Yucca Mountain – Geologically Speaking, is it the Right Spot?

Talk to SME Tucson section

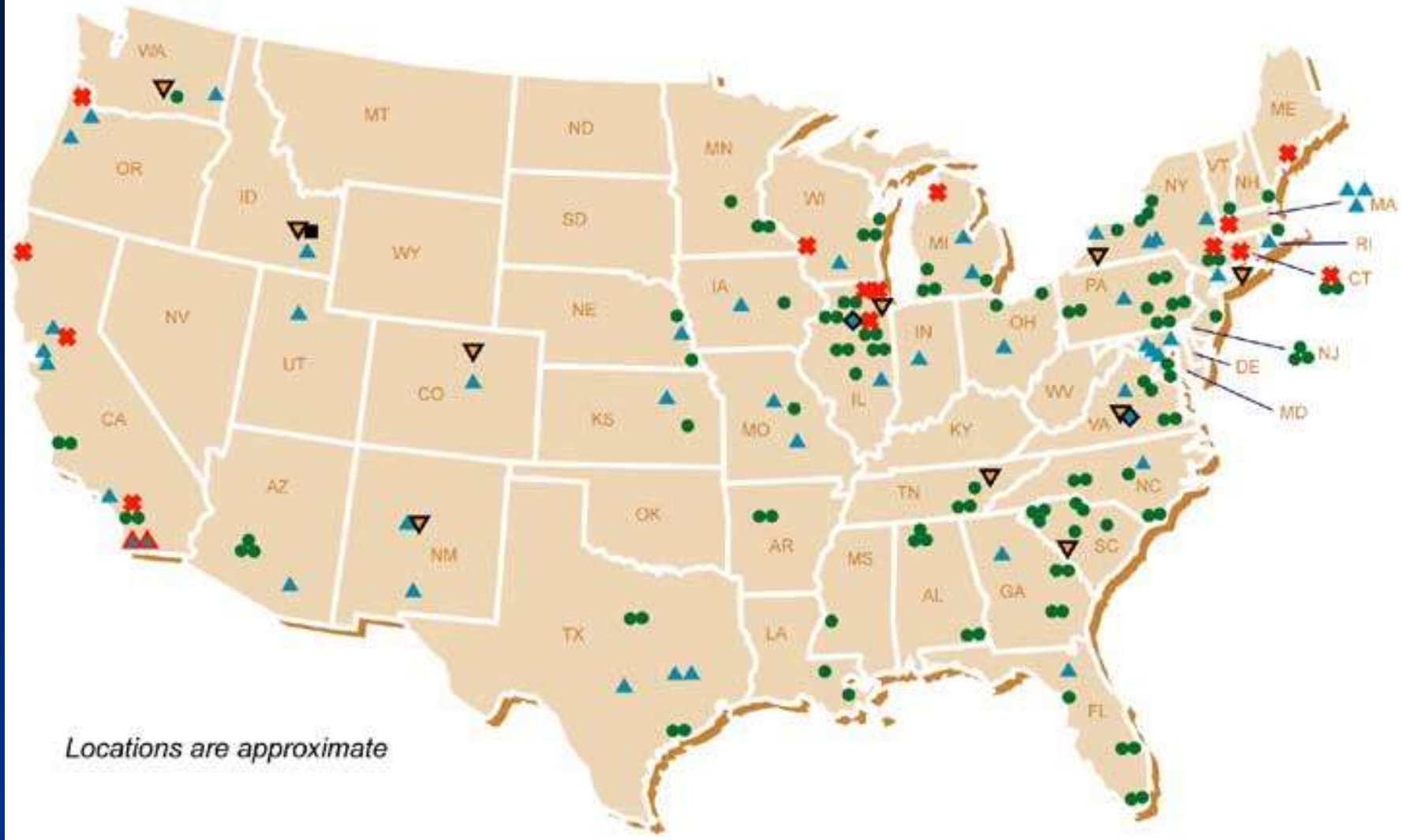
August 14, 2002

By Jan C. Rasmussen

Looking SW over Yucca Mtn.

