6IAS Workshop on 3D Modelling

Welcome

Angela Alfonso Rodrigues (Monash)
Lachlan Grose (Monash)
Leo Portes (UWA)
Mark Jessell (UWA)
Mark Lindsay (CSIRO)
Michel Nzikou (UWA)
Vitaliy Ogarko (UWA)
Guillaume Pirot (UWA)
Louie Zhang (CSIRO)

THE UNIVERSITY OF WESTERN AUSTRALIA

We acknowledge the traditional owners and custodians of this Walyalup land, the Wadjuk people of Nyungar nation and pay our respects to Elders both past and present for they hold the knowledge, the language, the traditions and culture of their people and their land

Day 1 Sat 22nd July		
Part 1: Principles of 3D geological modelling		
9:00 – 9:30		Registration and coffee
9:30 – 10:00	Mark Jessell (UWA)	Intro & History of 3D modelling
10:00 – 10:20	Mark Jessell	Different 3D model Use Cases- Outcrop Models, Geophysical Inversions, 3D geological models (Petroleum, Minerals, Hydro)
10:20 – 10:40	Break	
10:40 – 11:00	Mark Lindsay (CSIRO)	Visualisation and interaction methods for 3D phenomena
11:00 – 11:20	Mark Jessell	What data and conceptual constraints to use.
11:20 – 12:00	Mark Jessell/ Mark Lindsay	Introduction to the Loop3D project
12:00 – 12:30	All	Discussion – troubleshooting, demo setup and suggestions for case studies
12:30 – 2:00	Lunch	
Part 2: Knowledge and models from maps – hands-on		
2:00 - 2:45	Lachlan Grose (Monash)	3D Interpolation Schemes: Explicit vs Implicit Modelling and other approaches
2:45 – 3:00	All	Setup / break
3:00 – 4:30	Mark Jessell	Extracting knowledge from maps with demo
4:30 – 4:45	Mark Lindsay	Alternate uses for map2loop/model outputs (Fe ore example)
4:45 – 5:00	All	Summary and discussion

Agenda

Day 2 Sun 23rd July		
Part 3: Advanced 3D modelling Methods		
9:00 – 9:30	Angela Alfonso Rodrigues (Monash)	Kalgoorlie case study
9:30 – 10:15	Mark Jessell / Leo Portes (UWA)	Exploring 3D geological possibility with the Noddyverse
10:15 – 11:00	Michel Nzikou (UWA)	QGIS Plugins
11:00 – 11:30	Break	
11:30 – 12:00	Vitaliy Ogarko (UWA)	3D geophysics using Tomofast-x
12:00 – 12:30	Louie Zhang (CSIRO)	Spatial random forests
12:30 – 2:00	All	Summary and discussion
12:30 – 2:00	Lunch	
Part 4: Day Two demonstrations and discussion		
2:00 – 3:00	Mark Lindsay	Manual noddy and 3D geophysical interpretation support
3:00 – 4:00	Leo Portes	Noddyverse demonstration
4:00 – 5:00	Guillaume Pirot (UWA)	Loop 'Flow'
5:00 +	All	Summary and discussion

github.com/Loop3D/6IAS

Agenda

History of 3D geological modelling

"We've got enough rocks—what we need is better intelligence."

Lee Lorenz, New Yorker Magazine

30,000 BCE Early 2D & 3D Models

Water bird from the Hohle Fels Cave in southwestern Germany

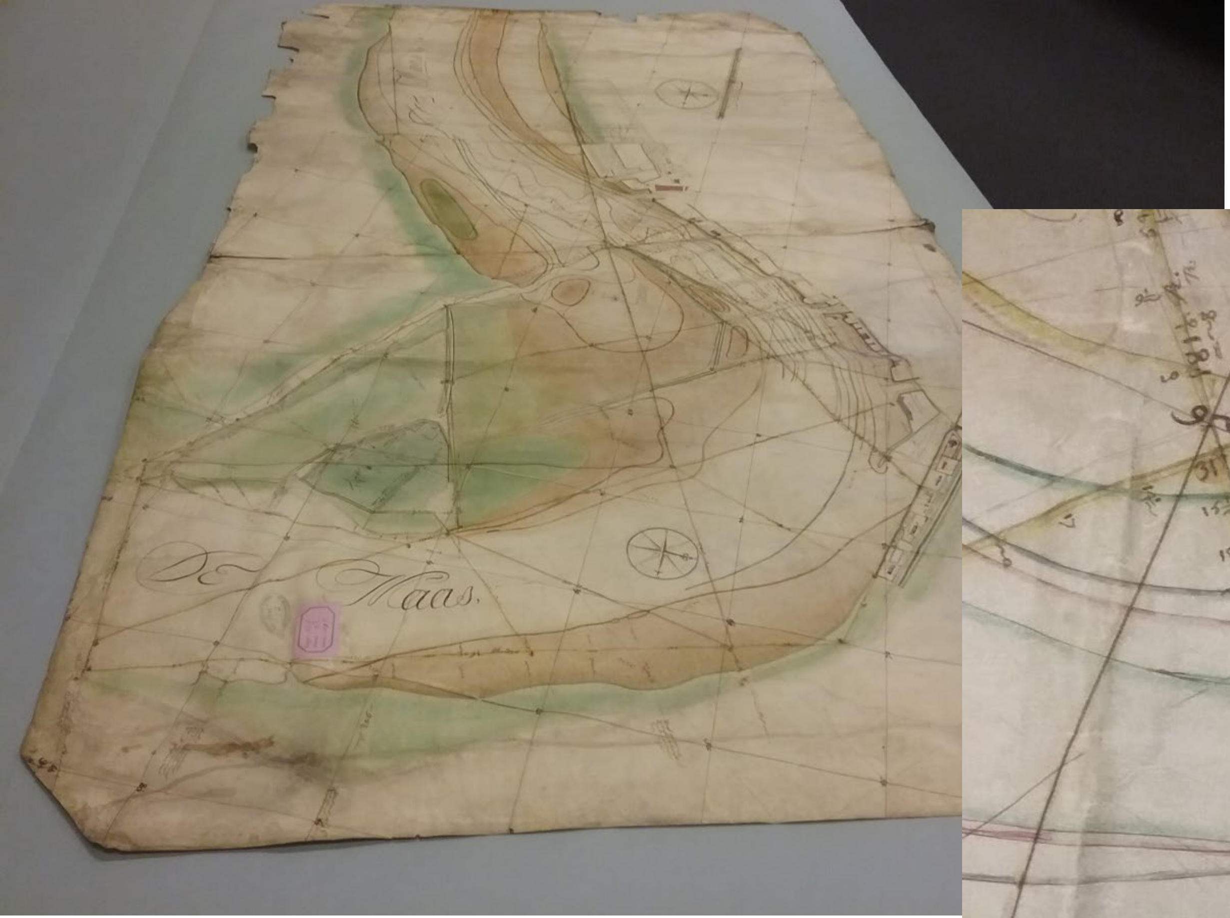
Fish from Nawarla Gabarnmang, Northern Territory

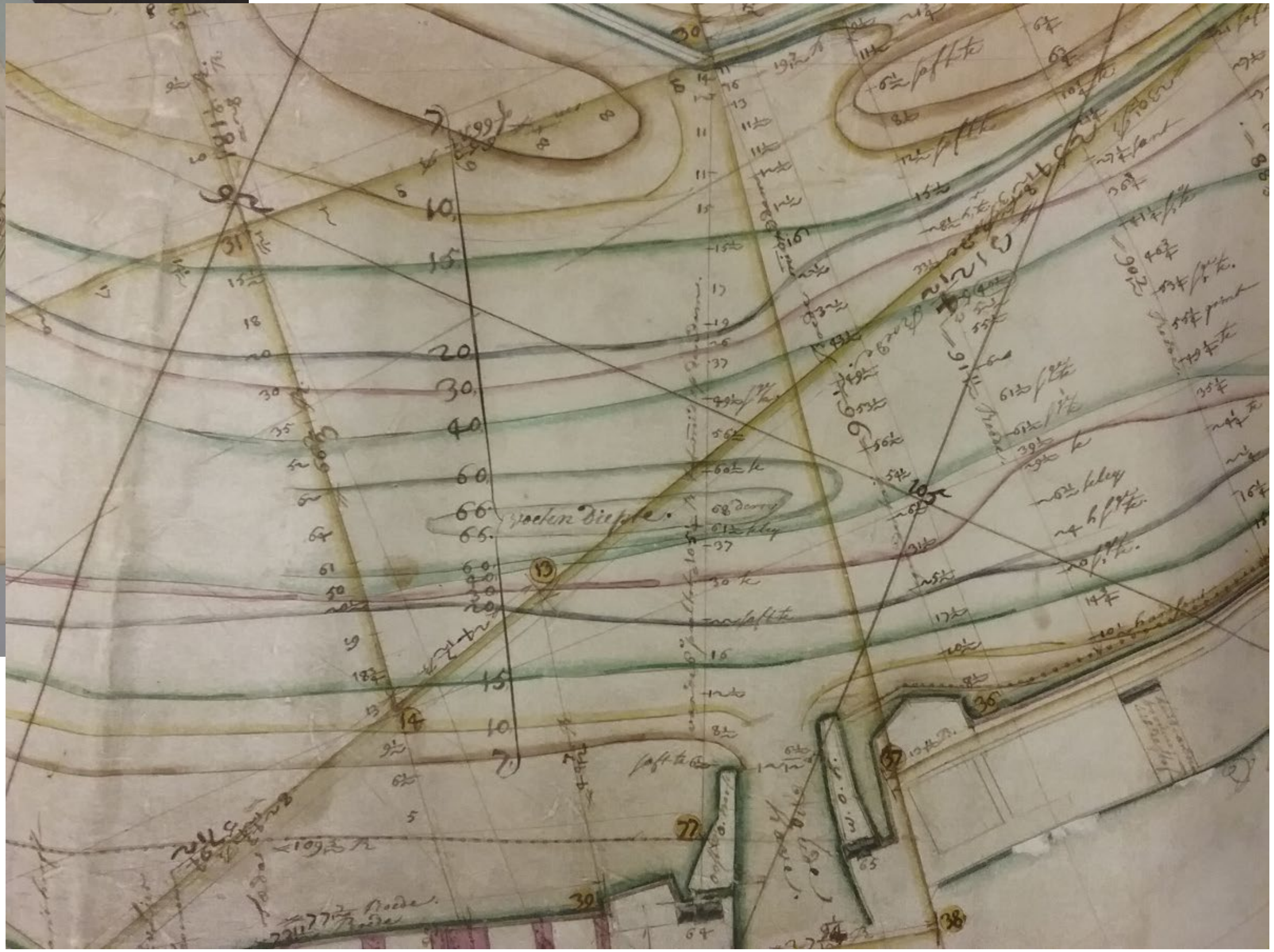
Photo: Jean-Jacques Delannoy

Scribe-of-the-Tomb Amennakhte, son of Ipuy, 1160 BCE

Map of sandstone quarry, gold mine and settlement at Bi'r Umm Fawakhir
Scribe-of-the-Tomb Amennakhte, son of Ipuy, 1160 BC

