

46. DATA REPORT: ONSHORE GEOCHEMICAL PROCESSING, LEG 145¹

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ABSTRACT

Geochemical well logs were obtained in the igneous and sedimentary sequences drilled at Sites 883 and 884 of Ocean Drilling Program Leg 145. Corrections have been applied to the logs to account for variations in borehole size, borehole fluid composition, downhole temperature, and logging speed, to derive the concentration of the elements Th and U, and the dry weight oxide percentages of the elements K and Al.

INTRODUCTION

Seven sites were drilled during Leg 145. Sites 883 and 884, situated on the Detroit Seamount in the northwest Pacific, were logged with the geochemical logging tool. These two sites represent the shallowest and deepest end members of a three-site depth transect down the slopes of the Detroit Seamount. The main objective was to define the nature and variability of the North Pacific Ocean deep waters.

Geochemical logs provide continuous in situ measurements of the major rock-forming elements in the formation at intervals of 0.1524 m (6 in.). They provide a large database of geochemical information unaffected by two main problems that inhibit core-based studies: incomplete or preferential core recovery and core disturbance.

This report describes the basic principles of the tool string, explains the data processing techniques, and presents the processed elemental and oxide data from the geochemical logs obtained at Sites 883 and 884.

GEOCHEMICAL TOOL STRING

The geochemical logging tool string (GLT) consists of four separate logging tools: the natural gamma-ray spectrometry tool (NGT), the compensated neutron tool (CNT), the aluminum activation clay tool (AACT), and the gamma-ray spectrometry tool (GST). A schematic drawing of the GLT, which was run in Holes 883F and 884E during Leg 145, is shown in Figure 1. These four tools use three separate modes of gamma-ray spectroscopy for a comprehensive elemental analysis of the formation. The NGT is located at the top of the tool string so that it can measure the naturally occurring radionuclides, thorium (Th), uranium (U), and potassium (K), before the formation is irradiated by the nuclear sources contained in the lower tools (Fig. 1). The CNT, located below the NGT, carries a low-energy californium (²⁵²Cf) neutron source to activate the Al atoms in the formation. The AACT, a modified NGT, is located below the ²⁵²Cf source, measuring the activated gamma rays in the formation. By combining the AACT measurement with the previous NGT measurement, the background radiation is subtracted out and a reading of formation Al is obtained (Scott and Smith, 1973). The gamma-ray spectrometry tool, at the base of the string, carries a pulsed neutron generator to induce prompt-capture gamma-ray reactions in the borehole and formation and an NaI(Tl) scintillation detector to measure the energy spectrum of gamma rays generated by the prompt-neutron-

capture reactions. As each of the elements in the formation is characterized by a unique spectral signature, it is possible to derive the contribution (or yield) of each of the major elements silicon (Si), iron (Fe), calcium (Ca), titanium (Ti), sulfur (S), gadolinium (Gd), and potassium (K) from the measured spectrum and, in turn, to estimate the relative abundance of each in the formation when combined with the elemental concentrations from the NGT and AACT. The GST also measures the hydrogen (H) and chlorine (Cl) in the borehole and formation, although these elements are not used for determining the rock geochemistry.

The only major rock-forming elements not measured by the geochemical tool string are magnesium (Mg) and sodium (Na); the neutron-capture cross sections of these elements are too small relative to their typical abundances for the GLT to detect. A rough estimate of Mg + Na can be made in some instances by using the photoelectric factor (PEF), measured by the lithodensity tool. Further explanation of this technique is found in Hertzog et al. (1989). This calculation could not be implemented on data from this leg due to the invalid GST data.

DATA REDUCTION

The well-log data from the Schlumberger tools are transmitted digitally up a wireline and are recorded and processed on the *JOIDES Resolution* in the Schlumberger Cyber Service Unit (CSU). The results from the CSU are made available as "field logs" for initial, shipboard interpretation. Subsequent reprocessing is necessary to correct the data for the effects of fluids added to the well, logging speed, and drillpipe interference. Processing of the spectrometry data is required to transform the relative elemental yields into oxide weight fractions.

The processing is performed with a set of log-interpretation programs written by Schlumberger but slightly modified to account for the lithologies and hole conditions encountered in ODP holes. The steps are summarized below:

Step 1: Reconstruction of Relative Elemental Yields from Recorded Spectral Data

This first processing step compares the measured spectra from the gamma-ray spectrometry tool with a series of "standard" spectra to determine the relative contribution (or yield) of each element. These "standards" approximate the spectrum of each element. Using a weighted, least-squares inversion method, the relative elemental yields are calculated at each depth level.

Six elemental standards (Si, Fe, Ca, S, Cl, and H) are used to produce the shipboard yields, but three additional standards (Ti, Gd, and K) can be included in the post-cruise processing to improve the fit of the spectral standards to the measured spectra (Grau and Schweitzer, 1989). Although Ti, Gd, and K often appear in the formation in very low concentrations, they can make a large contribution to the mea-

