Virtual Fieldtrips for Petroleum Engineers:

Challenges and prospects in a post-COVID world

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Summary

- The role of fieldwork within the applied geosciences and petroleum engineering
- In the virtual field: *from rigs to* [geological] *riches*
  - *Data capture*
  - *Data visualization and analysis*
- Prospects of virtual fieldtrips in subsurface engineering education

Fieldwork in Subsurface Education

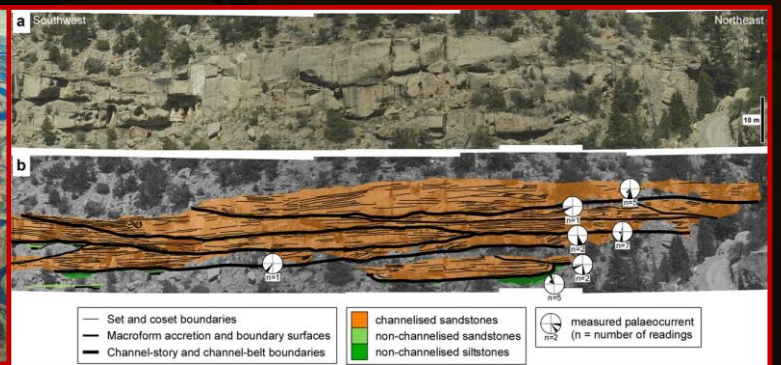
Fieldwork for Petroleum Engineers

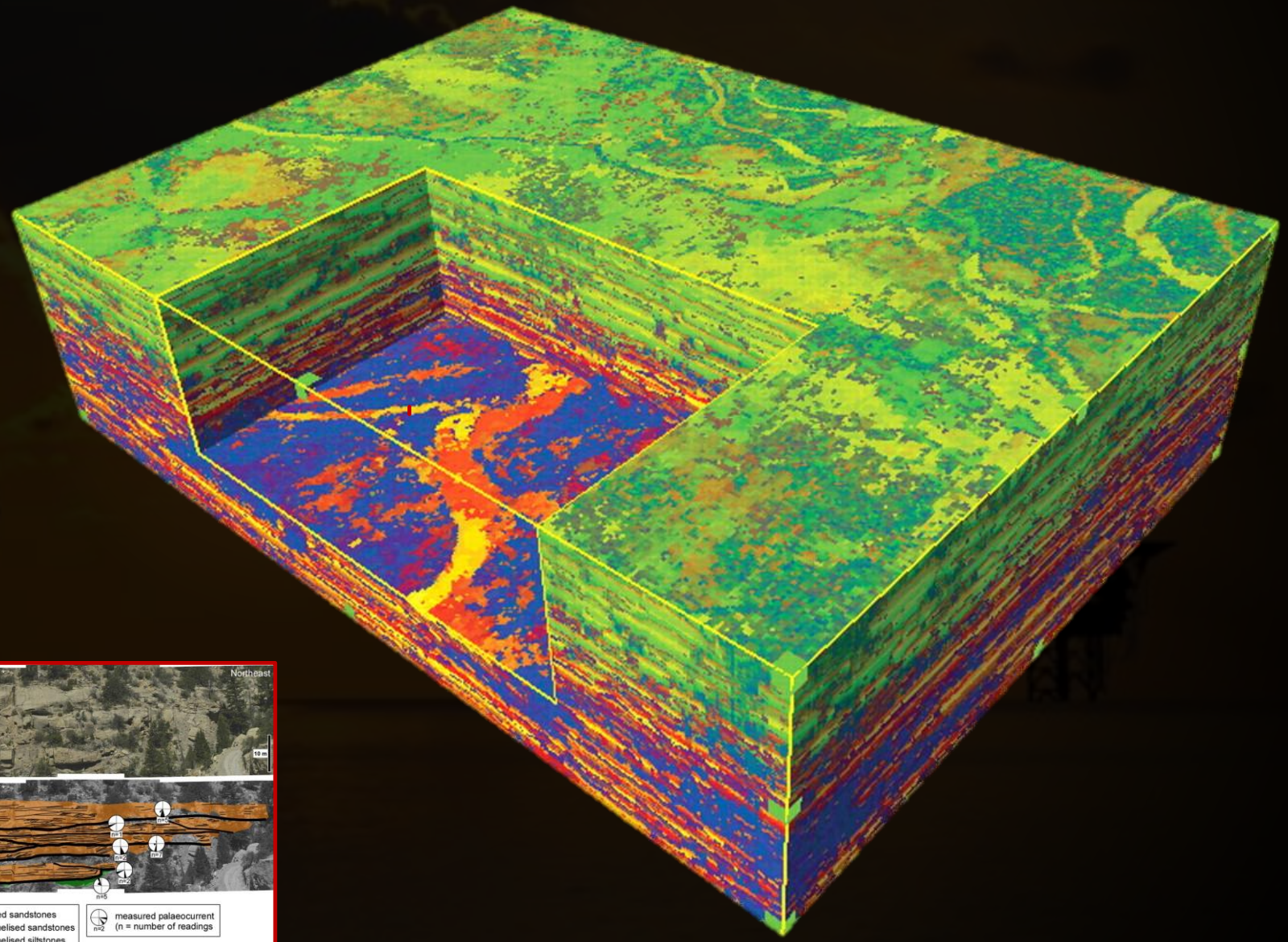
Fieldwork to be an essential component of petroleum engineering education, providing tangibility to study materials presented in the classroom

- Brings field operations and materials (e.g. drilling, rig components, lab analyses) to life
- *Opportunity to experience geology first hand**

Sources of Uncertainty: *Seismic Resolution*

- Seismic data has revolutionized E&P
- However, due to resolution limitations (voxel size: ~12 m edge length), we are not able to resolve sedimentary and structural architecture at a scale that impacts upon the movement of oil and gas in the subsurface





