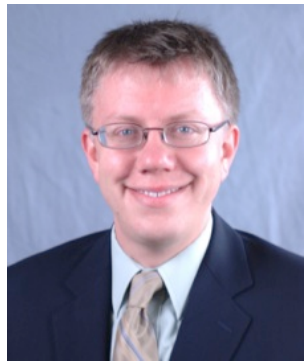
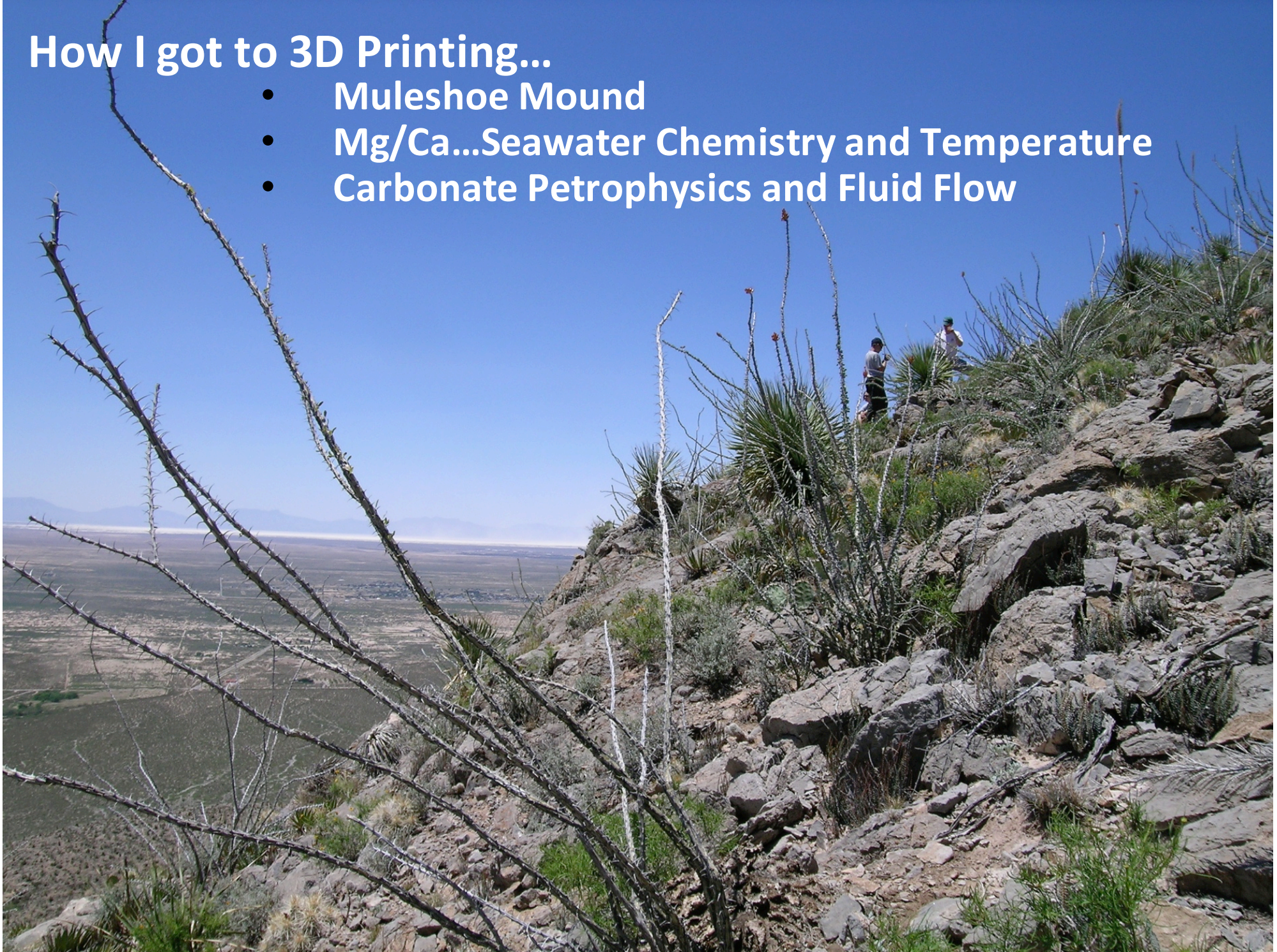
3D Printing in Teaching and Outreach



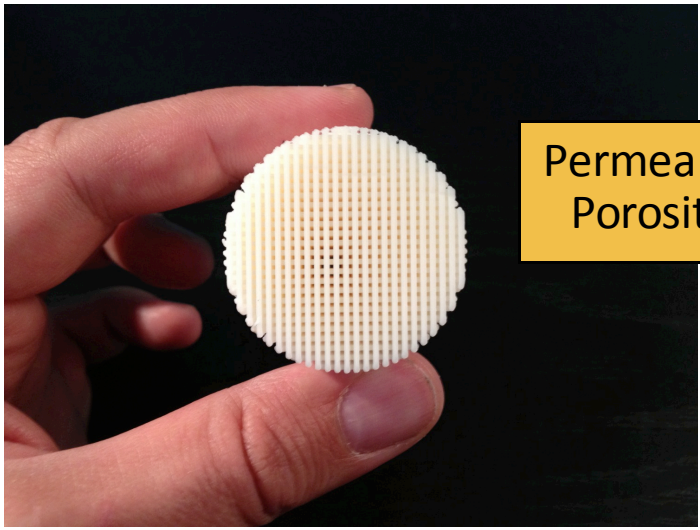
Dr. Franciszek "Franek" Hasiuk
Department of Geological
and Atmospheric Sciences
Iowa State University, Ames, IA

How I got to 3D Printing…

- Muleshoe Mound
- Mg/Ca…Seawater Chemistry and Temperature
- Carbonate Petrophysics and Fluid Flow