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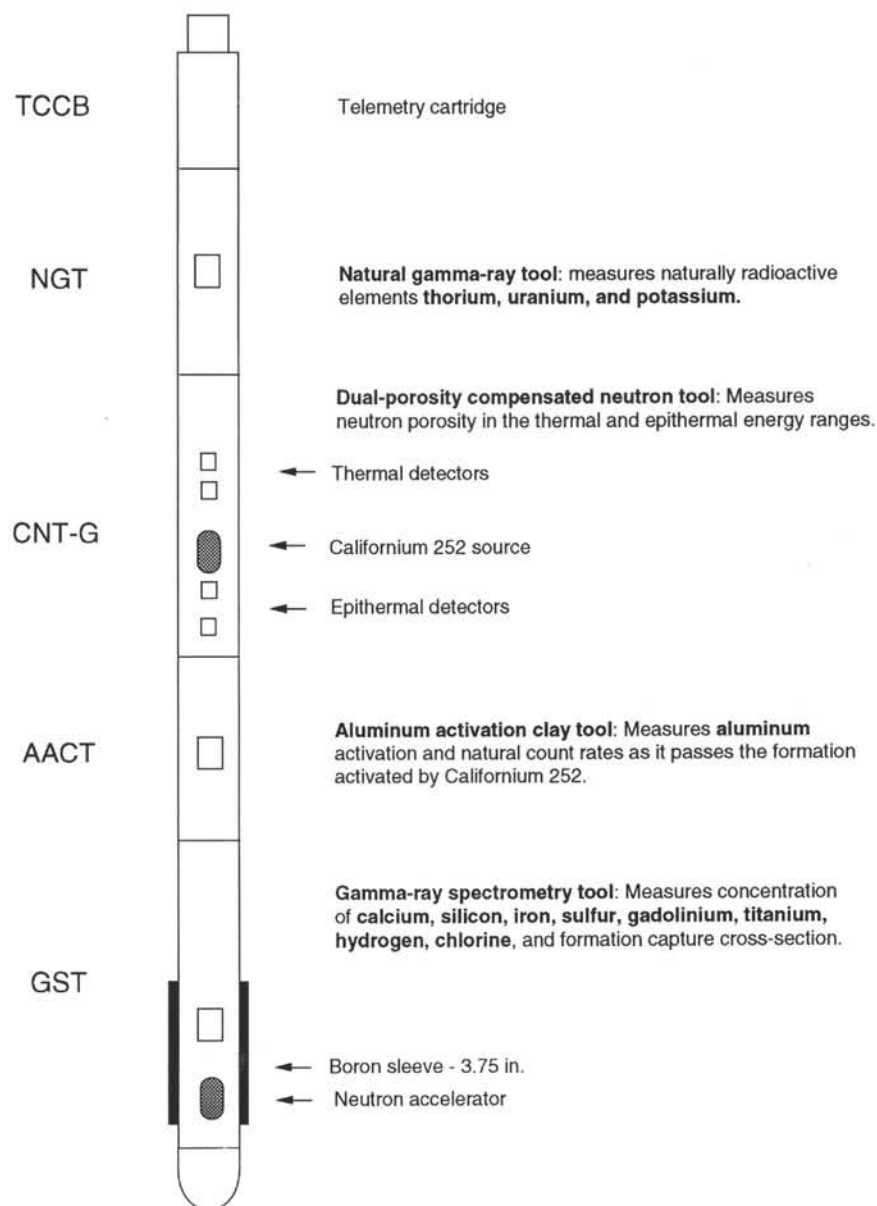


Figure 1. Schematic drawing of the Schlumberger geochemical logging tool string used in the Ocean Drilling Program.

sured spectra because they have large neutron-capture cross sections. For example, the capture cross section of Gd is 49,000 barns, whereas that of Si is 0.16 barns (Hertzog et al., 1989). Therefore, including Gd is necessary when calculating the best fit of the standard spectra to the measured spectrum.

During the spectral processing of the GST data from Holes 883F and 884E, it became apparent that there were serious data calibration errors caused by problems during the log acquisition phase. A hardware malfunction in the telecommunications cartridge (Fig. 1) had prevented the proper spectral calibration of the tool during logging operations at the two sites. The spectral inversion routine was run on the data, but unfortunately, due to the calibration errors, the data are invalid and are not presented. The data from the NGT and AACT are not similarly affected, and the processing of these data are described in the following.

Step 2: Depth-shifting

Geochemical processing involves the integration of data from the different tool strings; consequently, it is important that all the data are

depth-correlated to one reference logging run. The NGT, run on each of the logging tool strings, provides a spectral gamma-ray curve with which to correlate each of the logging runs. A reference run is chosen on the basis of constant, low cable tension and high cable speed (tools run at faster speeds are less likely to stick and are less susceptible to data degradation caused by ship heave). The depth-shifting procedure involves picking a number of reference points based on similar log character and then invoking a program that expands and compresses the matching logging run to fit the reference logging run. The geochemical tool string was chosen as the reference run in Holes 883F and 884E.

Step 3: Calculation of Total Radioactivity and Th, U, and K Concentrations

The third processing routine calculates the total natural gamma-ray radiation in the formation, as well as concentrations of Th, U, and K, using the counts in five spectral windows from the NGT (Lock and Hoyer, 1971). This routine resembles shipboard processing; however,

the results are improved during post-cruise processing by including corrections for hole-size changes and temperature variations. A Kalman filtering (Ruckebusch, 1983) is used in the CSU processing at sea to minimize the statistical uncertainties in the logs, which can otherwise create erroneous negative values and anticorrelations (especially between Th and U). An alpha filter has been introduced more recently and is now recommended by Schlumberger for shore-based processing. This filter strongly smooths the raw spectral counts but keeps the total gamma-ray curve unsmoothed before calculating out the Th, U, and K (C. Flaum, pers. comm., 1988). The outputs of this program are K (wet wt%), U (ppm), and Th (ppm), as well as total gamma-ray and computed gamma-ray (total gamma ray minus U contribution).

Step 4: Calculation of Al Concentration

The fourth processing routine calculates the concentration of Al in the formation using four energy windows recorded on the AACT. During this step, corrections are made for natural radioactivity, bore-hole-fluid neutron-capture cross section, formation neutron-capture cross section, formation slowing-down length, and borehole size.

Porosity and density logs are needed as inputs into this routine to convert the wet weight percentages of K and Al curves to dry weight percentages. Porosity logs from the neutron porosity tool and derived from resistivity and density logs were compared to core measurements to determine the best core-log correspondence. The calculated resistivity-porosity was found to be best in Hole 883F, and a spliced density- and resistivity-porosity was best for Hole 884E.

A correction also is made for Si interference with Al; the ^{252}Cf source activates the Si, producing the aluminum isotope, ^{28}Al , (Hertzog et al., 1989). The program uses the Si yield from the GST to determine the Si background correction. The program outputs dry weight percentages of Al and K.

The output weight percent concentrations of Al and K are normally input into an oxide closure model with the other GST-derived elements. As no useful GST data were obtained in Holes 883F and 884E, the processing moves straight on to the final step.

Step 5: Calculation of Oxide Percentages

The final routine converts the elemental weight percentages into oxide percentages by multiplying each by its associated oxide factor,

Table 1. Oxide factors used in normalizing elements to 100% and converting elements to oxides.

