Lecture 2

Investigation and Field Studies of Bimrocks

BIMROCKS SHORT COURSE

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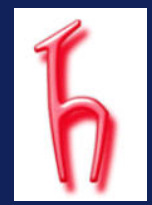
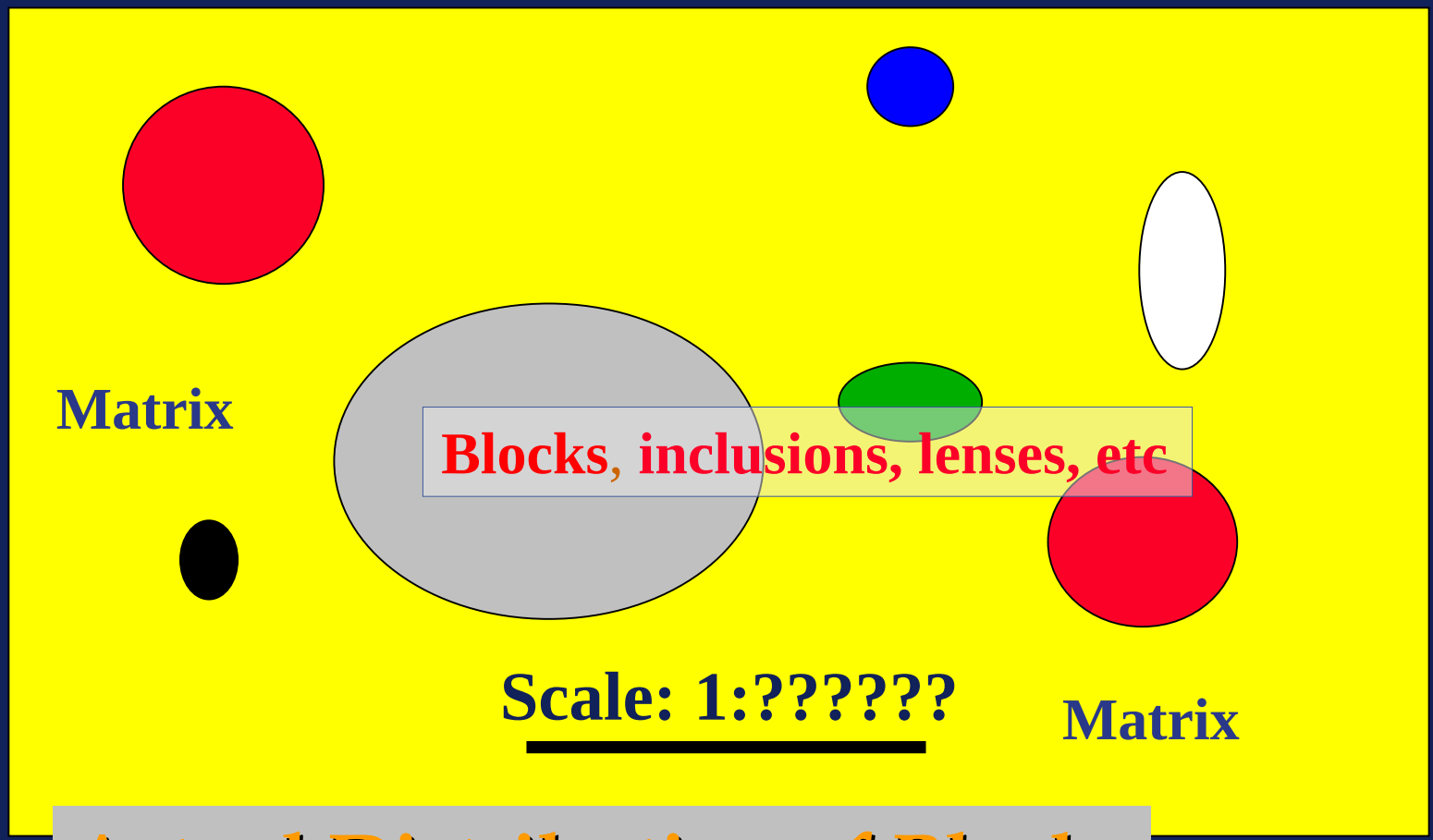


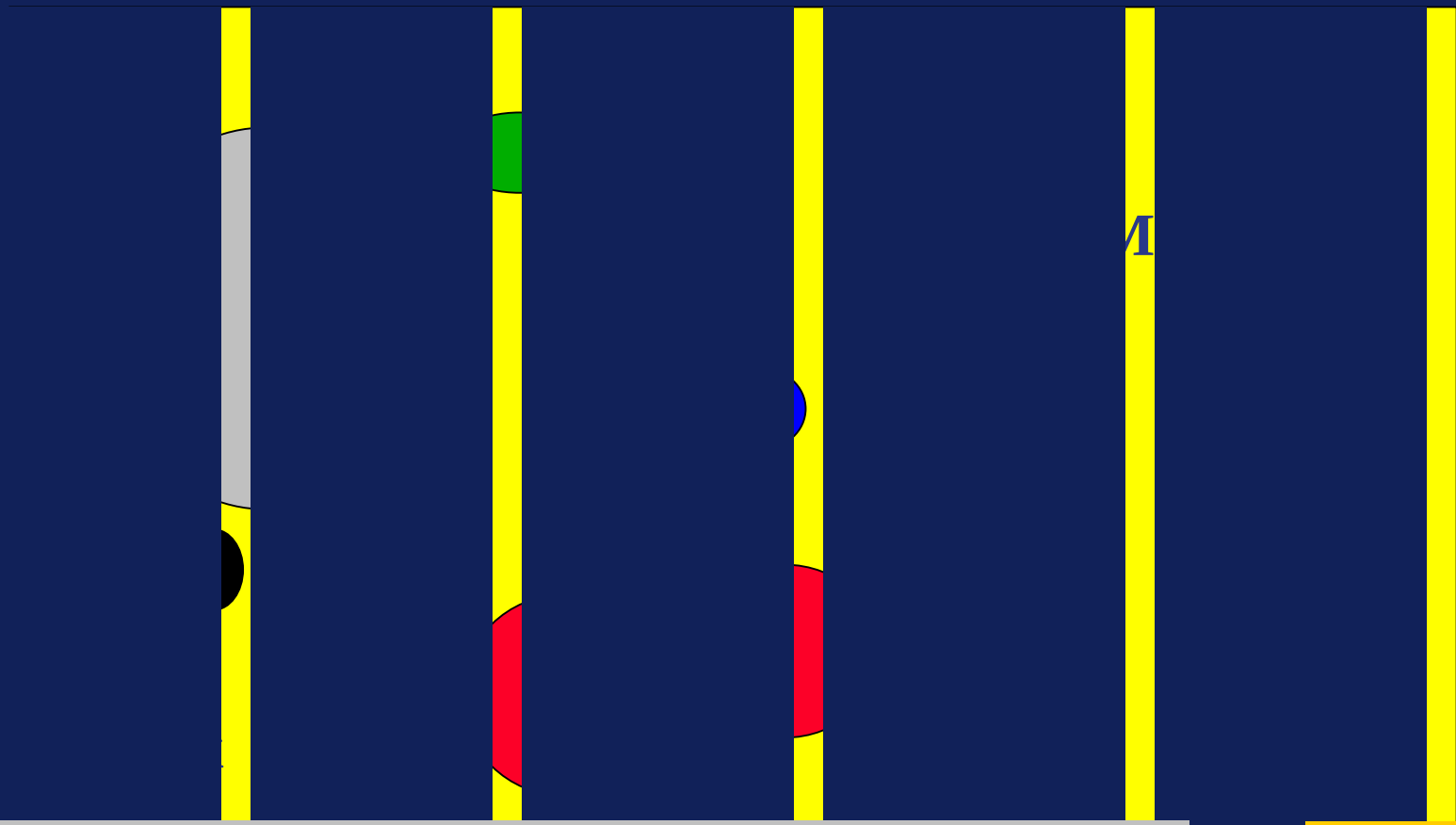
BIG CONCLUSION 1:
Remember this picture!!!



Actual Distribution of Blocks

Medley, 2000

BIG CONCLUSION 2:
Remember this picture as well!!!



Apparent Distribution of Blocks

Dana Willis

So, YES: bimrocks ARE chaotic…

But Practitioners should NOT say:

"those rocks are too chaotic, let's design for the weak matrix…"

General Procedure for Investigations

- Desk Studies
  - Satellite Images, Aerial Photographs, Maps etc.
- Geological Field Survey
  - Morphological Features
  - Outcrop Studies
    - Rock Mass Characterization
    - Paleostress Analysis
- Subsurface Investigation
  - Trenches, Trial Pits
  - Core Drilling
  - Borehole in-situ tests
  - Geophysical Survey
- Laboratory Analyses
  - Mineralogical Analyses
  - Mechanical Analyses

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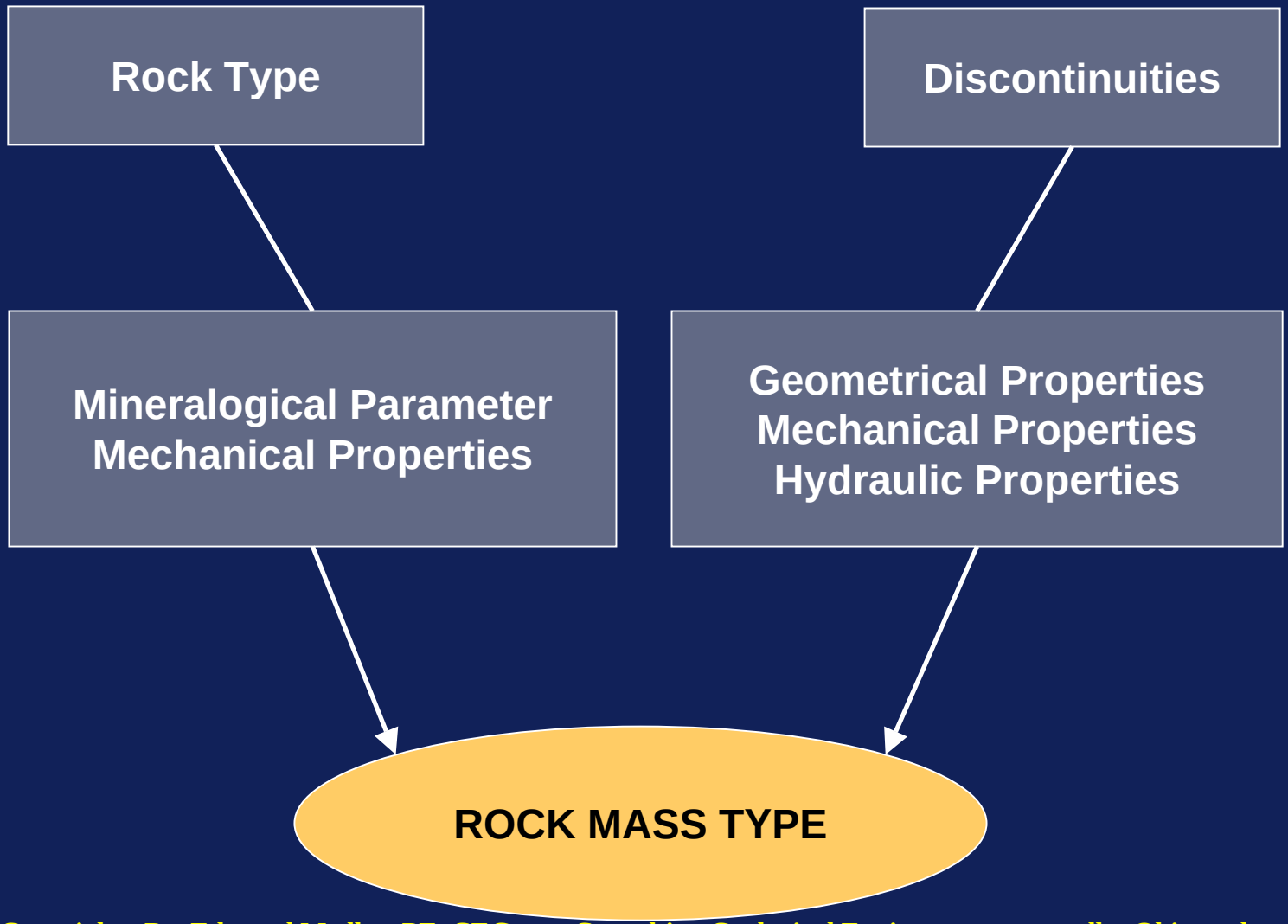
Investigation Strategies

Rock Mass Characterisation
Rock Mass Types



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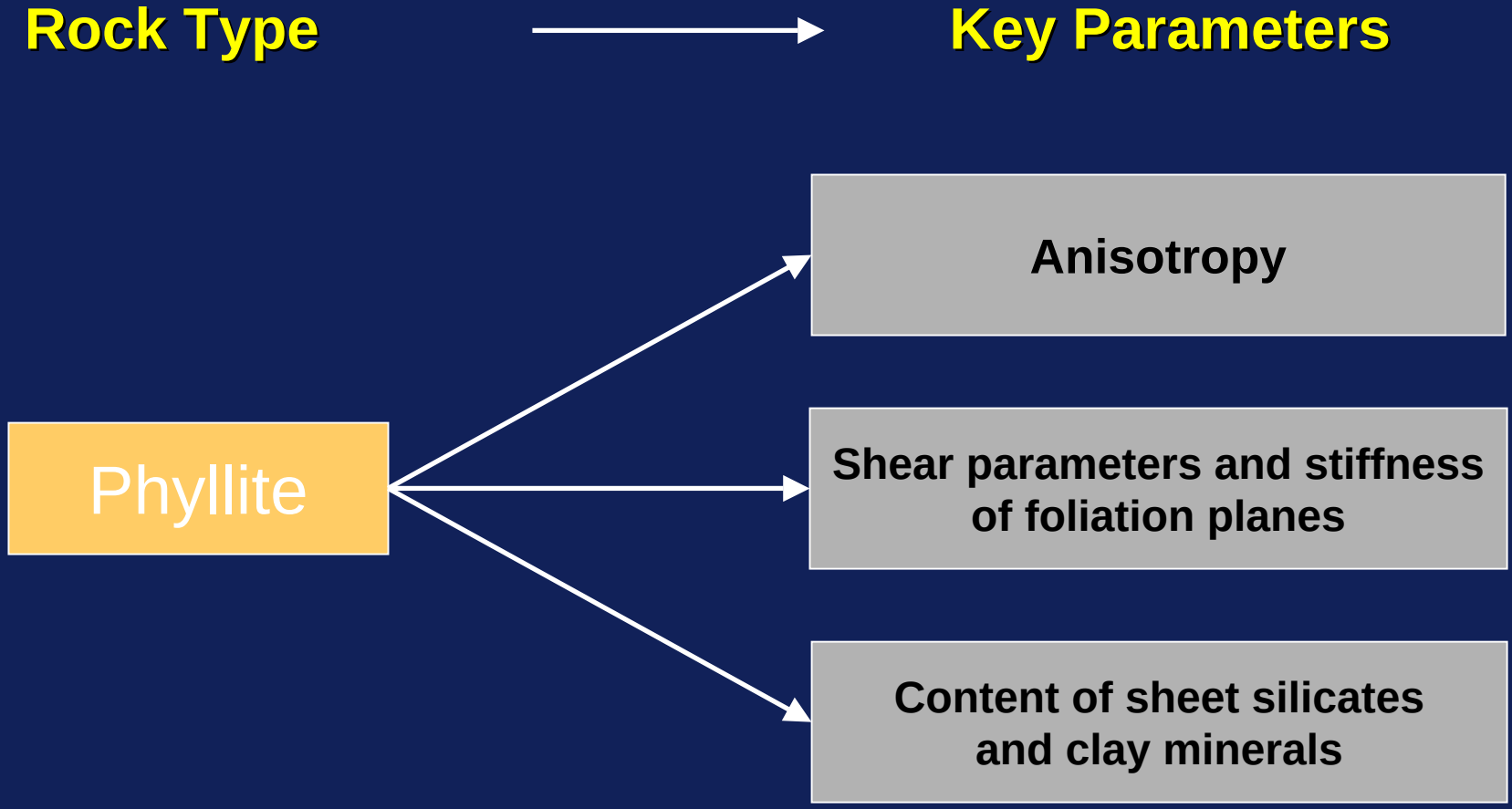
Definition of Rock Mass Types