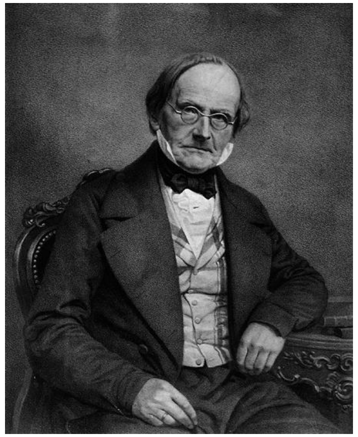
Pierre Ancelin, 1697





River Maas Isobaths

Johann von Charpentier, 1778

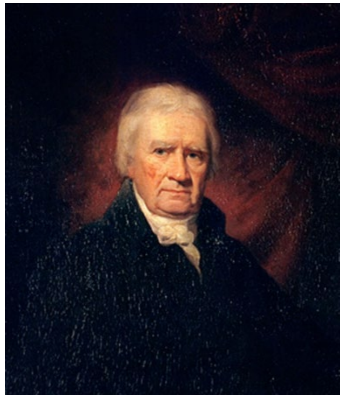


Johann Friedrich Wilhelm von Charpentier

Abraham Gottlob Werner

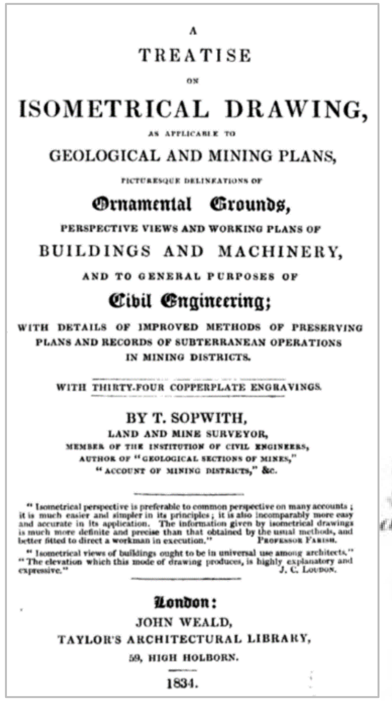
Johann Friedrich Wilhelm von Charpentier, 1778, Lithological map of Saxony (using colour scheme of Abraham Gottlob Werner)

John Clerk of Eldin, 1787



Engraving by D.B. Pyet based on a drawing made in 1787 by John Clerk of Eldin of the Unconformity at Jedburgh, Borders, forming Plate III in Volume I of James Hutton's Theory of the Earth, 1795

Thomas Sopwith 1834
Isometric drawings



A

TREATISE

ON

ISOMETRICAL DRAWING,

AS APPLICABLE TO

GEOLOGICAL AND MINING PLANS,

PICTURESQUE DELINEATIONS OF

Ornamental Grounds,

PERSPECTIVE VIEWS AND WORKING PLANS OF

BUILDINGS AND MACHINERY,

AND TO GENERAL PURPOSES OF

Civil Engineering;

WITH DETAILS OF IMPROVED METHODS OF PRESERVING PLANS AND RECORDS OF SUBTERRANEAN OPERATIONS IN MINING DISTRICTS.

WITH THIRTY-FOUR COPPERPLATE ENGRAVINGS.

BY T. SOPWITH,

LAND AND MINE SURVEYOR,

MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS,

AUTHOR OF "GEOLOGICAL SECTIONS OF MINES,"

"ACCOUNT OF MINING DISTRICTS," &c.

"Isometrical perspective is preferable to common perspective on many accounts; it is much easier and simpler in its principles; it is also incomparably more easy and accurate in its application. The information given by isometrical drawings is much more definite and precise than that obtained by the usual methods, and better fitted to direct a workman in execution." PROFESSOR FARISH.

"Isometrical views of buildings ought to be in universal use among architects." "The elevation which this mode of drawing produces, is highly explanatory and expressive." J. C. LOUDON.

London:

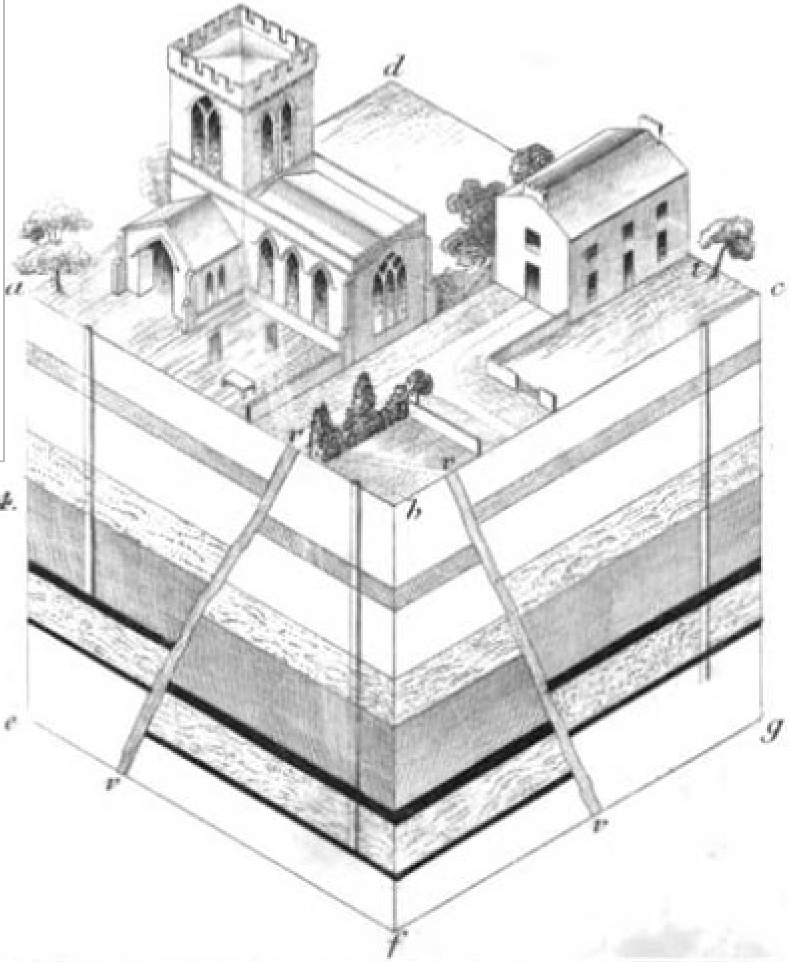
JOHN WEALD,

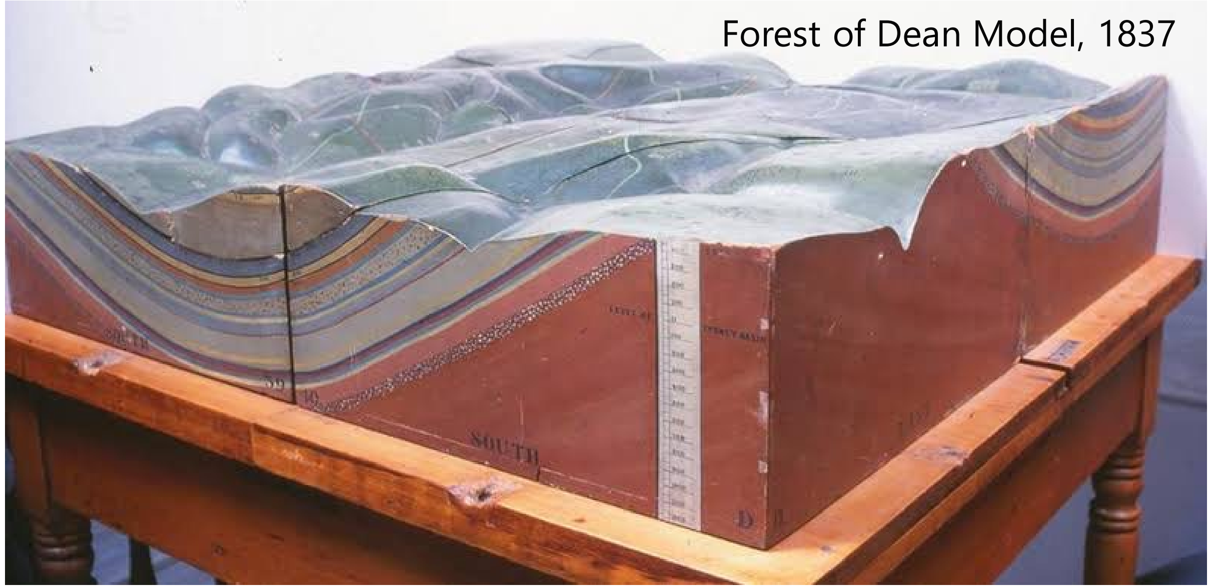
TAYLOR'S ARCHITECTURAL LIBRARY,

59, HIGH HOLBORN.

1834.

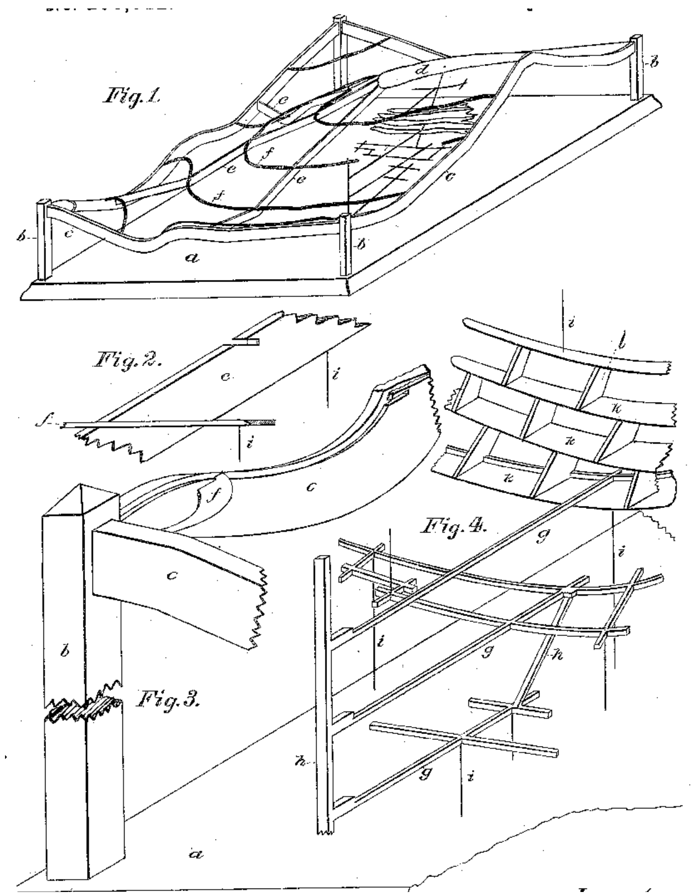
Fig. 4.

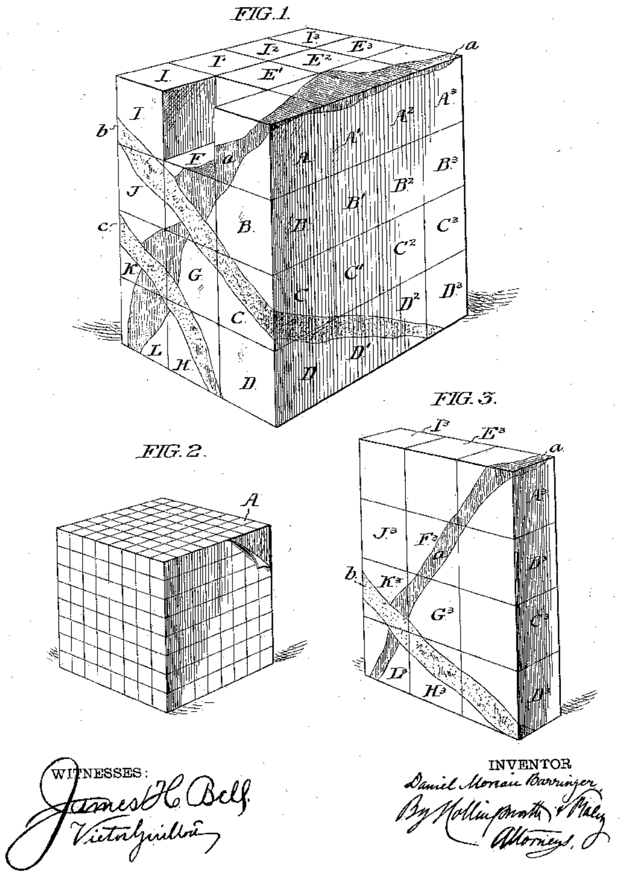




Clarence Anderson, 1884

Daniel Barringer,1892





The special adaptation of my invention is to a mine, of which I am thus enabled to <u>represent</u> clearly the shafts, drifts, or tunnels, stopes, and any other excavations, and also the surface of the country immediately surrounding it.