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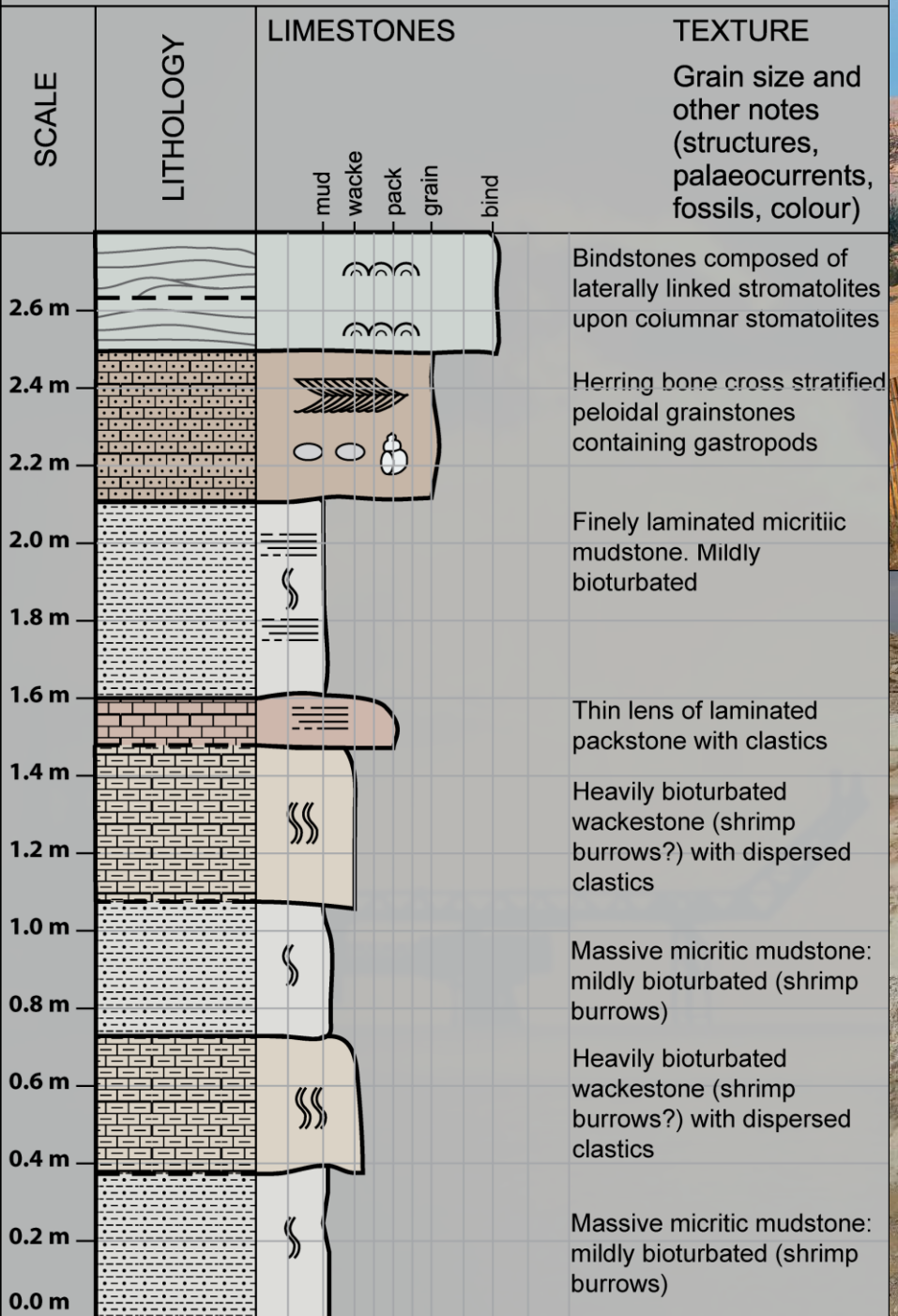

SCALE
LITHOLOGY
LIMESTONES
mud
wacke
pack
grain
bind
TEXTURE
Grain size and other notes (structures, palaeocurrents, fossils, colour)
2.6 m
2.4 m
2.2 m
2.0 m
1.8 m
1.6 m
1.4 m
1.2 m
1.0 m
0.8 m
0.6 m
0.4 m
0.2 m
0.0 m
Bindstones composed of laterally linked stromatolites upon columnar stomatolites
Herring bone cross stratified peloidal grainstones containing gastropods
Finely laminated micritiic mudstone. Mildly bioturbated
Thin lens of laminated packstone with clastics
Heavily bioturbated wackestone (shrimp burrows?) with dispersed clastics
Massive micritic mudstone: mildly bioturbated (shrimp burrows)
Heavily bioturbated wackestone (shrimp burrows?) with dispersed clastics
Massive micritic mudstone: mildly bioturbated (shrimp burrows)

Geological Fieldwork

Geological fieldwork is critical for learning subsurface disciplines. Students cannot readily appreciate the complexity and scale of the Earth's structure from lecture material or textbooks alone: "The best geologist is he [*or she*] who has seen the most rocks." Herbert Harold Read c. 1957.

Geological Fieldwork

For geologists, fieldwork provides the opportunity for *case based reasoning (CBR)*, whereby we draw from multiple instances of a phenomena, combining elements from the multiple experiences as problem solving tool.

Aeolian deposits of the Dam Formation, SW Qatar (Early Miocene: ~ 20 Ma) ↓

Geological Fieldwork

For geologists, fieldwork provides the opportunity for *case based reasoning (CBR)*, whereby we draw from multiple instances of a phenomena, combining elements from the multiple experiences as problem solving tool.

Fluvial deposits, of the Hofuf Formation SW Qatar (Late Miocene: ~ 5 Ma) ↓

Virtual Fieldwork

Digital Outcrop Data Capture

Digital Outcrop Data Capture

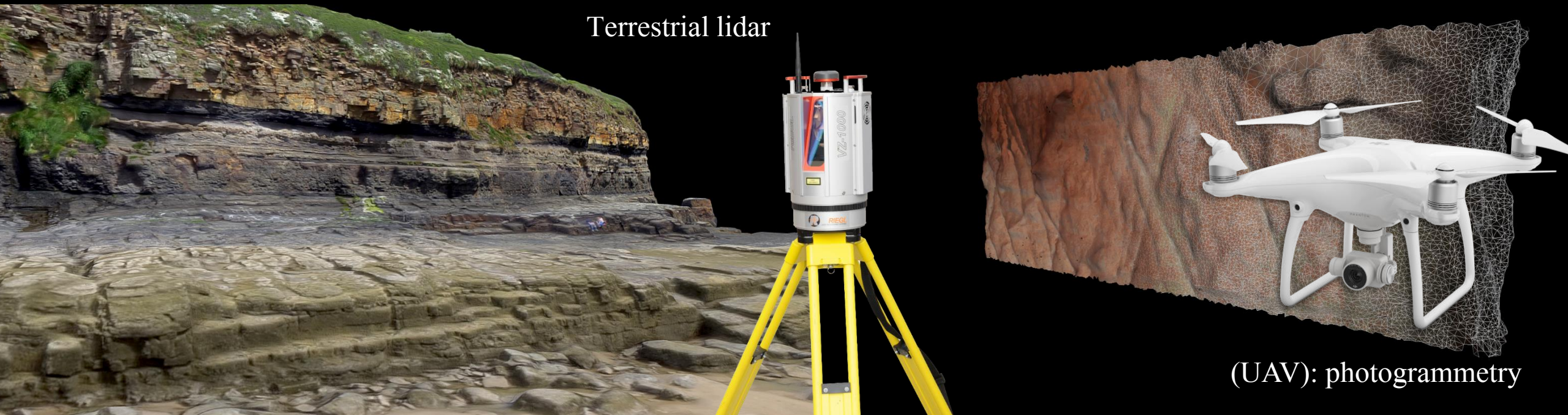
Produces fully interrogatable models… we can measure stuff