Element	Oxide	Conversion factor
K	K_2O	1.205
Al	Al_2O_3	1.889

as shown in Table 1. The resulting oxides are presented in Figures 2 and 3.

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- Grau, J.A., and Schweitzer, J.S., 1989. Elemental concentrations from thermal neutron capture gamma-ray spectra in geological formations. *Nucl. Geophys.*, 3:1-9.
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- Scott, H.D., and Smith, M.P., 1973. The aluminum activation log. *Log Analyst*, 14:3-12.

* Abbreviations for names of organizations and publications in ODP reference lists follow the style given in *Chemical Abstracts Service Source Index* (published by American Chemical Society).

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Hole 883F: Geochemical Log Summary

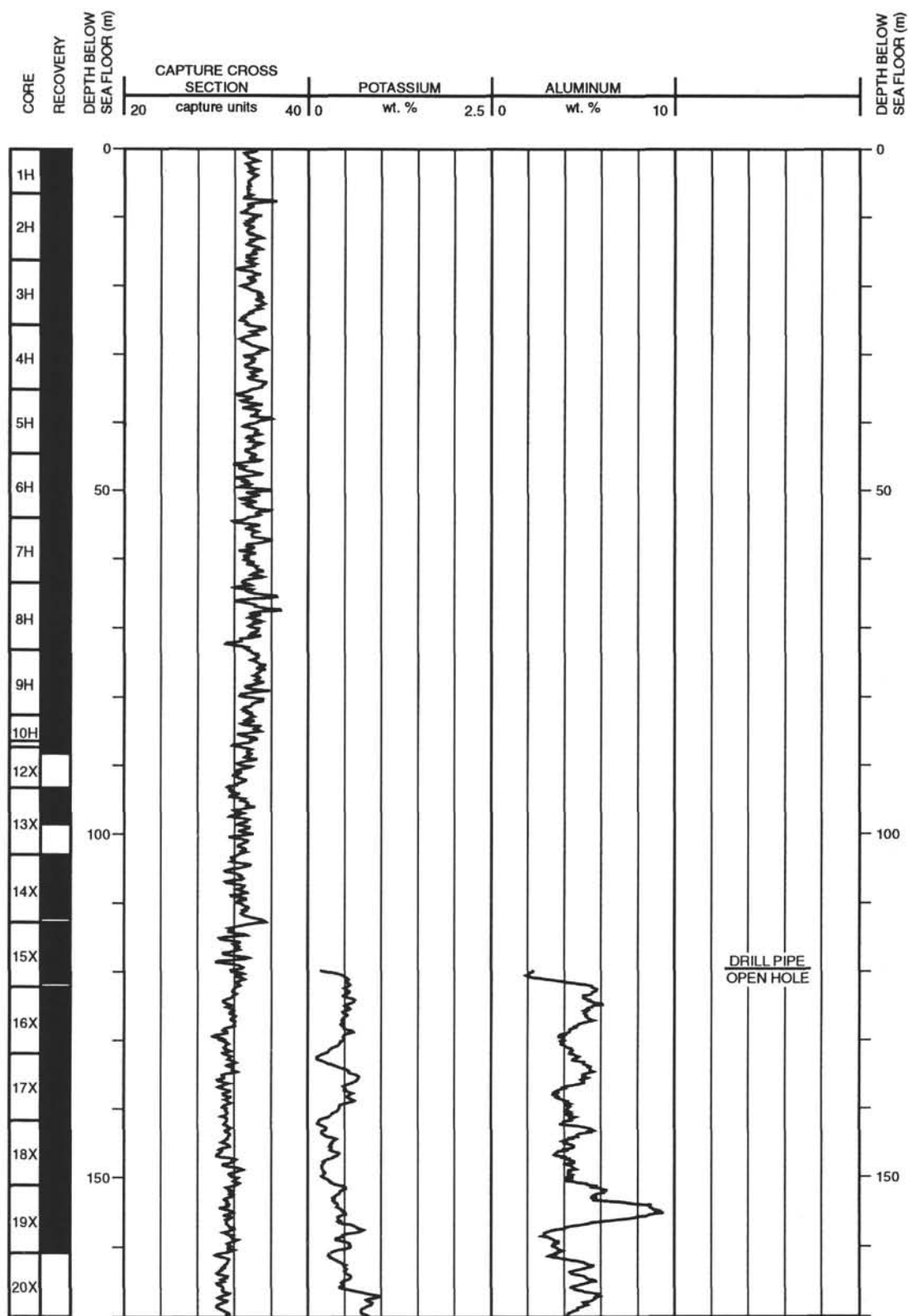


Figure 2. Processed oxides from the NGT and AACT for Hole 883F.

Hole 883F: Geochemical Log Summary (continued)