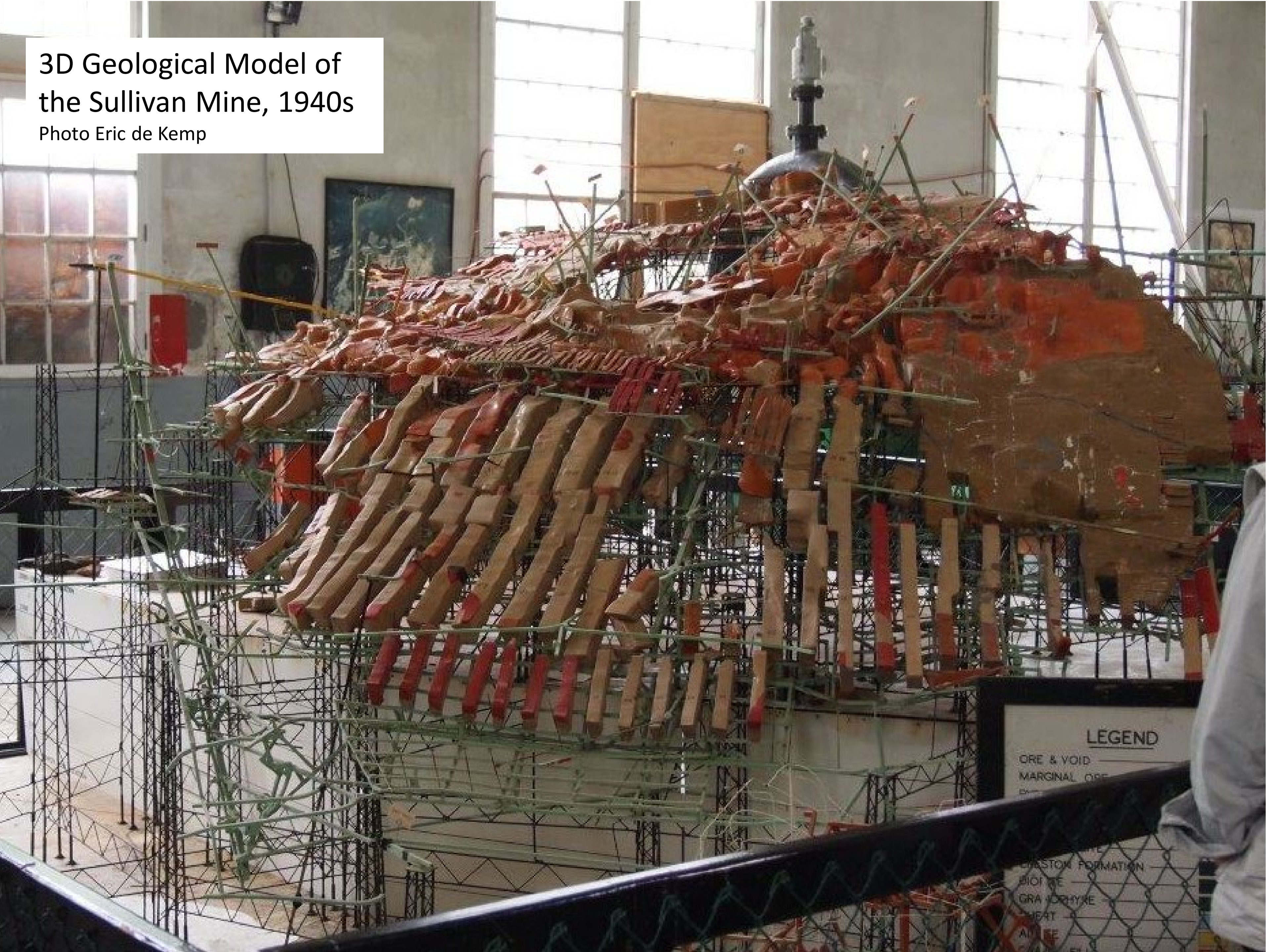
L. Anderson. 1884. Topographical Representation or Model. US Patent 298,812.

...primarily intended for facilitating mining operations by reproducing graphically and upon a uniform scale the geological structure of ore-beds and surrounding strata, so as to <u>exhibit</u> to the practical operator in a highly convenient manner sections upon any of the three coordinate planes and at any desired intervals.

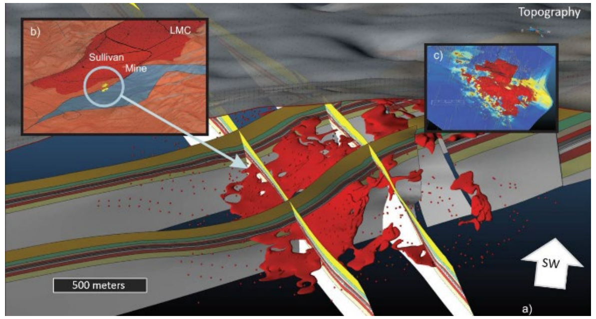
Daniel Moreau Barringer. 1892. Apparatus for Illustrating Geological Formations. US Patent 477,633

1940-1970s

3D Geological Model of the Sullivan Mine, 1940s
Photo Eric de Kemp

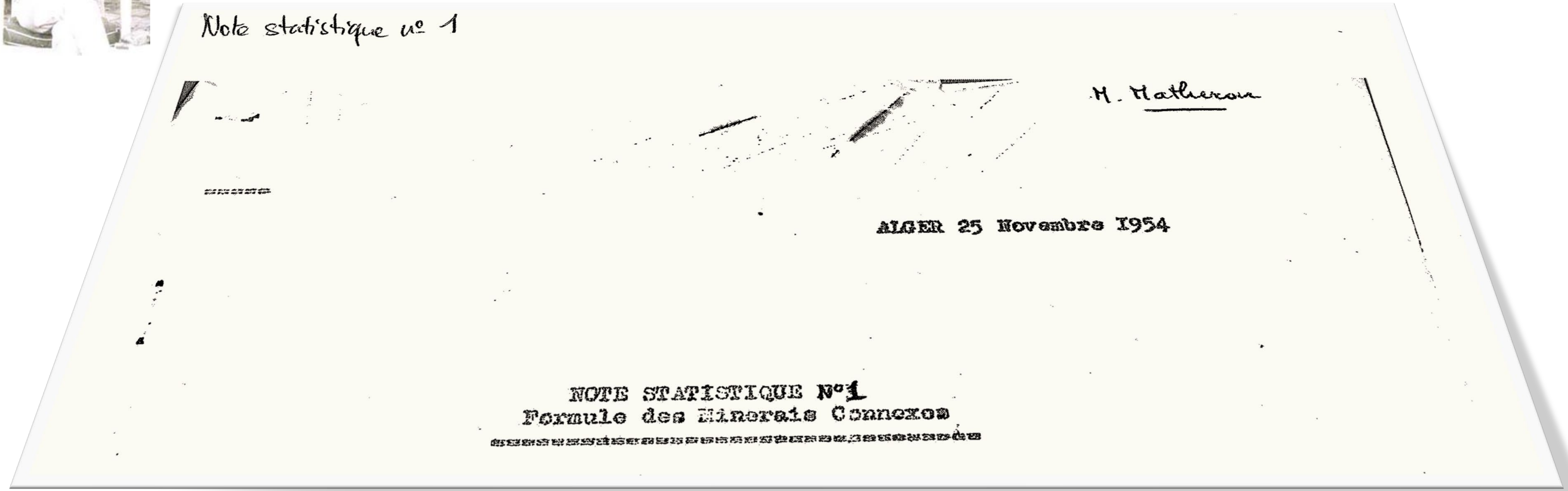


3D Geological Model of the Sullivan Mine, 2010s



de Kemp, E.A., Schetselaar, E.M., Hillier, M.J., Lydon. J.W., Ransom, P.W., Montsion, R., and Joseph, J., 2015. 3D Geological modelling of the Sullivan time horizon, Purcell Anticlinorium and Sullivan Mine, East Kootenay Region, southeastern British Columbia, Geological Survey of Canada, Open File 7838, p. 204-225.

Danie Krige, 1951
Georges Matheron, 1954



Note statistique n° 1

M. Matheron

ALGER 25 Novembre 1954

NOTE STATISTIQUE N°1
Formule des Minerais Connexes

Matheron, G. 1954. *Formule des Minerais Connexes*, *Note Statistique No 1*.

Krige, D.G, A statistical approach to some mine valuations and allied problems at the Witwatersrand, Master's thesis of the University of Witwatersrand, 1951

