Engineering Classification of Mélanges and Similar Block-in-Matrix Rocks — an Initial Step toward Rockmass Characterization

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Definitions:

Mélange

Block-in-Matrix rock.

1. Mélange (melange) = Fr. for 'mixture'

A body of rock mappable at a scale of 1:24000 or smaller, characterised by a lack of internal continuity, of contacts or strata, and by the inclusion of fragments and blocks of all sizes, both exotic and native, embedded in a fragmental matrix of finer grained material

(Glossary of Geology, 1987)

or, as defined by Cowan, 1985

a melange is:

'block-in-mudstone chaos'

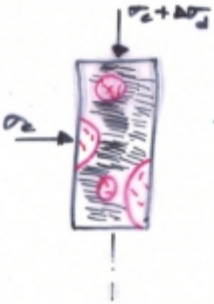
2. A definition of 'block-in-matrix rock' could be constructed like:

'A mixture of relatively large fragments of material within a bonded matrix of finer texture'

'Block-in-Matrix rock' is abbreviated to: 'bimrock'

2. Melanges are difficult to sample and test:

exploring



..... dreaming ....
but value of data?

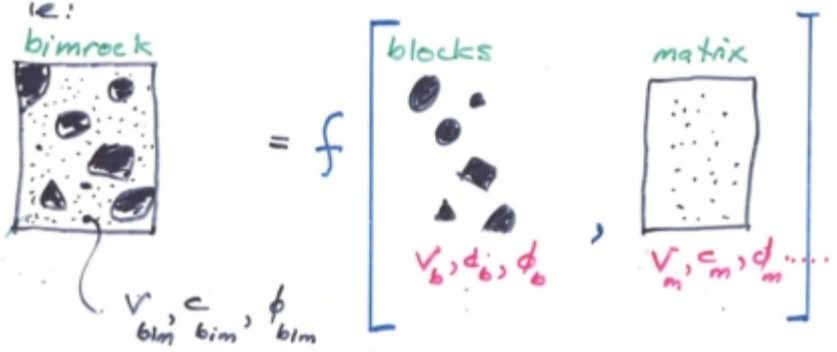
reality . . .

Outline of the Research Problem

- Scott Dam built on melange
- Dam is concrete gravity, built 1920's. Stability under DSOD review 7 10 years.
- Dam founded on 3 'bands' of melange, each of which has a different proportion of 'stronger' blocks within 'weaker' matrix.
- F.S. = 0.6 (sliding) if strength of matrix alone is used.
- Proposed approach is to assign overall rockmass strengths to melange bands on the basis of volumetric proportion of the 'stronger' blocks in the 'weaker matrix'.
- This approach is novel.

Fundamental Research Premise

There is a primary relationship between the volumetric proportion of blocks in a matrix and the overall strength of the block-in-matrix (bimrock) composite.



Approaches taken to research the basic premise :

1. Physical modelling (Eric Lindquist)
2. Numerical modelling (Te-Chih Ke)
3. Empirical — Ed Medley.

ie :

attempt to understand melange behaviour by reviewing practical experience and field study of melange and similar bimrocks

Proposed Research approach :

1. Construct an engineering classification for blmrocks

2. Use the engineering classification as a means to broaden literature and case history research beyond melanges

3. Adapt an existing Rockmass classification scheme to include consideration of block volume proportions

4. Use modified Rockmass classification to correlate block volume proportions to rockmass c, ϕ etc. for any given blmrock type

5. Predict c, ϕ for some Franciscan complex melanges and test predictions using case history and field data.

Some aspects of block-in-matrix materials

As defined previously, a block-in-matrix material is:

'a mixture of relatively larger fragments within a bonded matrix of finer texture'

ie:

- No genesis implied
- weaker blocks may be enclosed within a stronger matrix
- blocks of fine grained material can be included within a matrix of coarse grained material.