GeoFabLab

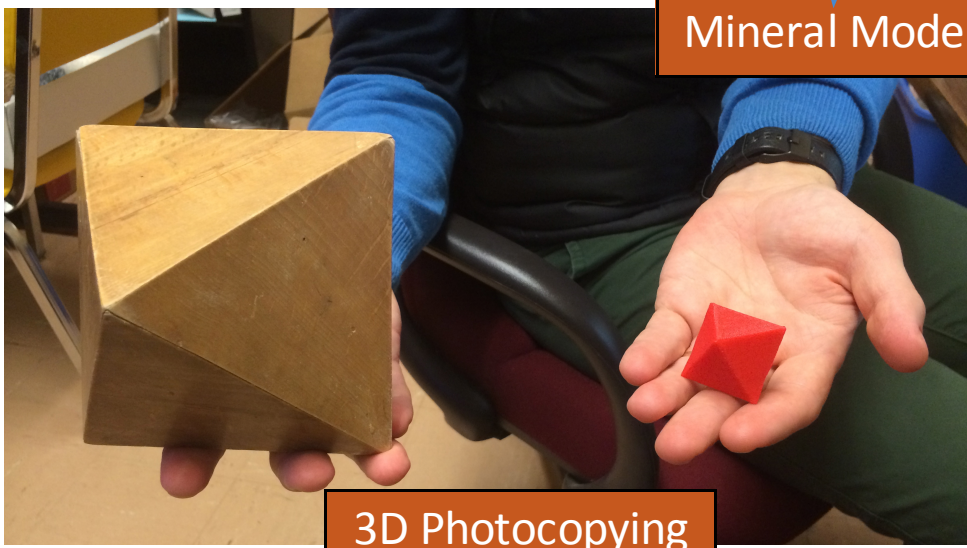


Permeable
Porosity

Earth Models

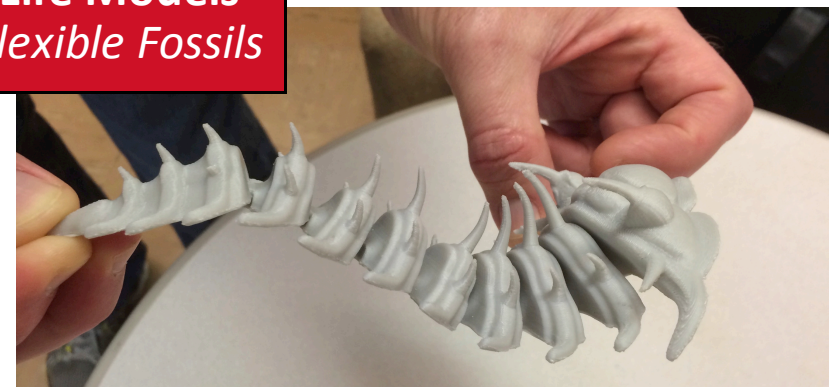
XYZD

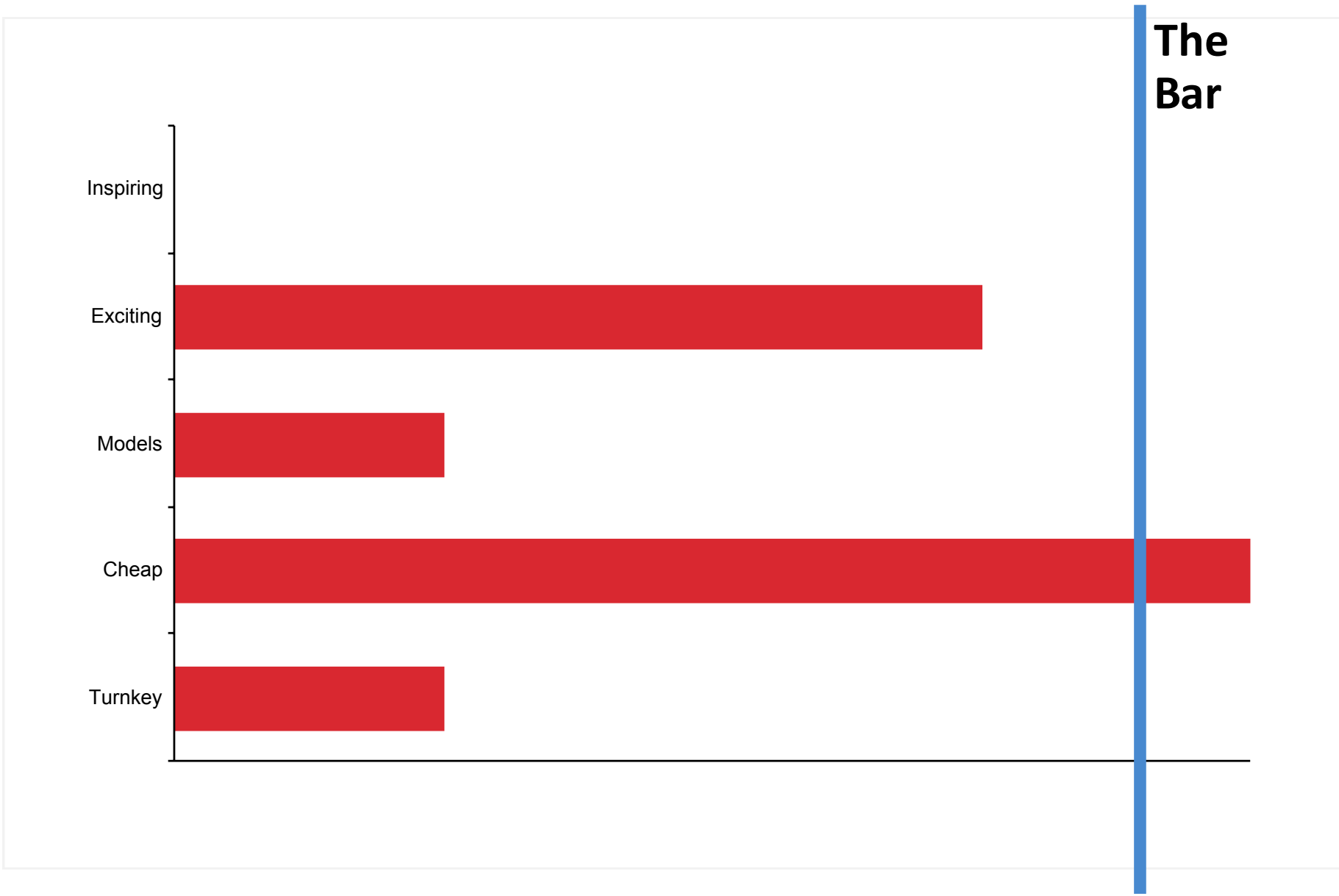
Mineral Models



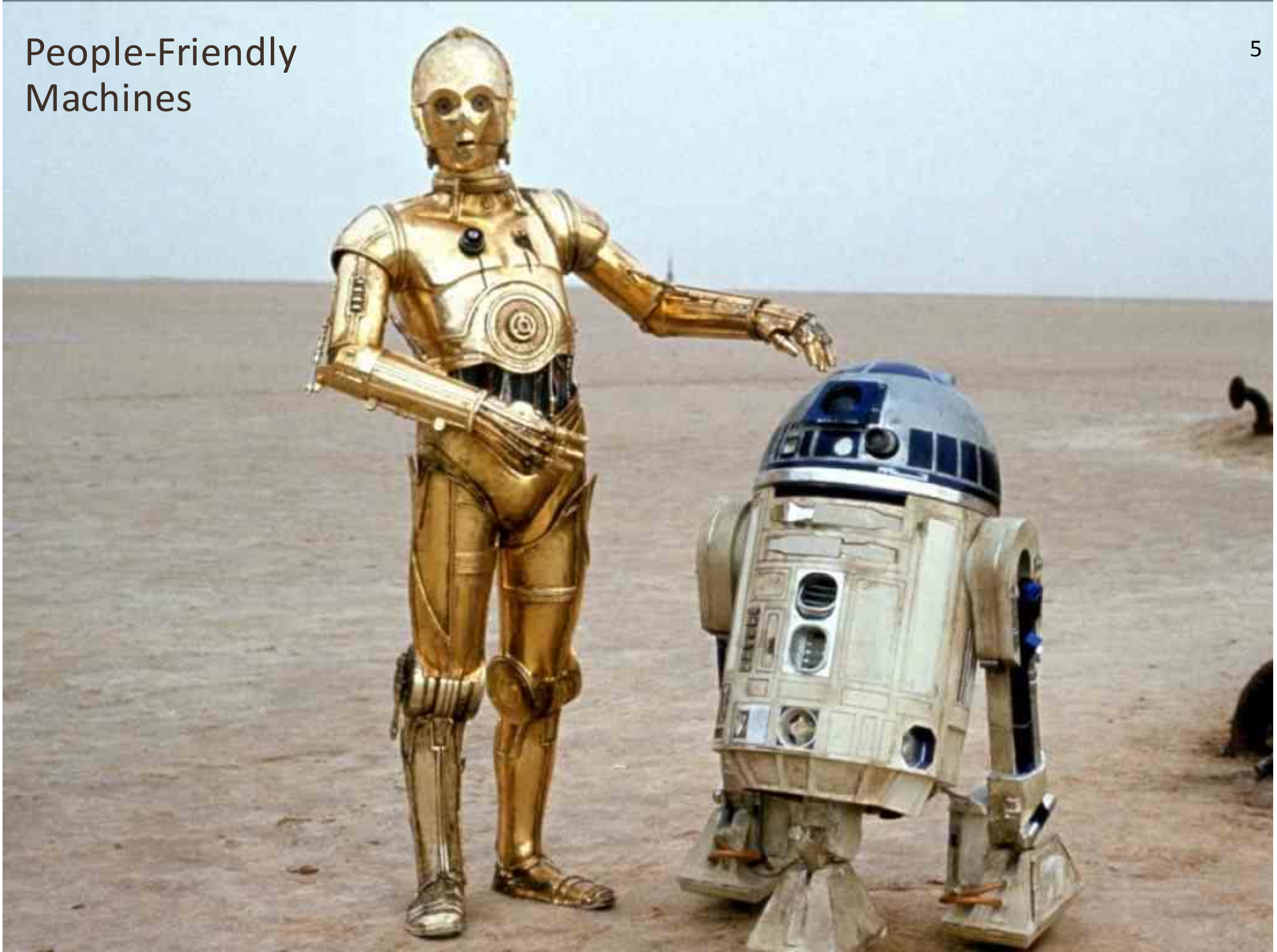
3D Photocopying

Life Models
Flexible Fossils




The Bar
Inspiring
Exciting
Models
Cheap
Turnkey

People-Friendly Machines

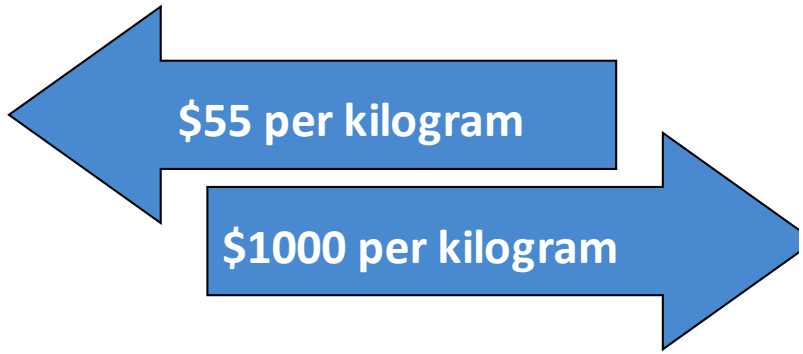


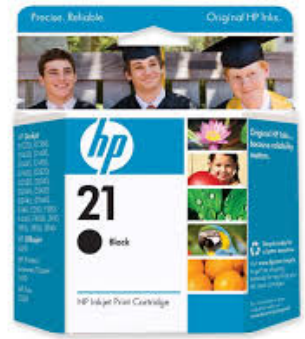
People-Un-Friendly Machines

Turnkey-ish 3D Printers

Makerbot Mini

Cheap





$3000 printer with PC

Free Software

MakerWare™ BETA

SketchUp

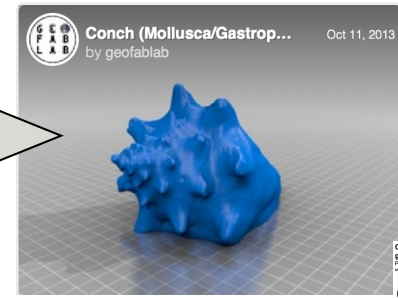
Meshlab

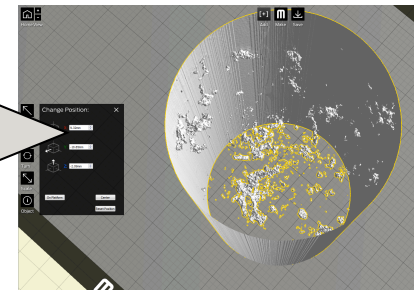
blender™

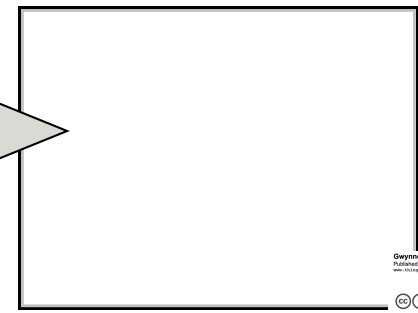
123D DESIGN

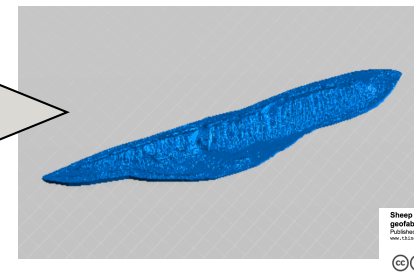
Models of *Things*

	Method
Most Things (like minerals, Crystal models, Simple fossils**)**	*3D Scanning*
Intricate Things (like fossils, pore networks)	*Computed Tomography (CT)*
Big Things (like boulders, outcrops**)**	*Image Processing*
Really Big Things (like landscapes)	On-line Elevation Data Free Software (e.g. MeshLab)



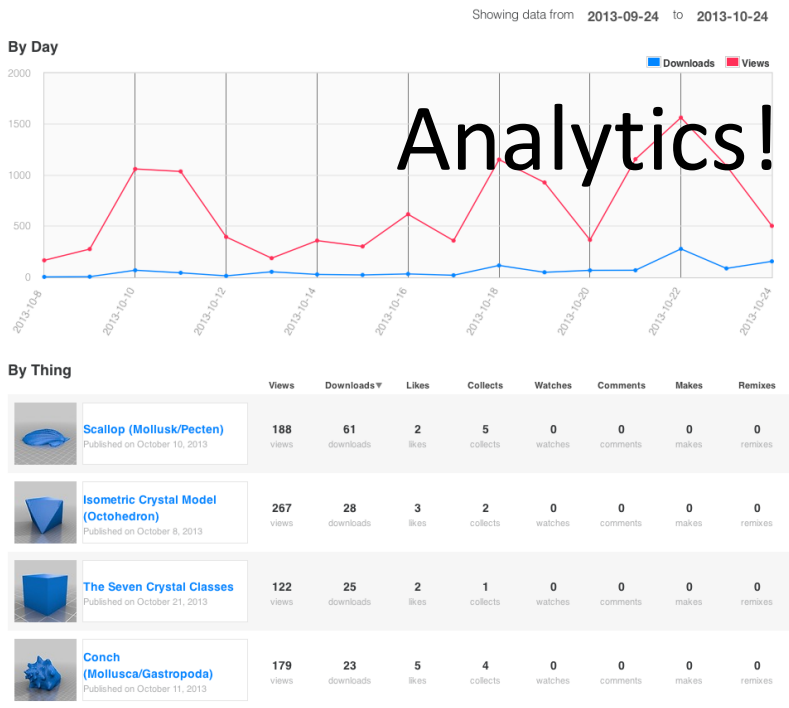






Models

MakerBot Thingiverse



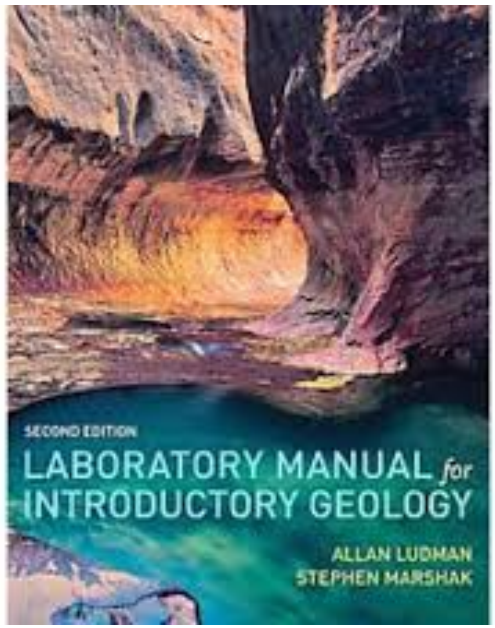
Analytics!

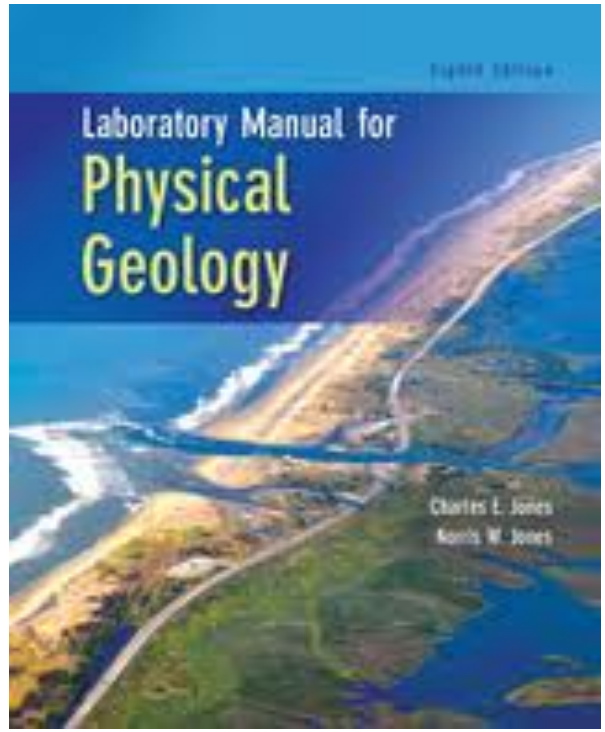
CAD and STL Files

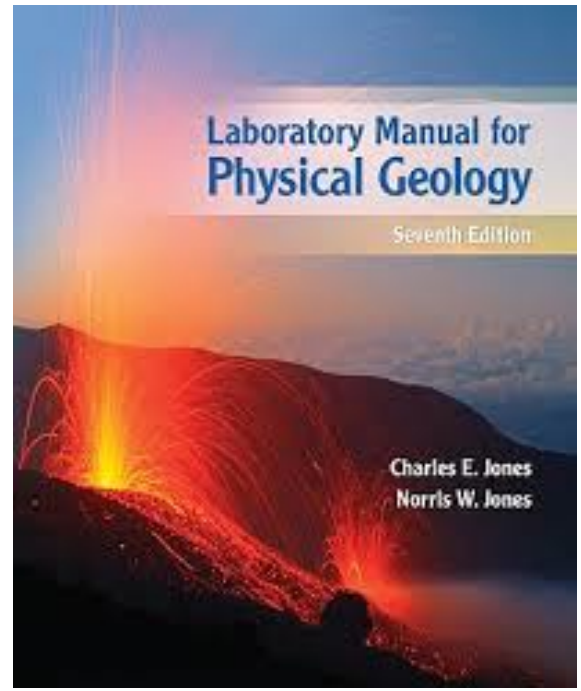
Author sets copyright

Trimble 3D Warehouse
powered by Google

The Playbooks







Recruiting Booth at GSA

Digital Poster at GSA

Gwynne's Rock
In Cyberspace

Gwynne's Rock
In Place

Terrain Models

GeoMapApp to *.stl

GeoMapApp → .stl

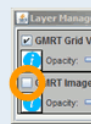
Highest Point (m) 100 | Lowest Point (m) 0 | Vertical Exaggeration 1.0

Enter Area (sq km): 1

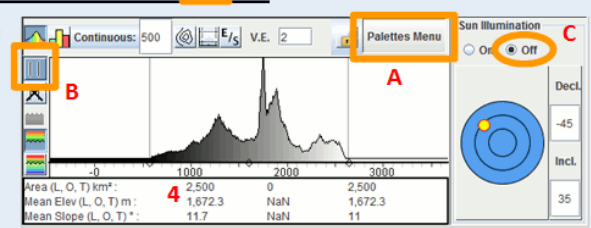
Although there are other possibilities, this program has been designed to be used in conjunction w
free earth science exploration and visualization tool from the Lamont-Doherty Earth Observatory
University. You can download the most recent version of GeoMapApp at http://www.geomapap
how to use GeoMapApp can be found within that application.

Pre-Instructions

1. From within GeoMapApp locate the area that you wish to have converted into an 3D printa
possible results without vertical exaggeration you should select an area that has no more th
height ratio.
2. The default base layer is the GMRT Image - you will need to turn on the GMRT Grid by selecting the Show/Hide Grid Dialog icon in the GeoMapApp toolbar. You can also uncheck the GMRT Grid in the Layer Manager for faster processing of the image



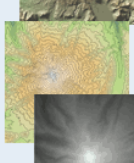
3. From the Global Grids dialog that Opens:
   a. Select black_white from the Palettes Menu
   b. Renormalize the histogram which now appears flat by clicking on the Normalize histogram button
   c. Turn off Sun Illumination

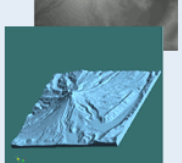


4. Determine the highest elevation and lowest elevation of the image. Record this along with the area (sq km) of the image which can be read from the Global Grids dialog.
5. Save your file as a PNG (best resolution). To save time later, it is recommended that you save it in the format [location].[high elevation]_[low elevation]_[area]. For example: MtHood.3420_1831_12

GeoMapApp --> .stl Conversion Instructions

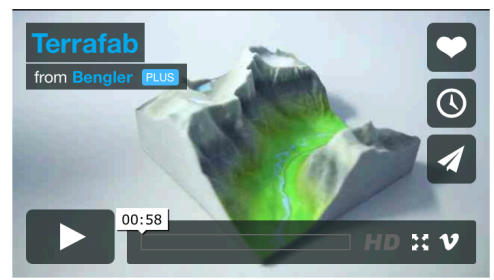
1. Choose the file that you wish to use from within the dialog window. If you saved it in the recommended fashion, the information needed to complete the next steps is now readily available.
2. Move the sliders to select the highest point, lowest point, and the area. The vertical exaggeration (VE) is defaulted to 1, you can choose to either flatten the image (a VE less than 1) or stretch the image (a VE greater than 1).
3. Click start. Once the file is processed it will be placed back in the original location it came with the extension .stl and the file can now be uploaded to your 3D printer.





