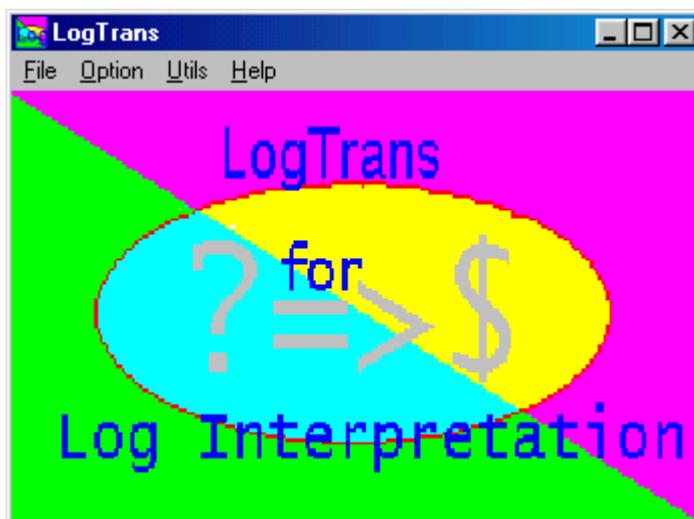


LogTrans 5.01 USER NOTES



P.K. Fullagar

2018

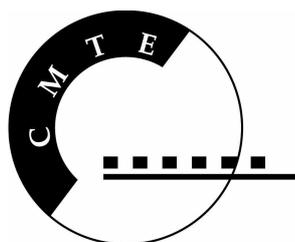


Table of Contents

	Page
1. Introduction	3
2. Operational Basics	4
3. File formats	5
3.1 Borehole log data formats	5
3.2 Core-based data format	5
3.3 Assigned Lithotype (*.ALT) files	5
3.4 Batch Data files	6
3.5 Global output (formerly *.LTG) files	7
3.6 Stratigraphic key (*.KEY) files	10
4. Directory structure	10
5. Statistical characterisation (GRSTAT)	10
5.1 Select <i>control holes</i>	10
5.2 Create the Batch Data (*.DAT) file	10
5.3 Run GRSTAT	10
5.4 Examine statistics	13
6. Auto-interpretation (FLUSTER)	14
7. Special Features	19
7.1 Create a Batch Data File	19
7.2 Convenient mathematical manipulation of parameters	20
7.3 Insertion of core-based data into LAS files	21
7.4 Deletion of LAS file parameters	23
7.5 Compute standard parameter statistics	23
7.6 Display parameter histograms	24
7.7 Display control statistics	26
7.8 Merge two ALT files	27
7.9 Compute interval averages	29
7.10 Stratigraphically-constrained interpretation	29
8. Trouble shooting	32
9. User support contact details	33
10. References	33

1. Introduction

LogTrans performs automated interpretation of drillhole data. The program was originally developed to interpret geophysical borehole logs (Fullagar et al., 1996), but has been adapted to facilitate joint interpretation of logs and core-based data such as assays. The following notes are intended to provide a general framework for running Logtrans. Although the program includes a *Help* facility, much of the information is currently out of date.

The LogTrans algorithm can be understood as an extension of scatterplot interpretation from two to multiple dimensions. Each rock type or interpretation class occupies a certain domain in “parameter space”. For each class (e.g. lithotype) a centroid can be defined in parameter space, representing the typical parameter values for that lithotype. In LogTrans the centroids are the class medians or means for a control data set. To the extent that it defines classes with respect to *a priori* control data sets, LogTrans is akin to discriminant analysis (Davis, 1986, p479). The control data must be representative of the material intersected in all the holes to be interpreted; different control data sets can be used for different ore styles within a mine.

When new data are collected, they define new points in parameter space. This mapping of data points into parameter space can be extended into any number of dimensions as the number of petrophysical parameters increases. The interpreted lithology for each new data point is the class to which the point most plausibly belongs. A data point does is classified as a member of the class with the nearest centroid in parameter space.

Petrophysical parameters are expressed in different units, and vary over very wide ranges of values. Accordingly the “distances” between data points in multi-parameter space must be normalised to lie in the same numerical range. Standard deviations or spreads (based on range from the median to the 16th and 84th percentiles) are employed in LogTrans for normalisation. The use of standardised distances to assess membership of groups is a feature of cluster analysis (e.g. Davis, 1986, pp503-504). Thus LogTrans is a hybrid scheme, intermediate between a *discrimination* and a *classification* process (Davis, 1986, p479).

LogTrans does not explicitly rely on conformity of parameter distributions to a particular model. Skewed data distributions can be accommodated using medians and spreads rather than means and standard deviations. However, LogTrans does assume that the parameter distribution is unimodal, i.e. concentrated around the median or mean. If a class is comprised of two or more distinct sub-populations, these should be treated as separate classes. It is instructive to plot histograms of the parameters to identify any distinct sub-populations.

The normalised distance, r_{min} , to the nearest centroid is one measure of the degree of confidence in the interpretation: the closer the centroid, the higher the confidence. However, the domains or clusters will frequently overlap. A second measure of the confidence in interpretation is therefore the ratio of the distances, r_{min} and r_{next} , to the closest and second closest centroid respectively. The smaller the ratio, the less the

ambiguity, and the greater the confidence. The overall confidence is high, therefore, when both r_{min} and r_{min}/r_{next} are small.

If the normalised distance from a measured point (n-tuple) to the nearest centroid is greater than a user-defined threshold value, the point is deemed “unclassified”. Selecting a threshold of 3 would define a region with radius of 3 standard deviations (spreads) centred on the mean (median). For a truly Normal distribution, 99.7% of all realisations would lie within this region.

The data values used for interpretation need not be point values: data can be windowed over depth ranges using running average or running median filters. For example, if grade estimation is the ultimate objective, it may be desirable to compute the average or median value of the petrophysical data over a depth interval corresponding to the geochemical sampling interval.

Two styles of interpretation can be produced: multi-class (e.g. lithology log for geologists), or binary (e.g. “rock-ore” log for engineers). The classes may be based on geological, geochemical, geomechanical, or geophysical contrasts.

The algorithm is described in more detail, and illustrated with examples, by Fullagar et al. (1999).

The optional STRAT module, which imposes a stratigraphic order on a LogTrans interpretation, is described by Fullagar et al. (2004).

The optional LogQA module, which performs quality checks on wireline log data, is described by Fullagar et al. (2005).

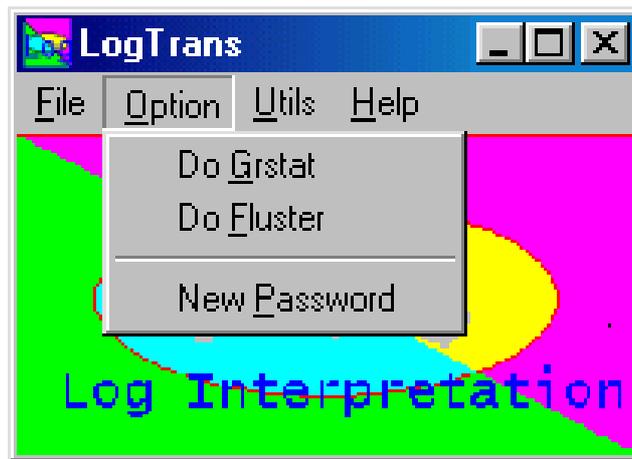
2. Operational Basics

LogTrans interpretation is comprised of two stages:

1. *Statistical characterisation*, using program GRSTAT, and
2. *Auto-interpretation (discrimination)*, using program FLUSTER.

Statistical characterisation refers to calculation of the group statistics from the control data: centroids (means or medians) and measures of the population ranges (standard deviations or spreads) for each petrophysical parameter in each class.

Discrimination refers to the process of interpretation as described above, using the group statistics.



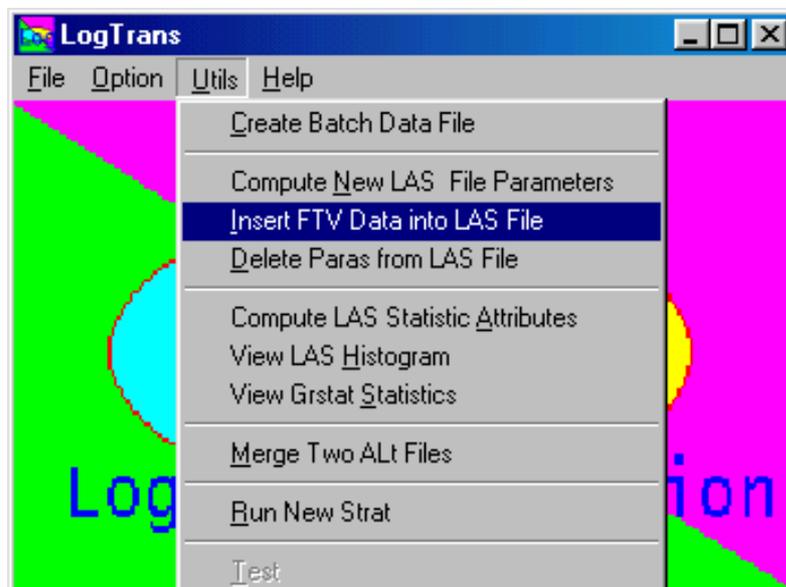
3. File formats

3.1 Borehole log data formats

LogTrans reads data in LAS format or in Minex format (with DFN header). The *.TXT format described in the *Help* is no longer supported.

3.2 Core-based data format

Data in From,To,Values (FTV) format, e.g. assays, can be inserted into LAS files using the *Insert FTV Data into LAS File* option under *Utils*. See Section 7.3 below.



3.3 Assigned Litho-Type (*.ALT) files

Geological and other rock type interpretations are read and outputted in variants of ALT format.

1st line = heading

2nd line = sub-heading

3rd & subsequent lines: type_name [,] from [,] to [, optional additional fields]

If the type_name includes one or more spaces, it must be enclosed by quotation marks (“type name”); however, names without spaces are strongly recommended.

The name and depths can be separated by tabs, commas, or spaces. This is a free format, not a fixed format. A sample *.ALT file is appended.

Geology

(log)

IG_L	0	9.5	
IG_Lox	9.5	18	
IGox	18	21	D010
TKBox	21	25.75	D010
IGox	25.75	38.7	D010
HMKw	38.7	41.32	D010
IGw	41.32	42.55	D010
HMKw	42.55	43	D010
IGw	43	43.5	D010
HMKw	43.5	44.2	D010
IGw	44.2	47.1	D010
HMKw	47.1	48.5	D010
TKBw	48.5	102.98	D010

Note that BLANK is an illegal class name.