Reasons for Geologic Disposal

- Currently waste is stored at temporary facilities – DOE sites and Power Plants
- Need to have secure, safe, long term storage for decommissioned weapons
- Legal requirement for DOE to accept spent fuel from nuclear power plants



Storage Locations

Commercial Reactors
(72 Sites in 33 States), including
- ● - 104 Operating Reactors, and
- ✖ - 14 Shut Down Reactors with Spent Nuclear Fuel on Site

- ■ Naval Reactor Fuel (1)
- ◆ Commercial Spent Nuclear Fuel (Not at Reactor) (2)

- ▲ Operating Non-DOE Research Reactors (45)
- ▲ Shut Down Non-DOE Research Reactors with Spent Nuclear Fuel on Site (2)

- ▽ High-Level Radioactive Waste and DOE Spent Nuclear Fuel (10)

Modified from MAP999 tables hqcc.fh7

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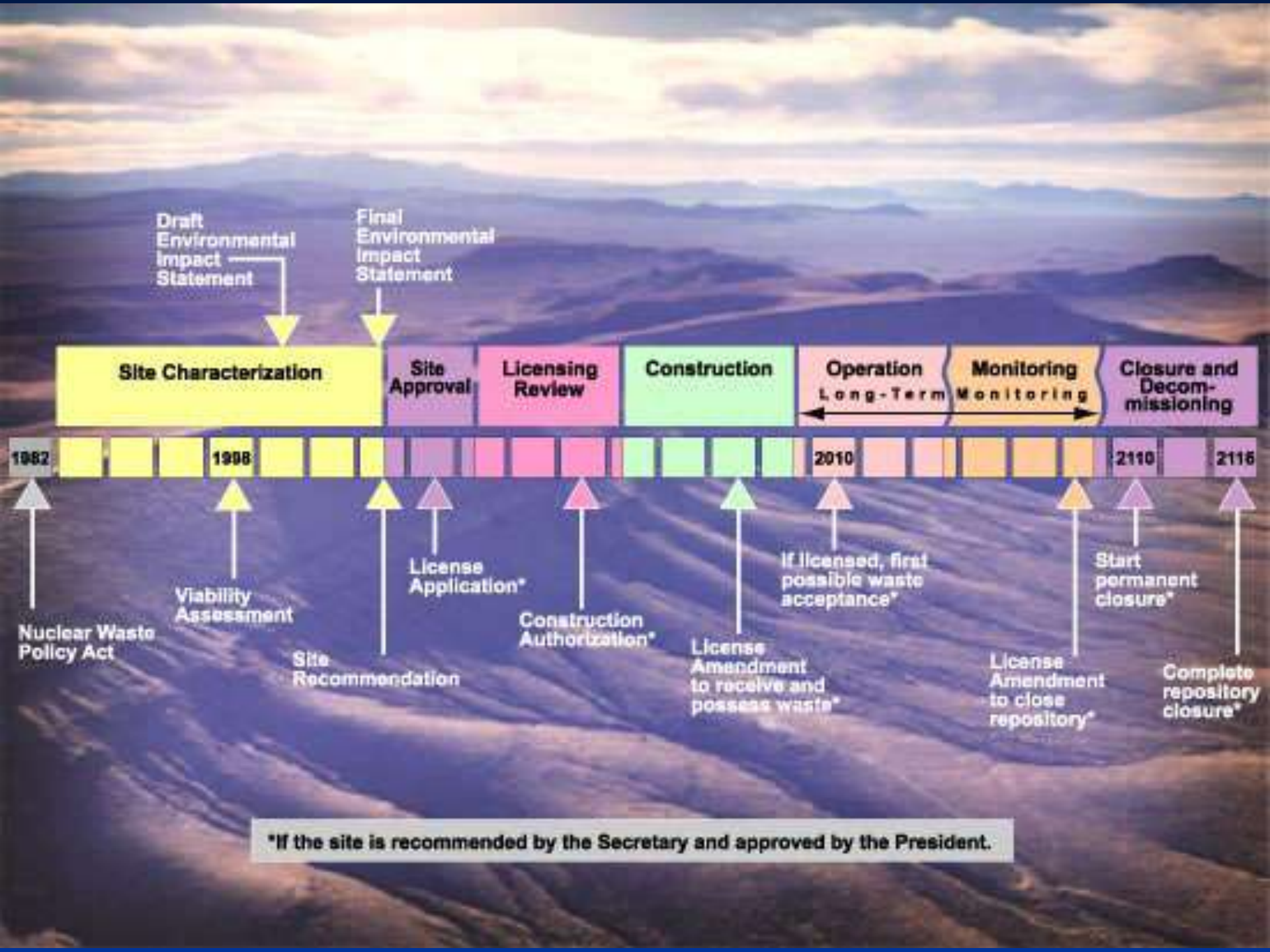
Concepts