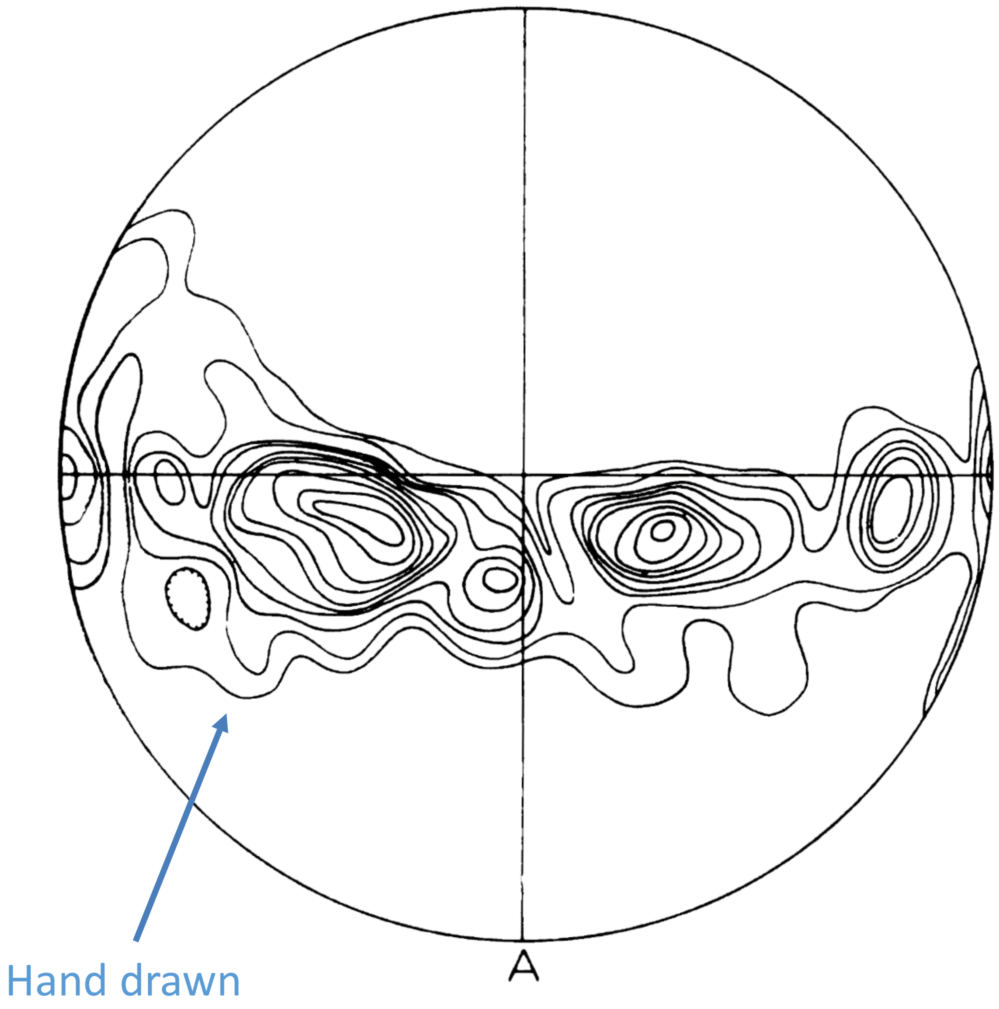
Robinson et al., 1963

Matrix output for sector 1

SECTOR 1

	11	10	9	8	7	6	5	4	3	2	1
1	1	2	12	26	42	200	416	710	1023	715	223
2	3	5	10	14	56	157	284	541	863	632	184
3	5	6	10	26	74	137	247	372	351	232	123
4	5	7	13	40	62	137	295	277	142	100	72
5	5	10	9	33	58	111	183	121	29	16	20
6	4	10	18	40	55	68	76	47	20	7	9
7	3	13	21	39	31	25	29	16	9	2	3
8	5	12	15	25	24	15	14	11	5	0	2
9	5	9	13	18	22	12	2	6	6	1	1
10	6	7	16	21	18	13	5	4	4	3	0
11	6	4	19	22	16	18	11	4	3	4	2
12	5	6	12	18	18	22	17	5	2	3	4
13	4	7	8	15	16	16	14	7	5	2	3
14	2	7	9	15	20	16	9	13	12	2	1
15	2	6	8	7	21	26	18	21	24	14	3
16	2	3	6	4	12	19	25	28	30	33	17
17	2	1	3	6	7	17	28	27	37	46	33
18	3	0	1	3	4	14	21	19	29	46	53
19	6	2	0	1	4	4	6	17	18	34	55
20	5	2	3	0	4	5	4	14	23	51	124
21	8	5	3	1	3	3	8	14	25	79	223
22	7	5	3	3	7	14	19	20	24	64	184
23	3	3	7	13	16	18	15	11	12	40	123
24	3	3	5	12	10	6	4	3	11	34	72
25	0	0	1	1	0	1	2	4	12	21	20
26	0	0	1	0	0	0	1	9	11	8	9
27	0	1	1	0	1	2	5	11	10	6	3
28	0	1	1	0	3	4	6	5	3	5	2
29	1	2	1	1	3	3	4	6	4	2	1
30	1	2	0	1	1	4	6	6	6	2	0
31	2	2	0	0	1	5	6	4	4	3	2
32	2	2	1	1	4	6	3	4	3	3	4
33	1	2	1	1	4	5	4	5	2	3	3
34	1	3	1	1	3	2	6	6	1	2	1
35	0	2	3	4	5	1	6	8	3	1	3
36	0	2	4	5	5	1	14	16	4	2	17
37	0	1	5	3	4	4	24	31	26	27	33
38	0	0	10	9	5	13	56	107	91	55	53
39	0	0	11	42	49	52	125	206	154	65	55
40	0	1	7	47	66	144	288	466	473	261	124

L12 6



Peter Robinson, Robin Robinson and Stephen J. Garland. 1963. Preparation of Beta Diagrams in Structural Geology by a Digital Computer, American Journal of Science, 261, 913-928.

Cole, 1968

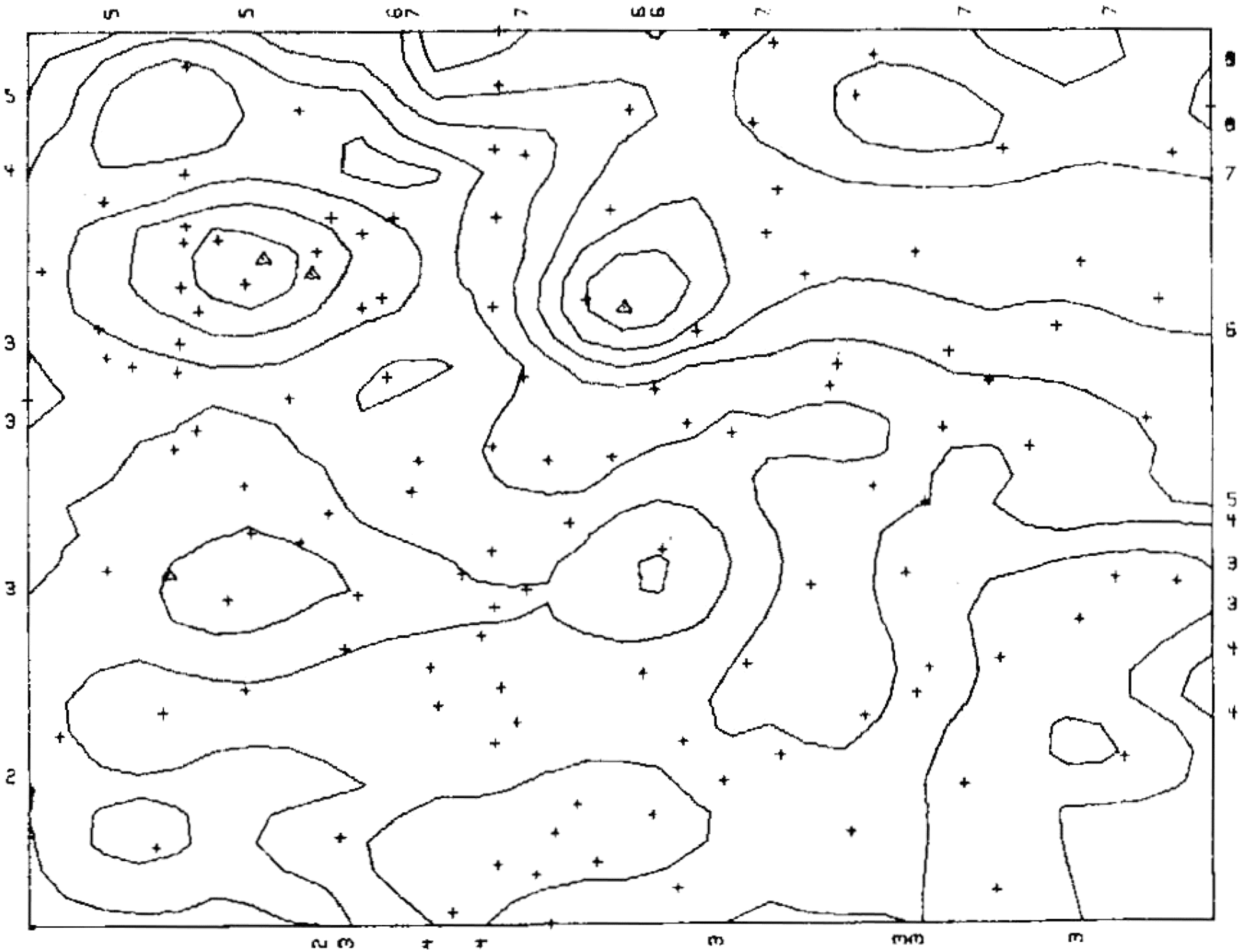
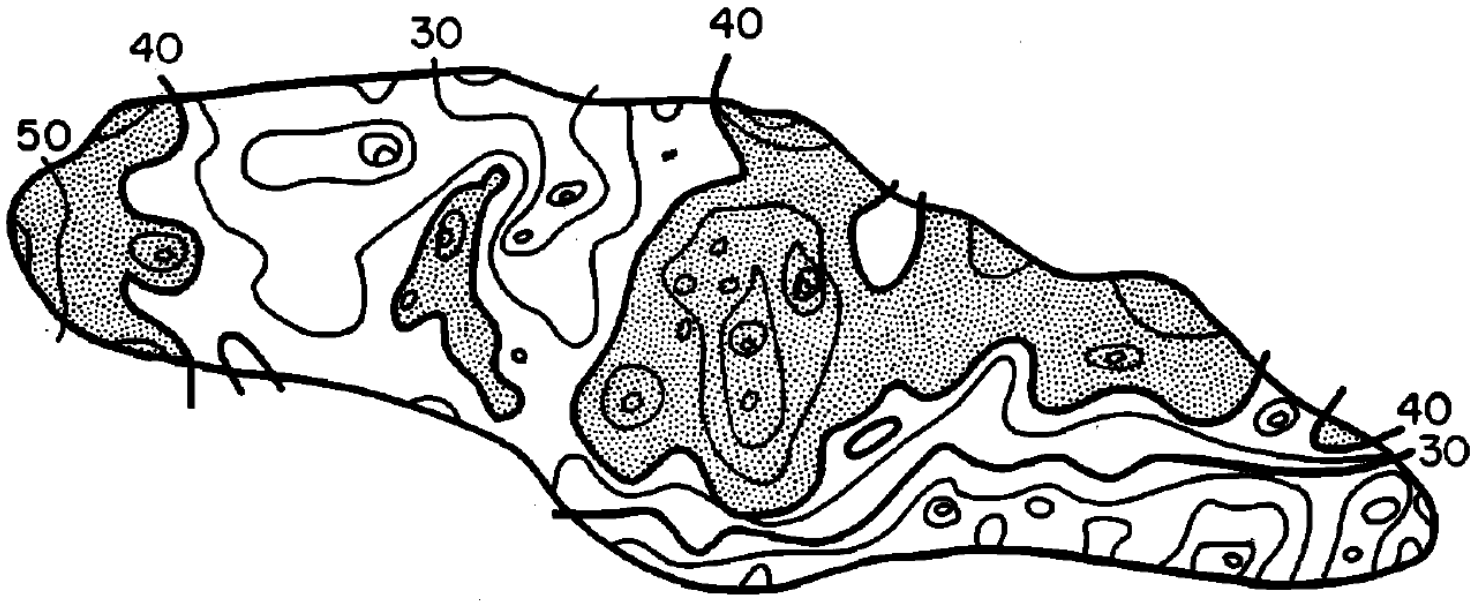


