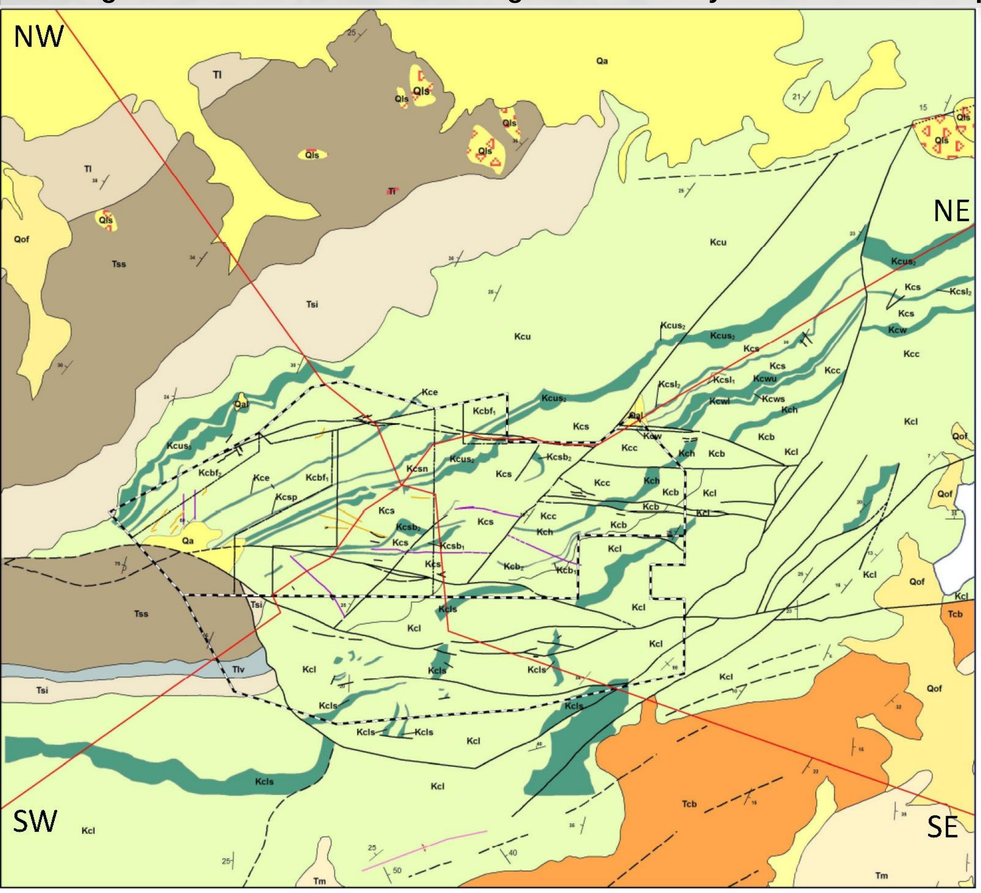
Hydrogeologic Tour of SSFL
Stop 1 – Expendable Launch Vehicle (ELV) Site

The first stop will be in the north-central part of SSFL at a site referred to as the ELV. At this stop, the Groundwater Advisory Panel will point out some of the geologic and topographic features that influence the local groundwater conditions. This stop will include a corehole (C-7) that illustrates many of the innovative tools that have been used to characterize the subsurface. Some of the characterization technologies will also be on display. An explanation of why the corehole location was selected will be provided along with an explanation of key findings.

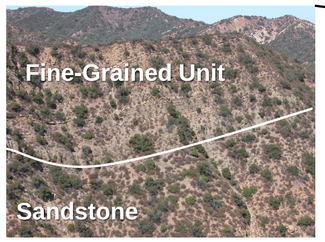
Geologic Framework at SSFL

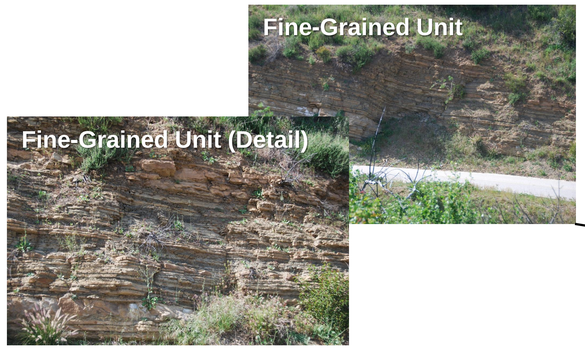
Basement rocks of Simi Hills primarily of sedimentary origin, part of Western Transverse Ranges. The Chatsworth Formation underlies nearly all of SSFL, was deposited 65-70 million years ago and is ~6,000 feet thick. Its geologic evolution is complex and includes several episodes of deformation including tectonic extension, rotation, compression and shearing. The Western Transverse Ranges are currently in north-south compression.

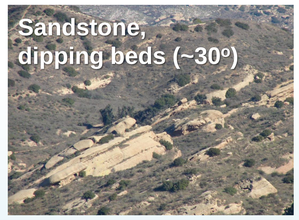


Chatsworth Formation Lithology

Predominately sandstone, with interbeds of siltstones and shales. Conglomerates also present.

