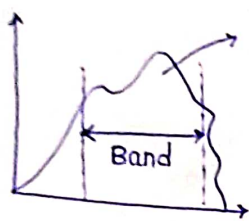


# Seismic Data Processing and Interpretation

Date: 28.08

Brute Stack is used for QC.



The seismic band contains noise which can be removed by - (i) Filter → Band-pass filter  
(ii) Edit / Kill / Mute

High pass → mean low cut filter  
and low pass → high cut filter

- High pass
- Low pass
- Notch

Seismic band →  $n(t)$  → Edit / Kill / Mute → Filter → High cut / low cut / Notch / High pass / low pass

Noise comes from → (i) Acquisition

(ii) Incompetence (means i am unable to setup the value of  $f_1$  and  $f_2$  and remove the noise in the setup of the bandpass)

Produces FFID from 1 to n

$T_1$	$T_8$	$T_9$
$T_2$	$T_3$	$T_4$
$T_7$	$T_6$	$T_5$

Generates FFID from 1 to n

Why we have missed shot ?

Energy was generated but couldn't create the reflection signal because the layers are not compressed properly.

Delay trigger →

Surgical mute is easier than Top mute. (Removing the top portion)  
The far-offset data is reaching earlier to that assumed i.e. may be there is a low-velocity layer / the velocity is not estimated properly → NMO stretch.

## Geophysical Inversion

Orthogonal Transformation :

Linear Inverse Problem :

Matrix :  $d = Gm$

$G = UGU^T$

$U$  = Orthogonal Matrix

$G$  = Diagonal matrix

Limitation : The matrix lying both side of the  $G$ -matrix may not be same.

In Inverse problem, we face with  $G$  can be rectangular / non-square

Singular Value Decomposition (SVD) :

$G = UGL^T$

$n \times n$  or  $n \times m$

$n$  = no. of data

$m$  = no. of model parameters

$U = (n \times m)$  : Contains the information Orthonormal data-space

$L = (m \times m)$  : Orthonormal matrix

$G$  = Diagonal matrix

Contains the eigen values of  $\alpha_1, \alpha_2, \alpha_3$  and  $\alpha_4$

The area arrange as  $(\alpha_1 > \alpha_2 > \alpha_3 > \alpha_4)$

Note: The columns of  $U$  is the eigen vectors of  $G_1 G_1^T$   
 The columns of  $L$  is the eigen vectors of  $G_1^T G_1$ .  
 The diagonal elements of  $\mathcal{Q}$  is the singular values of  $G_1$  matrix.

- (i) Small-scale Inverse
  - (ii) Resolution Analysis
- Deficient Inverse Problem

Least Squared Generalised Inversion :

$$\Delta m = (G_1^T G_1 + \beta^2 I)^{-1} G_1^T \Delta d$$

$$G_1 = U \mathcal{Q} L^T$$

$$G_1^T = (U \mathcal{Q} L^T)^T = (L^T)^T \mathcal{Q}^T U^T = L \mathcal{Q} U^T$$

$$G_1^T G_1 = L \mathcal{Q} U^T \cdot U \mathcal{Q} L^T \quad (U^T U = I)$$

$$= L \mathcal{Q} U^T U \cdot \mathcal{Q} L^T$$

$$= L \mathcal{Q}^2 L^T$$

$$(L \mathcal{Q}^2 L^T + \beta^2 I)^{-1} = L \text{ dia } \left\{ \frac{1}{\alpha_i^2 + \beta^2} \right\} L^T \quad \left[ L^T = L^{-1} \rightarrow L L^T = I \right]$$

$\beta^2 = \text{damping factor}$

$$(G_1^T G_1 + \beta^2 I)^{-1} G_1^T = L \text{ dia } \left\{ \frac{1}{\alpha_i^2 + \beta^2} \right\} L^T L \mathcal{Q} U^T$$

$$= L \text{ dia } \left\{ \frac{1}{\alpha_i^2 + \beta^2} \right\} \mathcal{Q} U^T = L \text{ dia } \left\{ \frac{\alpha_i}{\alpha_i^2 + \beta^2} \right\} U^T$$

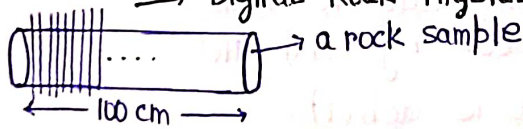
$$\Delta m = L \text{ dia } \left\{ \frac{\alpha_i}{\alpha_i^2 + \beta^2} \right\} U^T$$

$\beta = \text{Damping factor} = \text{Regularisation constant}$   
 $\beta = \text{Large} = \text{Gradient Descent.}$   
 $\beta = \text{small} = \text{Newton / Least squared.}$

Formation      Evaluation

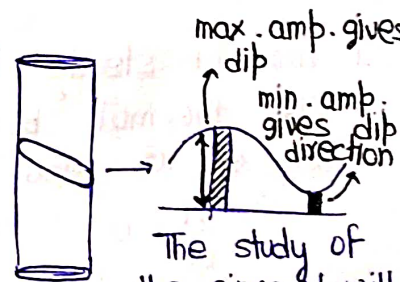
Borehole Image Log :

Imaging can be done by X-ray, Thermal, Digital  
 → Digital Rock Physics



The whole rock sample is divided into several parts for better resolution in CT-scan ] → This is how the Borehole imaging is done.  
 Each slice is called "Image Slide"

[CT-Scan]

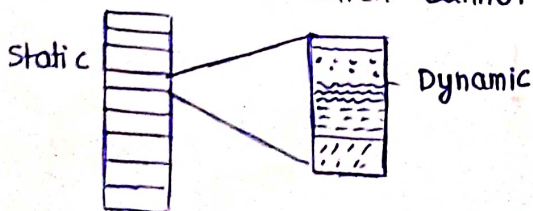


The study of the sinusoid will give us the dip magnitude and dip azimuth.