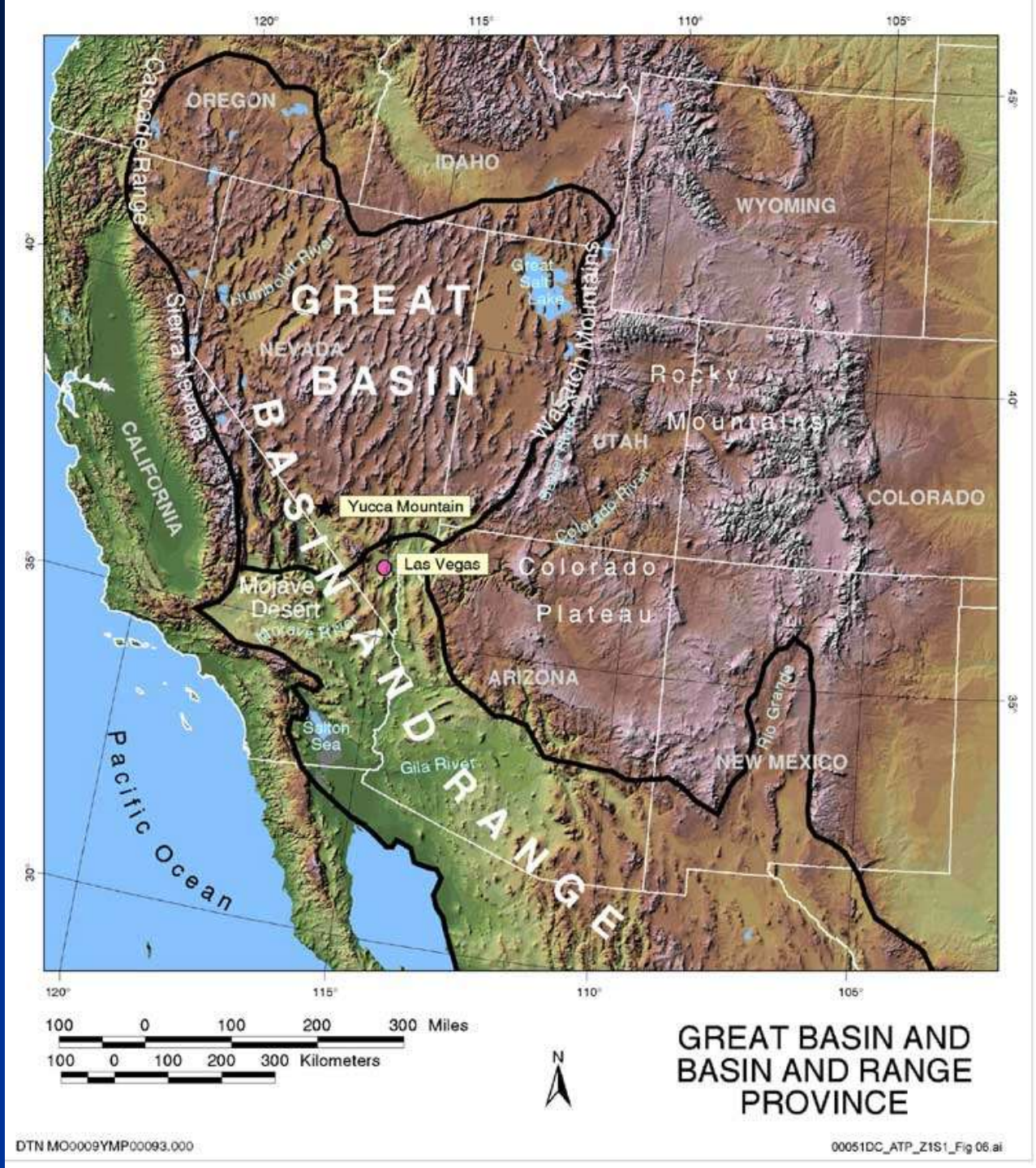
- 20 years of scientific and technical investigations
- Oversight - NRC, EPA, NAS, NV, Nye Co.
- Must comply with RCRA, CERCLA
- NRC licensing
- No likelihood of volcanism, earthquakes
- 1000’ below surface, 1000’ above water table