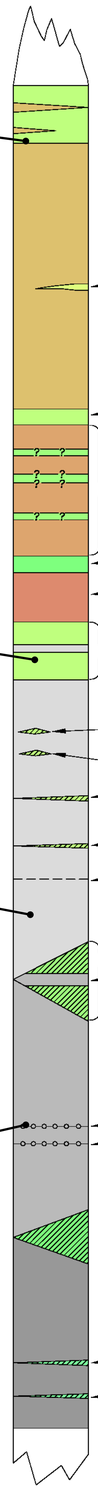






Note: Position of photos in stratigraphic column not representative of actual

SSFL Chatsworth Formation stratigraphic column



Shale 3 – KUCS–3
Interbedded Medium–Grained Sandstone and Finer–Grained Units Comprised of Thin–Bedded Fine– and Medium–Grained Sandstone, Siltstone and

Upper Burro Flats Member – KUCUB
Primarily Medium–Grained Sandstone w/ Minor Siltstone/Shale Interbeds

Lot Bed
Interbedded Fine–grained Sandstone, Siltstone & Shale

ELV Member – KUCE
Fine–Grained Sandstone, Siltstone and Shale

Lower Burro Flats Member – KUCLB
Primarily Medium–Grained Sandstone. Also Contains Significant Siltstone/Shale Interbeds

Spa Member – KUCSA
Interbedded Fine & Medium–Grained Sandstone, Siltst and Shale

Silvernale Member – KUCSN
Primarily Medium–Grained Sandstone w/ Minor Siltstone Sandstone Units

Shale 2 – KUCS–2
Thin–Bedded Shale, Siltstone and Sandstone. Middle Sandstone Unit that Extends Throughout the S Separates an Upper and Lower Fine–Grained Unit

Sage Member – KUCS
Predominantly Medium Grained Sandstone with Minor Interbeds of Siltstone & Shale

Upper Bravo Bed
Interbedded Fine & Medium–Grained Sandstone, Siltstone & Shale

Lower Bravo Bed
Interbedded Fine & Medium–Grained Sandstone, Siltstone & Shale

Upper Line Bed
Interbedded Fine & Medium–Grained Sandstone, Siltstone & Shale

Lower Line Bed
Interbedded Fine Grained Sandstone, Siltstone & Shale

Sage Gamma Bed

Woolsey Member – KUCW
Thin Bedded Sandstone, Siltstone & Shale

Woolsey Sandstone Bed
Medium Grained Sandstone

Canyon Member – KUCC
Predominantly Medium Grained Sandstone with Minor Interbedded Siltstone & Shale

Upper Canyon Bed

Lower Canyon Bed

Happy Valley Member – KUCH
Thin Bedded Sandstone, Siltstone & Shale

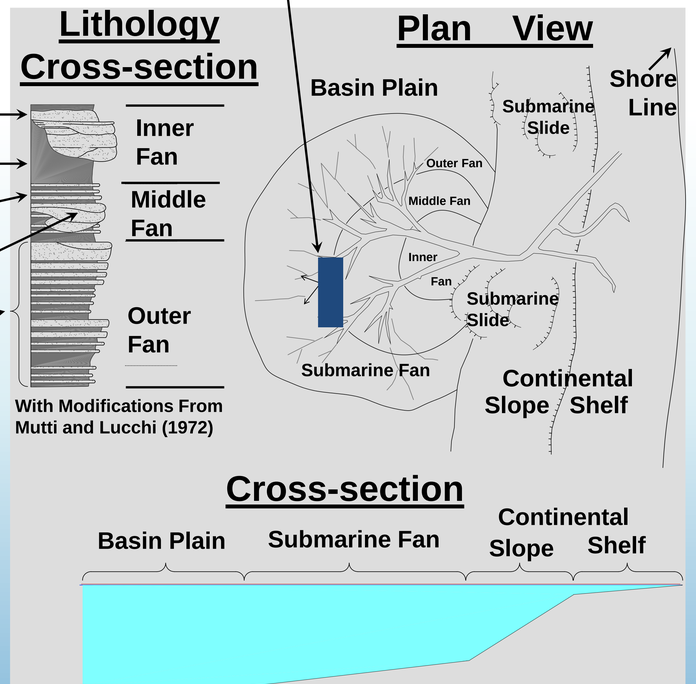
Bowl Member – KUCB
Predominantly Medium Grained Sandstone with Minor Amounts of Interbedded Fine Sandstones, Siltstones & Shale.

Upper Bowl Bed
Thin Bedded Sandstone, Siltstone & Shale

Lower Bowl Bed
Thin Bedded Sandstone, Siltstone & Shale

Lower Chatsworth Formation – KLC
Stratigraphically Higher Parts of this Stratigraphic Unit Consist of Interbedded Sandstone, Siltstone and Shale.
Bedding Typically Three Feet or Less Thick

