Geotechnical and Geological Engineering with Melanges, Fault Rocks and Other Bimrocks

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Aula Máxima Facultad de Minas
Sept 18 -22 2017

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1. Introductions

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Medley

- Mineral exploration prospector (1969~1973) in Canada
- Education:
  - Geological Engineering (U. British Columbia 1978)
  - Geotechnical Engineering (U. Cal Berkeley 1991, 1994)
- Geopractitioner Consultant since 1978
- Principal Consultant at Terraphase Engineering, Oakland
- Investigate geo-failures (landslides, ground movements, etc)
- Specialize in characterization of geological chaos
- Licensed Geologist/Engineer in US, Canada, UK
- Lecture, teach, occasional TV work, **likes words**:

- *Humuhumunukunukuapu'a'a*
- *Llanfairpwllgwyngyllgogerychwyrndrobwllllantysiliogogogoch*
- *Vaðlaheiðarvegavinnuverkfærageymsluskúraútidyralyklakippuhringur*
- *Pablo Diego José Francisco de Paula Juan Nepomuceno María de los Remedios Cipriano de la Santísima Trinidad Ruiz y Picasso*
- *Bimrocks (block-in-matrix rocks)*

https://youtu.be/UWMOLJVHXDs

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Fundamental Questions

1. What is the strength of a geological mixture composed of strong blocks within a weaker matrix??
2. How much stronger do blocks have to be compared to matrix?
3. Does the strength of the blocks matter?
4. Is strength influenced by block geometries; orientations, and so on?
5. Why not just use the strength of the weak matrix and be “conservative”?
6. Does scale matter?

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Fundamental Answers

Some are answered in these Lectures

Some questions have not yet been asked

Some have yet to be answered

Some of you will one day answer some of them???

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The Course Lectures include

CONTENTS

- Introduction to bimrocks.
- Site investigation and characterization of bimrocks.
- Evaluation of geomechanical properties of bimrocks.
- Uncertainties when working with bimrocks.
- Slopes, tunnels and construction in bimrocks.
- Some empirical approaches to working with bimrocks.
- Geopractice experience and case histories.
- Ideas for research.

Lectures are/will be available as PDFs at the Course website:

http://www.geomecanica.org/groupBIM/courseMedley2017.html

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By the end of these Lectures, I hope you will:

- appreciate that there is an ubiquitous geological fabric of strong blocks surrounded by weak matrix
- think twice before drawing straight lines between boring contacts on your cross sections
- not always “design for the weaker soil component” when working with “rock/soil mixtures”
- test lab specimens with included rock fragments when appropriate
- be inspired to develop scarier “What If?” scenarios
- consider that Contractors will have to construct your simple designs in complex geology
- forever remember the most important **Conclusions** of this Lecture…

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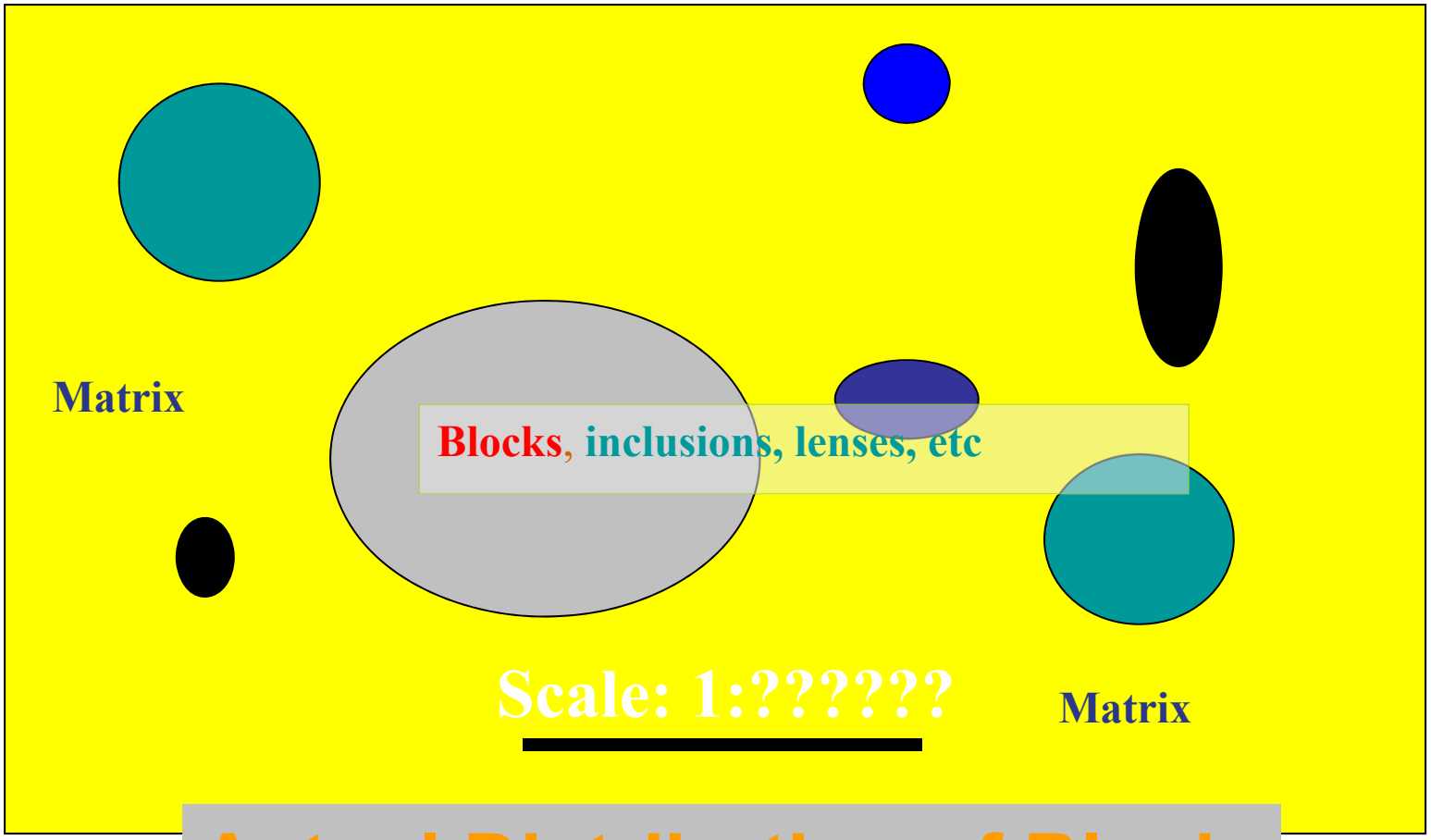
BIG CONCLUSION 1: Remember this picture!!!