Rock Mass Types are defined by

“KEY PARAMETERS“

Example Rock Mass Type



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Rock Type Specific Key Parameters

Basic Rock Types	Key Parameters																			
	Intact Rock Properties														Discontinuities					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Volcanic Rocks				o	x	x						x	x		x	x		o	x	o	
Plutonic Rocks		x	x	x		o						x			x	x		o	x	o	
Fine-Grained Clastic Rocks (massive)			x				x	x	x		x	o			o	o					
Fine-Grained Clastic Rocks (bedded)	x		x				x	x	x		x			x			x			o	x
Coarse-Grained Clastic Rocks (massive)		o	x	o	o			o			x	x	x		o	o		o	o		
Coarse-Grained Clastic Rocks (bedded)	x	o	x		o			o			x	x	x	x			x				x
Carbon. Rocks		x								x		x			x	x		o	x	o	
Sulfatic Rocks		x							x	x		o									
Metam. Rocks (massive)		x	x	x		o						x			x	x		o	x		
Metam. Rocks (foliated)	x	x	x	x		o						x		x						x	x
Brittle Fault Rocks		o				o	x	x	x		x	x	x								

LEGEND

x Significant Parameter

o Less Important Parameter

(1) Anisotropy
(2) Mineral Composition
(3) Grain Size
(4) Texture
(5) Porosity
(6) Secondary Alteration
(7) Clay Mineral Composition
(8) Clay Content
(9) Swelling Properties
(10) Solution Phenomena
(11) Cementation
(12) Strength Properties
(13) Ratio Matrix/Components
(14) Orientation of Dominant Set
(15) No. and Orientation of Sets
(16) Fracture Frequency
(17) Roughness
(18) Persistence
(19) Aperture
(20) Infilling
(21) Shear Strength

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Key Parameters in Investigating Faulted Rock Masses

- **Block / Matrix Ratio**

- **Matrix Properties**
  - Particle Size Distribution
  - Clay Mineral Composition
  - Swelling Properties
  - Shear Strength

- **Block Properties**
  - Lithology
  - Size
  - Shape
  - Strength

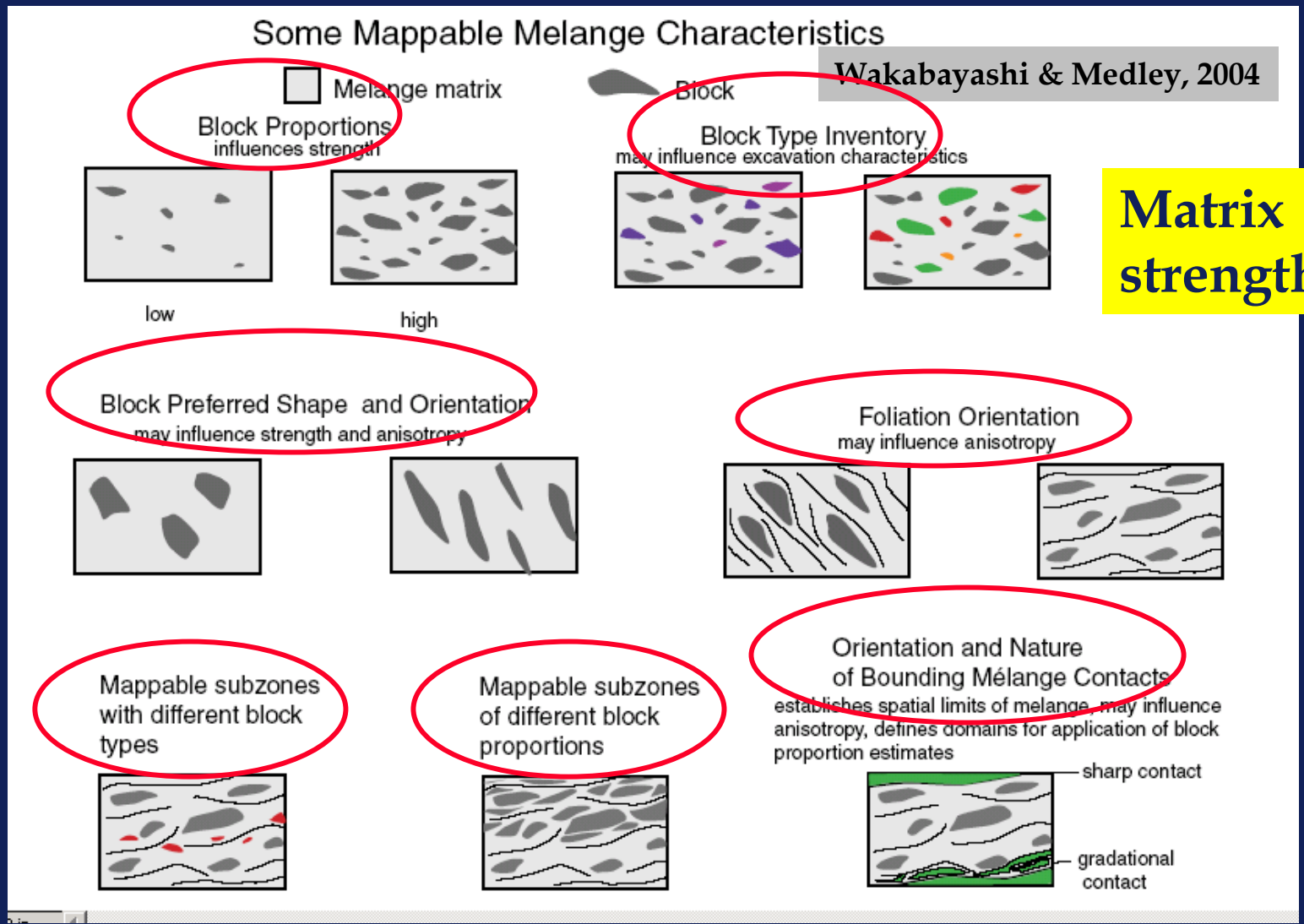
- **Discontinuities**
  - Type (shear, extension fractures etc.)
  - Orientation
  - Fracture Degree
  - Relative Movements on Slickensides

Some elements of CHARACTERIZATION

- Block/matrix discrimination Matrix lithology,
- block lithology, block size, block shape,
- block orientation
- Block size distribution
- Block discontinuities
- Etc…

ALL are straight forward geological engineering during field investigation…

Systematic investigation of chaos



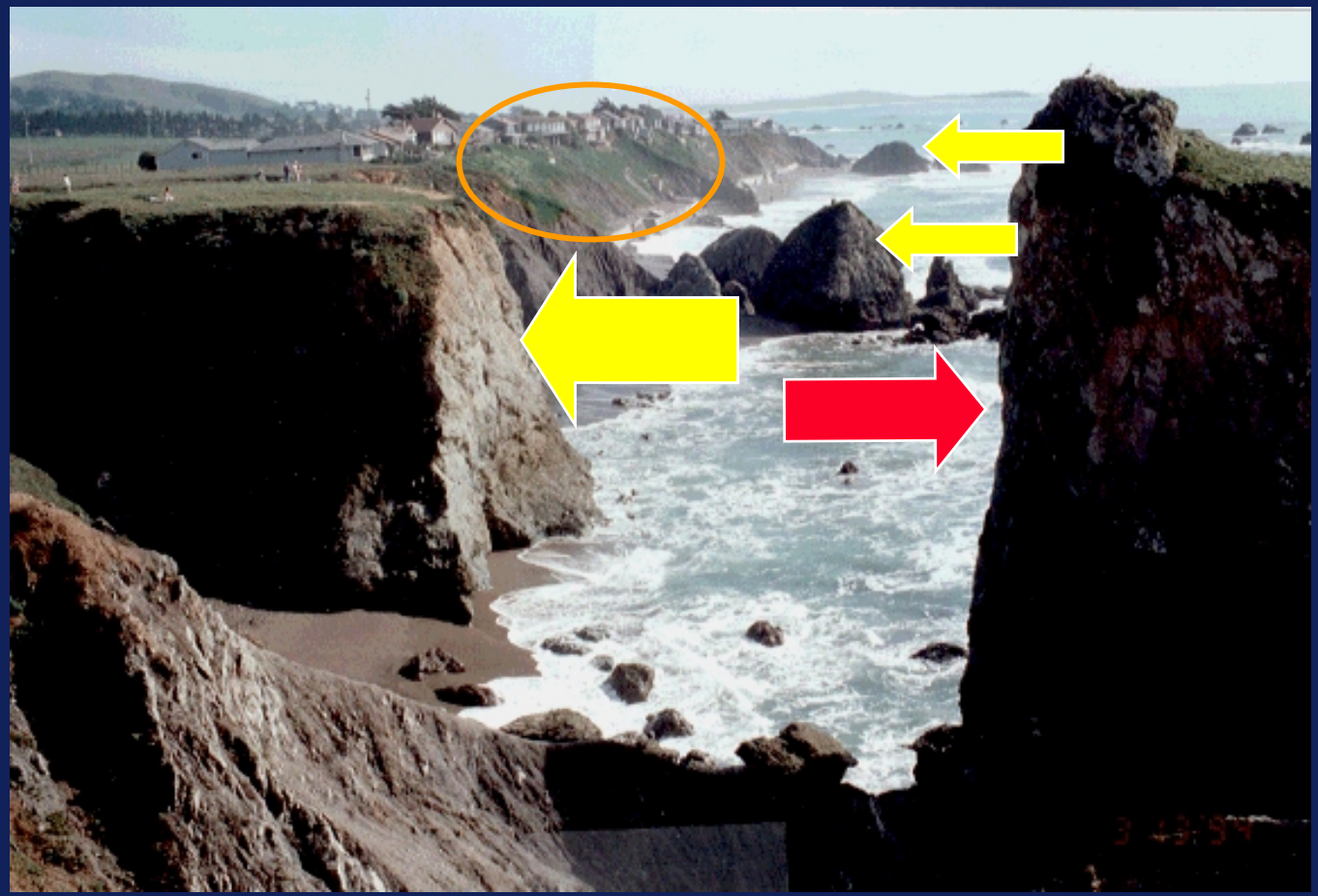
Matrix strength

First: know you working in a bimrock!

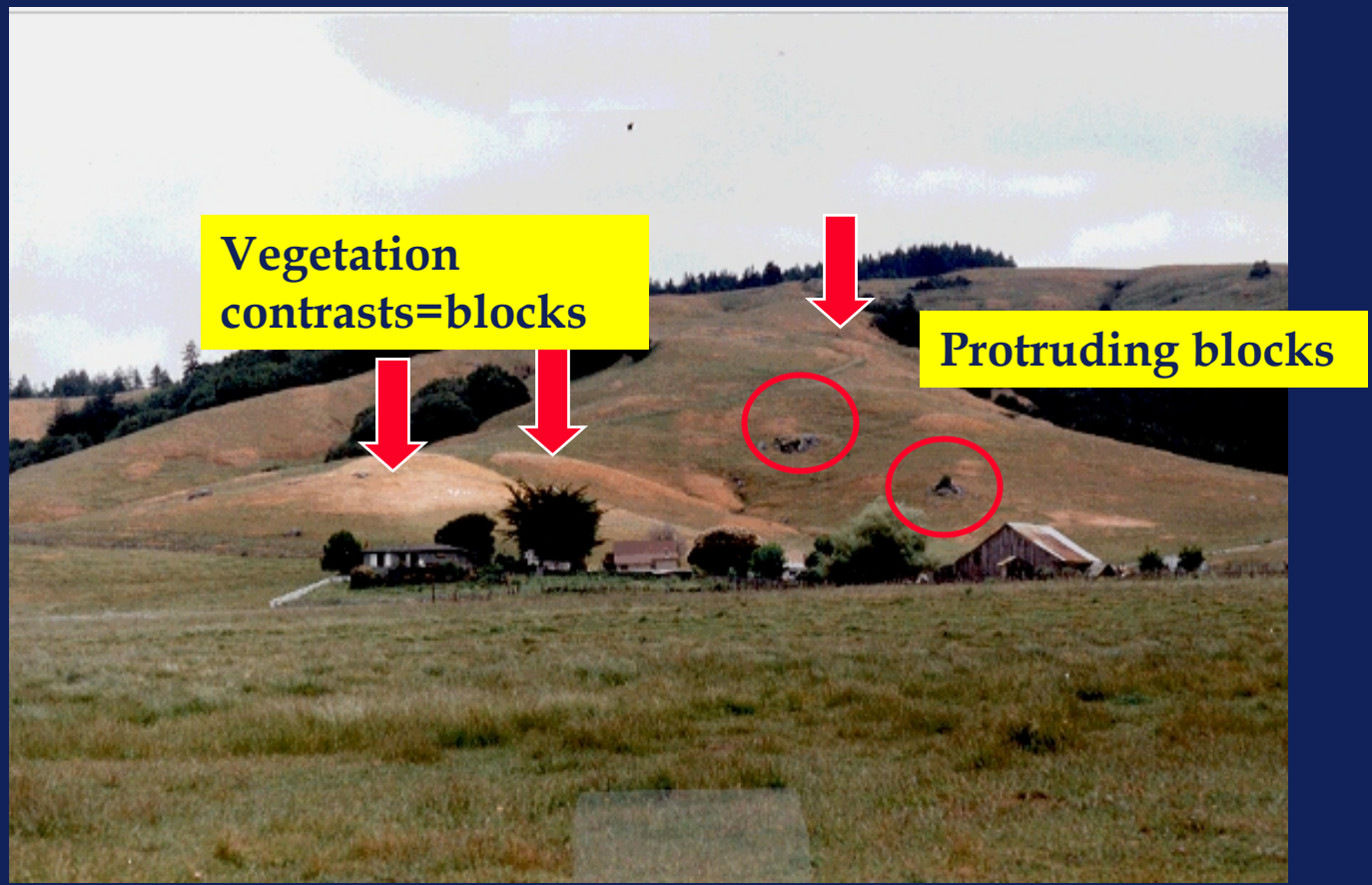
Really obvious melange….