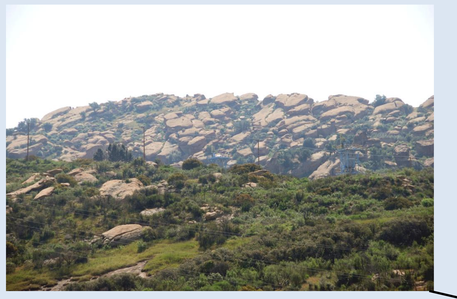
Conceptual Location of SSFL

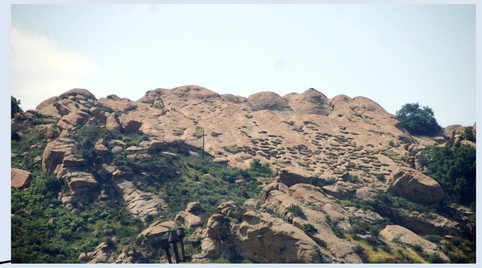


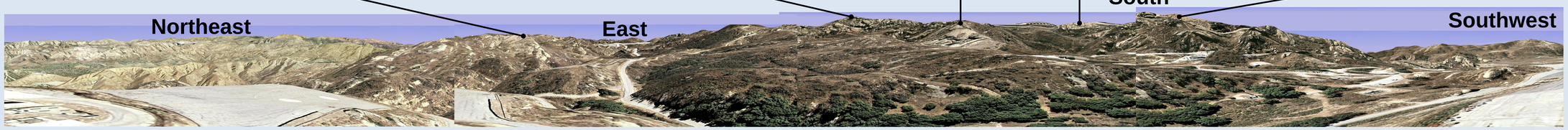
SSFL Depositional Environment:

Interpreted by Link to have been deposited on surface of sand-rich submarine fan at depths between 600 and 3,000 feet.

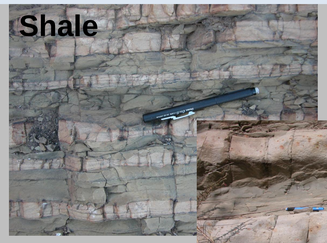
Visible fracture spacing in outcrop varies across SSFL…



