Reflection Seismic Processing

- Objective
- Processing Systems
- General concept of CMP processing
- Processing Tools
- SEGY and similar file formats
- General features of ProMAX

- Reading:
  - ProMAX manual (Introduction)

Reflection Seismic Processing

- Objective - transform redundant reflection seismic records in the *time domain* into an interpretable *depth image*.
  - Data reduction and editing;
    - Transformation into conveniently computer-manageable form;
    - Removal of bad records;
  - Gathering;
    - CMP sorting;
  - Filtering in time and space;
    - Attenuation of noise;
  - Imaging
    - Final velocity and reflectivity image.

Seismic Processing Systems

- Usually geared to a particular type of application
  - Mostly CMP reflection processing;
  - Land or marine, 2D or 3D.
- Commercial:
  - ProMAX (Landmark);
  - Omega (Western Geophysical, marine);
  - Focus (Paradigm);
  - Amoco and almost every other company have their own…
  - Vista (Seismic Image Soft.).
- Open-source/Universities:
  - Stanford Exploration Project;
  - Seismic UNIX (Colorado School of Mines);
  - FreeUSP (Amoco);
  - SIOSEIS (Scrippts, marine, not free!);
  - I. Morozov's very own http://w3.uwyo.edu/~seismic/sia/

Seismic data formats
SEG-Y

- Most seismic data formats are similar, and include:
  - Text file header (comments for the user, line description);
  - Binary file header (number of traces, other vital formatting information);
  - 'Traces', each including:
    - Binary trace header (channel number, coordinate, offset, statics, mute times, filter parameters, etc.). Some formats allow user-defined trace headers.
    - Trace sample values (integer or floating-point).
- SEG-Y (adopted by SEG as the standard data exchange format):
  - Text file header of 3200 bytes (40 80-character lines);
  - Binary file header of 400 bytes;
  - Traces include:
    - 240-byte headers, fixed predefined format.
    - Samples in any of the 2- or 4-byte formats (usually stored as 4-byte IBM REAL).
- A moderate 2-D seismic line with 800 shots recorded by 96 channels at 1500 samples per trace takes about 500 Mb of storage in SEG-Y format (verify this!)

Processing Hardware
Gigabytes and Gigaflops

- Memory
  - 1 byte = 8 bits;
  - 1 kbyte (kilo-) = 1024 bytes;
  - 1 Mbyte (mega-) = 1024^2 bytes;
  - 1 Gbyte(tera-) = 1024^3 bytes;
  - 1 Tbyte(tera-) = 1024^4 bytes.
- Flop
  - Number of floating point operations per second (‘+’, ‘-’, ‘*’, ‘/’);
  - Sqrt() takes about 10-15 operations;
  - Multiples:
    - 1 Mflop = 10^6 flop;
    - 1 Gflop = 10^9 flop;
    - 1 Tflop (tera-) = 10^{12} flop;
    - 1 Pflop (penta-) = 10^{15} flop;
    - 1 Eflop (exa-) = 10^{18} flop.
- For top performers, check out http://www.netlib.org/benchmark/top500/top500.list.html
- 3-D seismic processing routinely utilizes *massively* parallel systems (thousands of processors)

General CMP Processing Sequence

1) Demultiplex, Vibroseis correlation, Gain recovery
   - Conversion from file formats produced by field data loggers into processing-oriented formats
     - SEG-Y, SEG-2.
     - ProMax, Focus, Omega, SU, Vista, etc., internal formats.
   - These days, may not be required (done in the field).
2) Field Geometry
   - Assignment of source-receiver coordinates, offsets, etc. in the *trace headers*.
3) Edit
   - Removal of bad traces (noisy channels, poorly planted geophones, channels contaminated by power line noise, etc.).

General CMP Processing Sequence (continued)

4) First arrival picking
   - May be semi-automatic or manual;
   - Required for generation of *refraction statics*; models and for designing the *mutes*.
5) Elevation statics
   - Based on geometry information, compensates the travel-time variations caused by variations in source/receiver elevations.
   - Transforms the records as if recorded at a common horizontal *datum* surface.
6) Refraction statics
   - Builds a model for the shallow, low-velocity subsurface;
   - Compensates the travel-time variations caused by the shallow velocities.
7) 'Top', 'bottom', and 'surgical' *mute*
   - Eliminates (sets amplitude=0) the time intervals where strong non-reflection energy is present:
     - First arrivals, ground roll, airwave.

General CMP Processing Sequence (continued)

8) Gain recovery
   - Compensates geometrical spreading;
   - Based on a simple heuristic relation.