Electrical property (Resistivity)

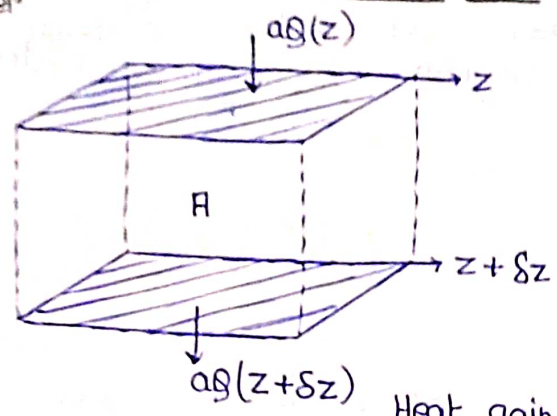
More the no. of pads (or electrodes) better will be the coverage and hence we get a clearer image for accurate correlation.

For detailed information like texture, colour etc we need Dynamic presentation which cannot be done with static presentation.



Fowler

Geothermics and Geodynamics



A = Heat production per unit volume per second

a = Area of the cross-section

$$g(z + \delta z) = g(z) + \delta z \cdot \frac{\partial g}{\partial z} + \frac{\delta z^2}{2!} \frac{\partial^2 g}{\partial z^2} + \dots$$

$$= g(z) + \delta z \cdot \frac{\partial g}{\partial z}$$

$\approx g(z) + \delta z \frac{\partial g}{\partial z}$  [neglecting higher order terms]

Heat gain per second =  $a g(z) - a g(z + \delta z)$

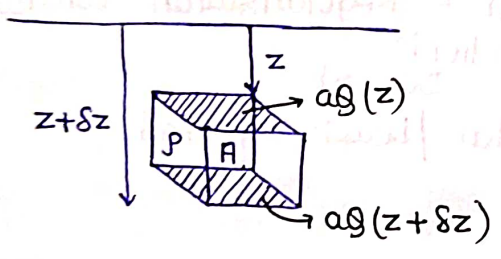
Heat gain per second =  $-a \delta z \cdot \frac{\partial g}{\partial z}$  because of external heat flow.

Total heat gain per second =  $A a \delta z - a \delta z \cdot \frac{\partial g}{\partial z}$

If 'rho' is the density of the materials and  $C_p$  is the specific heat at constant pressure  $\delta T$  is the temp. increase in  $\delta t$  time

$$m C_p \frac{\delta T}{\delta t} = A a \delta z - a \delta z \frac{\partial g}{\partial z}$$

$$\rho a \delta z \cdot C_p \frac{\delta T}{\delta t} = A a \delta z - a \delta z \cdot \frac{\partial g}{\partial z}$$



if  $\delta z, \delta t \rightarrow 0$

then,  $g = -k \frac{\partial T}{\partial z}$

$$\therefore \rho C_p \frac{\partial T}{\partial t} = A + k \frac{\partial^2 T}{\partial z^2}$$

$$\frac{\partial T}{\partial t} = \frac{A}{\rho C_p} + \frac{k}{\rho C_p} \frac{\partial^2 T}{\partial z^2}$$

$\frac{A}{\rho C_p} = K$  = Thermal diffusivity (its the ability of the material to transfer

In case of steady state, (In thermal equilibrium) heat by conduction)

No thermal perturbation due to no tectonic activity  
No erosion and no deposition of sediments

$$\therefore \frac{\partial T}{\partial t} = 0$$

$$\frac{\partial^2 T}{\partial z^2} = -\frac{A}{K}$$

$$\frac{\partial T}{\partial t} = \frac{K}{\rho C_p} \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} \right) + \frac{A}{\rho C_p}$$

-(1)

When the molten material comes out from the mid-oceanic ridges then we used 3D heat flow equation.

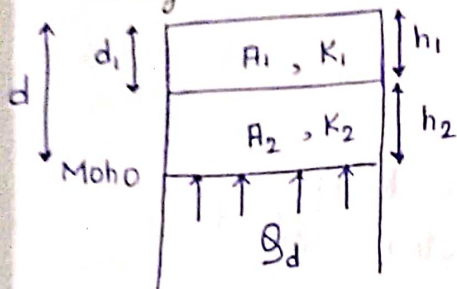
But when we consider only the vertical direction then 2D equation.

If we don't have any heat generation by radioactive nuclides then  $A = 0$ , hence eqn - (1) becomes,

$$\frac{\partial T}{\partial t} = \frac{K}{\rho C_p} \nabla^2 T$$

[Diffusion Equation]

## Assignment :



Under Thermal equilibrium.  
Derive the equation.

Variation of temp. with depth is called the Geotherm of that particular location



After time  $t$ , the displacement =  $U_z t$

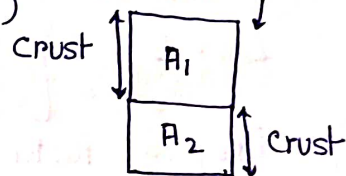
$$\frac{\partial T}{\partial t} = \frac{A}{\rho C_p} + \frac{K}{\rho C_p} \cdot \frac{\partial^2 T}{\partial z^2}$$

$$\frac{\partial T}{\partial t} + U_z \frac{\partial T}{\partial z} = \frac{A}{\rho C_p} + \frac{K}{\rho C_p} \cdot \frac{\partial^2 T}{\partial z^2}$$

$$\frac{\partial T}{\partial t} = \frac{K}{\rho C_p} \nabla^2 T + \frac{A}{\rho C_p} - \vec{U} \Delta T \quad (\text{Advection Equation})$$

$$\begin{aligned} & 50 \text{ million years} \times 5 \text{ cm/year} \\ & = 50 \times 10^6 \text{ years} \times 5 \text{ cm/year} \\ & = 25 \times 10^7 \text{ cm} = 25 \times 10^2 \text{ km} = 2500 \text{ km} \end{aligned}$$

Double crust in Tibet  
75-80 km  
(crustal thickness)  
So the heat production  
will be more



## Environmental Geology

### Environment of Land :

Black lung disease is caused due to coal mine fire / due to coal mine  
Radon may be released during mining.