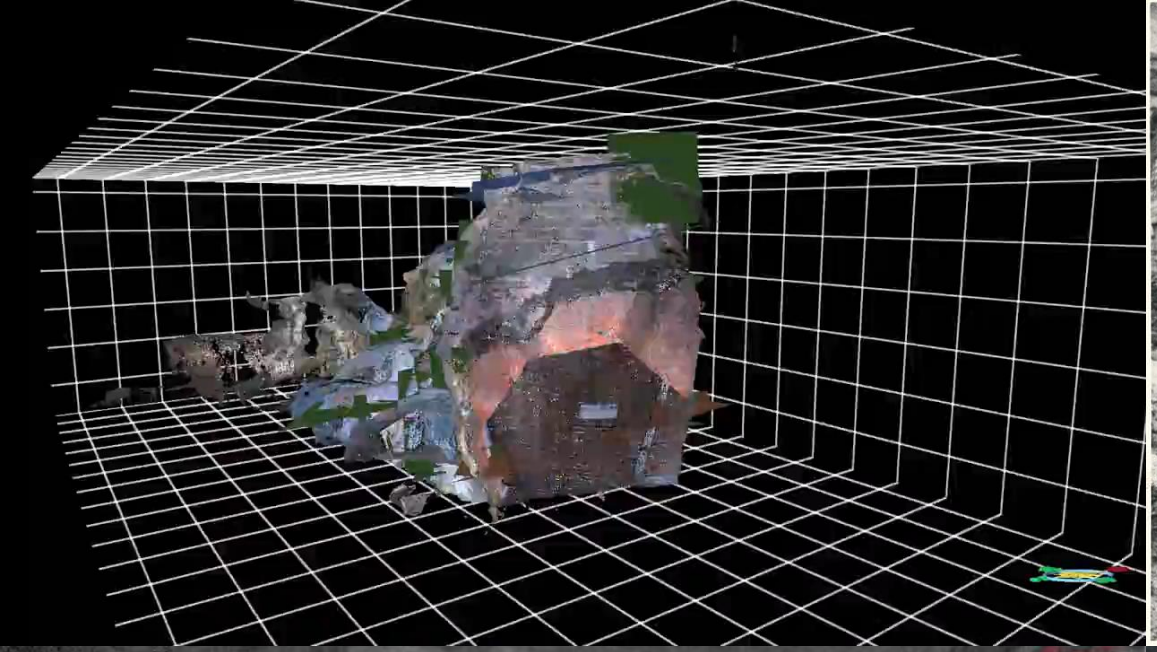
Permits measurements away from the outcrop edge… we can measure stuff safer

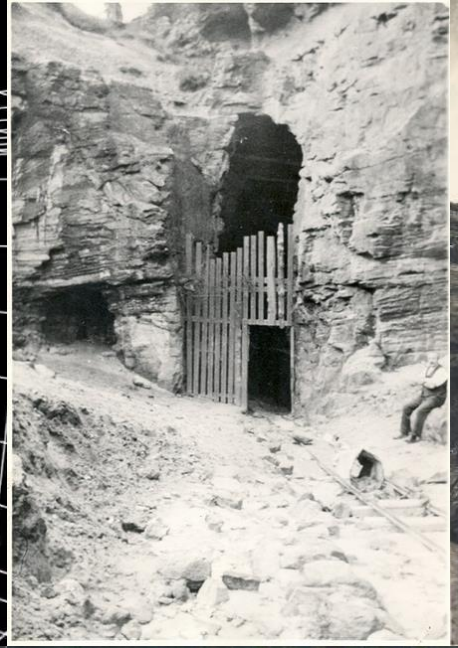
Allows mapping of geology away from the field… we can measure more stuff

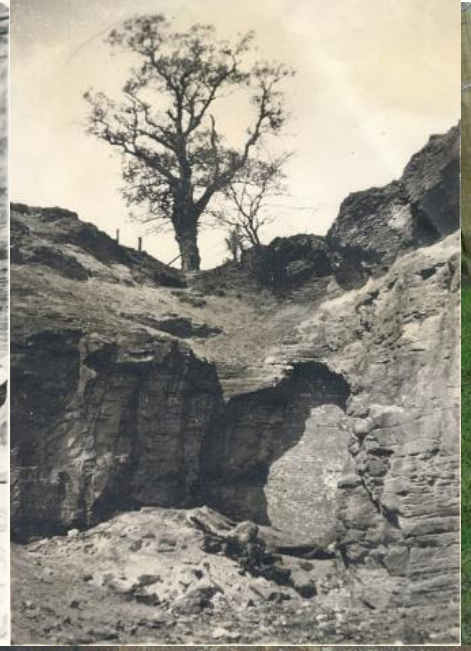
Enables greater access to the sampling domain… we can measure even more stuff