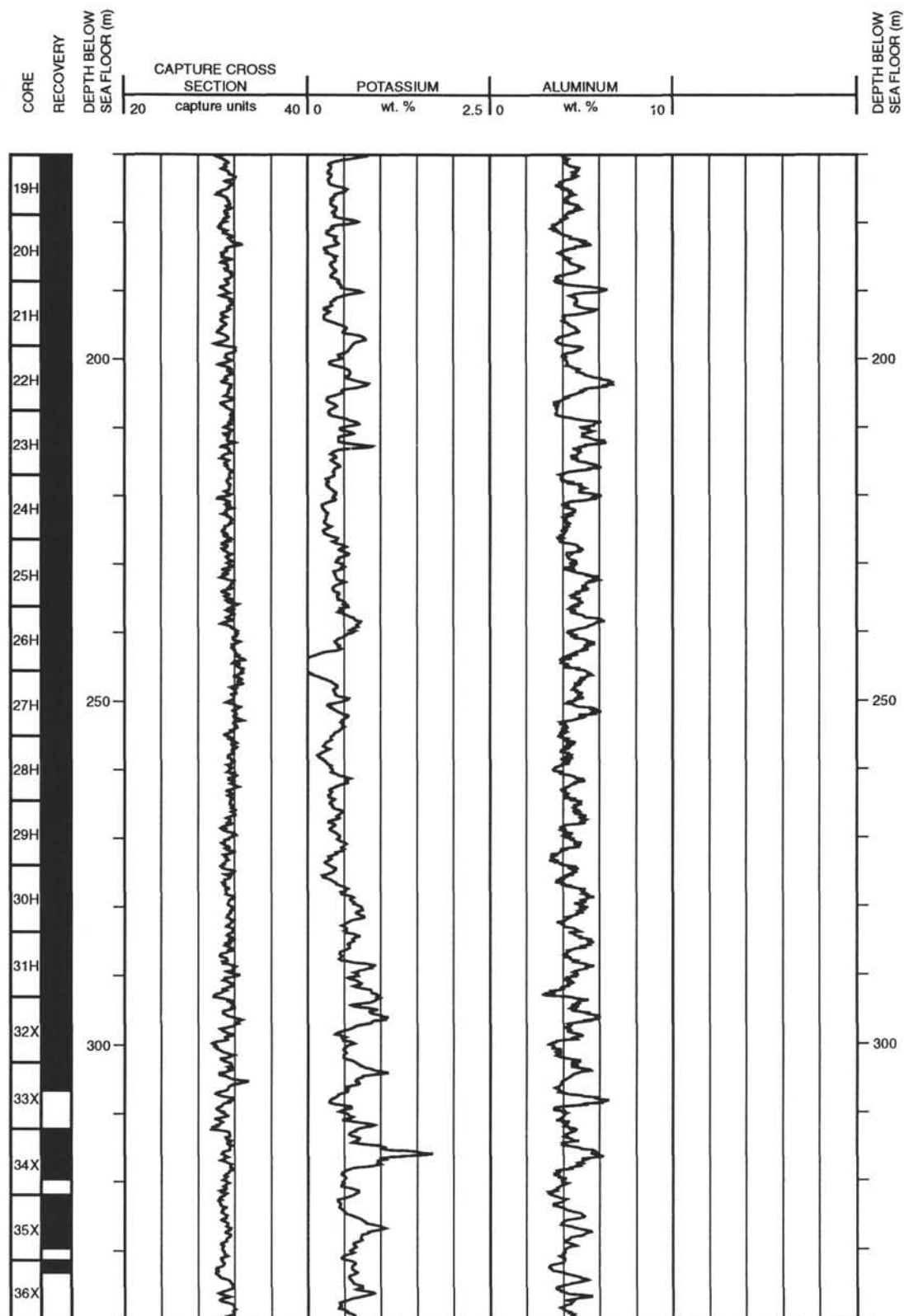


Figure 2 (continued).

Hole 883F: Geochemical Log Summary (continued)

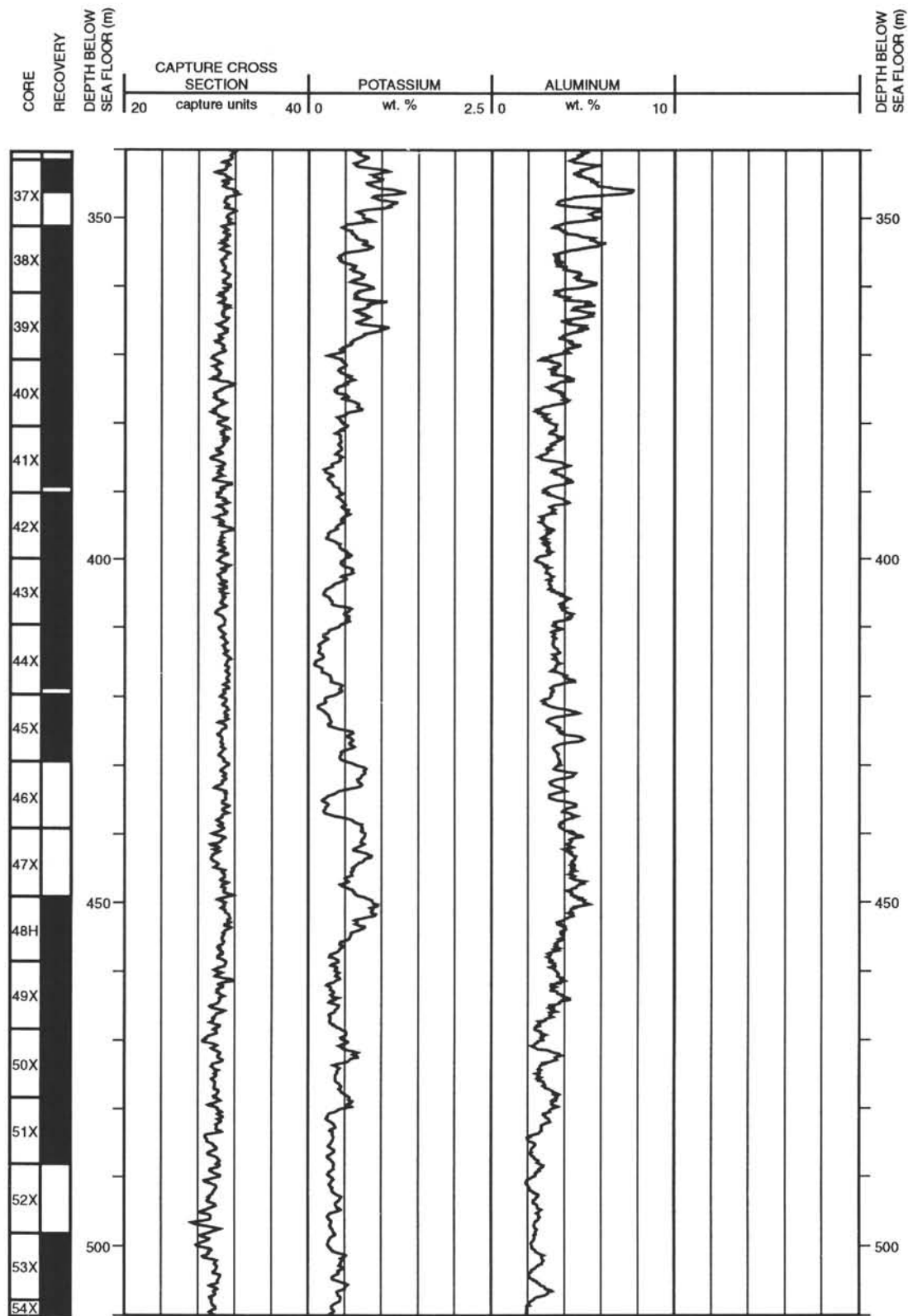


Figure 2 (continued).