OWN A SLICE OF NORWAY!

Terrafab is an experimental service that displays really detailed 3d-models in the browser. Unfortunately, we haven't tested it with your browser yet, but it might just work anyway! For an optimal experience try the latest version of Chrome.



Arguably, Norway has one of the top five most incredible terrains in the known universe. Now you can create your own 3D-printed genuine gypsum heirloom mantelpiece display replica of your favorite part of this formidable landscape in two easy steps:

1. Drag the selector around until you love what you see in the floating 3D preview.
2. Hit the big, orange button that says "Get this model 3D-printed"

OK, GOT IT!

Terrafab.no

Implementation Models

Lesson Plans

Tutorials

Lab Exercises

Science Fair Projects

Science Night Demos

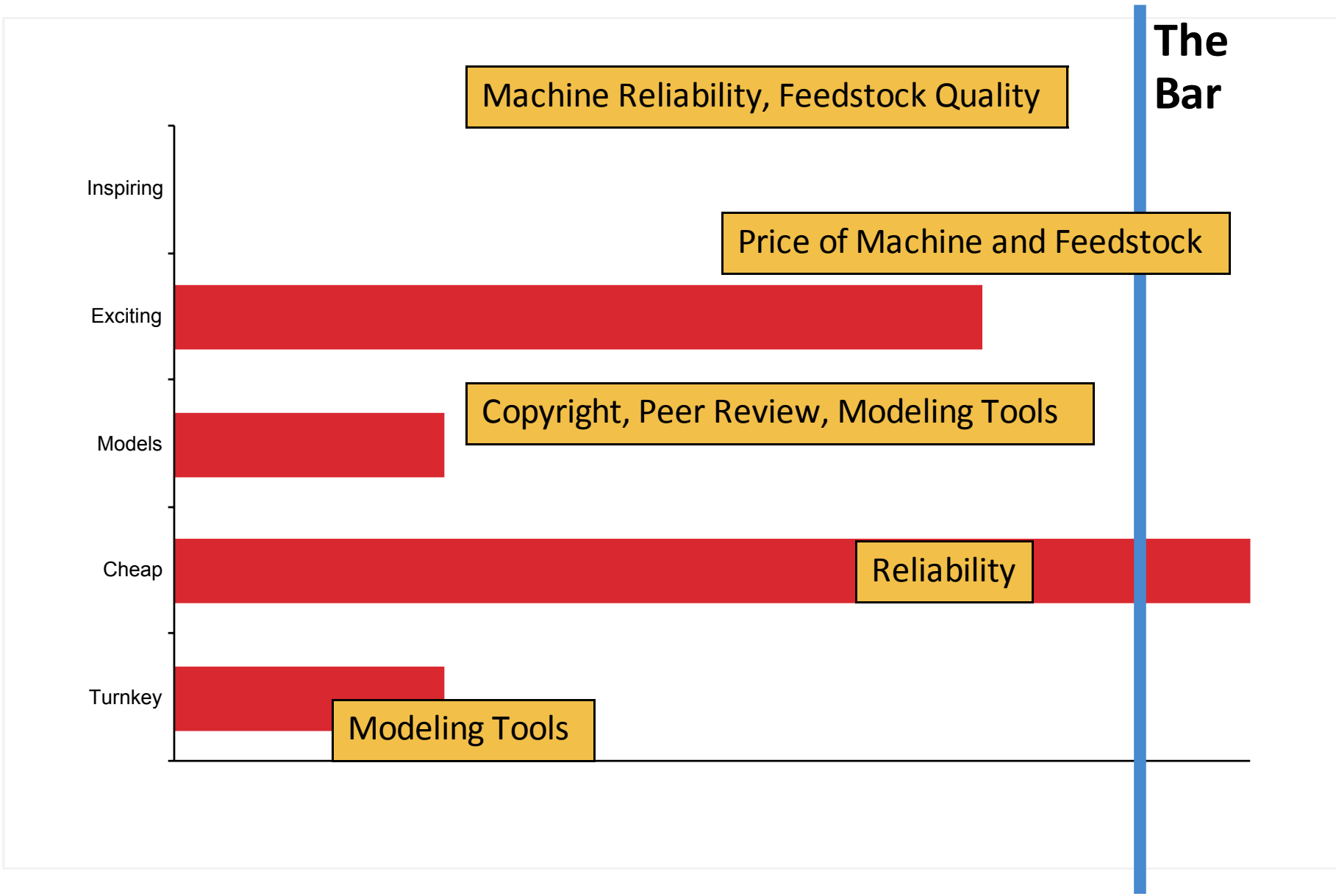
Field Trips

Elder Hostels

BBC

NASA’s Pizza Printer


Exciting


The Bar
Machine Reliability, Feedstock Quality
Inspiring
Price of Machine and Feedstock
Exciting
Copyright, Peer Review, Modeling Tools
Models
Cheap
Reliability
Turnkey
Modeling Tools

Proposal: Outreach/Teaching 3D Printer

Description of equipment:

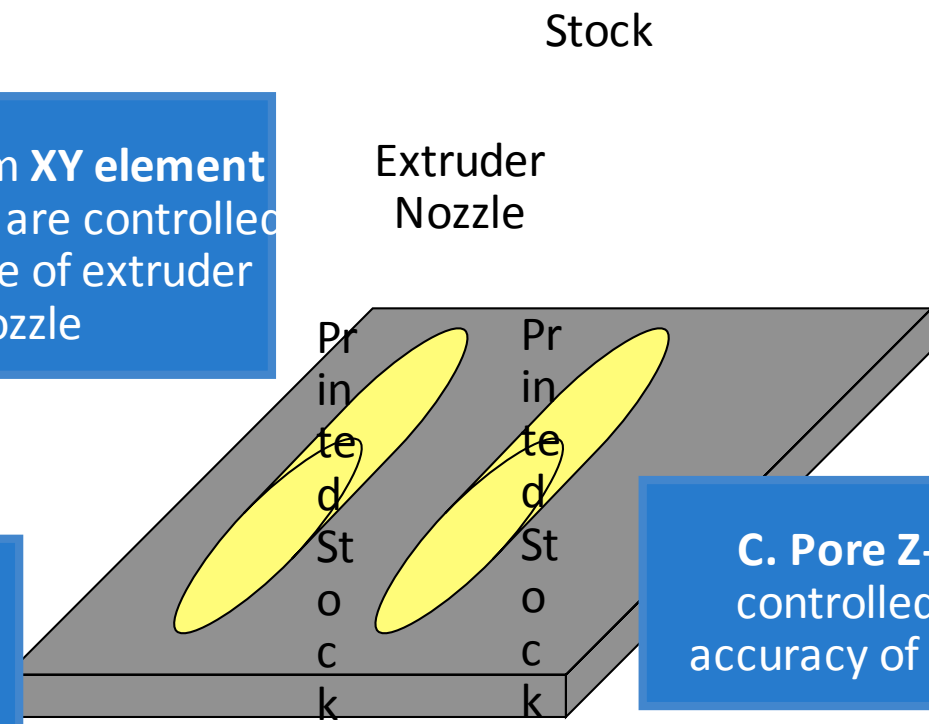
Makerbot Replicator Mini		$1,500
10 spools of plastic filament (feedstock for printer)		$500
MakerCare Protection Plan		$350
Extension cord and power strip		$20
Small tools		$50
Apple MacBook Air to run 3D printer		$1,600
Laptop bag		$50
	Total	$4,070

This 3D printer will be used to:

1. Print out teaching models for learning topography, fossil identification, crystal symmetry, and structural geology. These models are very costly to purchase from suppliers.
2. Use at outreach events like K12 science events.
3. Use at recruiting events like graduate student information booths at national conferences.

Printing Permeable Porosity

The key is being able to control the distance between two elements.



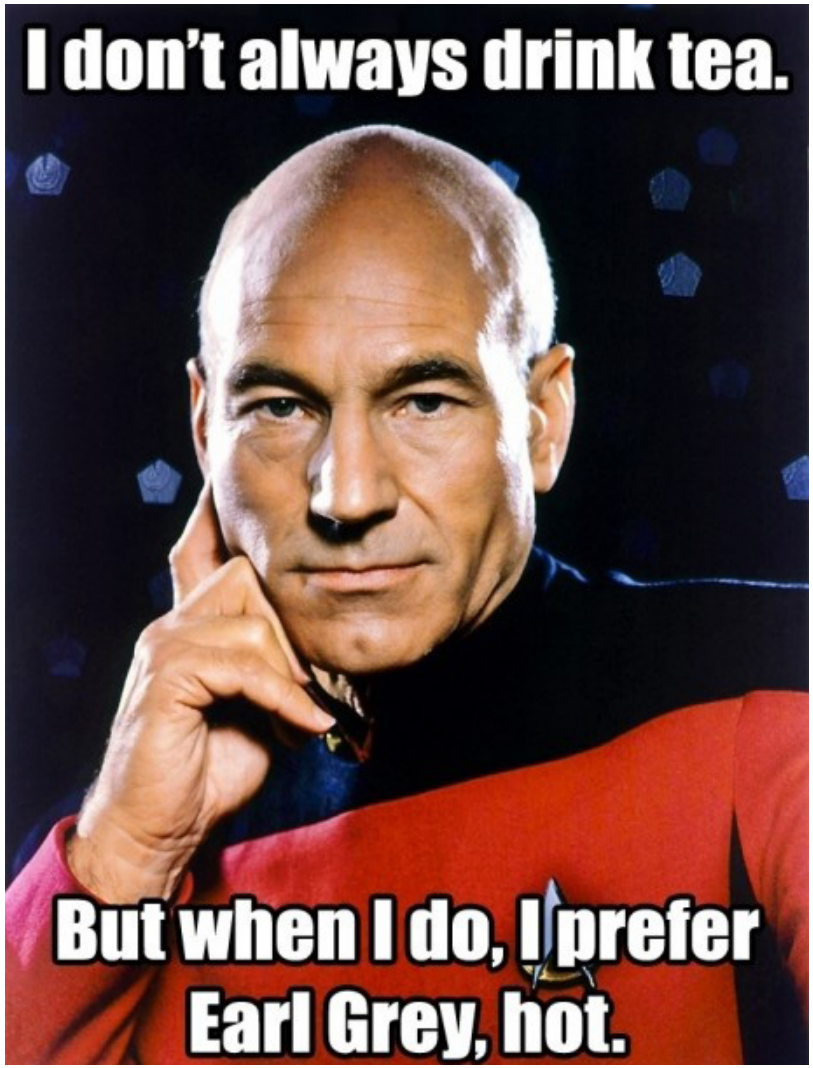
A. Minimum **XY element dimensions** are controlled by aperture of extruder nozzle

B. Element thickness is controlled by positional accuracy of Z stepper motor

C. Pore Z-dimension is controlled by positional accuracy of Z stepper motor

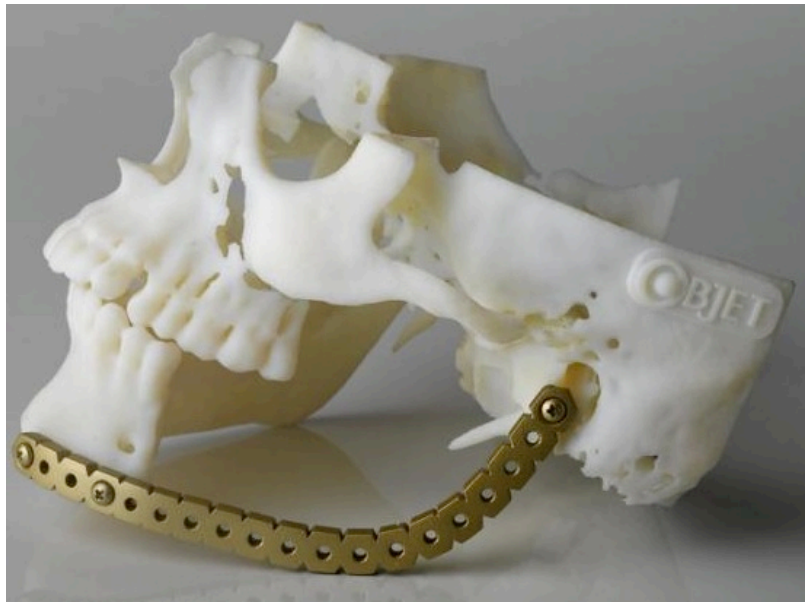
D. Pore XY-dimension is controlled by positional accuracy of XY stepper motors

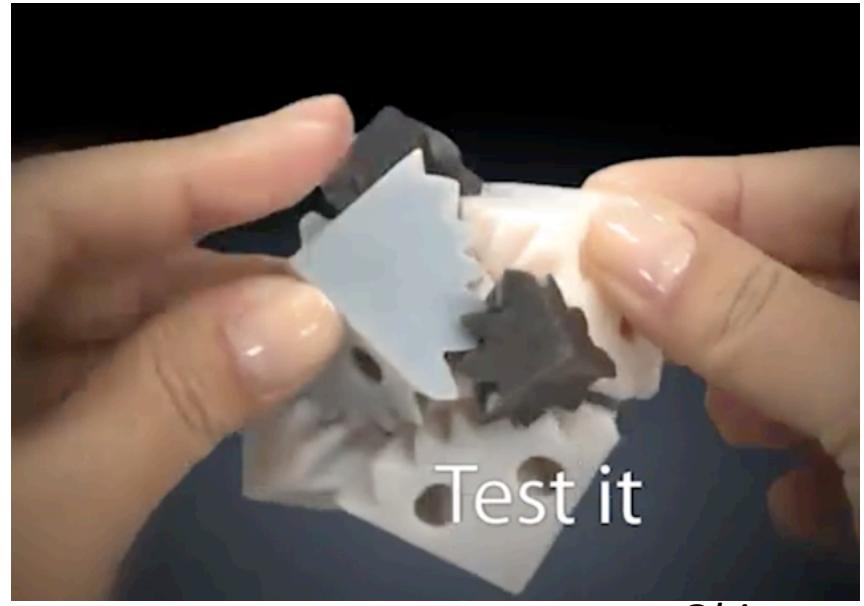
Star Trek: The Manufacturing



cf. Sternbach and Okuda, 1991

What *can* you print these days?