LogTrans interpretations have extension AL*, where * denotes “wild”. If “lithology” and “ore/waste” interpretations are performed simultaneously (see Section 6), both interpretations are recorded in the AL* file. A sample dual interpretation file is listed below.

INTERP

Log	3	WEAK	FLR1	ROF1A	ROF3	
ROF1A	376.700	376.850	Gn0dd348			WEAK
FLR1	376.850	377.150	Gn0dd348			WEAK
ROF1	377.150	378.350	Gn0dd348			STRONG
ROF4	378.350	387.650	Gn0dd348			STRONG
ROF2	387.650	395.050	Gn0dd348			STRONG
FLR3	395.050	405.150	Gn0dd348			WEAK
ROF1A	405.150	405.950	Gn0dd348			WEAK

3.4 Batch Data (*.DAT) files

Multiple holes can be batch processed using Batch Data files. The depth range for interpretation can be restricted by specifying minimum and maximum depths of interest for each hole. The format is as follows:

1st line = #lasalt#

2nd and subsequent lines = path*.LAS [path*.alt] [min depth, max depth]

Each line defines the location of the LAS and (if available) ALT file for each borehole. An ALT file must be included for statistical characterisation (GRSTAT), but is optional for interpretation (FLUSTER).

The minimum and maximum depths are optional, but both (or neither) must be specified, i.e. defining a minimum depth alone is not acceptable. Depth limits are applied by both GRSTAT and FLUSTER.

Records beginning with “!” are ignored. A sample DAT file is listed below.

```
#lasalt#
d8\d8lith.las      d8\d8.alt
d9\d9lith.las      d9\d9.alt      27.3  55.8
d10\d10lith.las    d10\d10.alt
d11\d11lith.las    33.9  100.45
d12\d12lith.las    d12\d12.alt
d13\d13lith.las    d13\d13.alt
d14\d14lith.las    d14\d14.alt
!d15\d15lith.las   d15\d15_K%.alt
!d16\d16lith.las
!d17\d17lith.las    d17\d17_K%.alt
!d18\d18lith.las    d18\d18_K%.alt
d19\d19lith.las    d19\d19.alt
```

Batch Data files can be created using the *Create Batch Data File* option under *Utils*. See Section 7.1 below.

3.5 Global output GLL (formerly *.LTG) files

The global output file contains LogTrans interpretations for all holes processed during a single FLUSTER run. The average “confidence” (see Section 6 below) over each interval is recorded also. If both “Lithology” and “Ore-waste” interpretation is selected (Section 6), both interpretations are recorded in the global output file. Likewise, the “agreement” log (Section 6) is recorded if available???

When operating on LAS format data, the global output from FLUSTER is recorded in a file with GLL extension (Global, LogTrans, Las). The header for the *.GLL file records the parameters for FLUSTER; header lines begin with double semi-colons. Subsequent records contain

```
HOLEID, TYPE_NAME, FROM, TO, RANK, AVCONF, [OREW], [AGREE],
[DOMINANT]
```

where

HOLEID is the drill hole name

TYPE_NAME is the rock type

FROM is the start depth

TO is the end depth

RANK is the stratigraphic rank of the interpreted rock class (see Section 7.9)

AVCONF is the average of the LogTrans “confidence” measure over the interval,
 OREW is “ore” super-class name or the “waste” super-class name, according to
 which super-class the interpreted rock type belongs to (see Section 6);
 OREW is null? when ore/waste interpretation is not performed.
 AGREE indicates correspondence between the LogTrans interpretation and the
 interpretation in the ALT file (if any) for this hole in the Batch Data File (see
 Section 6).
 DOMINANT is the dominant rock class over this depth interval in the interpretation in
 the ALT file (if any) for this hole in the Batch Data File (see Section 6)

A sample GLL is listed below:

```
;; GLL File Generated by
;; LogTrans
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;; Fluster Parameters
;; C:\GermanCreek\Central\Geotech.dat !Data file name
;; C:\GermanCreek\Central\Geotech.NEW !Grstat file name
;; 0.2 0.1 !Window Length & Depth Interval
;; FLR1 ROF1A ROF3 !Interp. Ore Classes
;; 2 !Ore-waste Interp. type flag
;; 100 !Max. SD Value
;; 1 !Median Filter Flag
;; AL !Interp. File Extension
;; AZ !Confidence File Extension
;; DENB FI GRDE LSDU RV2 S20 UCS !Selected Parameters for
Interp.
;; FLR1 FLR2 FLR3 GC GU ROF1 ROF1A ROF2 ROF3 ROF4 &
!Selected classes for Interp.
;; 1 !Spread Weight
;; 0 !Optimisation flag =1 for Opt. 0 for no opt.
;; 0 !Create LDL File flag =1 for Opt. 0 for no opt.
;; Central control hole win=(0,0.2) prior=1 !LogVew Common
title
;; WEAK !Ore mnemonic
;; STRONG !Waste mnemonic
;; AL !Interp File Extension
;; 0 !Use Output Path
;; !Output Path
;; 0 !Run New Strat
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
"GNODD348","ROF1A",397.800, 397.650,0,0.335, "WEAK","OK", "ROF4"
"GNODD348","GC", 397.650, 395.650,0,0.364, "STRONG","NO", "ROF1A"
"GNODD348","ROF1A",395.650,394.650,0, 0.516, "WEAK","NO", "ROF4"
"GNODD348","ROF1",394.650,392.350,0, 0.552, "STRONG","NO", "FLR1"
"GNODD348","ROF1A",392.350, 392.250,0, 0.469, "WEAK","OK", "ROF1"
"GNODD348","FLR1",392.250,392.150,0, 0.736, "WEAK","OK", "ROF1A"
"GNODD348","ROF1",392.150, 391.950,0, 0.537, "STRONG","OK", "GC"
"GNODD348","FLR1",391.950, 391.850,0, 0.452, "WEAK","NO", "ROF1A"
"GNODD348","ROF1A",391.850, 390.250,0, 0.588, "WEAK","NO", "ROF1A"
```

When the input to LogTrans is in Minex format, the global output file will be in Minex format. There are currently three Minex output options, denoted "A" (for Anglo Coal), "C" (for Capcoal lithology), and "G" (for Capcoal geotech). The range of format options can be expanded as required. The default Minex output format is "A".

The Minex global output format can be specified by the user if LogTrans is launched via command line. The syntax is as follows:

```
path\logtrans.exe -f"INFFILE_PATH_NAME.INF" -tminextype
```

where INFFILE_PATH_NAME.INF is the file path and name for the FLUSTER input (*.INF) file, and where minex_{type} is either MinexA, MinexC, or MinexG. The double quotes are only necessary for file names with spaces. Command line parameters are all case insensitive. The order of the -f and -t switches is not important.

When the input to LogTrans is in Minex format, the global output file will have extension GLA (Global, LogTrans, Minex A), GLC (Global, LogTrans, Minex C), or GLG (Global, LogTrans, Minex G) according to the output format selected.

Global output files are also generated by the algorithm, STRAT, which enforces stratigraphic order (Section 7.9). In this case the global files contain the stratigraphically-consistent interpretations only.

When operating on LAS format data, the global output from STRAT is recorded in a file with GSL extension (Global, Strat, Las). After two header lines, each record of the GSL contains the following:

```
HOLEID, TYPE_NAME, FROM, TO, RANK
```

where

HOLEID is the drill hole name

TYPE_NAME is the rock type

FROM is the start depth

TO is the end depth

RANK is the stratigraphic rank of the interpreted rock class (see Section 7.9)

```
;; GSL File Generated by  
;; STRAT  
"GN0DD348", "ROF4", 377.27, 384.65, 1  
"GN0DD348", "ROF3", 384.65, 385.65, 2  
"GN0DD348", "ROF2", 385.65, 390.05, 3  
"GN0DD348", "ROF1", 390.05, 395.03, 5  
"GN0DD348", "ROF1A", 395.03, 395.65, 6  
"GN0DD348", "GC", 395.65, 397.80, 7  
"GNCCD354", "ROF4", 381.35, 388.55, 1  
"GNCCD354", "ROF3", 388.55, 389.55, 2  
"GNCCD354", "ROF2", 389.55, 399.05, 3  
"GNCCD354", "ROF1A", 399.05, 400.95, 6
```

"GNCCD354", "GC", 400.95, 402.95, 7
"GNCCD354", "FLR1", 402.95, 403.30, 8

When the input to LogTrans is in Minex format, the global output file created by STRAT will have extension GSA (Global, Strat, Minex A), GSC (Global, Strat, Minex C), or GSG (Global, Strat, Minex G) according to the output format selected.

3.6 Stratigraphic key (*.KEY) files

See Section 7.9 below.

4. Directory structure and destination of output

When processing LAS data, LogTrans assumes that the LAS file for each hole is located in a separate sub-directory below a common root ("base") directory. Likewise, the geological log or other prior interpretation by a human expert for each hole (if available) is stored in ALT format in the appropriate sub-directory for that hole. Output files specific to individual holes are written to the appropriate sub-directory also.

Global output files are written to the directory containing the Batch Data File. Normally this is the root directory when processing LAS data.

When operating on Minex data, individual interpretation files (with AL* or AZ* extensions) are written to the directory containing the Minex data by default. However, a different target directory for LogTrans output can be specified on the FLUSTER form (or in the INF file) if desired.

Minex files can contain data from more than one hole. If a multi-hole Minex file were processed, LogTrans output for those holes would be written to the same directory.

