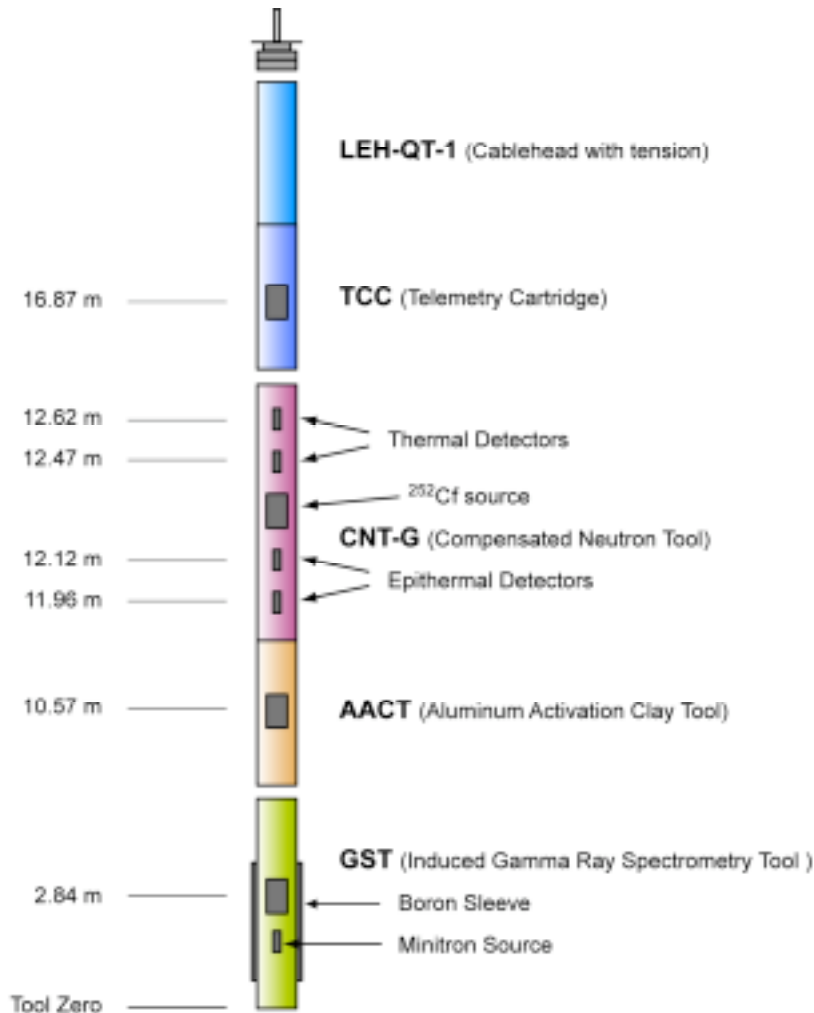


## Leg 145: Geochemical Processing Report

(based on: Bristow, J.F et al. (1993). Data Report: onshore geochemical processing, Leg 145. NOTE: the paper was erroneously omitted from both the Initial Reports volume and the CD-ROM (Rea, D. K., Basov. I. A., Janecek, T. R. et al., Proc. ODP, Init. Reports, 145: College Station, TX (Ocean Drilling Program).

### Geochemical Tool String

The Schlumberger geochemical tool string consists of four logging tools: the natural gamma-ray tool (NGT) the compensated neutron tool (CNT), the aluminum activation clay tool (AACT), and the gamma-ray spectrometry tool (see figure below). The natural gamma-ray tool is located at the top of the tool string, so that it can measure the naturally occurring radio nuclides, Th, U, and K, before the formation is irradiated by the nuclear sources contained in the other tools below. The compensated neutron tool, located below the natural gamma-ray tool, carries a low-energy californium source ( $^{252}\text{Cf}$ ) to activate the Al atoms in the formation. The aluminum activation clay tool below subtracts out the aluminum activation background radiation 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 bombard the borehole and formation and an NaI(Tl) scintillation detector, which measures the

spectrum of gamma rays generated by neutron-capture reactions. Because each of the elements measured (silicon, iron, calcium, titanium, sulfur, gadolinium, and potassium) is characterized by a unique spectral signature, it is possible to derive the contribution (or yield) of each of them to the measured spectrum and, in turn, to estimate their abundance in the formation. The GST also measures the hydrogen and chlorine in the borehole and formation, but the signal for these elements is almost entirely due to seawater in the borehole, and they are hence of little value.

The only major rock-forming elements not measured by the geochemical tool string are magnesium and sodium; the neutron-capture cross-sections of these elements are too small relative to their typical abundance for the tool string to detect them. A rough estimate of Mg+Na can be made by using the photoelectric factor (PEF) measured by the lithodensity tool. This measured PEF is compared with a calculated PEF (a summation of the PEF from all of the measured elements). The separation between the measured and calculated PEF is, in theory, attributable to any element left over in the formation (i.e., Mg and Na). Further explanation of this technique is found in Hertzog et al. (1989). This calculation could not be implemented on the geochemical data from this leg due to the invalid GST data.

