Chapter 9: Basin-Filling Models

Pattern + geometry of subsidence in basins exerts a strong control on the distribution of fine- and coarse-grained facies. Varying the geometry + rates of subsidence causes changes or shifts in distribution of facies thru time ... this creates stratigraphy

[Note: For foreland basins, "Traditional Model" = flux-driven "Two-Stage Model" = subsidence-driven ← H + P (1992)]

Quantitative Dynamic Stratigraphy = quantitative, model-based study of dynamic stratigraphic response to changes in basin subsidence, sediment input, climate, sea level, etc. Includes a variety of techniques and approaches.

Theoretical models for sedim. basins:
many assumptions, restrictions, simplifications make ~~them~~ it difficult for them to describe the real world.

So why models? What good are they? what uses?

1. They are a means of generalizing - They are based on basic physical laws that govern basin + sediment dynamics; they attempt to clarify general, universal processes of basins ... "local effects can be resolved only through detailed field work".

2. They are a means of exploring the effects of varying parameters in complex systems. Help with conceptual thinking, help us to understand key processes.

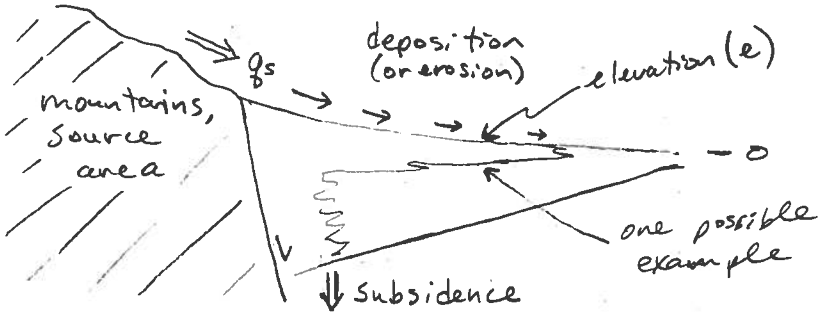
3. They are a means of organizing field projects. The models make interesting predictions which help us look for critical stratigr relationships in the field. Give some idea of spatial + temporal resolution needed to observe predicted effects.

BASIN FILLING MODELS, 1st Day

1. Introduce models - what, why
2. Consider Mass Balance - qualitative
3. Express as Sediment Continuity eqn
4. A little math → universal diffusion eqn

2. The Basic Problem:

(Fig. 9.1 or 9.7)



Question: how far into basin does coarse sediment get? That is, where are the major facies boundaries?

* This will be a model result, = dependent variable.

The Independent (fixed or specified) variables are:

- geometry and rate of subsidence
- rate and grain-size distrib. of sediment influx (q_s)
- climate, distribution of rainfall
- size and gradient of streams in source

} control q_s

- eustatic sea level.

* we specify model conditions (indep. variables) and use physical laws (cons. of mass + mom.) to predict result

3. Sediment Continuity:

$$\sigma + \frac{\partial e}{\partial t} = \frac{-1}{C_o} \cdot \frac{\partial q_s}{\partial x}$$ Eqn 9.1 (simplif.)

Define terms.

Discuss what's happening, work examples.

4. Sediment-Transport Eqns: (start w/ eqn 9.6)

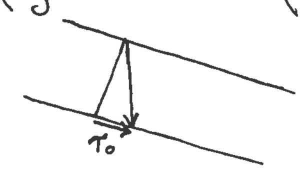
- $$\sigma + \frac{\partial e}{\partial t} = \frac{-1}{C_o} \cdot \frac{\partial(\beta\langle q_s\rangle)}{\partial x}$$

β = total width of channels
$\langle q_s\rangle$ = sed flux rate per unit width of channel

- $$q_s = \frac{8(\tau - \tau_c)^{3/2}}{g(s-1)}$$ (eqn 9.7)

τ = applied shear stress
τ_c = critical shear stress required for grain motion
s = grain ~~spec. gravity (sg)~~ density

- $$\tau_o = \rho g h \tan\theta = \rho g h \frac{\partial e}{\partial x}$$ (eqn 9.5)



τ_o = basal shear stress applied on stream bed by weight of water

- $$\sigma + \frac{\partial e}{\partial t} = \frac{-8I}{C_o(g)(s-1)} \cdot \frac{\partial\left(\beta(\tau-\tau_c)^{3/2}\right)}{\partial x}$$ (9.8)