Blow-out → These are the main problems in Petroleum Mining.  
and subsidence

EIA → Environmental Impact Assessment

EMP → Environmental Management Plan → (Means taking the necessary measures

Elephant Path → Mining are prohibited after assessment done in EIA)

in these paths in other  
way maintaining social ecology.

LULC → Land Used Land Consultancy

Bingham Porphyry Copper Mine, Arizona, USA → Largest Copper Mine  
(Bench height = 12 m)

4 gm/tonne is economical

Land Used Planning → Dumping of the remaining waste apart from the  
economical 4 gm in each tonne.

Cleat → Joints and fractures along Coal where CBM usually occurs.

Vertical opening of mine → Shaft

Horizontal opening of mine → Adit

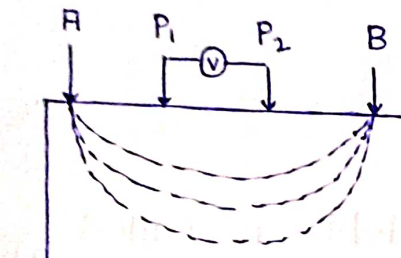
Chrono-corpus trees plantation need to be stopped.

Gold can be dissolved in cyanide (cyanidization)

Bio-leaching is safer than cyanide

ARD/ARD

# Geophysical Inversion



Apparent Resistivity ,

$$\rho_a(s) = \int_0^{\infty} T(\lambda) J_1(\lambda s) \lambda d\lambda$$

\$s\$ = Half of the current electrode spacing  $(\frac{AB}{2})$

Schlumberger sounding or Vertical Electrical Sounding (VES)

\$J\_1\$ = First order Bessel's function.

\$\lambda\$ = Integral Variable.

Koefoed (1970)

$$T_i(\lambda) = \frac{T_{i+1}(\lambda) + \rho_i \tanh(\lambda h_i)}{1 + T_{i+1}(\lambda) \frac{\tanh \lambda h_i}{\rho_i}}$$

\$\rho\_i\$ = True resistivity of the \$i\$th layer  
 \$h\_i\$ = True depth of the \$i\$th layer  
 \$n\$ = No. of layers.

Damped Least - Squared Solution :

$$\Delta m = (G_1^T G_1 + \beta^2 I)^{-1} G_1^T \Delta d$$

Using SVD we can write,

$$\Delta m = L \text{diag} \left\{ \frac{\alpha_i}{\alpha_i^2 + \beta^2} \right\} U^T \Delta d$$

Damping factor = \$\beta\$

\$\beta\$ can be modified according to \$\frac{1}{w}\$ (Arnason & Hersir, 1988)

\$\beta = \alpha w \Delta c\$, \$w\$ = Test number for the damping factor

$$\Delta C_r = \frac{C_{r-1} - C_r}{C_{r-1}}, C_r = \text{Misfit value of iteration}$$

\$\alpha\$ = parameter eigen values.

Moore - Penrose Matrix :

\$A^+\$ = Generalised Inverse

- (i) \$A \cdot A^+ \cdot A = A\$
- (ii) \$A^+ \cdot A \cdot A^+ = A^+\$
- (iii) \$(A^+ A)^H = A^+ A\$
- (iv) \$(A A^+)^H = A A^+\$

$$Ay = b$$

$$\therefore y = A^+ b \quad (1)$$

$$A^+ = (A^H A)^{-1} A^H$$

$$= (G_1^T G_1)^{-1} G_1^T$$

$$y = (A^H A)^{-1} A^H \cdot b$$

Note : \$A^+\$ will not possess all the properties of \$A^{-1}\$

\$A^{-1}\$ can be defined only if \$A\$ is non-singular matrix.

## Environmental Geology

Pollution during Gold Extraction :  
(i) Cyanide , (ii) Mercury - it is to be amalgamated with gold  
↓  
Bio-magnifier of gold (1 tonne of mercury is amalgumated with 1 tonne of gold for processing) and extraction.

Native occurrence of gold and silver is known as Electrum.

Trailing - waste minerals that remains after the valued minerals is extracted from ore  
Arsenochosis , silicosis → inhaling of silica dust in the mine causes silicosis

Difference between Contaminant and Pollutant

Minamata disease is caused due to mercury.

Surat became one of the cleanest city after being ranked in the top 10 as the most pollutant cities in India.

Blue dust → Haematite (An iron ore mining site)

One solution to the all the problems of "mine development" is LULC

Bailadilla iron ore mine in Chattisgarh

# Environmental Geology

Coal mine fire and related subsidence :

Coal Fire is a natural / anthropogenic hazard.

large cracks called cleat helps in the channeling of oxygen thereby helping in the spontaneous burning of coal.

Normal Fault are found in the rift zones.