Actual Distribution of Blocks

Medley, 2000

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The Hand Game

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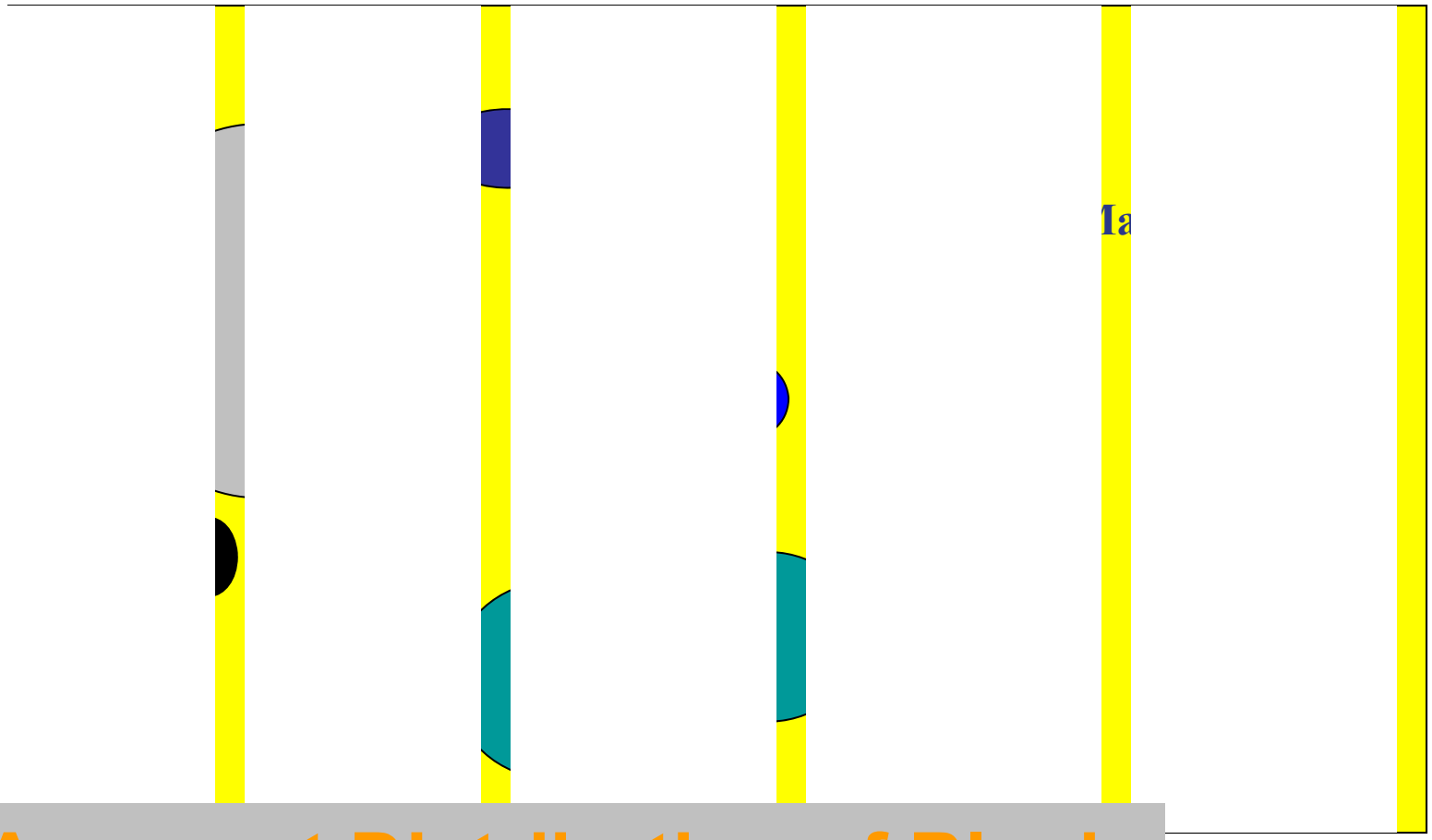
BIG CONCLUSION 2: Remember this picture as well!!!