Amenable to numerical techniques… we can measure stuff faster and smarter

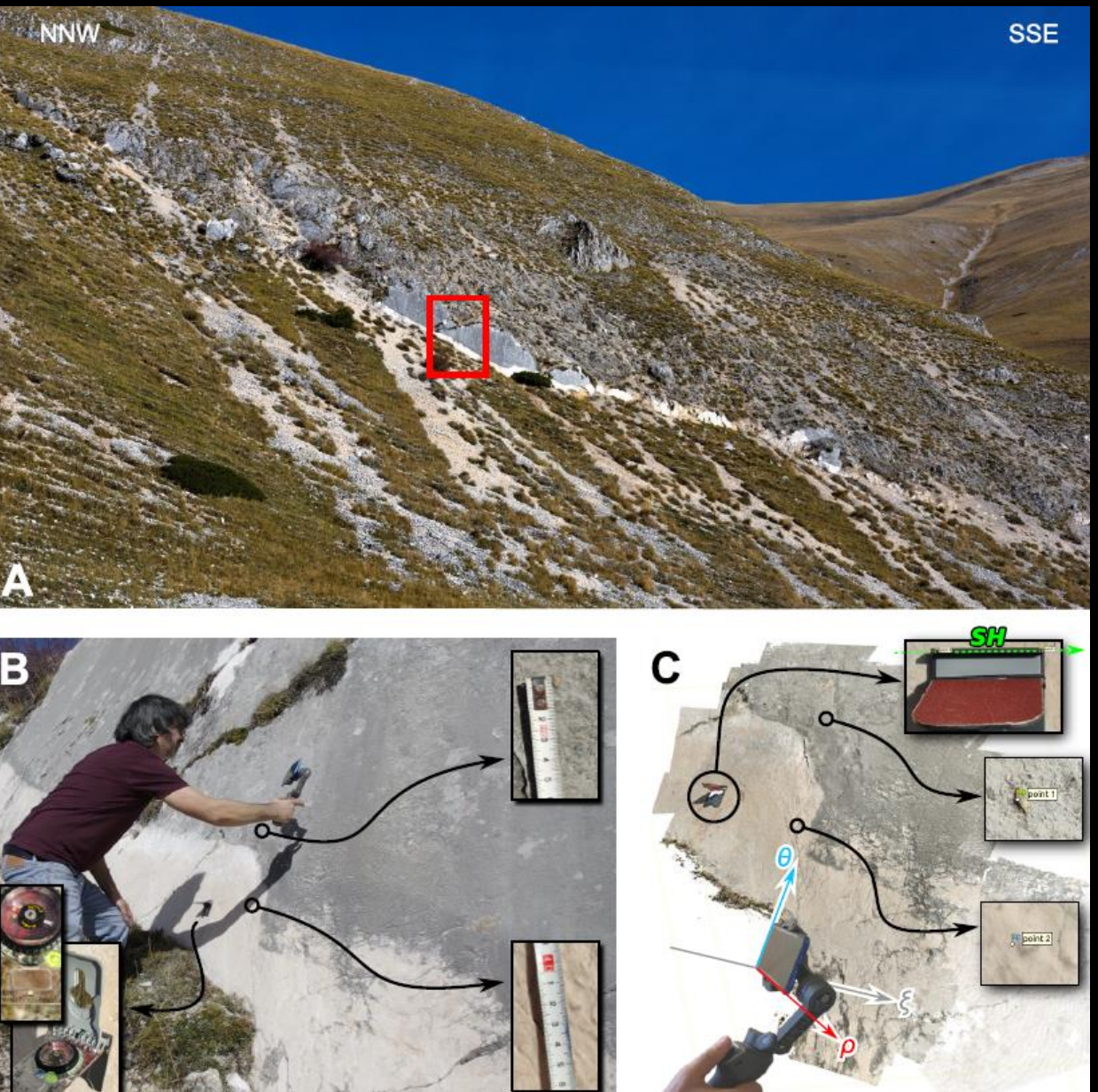








Digital Data Capture for All

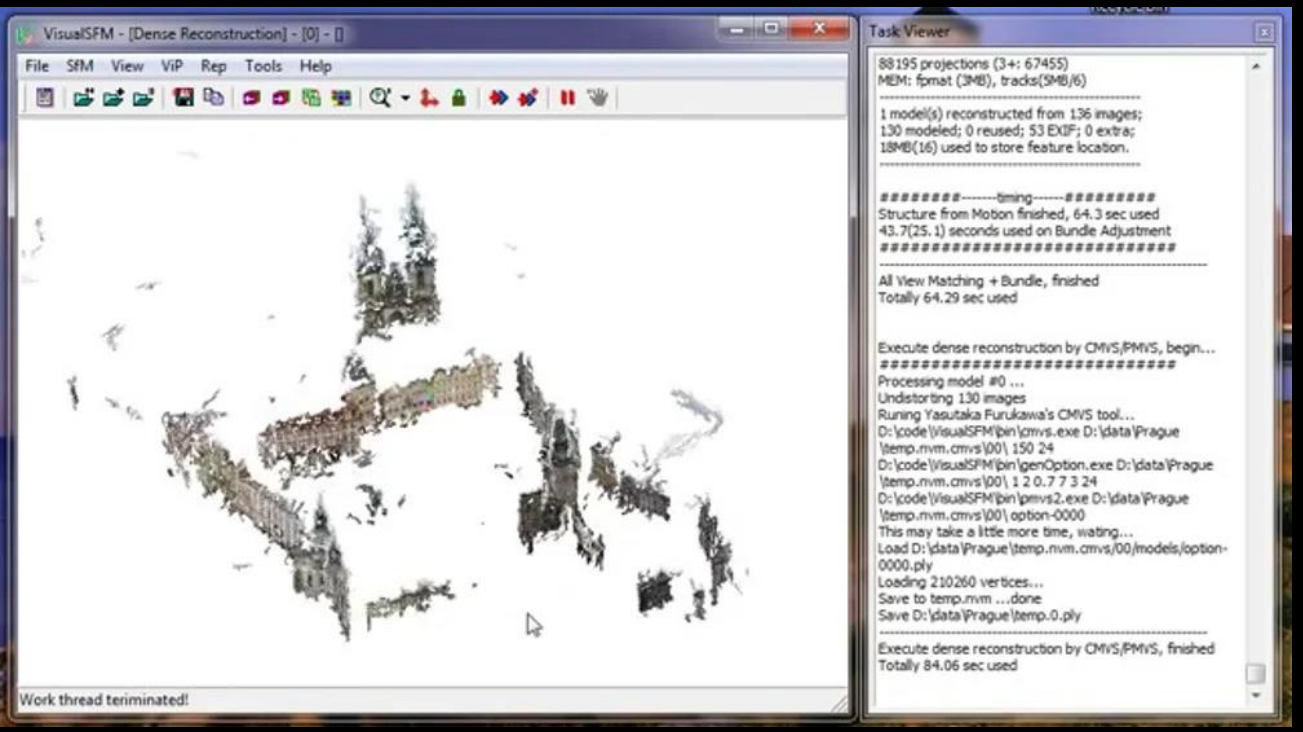


Improvements in smartphone cameras and sensors (IMUs / GNSS) now permit the capture of digital data capture with minimal equipment