Gpacf

Date - 31.08.2024

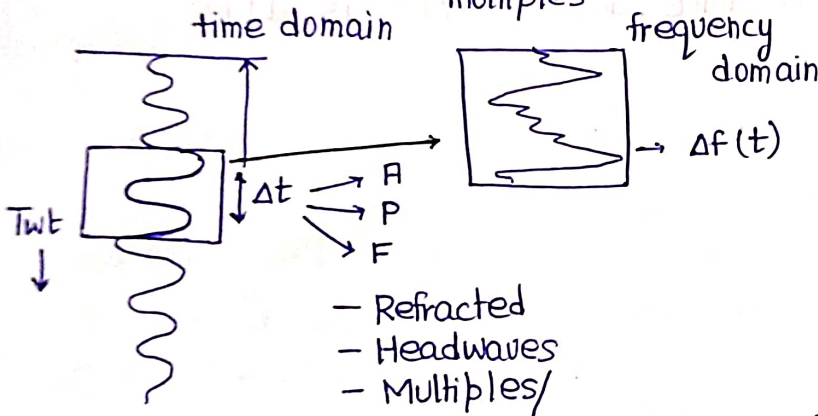
## Seismic Data Processing and Interpretation

F-K Filter :

F → Frequency

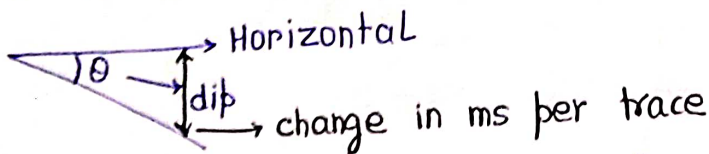
N → Wave number

Why wave number parameter will work better for suppression of noise. → generalised multiples



Fourier transformation in space or fourier transform of the trace is known as the wave number. (K)

- K is the Fourier transformation of the space domain.
- The space domain is taken care through character of the traces.
- It is required to prepare / take care of the Nyquist corr due to spacial aliasing which is improper information due to actual dip of the bed.



Dipping is the shifting of the time in reference to Horizontal reflector during pre-processing. This shifting can be properly handled through proper Nyquist correction due to spacial aliasing.

Acquisition Footprints

## Formation Evaluation

Image Log  $\rightarrow$  Any physical property which we can map in a borehole  
It can be electrical or acoustic

Sand is charged with hydrocarbon, hence it will have higher resistivity while clay contains water hence has low resistivity.

Carbonate rocks have low primary porosity hence difficult to interpret.

The identification of the bedding is important before "fracture identification"

The image obtained from the image log may not be clear due to noise hence pre-processing is required.

Fractures opening due to drilling are generally vertical

### Acoustic Image Log:

Televiwer  $\rightarrow$  Rotating camera

The speed of rotation of the camera is to be taken care of.

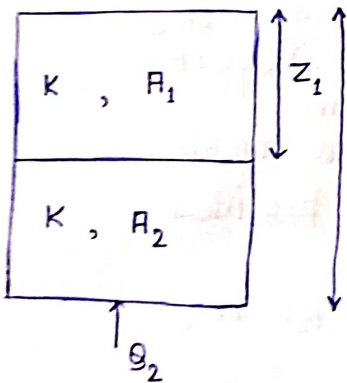
## Geothermics and Geodynamics

Penetration rate of the Indian northern part below the Himalaya is 10-12 mm/yr.

GG Quiz  
11.09.2024  
12:15 PM

Home Assignment: Fowler Page No. -

Fowler numerical



$$T_1 = -\frac{A_1}{2k} z^2 + \left[ \frac{Q^2}{k} + \frac{A_2}{k} (z_2 - z_1) + \frac{A_1 z_1}{k} \right] z \quad 0 \leq z < z_1$$

$$T_2 = -\frac{A_2}{2k} z^2 + \left[ \frac{Q^2}{k} + \frac{A_2 z_2}{k} \right] z + \frac{A_1 - A_2}{2k} z_1^2$$

for  $z_1 \leq z < z_2$

9<sup>th</sup> Sept, 2024

calculate the heat production when the given parameters are given in PPM / %  
(Numerical)

Calculate the equilibrium geotherm with the following boundary condition  
 $T=0$ , at  $z=0$  and surface heat flow,  $Q = Q_0$  at  $z=0$

$\rightarrow$  For equilibrium geotherm,  $\frac{d^2 T}{dz^2} = -\frac{A}{k}$  Here,  $-k \cdot \frac{\partial T}{\partial z} = -Q_0$

$$\frac{\partial T}{\partial z} = -\frac{2A_1}{2k} z + \left[ \frac{Q^2}{k} + \frac{A_2}{k} (z_2 - z_1) + \frac{A_1 z_1}{k} \right]$$

$$\frac{\partial^2 T}{\partial z^2} = -\frac{A_1}{k}$$

$$\frac{\partial T}{\partial z} = \frac{Q_0}{k}$$

$$T = -\frac{A_1 z^2}{2k} + \frac{Q_0}{k} z$$

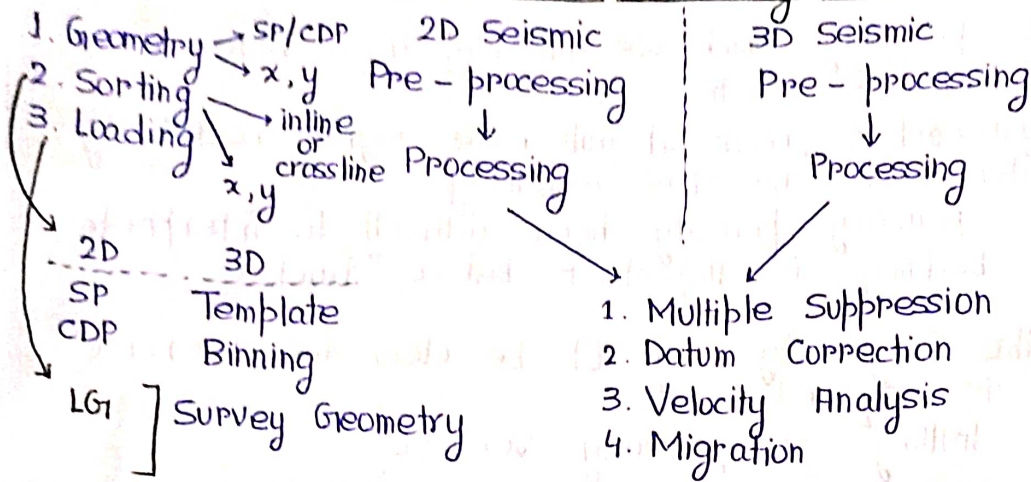
Draw the plot

Derive the equilibrium geotherm with the following boundary conditions  
 $T=0$  at  $z=0$  and  $Q = -Q_d$  at  $z=d$