Apparent Distribution of Blocks

Willis, 2000

engineering

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Particular Thanks for Lecture Content to:

- Dr. Harun Sönmez, Haceteppe Univ., Turkey
- Prof. Resat Ulusay, Haceteppe Univ., Turkey
- Prof. Wulf Schubert, Tech. Univ Graz, Austria
- (late) Prof. Gunter Riedmueller, Univ. Graz, Austria
- 3G (Gruppe Geotechnik Graz, Austria)
- Prof. R. E. Goodman, Univ. California, Berkeley,

Late Prof. Gunter Riedmueller, Technical Univ., Graz and President of 3G

Prof. Richard E. Goodman at outcrop of sheared serpentinite, Fort Point , San Francisco June 2015 (E Medley)

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The important aspects of this Course is summarized here:

Medley, E.W., and Zekkos, D., 2011, ***Geopractitioner approaches to working with antisocial mélanges***, in Wakabayashi, J., and Dilek, Y., eds., *Mélanges: Processes of Formation and Societal Significance*: Geological Society of America Special Paper 480, p. 261–277, doi:10.1130/2011.2480(13).

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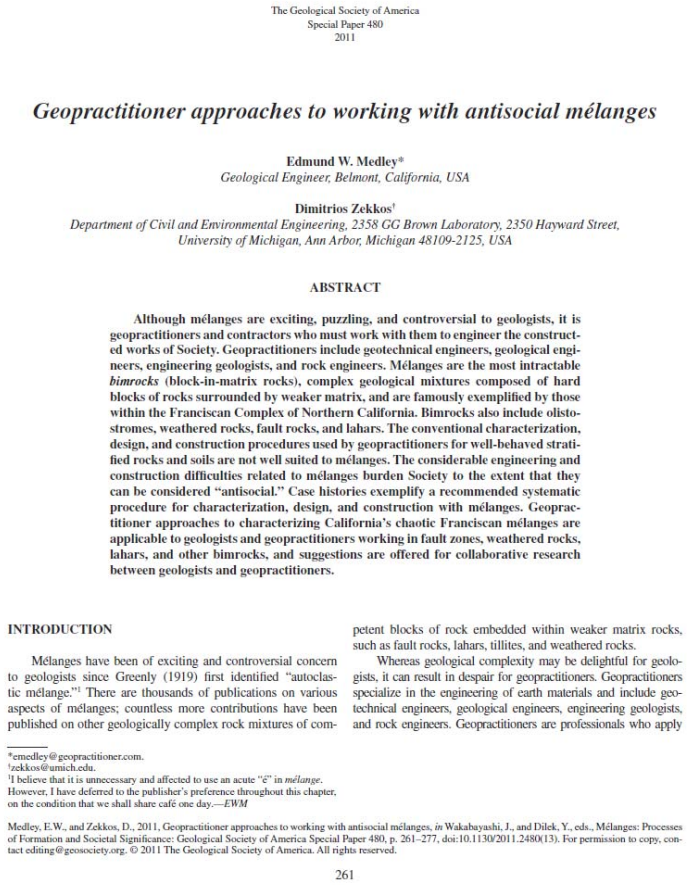

The Geological Society of America
Special Paper 480
2011

Geopractitioner approaches to working with antisocial mélanges

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ABSTRACT

Although mélanges are exciting, puzzling, and controversial to geologists, it is geopractitioners and contractors who must work with them to engineer the constructed works of Society. Geopractitioners include geotechnical engineers, geological engineers, engineering geologists, and rock engineers. Mélanges are the most intractable *bimrocks* (block-in-matrix rocks), complex geological mixtures composed of hard blocks of rocks surrounded by weaker matrix, and are famously exemplified by those within the Franciscan Complex of Northern California. Bimrocks also include olistostromes, weathered rocks, fault rocks, and lahars. The conventional characterization, design, and construction procedures used by geopractitioners for well-behaved stratified rocks and soils are not well suited to mélanges. The considerable engineering and construction difficulties related to mélanges burden Society to the extent that they can be considered "antisocial." Case histories exemplify a recommended systematic procedure for characterization, design, and construction with mélanges. Geopractitioner approaches to characterizing California's chaotic Franciscan mélanges are applicable to geologists and geopractitioners working in fault zones, weathered rocks, lahars, and other bimrocks, and suggestions are offered for collaborative research between geologists and geopractitioners.

INTRODUCTION

Mélanges have been of exciting and controversial concern to geologists since Greenly (1919) first identified "autoclastic mélange."[1] There are thousands of publications on various aspects of mélanges; countless more contributions have been published on other geologically complex rock mixtures of competent blocks of rock embedded within weaker matrix rocks, such as fault rocks, lahars, tillites, and weathered rocks.