I ← "inter-mitency"

- Adjust τ rel. to τ_c for braided vs. meandering... Express as parameter "A". Then add eqn 9.5:

- $$\sigma + \frac{\partial e}{\partial t} = \frac{-8A\langle q\rangle\sqrt{C_f}}{C_o(s-1)} \cdot \frac{\partial^2 e}{\partial x^2}$$ (9.12)

$\langle q\rangle$ = time-av. water discharge
C_f = drag coeff. (Manning's n)

* This is The Standard diffusion eqn.

$$\sigma + \frac{\partial e}{\partial t} = \left(\frac{-8I}{C_0\, g(s-1)}\right) \frac{\partial\left(\beta\,(\tau-\tau_c)^{3/2}\right)}{\partial x}$$ eqn 9.8

$$= \left(\frac{-8IA}{C_0\, g(s-1)}\right) \frac{\partial\left(\beta\,\tau^{3/2}\right)}{\partial x}$$ eqn 9.11

. . .

β = total width of streams per unit width of bas.

$\tau^{3/2} = \tau^{1/2}\,\tau^{3}$

water discharge, q, $= (U)(\text{width})(\text{depth})$

$= U\,\beta\,\text{depth}$

$\tau = -\cancel{\rho} g h \frac{\partial e}{\partial x}$

$\boxed{\text{Deriving Eqn 9.12}}$

$$\sigma + \frac{\partial e}{\partial t} = \left(\frac{-8IA}{C_0\, g(s-1)}\right) \frac{\partial\left(\beta\,\tau^{3/2}\right)}{\partial x}$$ eqn 9.11

$\boxed{\tau^{3/2} = \tau^{1/2}\,\tau}$

$\tau = -\rho g h \frac{\partial e}{\partial x}$ (Keep in $\frac{\partial}{\partial x}$ te

$\tau = C_f U^2$ (move to const.)

$[\tau = C_f U^2]$

$$= \left(\qquad\right) \frac{\partial\left(\beta\,\tau^{1/2}\,\tau\right)}{\partial x}$$

$$= \left(\frac{-8IA\sqrt{C_f U^2}\,\beta}{C_0\, g(s-1)}\right) \frac{\partial \tau}{\partial x}$$

$$= \frac{-8A\,\boxed{I\beta U}\sqrt{C_f}}{C_0\, g(s-1)} \frac{\partial \tau}{\partial x}$$

$\boxed{\tau = g h \frac{\partial e}{\partial x}}$

$$= \frac{-8A\,I\beta U\sqrt{C_f}}{C_0\, g(s-1)} \frac{\partial\left(g h \frac{\partial e}{\partial x}\right)}{\partial x}$$

$= \langle q \rangle$ time-averaged water discharge

$$= \frac{-8A\,I\beta U h\sqrt{C_f}\, g}{C_0\, g(s-1)} \frac{\partial\left(\frac{\partial e}{\partial x}\right)}{\partial x}$$

$$= \frac{-8A\,\langle q \rangle\sqrt{C_f}}{C_0\,(s-1)} \frac{\partial^2 e}{\partial x^2}$$

C_f = drag coefficient

= Manning's n

Summary of Sediment Continuity Equations

1. $$\sigma + \frac{\partial e}{\partial t} = -\frac{1}{C_o}\frac{\partial q_s}{\partial x}$$ (eqn 9.6, ~ same as eqn 9.1)

2. Because q_s is a fct of τ_o (eqn 9.7), Then:

$$\sigma + \frac{\partial e}{\partial t} = K \frac{\partial \tau_o}{\partial x}$$ (put all "fcts" into k)

3. Because τ_o is a fct of slope ($\frac{\partial e}{\partial x}$, eqn 9.5), then:

$$\sigma + \frac{\partial e}{\partial t} = K \frac{\partial\left(\frac{\partial e}{\partial x}\right)}{\partial x},$$ and so:

4. $$\sigma + \frac{\partial e}{\partial t} = K \frac{\partial^2 e}{\partial x^2}$$ (eqn 12)

This is the standard/universal equation used to model transfer of mass by diffusion. Chris Paola has derived it using physical laws of sediment transport.

σ = subsidence rate
e = elevation
C_o = volume conc. of sediment in bed
t = time
x = down-transport distance in basin
τ_o = basal shear stress on bed in a river channel
K = a big messy constant that includes all functional relationships used to convert variables in the eqn.