Examples of bim materials. :

- concrete
- glacial till (lodgement)
- colluvium
- breccias
- saprolites
- melange

Some characteristics of block-in-matrix materials:

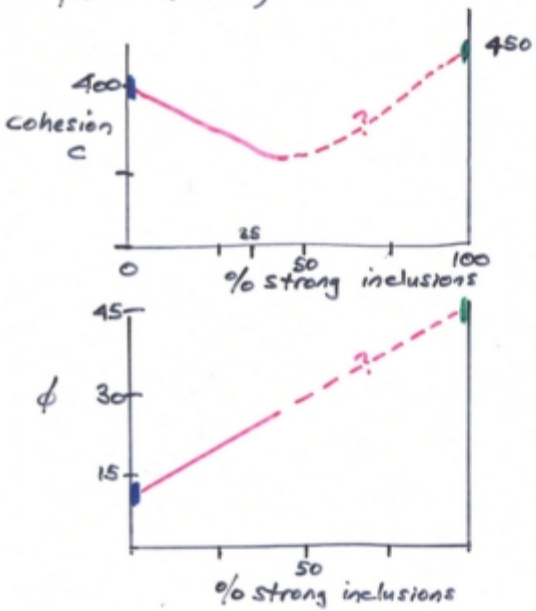
1. Concrete

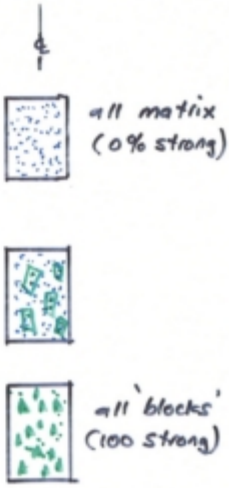
Various 'mixture models' for concrete are of the form:

$$E_{conc} = f(c_m, E_m, c_a, E_a)$$

m = matrix
a = aggregate
c = concent.
E = modulus

also, in modelling a simple melange, Eric Lindquist found (1992):





2. Franciscan Complex melange

Slopes in Franciscan Complex melanges appear to be more stable where there is a higher proportion of blocks in the sheared matrix

(Savina, 1982; Trautmann, 1976; Peterson, 1979)

3. Debris Flow modelling

Rodine & Johnson (1976) show that a model slurry is strengthened by a higher proportion of inclusions.

ie: For 2 sizes of spheres, strength increase occurs at 60% volume proportion.

But for a well graded distribution, strength increases at 95% volume proportion

Discontinuities in bimrock fabric

In addition to blocks and matrix, discontinuities influence bimrock behaviour.

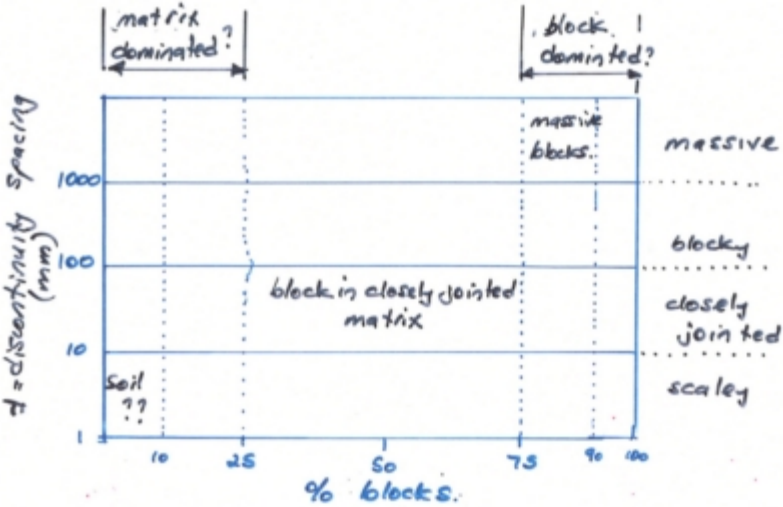
Discontinuities occur in the matrix

Discontinuities occur in the blocks

Discontinuities occur in both blocks and matrix

However, the presence of discontinuities in the weaker component may be more critical.

Engineering Classification of Bimrocks



- d – discontinuity spacing is a measure of spacing.

Example bimrocks:

block-in closely jointed matrix: melange
volcanic breccia
mylonite

Use of Bimrock Classification

- The classification will allow literature and case history research to be broadened, beyond study of melange

- allows correlation of volumetric proportion of blocks to e, ϕ within bimrock categories.