$\rightarrow -k \frac{\partial T}{\partial z} = -Q_d$        $\frac{\partial T}{\partial z} = \frac{Q_d}{k}$

# Seismic Data Processing and Interpretation

Date - 02.09.20

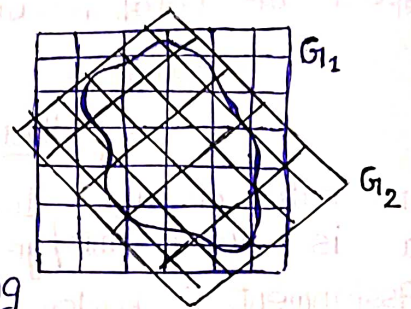


(i) Outcrop  
(ii) Sub-surface geology } Both are considered while Survey Geometry

Why de-convolution ?

Pre-processing :

(i) De-sampling  $\rightarrow$  Processing can be done at a sample rate different to that of recording (1, 2, 4 ms). Usually processing is performed at 4 ms, If the accuracy is sufficient as the processed time and cost are less. If we are looking for an improvement in resolution or if we want more accuracy in measurements (velo analysis, static correction) a sample rate of 4 ms or even 1 ms can be taken provided that recording was at this rate.



Frequency aliasing effects can be avoided by high freq filter adopted to the new sample rate :

(i) Sample rate: 4 ms ; cutoff  $\rightarrow$  125 Hz  
 2 ms ; 250 Hz  
 1 ms ; 500 Hz

for sample to go from a sample rate of 1 ms to 4 ms it is necessary to filter all the information of frequency greater than 125 Hz

Noise attenuation Technique :

Random :

Filter : Band-pass filter, Notch filter, K-filter (Trace-shot summation) F-K filter, Static, despiking, F-X filter, Coherency filter, Editing

Coherent : Velocity filter (i.e F-K filter), Bandpass, muting, coherency.

## Land Data and type of Noise :

Noise / Problem	Nature	Solution
High-line	Random	Kill, Notch filter
Ground-line / Grand-roll	coherent	F-K filter
Air-wave	Coherent	High cut, surgical mute
Correlation noise	Random	Mute
Traffic noise	Random	Filter, Stack
Falling debris	Random	Filter, Stack
Wind noise	Random	Filter, Stack

### Formation   Evaluation

Seismic → 5-100 Hz  
 Ultrasonic → kHz - MHz } so to merge these two types of data we need to apply filter  
 Well to seismic tie

Bulk-shifting  
 Stretching and Squeezing } These are the two way to match the log data with the seismic

FMI is very costly as compared to that of UBI  
 \* oil based mud

## Geothermics   and   Geodynamics

- Determine the heat flow near a continental area
- Variation of heat flow near an undulated topography

[ Lowrie  
 Page No. - 233  
 and 235 ]

In the continental area :

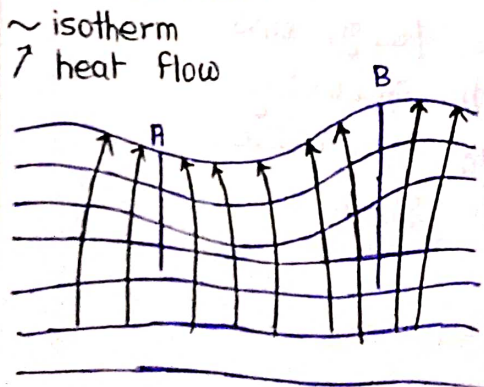
$$q_z = -k \frac{\partial T}{\partial z}$$

Keep the borehole undisturbed to attain thermal equilibrium i.e not affected by the external agency, or convection. Then when equilibrium is attained the temp. log is lowered to measure the temp. of the subsurface whose Harmonic mean is taken to evaluate the thermal conductivity

Factors affecting the measurement :

- Topography correction
- Correction due to climate changes or ice age (in the Scandinavian Countries - Holland, Finland)
- Erosion, deposition and other neo-tectonic activities.

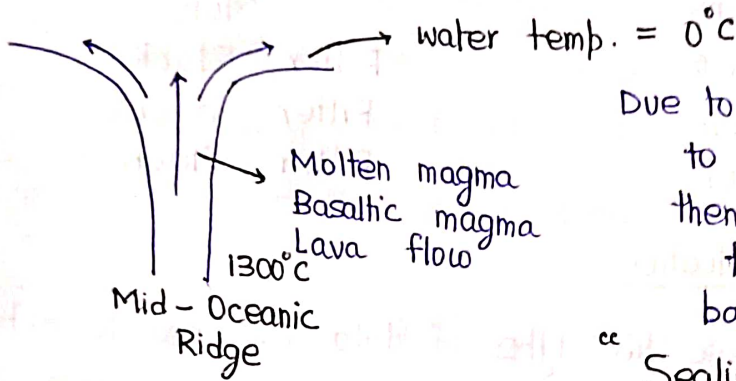
High topography → here the value of the (B) heat flow will be less than the actual value (the heat flow lines diverge)



## Oceanic Heat Flow :

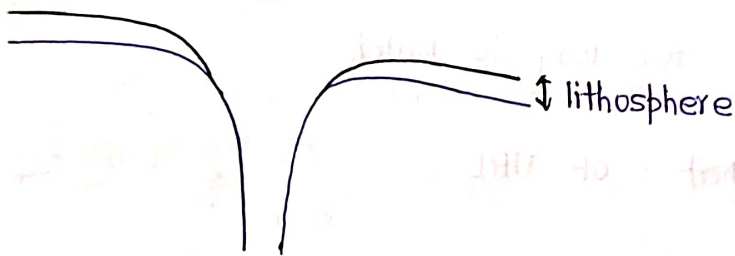
In the lithosphere is younger, then the heat flow increasing and if the lithosphere is older then we have the decreasing.