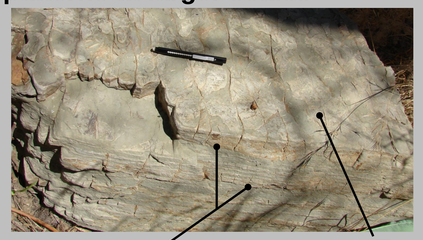


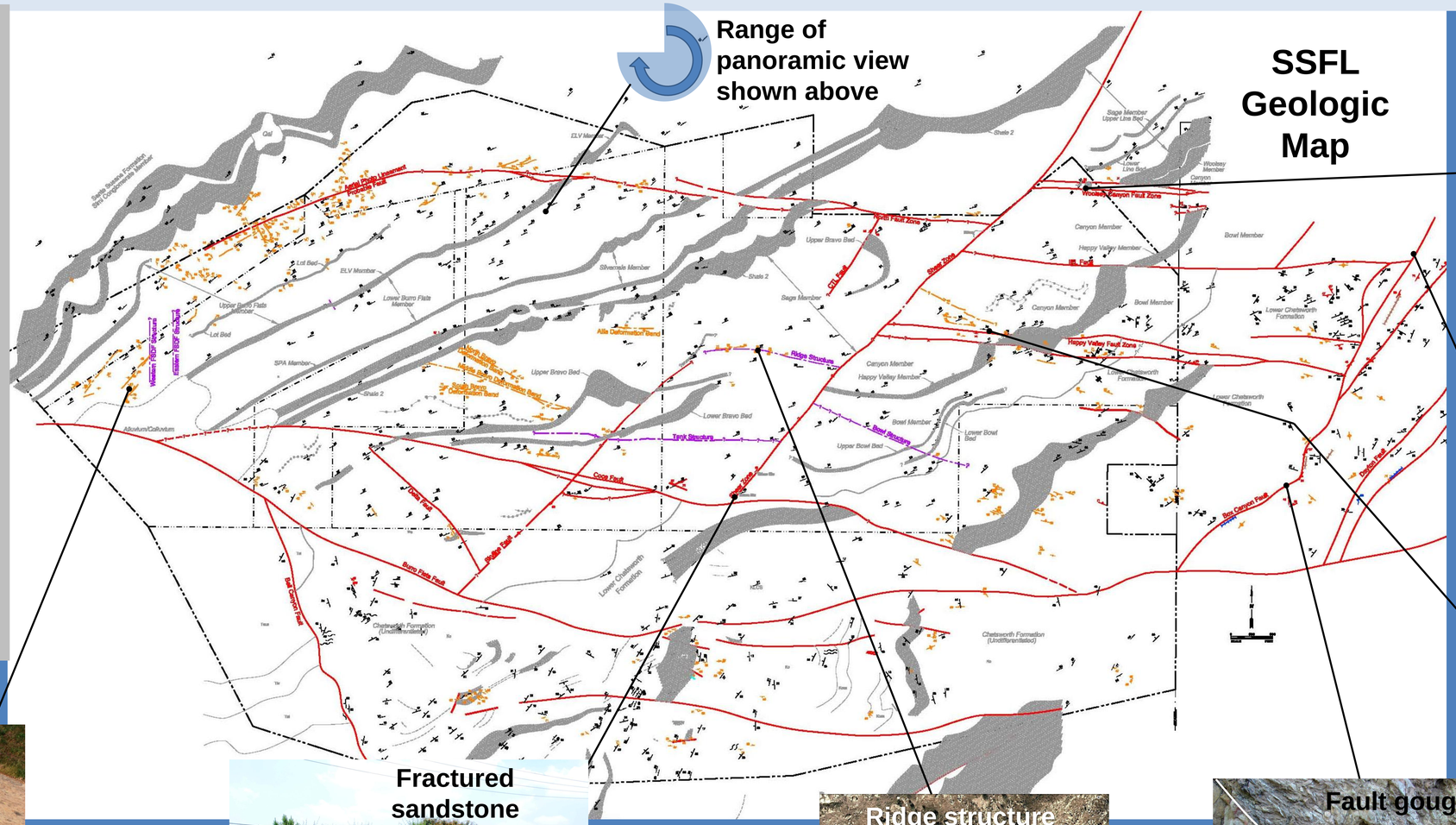


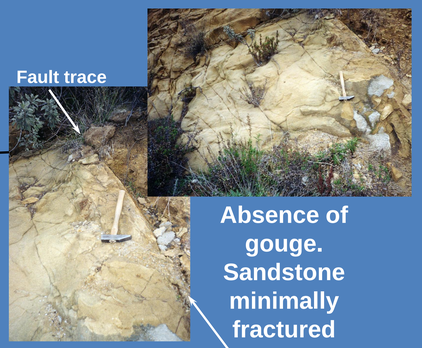
Panoramic View from ELV (created using Google Earth®)

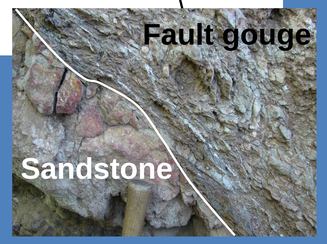


Fracture patterns in small scale outcrops are useful for describing patterns at larger scales