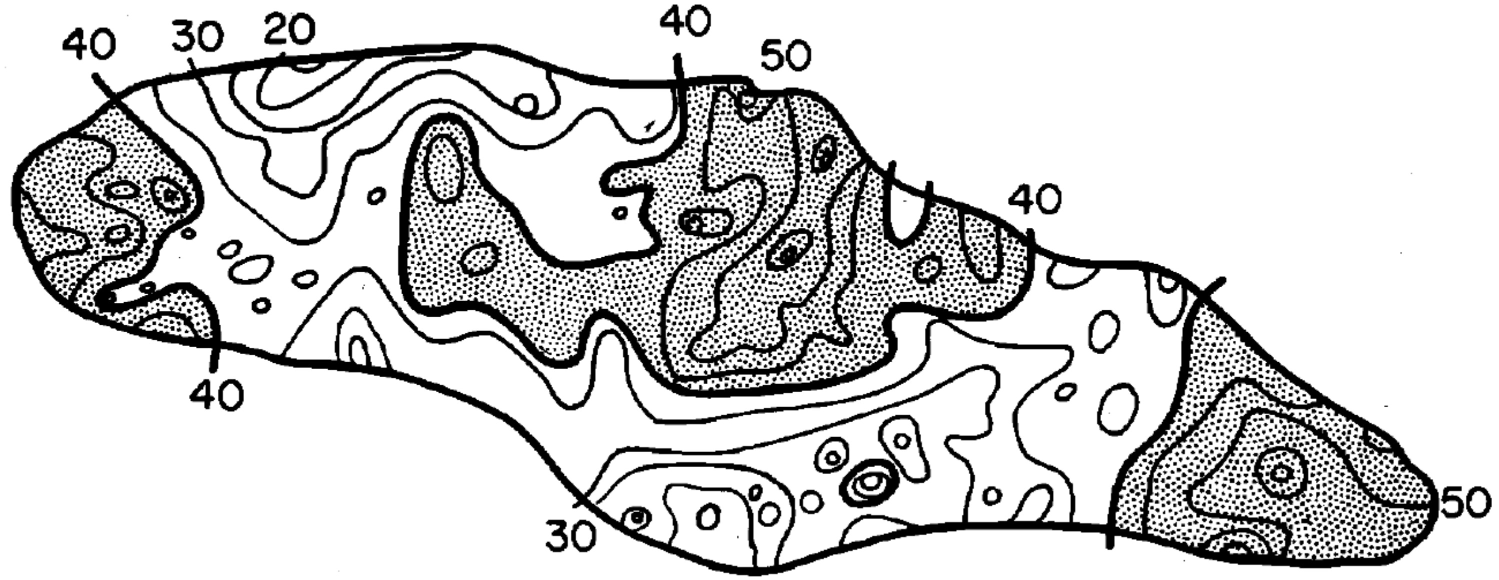
Fig. 2. Iterative fit based on a global linear fit.

A.J. Cole, 1968, Algorithm for the Production of Contour Maps from Scattered Data, Nature, 220, 92-94.

Journel,
1974



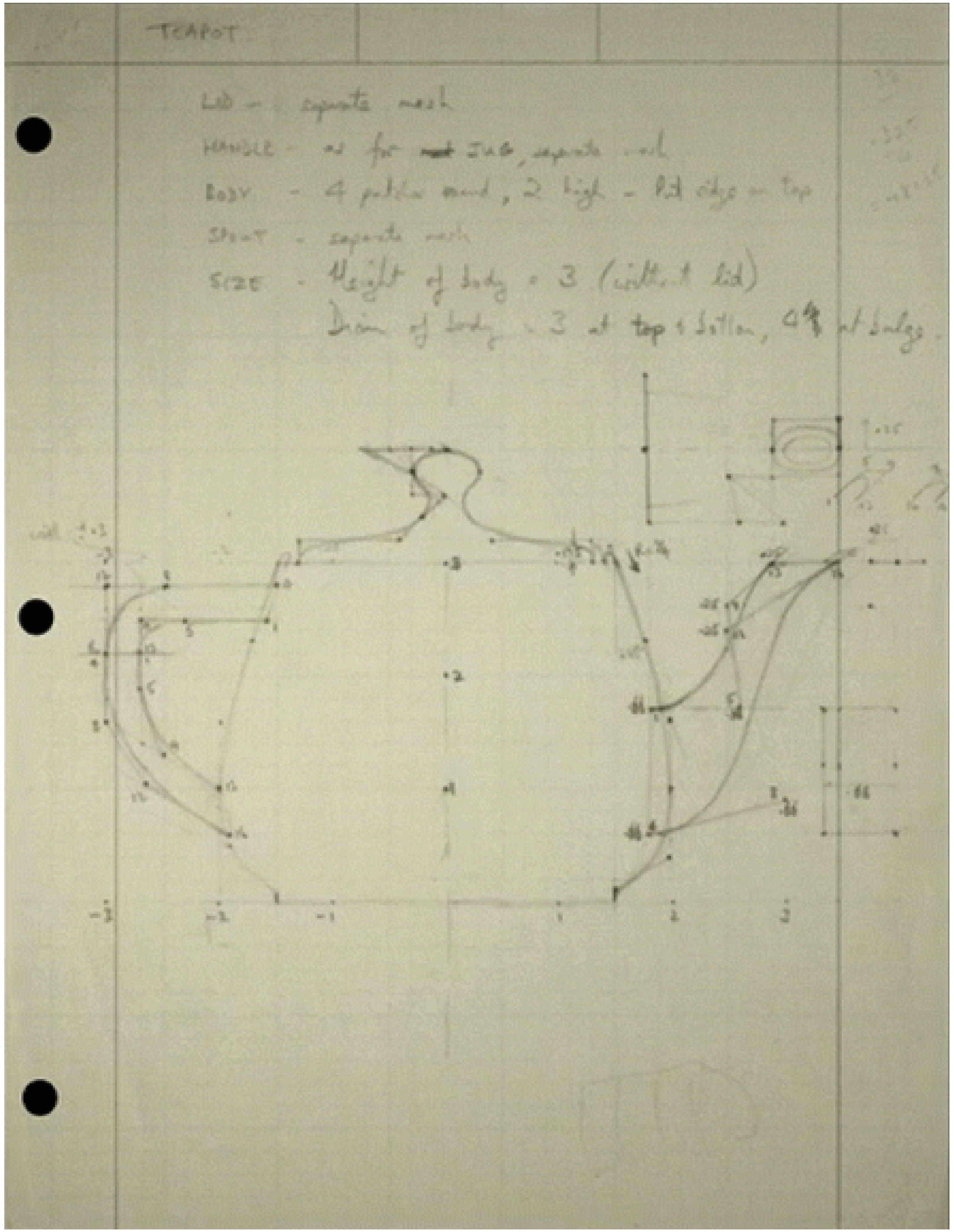
Variant No1

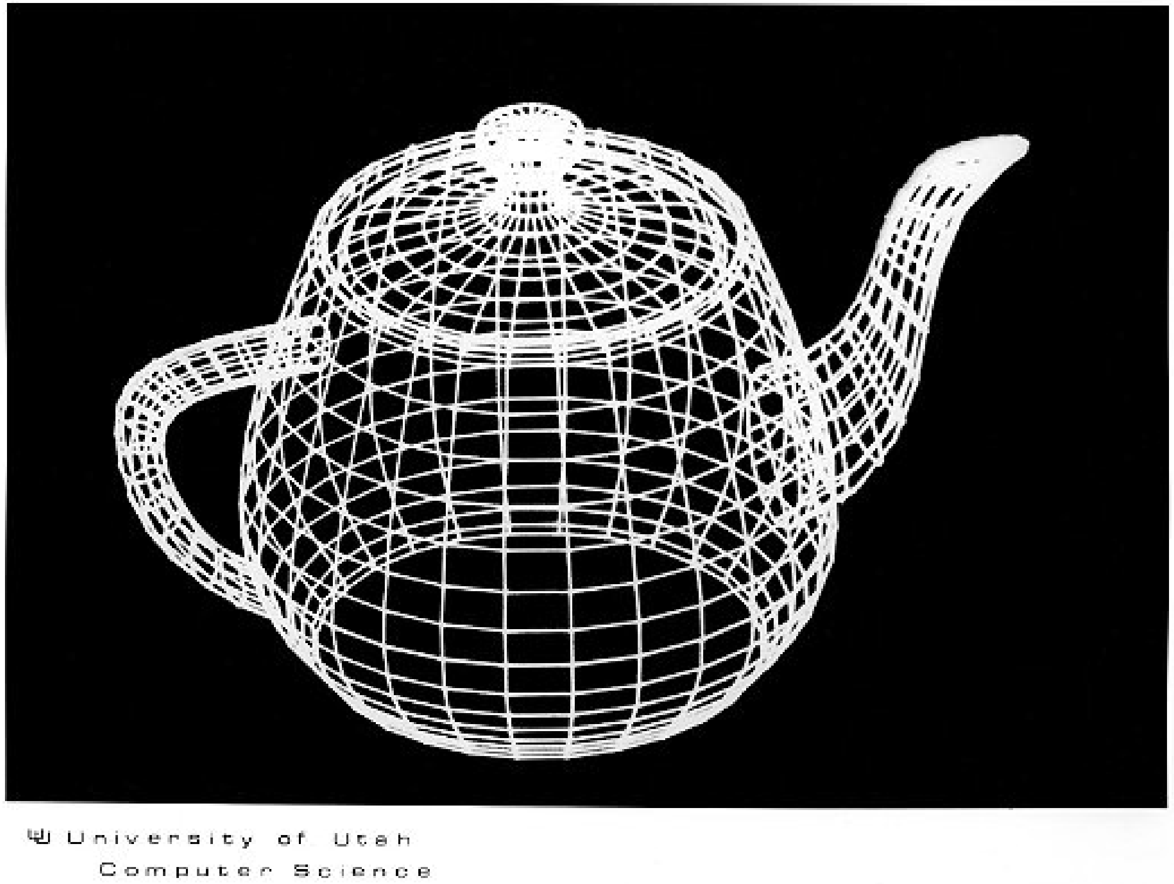


Variant No2

A. G. Journel. 1974. Geostatistics for Conditional Simulation of Ore Bodies Economic Geology and the Bulletin of the Society of Economic Geologists, 69, 673-687

Martin Newall, 1975





hateplow@giphy

M. Newall, 1975

John Tipper, 1976

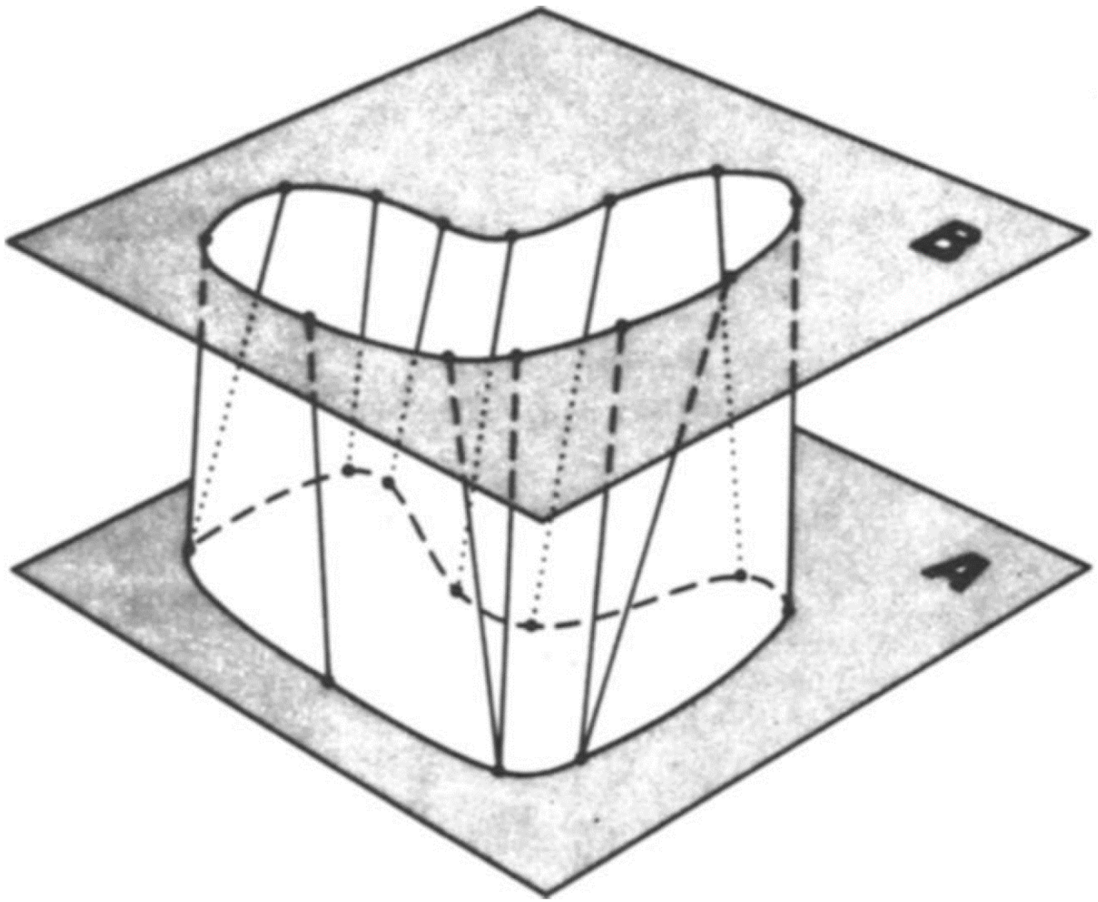


FIG. 3.—Result of point-to-point matching between sections A and B, showing the network of quadrilateral and triangular patches.