Hole 883F: Geochemical Log Summary (continued)

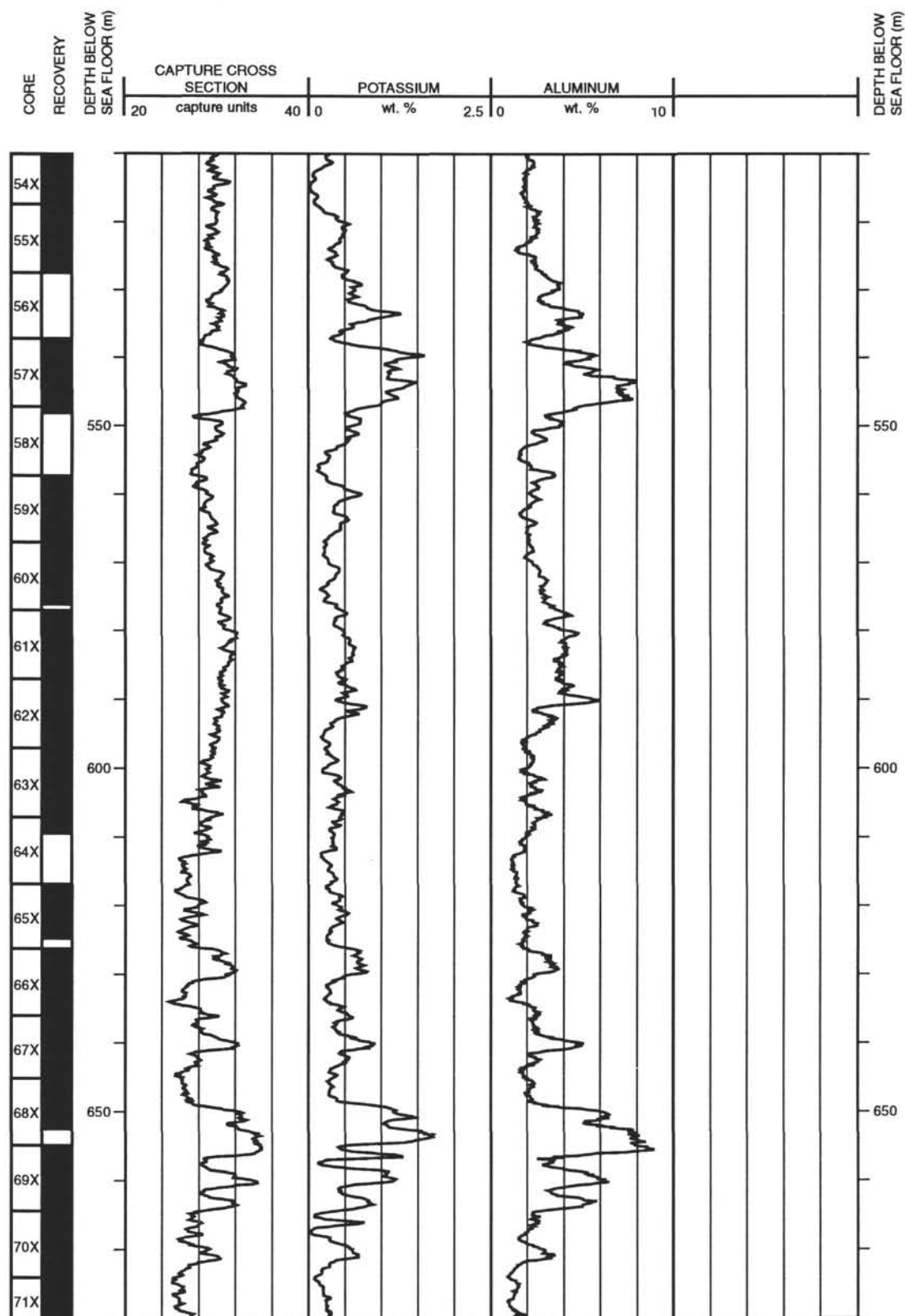


Figure 2 (continued).

Hole 883F: Geochemical Log Summary (continued)