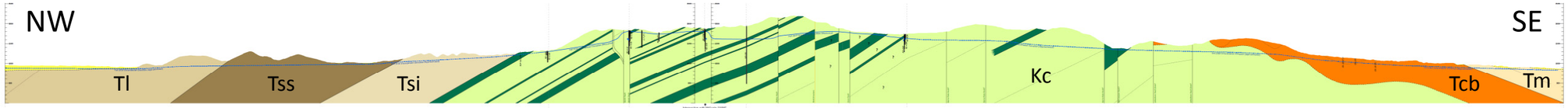


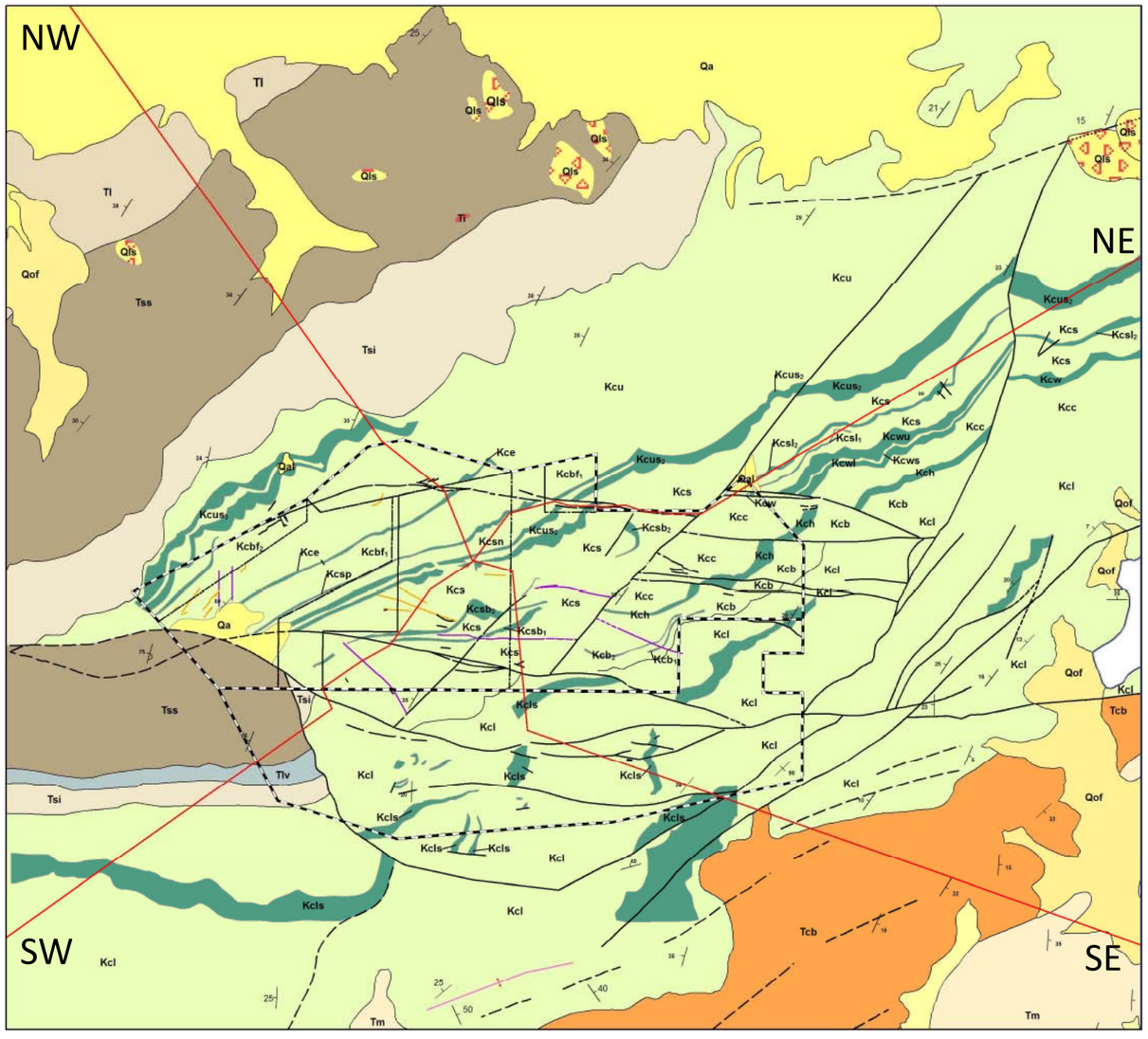






…..and the geomorphic expression of faults and fault features also varies





Mountain Scale Cross Sections

Site Area

SSFL Site Property

Geologic Units

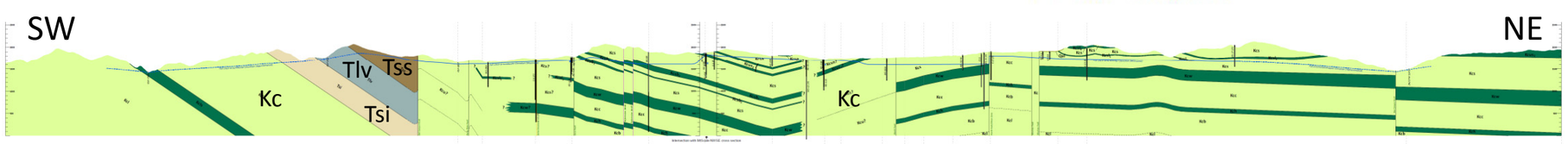
- Qls Landslide deposits
- Qyf Young alluvial-fan deposits
- Qa Alluvium
- Qof Old alluvial-fan deposits
- Tm Modelo Fm
- Tcb Calabasas Fm
- Ti Tertiary Intrusive
- Ts Sespe Fm
- Tl Llajas Fm
- Tss Santa Susana Fm
- Tlv Las Virgenes Fm
- Tsi Simi Conglomerate
- Kc Chatsworth Fm Undifferentiated or Coarse Grained Units
- Chatsworth Fm. Shale

Faults/Contacts

- deformation band (dashed where approx.)
- structure (dashed where approx.)
- contact, certain or approximately located
- contact, inferred or poorly located
- fault, certain
- fault, approx. located or inferred
- fault, concealed
- anticline, approx. located

Chatsworth Formation Stratigraphy

- Kcu - Upper Chatsworth Fm
- $Kcus_3$ - Shale 3
- $Kcbf_2$ - Upper Burro Flats Mbr
- Kce - ELV Mbr
- $Kcbf_1$ - Lower Burro Flats Mbr
- Kcsp - Spa Mbr
- Kcsn - Silvernale Mbr
- $Kcus_2$ - Shale 2
- Kcs - Sage Mbr
- $Kcsb_2$ - Upper Bravo Bed
- $Kcsb_1$ - Lower Bravo Bed
- $Kcsl_2$ - Upper Line Bed
- $Kcsl_1$ - Lower Line Bed
- Kcwu - Upper Woolsey Mbr
- Kcws - Woolsey Sandstone
- Kcwl - Lower Woolsey Mbr
- Kcc - Canyon Mbr
- Kch - Happy Valley Mbr
- Kcb - Bowl Mbr
- Kcb_2 - Upper Bowl Bed
- Kcb_1 - Lower Bowl Bed
- Kcl - Lower Chatsworth Fm



The Discrete Fracture Network (DFN) Approach

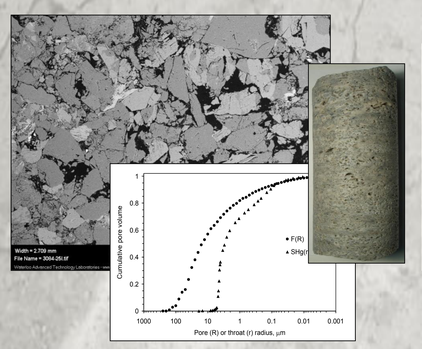
Use of Rock Core

Core Drilling and Inspection

Continuous cores 5 ft (1.5 m) in length are obtained by drilling. The geology and all features of potential hydrogeological relevance (e.g., fractures, fracture coatings, weathering) are described and recorded into an electronic database.

Contaminant Analysis

Samples of the core are removed and crushed. The crushed rock is placed in containers with methanol for microwave extraction. Volatile organic contaminants extracted from the crushed rock are analyzed by GC or GC/MS. Direct injection of the methanol extractant and a GC/ECD detector results in extremely low detection limits. Other samples of the core are collected for measurement of physical, chemical, and microbial properties/characteristics.



Measurement of Properties/Characteristics

Rock physical and chemical properties such as porosity, bulk density, hydraulic conductivity, diffusion coefficient, fraction of organic carbon, and mineralogy are measured on samples collected from the core.