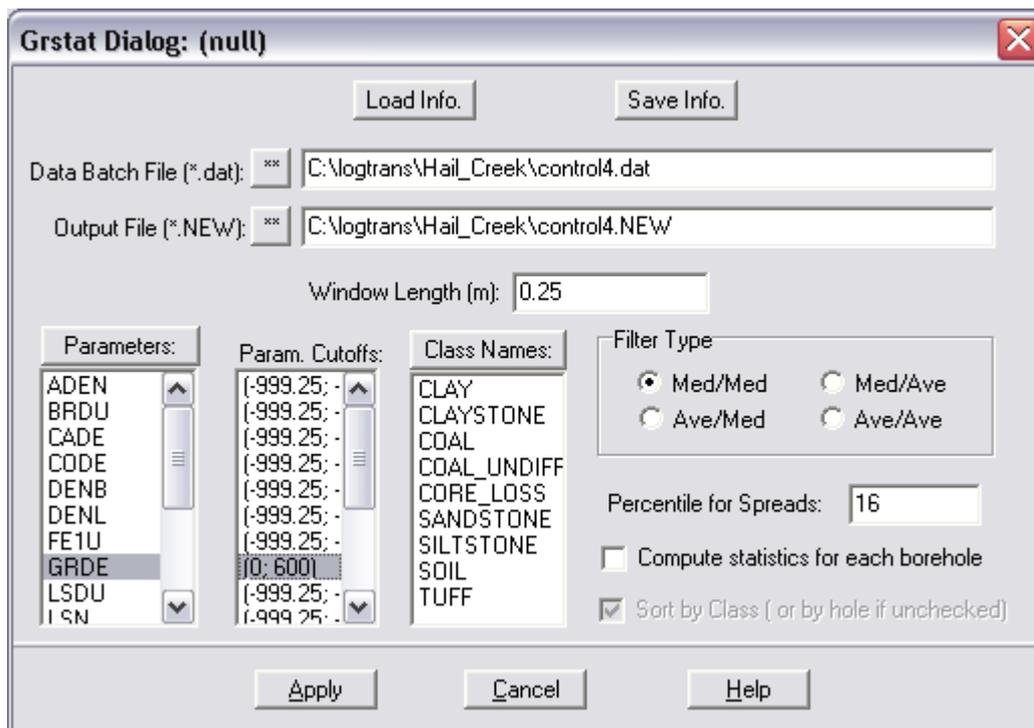
5. Statistical characterisation (GRSTAT)

Means or medians of each parameter within each rock type are computed by program GRSTAT for a suite of control holes. The output file (*.NEW) is written to the root directory. These statistics provide the basis for auto-interpretation of data from other holes. The operation of GRSTAT is described step by step below.

5.1 Select control holes. These should be representative, intersecting all stratigraphy of interest, and reliable, exhibiting high data quality.

5.2 Create the Batch Data (*.DAT) file in the root directory. (See section 7.1)

5.3 Run GRSTAT. Select *Do GRSTAT* under the LogTrans *Option* menu.



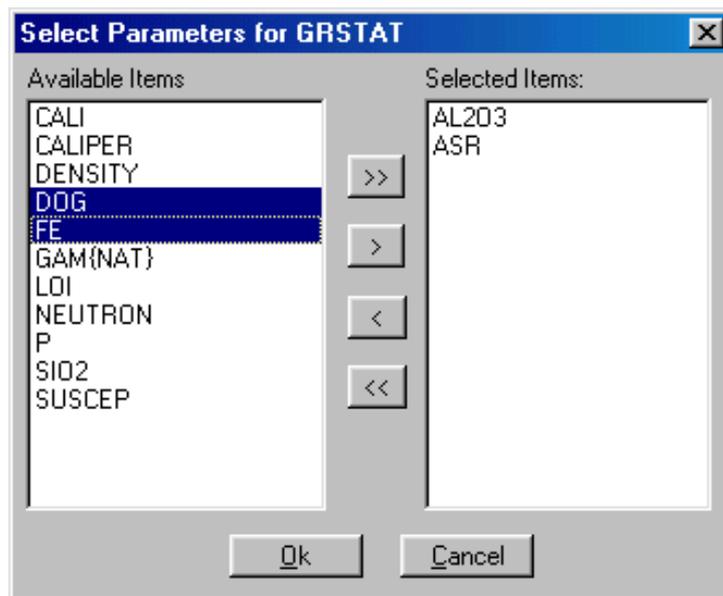
Browse to find the Batch Data file by clicking the ** button next to the **Batch Data File** text box. The Batch Data file should be located in the root directory.

Default statistics file is "GROUP.NEW". Re-name the **Output File** as desired. The output (statistics) file will be written to the root directory.

The log data can be windowed. Define the length of the window for computation of running average or running median values in the **Window Length** text box. Enter zero to process point readings.

Click on the **Parameters** button to list parameters. All parameters can be listed, or optionally only those which are common to all the LAS files nominated in the Batch Data file. For example, if MSUS was not recorded in one hole, then MSUS is not regarded as a common parameter by GRSTAT. Likewise, if natural gamma is labelled as GRDE in some holes and GRNP in others, then GRSTAT will either treat the two types of gamma logs as different parameters (if all parameters are listed) or else ignore all gamma data (if only the common parameters are listed).

To select parameters for statistical characterisation, highlight their names in the *Available* list and click the > button to transfer them to the *Selected* list. The >> button selects all the available classes. Similarly, de-select classes by highlighting them in the *Selected* list, and clicking on the < button. The << button de-selects all classes.



To avoid processing noise, data outside the range defined by the **Parameter Cutoffs** for each parameter are assigned the closest cutoff value, i.e. either the minimum or the maximum. Dummy value (-999.25) parameter cutoffs are ignored. To enter a parameter cutoff value, double click on the parameter in question and enter the desired values in the *Cutoff Editor* text boxes.

Click the **Class Names** button to list all the classes detected in all the ALT files defined in the Batch Data file. The user can select the classes wanted for statistical characterisation by highlighting them on the *Available* list, and transferring them to the *Selected* list. GRSTAT can compute statistics for up to 2048 classes.

Four **Filter Types** are offered:

- Med/med implies that the median value is selected from the running window at each depth, and that the median of all the running medians is adopted as the characteristic value.
- Med/ave implies that the median value is selected from the running window at each depth, and that the average of all the running medians is adopted as the characteristic value.
- Ave/med implies that the average value is selected from the running window at each depth, and that the median of all the running averages is adopted as the characteristic value.
- Ave/ave implies that the average value is selected from the running window at each depth, and that the average of all the running averages is adopted as the characteristic value.

Medians are more robust (less sensitive to outliers and slight depth errors) than averages, so med/med is the normal selection.

For */med filter types, the range of a certain parameter for a particular class is represented by “spread” values. The upper and lower spreads are normally defined as the parameter ranges between the median value and the 16th and 84th percentile values. As such the spreads capture 68% of the sample population, the same proportion which resides within one standard deviation of the mean in a Normal distribution. The user may change the **Percentile** range of the spreads if desired.

One advantage of a */med filter type is that it can represent statistical skew. If a */ave filter type is selected, symmetry is assumed and a standard deviation is computed.

If the **Compute statistics for each borehole** box is checked, and if the **Sort by class** box is also checked, individual NEW files are generated for each class, and saved to the root directory. This output is valuable for quality appraisal, since hole-to-hole variations for each parameter are immediately apparent.

Similarly, if the **Compute statistics for each borehole** box is checked, but the **Sort by class** box is unchecked, individual NEW files are generated for each borehole, and saved to the root directory. This output reveals class-to-class variations for each parameter within each borehole.

Once the GRSTAT form has been completed, the settings can be saved in a *.ING file by clicking the **Save Info** button. Saved parameter settings can be re-loaded in subsequent GRSTAT runs by activating the **Load Info** button.

For a first run of GRSTAT, the parameter selections need not be final: an initial dummy run through GRSTAT and FLUSTER is a way to expedite plotting of the data.

All windowed data accepted for statistical characterisation can optionally be written to a single **Global File** for further analysis, e.g. histogram construction. The user is given the option of creating a global file after GRSTAT has completed.

5.4 Examine statistics (medians and spreads or averages and standard deviations) for each parameter using the *View GRSTAT Statistics* option under *Utils* (see Section 7.7 below). Identify the “problem classes” with large spreads at this stage, and take remedial action if necessary, e.g. create sub-classes.

Large spreads are sometimes due to small population sizes; the maximum number of points per class (NPTS) are recorded in the statistics (NEW) file. {This is the maximum number, since there may be some parameters missing over a subset of the depth intervals for any given class}. It is often advisable to disallow classes with small populations during interpretation (discrimination) with program FLUSTER. Alternatively, their effect can be reduced using the *Optimisation* option described in Section 6 below.

Basic statistics for each parameter distribution are recorded in a *_Stats.xls file in the root directory. If the **Compute statistics for each borehole** box is checked,

basic statistics for each parameter distribution in each hole are recorded in a *_Stats.xls file in the appropriate sub-directory. [The status of the **Sort by class** box does not affect the generation of XLS files.]

6. Auto-interpretation (FLUSTER)

Interpretation is performed by program FLUSTER, using the statistics computed by GRSTAT.

Run FLUSTER to interpret a suite of logs: select *Do FLUSTER* under the LogTrans “Option” menu.

The screenshot shows the 'Fluster Dialog' window with the following settings:

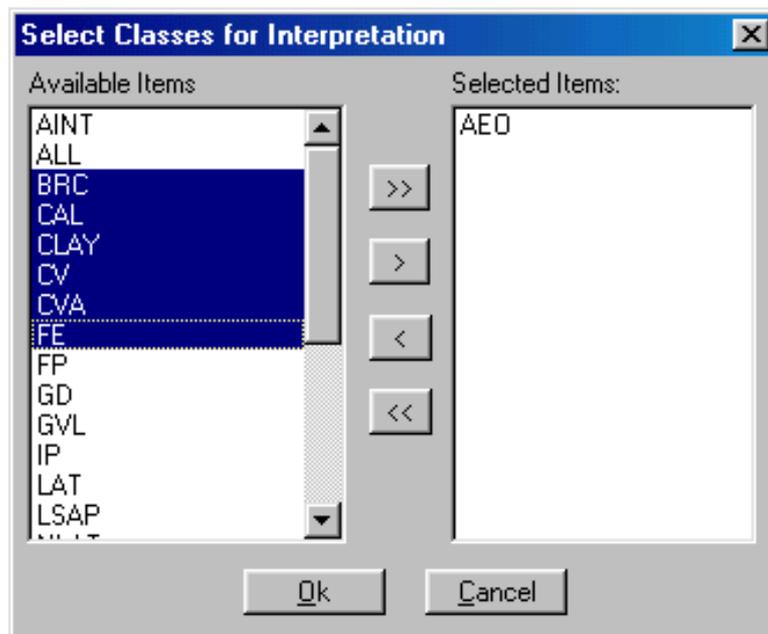
- Data Batch File (*.DAT):** C:\Placer\Grannys\WBAD.dat
- GrstatFile (*.NEW):** C:\Placer\Grannys\Group.new
- Window Length (m):** 2
- Depth Sampling Interval (m):** 0.1
- Selected Paras:** DELTAT, DENSITY, DOG, GAM{NAT}, VP
- Selected Classes:** AEO, AINT, ALL, BRC, CAL, CLAY, CV, CWA
- Ore Classes:** (Empty)
- Interp. Type:** Ore-Waste, Lithology
- Ore Mnemonic:** ORE
- Waste Mnemonic:** ROCK
- Filter Type:** Median, Average
- Max. Value of SD's:** 10
- Spread Weight:** 1
- LogView Common Second Title:** Control hole win=(1,2)
- Optimisation
- Create LDL File
- DELTAT** (selected in dropdown)
- Edit Param. MinMax Values** (button)
- Interpretation File Extension:** AL

Buttons at the bottom: Apply, Cancel, Help

The top four text boxes serve the same functions as for the GRSTAT form, described above. Note that the **Batch Data File** may define control holes (used for statistical characterisation), but in production mode it will specify new holes for which no independent interpretation (*.ALT file) exists. The **Window Length** can be set to the same value adopted for the GRSTAT run, or the user may choose a different window size. Empirically, it has proved beneficial to use a larger window for FLUSTER than for GRSTAT in some cases.