Whereas geological complexity may be delightful for geologists, it can result in despair for geopractitioners. Geopractitioners specialize in the engineering of earth materials and include geotechnical engineers, geological engineers, engineering geologists, and rock engineers. Geopractitioners are professionals who apply

*emedley@geopractitioner.com.
†zekkos@umich.edu.
[1]I believe that it is unnecessary and affected to use an acute "é" in *mélange*. However, I have deferred to the publisher's preference throughout this chapter, on the condition that we shall share café one day.—*EWM*

Medley, E.W., and Zekkos, D., 2011, Geopractitioner approaches to working with antisocial mélanges, *in* Wakabayashi, J., and Dilek, Y., eds., Mélanges: Processes of Formation and Societal Significance: Geological Society of America Special Paper 480, p. 261–277, doi:10.1130/2011.2480(13). For permission to copy, contact editing@geosociety.org. © 2011 The Geological Society of America. All rights reserved.

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Two other important References:

Roadifer, J.W., Forrest, M.P., and Lindquist, E.S., Evaluation of Shear Strength of Mélange Foundation at Calaveras Dam, Proceedings of 29th US Society for Dams, Annual Meeting and Conference: "Managing our Water Retention Systems", April 20-24, 2009 - Nashville, Tennessee.

EVALUATION OF SHEAR STRENGTH OF MÉLANGE FOUNDATION AT CALAVERAS DAM

John W. Roadifer[1]
Michael P. Forrest[2]
Eric Lindquist[3]

ABSTRACT

The existing 220-foot-high Calaveras Dam, located within 1,500 feet of the active Calaveras Fault, is a composite hydraulic fill and rolled earthfill dam. The existing dam was found to have inadequate seismic stability and the potential to undergo very large seismic deformations. Alternative studies to remediate or replace the dam determined that a replacement dam should be constructed downstream of the present structure.

The new Calaveras Dam will be a modern earth- and rockfill dam that will be founded on Franciscan mélange in the valley bottom and right abutment. Franciscan mélange, which covers a large part of northern California, is a classic example of a rock formation that exhibits block-in-matrix characteristics. Block-in-matrix rock is comprised of an assemblage of harder stronger rock blocks within a matrix of softer weaker rock. Previous studies have shown that evaluating the shear strength of block-in-matrix rock on the basis of the strength of the weaker matrix alone can be overly conservative. For example, at Scott Dam in northern California, the shear strength of the Franciscan foundation was shown to be a function of the proportion of harder blocks in the rock mass.

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journal homepage: www.elsevier.com/locate/enggeo

An approach to predicting the overall strengths of unwelded bimrocks and bimsoils

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[b] Oakland, CA 94612, USA
[c] General Directorate of Mineral Research and Exploration, Ankara, Turkey

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ABSTRACT

The strength of geological materials is a fundamental property used in the design of civil engineering works; including projects constructed in complex geological mixtures or fragmented rocks such as mélanges, fault rocks, coarse pyroclastic rocks, breccias and sheared serpentines. These and other, often chaotic, mechanically and/or spatially heterogeneous rock masses are composed of relatively strong rock blocks surrounded by weaker matrix rocks. These common rock mixtures, known as bimrocks (block-in-matrix-rocks) or bimsoils (when the matrix material is soil-like) are very difficult to evaluate. It is almost impossible to recover high quality, undisturbed drill core samples or to prepare laboratory specimens perform laboratory studies and evaluate geomechanical parameters such as cohesion, internal friction angle and uniaxial compressive strength from these complex mixtures. There is sparse literature describing empirical and laboratory studies on strength of bimrocks. Hence, this study was devised to develop a preliminary Bim strength criterion, a generalized conceptual empirical approach for predicting the overall strength of unwelded bimrocks and bimsoils. The approach considered fundamental rules of rock and soil mechanics and the reported mechanical behavior of bimrocks as a function of volumetric

Roadifer, J.W., Forrest, M.P., and Lindquist, E.S. 2009. , *" Evaluation of Shear Strength of Mélange Foundation at Calaveras Dam",* Proceedings of 29th US Society for Dams, Annual Meeting and Conference: "Managing our Water Retention Systems", April 20-24, 2009 - Nashville, Tennessee.

A. Kalender, H. Sonmez, E.Medley, C. Tunusluoglu , K.E. Kasapoglu, 2014 , *"An approach to predicting the overall strengths of unwelded bimrocks and bimsoils*", Engineering Geology 183 (2014) 65–79.

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Some References (Medley & Zekkos, 2011 has comprehensive list)

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Medley, E., 2008; *Engineering the Geological Chaos of Franciscan and Other Bimrocks*, Proc. Session 12: Melanges, Mixed Materials and Chaotic Rocks, 42nd U.S. Rock Mechanics Symposium and 2nd U.S.-Canada Rock Mechanics Symposium, San Francisco, July 2008 (Also: June 28 2008 Field Trip Guide for an informal tour of Franciscan complex melanges in the San Francisco Bay Area)

Medley, E. and E.S. Lindquist, 1995; *The engineering significance of the scale-independence of some Franciscan melanges in California USA*, Proceedings, 35th U.S. Rock Mechanics Conference, Lake Tahoe, California, June 1995.