DRILL CORE HOLE

CORE

- Contaminant Analysis
- Physical & Chemical Properties

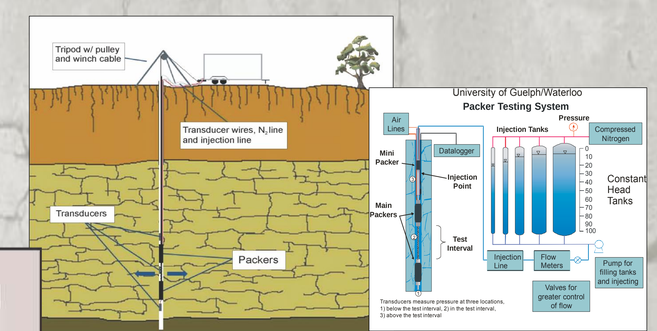
HOLE

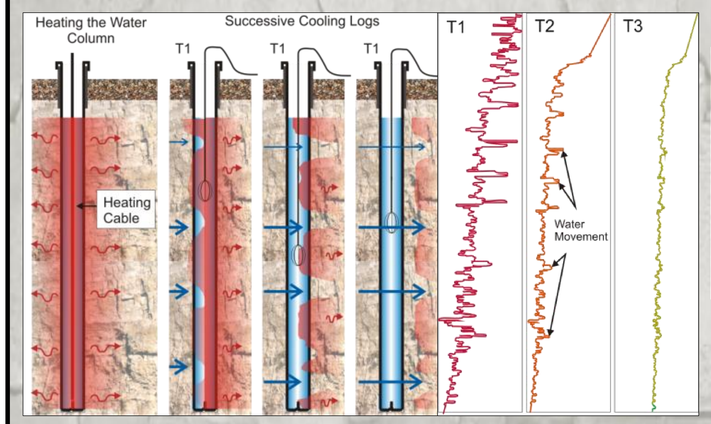
- Packer Tests K-Profiler
- Geophysics & Hydrophysics
- Multilevel Systems

Use of Drillhole

Packer Tests K-Profiler

Hydraulic tests are conducted in short (1-5 m) intervals chosen based on the geologic and fracture logs to provide measurements of hydraulic conductivity and fracture apertures.



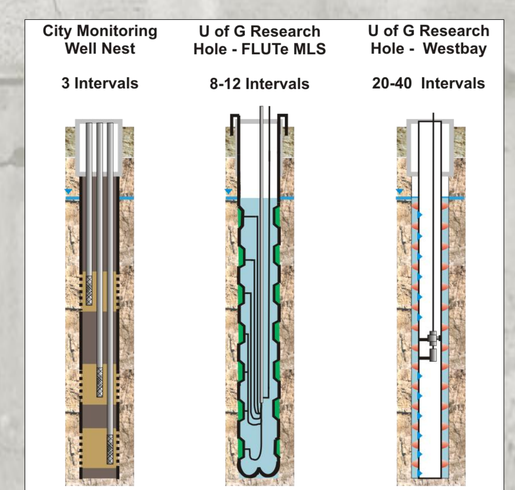


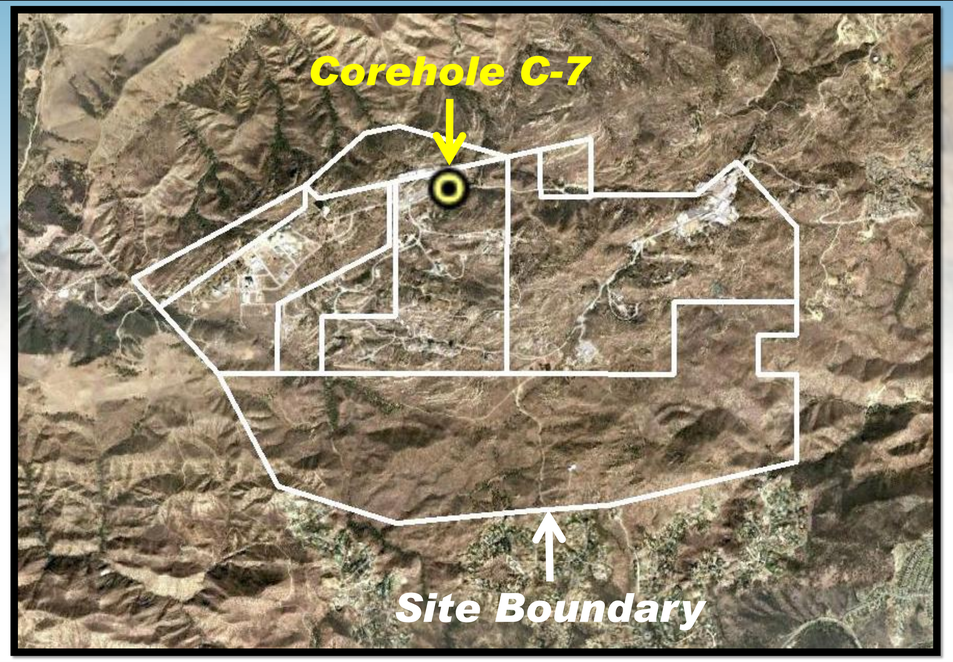
Geophysics and Hydrophysics

Geophysical logging (e.g., gamma, resistivity, conductivity, televiewer) is used to identify geological characteristics relevant to groundwater flow pathways