Click on the **Selected Paras** button to list the available parameters. These are parameters for which statistics exist in the GRSTAT (*.NEW) file. The user can select parameters for the interpretation by highlighting them in the *Available* list and transferring them to the *Selected* list using the > button. The >> button selects all available parameters. Conversely, de-select parameters using the < and << buttons.

Click on the **Selected Classes** button to list the range of possible classes, as defined in the GRSTAT (*.NEW) file. The user can select the permissible interpretation classes by highlighting them in the *Available* list and transferring them to the *Selected* list using the > button.



Three **Interpretation Types** are offered:

- **Ore/Waste** interpretation, where a binary discrimination is performed: each depth point is interpreted as either “ORE” or “ROCK”. This option is selected by clicking the Ore/Waste button. The **Ore Classes** must be specified. Click on the *Ore Classes* button to list all possible ore classes. Select the ore classes by highlighting them in the *Available* list and transferring them to the

Selected list using the > button. The names of the two classes of material can be customised by editing the *Ore Mnemonic* and *Waste Mnemonic* boxes.

- **Lithology** interpretation, where the individual rock type class is interpreted at each depth. This option is selected by clicking the Lithology button. The *Ore Class* text box should be left empty in this case.
- Simultaneous **ore/waste and lithology** interpretation.

Depths with combinations of parameter values unlike any encountered in the control holes are interpreted as type “NEW”. The user controls the demarcation between the “known” and “new” realms by setting the **Maximum Value of SDs** parameter. For Normal distributions, 99.5% of all occurrences lie within 3 standard deviations of the mean; hence setting Maximum Value of SDs to 3 would be a typical choice. If Maximum Value of SDs is large, LogTrans will assign an interpretation at every depth, even if the data plots far from any control hole points in multi-parameter space.

Either running averages or running medians of the logs are processed, according to the selected **Window Filter Type**. Point data are processed if a Window Length of zero is selected, in which case the Window Filter Type makes no difference.

It may be desirable to reduce the parameter spreads or standard deviations for classes with small population sizes. This can be achieved using the parameter **Spread Weight**. The original spread values are adopted if *Spread Weight* = 1. Any given depth interval is most likely to belong to the class with the largest population – assuming always that the relative population sizes in the control holes are representative of ALL holes. In FLUSTER, a class with large spreads but a small population could be assigned to a disproportionately large number of depth intervals. In extreme cases, such classes can be disallowed (deleted from the *Selected Classes* list). An alternative approach is to set the *Spread Weight* to a value less than 1, in which case the spreads or standard deviations for each class are reduced according to the following formula:

$$spread_{new} = \min\left\{1, Spread_Weight + \frac{N_{class}}{N_{total}}\right\} * spread_{old}$$

where N_{class} is the population of the class, and where N_{total} is the total number of points in the control data set.

When FLUSTER is being run on control holes, **Optimisation** can be selected to determine the value of *Spread Weight* which delivers the maximum success rate. Optimisation entails 22 successive runs of FLUSTER (for *Spread Weight* values between 0 and 1 at intervals of 0.05), and can therefore take some appreciable time if the data set is large. The optimal value of *Spread Weight* should then be selected for subsequent runs of FLUSTER on other holes.

For the first FLUSTER run on any suite of holes it is useful to check the **Create LDL Files** box to generate the *.LDL files required by the plotting program, LogView. An LDL file is created for each hole, and written to the corresponding directory. On later runs of FLUSTER, uncheck this box, otherwise changes made to the original LDL files (in LogView) will be lost.

An optional second line of title for the LogView plots, common to all holes, can be entered in the **LogView Common Second Title** text box. LogTrans parameters such as window widths can be conveniently recorded on plots using this feature.

By default, the limits on the parameter value axes (“Y-axes”) in the LogView plots are set to the maximum and minimum values encountered in the control holes. To define new parameter limits for plotting, select a parameter from the pull-down list in the lower RH corner of the FLUSTER form, click on the **Edit Param MinMax Values** button, and enter the desired limits.

An Interpretation File in ALT format is created for each hole and written to the appropriate directory. The interpretation file for each hole has the same rootname as the LAS file, and default extension “AL” . Different interpretation file extensions can be specified in the **Interpretation File Extension** text box. The ability to control the file extensions allows the user to save the results from a series of runs of FLUSTER using different parameter settings.

The class recorded in the interpretation file is that whose properties best match the data at each depth. The second and third best matches are recorded also; the corresponding files are distinguished from the standard interpretation file by the addition of a suffix “1” and “2” respectively to the extension.

LogTrans computes a measure of confidence in the interpretation at each depth (Fullagar et al., 1999). The confidence values provide a crude indication of the variation in the perceived degree of ambiguity from one depth to another. The values have no precise meaning in probabilistic terms, but 1 is “high” and “0.1” is low. The **Confidence File** for each hole is in LogView profile (depth, value) format, and has extension “AZ” by default. The extension on the Confidence File will reflect the extension specified for the Interpretation File. For example, if the Interpretation File Extension is defined as ALH, the associated Confidence File will have extension AZH.

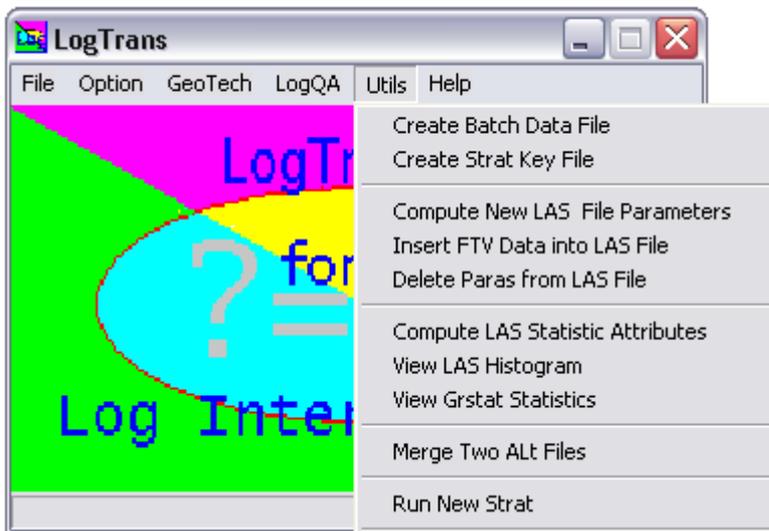
When a geological (or other) interpretation (ALT file) is specified in the Batch Data File, FLUSTER automatically compares the “control” geo-interpretation with the LogTrans interpretation. The result is recorded in file **Agreement File** with name “holenameAGREE.ALT”, where holename.LAS is the corresponding LAS file. Depth intervals over which the dominant LogTrans interpretation is in agreement with the original interpretation are labelled “OK”; those for which the LogTrans and original interpretation differ are labelled “NO”. The comparison is performed over the depth intervals defined in the Interpretation File. Because the depths of contacts between different rock types will not necessarily correspond in the control and LogTrans interpretations, the rock type interpreted by LogTrans is compared with the “dominant” rock type over the corresponding depth range in

the control interpretation. The dominant class is that which accounts for the greatest proportion of the depth interval.

To facilitate transfer of LogTrans interpretations to data bases, FLUSTER interpretations for all holes specified in the Batch Data (DAT) File are also recorded in a single **Global Output (GLL) File** (formerly LTG file). The LogTrans global file is written to the same directory as the DAT file; its rootname is identical to that for the DAT file, but its extension is GLL (for LAS format input data) or GLA, GLC, or GLG (for Minex format input data). The format of the Global Output File is defined in Section 3.5.

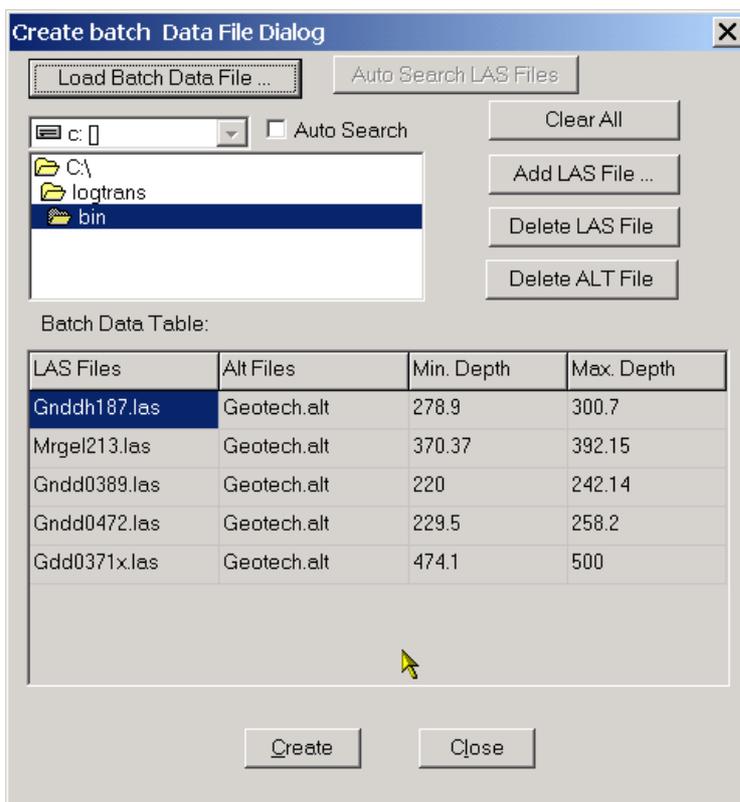
7. Special Features

The following special utilities are available under *Utils*.



