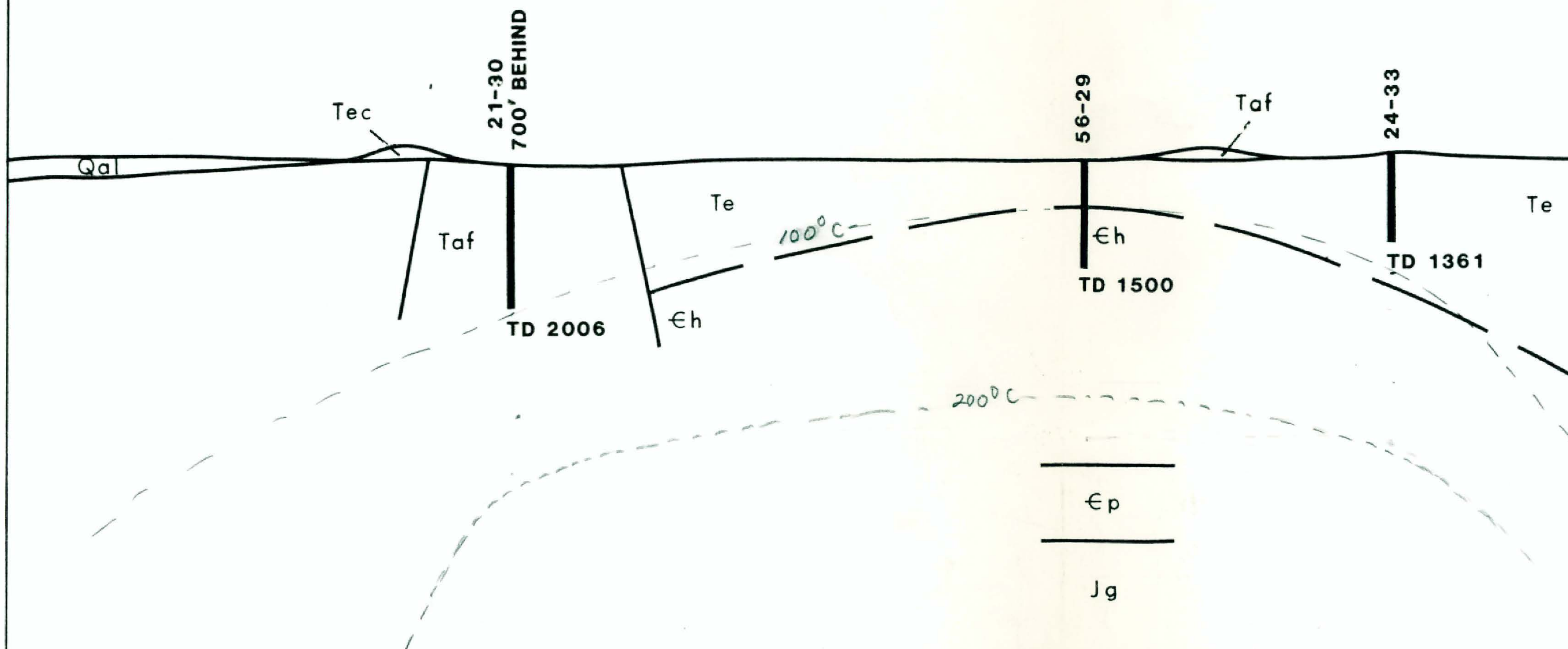


SOUTHWEST-NORTHEAST CROSS-SECTION THROUGH 56-29



SOUTHWEST-NORTHEAST CROSS-SECTION THROUGH 56-29

Scale 1":= 2000'



NORTHWEST-SOUTHEAST CROSS-SECTION THROUGH 21-30, 56-29 & 24-33

Scale 1": 2000'