Mid-oceanic ridge will have high heat flow. The oldest ocean floor is about 175-180 Ma near Kamchatka.



of temp. Due to sudden change of magma at to / comes in contact with 0°C then it leads to sudden cooling to development of fracture in basaltic magma.

"Sealing Age" → 65 ± 10 Ma



Bathymetry → depth of floor

## Seismic Data Processing and Interpretation

Date - 03.09

Pre-processing

Processing Unit :

Shorting :

Seismic data acquisition with multiple fold coverage is done in shot receiver co-ordinates (s = shot, g = receiver). Seismic data processing, on the other hand, conventionally is done in mid-point offset (y, h) co-ordinate. The required co-ordinates transformation is achieved by shooting the data into CMP gather based on the field geometry information each individual trace is assigned to the midpoint of shot and receiver position associated with that trace, those traces with the seismic midpoint location are brute together, and making up a CMP gather. The term CDP, CMP often are used interchangeably. Superposition of shot receiver (s, g) and midpoint offset (y, h) co-ordinates and ray path geometry for various gather types. For most recording geometries the fold coverage  $n_f$ , for CMP stacking is given by,

$$n_f = \frac{n_g \Delta g}{2 \Delta s}$$

By using the relationship the following rules can be established;

- (i) The fold does not change when alternating traces in each shot record is dropped
- (ii) The fold is half when every shot record is skipped. Whether or not alternating traces in each shot record are dropped.

Detectability :

Formation Evaluation

NMR → Nuclear Magnetic Resonance



Lithology independent tool  
 IF can identify different types of fluid - Clay bound water, Capillary bound  
 We want to know the response of the atomic nuclei to the magnetic field.

$T_1$  = Longitudinal relaxation time  
 = time required for most of the proton to align along the direction of the magnetic field.

$T_1 = 63\%$  of  $T_0$ .

At first we apply the static magnetic field due to which the proton are aligned along the direction of the magnetic field i.e in a vertical direction. Now, we apply another magnetic field in a direction  $\perp$  to the magnetic field to disturb the alignment of the proton and the time taken by the proton to get disturbed after the application of the horizontal component of the magnetic field, is known as Transverse relaxation time.

Geothermics and Geodynamics

Deep sea drilling project  
 Ocean drilling project.

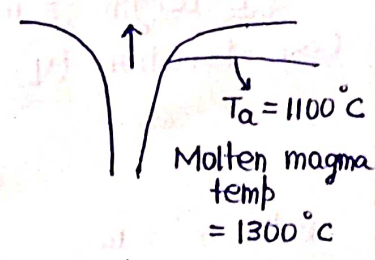
- GDH → Global Depth Heat flow Model
- PSM Model
- and Half-space Model
- Finite Half-space Model

} These 3 Models gave the formula to determine the bathymetry when  $t$  is known.

$$\frac{T(z,t) - T_s}{T_a - T_s} = \text{erf}\left(\frac{z}{2\sqrt{kt}}\right)$$

$T_s = 0^\circ\text{C}$ ,  $T(z,t) = T_a \text{erf}\left(\frac{z}{2\sqrt{kt}}\right)$   
 ↓  
 Temp. of the Asthenosphere  
 if  $\eta = \frac{z}{2\sqrt{kt}}$  → depth

$k = 10^{-6} \text{ m}^2/\text{sec}$   
 $t$  is age  
 ↓  
 temp. at the base of the lithosphere ( $t$ )



$\text{erfc}(\eta) + \text{erf}(\eta) = 1$

$\text{erf} \sim \eta$   
 $\text{erfc}$

$q_z = -\frac{kT_m}{\sqrt{\pi kt}}$  (Heat chapter in LOWPIE)

if  $\eta$  is known then from,  $\eta = \frac{z}{2\sqrt{kt}}$  we can find  $z$

# Seismic Data Processing and Interpretation

Date - 04/03

## Time Variant Deconvolution (TVD) :

$$s(t) = w(t) * R(t) + n(t)$$

$$y(t) = w(t) * e(t) * i(t) * g(t) * m(t) * n(t) \rightarrow \text{Basic equation}$$

A whitening deconvolution : - (1)

$$y(t) * n(t) = e(t) \quad - (2)$$

Combining (1) and (2) we have,

$$n(t) = w^{-1}(t) * i^{-1}(t) * g^{-1}(t) * m^{-1}(t)$$

$$\phi_{ii}(I) * n(I) = \phi_{id}(I) \quad ; I > 0$$

$\phi_{ii}(I)$  = auto-correlation of <sup>input</sup> trace

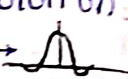

$n(I)$  = Decon filter

$\phi_{id}(I)$  = Cross-correlation of input trace of 2 output.

- $y(t)$  = seismic trace
- $w(t)$  = source wavelet
- $e(t)$  = earth impulse response
- $i(t)$  = instrumental filter response
- $g(t)$  = ghosting operator
- $m(t)$  = multiple reflection operation
- $n(t)$  = noise



\* Here we should have zero amplitude but here we see the R.c is having some value, so amplitude will be developed which shouldn't have been developed as it is an unwanted signal (or noise), hence if it taken into consideration in further processing our interpretation will be wrong. Hence this unwanted by signal are removed through deconvolution.

- \* If at  $t=0$  we have zero phase wavelet  $\rightarrow$  Causal wavelet  $\rightarrow$  
- But if we have minimum phase wavelet  $\rightarrow$  non-causal  $\rightarrow$  
- If we have causal wavelet then it is to be transformed into non-causal

\* Geology is random but the data is found to be as alternate peak and trough, hence to get the correct geology interpretation a phase correction is done which is performed in deconvolution.