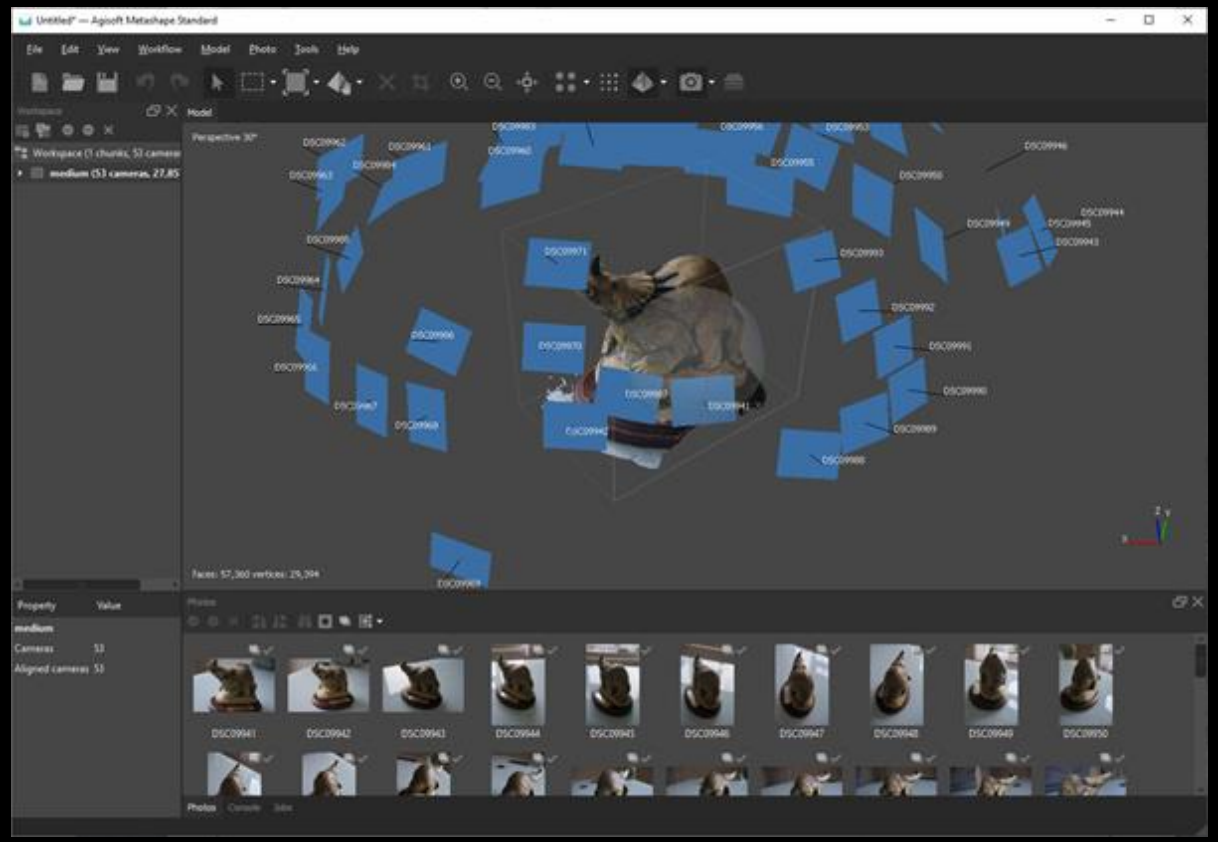
Utilizing these integrated sensors (esp. the magnetometer and inclinometer [rotational acceleration]) solves one of the major bottlenecks in 3D close range remote sensing: *model georeferencing (Tavani et al. 2019; 2020a, 2020b; Corradetti et al. [in-review])*

Digital Data Capture for All

Several free or low cost solutions for photogrammetric 3D modelling are available: Visual SfM [free], 3D Zephyr [free limited version / paid full version], Agisoft Metashape [commercial: ~$200]



VisualSfM

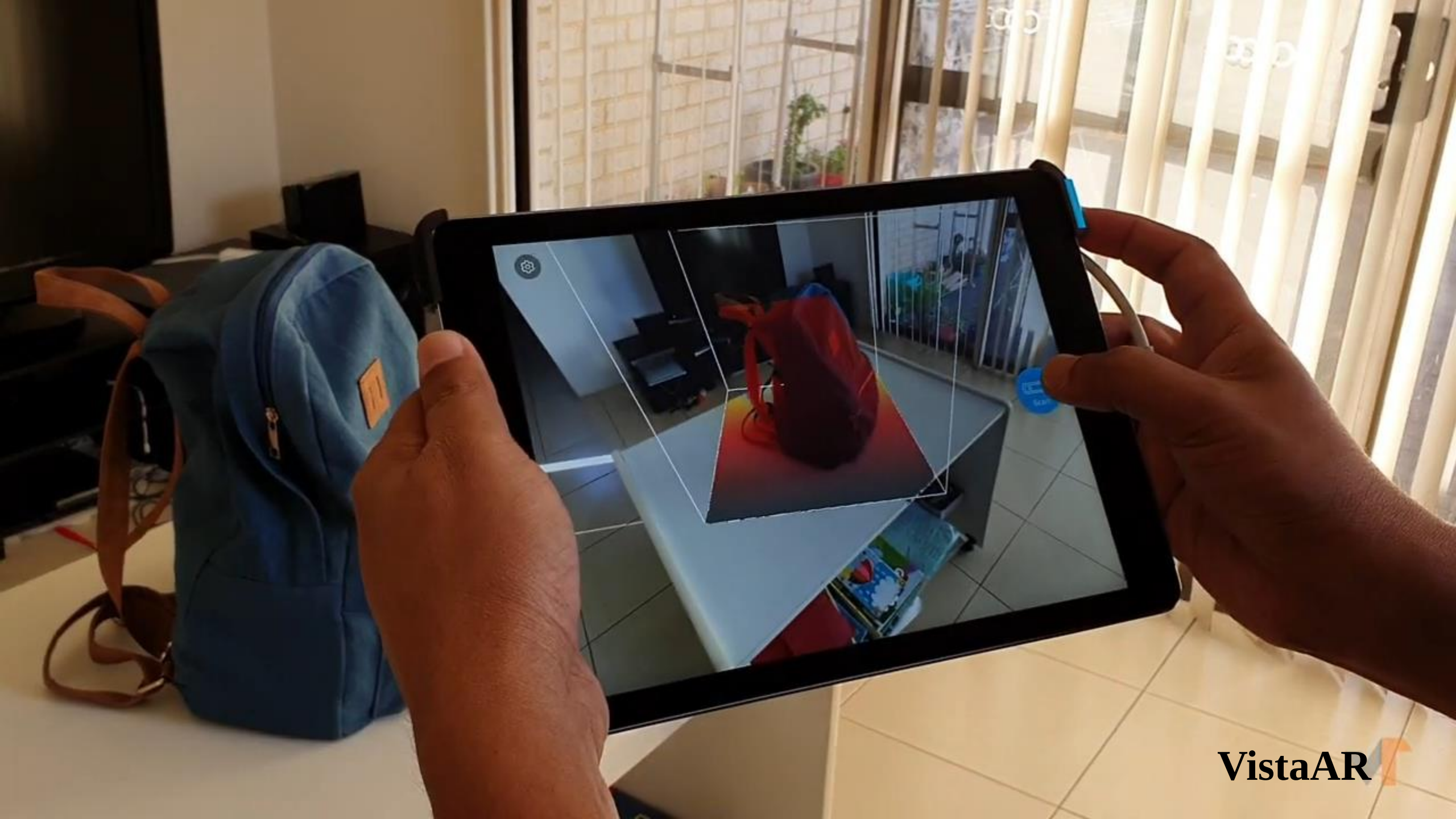


Agisoft Metashape

Digital Data Capture for All

Emerging technologies, such as mobile lidar scanning (Apple iPad Pro, iPhone 12 Pro / Pro Max) and structured light (e.g. Occipital Structure Sensor II) promise to make 3D modelling techniques even more accessible. These systems provide instantaneous results (i.e. compared to SfM-MVS photogrammetry)