Gwna Melange, N. Wales photo Ed Medley

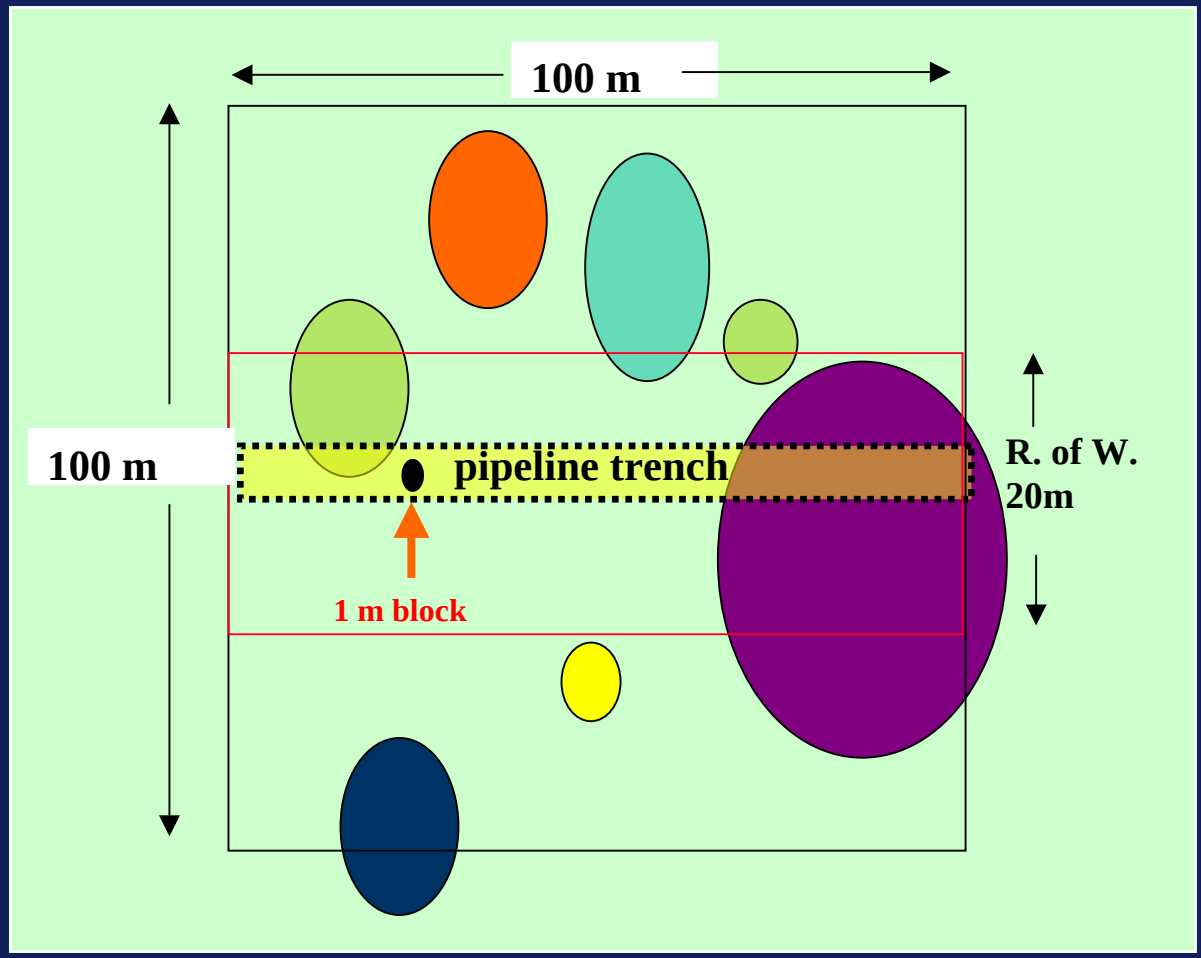
Geomorphic clues: obvious blocks!!



Geomorphic clues: subtle!!



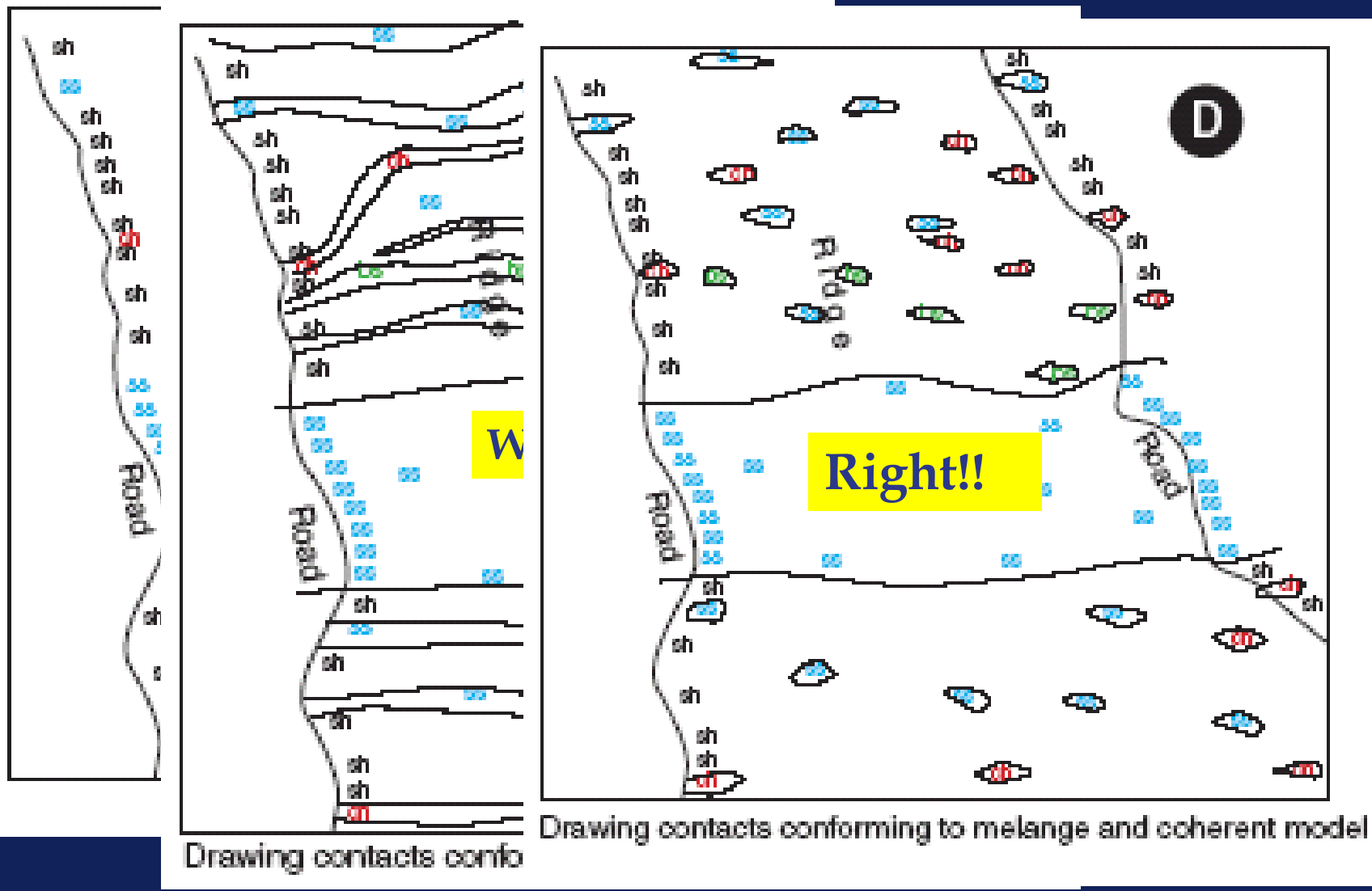
Decide on Characteristic Engineering Dimension and Block Sizes to Map



When is a block not a block?

depends on scale of interest..

Right and wrong way to map melanges



Investigating Fault Rocks

North Anatolian Fault Zone, Turkey
Fault Escarpment of Active Segment, near Bolu Tunnel

Observe block/matrix contacts

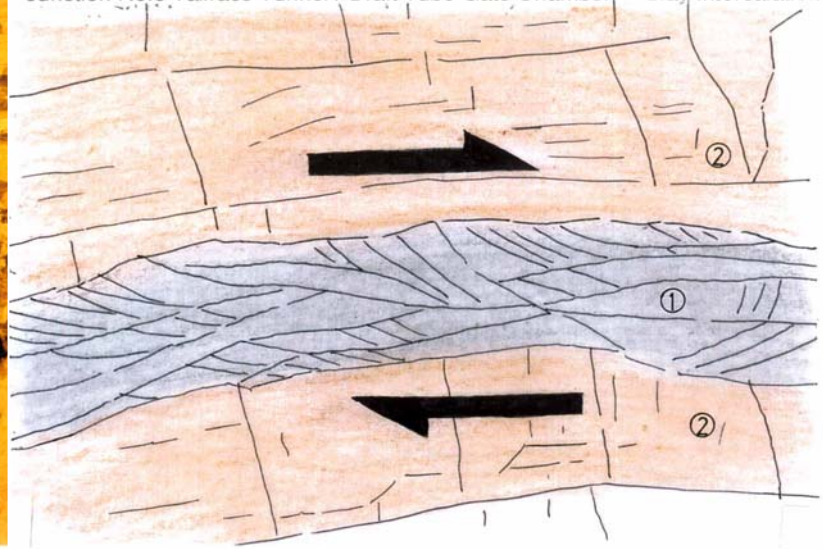
Outcrop Studies: kinematics

Photographic Substantiation of Selected Outcrops

Junction No.3 Tailrace Tunnel / Draft Tube Gate Chamber - Clay Intercalation

Geological Conditions of Selected Outcrops

Junction No.3 Tailrace Tunnel / Draft Tube Gate Chamber - Clay Intercalation



① SHEARED CLAY INTERCALATION WITH ADDITIVE SHEARS
(THICKNESS 15 - 20 cm)

② SANDSTONE

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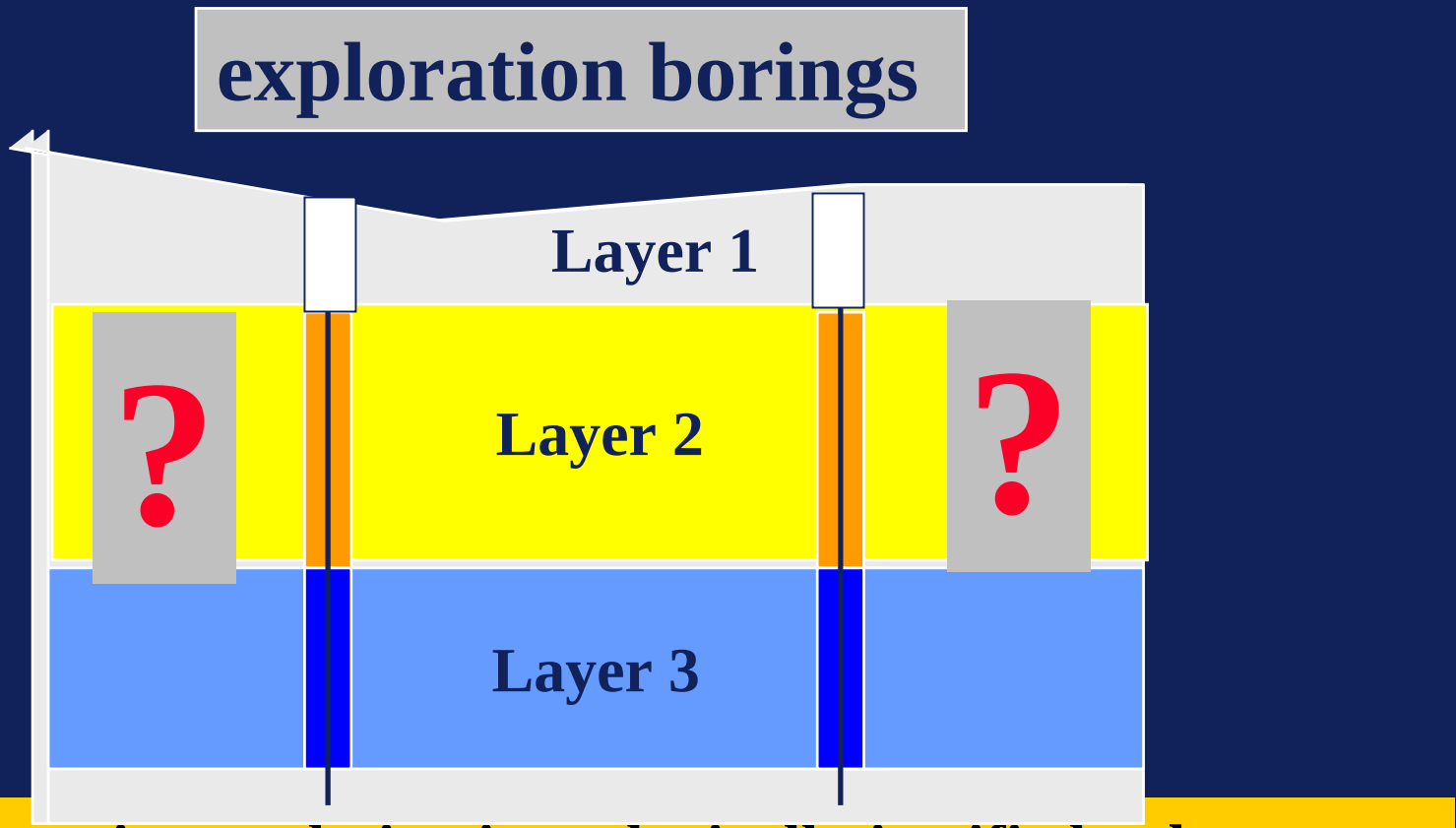
Hydro Power Project Xiaolangdi