Objet.com

Geoscience Uses of 3D Printing

New frontiers in ichnology using [3D scanning and 3D printing] for [3D] analysis, printing, and sharing of modern and ancient traces with other ichnophiles.

Hasiotis et al.
2011 GSA Annual Meeting

Soil Geomorphology Research Group

Dr. Steve Hasiotis

KU

Current Geoscience Uses of 3D Printing

University of Michigan 3D Lab

3D Scanning and Printing Brings Mastodons into 21st Century

January 23, 2013

Dr. Dan Fisher holds a mastodon rib.

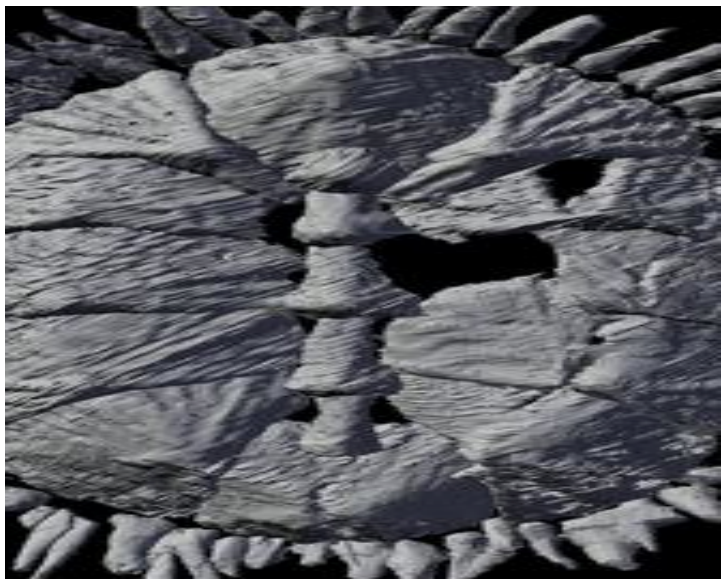
Current Geoscience Uses of 3D Printing

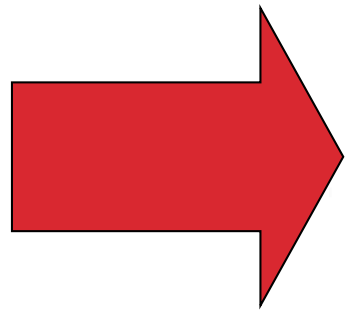
Friday, October 5. 2012

The Shapeways Blog: 3D Printing News & Innova

New School 3D Tech Goes Very, Very Old School With Fossils

i.e. Devonian Multiplacophoran was digitally extracted from rock and printed in 3D





Vinther et al., 2012
Paleontology 55: 1007

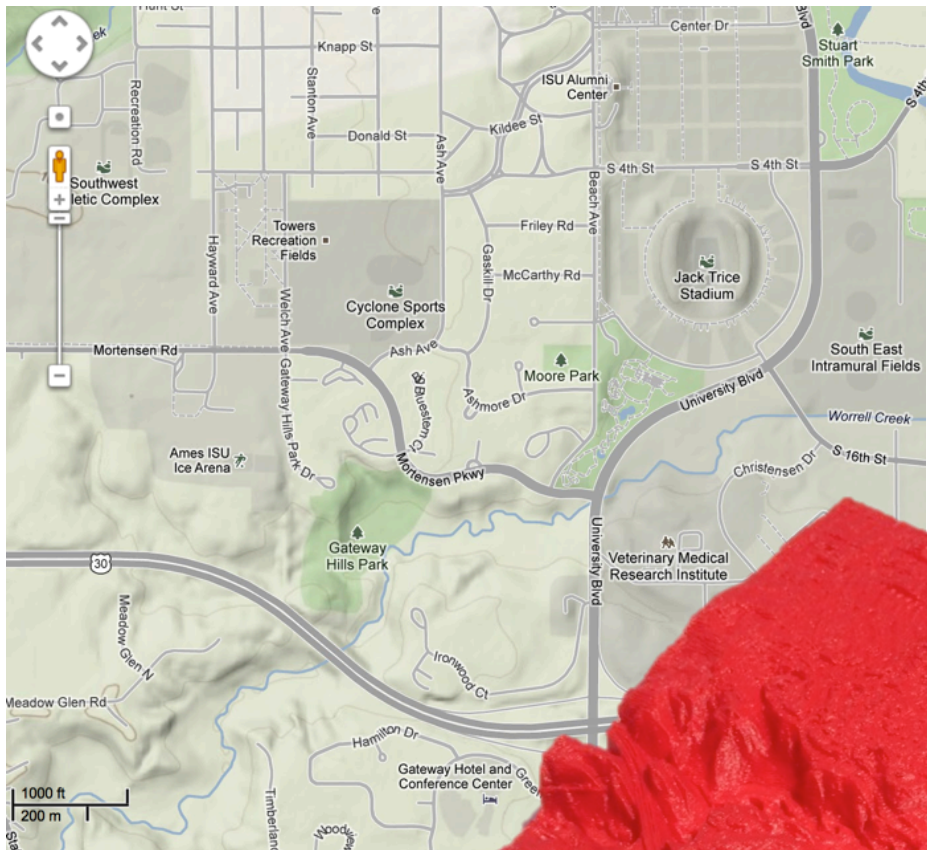
Geoscience Uses of 3D Printing

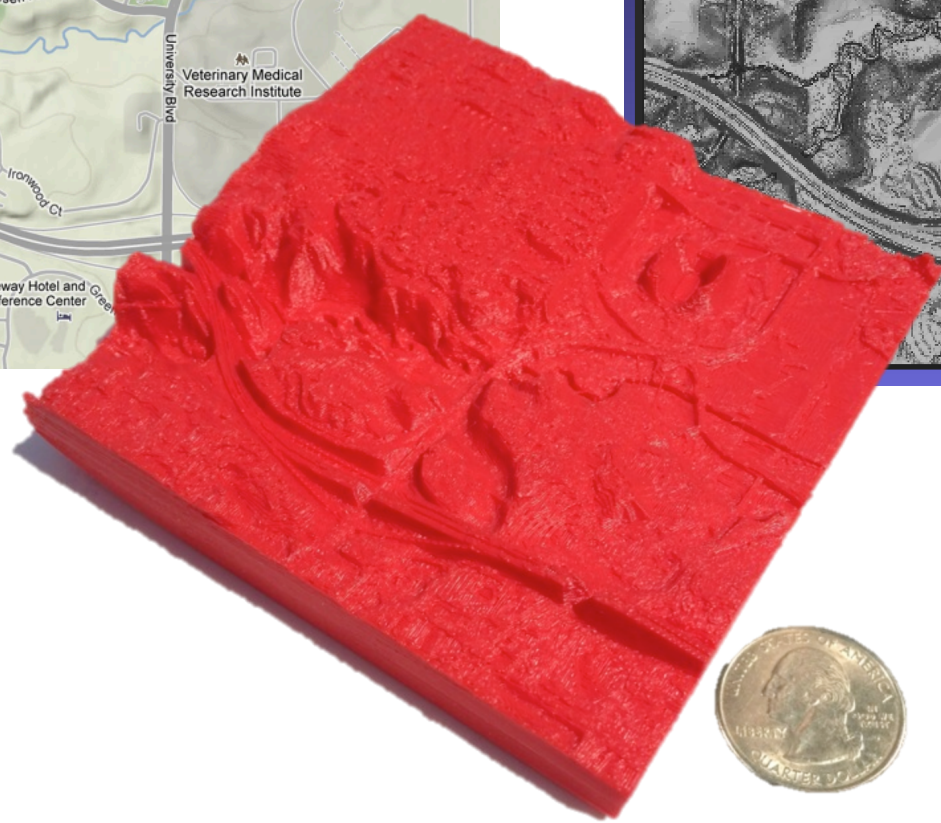
Printing space; 3D printing…digital terrain models…enhances student comprehension and educational outreach.

Horowitz and Schultz
2012 GSA Annual Meeting

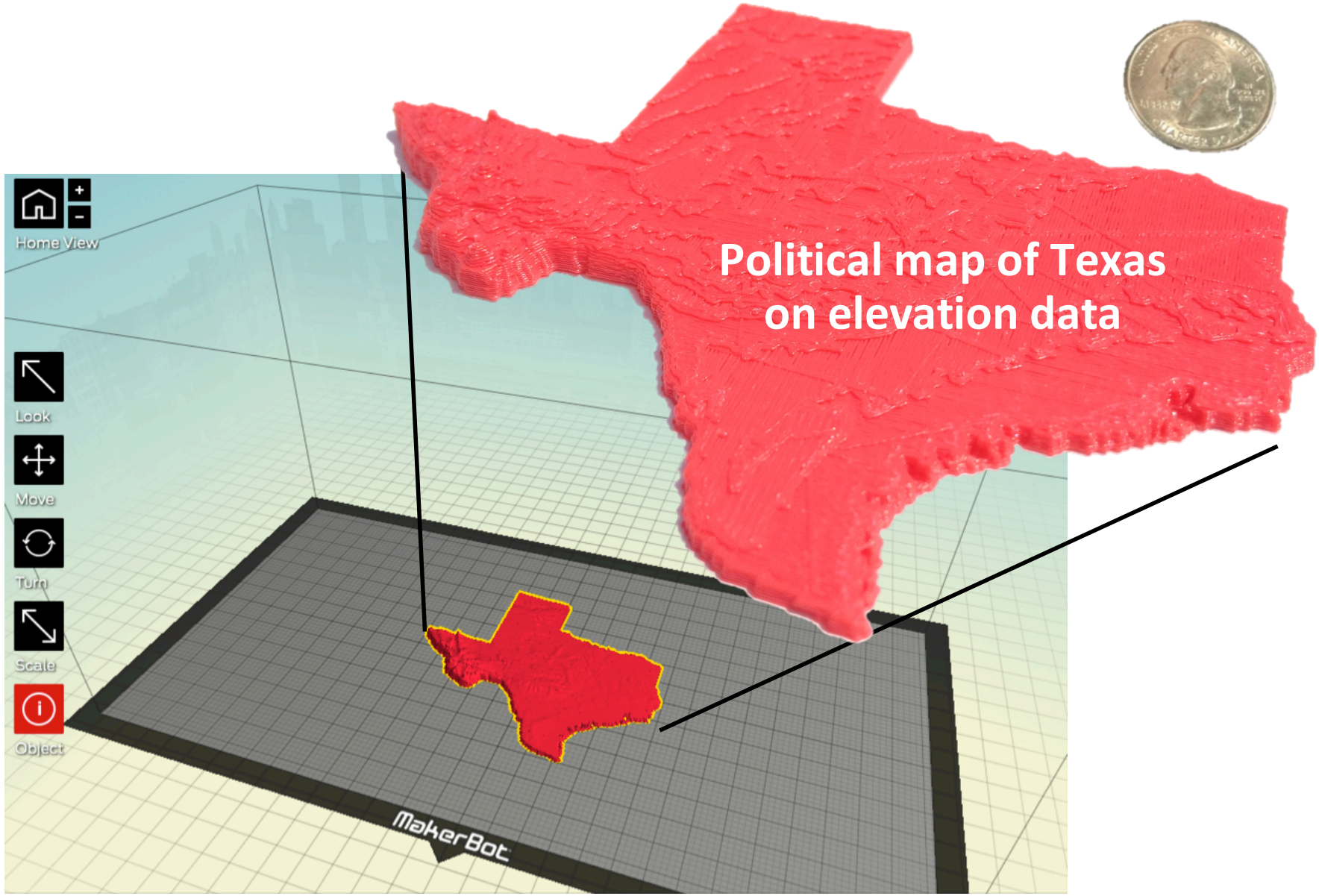
Photo of/by Dr. Seth Horowitz
Brown University