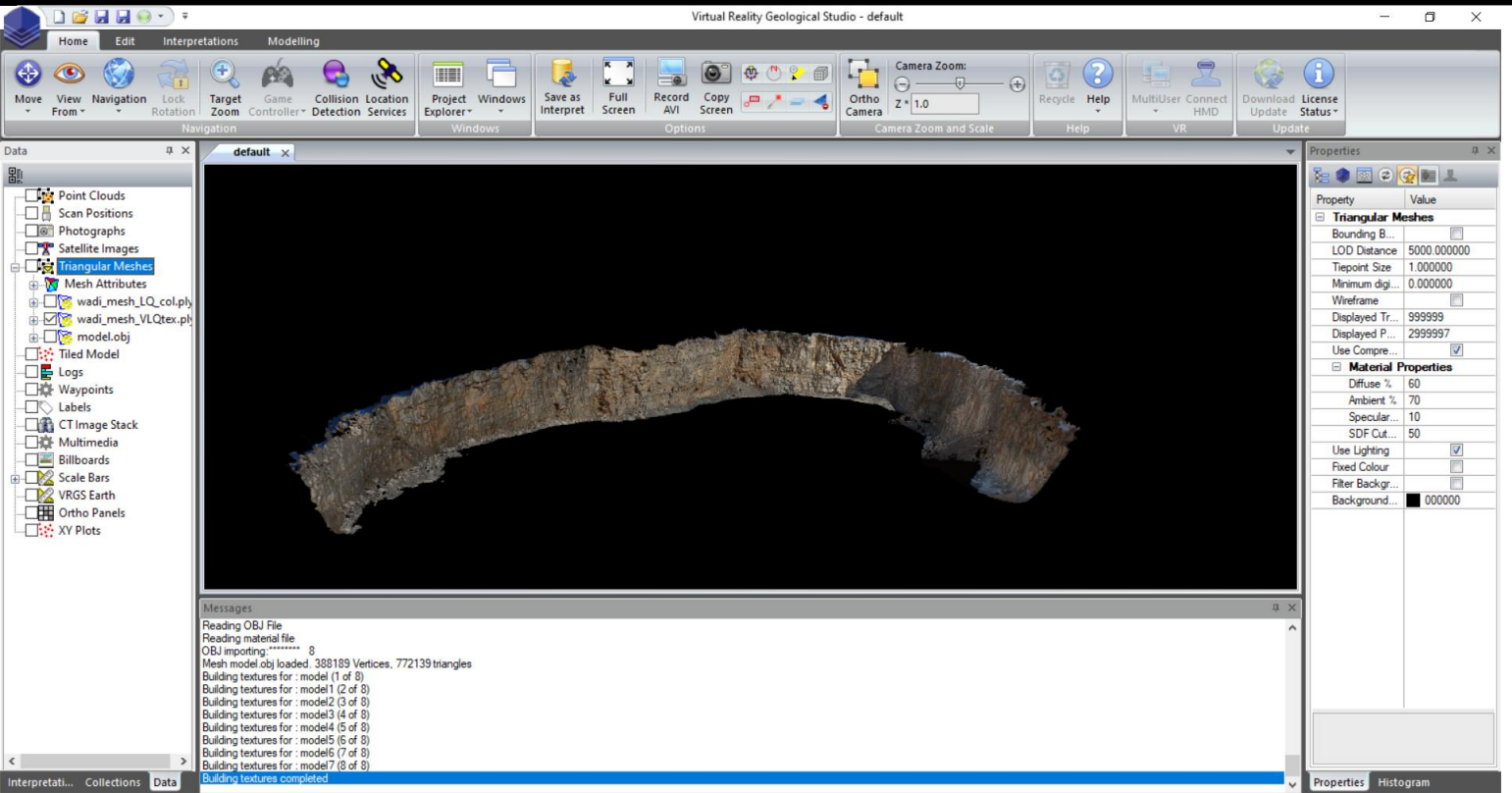

HELL DIGHT
laanlabs

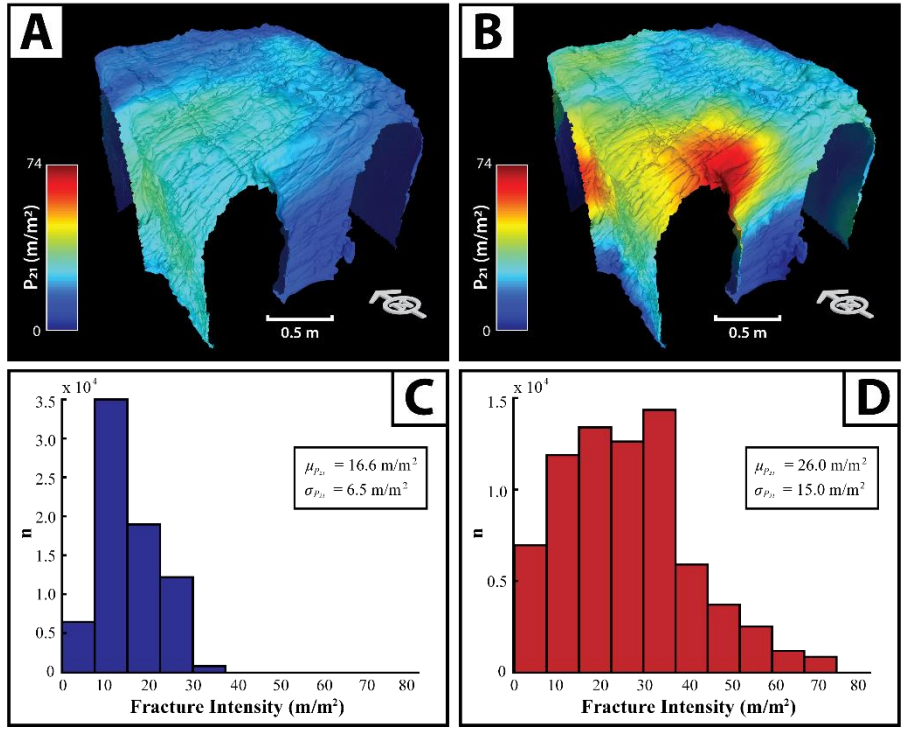

VistaAR

Digital Outcrop Data Visualization and Analysis

Visualization and Analysis

A lack of geologically focused tools led to numerous efforts to build geo-focused mesh viewer / analysis tools over the past decade (e.g. OpenPlot: Tavanni et al. 2011 / Virtual Reality Geological Studio: Hodgetts, 2010; Seers and Hodgetts, 2016)