John C. Tipper. 1976. The Study of Geological Objects in Three Dimensions by the Computerized Reconstruction of Serial Sections. The Journal of Geology, Vol. 84, No. 4, 476-484

Bridge and Leeder, 1979

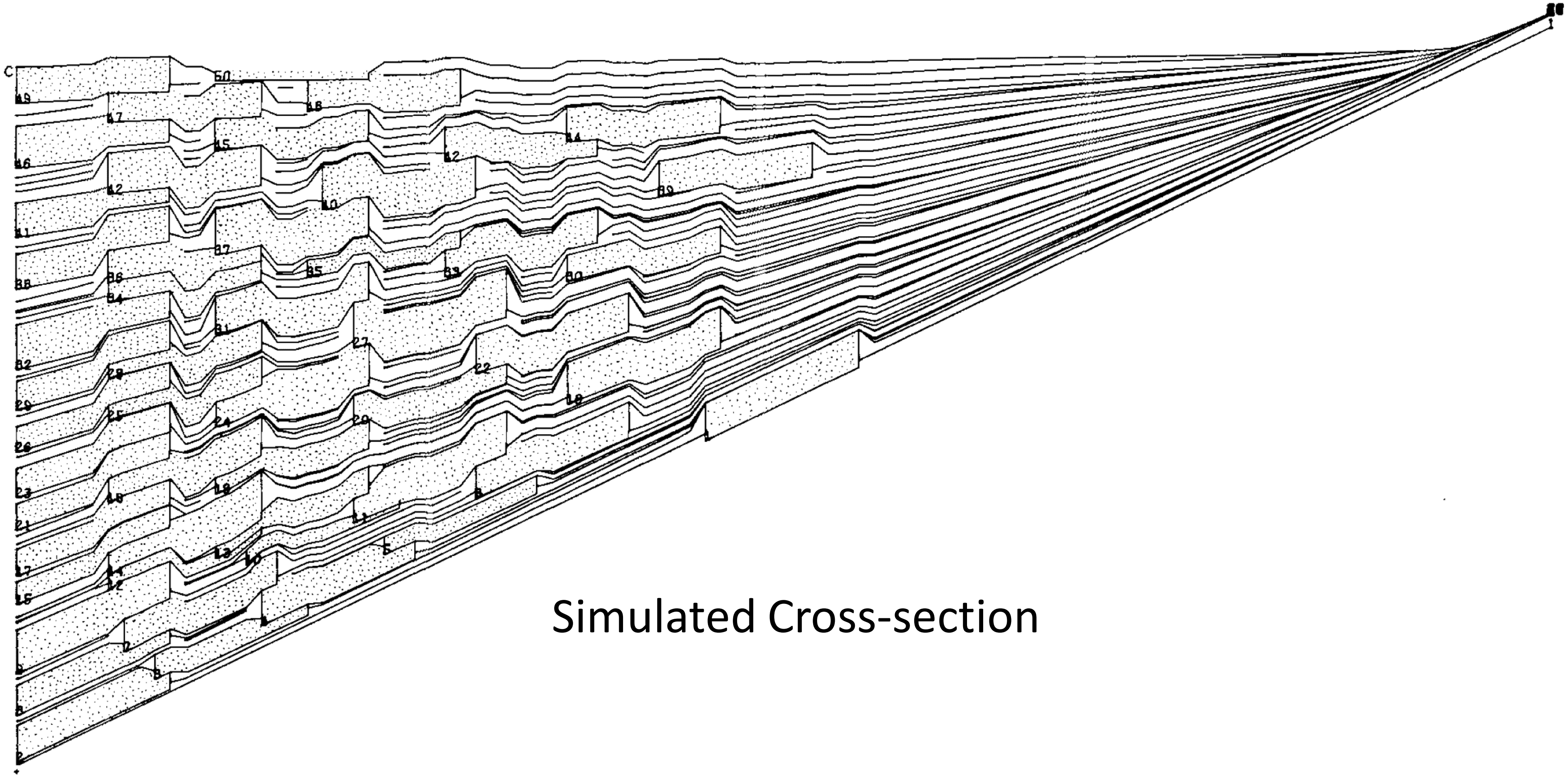
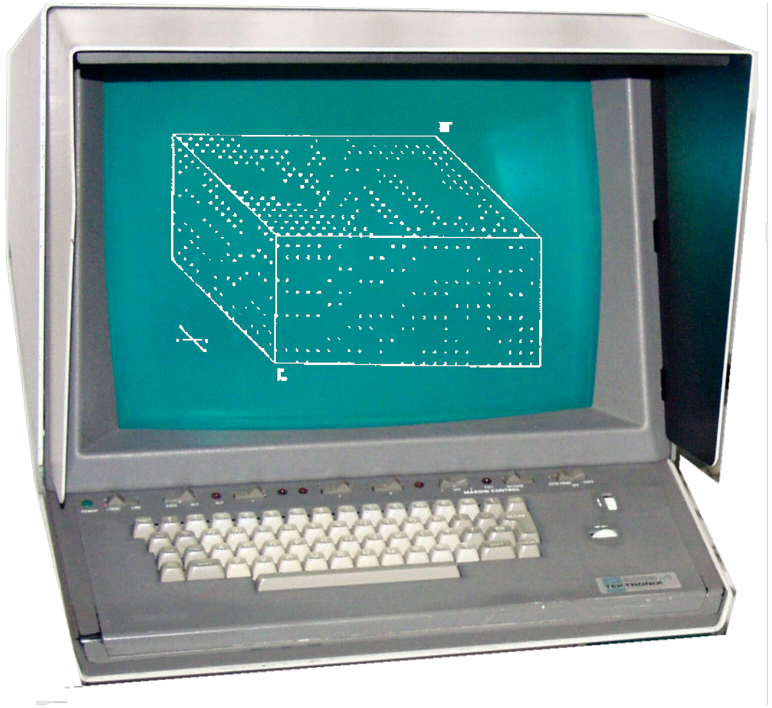
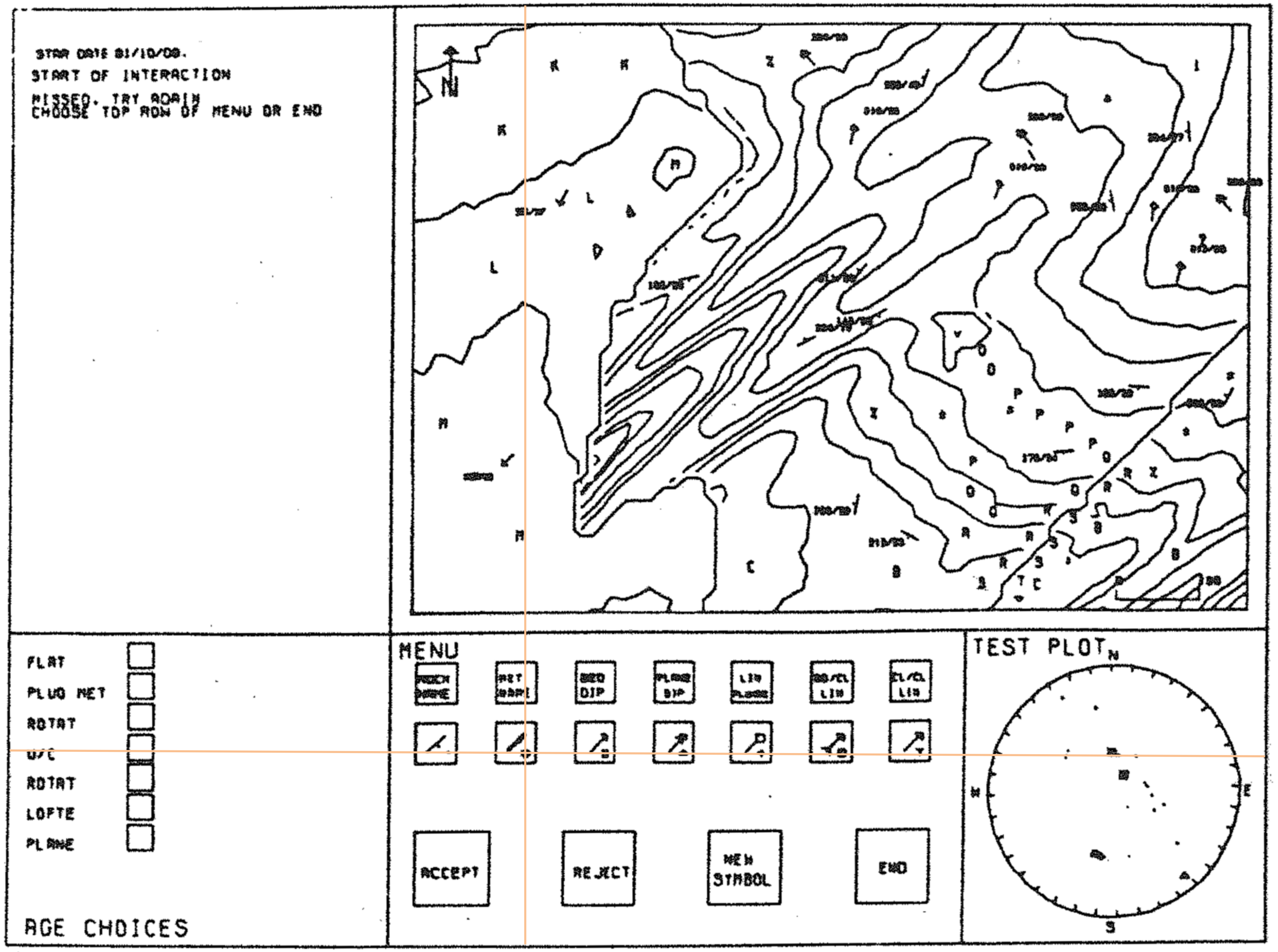


Fig. 7. Simulated cross-sections for selected set 4 (half graben) experiments. Vertical exaggeration is about 10. Mean and standard deviation of relative vertical movement at floodplain margins are 1·0 and 0·5 m respectively. Mean periods between tectonic events are (a) 890 years, (b) 445 years, (c) 89 years.

Bridge, J. S., and Leeder, M. R., 1979, A simulation model of alluvial stratigraphy: Sedimentology, v. 26, p. 617–644.