3D Printing Elevation Data



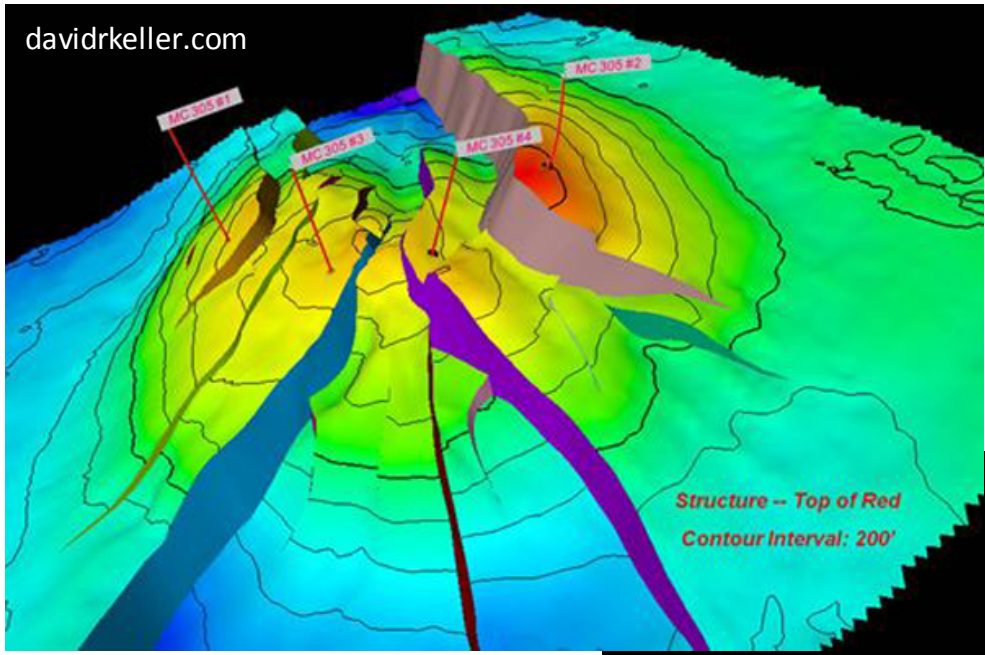


Printing Data on Elevation



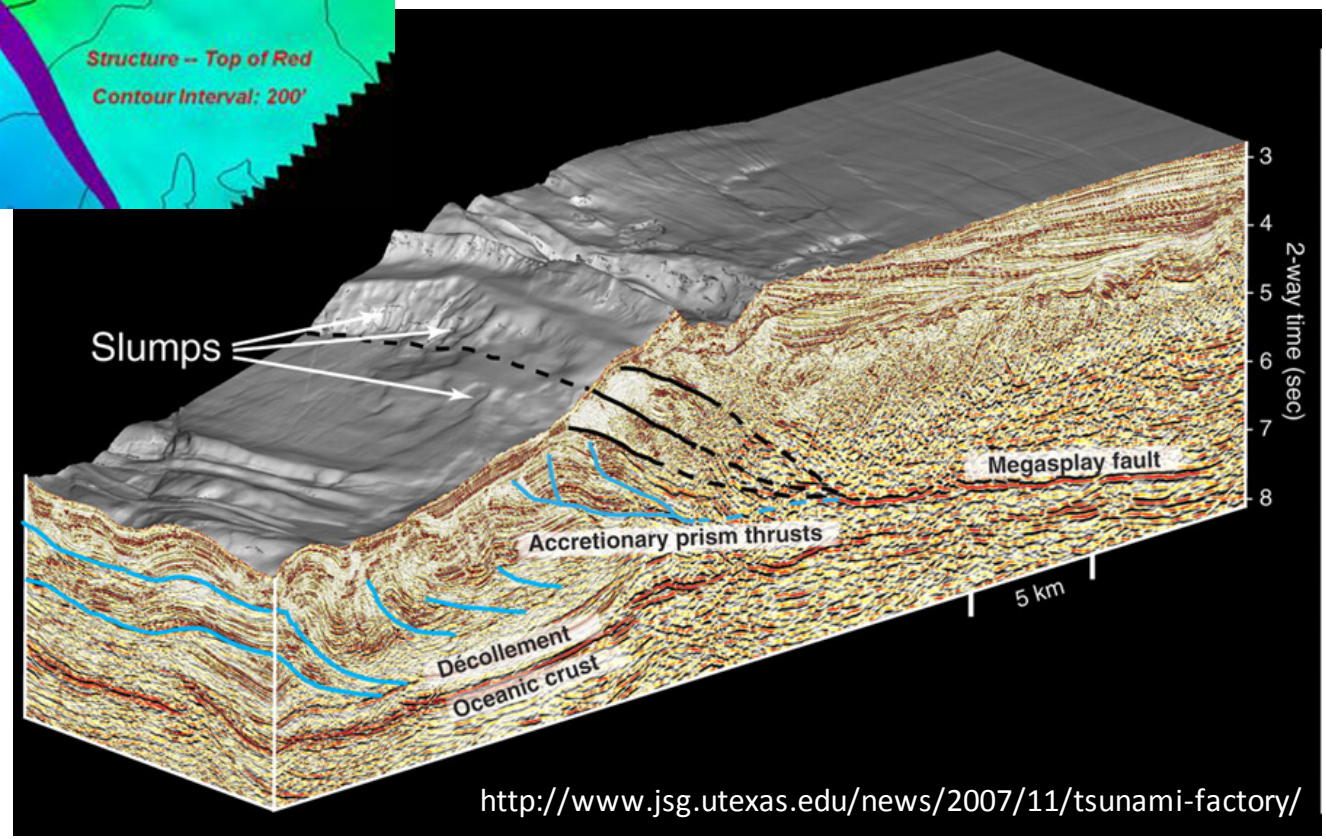
Model from Thingiverse.com

What other 3D data is difficult to communicate?

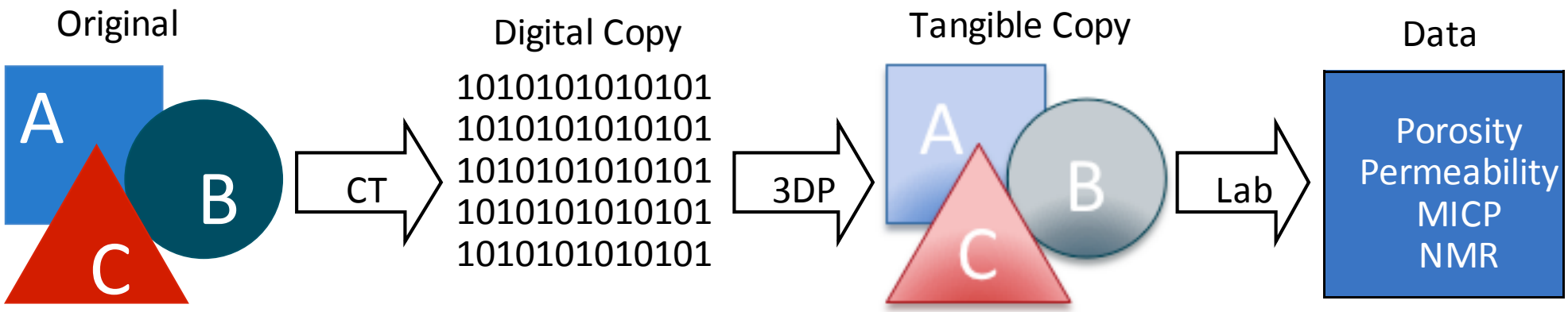


Geological Models

3D Seismic

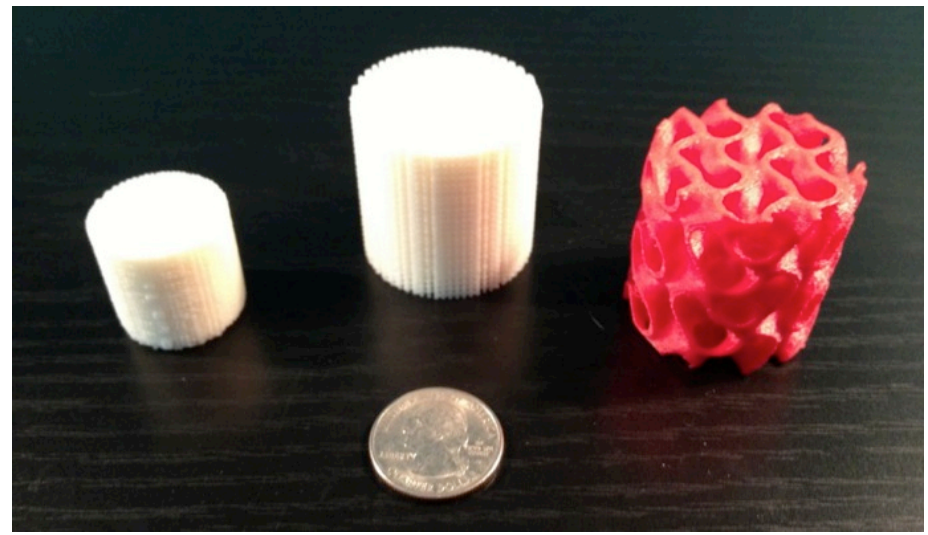


A workflow to "photocopy" rocks



- Core analysis simplifies complicated pore systems into single values (F, k) or histograms (PTSD).