7.1 Create a Batch Data File

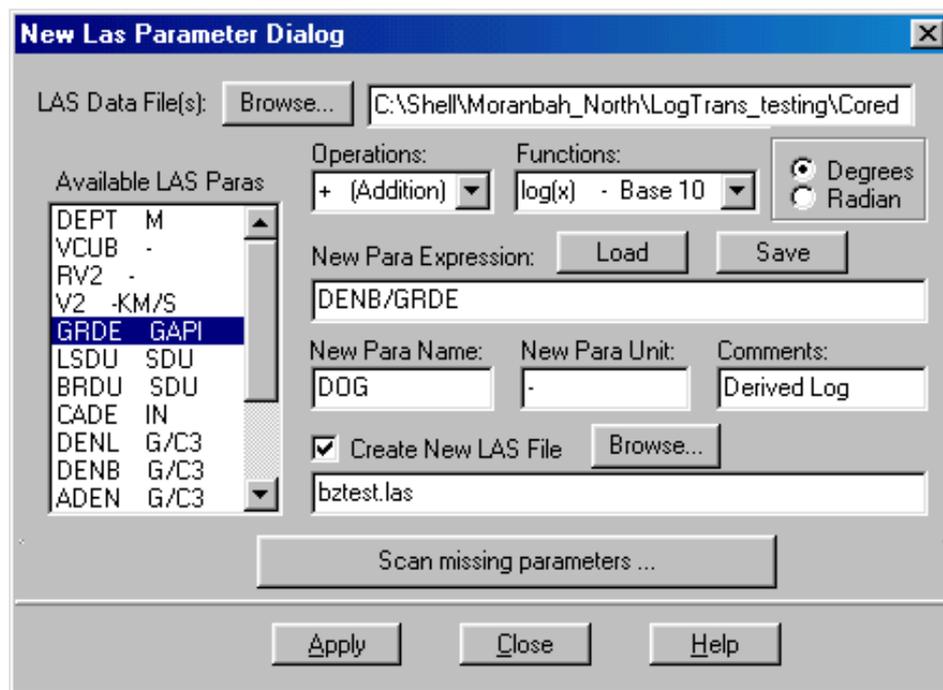
Batch Data files can be created and edited by invoking the utility under *Utils*.



The **Auto Search** button lists all LAS files residing in sub-directories below the selected root directory. Mouse click on a particular LAS or ALT file to add, delete, or modify.

7.2 Convenient mathematical manipulation of parameters

Mathematical transformation and combination of parameters in LAS files can be performed in an efficient manner using the *Compute new LAS file parameters* option, available under *Utils*. For example, logarithms, ratios, and linear combinations of parameters can be inserted in LAS files as extra parameters. New parameters can be introduced either to a single LAS file, or to a suite of LAS files as defined in a Batch Data (DAT) file.



Define a *New Parameter Expression* in the text box provided, assign a name and (optionally) physical unit, then click on the *Apply* button to add the new parameter to all the files listed in the Batch Data File.

Most standard mathematical functions are available under *Functions*. Note that the trigonometric functions can be toggled between degrees and radians using the radio buttons at top right.

Functions include derivative, running average, and running median. For the running average and median, the filter length (flten) is defined in terms of the unit of depth in the LAS file. The filter window is always spanned by an odd number of points, so it is symmetric about the centre point. Filter length is automatically increased by one point if necessary; for example, if the filter length is specified as 0.37m for 1cm sampled data, the actual filter length will be 0.38m (comprising 39 points).

Formulae can be applied conditionally using the IF function; the syntax is IF(condition, formula if true, formula if false).

Parameter expressions can be read or preserved using the **Load** and **Save** buttons respectively. Formulae are stored in files with extension EQN.

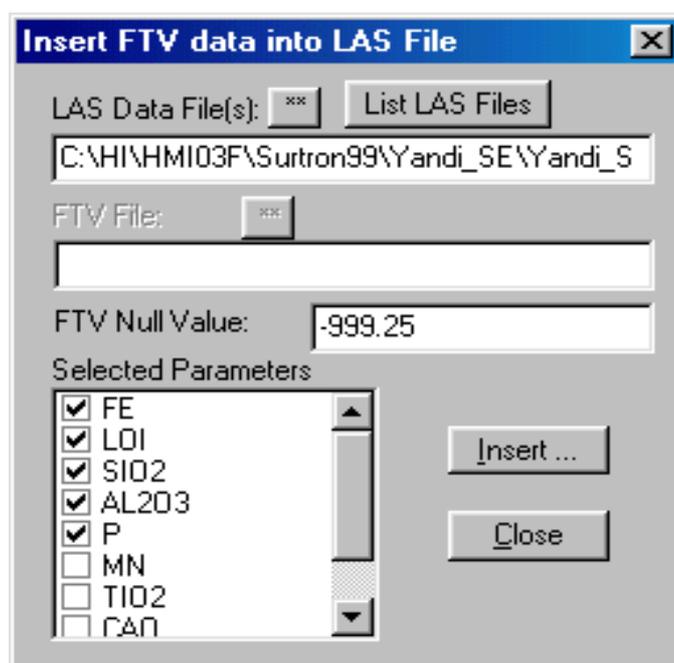
Only “common” parameters are displayed in the window at the left of the form, i.e. only parameters which occur in all the LAS files listed in the Batch Data File. In order to establish which parameters are missing from which holes, click on the *Scan Missing Parameters* bar near the bottom of the form.

LogTrans will not allow two parameters with the same name to be created.

Parameters can also be deleted from LAS files using the *Delete Paras from LAS files* option (see Section 7.4 below).

7.3 Insertion of core-based data into LAS files

LogTrans operates on LAS files. Therefore core-based data such as assays or UCS measurements must be re-sampled at the borehole log sampling interval and inserted into the appropriate LAS file. Core-based data in FTV format can be inserted into LAS files using the *Insert FTV Data into LAS File* option under *Utils*.



A sample FTV file is listed below:

\FTV File

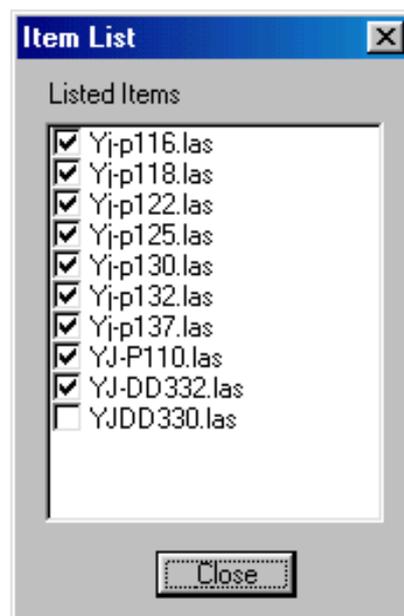
```
HOLEID, FROM, TO, Ag_ppm, Ba_ppm, Ca_ppm, Cd_ppm, Co_ppm, Cr_ppm, Cu_ppm,
Mn_ppm, Ni_ppm, Pb_ppm, S_ppm, Zn_ppm
HOLE001, 12, 14, 6, 2506, 18974, 9, 15, -999.25, 280, 7171, 30.00, 500, 1028, 16547
HOLE001, 14, 16, 9, 6385, 3543, 27, 15, -999.25, 455, 23547, 37.00, 500, 500, 13983
HOLE001, 16, 18, 12, 7047, 2373, 7, 15, -999.25, 362, 23556, 34.00, 500, 500, 17738
HOLE001, 18, 20, 6, 2465, 2294, 5, 15, -999.25, 262, 7375, 42.00, 500, 500, 37031
HOLE001, 20, 22, 10, 2324, 2998, 3, 15, -999.25, 236, 6712, -999.25, 500, 500, 15759
HOLE001, 22, 24, 9, 2961, 6845, 12, 15, -999.25, 656, 10681, 60.00, 500, 3689, 59702
HOLE001, 24, 26, 7, 1230, 2176, 3, 15, -999.25, 802, 2287, 62.00, 500, 500, 73524
```

HOLE001,26,28,3,1405,2713,14,15,-999.25,2016,2108,79.00,500,500,130731
 HOLE001,28,30,6,3155,3571,25,15,-999.25,2844,13752,73.00,500,500,162143
 HOLE001,30,32,3,2880,1932,15,15,-999.25,859,7604,40.00,500,500,34280
 HOLE001,32,34,3,1083,1693,3,15,-999.25,451,1082,26.00,500,500,14803
 HOLE001,34,36,9,1474,2441,18,15,-999.25,598,2287,48.00,500,500,23349
 HOLE001,36,38,3,1447,2105,8,15,-999.25,365,2113,26.00,500,500,9817

HOLEID is the hole name, which must correspond to the rootname of a LAS file.

Data may be inserted into a single LAS file or into a series of LAS files listed in a Batch Data (DAT) file. Click on the [**] button to select the desired LAS or DAT file.

If a Batch Data file is selected, click on the *List LAS Files* button to examine the DAT file contents. If a listed LAS file is checked, *LogTrans* has identified an FTV file with the same root name as the LAS file, residing in the same sub-directory. No FTV file has been found for YJDD330 in the example below. Often the failure to marry a LAS file to an FTV file is due to an incompatibility in file naming, i.e. missing hyphen in this case.



Specify the null value for the FTV files in the *FTV Null Value* text box.

The core-based parameters common to all the selected holes are listed in the window in the lower left of the *Insert FTV Data into LAS File* form. Select or de-select a parameter for insertion into LAS files by clicking on the appropriate check box. Only checked parameters will be inserted.

Click the *Insert...* button to insert the data. *LogTrans* re-samples the core-based data (e.g. assays) at the borehole logging sample interval, and pads with nulls if the borehole logging depth coverage is more extensive than the assay depth range. The convention for repeat assays is to accept the first value and ignore repeats.

LogTrans edits the LAS file header, adding new parameter names and, if necessary, adjusting the depth range.