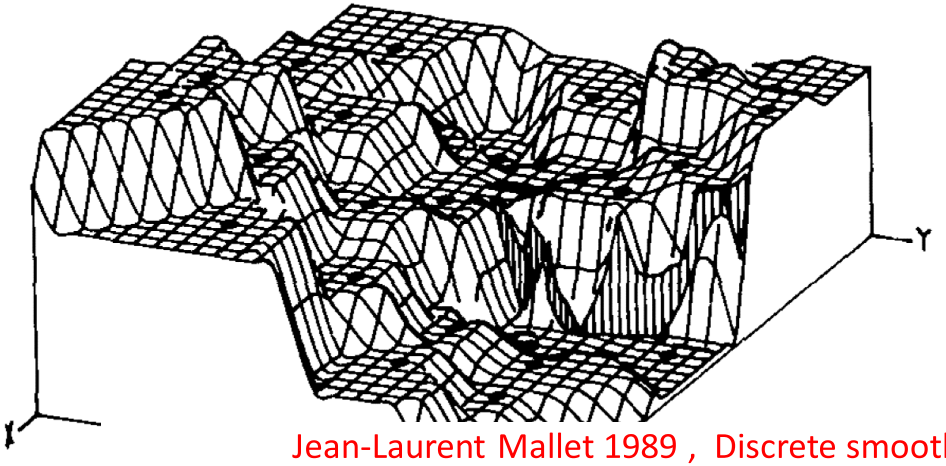
Jessell, 1981





Jessell, M.W. 1981. An interactive Map Creation Package, Unpublished MSc thesis, University of London

Jean-Laurent Mallet,1989



Jean-Laurent Mallet 1989 , Discrete smooth interpolation. ACM Transactions on Graphics, 8, 121-144

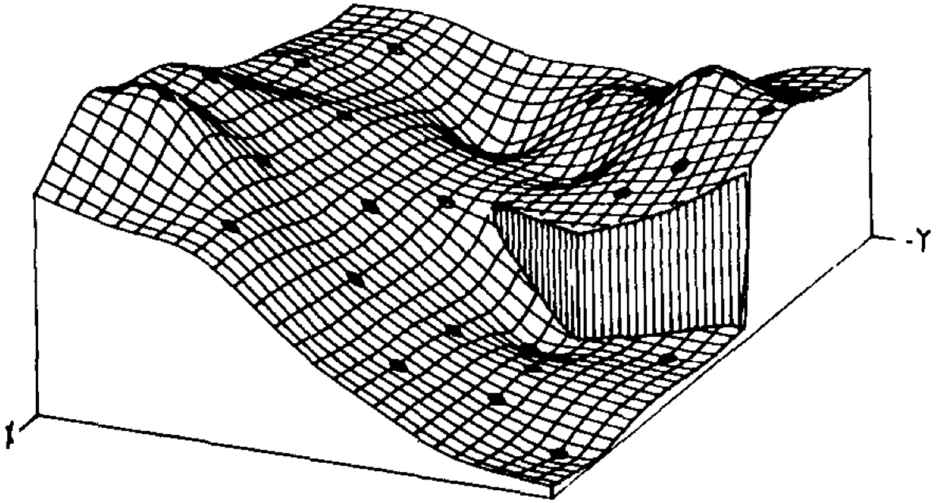
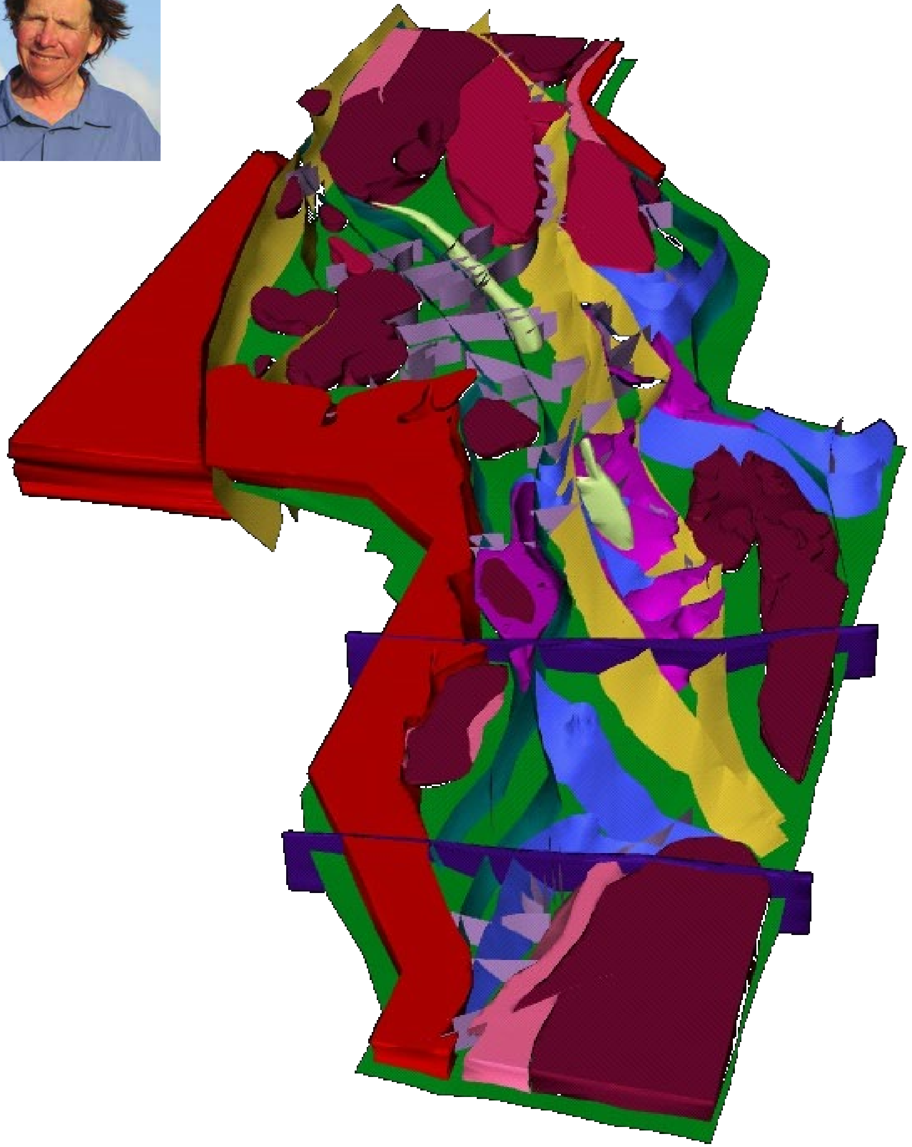


Fig. 8. The rough initial solution φ^0 and corresponding interpolation obtained with $\gamma = 0.2$ after 10 iterations (to be compared with Figure 9).

Fractal Graphics,1998



Fractal Graphics (Norseman-Menzies)

Smith & Paradis 1989

earthVision

Stirewalt and Henderson, 1995

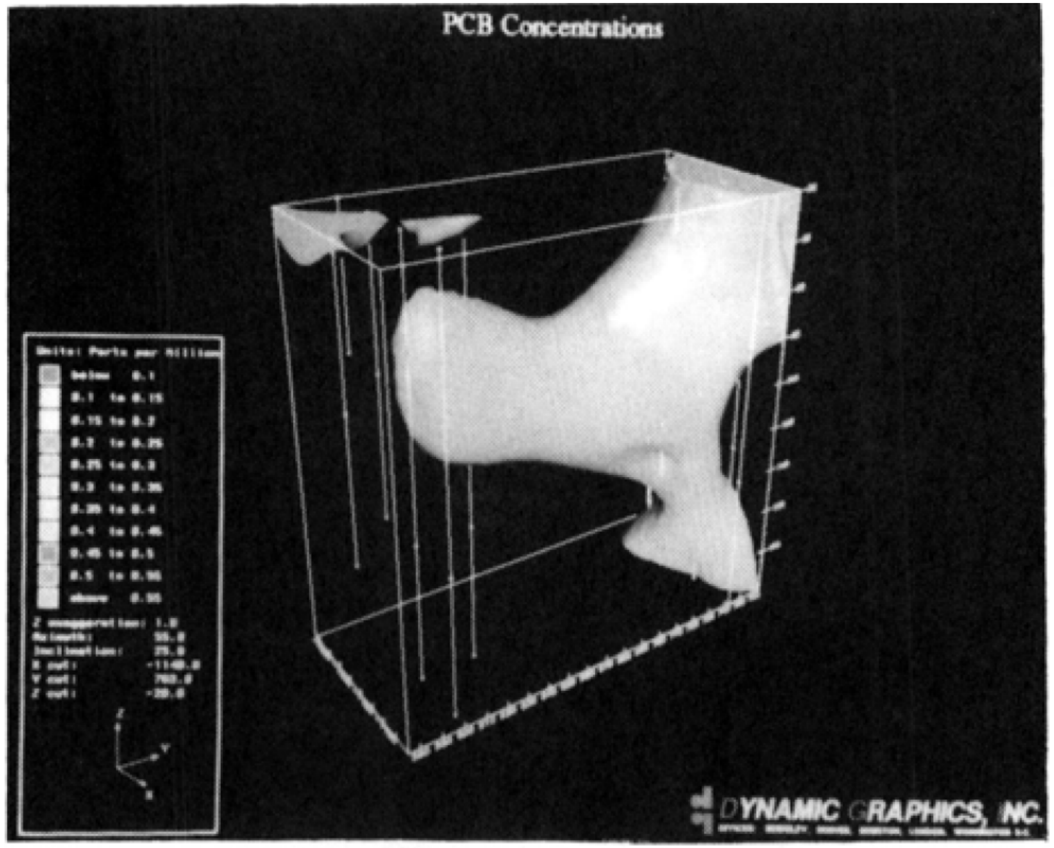
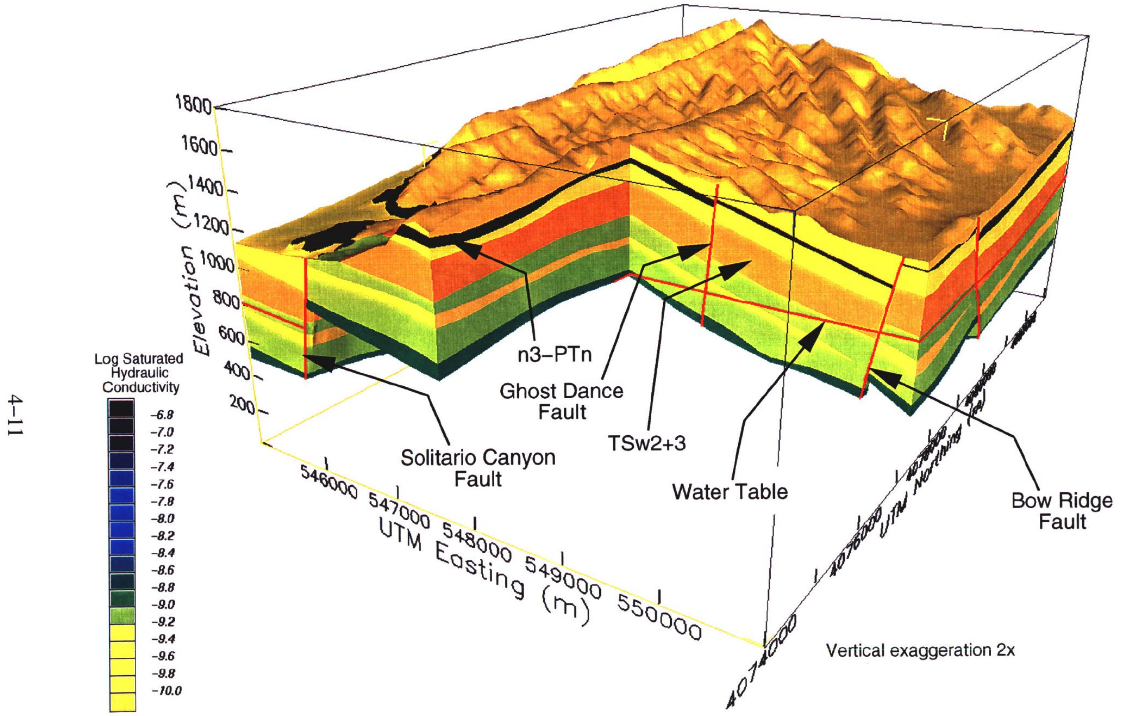