Spiking Deconvolution  $\rightarrow$  initial step of deconvolution

## Geophysical Inversion

Solution of a purely undetermined Inverse problem :

$$L = \text{Length} = m^T m = \sum m_i^2$$

$$\text{Cost Function } (q) = m^T m + \lambda (d - Gm)$$

$\downarrow$   
measure of  
Model complexity

$\downarrow$   
measure of  
data misfit

- $\lambda$  = Lagrange multiplier
- $d$  = data
- $m$  = model
- $G$  = Generalised Matrix operator

Let,  $m^T = m$ ,

$$\frac{\partial q}{\partial m} = 2m + 0 - \lambda G$$

$$\therefore 2m - \lambda G = 0$$

$$\therefore m = \frac{\lambda}{2} G$$

$$\therefore m^T = -\frac{\lambda}{2} G$$

First partial derivative of cost function is zero for minimization problem

Data - model relation :

$$d = Gm$$

$$= G \cdot \frac{\lambda}{2} G^T$$

$$\lambda = 2(G \cdot G^T)^{-1} d$$

$$\therefore m^{\text{est}} = \frac{\lambda}{2} \cdot G^T d = \frac{1}{2} \cdot G^T \cdot 2 (G \cdot G^T)$$

$$m^{\text{est}} = G^T (G \cdot G^T)^{-1} d$$

$$m^{\text{est}} = G^{-g} d$$

$$\therefore G^{-g} = G^T (G \cdot G^T)^{-1}$$

} Under-determined

$G^{-g} = (G^T G)^{-1} G^T \rightarrow$  Over determined inverse problem.

Least Squared Solution :

Cost Function :  $q = \underbrace{\beta^2 m^T m}_{\text{model misfit}} + \underbrace{(d - Gm)^T (d - Gm)}_{\text{Data misfit}} \quad \beta = \text{Damping factor}$

$$\frac{\partial q}{\partial m^T} = \beta^2 I m + \frac{\partial}{\partial m^T} \left\{ (d^T - m^T G^T) (d - Gm) \right\}$$

$$0 = \beta^2 I m + d^T d - d^T Gm - m^T G^T d + m^T G^T Gm$$

$$\Rightarrow 0 = \beta^2 I m + 0 - 0 - G^T d + G^T Gm$$

$$\therefore m (G^T G + \beta^2 I) = G^T d$$

$$\therefore m^{\text{est}} = (G^T G + \beta^2 I)^{-1} G^T d$$

Data Resolution and Model Resolution Matrix :

N = Data Resolution Matrix

R = Model Resolution Matrix

Least squared solution (Over determined problem)

$$N = G \cdot G^{-g} = G (G^T G)^{-1} G^T$$

$$R = G^{-g} G = (G^T G)^{-1} G^T G = I$$

$$N = G \cdot G^{-g} = G G^T (G \cdot G^T)^{-1} = I$$

$$R = G^{-g} G = G^T (G G^T)^{-1} G = I$$

Minimum Length Solution  
(Under determined problem)

$$\text{Covariance (m)} = G^{-g} G^{-gT} = G^T (G \cdot G^T)^{-1} \left[ G^T (G G^T)^{-1} \right]$$

## Formation Evaluation

$B_0$  ↑  $T_1$  → Longitudinal Relaxation Time

⊗  $T_2$  → Transverse relaxation time

First we apply a 'static' magnetic field  $B_0$  is applied  
An oscillating magnetic field perpendicular to  $B_0$  is applied  
in a transverse direction. ( $B_1$ )

→ oscillating magnetic field  
A transverse magnetic field ( $B_1$ ) is applied at an angle  $\theta$  known  
as tip angle, a magnetization is developed and after some  
time this magnetic field is stopped hence  $B_1$  tries to  
come back to the original orientation along  $B_0$ , hence  
there is a decrease in the magnetization → Decay induction

⇓

After this an  $180^\circ$  pulse is applied after a certain time  $\tau$   
A single spin echo is very small and decay quickly, so,  $180^\circ$  pulse is applied  
repeatedly to rephase the magnetization to generate a  
series of spin echoes.

## Geothermics and Geodynamics

Question:

$$q_z = \frac{KT_m}{\sqrt{\pi Kt}} \quad \text{if } T_m = 1350^\circ\text{C}, K = 3.138 \text{ W/m}^2$$

Fowler  
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$$- (i) \quad t = 60 \text{ Ma}, K = 0.8 \times 10^{-6} \text{ m}^2/\text{sec} \quad q_z = 480 \times t^{-1/2}$$

Calculate the heat flow and bathymetry for  $t = 60 \text{ Ma}$  age  
→  $d = 2.6 + 0.345 t^{1/2}$  } When only 't' is provided based on Half-space model  
 $q_z = 480 \times t^{-1/2}$

Question:

But if the values of  $K, T_m, k, t$  are provided then  
equation - (i) is to be used

$$T = T_m \operatorname{erf} \left( \frac{z}{2\sqrt{Kt}} \right)$$

at depth  $z$  km,  $T = 1100^\circ\text{C}$   
 $T_m = 1300^\circ\text{C}, K = 10^{-6} \text{ m}^2/\text{sec}$

Establish the relation b/w  $z$  and  $t$

$$\rightarrow \frac{1100}{1300} = \operatorname{erf} \left( \frac{z}{2\sqrt{Kt}} \right)$$

$$z = 11\sqrt{t}$$

$t$  in Ma  
 $z$  in km

$$\eta = \frac{z}{2\sqrt{Kt}}$$

$$\Rightarrow \operatorname{erf} \left( \frac{z}{2\sqrt{Kt}} \right) = 0.846$$

$q_z = 61.41 \text{ mW/m}^2$   
Bathymetry = 5.272 km  
lithospheric  
thickness = 87.6 km

Calculate the thickness of the lithosphere of the ocean  
for  $t = 60 \text{ Ma}$

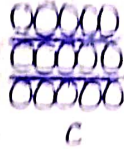
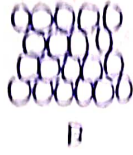
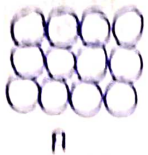
## Environmental Geology

### Environment of Soil :

Soil is the resource, building material and nutrient supplier for plants.