Medley, E. and P. Sanz Rehermann, 2004; *Characterization of Bimrocks (Rock/Soil Mixtures) with Application to Slope Stability Problems*, Proceedings of Eurock 2004 and 53rd Geomechanics Colloquium, Salzburg, Austria, October 2004

Wakabayashi, J. and E. Medley, 2004; *Geological Characterization of Melanges for Practitioners*; Felsbau Rock and Soil Engineering-Journal for Engineering Geology, Geomechanics and Tunneling, vol. 22, No. 5, September 2004.

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MANY References are/will be uploaded to the course website.

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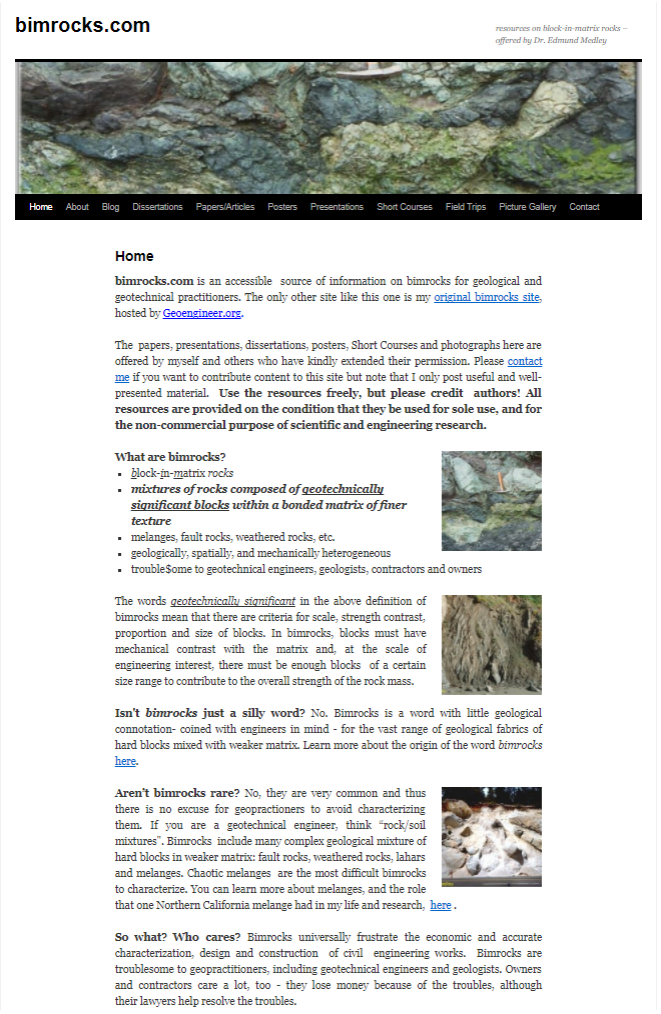
Much information available here

bimrocks.com



bimrocks.com

resources on block-in-matrix rocks – offered by Dr. Edmund Medley

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Home

bimrocks.com is an accessible source of information on bimrocks for geological and geotechnical practitioners. The only other site like this one is my original bimrocks site, hosted by Geoengineer.org.

The papers, presentations, dissertations, posters, Short Courses and photographs here are offered by myself and others who have kindly extended their permission. Please contact me if you want to contribute content to this site but note that I only post useful and well-presented material. **Use the resources freely, but please credit authors! All resources are provided on the condition that they be used for sole use, and for the non-commercial purpose of scientific and engineering research.**

What are bimrocks?

- *block-in-matrix rocks*
- ***mixtures of rocks composed of geotechnically significant blocks within a bonded matrix of finer texture***
- melanges, fault rocks, weathered rocks, etc.
- geologically, spatially, and mechanically heterogeneous
- trouble$ome to geotechnical engineers, geologists, contractors and owners

The words *geotechnically significant* in the above definition of bimrocks mean that there are criteria for scale, strength contrast, proportion and size of blocks. In bimrocks, blocks must have mechanical contrast with the matrix and, at the scale of engineering interest, there must be enough blocks of a certain size range to contribute to the overall strength of the rock mass.

Isn't *bimrocks* just a silly word? No. Bimrocks is a word with little geological connotation- coined with engineers in mind - for the vast range of geological fabrics of hard blocks mixed with weaker matrix. Learn more about the origin of the word *bimrocks* here.

Aren't bimrocks rare? No, they are very common and thus there is no excuse for geopractioners to avoid characterizing them. If you are a geotechnical engineer, think "rock/soil mixtures". Bimrocks include many complex geological mixture of hard blocks in weaker matrix: fault rocks, weathered rocks, lahars and melanges. Chaotic melanges are the most difficult bimrocks to characterize. You can learn more about melanges, and the role that one Northern California melange had in my life and research, here .

So what? Who cares? Bimrocks universally frustrate the economic and accurate characterization, design and construction of civil engineering works. Bimrocks are troublesome to geopractitioners, including geotechnical engineers and geologists. Owners and contractors care a lot, too - they lose money because of the troubles, although their lawyers help resolve the troubles.

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Extra: some personal history…

How Medley got to be so confused/enchanted by geological complexity….