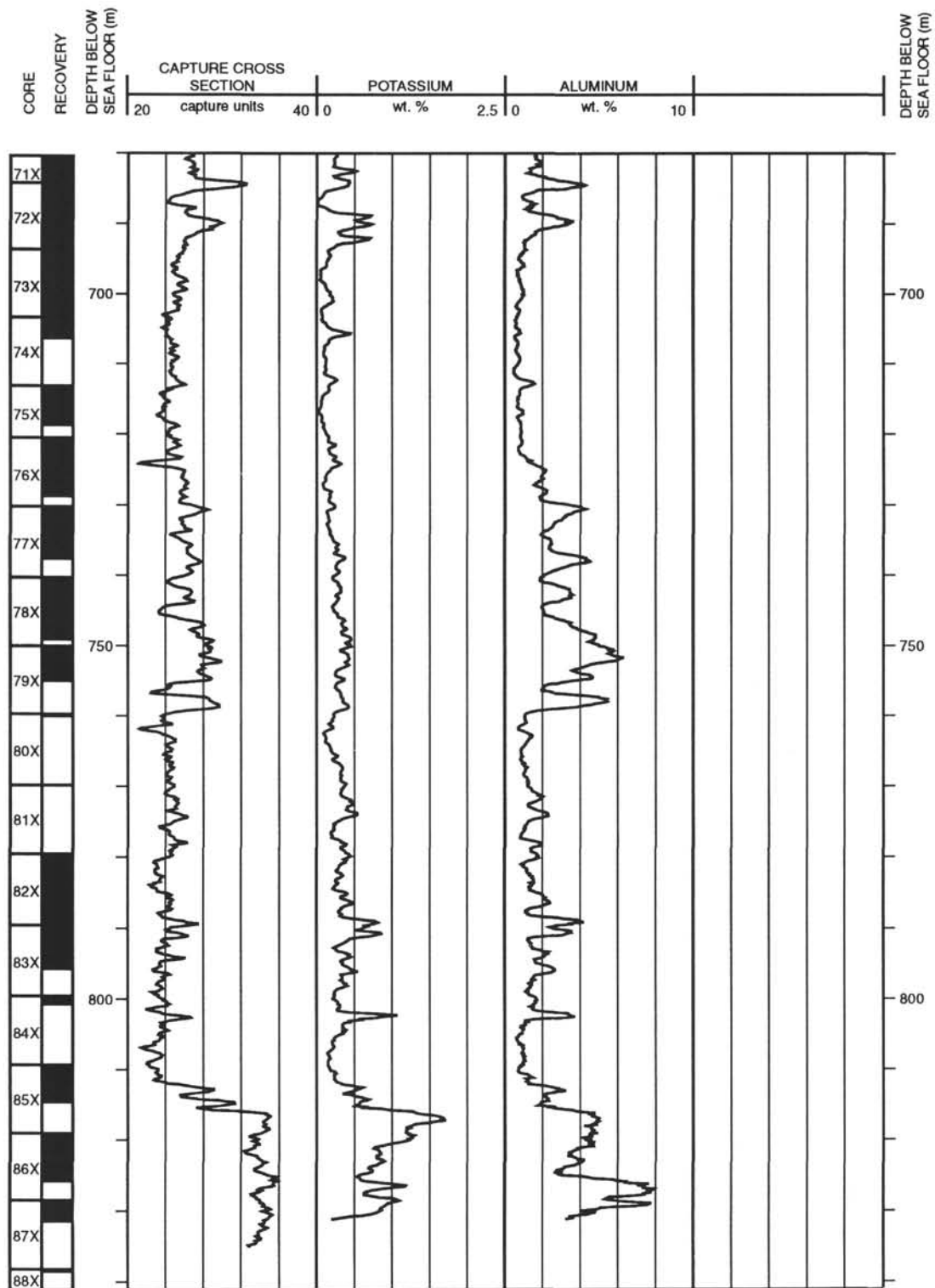


Figure 2 (continued).

Hole 884E: Geochemical Log Summary

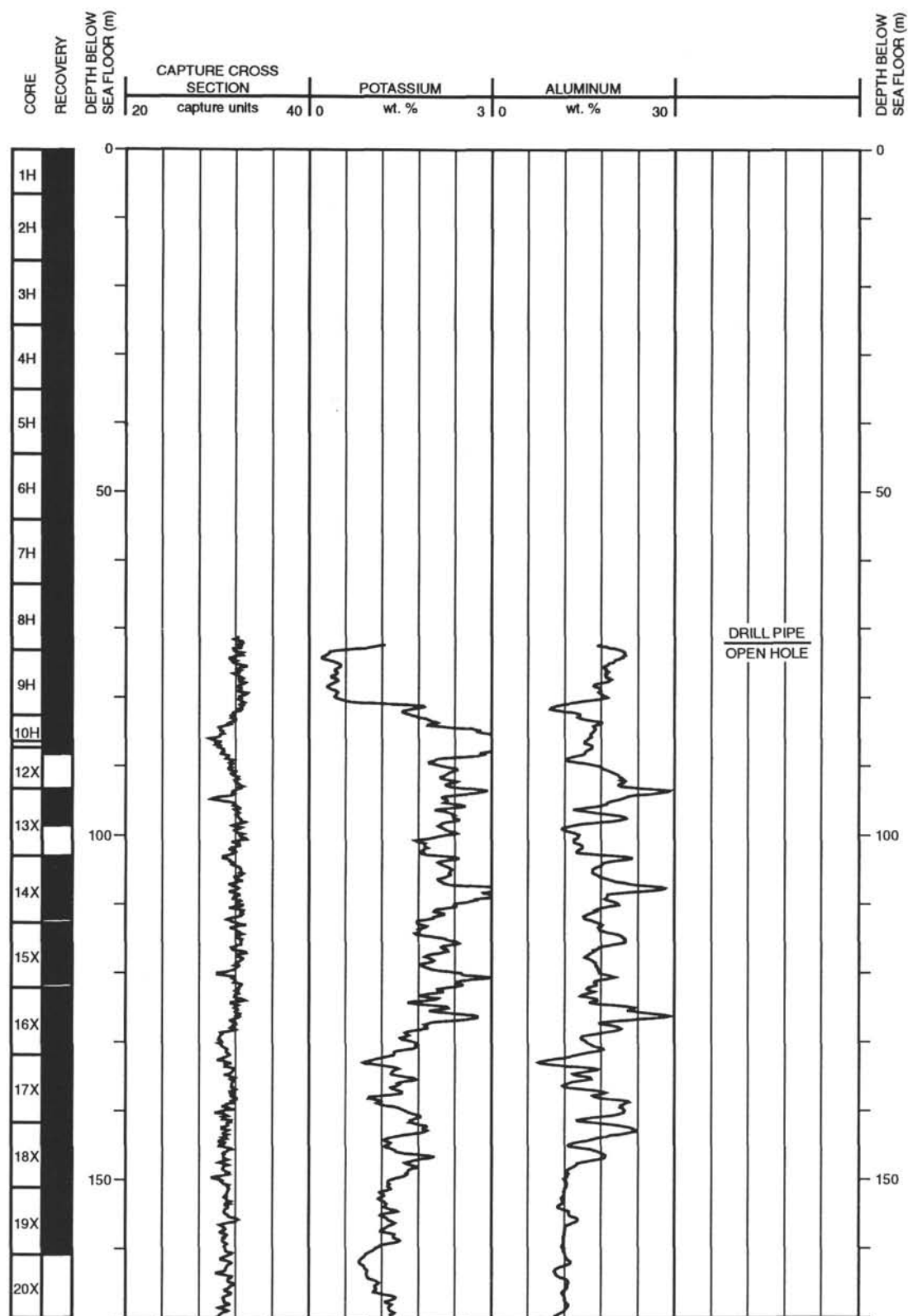


Figure 3. Processed oxides from the NGT and AACT for Hole 884E.