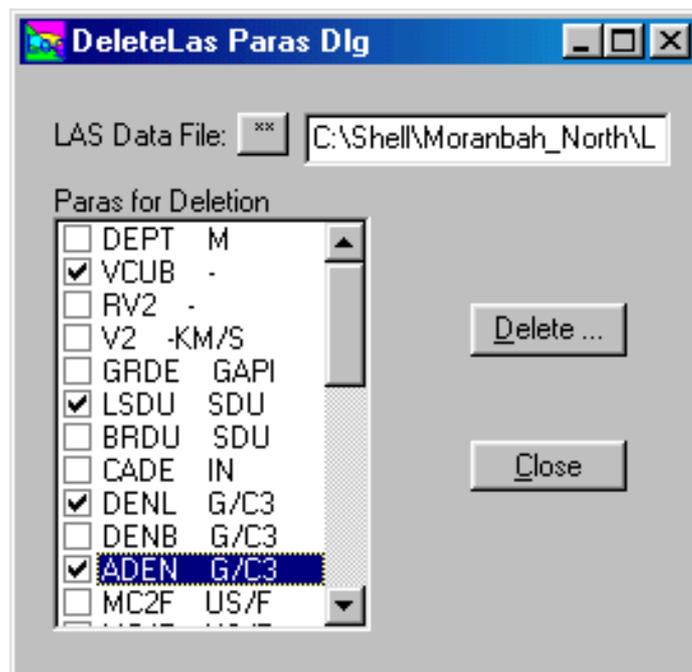
LogTrans will not allow two parameters with the same name to be inserted. It may be necessary to delete a parameter, then re-insert, if LAS files in a *Batch Data File* have different histories.

Click the *Close* button once all FTV data insertions have been completed.

Data will be inserted within the existing depth range in the target LAS file(s); FTV data beyond the original depth range will be ignored.

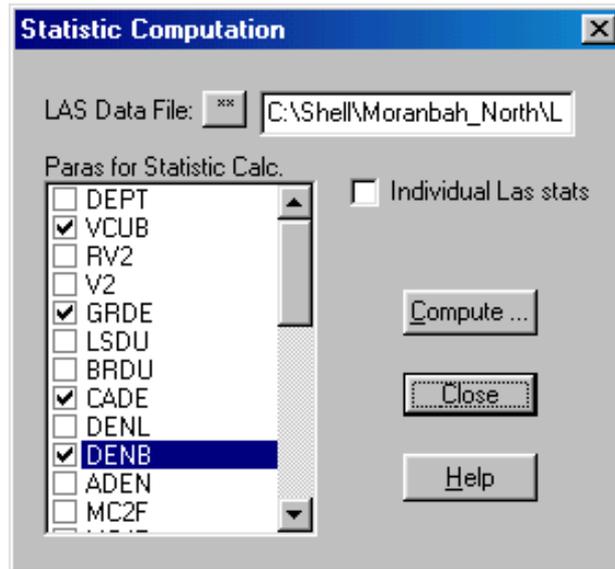
7.4 Deletion of LAS file parameter(s)

Parameters can be deleted from one or more LAS files using the *Delete Paras from LAS File parameters* option, available under *Utils*. Select a LAS file or Batch Data File by clicking on the *LAS Data File Browse* button [**]. Only the checked parameters in the list will be deleted. Click the *Delete* button when parameter selection is complete.



7.5 Compute standard parameter statistics

A suite of standard statistics (mean, standard deviation, median, maximum, minimum, etc.) can be computed for selected parameters from one or more holes using the *Compute LAS Statistic Attributes* option under *Utils*. Select a LAS file or Batch Data File by clicking on the *LAS Data File Browse* button [**]. Statistics will be computed only for the checked parameters in the list. Click the *Compute* button when parameter selection is complete.



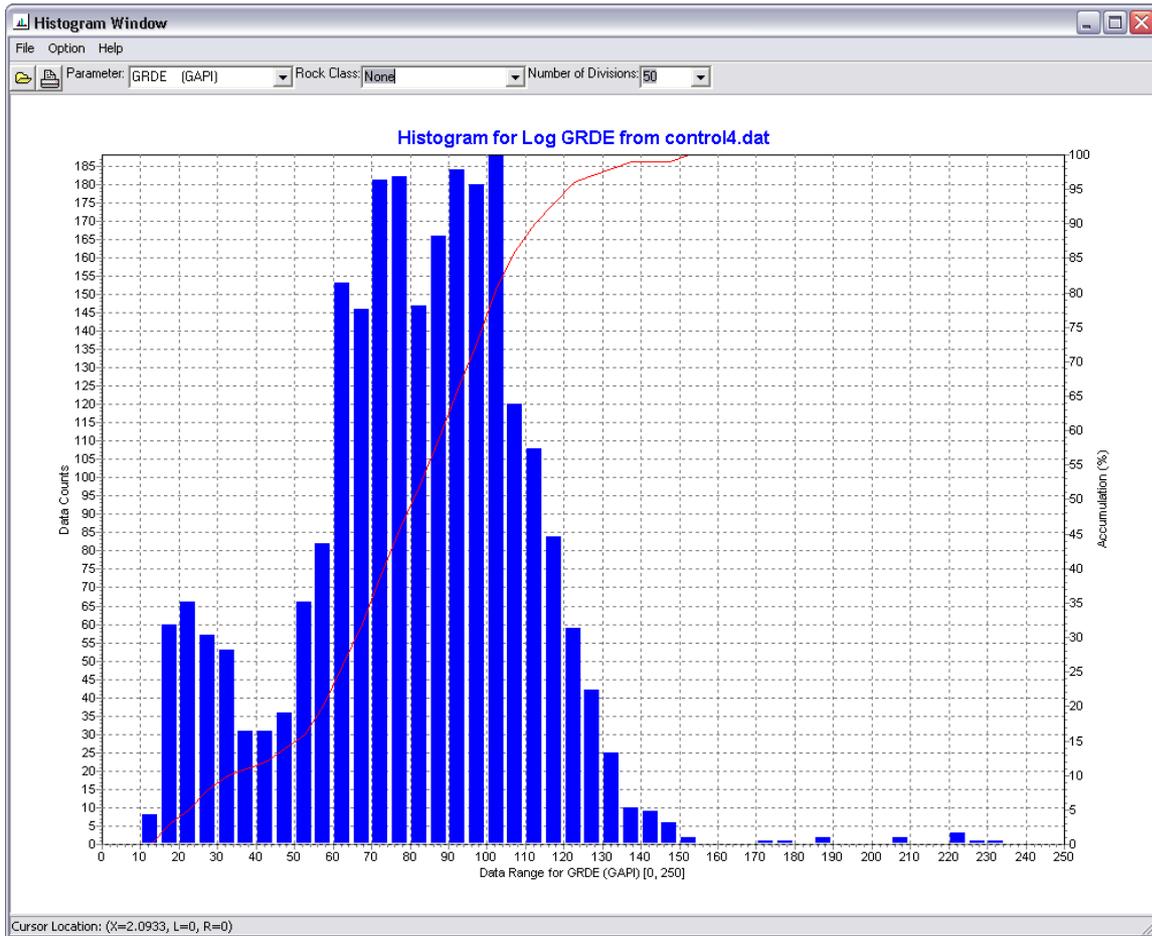
If statistics are required for individual LAS files, check the *Individual LAS Stats* box. Otherwise, if a Batch Data File has been nominated, the statistics will be “global”, i.e. will refer to the data from all the holes listed in the Batch Data File.

Statistics are recorded in an Excel file. Global statistics will be written to a file with the same root name as the Batch Data File, with suffix “_sts”, in the root directory. Statistics for individual LAS files will be written to a file with the same root name as the original LAS file, with suffix “_sts”, located in the same directory as the LAS file.

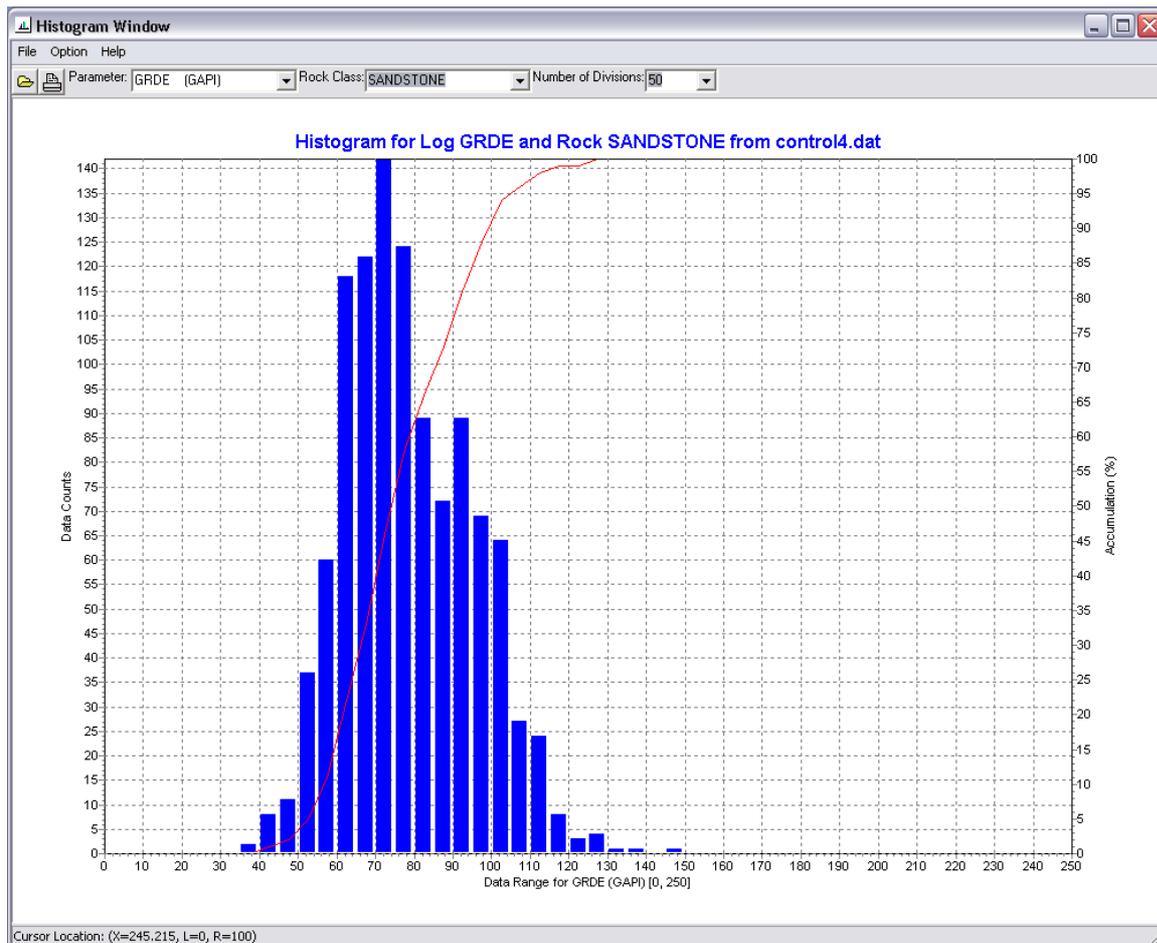
The computed values are point statistics, i.e. no windowing is applied.