Read the story here:
http://edmedley.com/blog/2009/02/07/on-first-encountering-melange/

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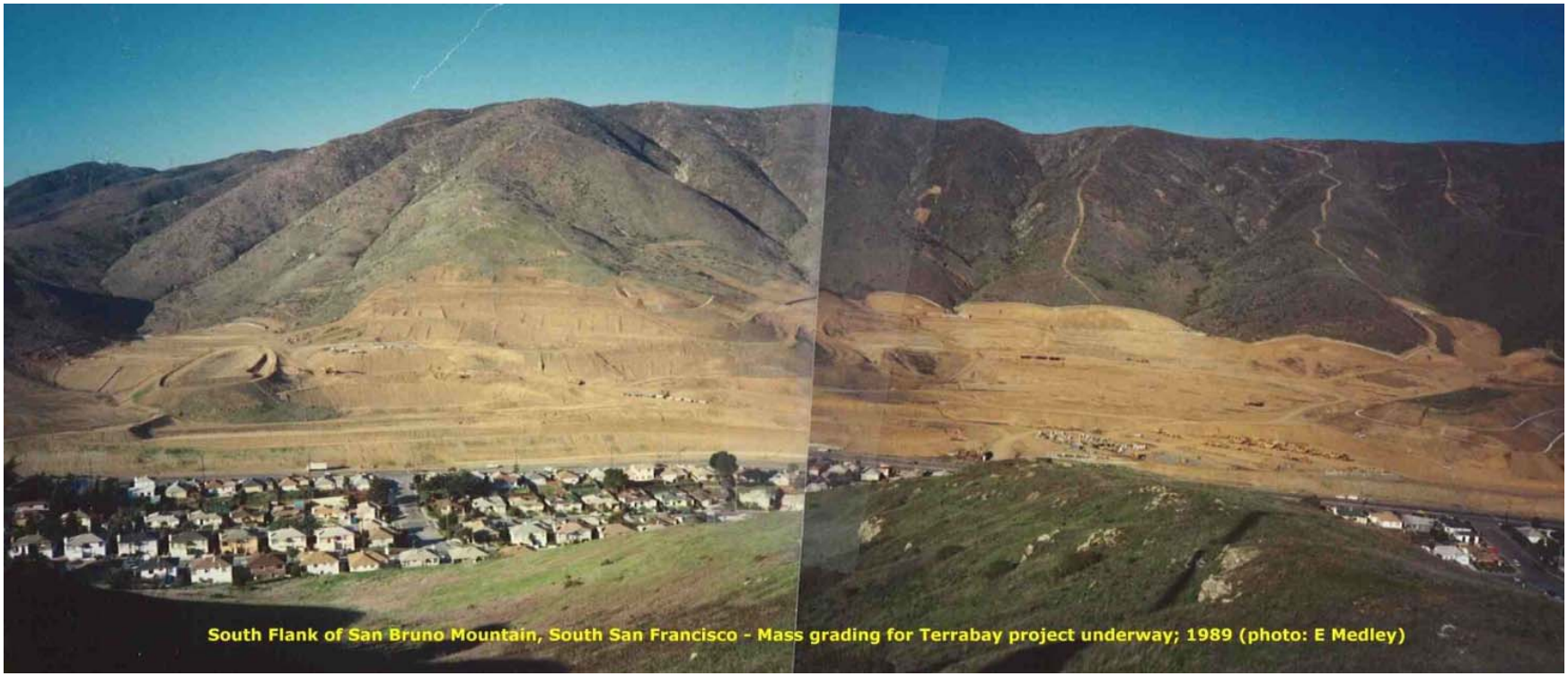
1989: *Encountering **melange at San Bruno Mt., San Francisco



Terrabay Project:- San Bruno Mt., So. San Francisco, 1989

WORDS:

**encountering*: unexpectedly experience or, to be faced with something difficult or hostile

***melange**: (aka mélange), geological chaos, a bimrock (to be discussed…)

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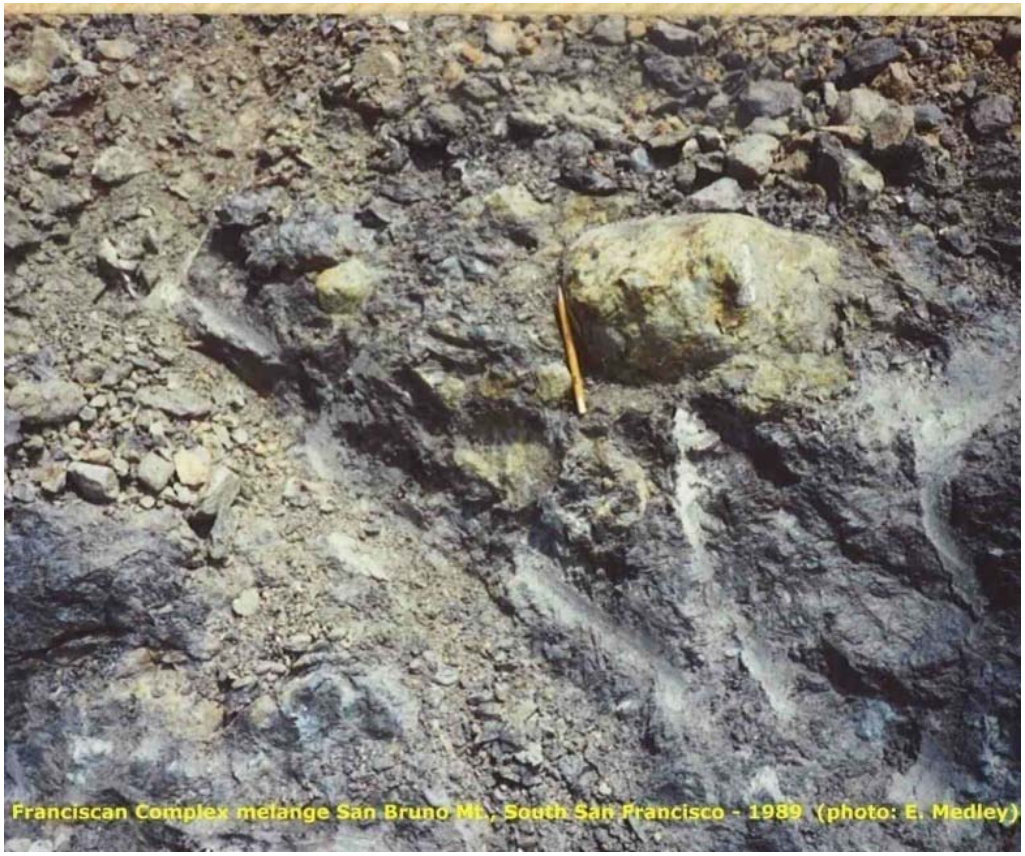
Upon first encountering melange: exasperation/puzzlement/confusion:



Franciscan Complex melange, at Terrabay Project

Landslide in colluvium composed of melange

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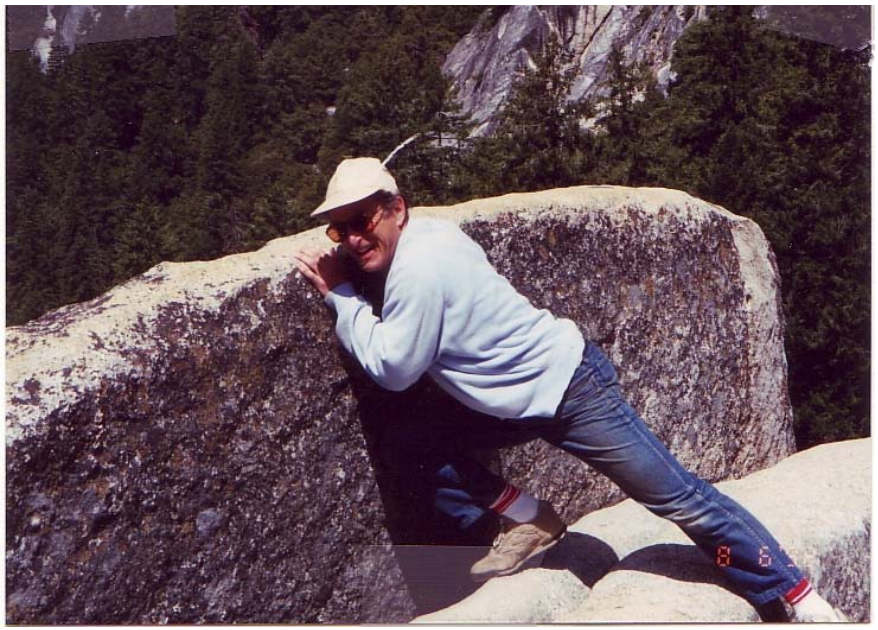
encountering MS/PhD, 1990-1994



Prof. Richard Goodman: and the Force was with me when he asked me to work with he and Eric Lindquist on….

.. a fundamental rock engineering problem at Scott Dam, on Eel River, N. California; founded on Franciscan Complex melange