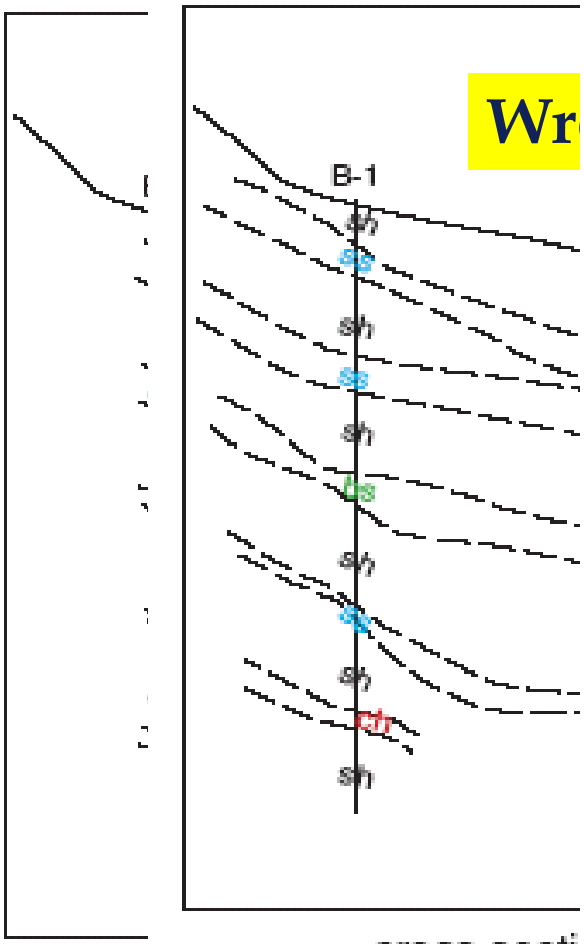
Investigations in bimrocks by Drilling

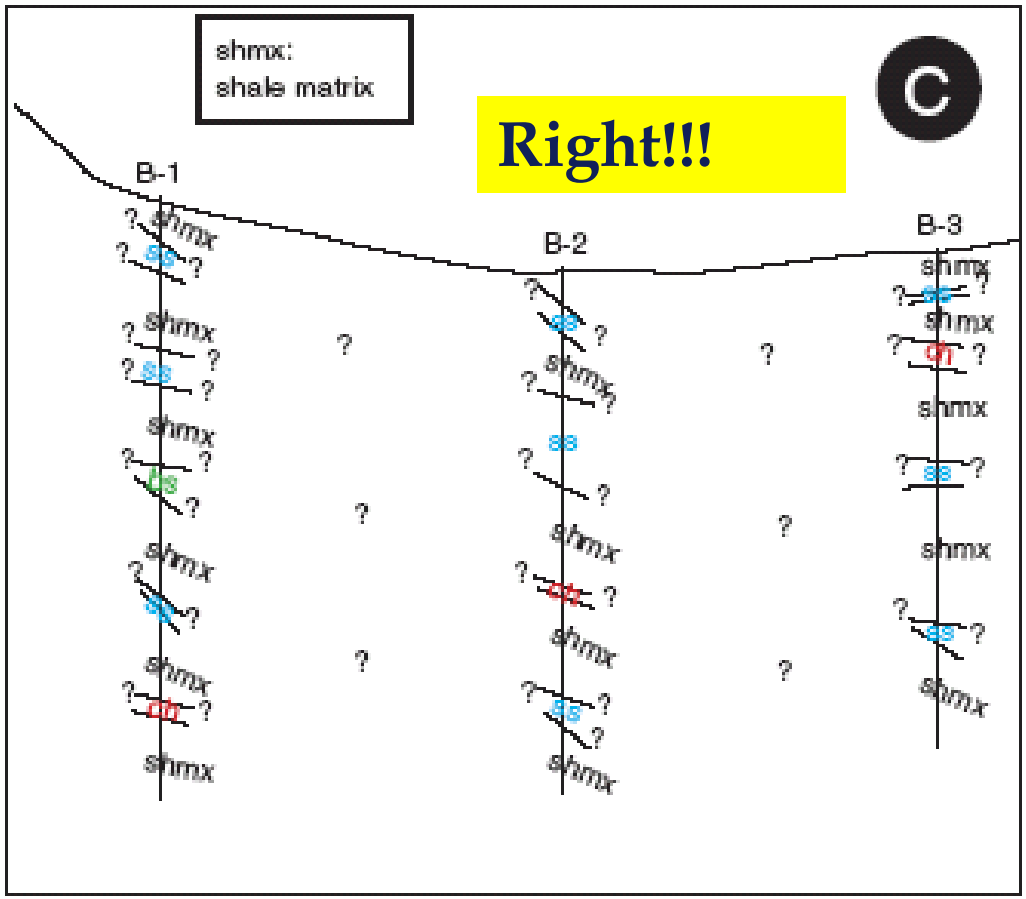
Geology 101 Subsurface characterization of layer cake geology



Linear interpolation is geologically justified only SOMETIMES; extrapolation RARELY