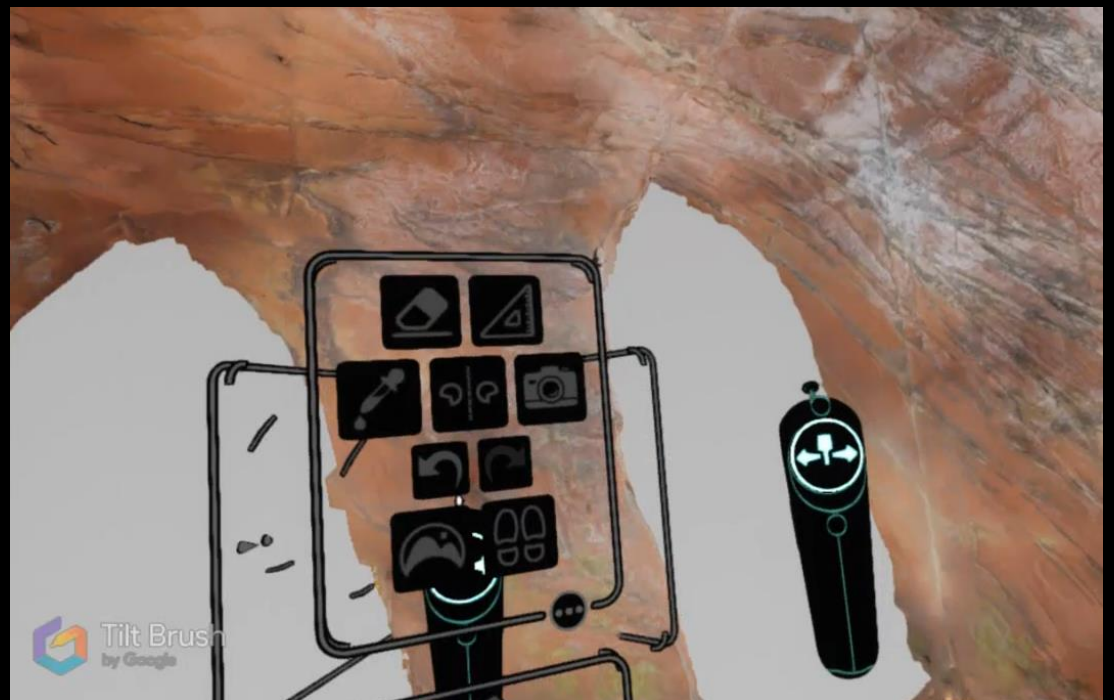


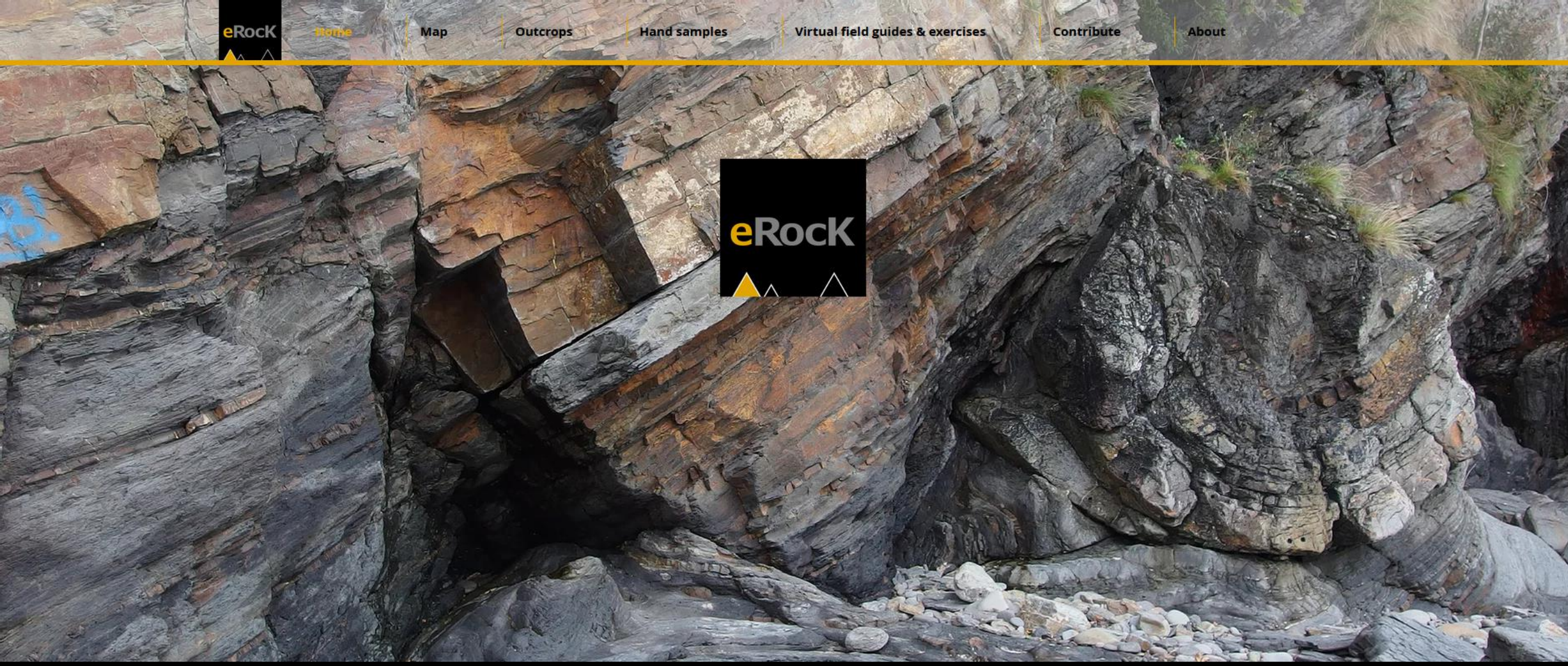
Visualization and Analysis

Augmented and virtual reality offer new opportunities both in research and in the classroom environment. Open access databases and server based mesh viewers allow access to a wide variety of models and visualization on any device / OS

Sketchfab

Mapping fault systems from Lacy Caves (Penrith Sandstone, NW UK) using the HTC Vive and Tiltbrush





eRock (Cawood & Bond, 2019): a community based project to collate and inventory virtual fieldtrip datasets for geoscience education...