10) Trace balance
   - Equalizes the variations in amplitudes caused by differences in *coupling*;
   - In true-amplitude processing, replaced with '*surface-consistent deconvolution'*.

9) Deconvolution
   - Compresses the wavelet in time, attenuates reverberations.

10) Gather, CMP sort
   - In modern processing systems (ProMax, Omega, Vista) done by using *trace lookup spreadsheets* rather than by creating additional copies of the dataset.

General CMP Processing Sequence (continued)

12) Velocity analysis
    - For each of the CMP gathers, determines the optimal *stacking velocity*.
13) Dip Moveout (DMO) correction
    - Transforms the records so that the subsequent NMO+stack work well even in the presence of dipping reflectors.
14) Normal Moveout (NMO) correction
    - Removes the effects of source-receiver separation from reflection records;
    - Transforms the records as if recorded at normal incidence.
15) Residual statics
    - Removes the remaining small travel-time variations caused by inaccurate statics or velocity model

General CMP Processing Sequence (continued)

16) Steps 12-15 above are usually iterated 3-5 times to produce accurate *velocity* and *residual statics* models.
   - Success of velocity analysis depends on the quality of DMO/NMO and residual statics, and vice versa.

17) Stack
   - Produces a *zero-offset section*;
   - Utilizes CMP redundancy to increase the *Signal/Noise ratio.*

18) Migration
   - Transforms the zero-offset *time* section into a depth image;
   - Establishes correct extents and dips of the reflectors.

Processing tools

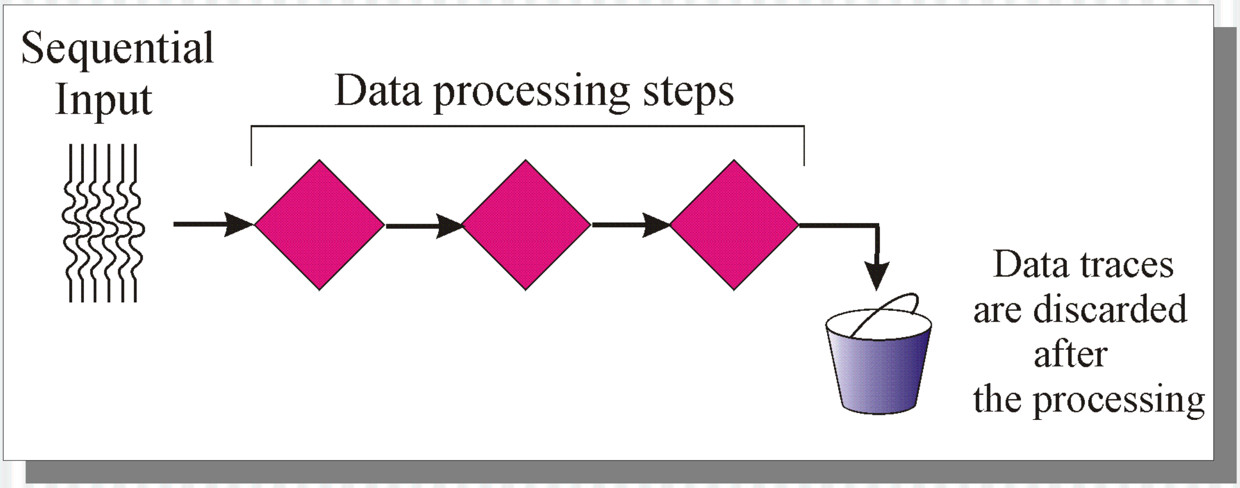
- Preprocessing
  - Demultiplex;
  - Editing;
  - Gain recovery;
  - Field geometry;
  - Elevation (‘field’) statics.
- Travel-time corrections
  - Statics, i.e., time shifts (elevation, refraction (weathering), residual);
  - Velocity analysis (testing for hyperbolic moveout);
  - Normal-moveout correction (NMO);
  - Dip moveout correction (DMO);
  - Migration.

Processing tools
Continued

- Wavelet adjustments
  - Vibroseis correlation,
  - Deconvolution;
  - Frequency filtering.
- Amplitude corrections
  - Compensation of Geometrical spreading;
  - Gain
    - Automatic Gain Correction (AGC,), trace normalization, etc.
- Noise reduction
  - Velocity filtering (*f*-*k* and τ-*p* filters);
  - ‘Vertical' stack, CMP stack;
  - Muting.