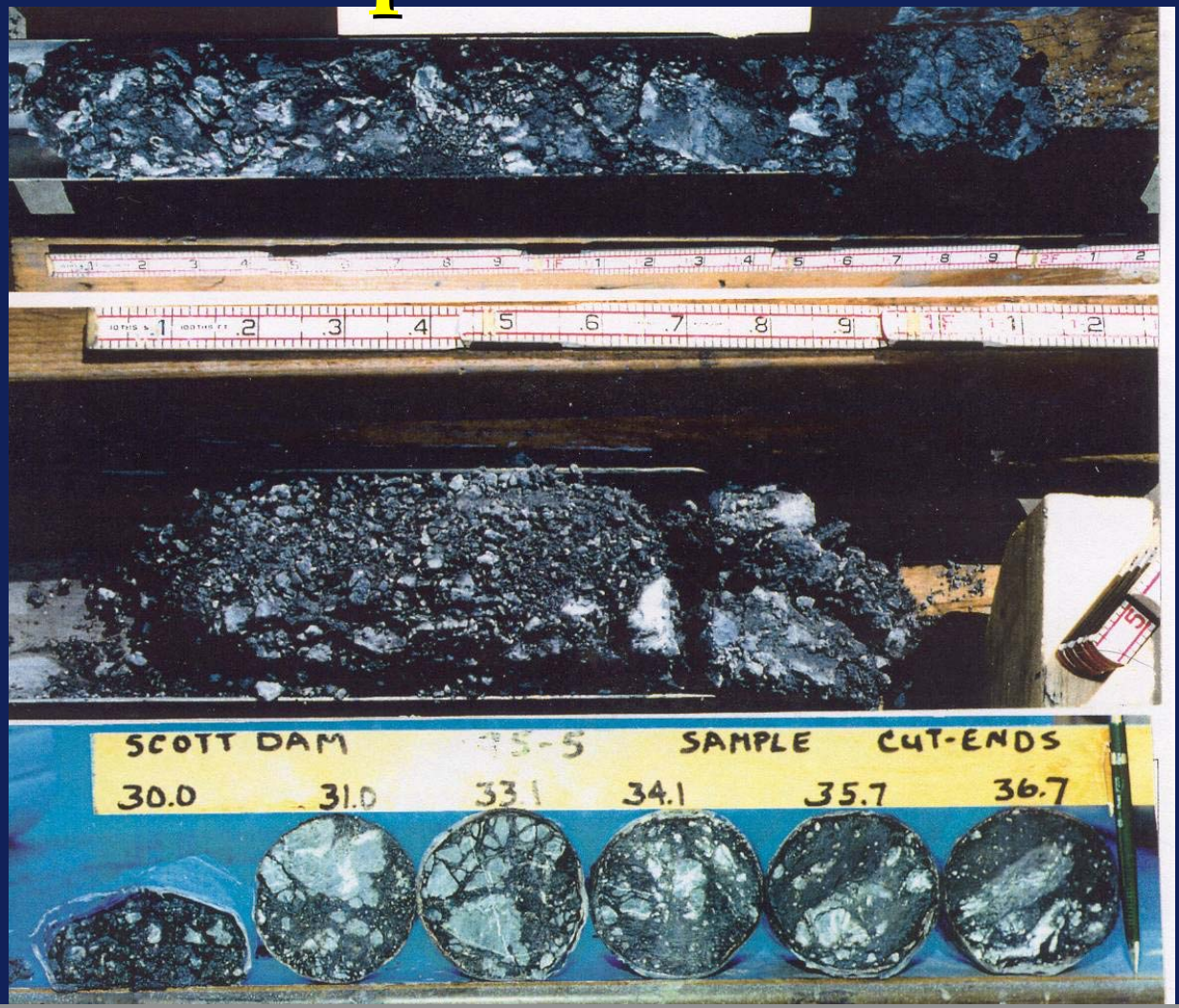
right way and the wrong way…





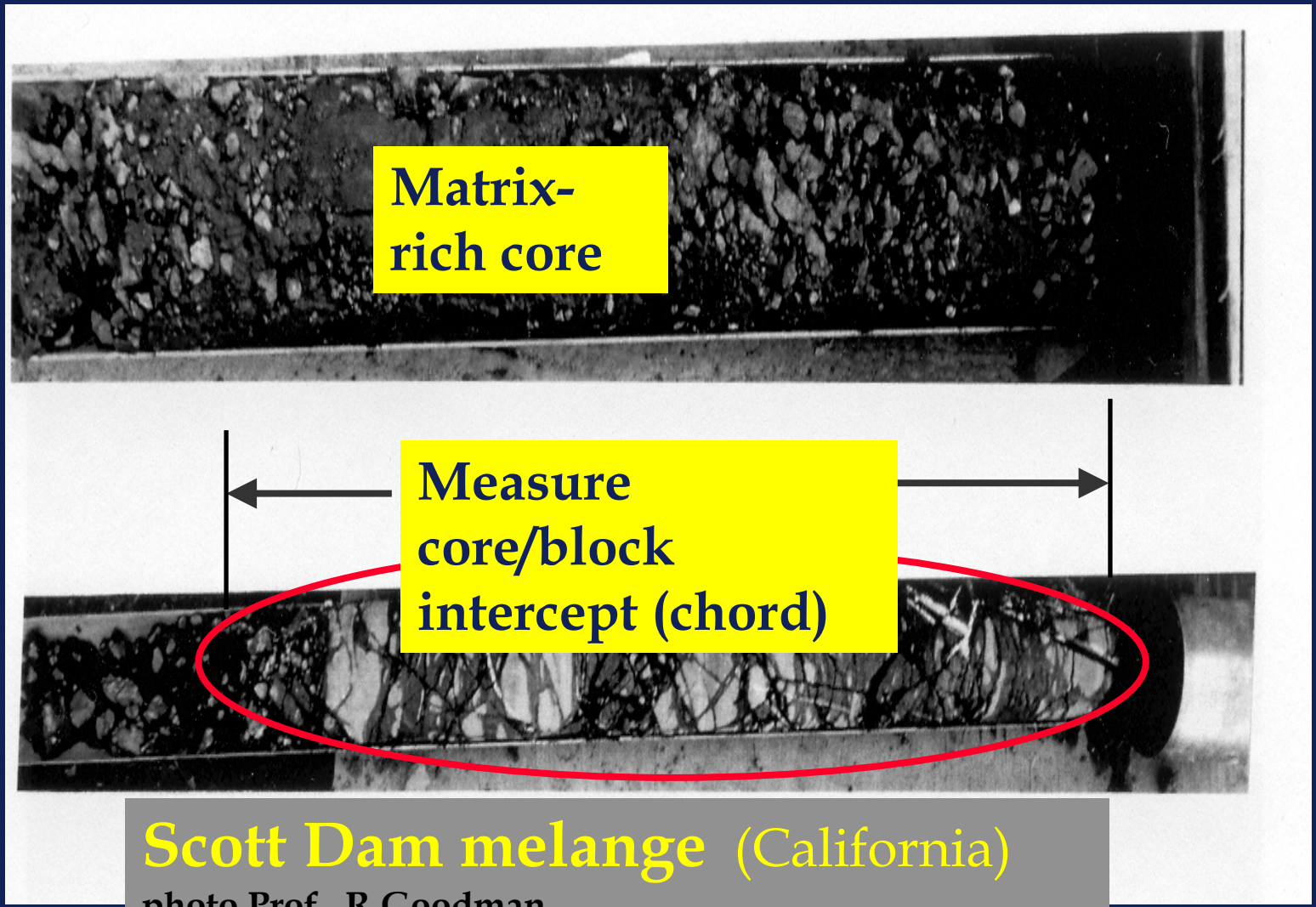
Wakabayashi & Medley, 2004

Take samples of matrix



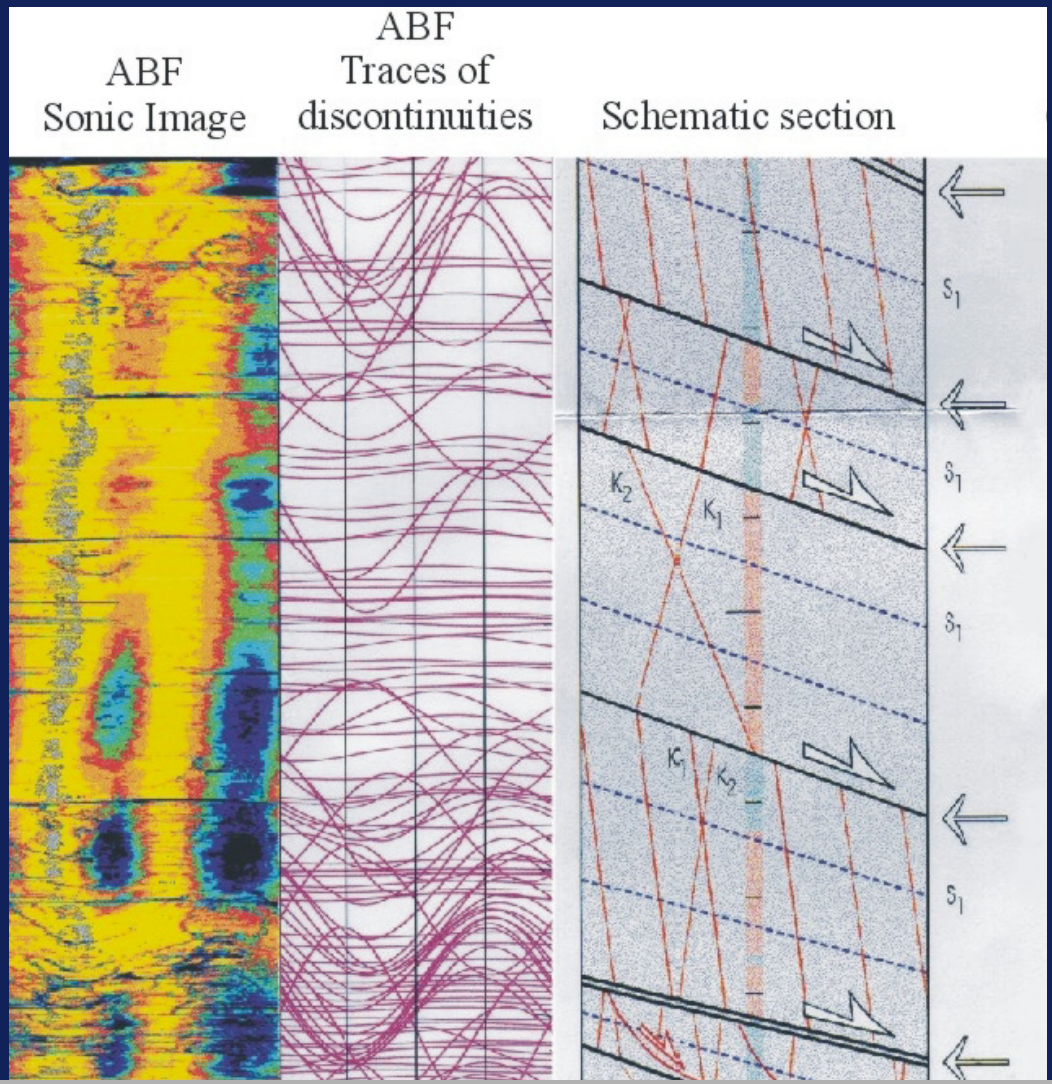
Scott Dam melange photo Prof. R Goodman

Measure block linear proportion



Scott Dam melange (California)
photo Prof . R Goodman

Drilling



Kinematic Discontinuity Analyses on Drill Cores

Detachment along foliation, development of clayey gouge

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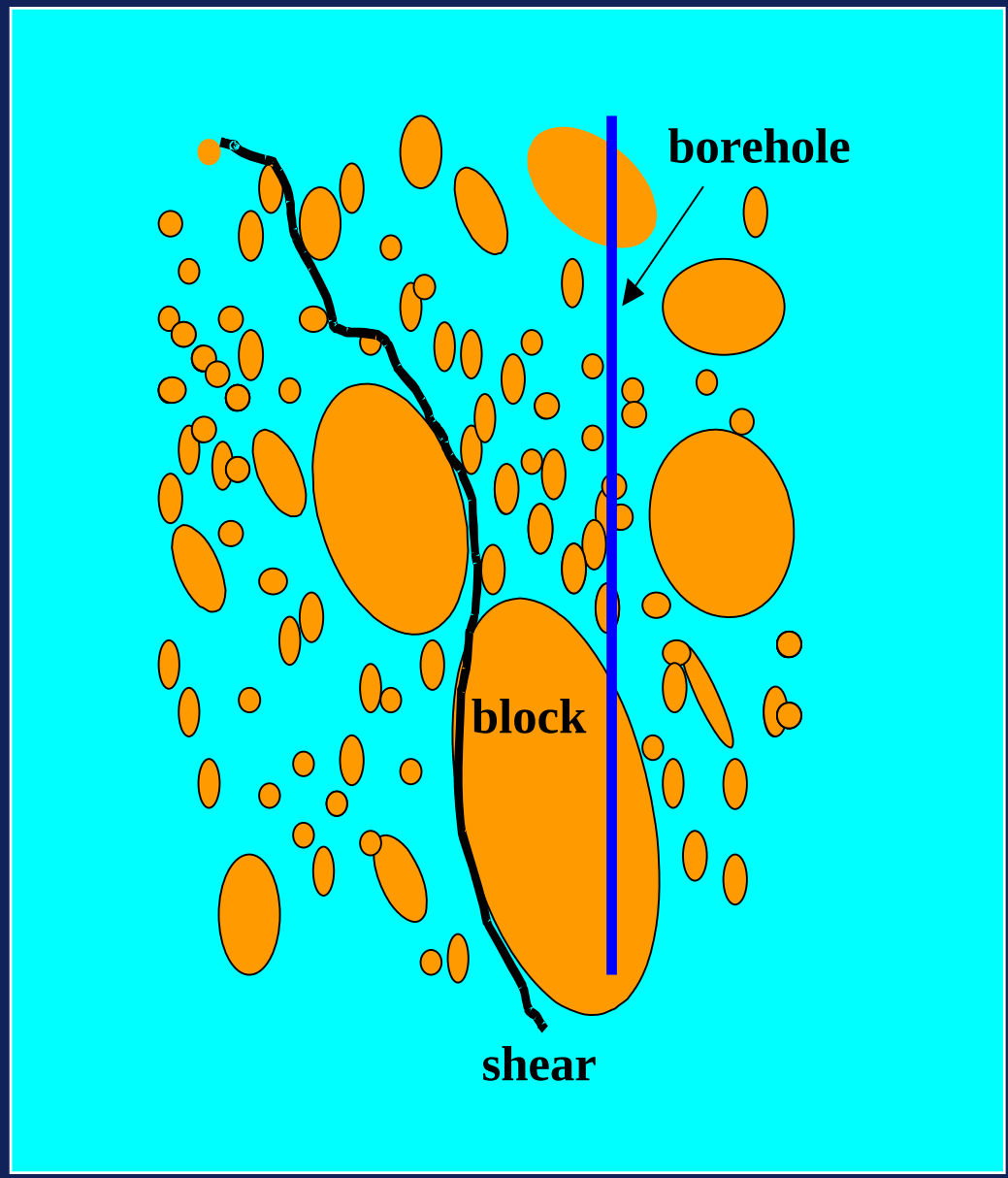
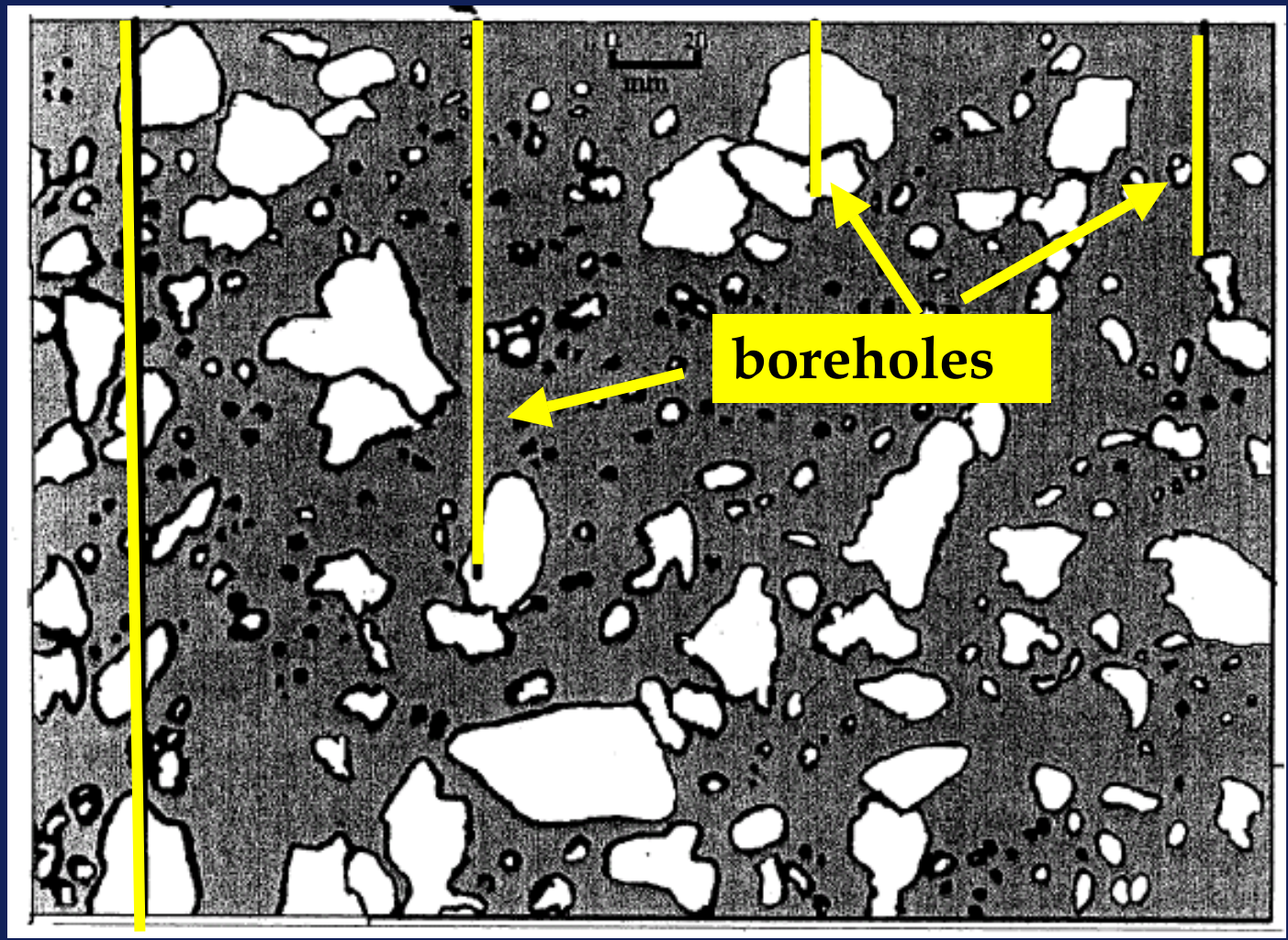
PROBLEM!!

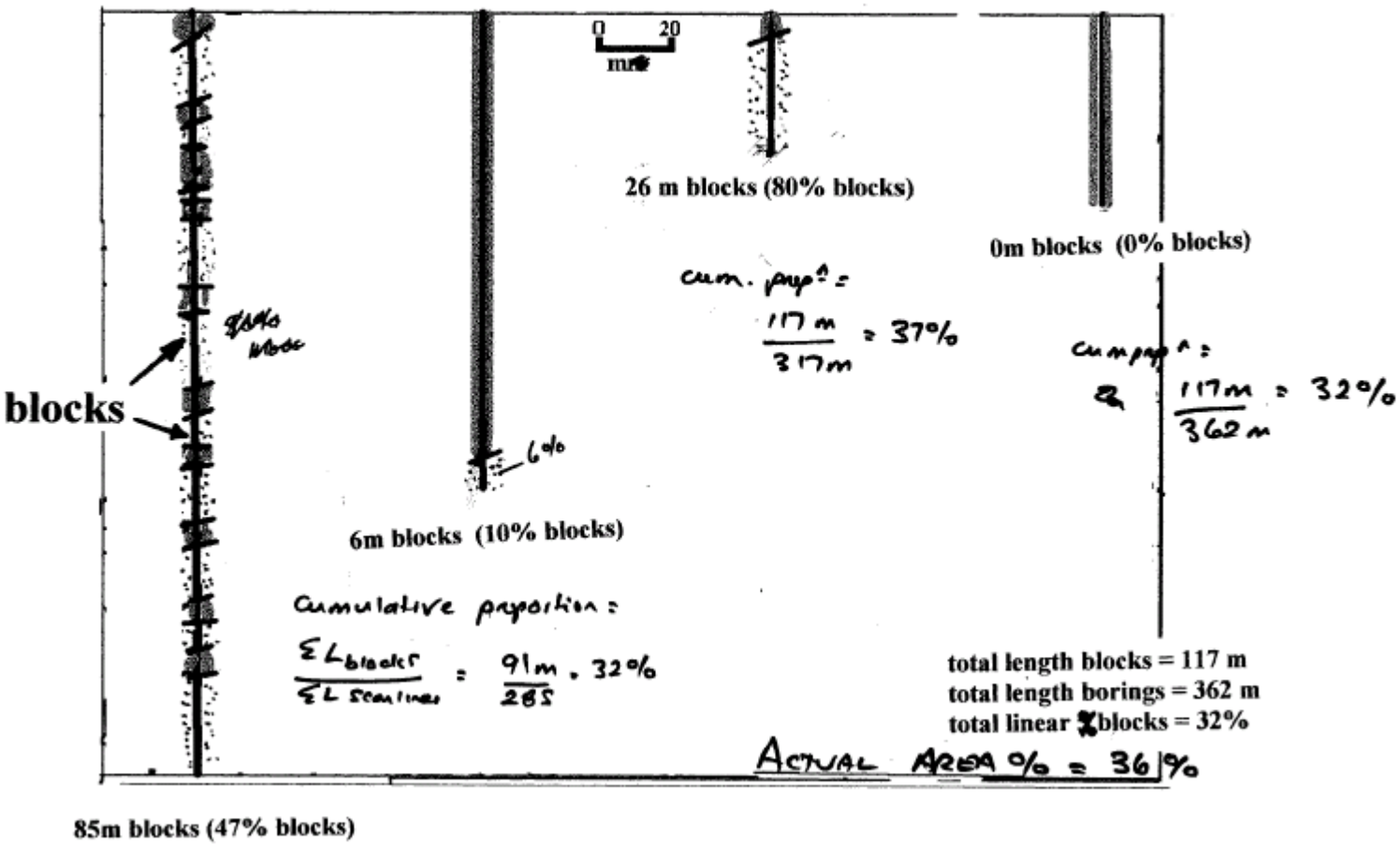
Can we estimate three-dimensional volumetric block proportion with one-dimensional boreholes and two-dimensional plans and cross-sections?