Hole 884E: Geochemical Log Summary (continued)

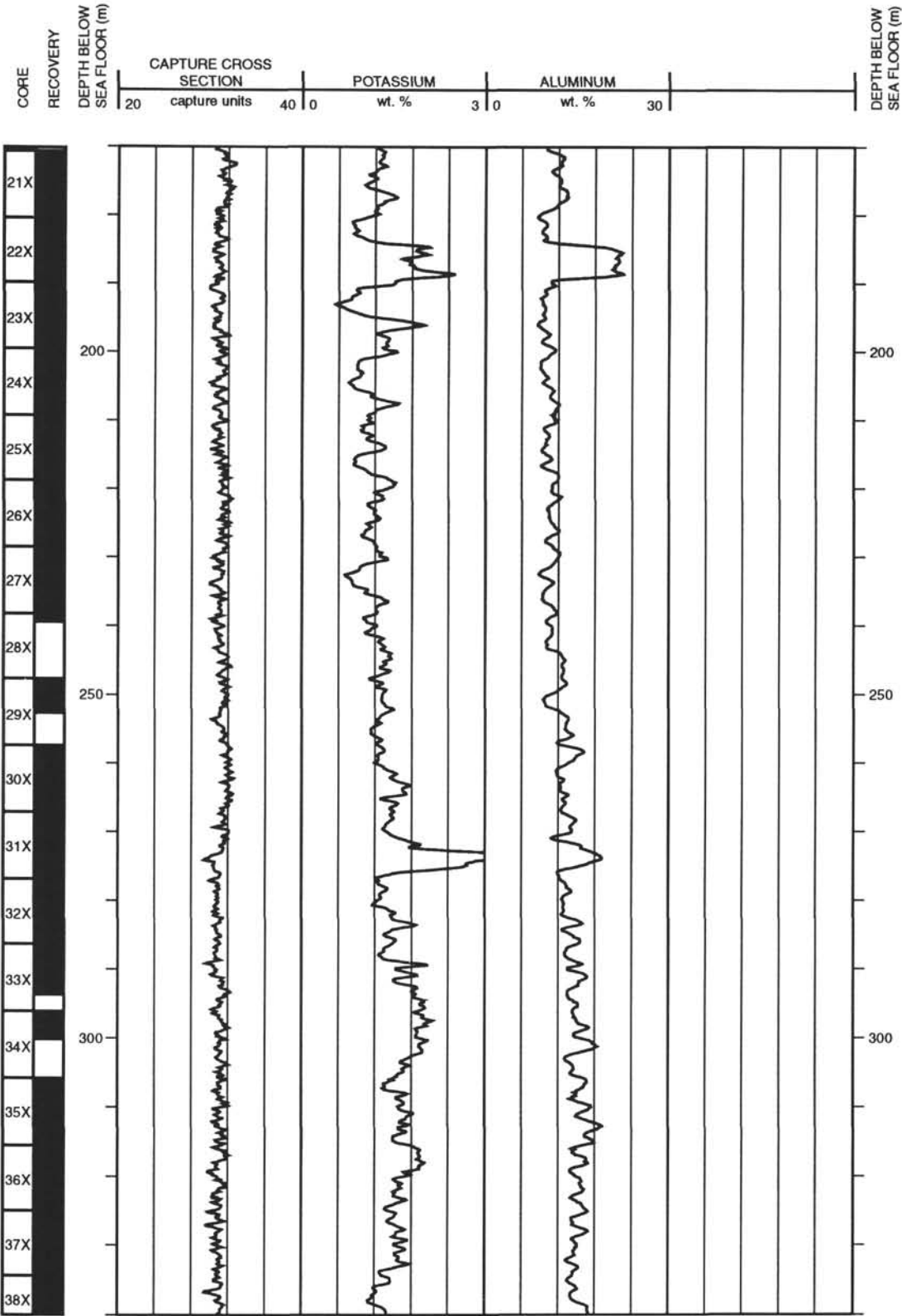


Figure 3 (continued).

Hole 884E: Geochemical Log Summary (continued)