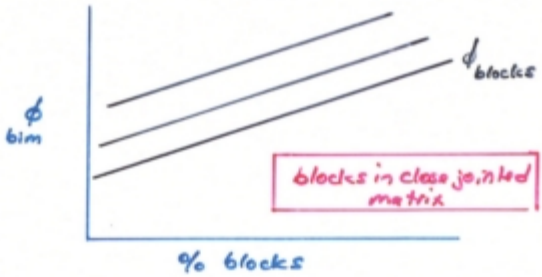
- can be enhanced by geological descriptors:
  eg: 'greywacke blocks in closely jointed argillite matrix'

Further Research Steps

1. Adapt an existing Rockmass Classification Scheme to include volumetric proportions of blocks

2. Review case histories to generate c, ϕ correlations with volumes of blocks for bimrock classification categories.

e.g.:



3. Study failure modes for bimrocks

4. Study weak block / strong matrix implications

5. Predict c, ϕ for Franciscan melange and test against experience / field observations.

Bimbools Discrimin

Discrimination of bimrocks

- In geology, 'fragmentites' or 'rudrocks' are classified on the basis of lithology, particle shapes, sizes, etc. ⇒ complexity

- For engineering purposes, one could discriminate bimrocks on the basis of property contrasts between blocks and matrix.

  e.g. : - strength contrasts
  - particle size contrasts.

For strength contrasts, say :

$$K_1 > \frac{(q_u)_{block}}{(q_u)_{matrix}} > K_2$$

K_1: blocks weaker than matrix

K_2: blocks stronger than matrix

or:

$$n_1 > \frac{(\tan\phi)_{block}}{(\tan\phi)_{matrix}} > n_2$$

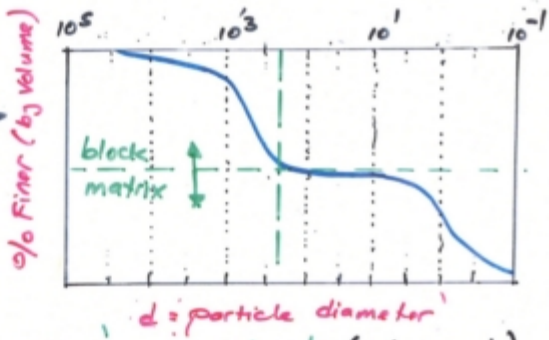
For example, at Scott Dam $\phi_{greywacke} \sim 55°$

$\phi_{argillite} \sim 30°$

$$\therefore \frac{(\tan\phi)_b}{(\tan\phi)_m} = \frac{(\tan 55)}{(\tan 30)} \simeq 2.5.$$

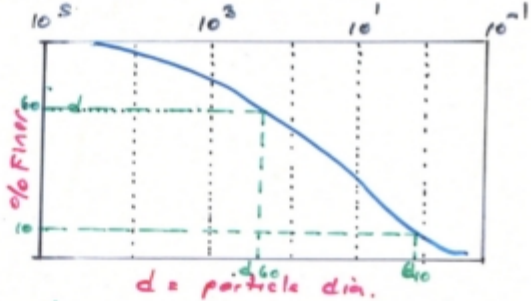
For material size contrasts, could use a particle size distribution concept.

ie:



This distribution is 'gap-graded', (clear cut).

Not so obvious:



For a 'well graded' bimrock, define a 'uniformity criterion'

ie: $\frac{d_{60}}{d_{10}} > 10$??

For above: $\sim \frac{300mm}{20\,mm} \sim 15$ ✓ ok.

Rockmass classif

Tentative outline of ideas for a Rockmass Classification Scheme for Bimrocks

- It is impracticable to characterise all rockmass properties, even for a homogeneous rockmass. A bimrock is more complex.

- Rockmass classification schemes are commonly utilised by rock engineers — particularly underground.

- Rockmasses can be described by several indicators. A total rockmass quality can be calculated as the sum or product of these indicator ratings.

eg. 0 to 100 — RMR method (Bieniawski, 76
extreme poor — excellent
0.001 to 1000 — Q-System (Barton et al, 1974

For example, RMR (Rock Mass Rating):

Indicator	max Rating	Range of values
q_u intact Rock	15	0 – 240 MPa (34,800psi)
drill core RQD	20	0 – 100 %
discont. spacing	20	<60mm – >2m
discont. condition	30	5mm gouge – rough, clean
groundwater	15	dry – flowing
	100	
discont. orientation adjustment	to −60.	

RMR classes:

RMR	81-100	61-80	41-60	21-40	0-20
	v. good rock	good rock	fair rock	poor rock	v. poor rock

← * bimrocks? →

* Bieniawski (1990) shows 350 case histories. 10 of these in breccia and mylonite. RMR range 37 → 9.