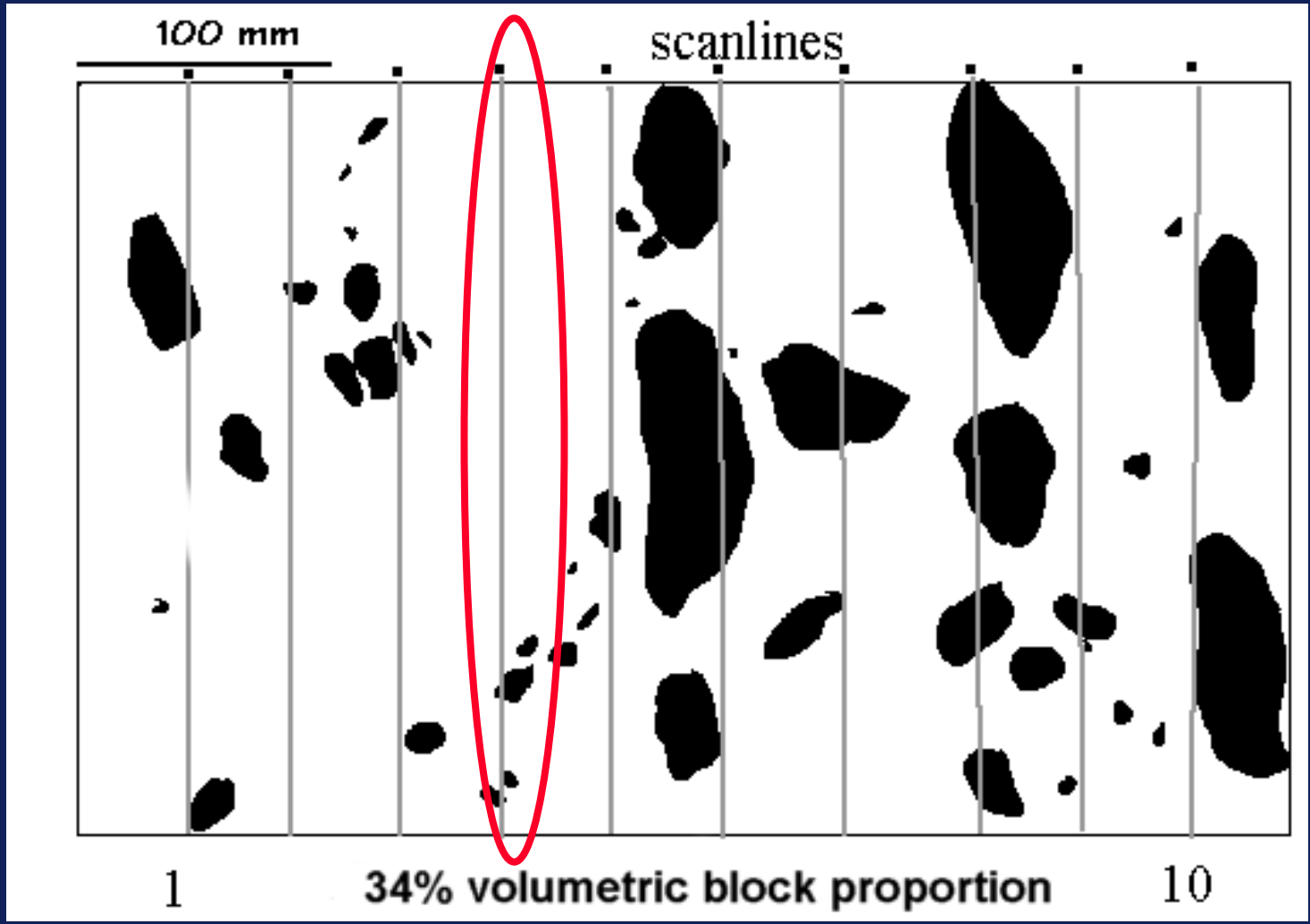
Drilling and coring bimrocks



Measuring Linear Proportion



Uncertainty in characterizing geometry and quantity of scant blocks



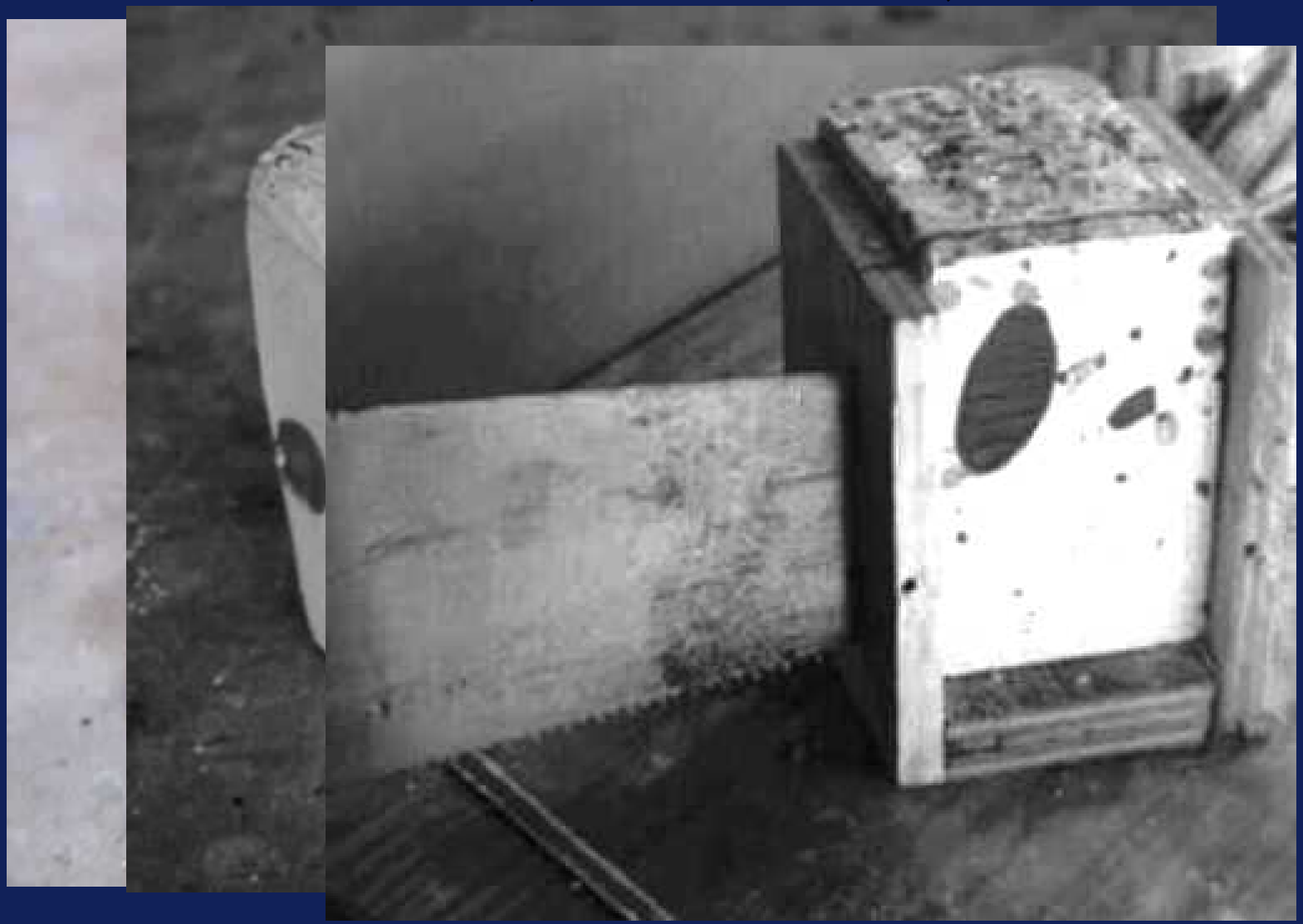
Adventures with Plaster of Paris Models

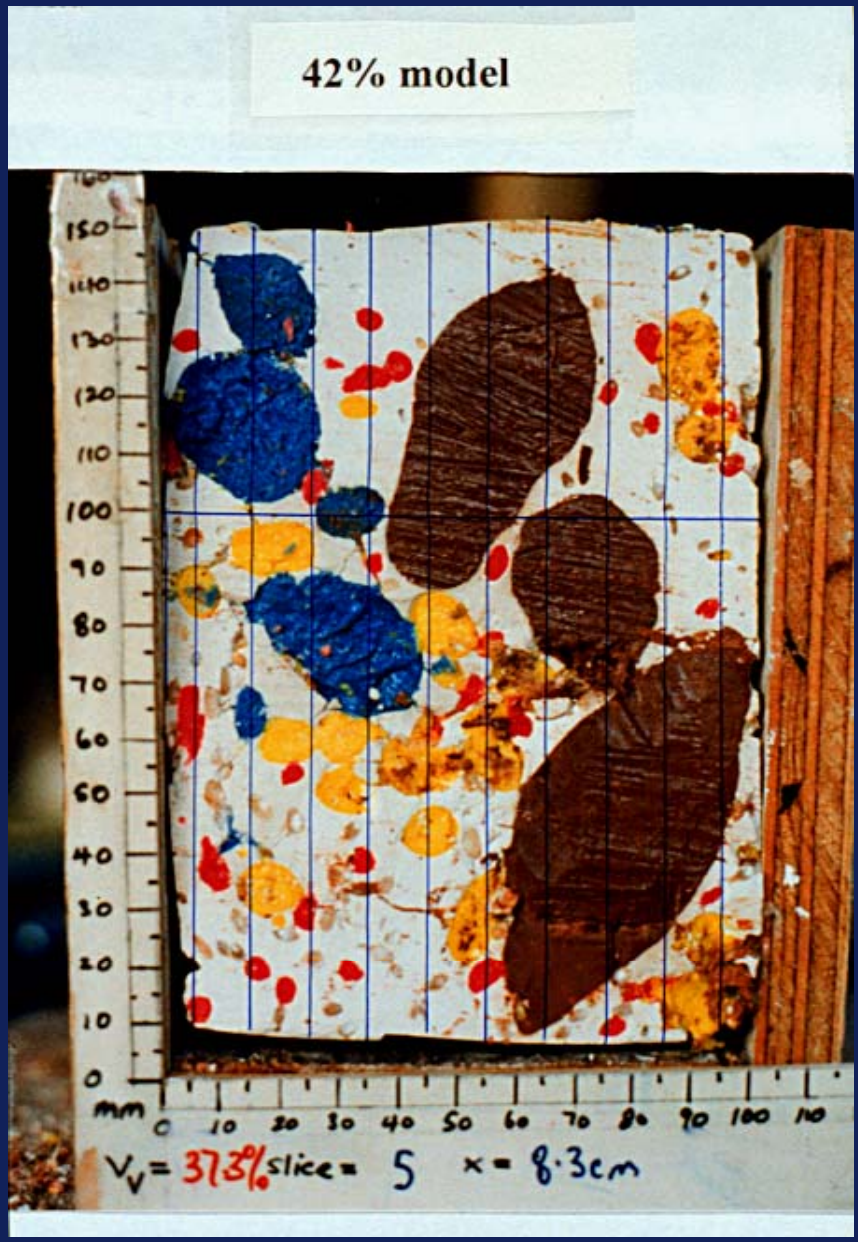
- Fabricated 4 physical melange models with known block size distributions, block proportions
- Generated 400 model borings

Fabrication of blocks in models

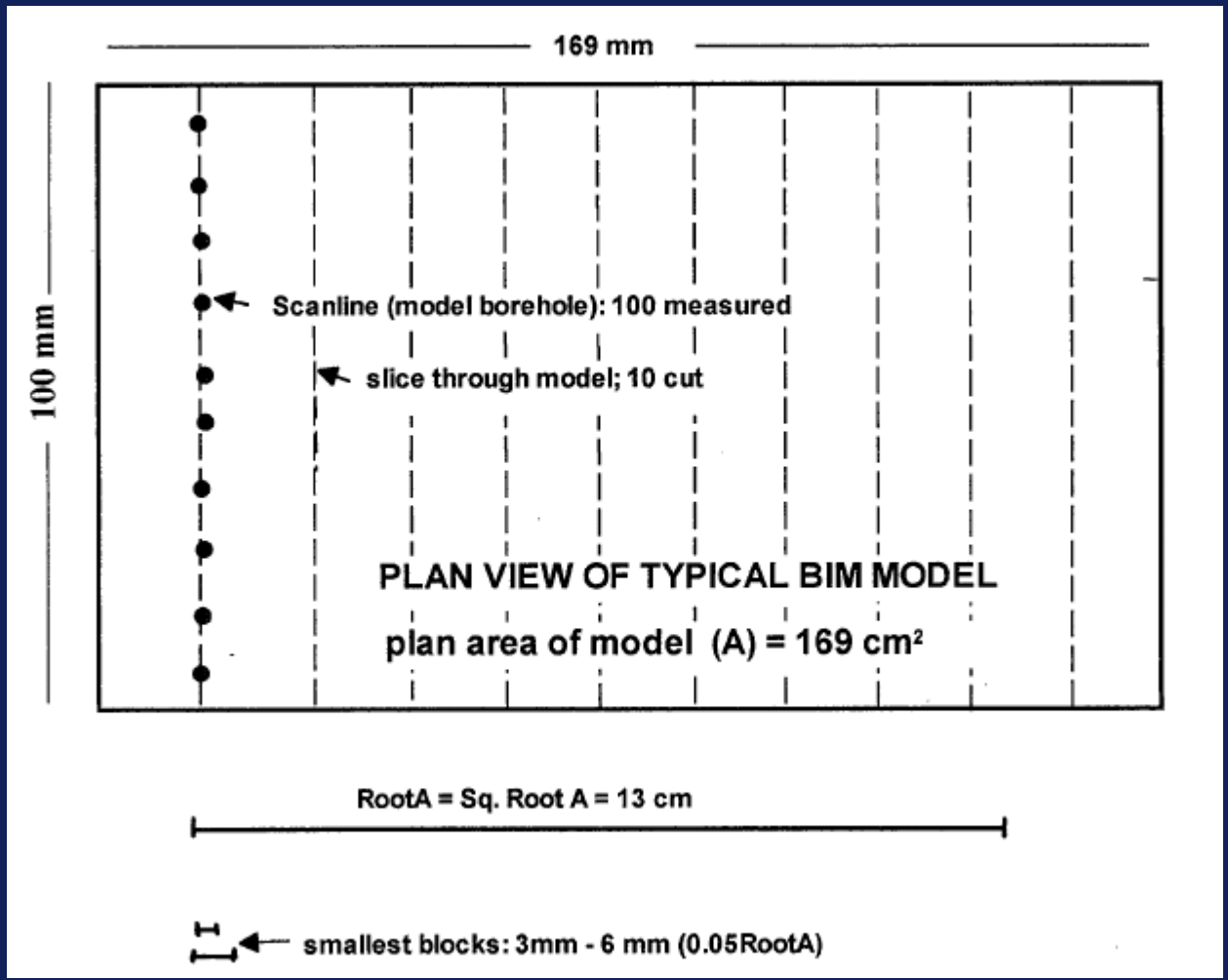
Clay, Play-Doh, rice for 2200 to 7350 blocks

Fabrication (continued)



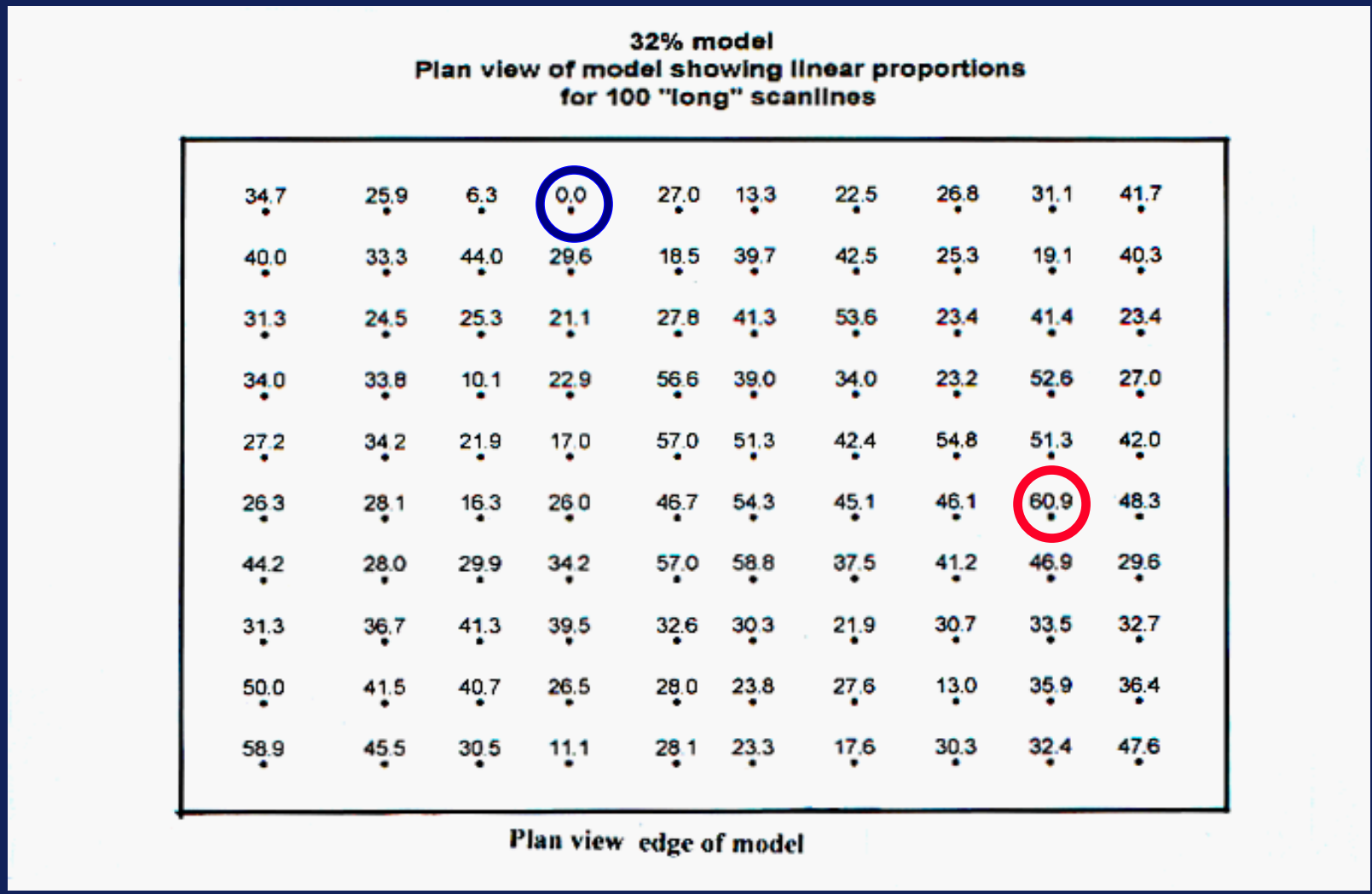


Slice of a physical model bimrock with a known volumetric block proportion and block size distribution, explored by model boreholes.

