1. Geological understanding is the point of maximum leverage.

2. The geological factors affecting resource quality and production engineering have moved from the meter scale to the centimeter or smaller scale.

3. We need to measure the things that matter at the scale that matters to power AI.
Robotized Multi-Sensor Geological Machine Vision

High-resolution non-destructive capture of structural, elemental and molecular information

- Fast, simultaneous, and precisely co-located for integrated data sets

Geoscientific Computing & AI

Data curation, visualization and analysis

- New algorithms required to work with new, large and complex data sets
- Workflow tools to make all that data useful
DIGITAL WORKFLOW – LIVE DEMONSTRATION

Digital Core Table

- Large touch enabled flat screen
- Online access
- Real time workflow
- Synchronizes with Strip Log view
IDENTIFY EACH FEATURE
Feature Map
FINDING GOLD

Where to drill

How to blast
OPTIMIZING HORIZONTAL WELLS AND COMPLEXIONS FROM CUTTINGS

HZ WELL TRAJECTORIES INTERPRETED FROM XRF DATA
NEXT STEPS: RESERVOIR MODELING

**Down-Well**
- Scanning & HR Data
  - New MV/ML solutions
  - High-res multi-sensor integrated data set
  - Lab and log data replacements
- Workflow
  - Digital core table & workflow tools
  - AI-automated description
  - Data storage, access and visualization tools
- Down Well Analytics
  - AI Solutions to better understand each well
  - Quantification of previously qualitative phenomena

**Reservoir**
- Cross-Well Analytics & Reservoir Modeling (Geospatial Context)
  - High-resolution 3D maps/models of detailed resource geology
  - Geospatial interpolation at high resolution between wells with geostatistic and geostochastic validity
  - Incorporation of other geospatial data (seismic, surface mapping)
  - (Near) real-time updating on new information

**Future Work**
- Downstream Workflows
- Reserves
- Valuation
- Optimization
- Production Modeling
  - New uses, tools and algorithms for getting value from better reservoir models
Appendix
WHY NOW

Hardware Capability
- Increasing sensor resolution and quality across electromagnetic spectrum
- Availability of sensor components and robotics for OEM integration

Cloud Computing
- Scalable on-demand storage & CPU power
- Web & mobile deployment
- Platform, open-source and 3rd party development tools and libraries

Algorithm Availability
- Big Data processing
- Machine vision
- Machine learning/AI
- GPU acceleration
- Unstructured data
- Scientific computing
Silicon Valley can provide access to the AI core:
- On-demand infrastructure (cloud/platform)
- Cutting-edge algorithms (TensorFlow, Azure ML)
- Cross-domain technology sharing (driverless cars, medicine, military, security, etc.)

Each domain needs to:
- Identify the main problems and opportunities
- Collect the data needed to actually solve the problem
- Modify the algorithms to solve industry-specific problems
- Build tools to transition workflows
- Manage people and culture
SCANNING PLATFORM & SENSORS

Describing what I do to my mom: 

“Robots With Fancy Cameras Taking Pictures of Rocks”

Robots = Fast, Precise, Accurate & Cheap
Fancy Cameras = High Res + Meaningful Degrees of Freedom

Really good photography for structure.
Infrared spectroscopy for molecular analysis.
X-ray fluorescence for elemental analysis.
+ More (gamma, laser profiling, thermal, etc.)

Fast + Cheap + Meaningful Data = Fuel for AI
MACHINE VISION & AI

• Extracting useful information from spatial data.
• Focus on identifying and describing features.
• Humanly impossible speed, scale and consistency.
• Borrow from medicine and other domains.
• Innovations in factoring in geostatistics, multi-dimensionality, and multi-scale aspects.
HIGH-RESOLUTION PHOTOGRAPHY

Conventional core photo

Enersoft core photo

- Stitched whole-core photography to get 100+ times the resolution as an overhead shot from the same camera.
- Achieve full-core microscopy at <20um/pixel.
- Custom spot sensors <1um/pixel
INFRARED SPECTROSCOPY

• In the short wave infrared (SWIR) specific wavelengths are absorbed through resonance vibration of different combination of non-parallel molecular bonds.

• Infrared spectroscopy captures and analyzed the relative reflectance/absorbance at individual wavelengths.

• Can detect CH, OH, and other bonds and therefore key rock properties such as hydrocarbon saturation.
HYPERSPECTRAL DATA & USES
XRF detectors measure the specific photonic energies, unique for each element, released when outer-orbit electrons to ‘fall’ into lower orbitals vacated by inner-orbit electrons bombarded with high-energy X-rays.
XRF RESULTS

Multi-Element Fluorescence from $^{109}\text{Cd}$

Counts

Energy (keV)

$^{109}\text{Cd}$ Excitation Source

22.1 keV

25 keV

K, Ti, Fe, Mn, Cu, Ni, Pb, Au, Rb, Zr, Mo
MORE THAN JUST FEATURES

Machine Vision:

Dumb AI: 4 sheep - meh

Smart AI: 4 sheep stacked in a tower formation! – probably something worth looking into

Intelligence requires understanding how adjacent individual features scale up in context in meaningful ways
INCREASING THE VALUE OF EACH GEOLOGIST

Exoskeleton
Augmentation of biological limits on strength, speed and endurance for physical tasks

Artificial Intelligence
Augmentation of biological limits in focus, memory, speed and endurance for mental tasks