- Organic matter
- Organic matter mixed with rock and mine fragments
- Zone of leaching = dissolved / suspended materials are carried downward by water
- Zone of accumulation
- Weathered parent material, partially broken down

Swelling and shrinking takes place in the soil



Shear Stress, Shear strain, Cohesion, normal strain - properties of the soil to be determined.

Mass washing  
Siltation

Erosion - control practice - agronomical factors i.e. changing / rotating the crops

## Geophysical Inversion

Date - 05.09.2024

### Null Vectors :

Let the linear Inverse problem has two solutions  $m_1$  and  $m_2$  which produces data say  $d_1$  and  $d_2$

$$Gm_1 = d_1$$

$$\text{Let } d_1 = d_2$$

$$Gm_2 = d_2$$

$$G(m_1 - m_2) = d_1 - d_2 = 0$$

$$\therefore m_1 = m_2 \quad [ \because G \neq 0 ]$$

But we assume

$$m_1 \neq m_2$$

The expression of Inverse solution in form of null vectors

$$m_{\text{general}} = m_{\text{particular}} + \alpha \cdot m_{\text{null}} \quad [ \text{Here } \alpha = \text{constants} ]$$

$$\text{Let } Gm = d$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} m_1 \\ m_2 \\ m_3 \\ m_4 \end{bmatrix} = \begin{bmatrix} d_1 \\ d_2 \\ d_3 \\ d_4 \end{bmatrix}$$

$$d = [ d_1 \ d_1 \ d_1 \ d_1 ]$$

$$m_{\text{null}} = m_1 - m_2 \neq 0$$

$$m_{\text{general}} = m_{\text{particular}} + \alpha_1 \begin{bmatrix} +1 \\ -1 \\ 0 \\ 0 \end{bmatrix} + \alpha_2 \begin{bmatrix} +1 \\ 0 \\ 0 \\ -1 \end{bmatrix} + \alpha_3 \begin{bmatrix} 0 \\ 0 \\ +1 \\ -1 \end{bmatrix} + \alpha_4 \begin{bmatrix} +1 \\ 0 \\ -1 \\ 0 \end{bmatrix}$$

# Null Space :

$$\begin{bmatrix} \text{Mixed} \\ \text{Determined} \\ \text{Inverse problem} \end{bmatrix} = \begin{bmatrix} \text{Over} \\ \text{Determined} \\ \text{In. problem} \end{bmatrix} + \begin{bmatrix} \text{Under} \\ \text{Determined} \\ \text{Inverse} \\ \text{problem} \end{bmatrix}$$

Parameter space (p)	Null Space (o)
---------------------	----------------

$$G [m_p + m_o] = [d_p + d_o]$$

$$\text{Minimum Length} = L = m^T m$$

$$= [m_p + m_o]^T [m_p + m_o]$$

$$= [m_p^T + m_o^T] [m_p + m_o]$$

$$= m_p^T m_p + m_p^T m_o + m_o^T m_p + m_o^T m_o$$

$$= m_p^T m_p + m_o^T m_o$$

[The other two terms are neglected as they occur in multiplicative form]

$$\text{Prediction Error} := e^T e$$

$$[d_p + d_o - Gm_p]^T [d_p + d_o - Gm_p]$$

$$Gm_o = 0$$

$$= [d_p^T + d_o^T - m_p^T G^T] [d_p + d_o - Gm_p]$$

$$= d_p^T d_p + d_p^T d_o - d_p^T Gm_p + d_o^T d_p + d_o^T d_o - d_o^T Gm_p - m_p^T G^T d_p + m_p^T G^T d_o + m_p^T G^T Gm_p$$

$$= [d_p - Gm_p]^T [d_p - Gm_p] + d_p^T d_o$$

## Formation Evaluation (Product Development)

### for Scientific GUI applications

Understand :

Control Structures  
Data Types  
OOPS

Basic GUI Elements  
(or different basic elements used in GUI window)

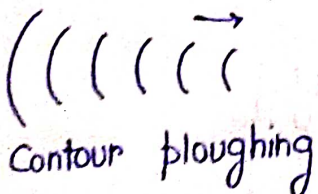
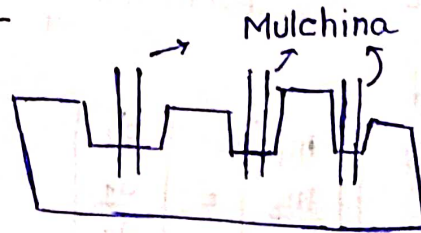
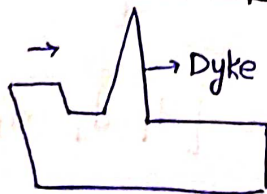
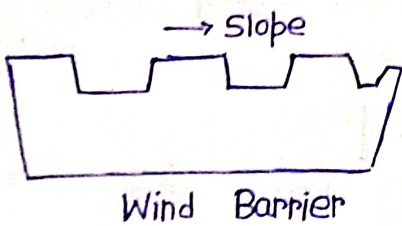
Python 3.8

Docstring (vscode) ctrl+shift+z

Pydantic

'OOP with Python'  
Qt and PyQt

## Environmental Geology



Environment of Land :

Dam-site failure can also lead to mass wasting

Not all mass-movement are landslides

"Rock-fall" occurs at sea-shore

↳ occur at the column of the joints.

nuée ardente is associated with volcanic ash flow

Slope stability' (important)

$$\text{Safety factor, } F_s = \frac{\text{Shear strength}}{\text{Shear stress}}$$

'Angle of Repose'