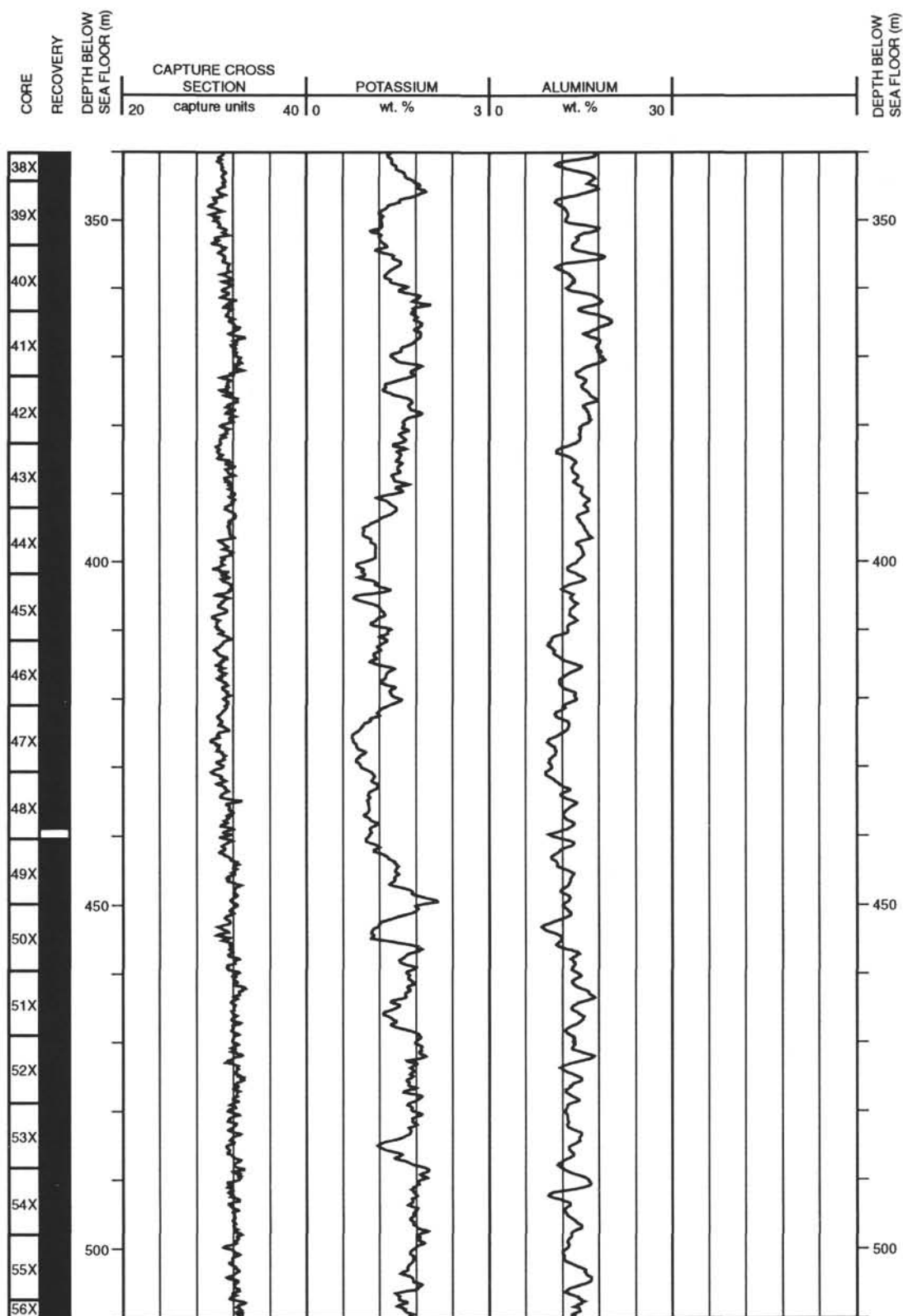


Figure 3 (continued).

Hole 884E: Geochemical Log Summary (continued)

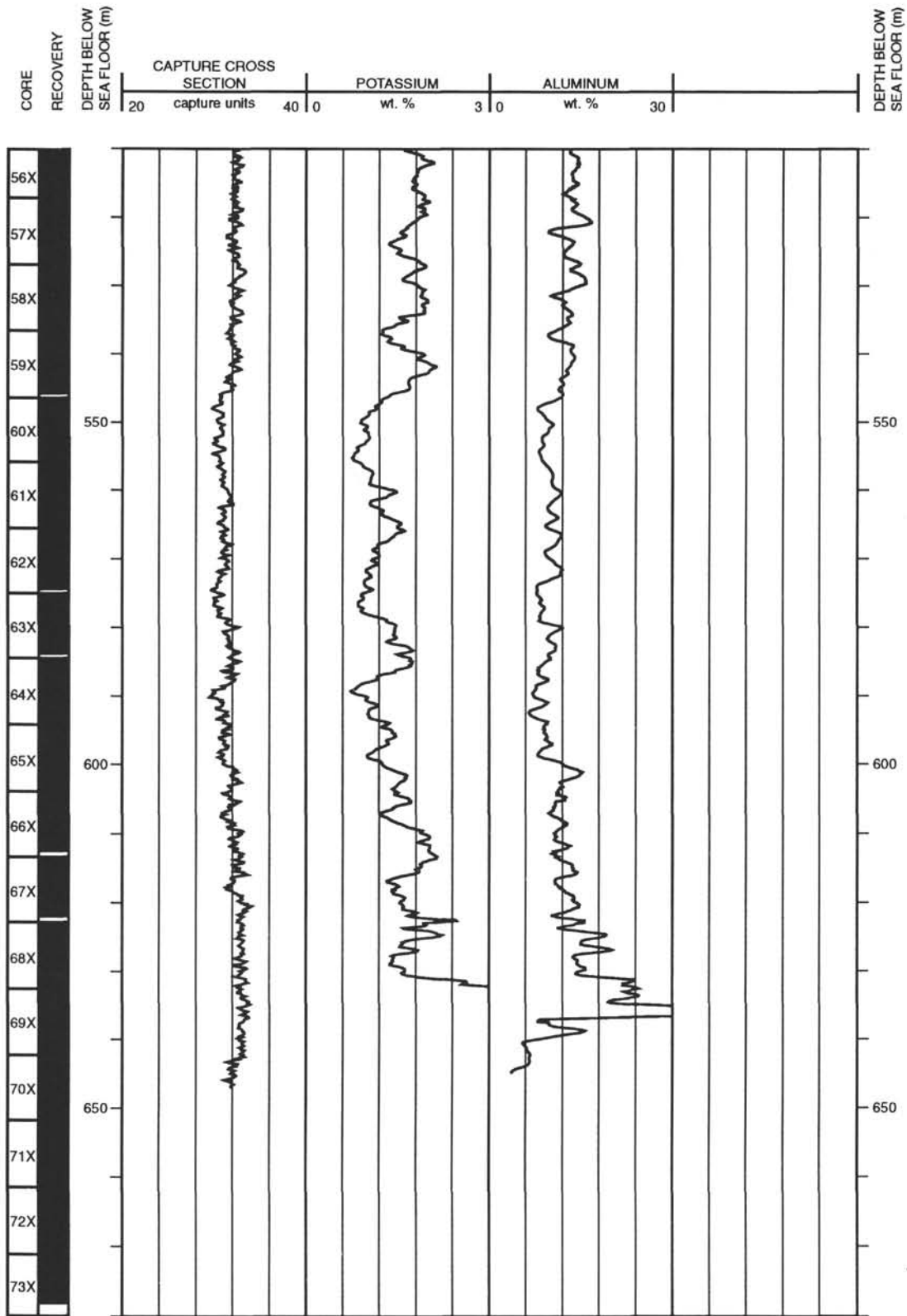


Figure 3 (continued).