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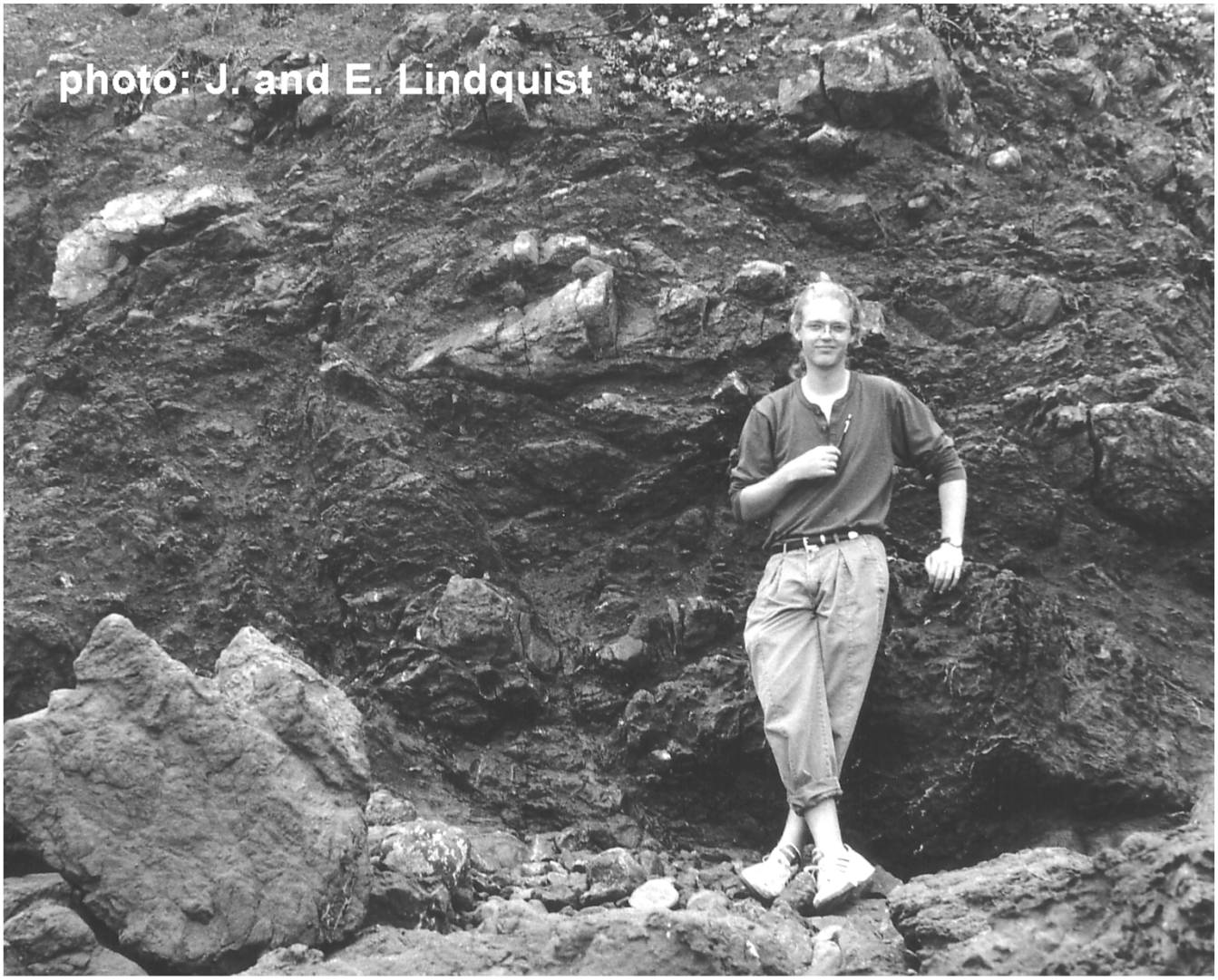
encountering brilliance…



Eric Lindquist near Mendocino, California about 1992

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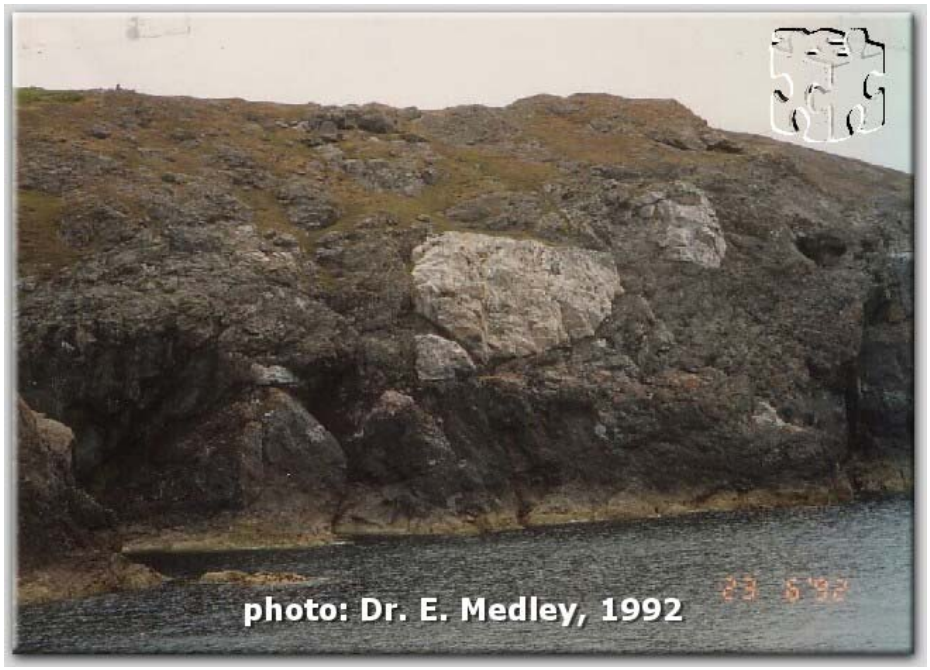
cosmic melange/Medley connections

1. melange = mélange French for “mixture; “medley” = English word for mixture
2. “mélange” first used for chaotic rock at North Wales by E. Greenley, 1919. Medley is Welsh.
3. Medley went back to school in 1990 because of melange; and ended up researching it!



Gwna Melange, Tryn-y-moel, Lleyn Peninsula, Wales

Franciscan Complex melange, Caspar Headland, near Mendocino, California

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Outline of Course Contents

- Introduction by Prof. Castro, Prof. Suarez and Dr. Medley
- Overview of BIMS Group work on complex geologic materials
- Overview of geologically complex rocks and soils (bimrocks/bimsoils)
- Site and laboratory characterization of bimrocks
- Geomechanical properties and their Uncertainties
- Field Trip (Wednesday)
- Slopes, tunnels and construction
- Empirical approaches
- Geopractice experience
- Ideas for research
- Summary
- Questions and Answers

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