7.6 Display parameter histograms

Parameter histograms can be displayed using the *View LAS Histogram* option available under *Utils*. Load a LAS file or a Batch Data File from the File menu. The histogram will refer to a single hole if a LAS file is loaded. If a DAT file is loaded, the histogram will be “global”, i.e. will refer to the entire suite of LAS files listed in the Batch Data File.



The user can control the Parameter, Rock Class, and Number of Divisions (bins) using the pull down menus at the top of the window. If Rock Class *None* is selected, the histogram will define the distribution for the selected parameter across all rock types. Otherwise, the histogram will refer to the selected Rock Class.



For a given parameter, the horizontal data range will be identical for all rock classes, for ease of comparison. The horizontal plot limits can be set by the user via *Option\Setup*.

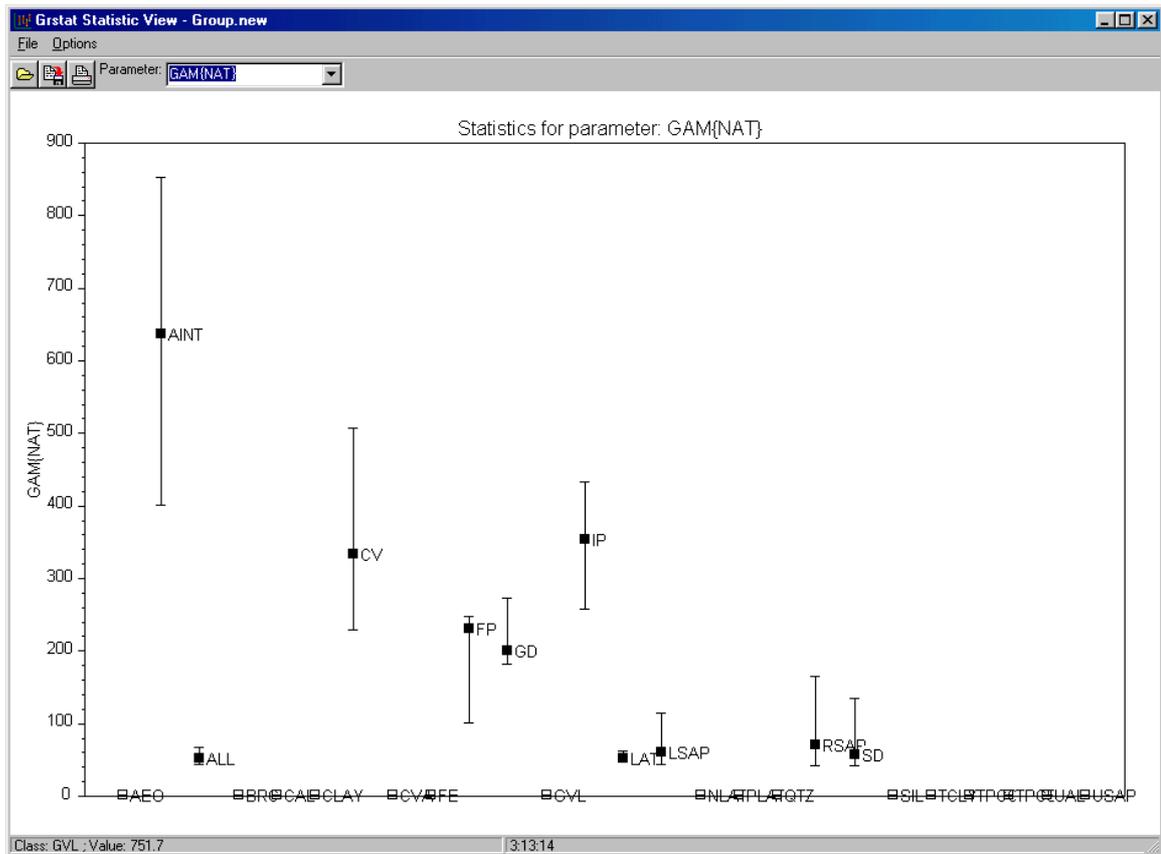
7.7 Display control statistics

After running GRSTAT, the control hole statistics can be displayed using the *View GRSTAT statistics* option under *Utils*.

The statistics (NEW) file is selected via the *Files* pull-down menu. This menu also controls printing.

On the graphs, the symbols define the median or average values of a particular parameter in the different classes. The bars indicate the parameter range within each class, as captured by the spreads or the standard deviation. The statistics displayed relate to the parameter selected using the *Parameter* list at the top left of the form.

Plot titles, colours, and the choice and ordering of classes are controlled via the *Options* menu.



7.8 Merge two ALT files

This utility updated in 2009, to permit batch operation.

This utility merges the information from two assigned litho-type (ALT) files into a single ALT file. This is beneficial if, for example, new “petrophysical” classes have been defined on the basis of the wireline logs.

Select the original (base) ALT file using the *Base Alt File* button. The *Merging Alt File* contains the new information or revisions. The two are merged in the *Output File*. The user can control which classes to insert from the merging file into the base file by means of the check boxes in the *Types to be merged* window.

For example, if the target ALT file is

```

Geology
Log
ALL, 0.0, 7.0
WCH, 7.0, 10.0
GVU, 10.0, 36.0
GVL, 36.0, 45.0
BCC, 45.0, 48.0
WW, 48.0, 51.8

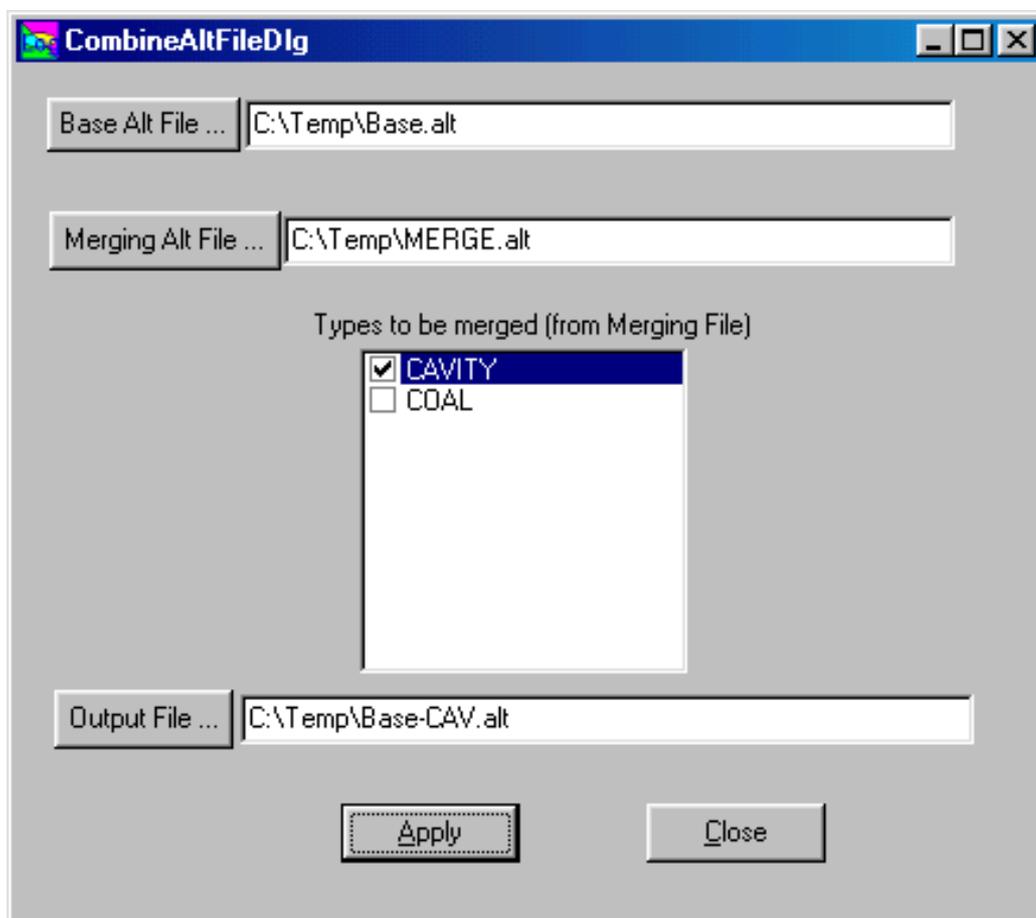
```

and if intervals of CAVITY are to be inserted from the following merging ALT file

Geology
Log
CAVITY, 1, 30
COAL, 31, 32
CAVITY, 38, 39
COAL, 46, 47
CAVITY, 49, 50

then the merged file is

Geology
Log
ALL 0 1
CAVITY 1 30
GVU 30 36
GVL 36 38
CAVITY 38 39
GVL 39 45
BCC 45 48
WW 48 49
CAVITY 49 50
WW 50 51.8.



7.9 Compute interval averages

This option introduced in 2009.

This utility computes interval averages for one or more LAS files parameters over depth ranges defined in a litho-type (ALT) file. The option is available under *Utils*.

Select the *Batch Data File* (DAT) file, and specify the extension for the litho-type file defining the depth intervals of interest. The root name of the litho-type file is presumed to be identical to the LAS file defined in the DAT file. The litho-type file is presumed to be located in the same directory as the LAS file.

The user can control the classes for which averages are required by means of the check boxes in the *Parameters to be averaged* window.

