# Leg 125: Geochemical Processing Report

(based on: Pratson, E. L. et al. (1992). Data report: results of geochemical well logging in the Izu--Bonin Forearc Basin, Sites 782 and 786, Leg 125. In Fryer, P., Pearce, J. A., Stokking, L. B. et al., Proc. ODP, Sci. Results, 125: College Station, TX (Ocean Drilling Program), 663-674.)

Note: A complete revision of all of the processed data from this leg was performed before putting the data online. This may have resulted in minor depth discrepancies between the published geochemical data and the online database version, particularly before Leg 128.

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}Cf) to activate the Al atoms in the formation. The aluminum activation clay background radiation is subtracted out by the aluminum activation clay tool below and a reading of formation Al is obtained (Scott and Smith, 1973).
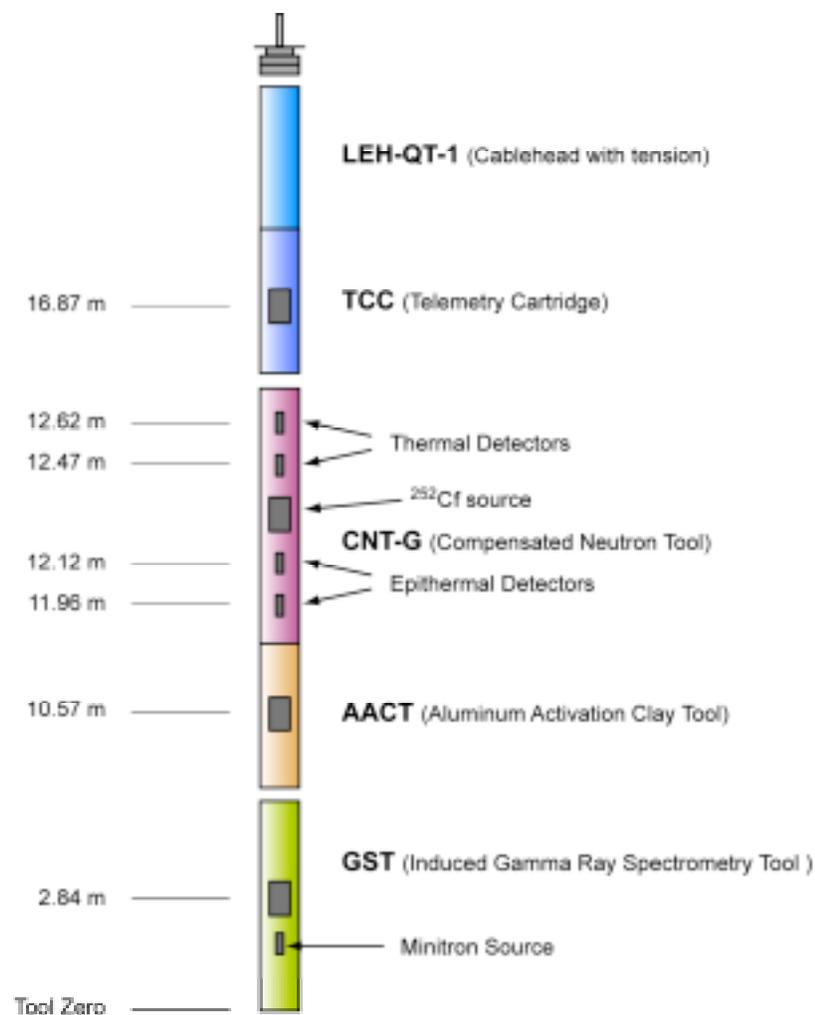
The gamma-ray spectrometry tool, at the base of the string, carries a pulsed neutron generator to bombard the borehole and formation and an NaI(Tl) scintillation detector, which measures the spectrum of gamma-rays generated by neutron-capture reactions. Because each of the elements measured (silicon, 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 of 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 was performed at Holes 782B and 786B and yielded zero Mg values throughout Hole 786B, with the exception of a few erratic spikes. Recovered core samples indicated that this was not correct; therefore, Mg was calculated based on an assumed constant relationship between MgO, FeO* (sum of FeO and Fe_2O_3), and SiO_2:

$$FeO^* + MgO = 577.5 \times 10^{-.0365} SiO_2$$
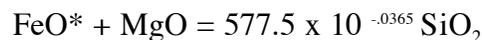
A similar equation is routinely used by Schlumberger when logging in the carbonate sequences typically encountered in oil field wells. This equation assumes a dolomite mineralogy and a constant relationship between $CaCO_3$ (calcite) and $CaMg(CO_3)_2$ (dolomite). Because this assumption would not be appropriate in igneous rocks or in igneous-derived lithologies, the program was altered to include a relationship among SiO_2, FeO*, and MgO for igneous lithologies. One mineral type cannot be assumed for a general rock environment; therefore, total oxide values for all types of igneous and metamorphic rocks were included (granites, tonalities, syenites, monzonites, diorites, andesites, gabbros, and dunites). The Mg equation used was obtained by looking at the relationship among SiO_2, FeO*, and MgO in these lithologies (Nockolds, 1954).