- Core material is precious
- Destructive core analysis is destructive



Carbonates have many pore types

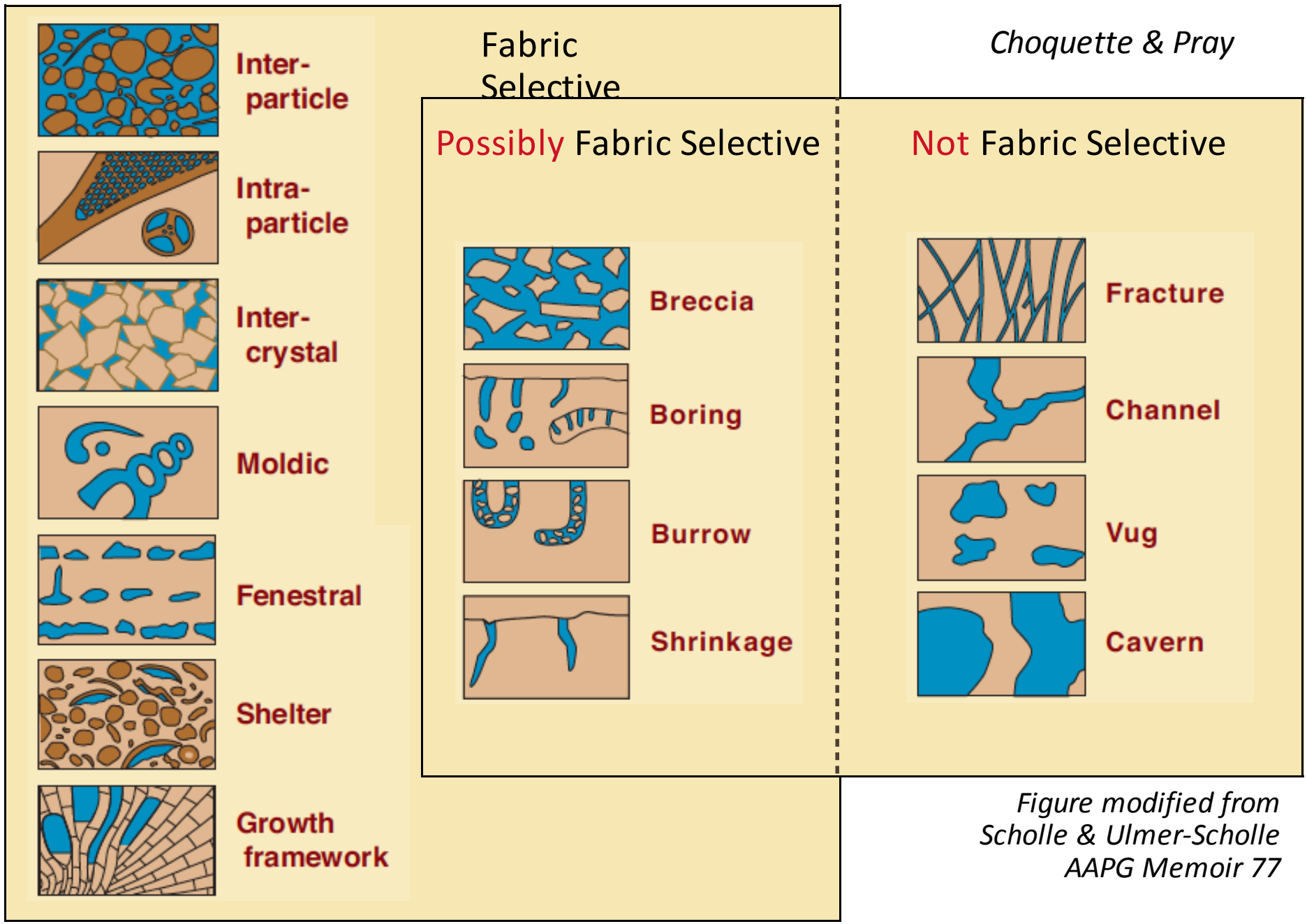
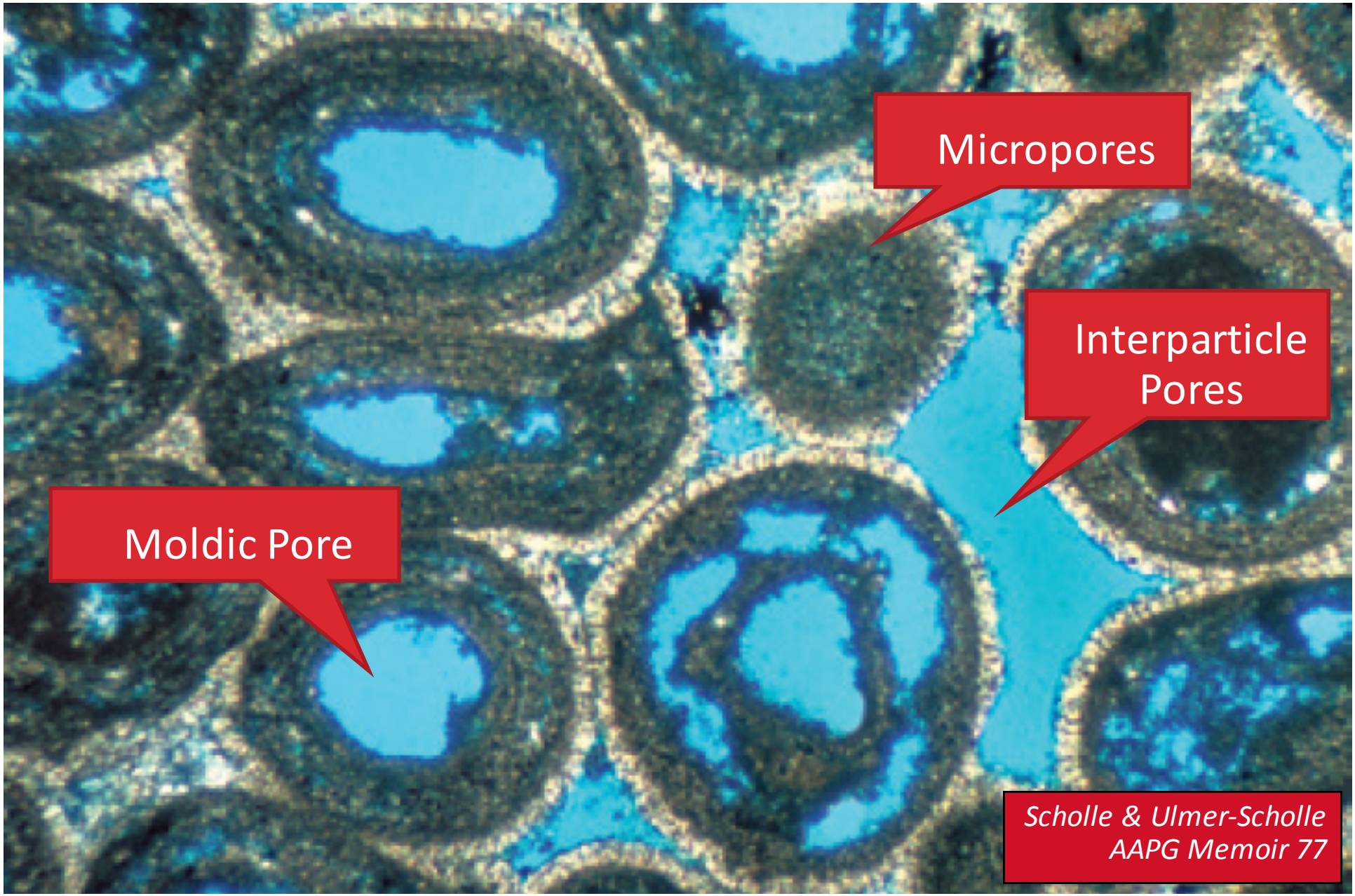
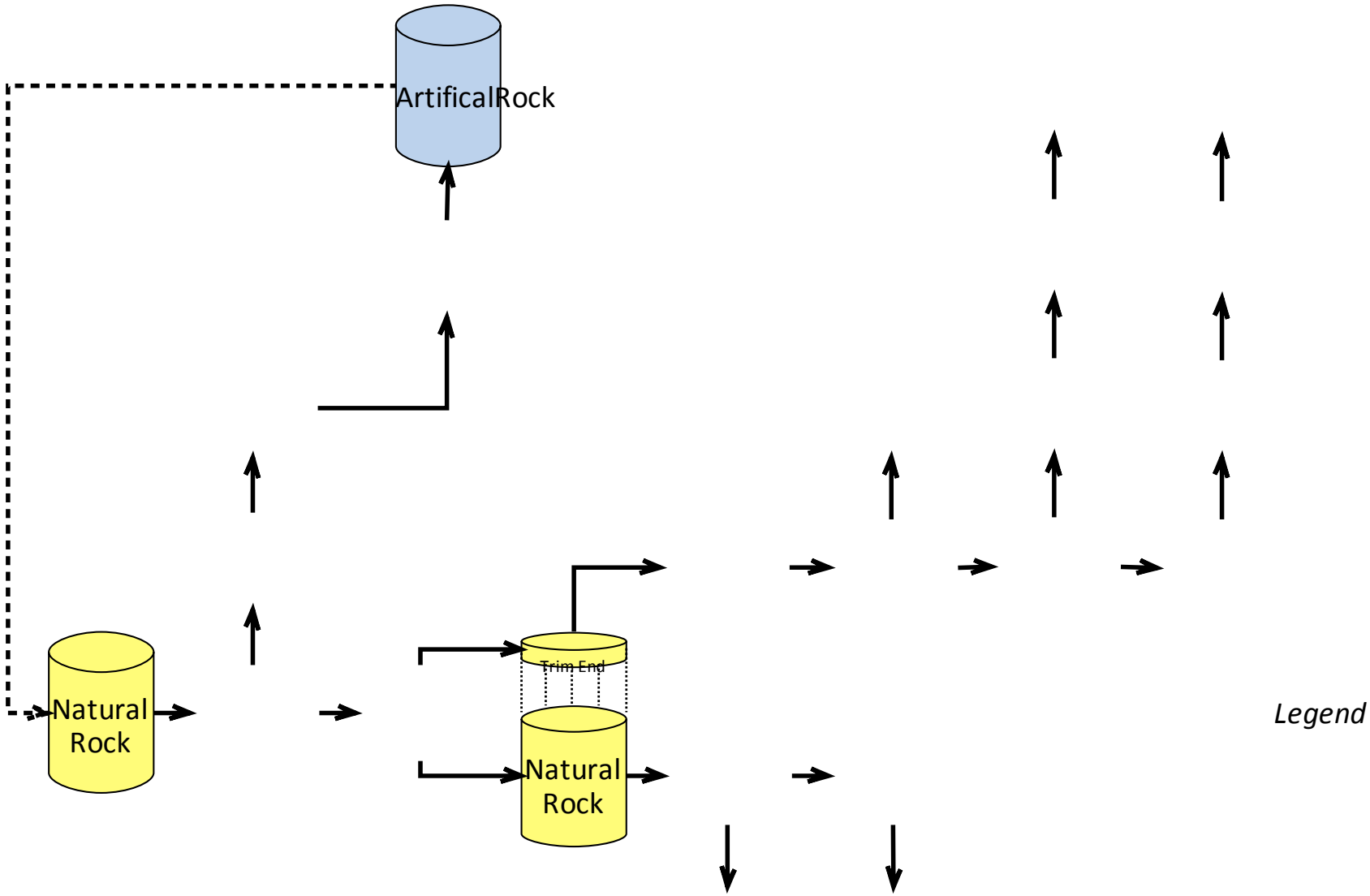


Figure modified from Scholle & Ulmer-Scholle AAPG Memoir 77

How do we deconvolve effects of pore type on flow?



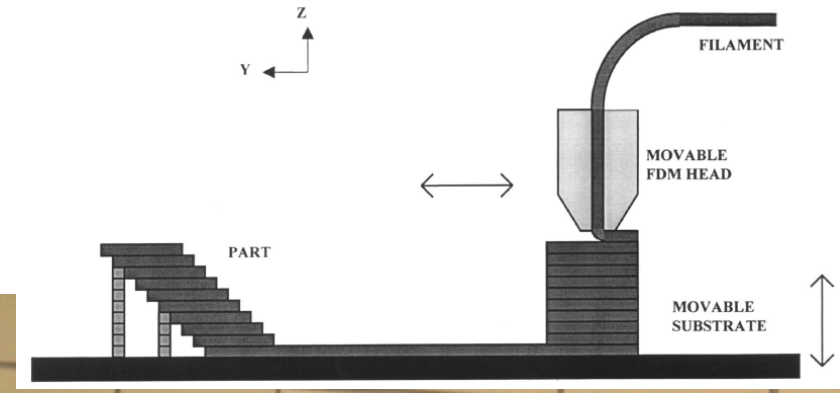
“Rock” Characterization



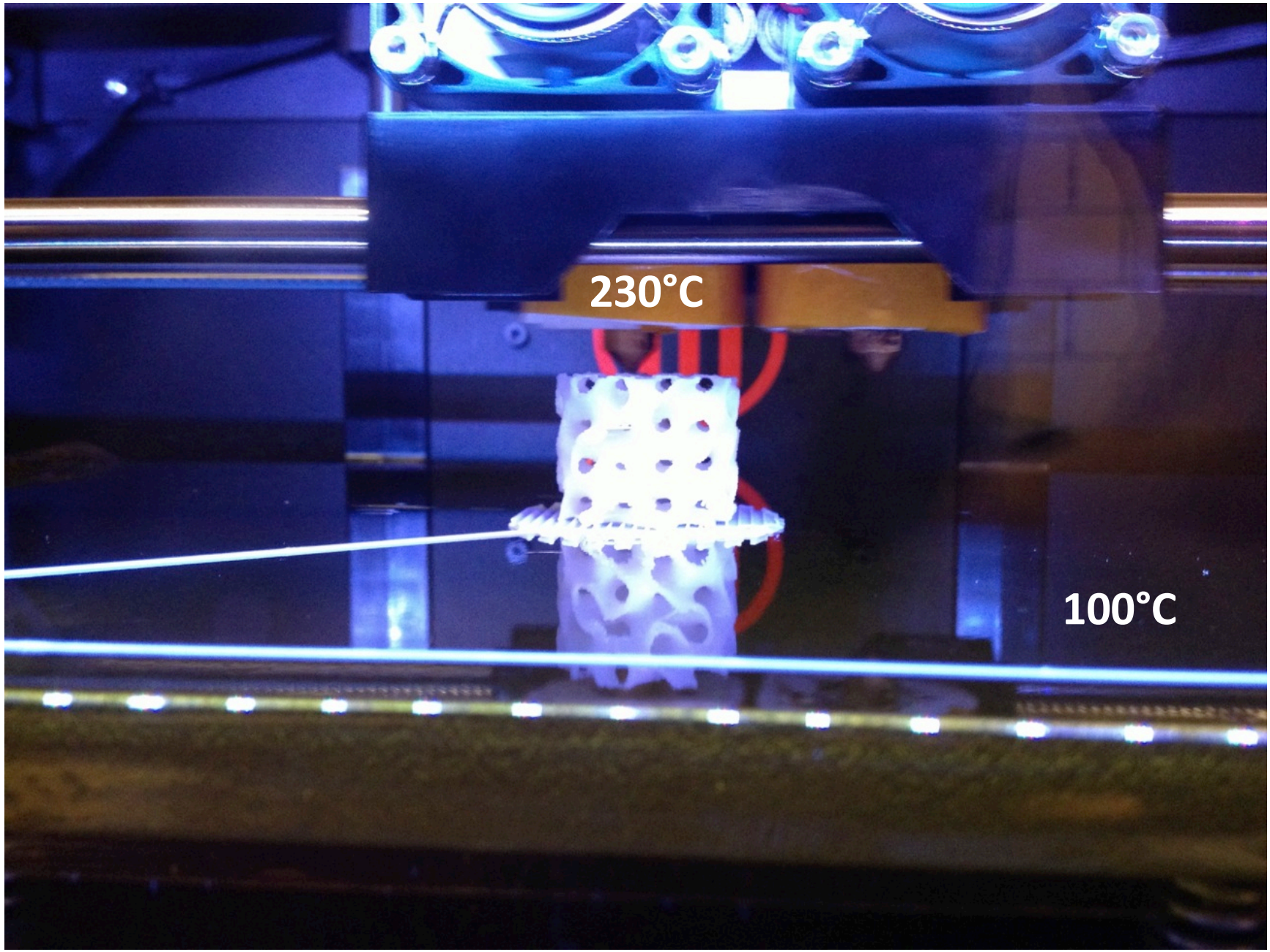
“Fancy Hot Glue Gun”

Makerbot Replicator 2X
- Fused Deposition Modeling
- 2 Print heads
- Prints *Acrylonitrile butadiene styrene (ABS)*

→ ♐♒♋♦ ☹♏♑□♦ ♋❒♏ ❍♋♎♏ □↗



3D printing in action



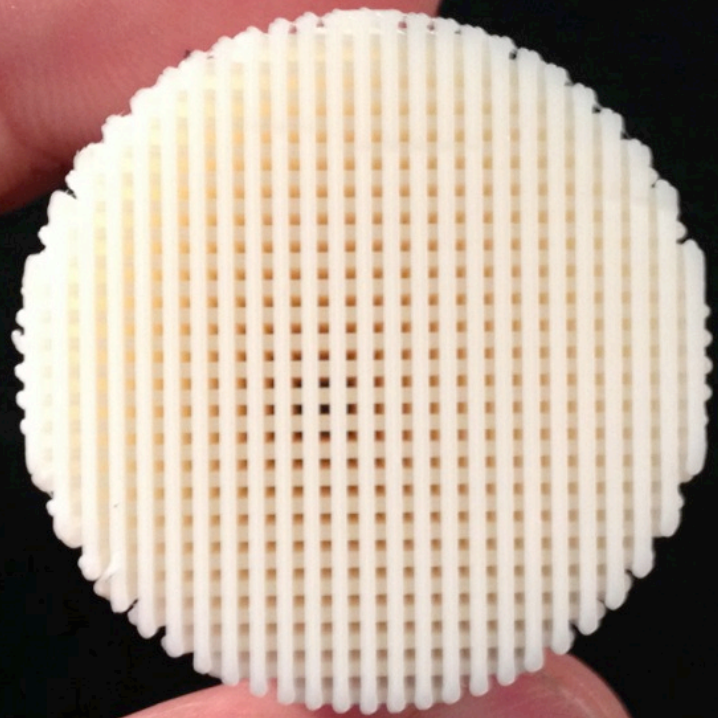
Artificial Sandstone (Very Coarse)