Leverages Sketchfab's server based mesh viewer... applicable to any device

Implementation in the Classroom: *Amroth, Wales, UK*

Deltaic Settings

- Delta: a discrete shoreline protuberance formed at a point where a river enters the ocean or other body of water (e.g. a lake)
- Planform morphology dependent upon the relative dominance of fluvial action, waves and tidal action at the river-marine interface (river dominated are elongated whereas tidal and wave reworking results in a wide delta front)
- Grain size characteristics determined by the fluvial source of sediment

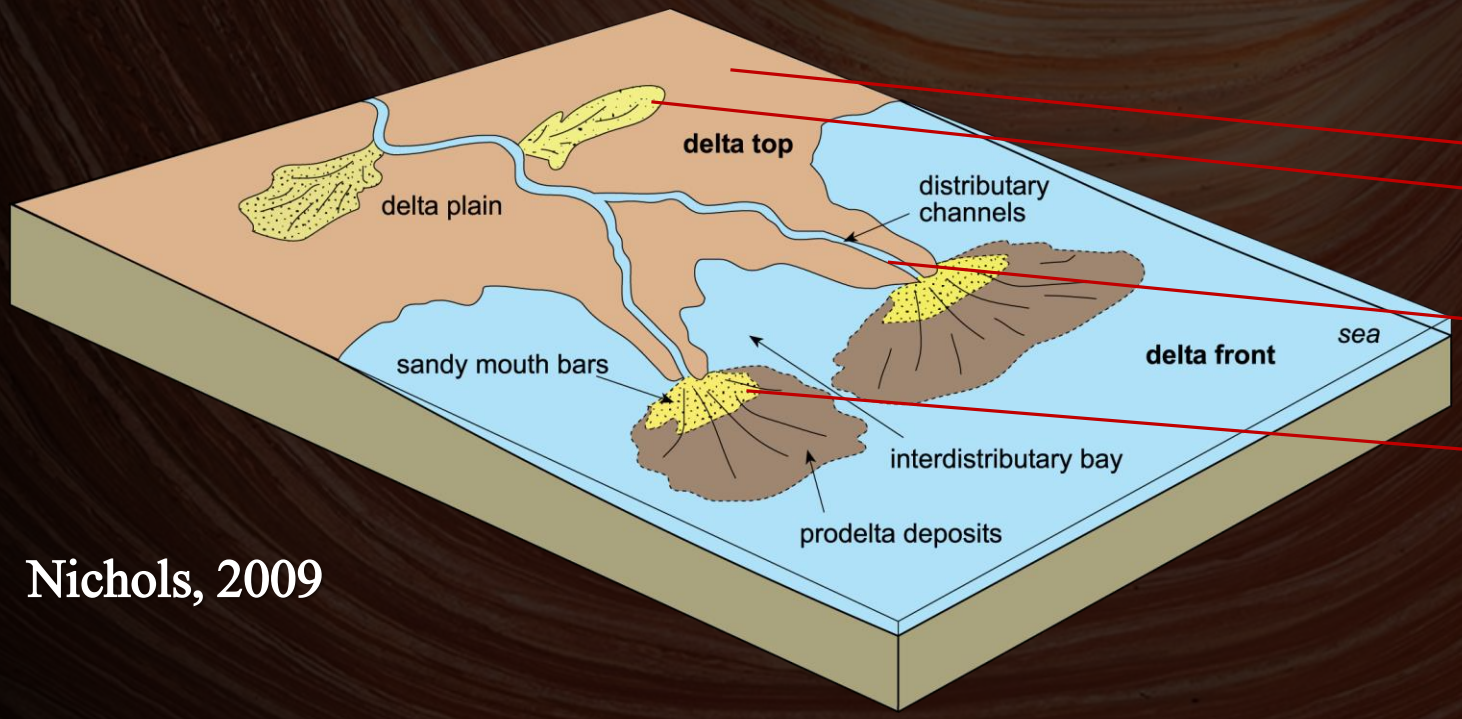
River dominated (Mississippi)

Wave dominated (Rhône, France)

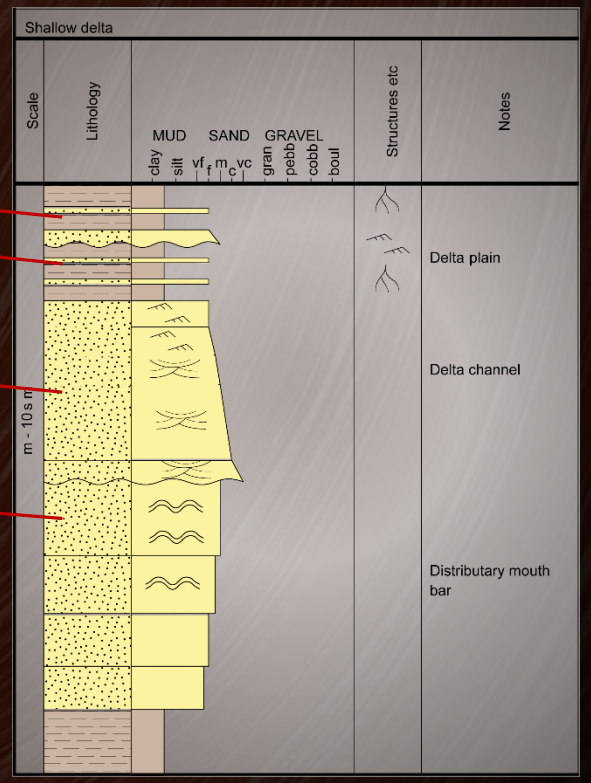
Tide dominated (Ganges, India)

Delta Environments

- Deltas may be divided into several sub-environments: **delta front** and the **delta top**
- **Delta top** shares the characteristics of the feeder fluvial system with coarser grained channel and finer grained overbank facies.
- Delta tops often accumulate vegetation in swamps and mires leading to peat (and with increasing burial coal) formation: source rock



Nichols, 2009



Prospects of virtual fieldtrips in subsurface engineering education

Prospects

- The COVID-19 pandemic has forced a change of approach in teaching methods for all: fieldwork, which is an essential component of subsurface education has been disproportionally affected by the current restrictions.
- 3D close range remote sensing techniques provide a medium through which students can experience outcrop scale structures within a virtual field setting, partly filling the role of conventional fieldwork.
- Community / web-based infrastructure for viewing and interrogating these geological surface reconstructions facilitates the routine adoption of these datatypes into the classroom setting.
- However, virtual fieldtrips are NOT a replacement for conventional fieldwork: there is really no replacement for field visits and viewing geology first hand.
- I believe that habits will change post-COVID-19 (for the better): regular use of virtual fieldtrips in the classroom and to supplement traditional field visits when we return to business as usual.

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Questions?

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