Figure 7. Iso-surface Display

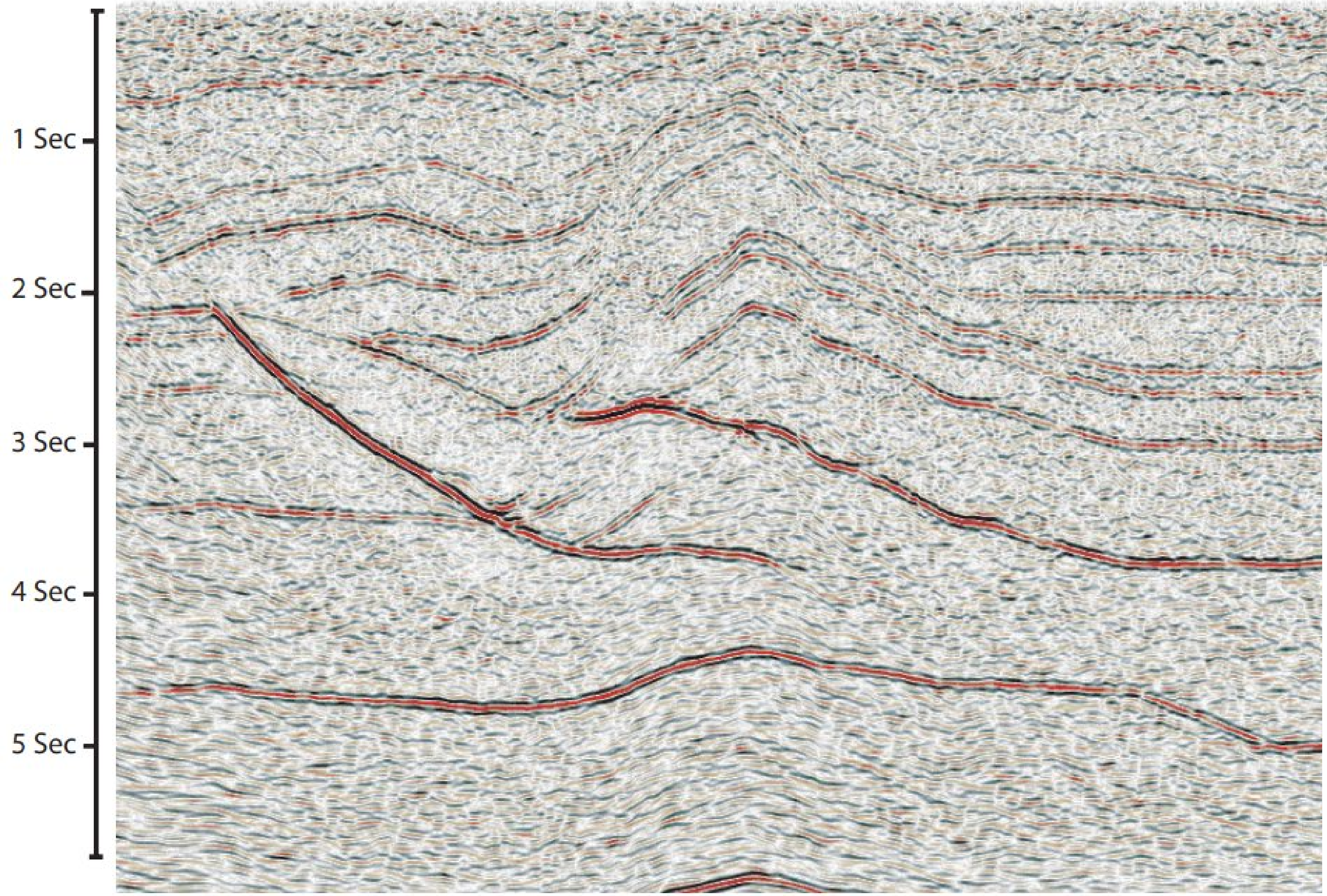


Smith, D.R. & Paradis, A.R. Three-Dimensional GIS of the Earth Sciences, Proceedings of the International Symposium on Computer-Assisted Cartography, April 2 - 7, 1989

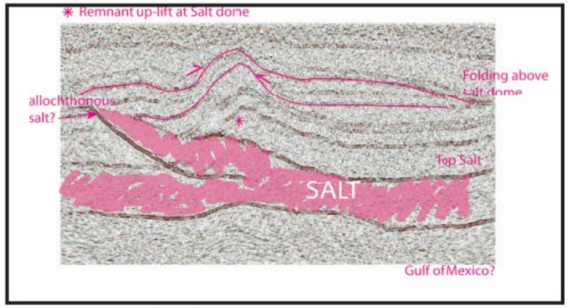
G. Stirewalt and B. Henderson, 1995, A Three-dimensional Geological Framework Model for Yucca Mountain, Nevada, with Hydrologic Application: Report to Accompany 1995 Model Transfer to the Nuclear Regulatory Commission

Bond et al. 2007

Synthetic seismic data

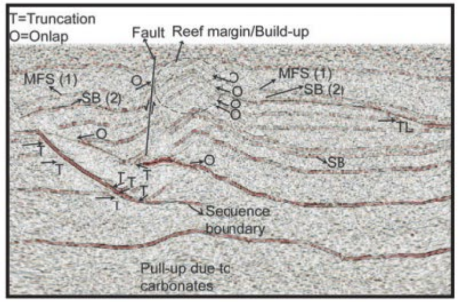


A



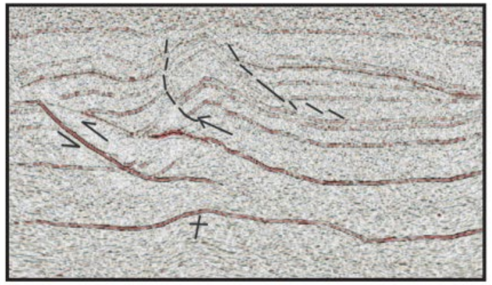
Student - PhD salt tectonics

B



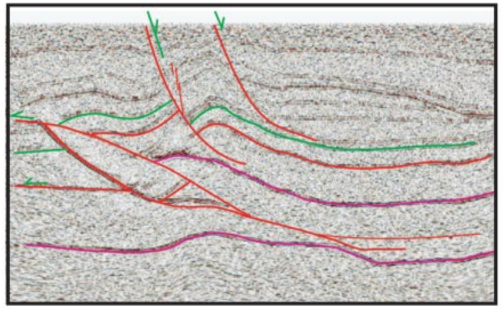
Student - MSc sequence stratigraphy

C



+15 yrs - thrust expertise

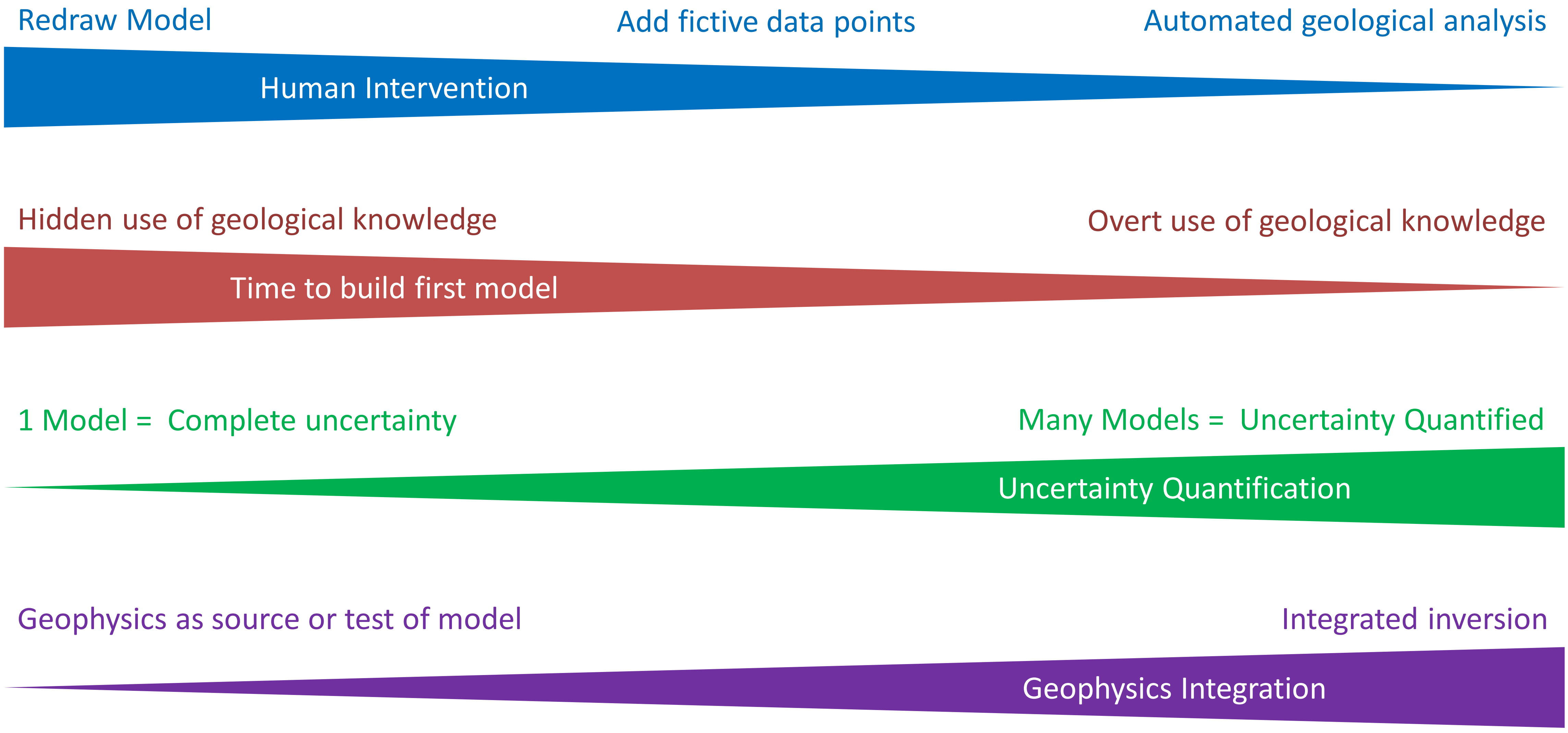
D



+15 yrs - extensional expertise

What do you think this is? “Conceptual uncertainty” in geoscience interpretation
C.E. Bond, A.D. Gibbs, Z.K. Shipton, and S. Jones. GSA Today: v. 17, no. 11 2007

Trends


Redraw Model
Add fictive data points
Automated geological analysis
Human Intervention
Hidden use of geological knowledge
Overt use of geological knowledge
Time to build first model
1 Model = Complete uncertainty
Many Models = Uncertainty Quantified
Uncertainty Quantification
Geophysics as source or test of model
Integrated inversion
Geophysics Integration