CAD Model

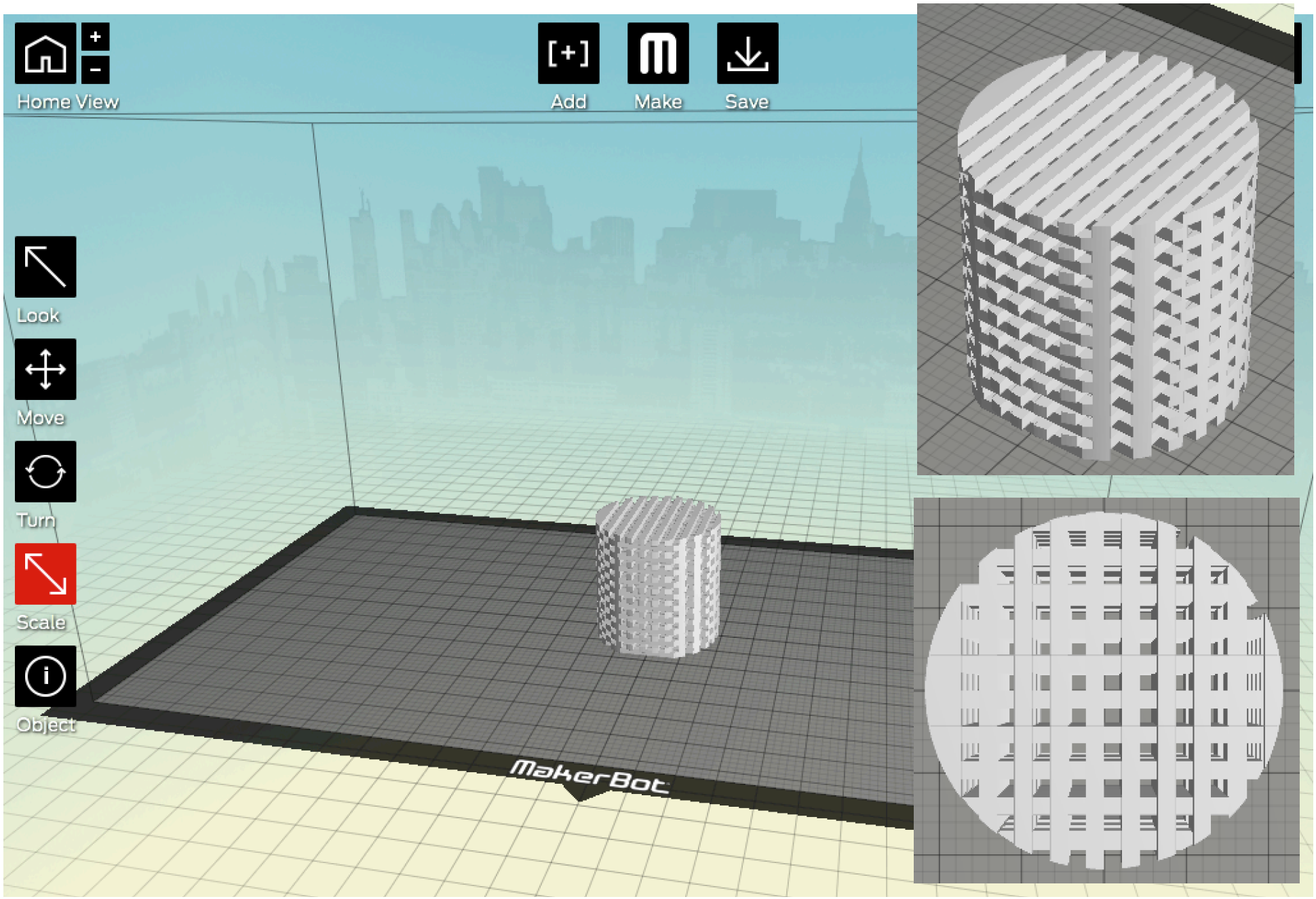
50% porosity

500 micron mesh

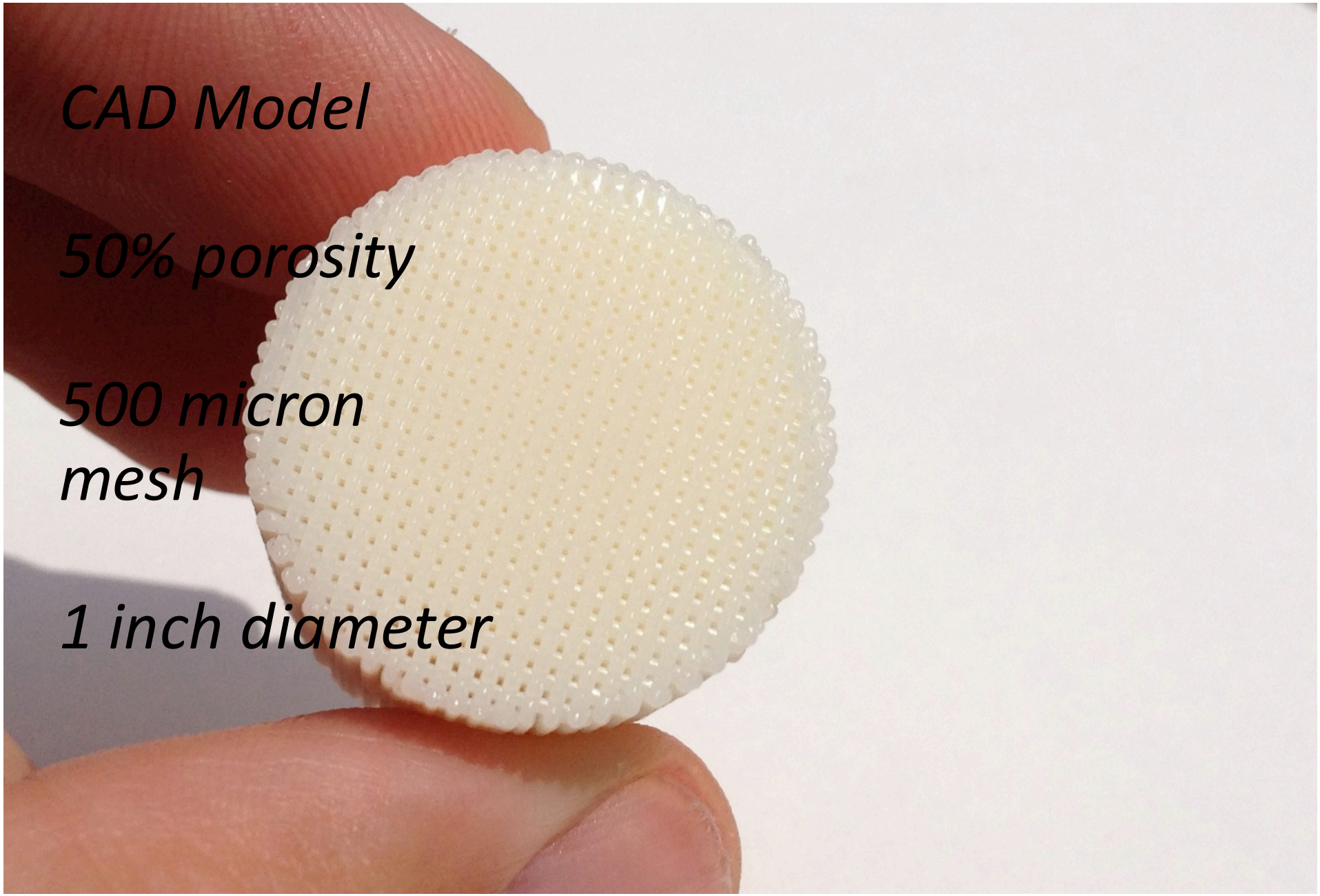
1½ inch diameter



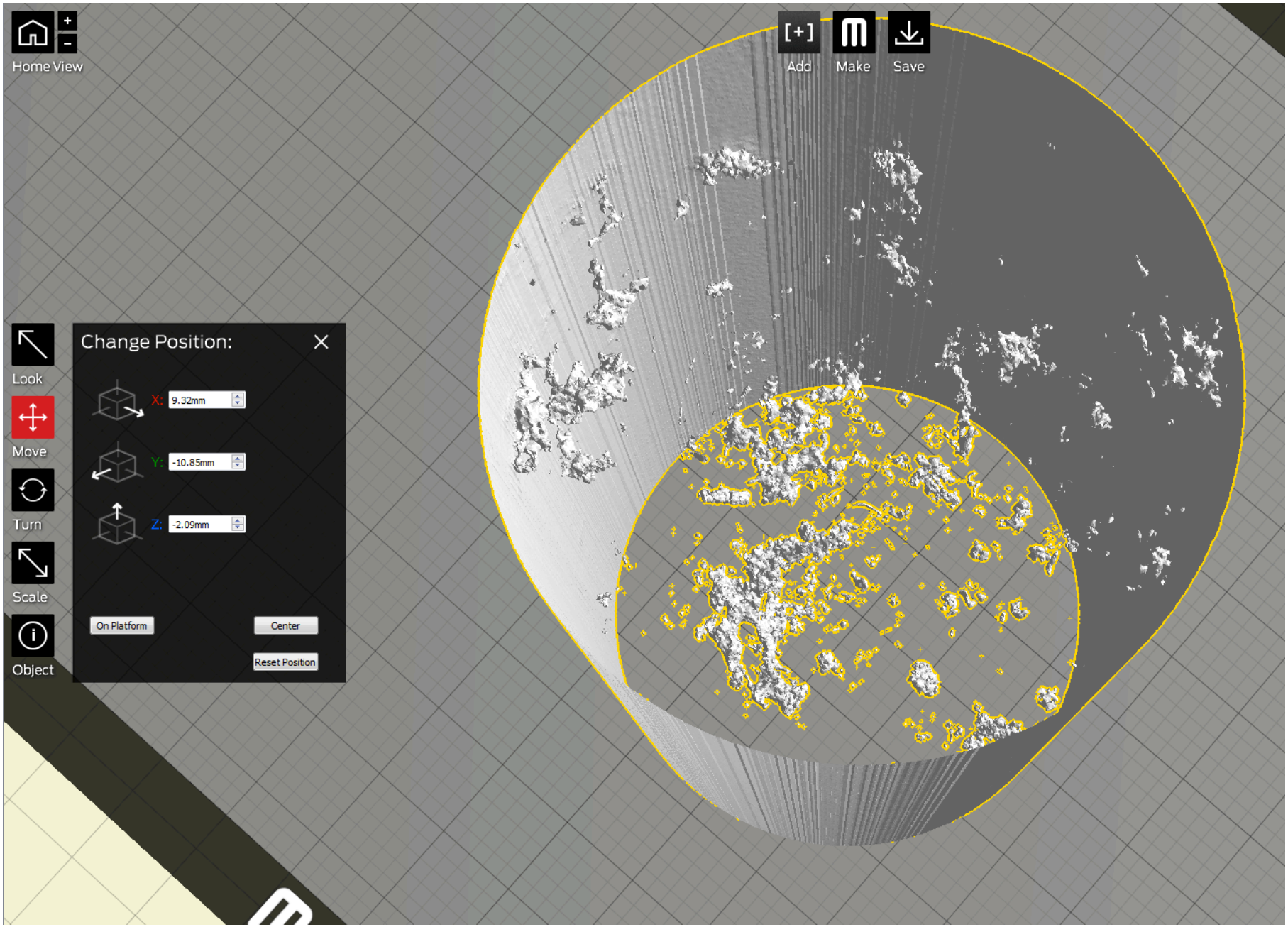
Simple Print Software



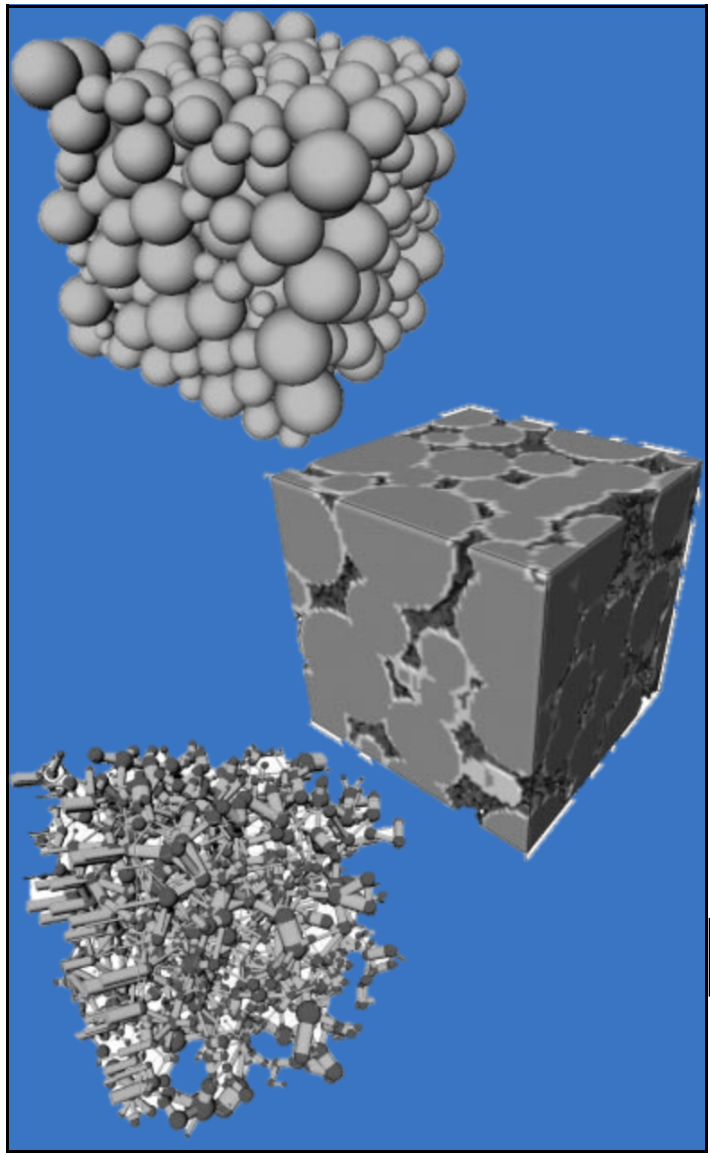
Artificial Coarse-Grained Sandstone



On-Going Research



Lab validation of digital models



Bakke and Øren, 1997

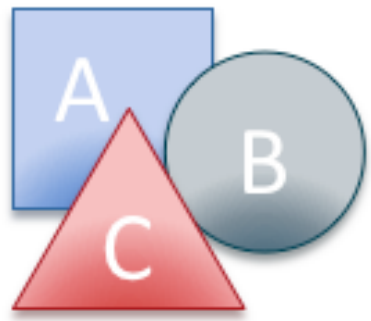
Network Analysis & Flow Simulation

Porosity
Permeability
MICP
NMR

Compa

Tangible Copy

3D Print



Lab

Porosity
Permeability
MICP
NMR

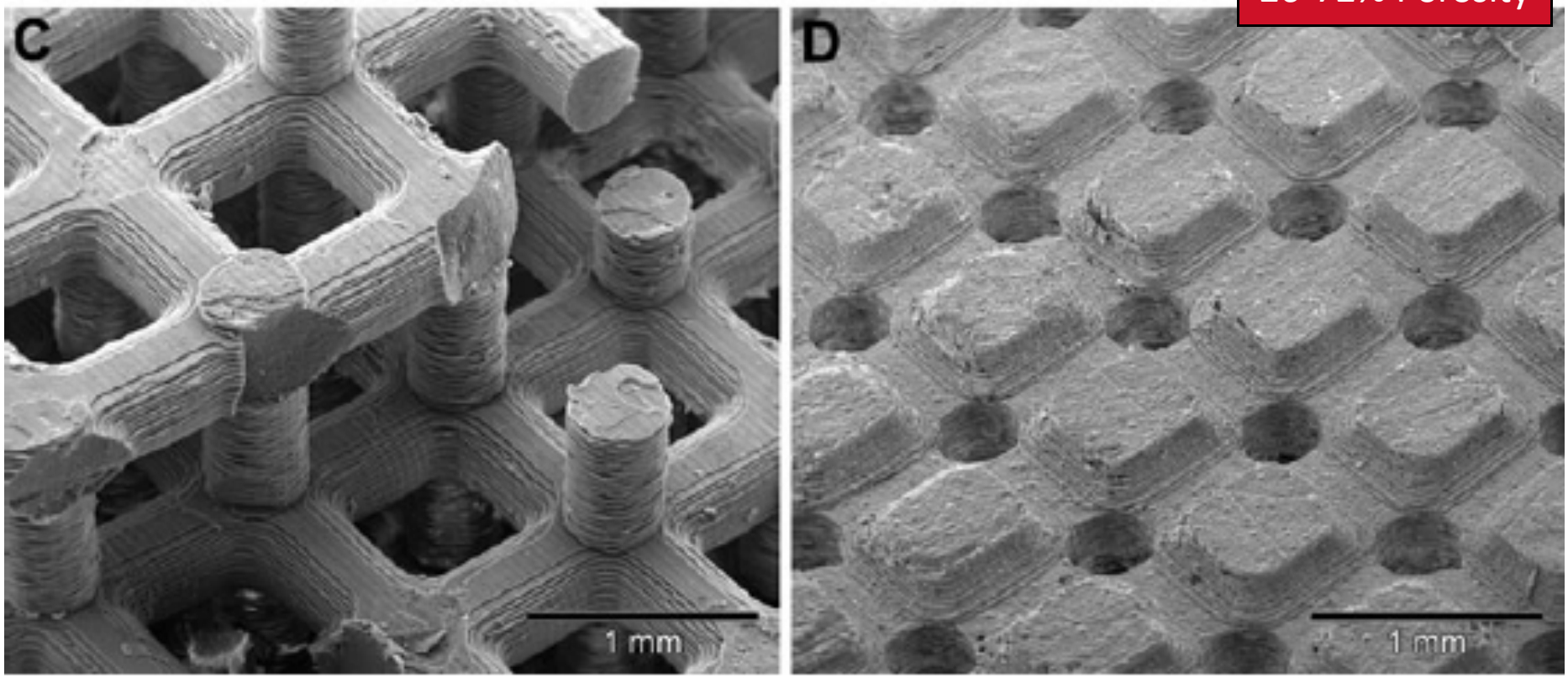
Future Directions: Printing with Minerals

J Mater Sci: Mater Med (2010) 21:3119–3127
DOI 10.1007/s10856-010-4166-6

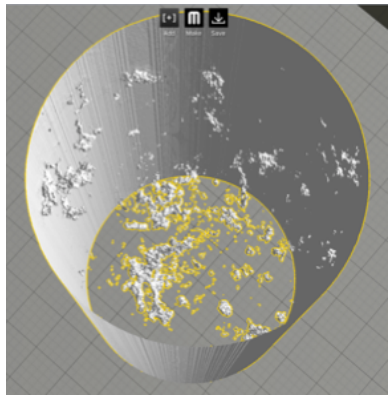
M. Schumacher • U. Deisinger • R. Detsch • G. Ziegler