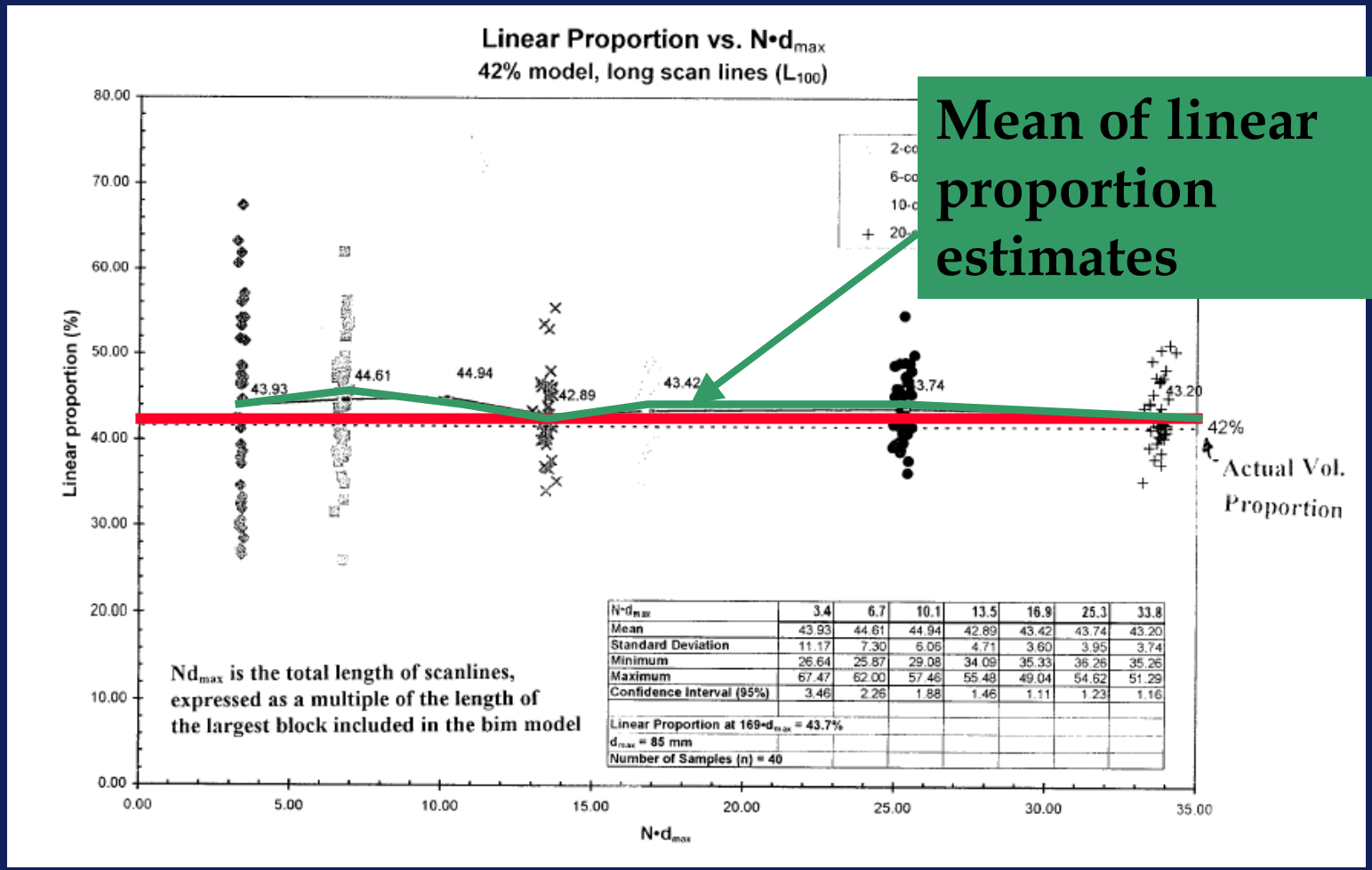

169 mm
100 mm
Scanline (model borehole): 100 measured
slice through model; 10 cut
PLAN VIEW OF TYPICAL BIM MODEL
plan area of model (A) = 169 cm²
RootA = Sq. Root A = 13 cm
smallest blocks: 3mm - 6 mm (0.05RootA)

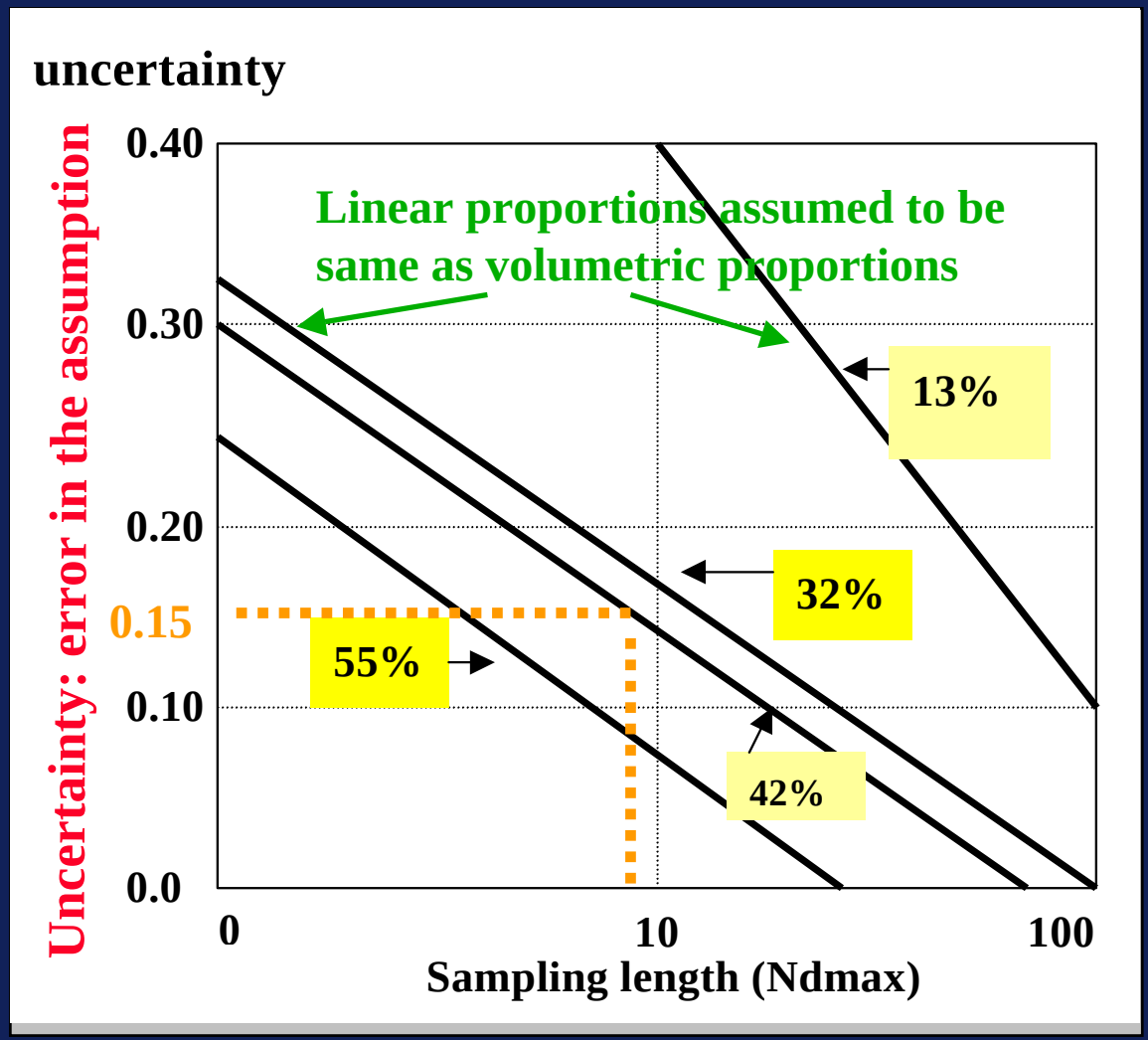
……. or, how wrong can we be?

Actual volumetric proportion is 32%



Monte Carlo analysis (Medley, 1997)





Estimating volumetric properties on the basis of linear boring measurements

(BULLDOZER APPROACH..)

0.15x40% = 6%: use 34% block proportion

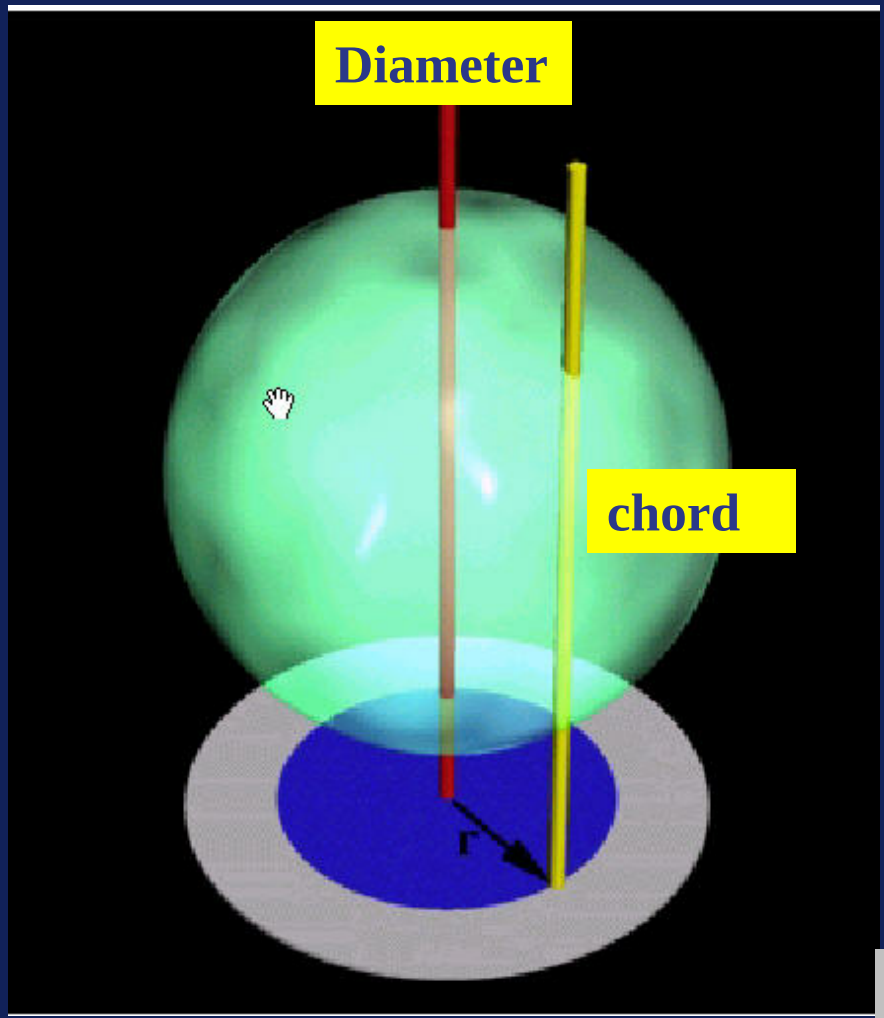
Guidelines for estimating block volumetric proportion

- Measure at least 10* d_{max} of drill core
- Take uncertainty into account, and:
  - adjust vol% estimate downwards for strength
  - adjust vol% estimate upwards for construction excavation purposes

The REALLY difficult problem:

Estimation of actual block size distributions in bimrocks from borings

Drilling through a block: chords and diameters



Only rarely will a drilled chord be the same as the diameter: so when drilling bimrocks be very careful when you use the words: "block diameter"

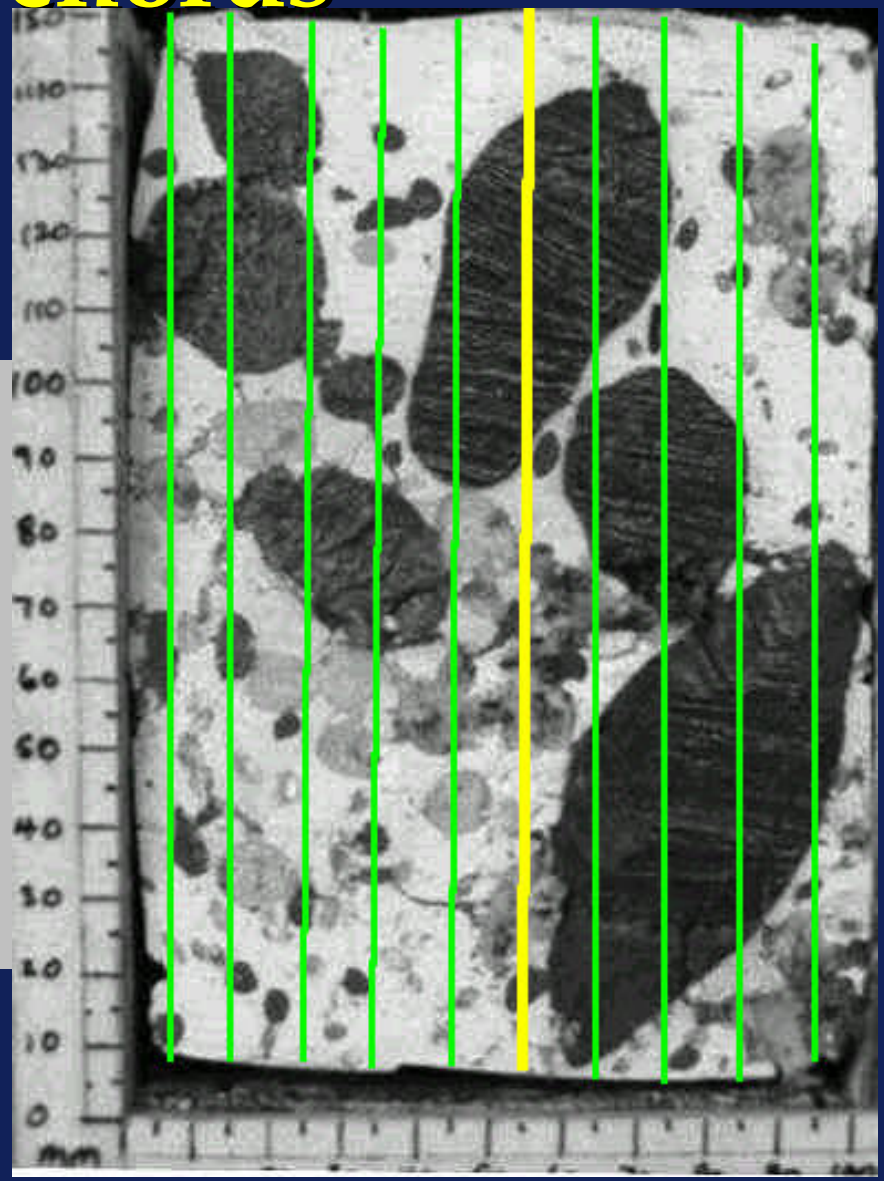
After Russ and Dehuff (2000), "Practical Stereology"