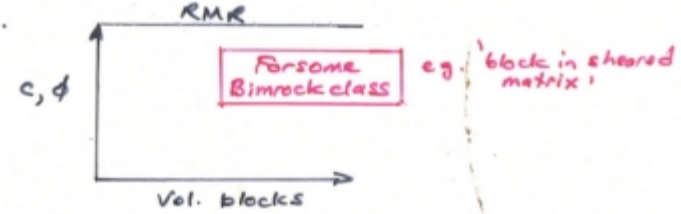
It may be possible to modify RMR method to accomodate bimrocks (as classified in presentation), with inclusion of a measure of volumetric proportion. ie:

Indicator (RMR)	Rating.	Indicator Bimrock RMC.
q_u Intact Rock	15	$\bar{q}_u$ blocks
drill core RQD	20	volume of matrix
discontinuity spacing	20	block discont. spacing
discontinuity condition	30	strength of matrix matrix discont. spacing
groundwater	15	groundwater
	100	
discont. orientation adjustment	to −60 (?)	matrix discont. orientation adjustment.

correlations exist between RMR and c, ϕ etc....

Reinterpretation of case histories of bimrock materials may allow a correlation of volumetric proportion of blocks to these values of c, ϕ etc.

ie.

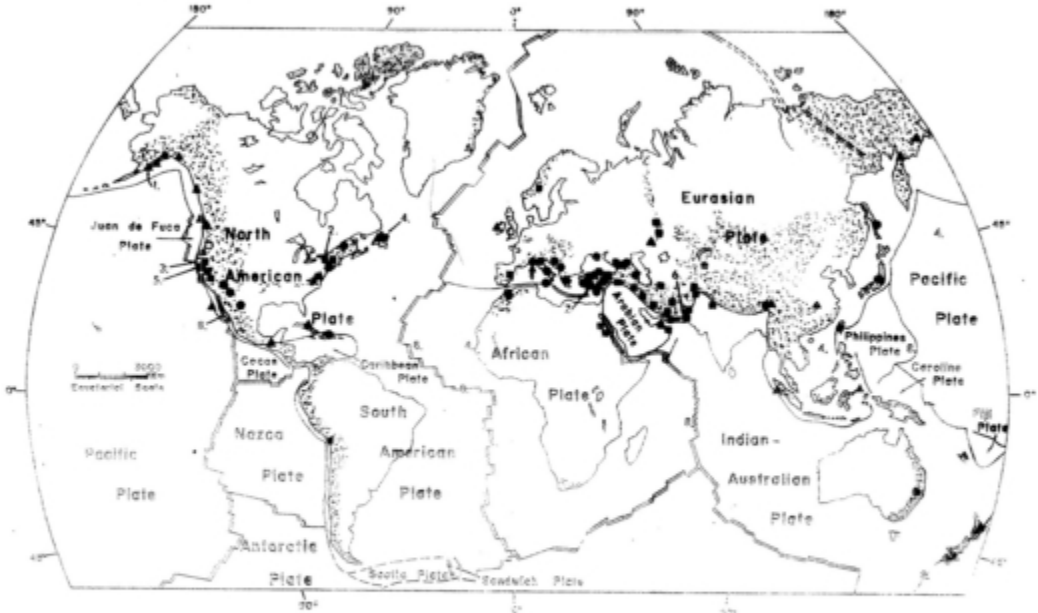


Once a relationship has been established, Test it!!

How? .....

- Review landslides in Franciscan melange, classify the rockmass, determine bimrock RMC rating, predict c, ϕ.
- check prediction against estimated c, ϕ for case history, or do field mapping, back-analysis.

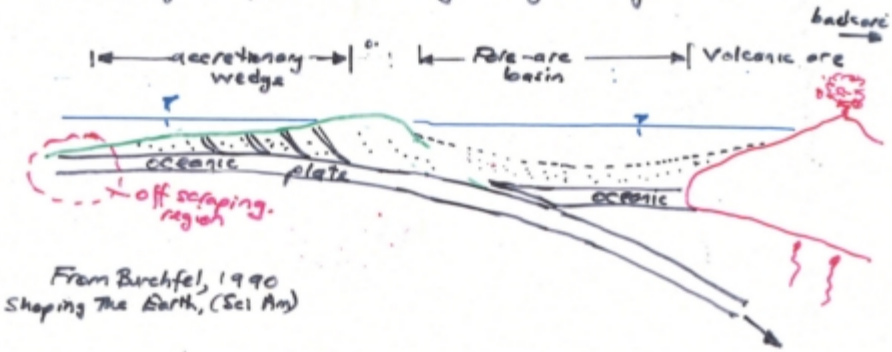
melange formation


Juan de Fuca Plate
North American Plate
Eurasian Plate
Pacific Plate
Philippines Plate
Caroline Plate
Cocos Plate
Caribbean Plate
African Plate
Arabian Plate
Nazca Plate
South American Plate
Indian-Australian Plate
Antarctic Plate
Scotia Plate
Scandinavian Plate

Formation of Mélange

- The occurence of mélange bodies correlates well with the location of suspected convergent crustal plate boundaries. (subduction zones). The details of plate tectonics/mélange formation are complex.....