Indirect rapid prototyping of biphasic calcium phosphate scaffolds as bone substitutes: influence of phase composition, macroporosity and pore geometry on mechanical properties

26-72% Porosity



GeoFabLab



Make artificial rocks

…to test hypotheses about fluid flow in porous media

Make 3D data easier to communicate and understand

…by printing data on topography

…by printing seismic and geomodels

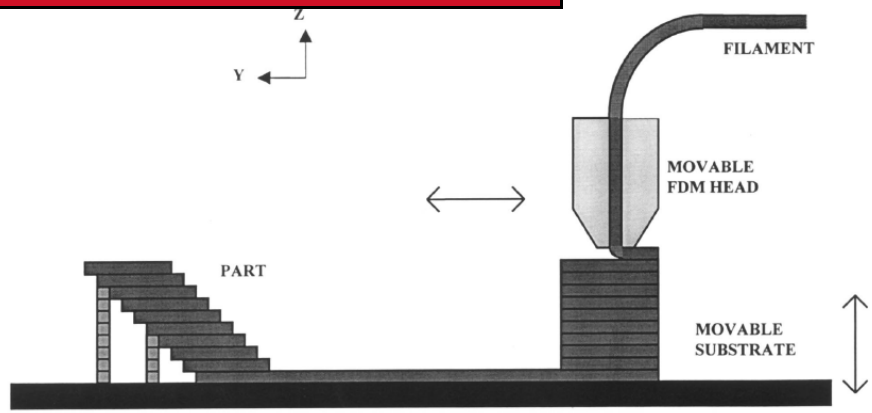
Dual Extrusion

Print with any combination of colors …including transparent

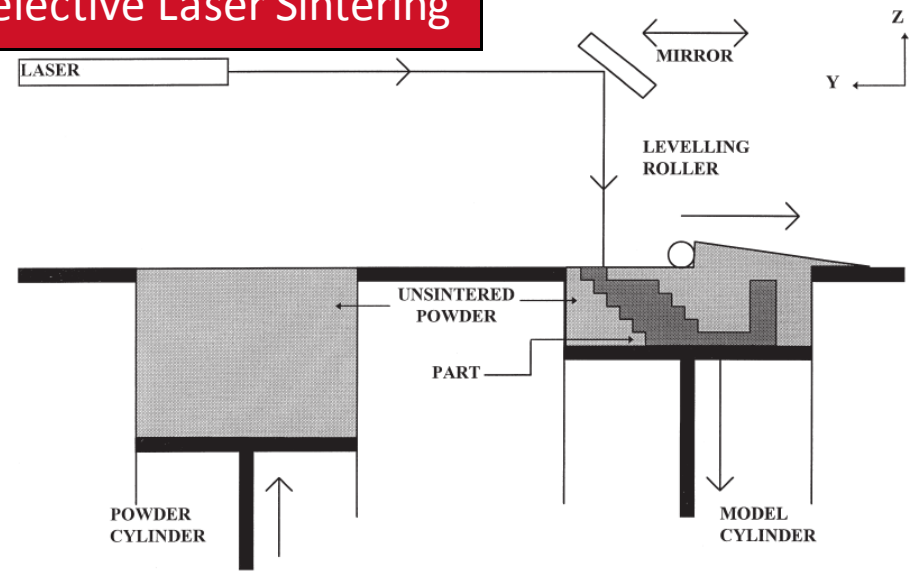
Model from Thingiverse.com

Common Rapid Prototyping Methodologies

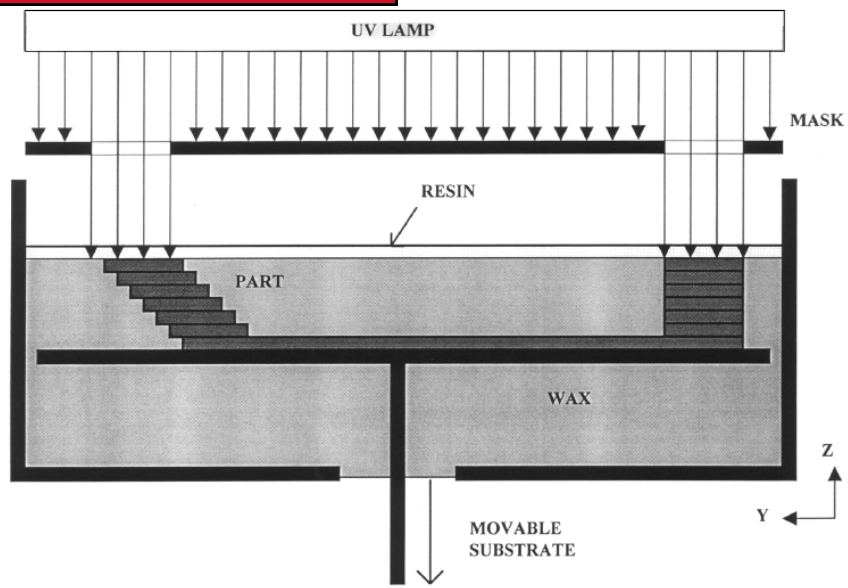
Fused Deposition Modeling



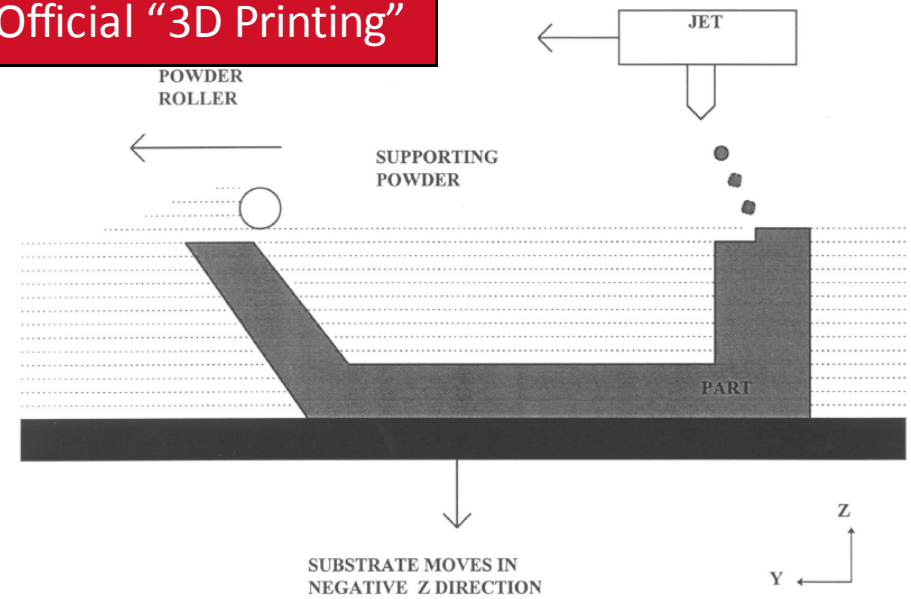
Selective Laser Sintering



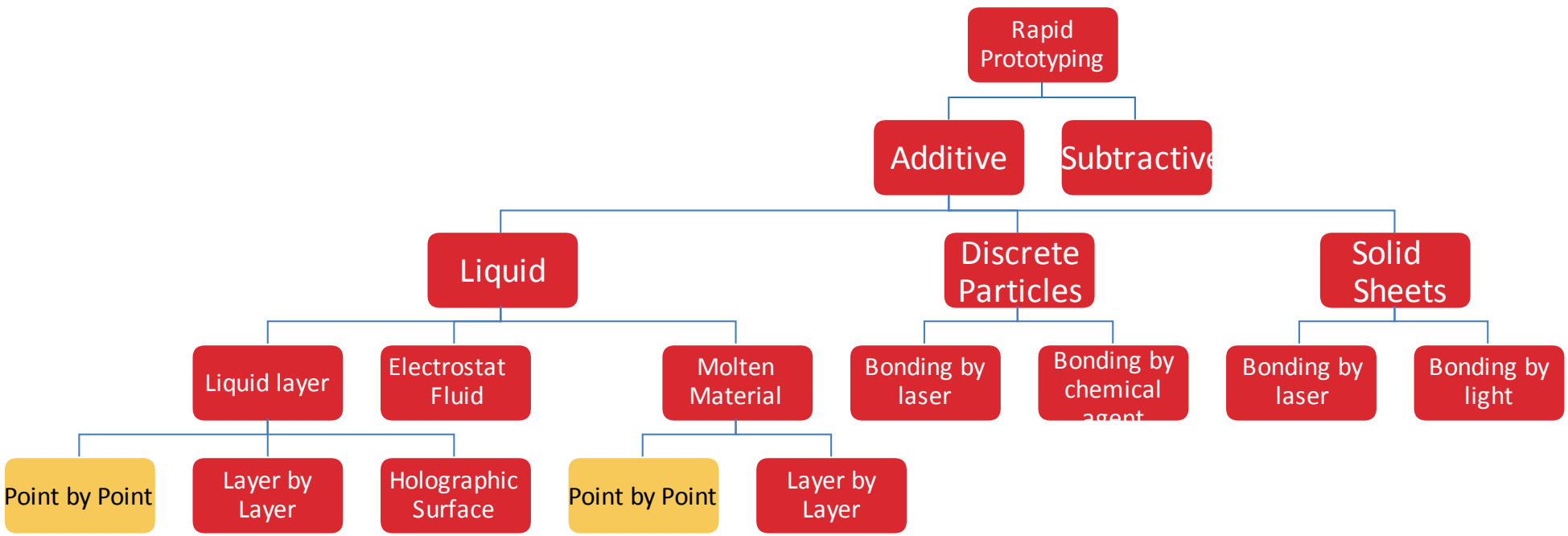
Solid Ground Curing



Official "3D Printing"



Types of Rapid Prototyping



Pham and Gault, 1998