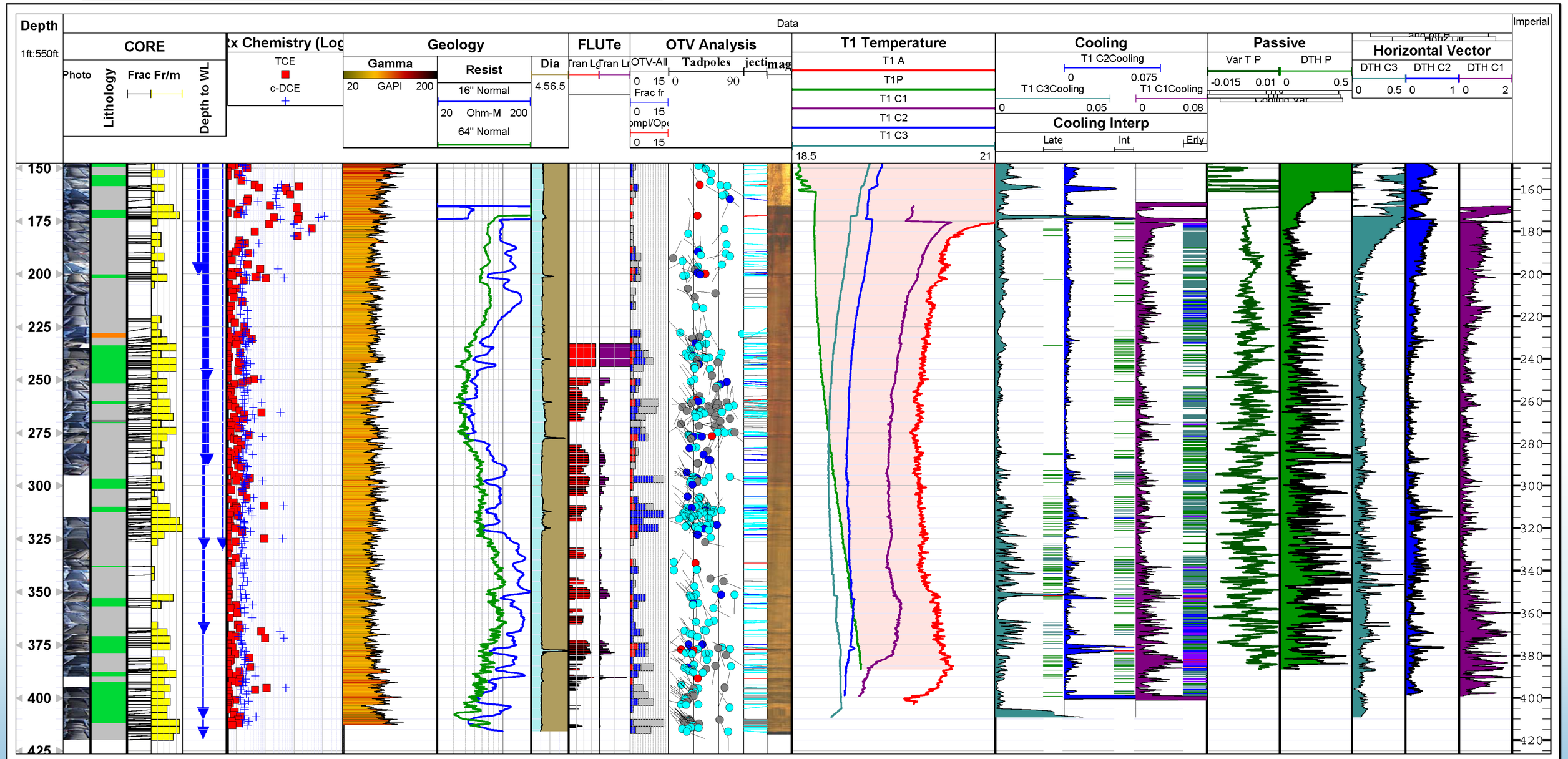
Multilevel Systems

A commercially available MLS with many monitoring ports (10-40) is installed to produce detailed profiles of hydraulic head and water chemistry. The monitoring intervals are selected based on examination of all of the data from the hole and the core analysis.