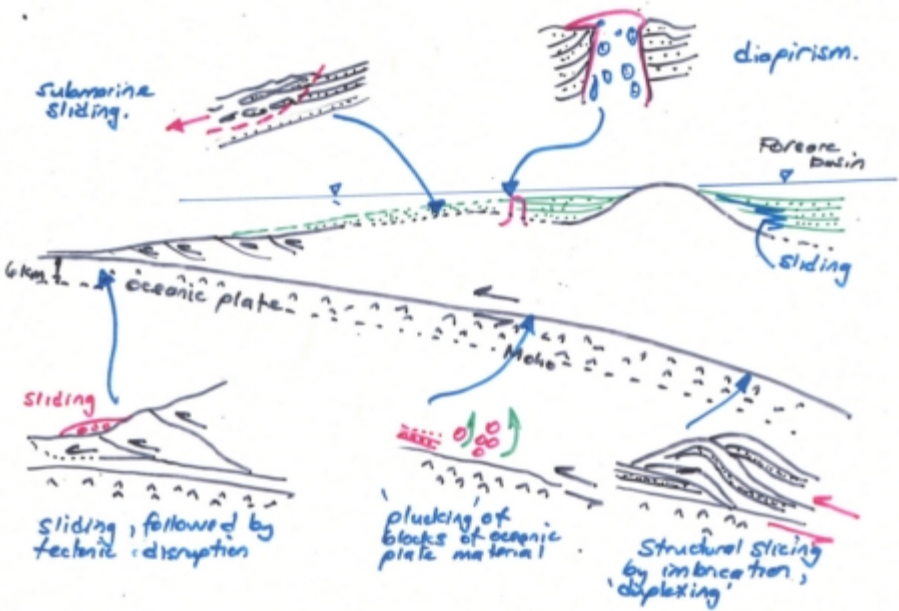
- A convergent plate boundary is generally:



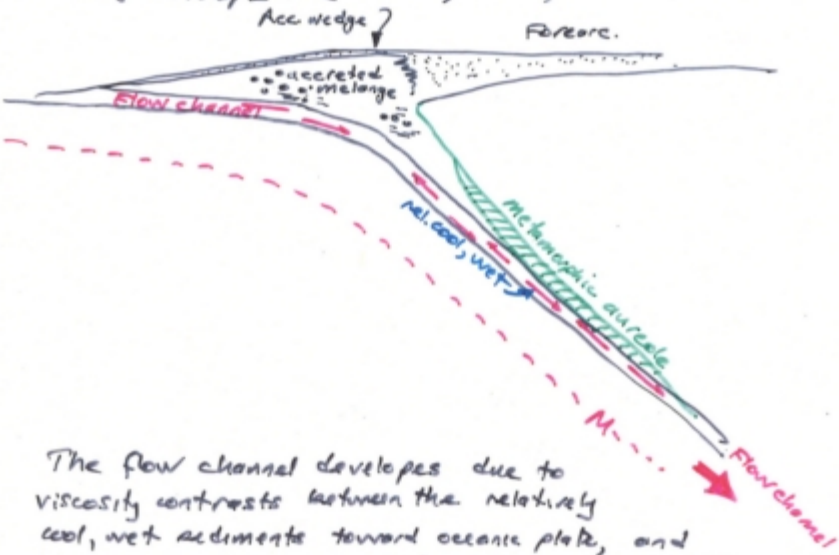
From Burchfel, 1990
Shaping the Earth, (Sci Am)

- Greater than 12 ways of forming mélanges (Labnicka, 1988) — most related to processes in the 'off scraping region' shown above.

Some concepts presented by Cowan, 1985.