### **Data Reduction**

The well log data from the Schlumberger tools have been transmitted digitally up a wireline and recorded on the JOIDES Resolution in the Schlumberger Cyber Service Unit (CSU). The results from the CSU have been processed to correct for the effects of drilling fluids, logging speed, and pipe 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 that have been modified to account for the lithologies and hole conditions encountered in ODP holes. The processing steps are summarized below:

#### **Step 1: Reconstruction of relative elemental yields from recorded spectral data**

The first processing step uses a weighted least-squares method to compare the measured spectra from the geochemical spectrometry tool with a series of standard spectra in order to determine the relative contribution (or yield) of each element. Whereas six elemental standards (Si, Fe, Ca, S, Cl, and H) are used to produce the shipboard yields, three additional standards (Ti, Gd, and K) can be included in the shore-based processing to improve the fit of the spectral standards to the measured spectra (Grau and Schweitzer, 1989). Although these additional elements often appear in the formation in very low concentrations, they can make a large contribution to the measured spectra, because they have large neutron-capture cross-sections. For example, the capture cross-section of Gd is 49,000 barns, that of Si 0.16 barns (Hertzog et al., 1989). Gd is, therefore, included in the calculation of a best fit between the measured and the standard spectra.

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 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 is described in the following steps.

#### **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 bases 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 which 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 radiation in the formation as well as concentrations of Th, U, and K, using the counts in five spectral windows from the natural gamma-ray tool (Lock and Hoyer, 1971). This resembles shipboard processing, except that corrections for hole-size changes are made in the shore-based processing of these curves. A Kalman filter (Ruckebusch, 1983) is applied to minimize the statistical uncertainties in the logs, which would otherwise create erroneous negative readings and anti-correlation (especially between Th and U). At each depth level calculations and corrections also were performed for K contained in the mud. This K correction is particularly useful where KCl is routinely added to the hole: because of dispersion, however, it is difficult to know exactly how much K is in the borehole. The outputs of this program are: K (wet wt %), U (ppm), and Th (ppm), along with a total gamma-ray curve and a computed gamma-ray curve (total gamma-ray minus U contribution).

The processed gamma-raydata are loaded in the files 883F-ngt-act.dat and 884E-ngt-act.dat.

### Step 4: Calculation of Al concentration

The fourth processing routine calculates an Al curve using four energy windows, while concurrently correct for natural activity, borehole fluid neutron-capture cross-section, formation neutron-capture cross-section, formation slowing-down length, and borehole size.

Porosity and density logs are needed in this routine to convert the wet weight percent K and Al curves to dry weight percent. 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 log was found to be best in Hole 883F and a spliced density and resistivity-porosity for Hole 884E.

A correction is also made for Si interference with Al; the <sup>252</sup>Cf source activates the Si, producing the aluminum isotope, <sup>28</sup>Al (Hertzog et al., 1989). The program uses the Si yield from the gamma-ray spectrometry tool to determine the Si background correction. The program outputs dry weight percentages of Al and K, which are used in the calculation and normalization of the remaining elements.

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, as shown in Table 1. The outputs are in the files 883F-act-proc.dat and 884E-act-proc.dat.

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

Element	Oxide	Conversion factor
---------	-------	-------------------

K	K <sub>2</sub> O	1.205
Al	Al <sub>2</sub> O <sub>3</sub>	1.889

---

## References

Grau, J. and Schweitzer, J.S. (1989). Elemental concentrations from thermal neutron capture gamma-ray spectra in geological formations. *Nuclear Geophysics* 3(1):1-9.

Hertzog, R., Colson, L., Seeman, B., O'Brien M., Scott, H., McKeon, D., Grau, J., Ellis, D., Schweitzer, J. and Herron, M. (1989). Geochemical logging with spectrometry tools. *SPE Formation Evaluation*, 4(2): 153-162.

Lock, G. A. and Hoyer, W. A. (1971). Natural gamma-ray spectral logging. *The Log Analyst*, 12(5): 3-9.

Ruckebusch, G. (1983). A Kalman filtering approach to natural gamma-rayspectroscopy in well logging. *IEEE Trans. Autom. Control.*, AC-28: 372-380.

Scott, H. D. and Smith, M. P. (1973). The aluminum activation log. *The Log Analyst*, 14(5): 3-12.  
For further information or questions about the processing, please contact:

Cristina Broglia  
Phone: 845-365-8343  
Fax: 845-365-3182  
E-mail: [chris@ldeo.columbia.edu](mailto:chris@ldeo.columbia.edu)

Trevor Williams  
Phone: 845-365-8626  
Fax: 845-365-3182  
E-mail: [trevor@ldeo.columbia.edu](mailto:trevor@ldeo.columbia.edu)