Estimating 3D Size distributions from 1D Borings

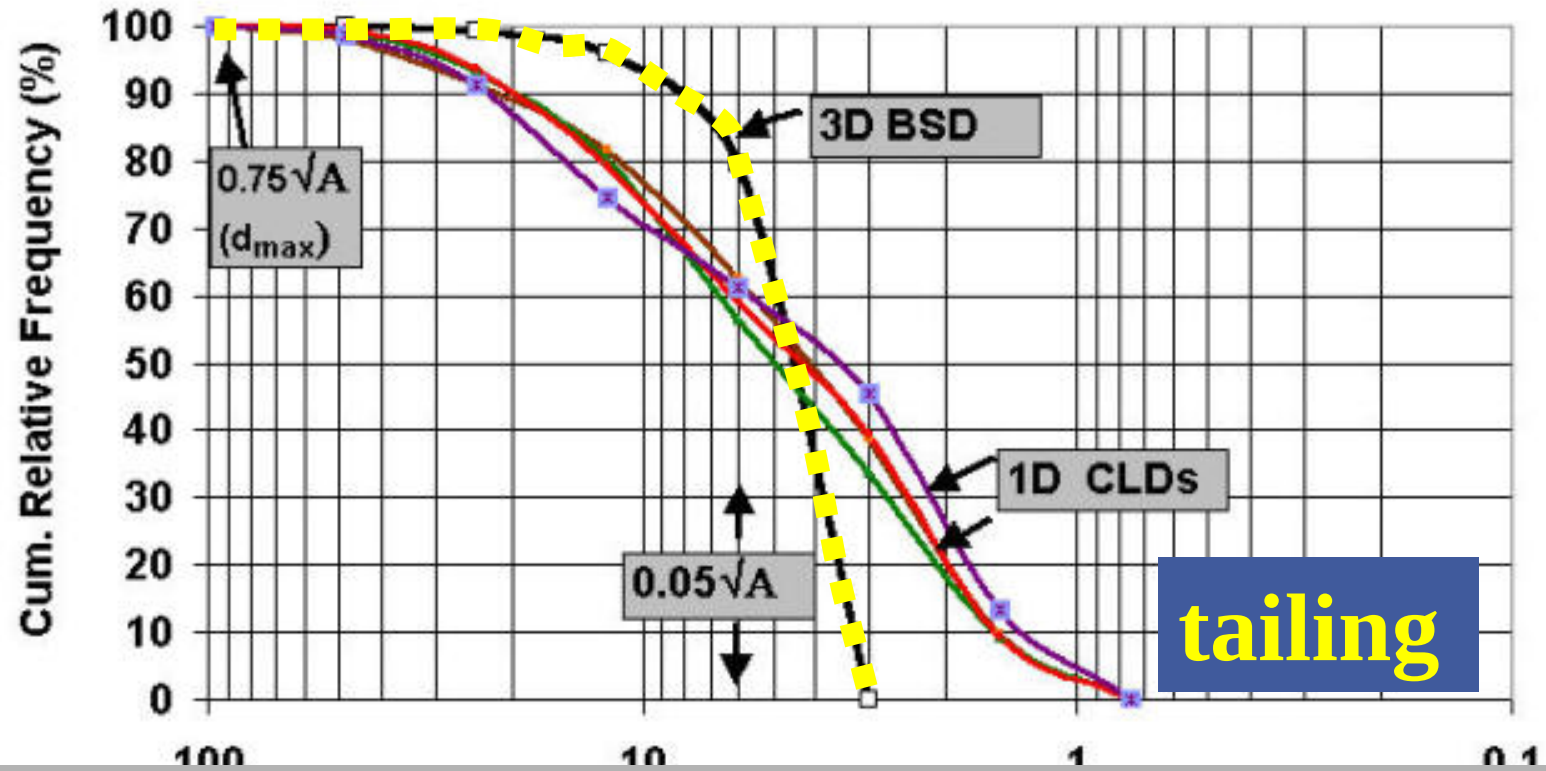
1D chord length distributions are **NOT** same as 3D block size distributions

Measurement of chords

- 10 scanlines per slice
- 100 borings per model
- “centerline” boring to model exploration for tunnel

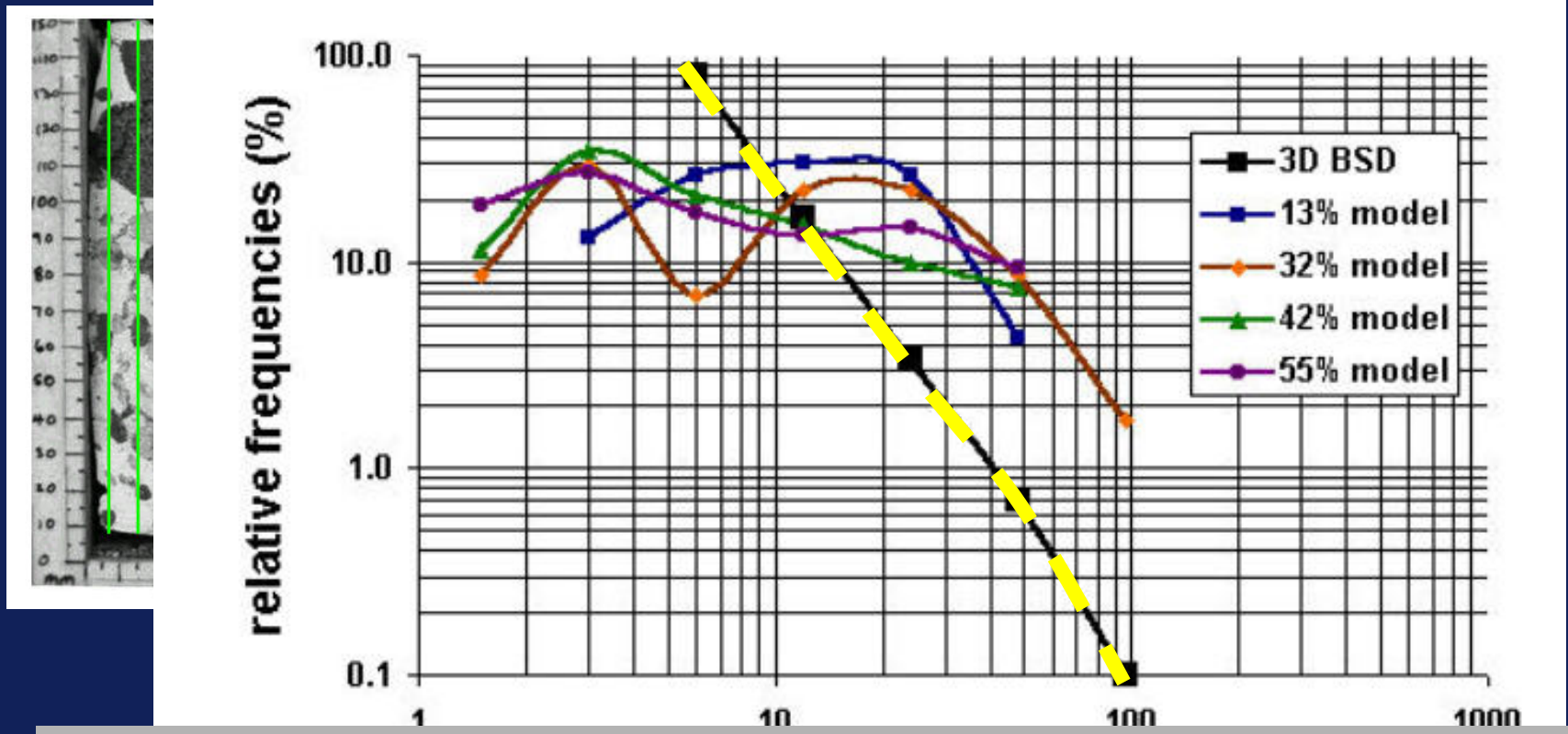


"PSD"-style plot of chord lengths for all models (~2150 chords)



Despite much data, still cannot duplicate original 3D BSD with chords…

Estimation of BSD along "centerline of tunnel alignment"



Generous amount of "exploration drilling" still insufficient to estimate 3D BSD

BIG CONCLUSION 1:
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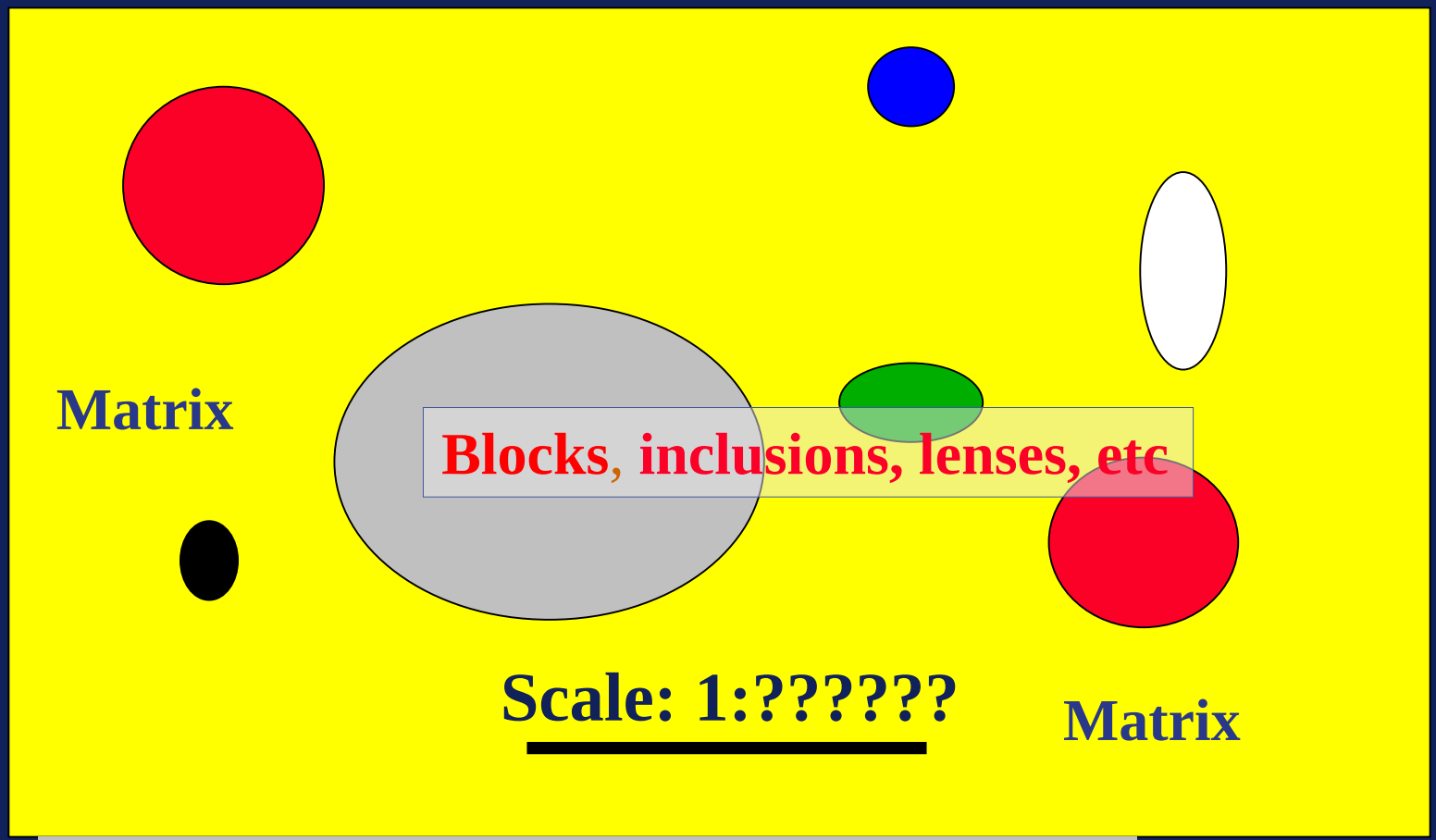

Actual Distribution of Blocks

BIG CONCLUSION 2:
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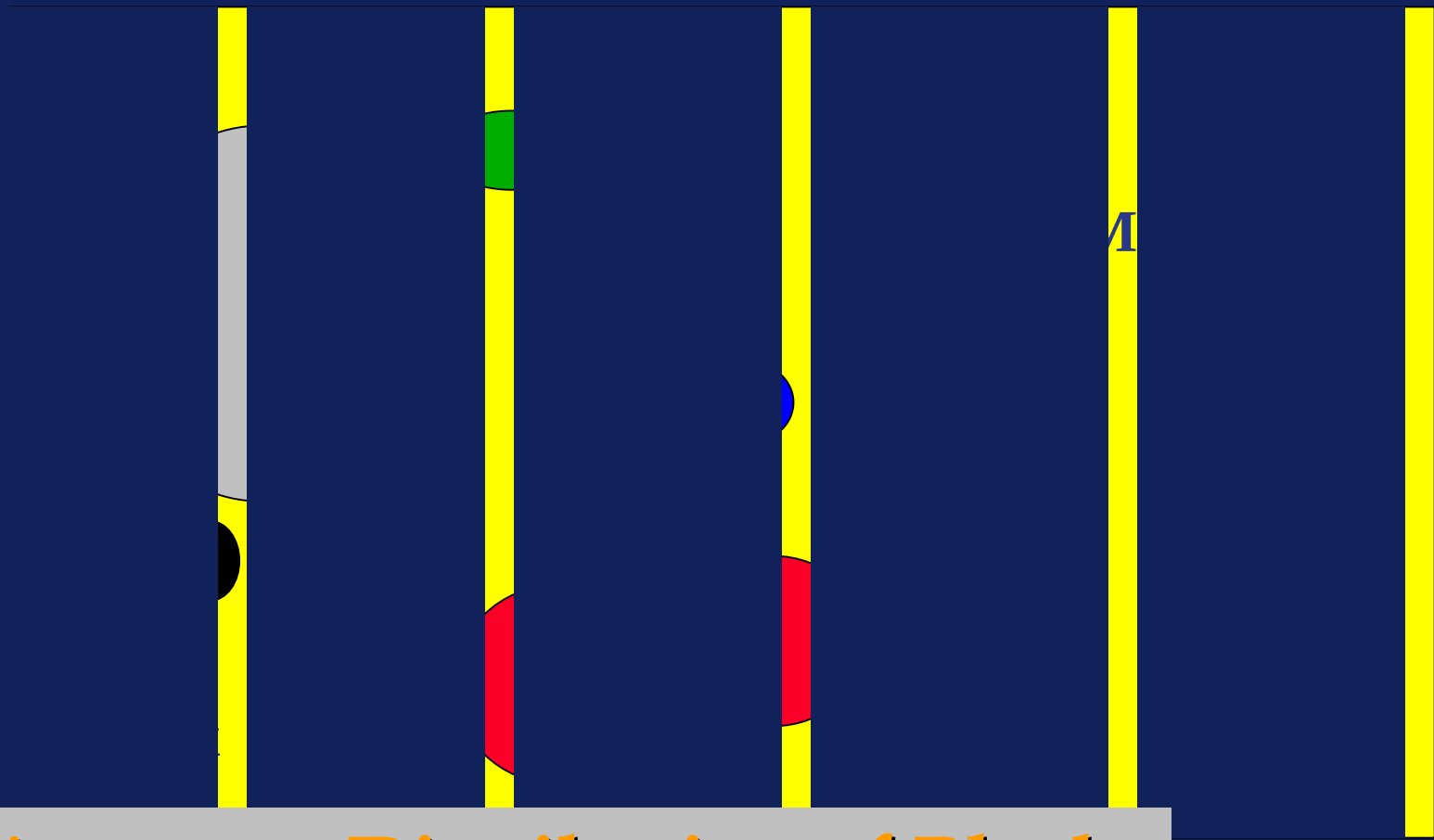

Apparent Distribution of Blocks

Willis, 2000