- Within the accretionary complex, Flow mélanges may develope (Cloos, 1984)



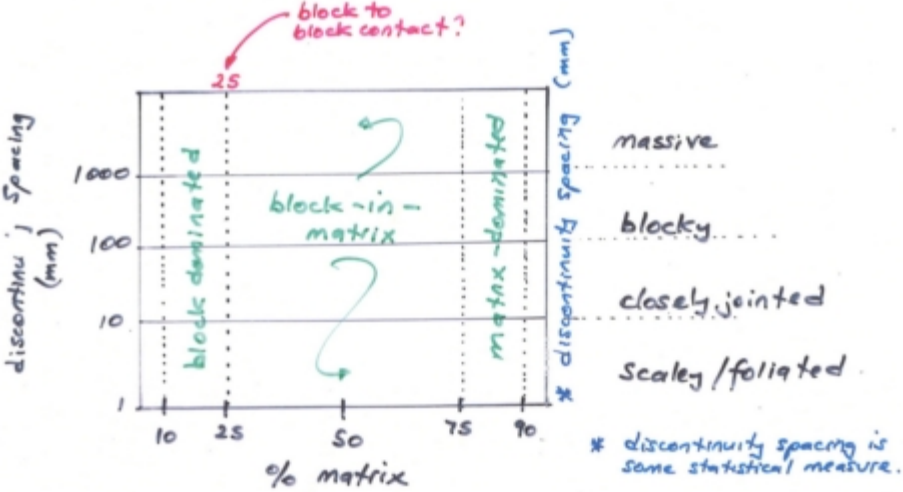
The flow channel develops due to viscosity contrasts between the relatively cool, wet sediments toward oceanic plate, and drier, hotter, more indurated seds. on upper plate side.

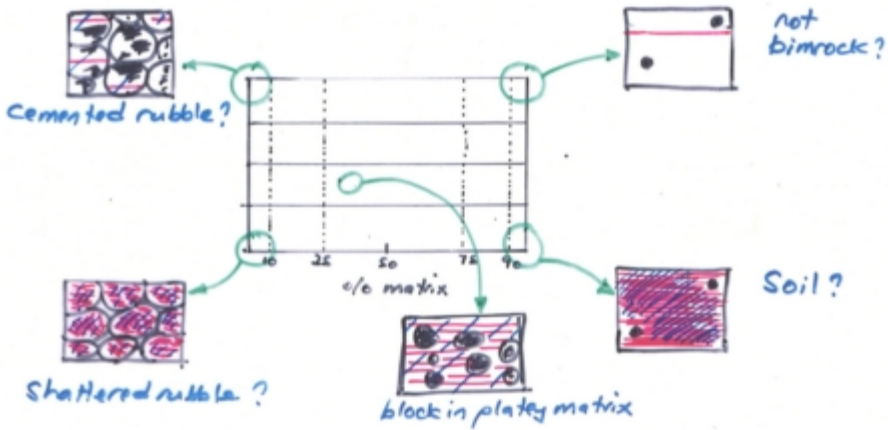
Shear resulting from viscosity contrasts are accomodated by flow in the flow channel — results in 'plucking' of previously metamorphosed sediments.

more on Bimrock classification

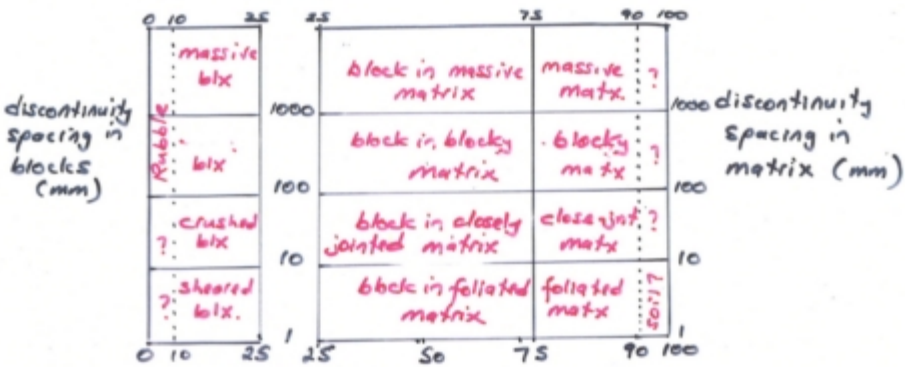
Bimrock Engineering Classification

The three components of a bimrock can be used to classify it:





Fully expanded the classification may appear like:



Advantage of classification:

rocks of diverse lithology & genesis may share the same classification, and may have similar engineering behaviour:-

block in foliated matrix : melange
olistostrome
mylonite

block in closely jointed matrix : melange
volc. breccia
indurated lahar

- The classification scheme allows a broader literature search