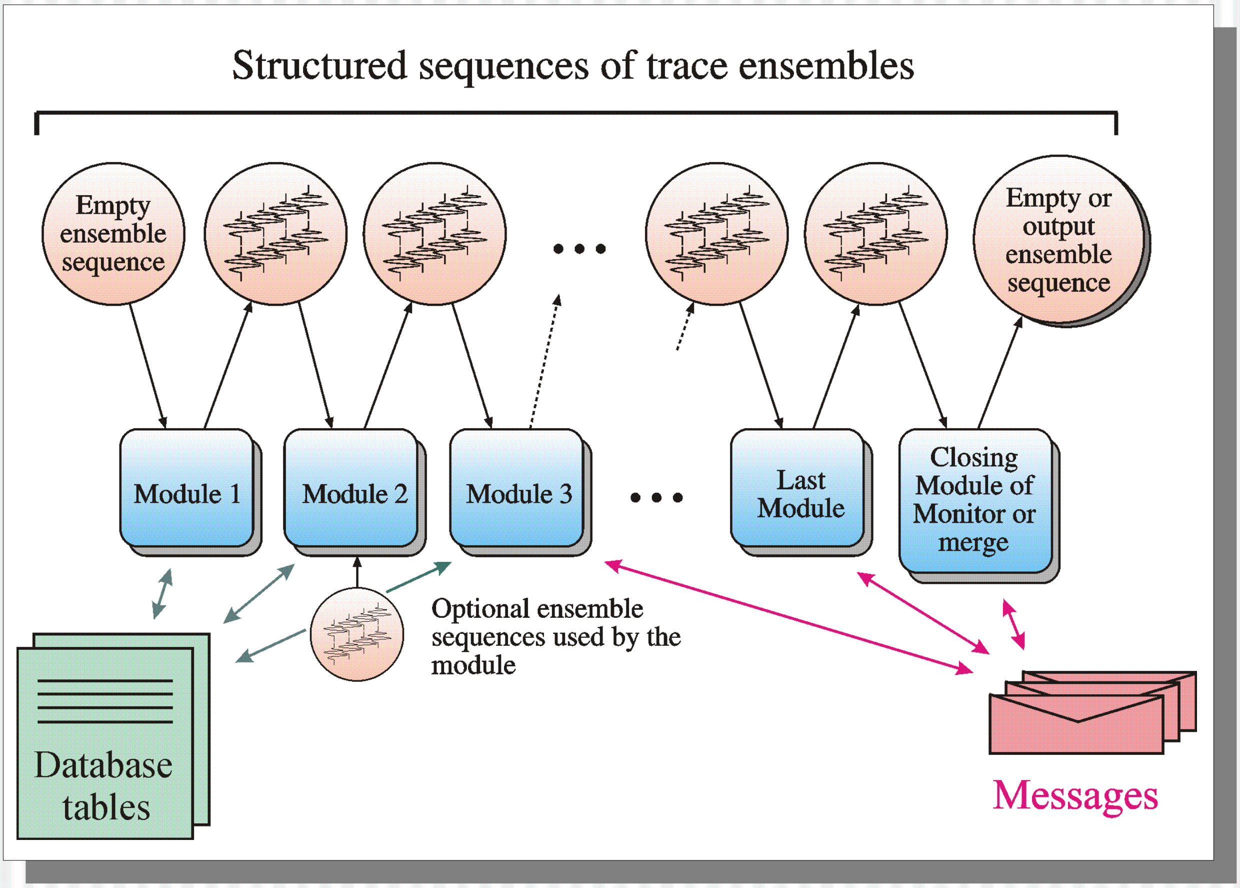
General Processing Flow

- Seismic processing flow is a *computer program*
  - Implemented as a 'script' (DISCO, SIA, SU), 'instruction list' (ProMAX), or visual 'graph' (Vista, Omega)
  - User builds the processing sequence using a collection of *tools* for data manipulation
  - Results in generation of a code *customized* to perform the specified task



The More General Processing Flow

- SIA Seismic processing logic is based on *independent* operation of the modules
  - Each module transforms an input *gather* of multicomponent traces into output one
  - SIA also maintains a system of *database tables* and inter-modular messaging mechanism



ProMAX
General data hierarchy

- Area (project)
  - Line
    - Processing Flows (perform specific processing tasks with the traces or databases)
    - Datasets (traces, headers, lookup tables)
    - Databases (most of them called OPF – Ordered Parameter Files)
    - Tables (travel times, velocity models, etc.)
- A special area used for *archiving* and restoring other projects ('areas')

ProMAX

Key components

- Front-end GUI
  - Navigates within areas, lines, flows, datasets, databases, tables, etc.
- Flow builder
  - Allows building processing flows from a library of modules
  - Send flows to execution
- Monitor
  - Monitors running jobs, allows suspending and killing them
  - Displays job logs
- Database editors
  - Display/edit various databases