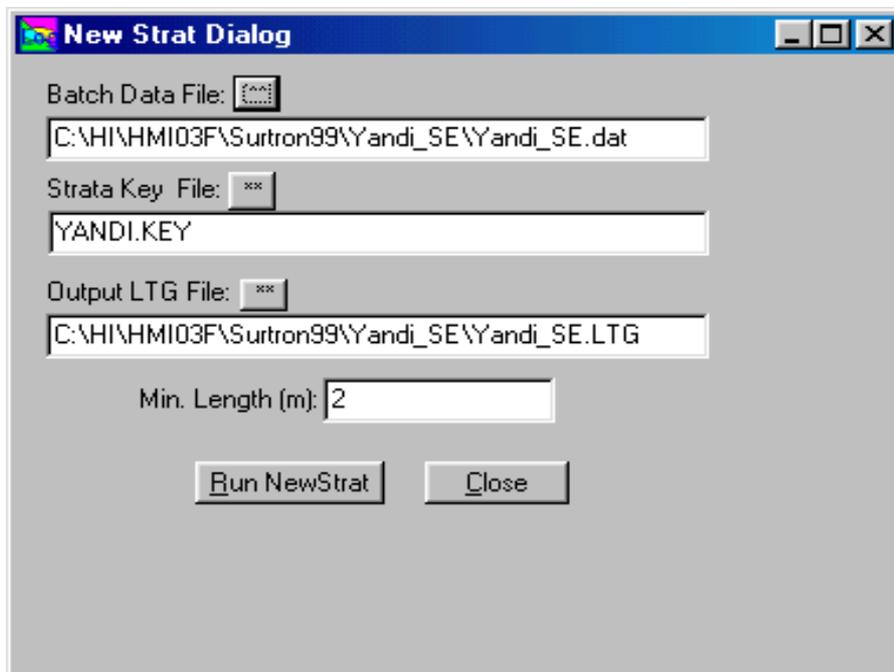
Define the extension for the output file. The root name for the output file is inherited from the batch (DAT) file. The output is written to the same directory as the DAT file.

7.10 Stratigraphically constrained interpretation

Interpretations can be constrained to conform to a prescribed stratigraphic order. When appropriate, e.g. in undisturbed sedimentary sequences, stratigraphic consistency is not only essential for geological acceptance, it is also a powerful constraint which can be exploited by LogTrans.

The operational procedure is to generate a standard LogTrans interpretation in the normal fashion, using FLUSTER, and then to run the *Strat* option, available under *Utils*. Stratigraphic conflicts are resolved, whenever possible, by substitution of the original interpretation over a given interval with the 2nd or 3rd choices defined by FLUSTER. The 2nd and 3rd choice interpretations are stored in ALT files with extension AL1 and AL2 respectively.

Stratigraphically constrained interpretation can be performed on either a single hole, or a suite of holes as defined in a Batch Data (DAT) file.



In order to enforce the stratigraphic order, the user must create a KEY file to define the stratigraphy. If NSTRAND is the total number of stratigraphic levels, or formations, the first NSTRAND records define the generic names for those formations, in order of increasing depth. Stratigraphic equivalents are permitted, and are listed on lines NSTRAND+1 and beyond, in any order.

Each record of the KEY file is of the form
CLASS, INDEX, MINL, MAXL, STDL
where

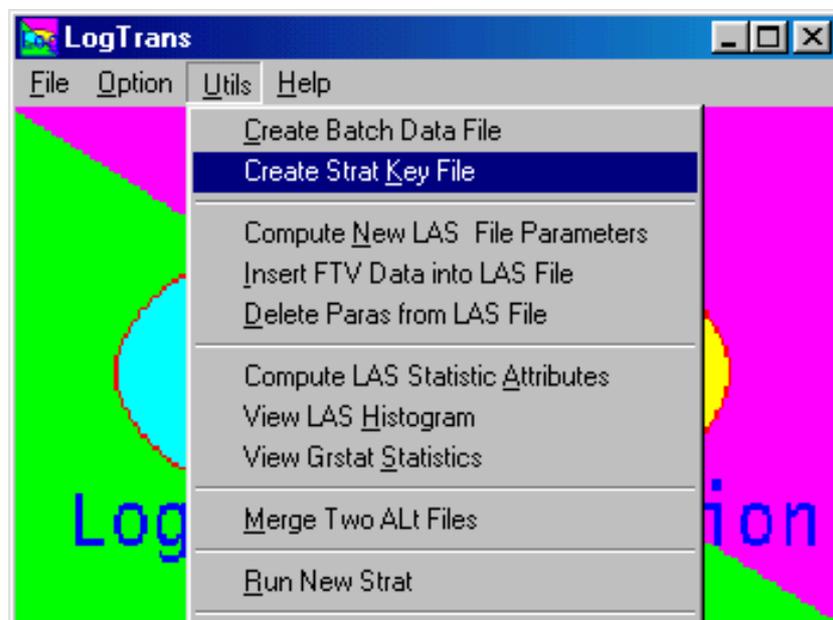
CLASS is the formation or class name,
INDEX is the stratigraphic rank or formation index of that class (1 for youngest),
MINL is the minimum length (depth interval) for the formation,
MAXL is the maximum length for the formation, and
STDL is the “standard” thickness for the formation.

The standard thicknesses define a type section which is used to eliminate excessively thick layers, i.e. layers which exceed the maximum thickness for a particular formation. If an excessively thick layer arises during a STRAT run, the standard stratigraphic section is moved past the original FLUSTER interpretations until the correspondence between standard and LogTrans output is maximised. The standard section is then adopted as the final interpretation within the excessively thick interval. In order for the standard stratigraphy to play a role, a maximum thickness must be defined for at least one formation, and a standard thickness must be defined for every formation. Standard thickness for stratigraphic equivalents should be set to the dummy value (-999.25).

The KEY file can be created and edited using the *Create Strat Key File* option under *Utils*. Skeleton documentation for this utility is available via the *Help* button at the bottom right of the form.

A sample KEY file with six stratigraphic formations is listed below:

COVER	1	-999.25	-999.25	10	} Generic formation names
CAS	2	-999.25	-999.25	6.5	
NOVA	3	2.	10	7.5	
CLAY	4	-999.25	-999.25	11	
WITS	5	5.	-999.25	12	
BASEMENT	6	-999.25	-999.25	30	
WCH-ALU	5	-999.25	-999.25	-999.25	
WCU-ORE	3	-999.25	-999.25	-999.25	
ECC-WAS	4	-999.25	-999.25	-999.25	
WCU-ALU	3	-999.25	-999.25	-999.25	
ECC-WAS	4	-999.25	-999.25	-999.25	



When running STRAT, the user must also specify a global *Minimum Length* parameter, MINLEN, which distinguishes “thick” layers from “thin” layers. In resolving stratigraphic conflicts in the original LogTrans interpretation, thick layers (with thickness \geq MINLEN metres) are treated as more reliable than thin layers.

If $MINL < MINLEN$ for a particular formation, intervals of classes which belong to that formation are treated as “thick” if they exceed MINL in thickness. If $MINL > MINLEN$, MINLEN is adopted as the minimum thickness for the unit in question. Set $MINL = -999.25$ if no formation-specific minimum length is to be applied.

A formation for which MINL is negative is a marker bed. A marker bed is treated as an unfailing indicator of stratigraphic position. Any interval in the original interpretation corresponding to the marker bed class is accepted as correct, provided it is greater than $|MINL|$ in thickness. There can be at most one marker bed formation, and at most one depth interval in the original interpretation which is

assigned to the marker bed formation. If more than one marker bed is detected in the (1st) interpretation, the marker bed is treated as a normal layer, with minimum thickness of |MINL|. Marker beds cannot have stratigraphic equivalent classes.

If the formation maximum length is exceeded by a particular member class, and no standard section has been defined, the interval is not concatenated, i.e. appears in the interpretation file (STRAT2.AL) as adjoining segments which are individually shorter than MAXL. Units other than marker beds which exceed their maximum thickness are treated as logically thin. Set MAXL = -999.25 if no formation-specific maximum length is to be applied.

8. Trouble shooting

LogTrans will not launch

For some unknown reason, LogTrans will not run from a directory called LogTrans. Move the EXE, DLL, and TXT files to another directory, e.g. LogTrans\Bin, and try again.

Password not accepted

Check the VSN. Ensure that the VSN supplied to Fullagar Geophysics (for generation of the password) is the appropriate VSN for the disk partition on which LogTrans resides.

No FTV file found during data insertion

Check the file naming: when run is controlled by a Batch Data File, the an incompatibility in file naming, i.e. missing hyphen in this case.

LogTrans will not permit insertion of core-based (FTV) data

In order to avoid confusion, LogTrans will not allow creation of two parameters with the same name in a LAS file. Insertion of FTV data will abort if a duplicate parameter is detected, e.g. if core-based parameters have already been inserted for some of the holes listed in a Batch Data File. If this problem is encountered, delete the offending parameter(s) using the *Delete Paras from LAS File* option under *Utils*. Then re-run the FTV insertion.

No output after running program STRAT

If STRAT runs to completion, but the LTG (or Strat2.AL file) is empty for one or more holes, try increasing MINLEN and re-running.

Program STRAT hangs up

If STRAT hangs up during execution, the problem could be the occurrence of a class in the AL, AL1, or AL2 files which does not appear in the KEY file. If NEW has been interpreted for some intervals, re-run FLUSTER with a larger *Maximum Value of SDs* parameter before re-running STRAT.

Most common problems with STRAT have been trapped, and produce error messages with suggested remedies.

9. User support contact details

Primary user support contact:

Peter Fullagar (FGCL Consulting Ltd, Vancouver)

Phone: Canada: (778) 847 3428 Intl.: +1 (778) 847 3428

E-mail: **peter@fullagargeophysics.com**

Vancouver time is GMT-8 hours (winter) or GMT-7 hours (summer).

Alternate support contact:

Binzhong Zhou (CMTE/CSIRO Exploration & Mining, Brisbane)

Phone: Australia: (07) 3327 4630 Intl.: +61 (7) 3327 4189

E-mail: **binzhong.zhou@csiro.au**

Brisbane time is GMT+10 hours.

10. References

Davis, J.C., 1986, Statistics and data analysis in geology: John Wiley & Sons, 646p.

Fullagar, P.K., Fallon, G.N., Hatherly, P.J., and Emerson, D.W., 1996, Implementation of Geophysics at Metalliferous Mines - AMIRA Project P436 Final Report: Centre for Mining Technology and Equipment, Brisbane, Report MM1-96/11.

Fullagar, P.K., Zhou, B., and Fallon, G.N., 1999, Automated interpretation of geophysical borehole logs for orebody delineation and grade estimation: Mineral Resources Engineering, 8, 269-284.

Fullagar, P.K., Zhou, B., and Biggs, M., 2004, Stratigraphically-consistent auto-interpretation of borehole data: J. Appl. Geophys., 55, 91-104.

Fullagar, P.K., Zhou, B., and Turner, R., 2005, Quality appraisal for geophysical borehole logs: Australian Coal Association Research Program (ACARP) Project C13016, Final Report.