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.

This best-fit analysis included the spectral standards for Si, Fe, Ca, Ti, Gd, S, K, H, and Cl at Hole 782B. For Hole 786B, the original spectral data were omitted on the proprietary tape except for a short repeat section at the bottom of the hole. Results of the processing in this short section were comparable to the unprocessed elemental yields in the main section, which, however, did not include Ti and Gd. The unprocessed yields were therefore used to compute the oxide percentages in this hole. A 10-point smoothing filter was applied to all yields in both holes to reduce noise. The iron yield in Hole 786B was corrected for the effect of the iron in the drill pipe and bottom hole assembly by applying an appropriate offset depending on the pipe thickness.

The recomputed yields are loaded in the file 782B-yields.dat.

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. A total gamma-ray curve (from the gamma-ray tool, which is run on each tool string) is usually chosen as a reference curve, based on cable tension (the logging run with the least amount of cable sticking) and cable speed (tools run at faster speeds are less likely to stick).

The logs were depth-referenced to the geochemical tool string at Hole 782B and to a spliced gamma-ray curve from the DIT/SDT/NGT runs at Hole 786B.

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 borehole fluid to inhibit clay swelling.
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-ray data are loaded in the files 782B-ngt.dat and 786B-ngt.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.

In Holes 782B and 786B, the density logs were in close agreement with core measurements, unlike the porosity from the neutron and sonic tools. Therefore, the density log was used to calculate the porosity from the following equation:

$$\phi_t = (\rho_m - \rho_b)/(\rho_m - \rho_f)$$

where:

ϕ_t = percentage of porosity,

ρ_m = matrix density

(a constant value or log matrix density can be used in g/cm^3),

ρ_b = bulk density from the log in g/cm^3, and

ρ_f = density of fluid = 1.05 g/cm^3.

A correction is also 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 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.

Step 5: Normalization of elemental yields from the GST to calculate the elemental weight fractions

This routine combines the dry weight percentages of Al and K with the reconstructed yields to obtain dry weight percentages of the GST elements using the relationship:

$$Wi = F\ Yi/Si$$

where
Wi = dry weight percentage of the i-th element
F = normalization factor determined at each depth interval
Yi = relative elemental yield for the i-th element
Si = relative weight percentage (spectral) sensitivity of the i-th element

The normalization factor, F, is a calibration factor determined at each depth from a closure argument to account for the number of neutrons captured by a specific concentration of rock elements. Because the sum of oxides in a rock is 100%, F is given by

$$F\ (\Sigma\ Xi\ Yi\ /\ Si) + XK\ WK + XAl\ WAl = 100$$

where
Xi = factor for the element to oxide (or carbonate) conversion
XK = factor for the conversion of K to K_2O (1.205)
XAl = factor for the conversion of Al to Al_2O_3 (1.889)
WK = dry weight percentage of K determined from natural activity
WAl = dry weight percentage of Al determined from the activation measurement

The sensitivity factor, Si, is a tool constant measured in the laboratory, which depends on the capture cross-section, gamma-ray production, and detection probabilities of each element measured by the GST (Hertzog et al., 1989).

The factors Xi are simply element to oxide (or carbonate, sulfate) conversion coefficients and effectively include the O, C or S bound with each element. In processing the GLT data the correct choice of Xi is important in the closure algorithm described above and requires geological input. In most lithologies the elements measured by the tool occur in silicates where the compositions can be expressed completely as oxides.

In Holes 782B and 786B, the carbonate/oxide calculation was performed assuming zone of an dominant CaO- and $CaCO_3$–bearing minerals. A factor for $CaCO_3$ is used in the upper sedimentary

section of each holes, while the oxide factor for CaO is used in the volcanic breccia and basement sections.

Step 6: Calculation of oxide percentages

This routine converts the elemental weight percentages into oxide percentages by multiplying each by its associated oxide factor (Table 1).

The oxide weight percentages are loaded in the files 782B-oxides.dat and 786B-oxides.dat. Core measurements are loaded in the file 782B-core.dat.

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

Element	Oxide/carbonate	Conversion factor
Si	SiO_2	2.139
Ca	CaO	1.339 (basement)
Ca	$CaCO_3$	1.497 (sediments)
Fe	FeO*	1.358
K	K_2O	1.205
Ti	TiO_2	1.668
Al	Al_2O_3	1.889
Mg	MgO	1.658

References

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