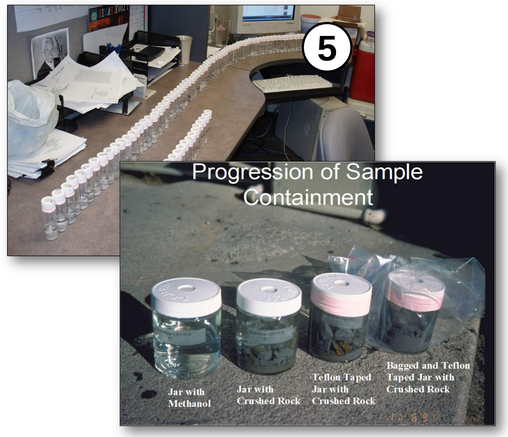


Corehole C-7 Characterization DFN™ Data Sets

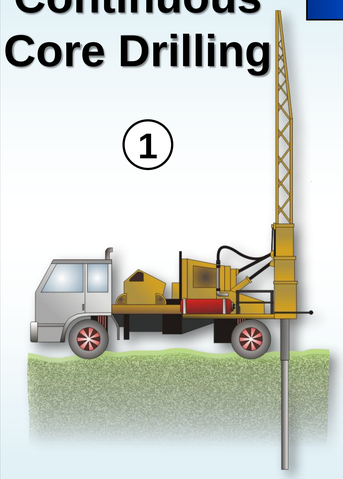


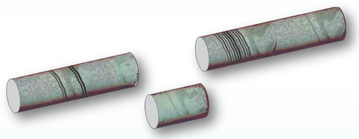
Rock Core VOC Sampling Methodology

To measure contaminant concentrations in the blocks of rock between fractures

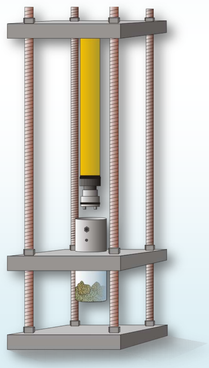


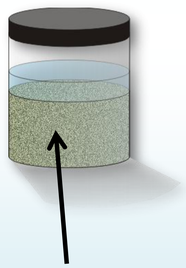
Continuous Core Drilling → **Core Inspection** → **Core Sampling** → **Rock Crushing** → **Methanol Extraction**



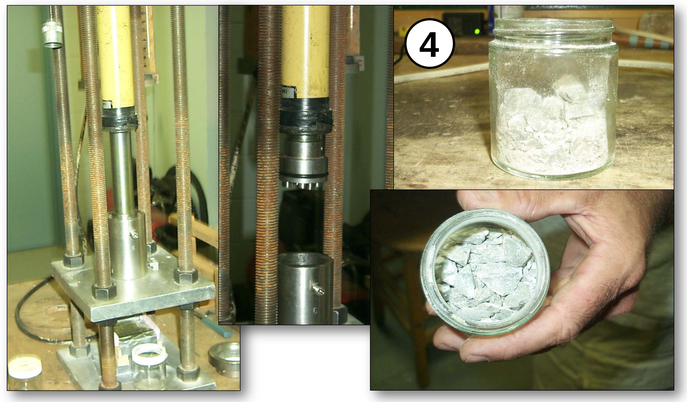
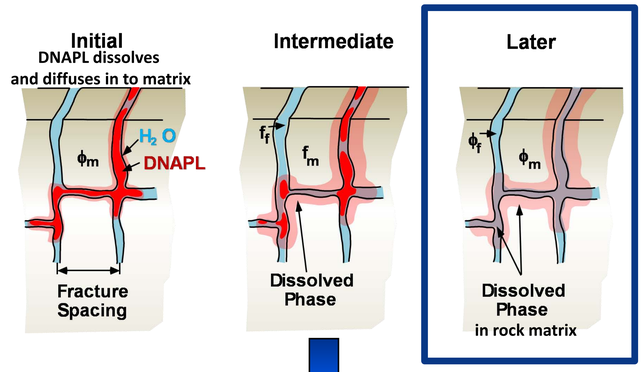
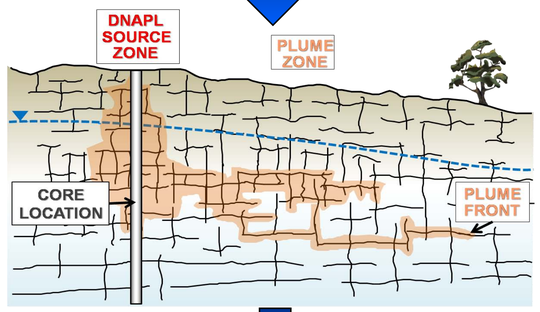
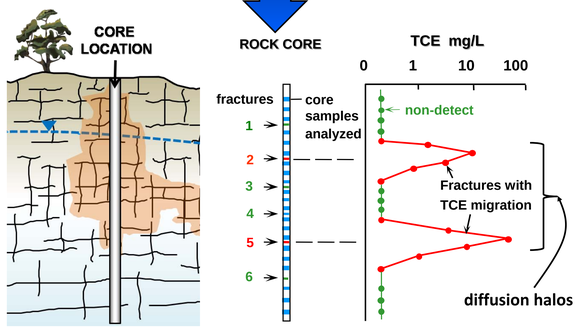
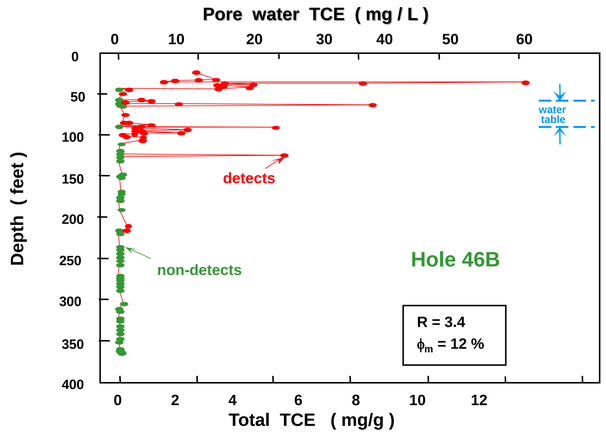


Sample length ~ 2 Inches





Crushed rock



Crusher **Crushed rock**