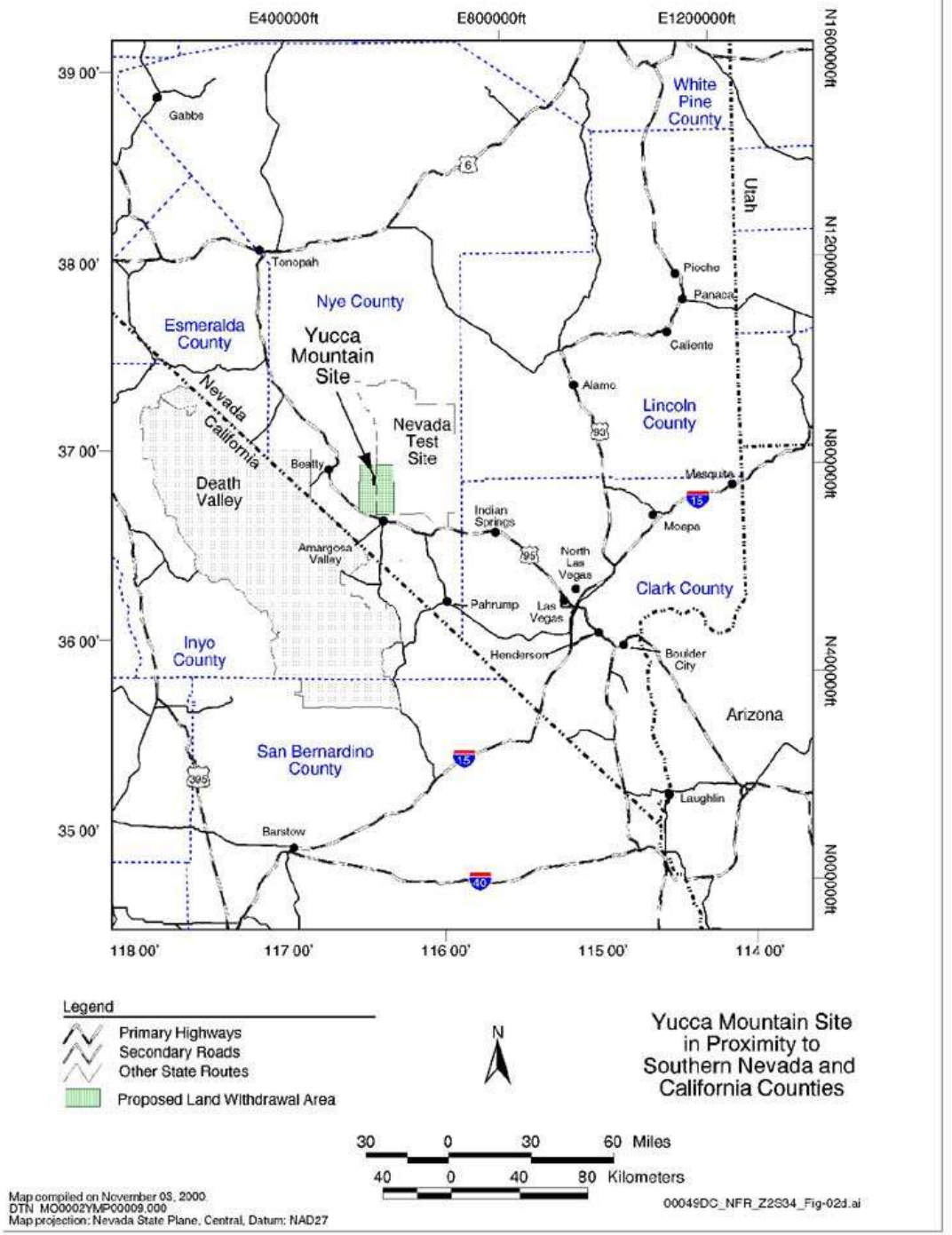

Draft Environmental Impact Statement
Final Environmental Impact Statement
Site Characterization
Site Approval
Licensing Review
Construction
Operation
Long-Term Monitoring
Monitoring
Closure and Decom-missioning
1982
1998
2010
2110
2116
Nuclear Waste Policy Act
Viability Assessment
Site Recommendation
License Application*
Construction Authorization*
License Amendment to receive and possess waste*
If licensed, first possible waste acceptance*
License Amendment to close repository*
Start permanent closure*
Complete repository closure*
*If the site is recommended by the Secretary and approved by the President.

Location

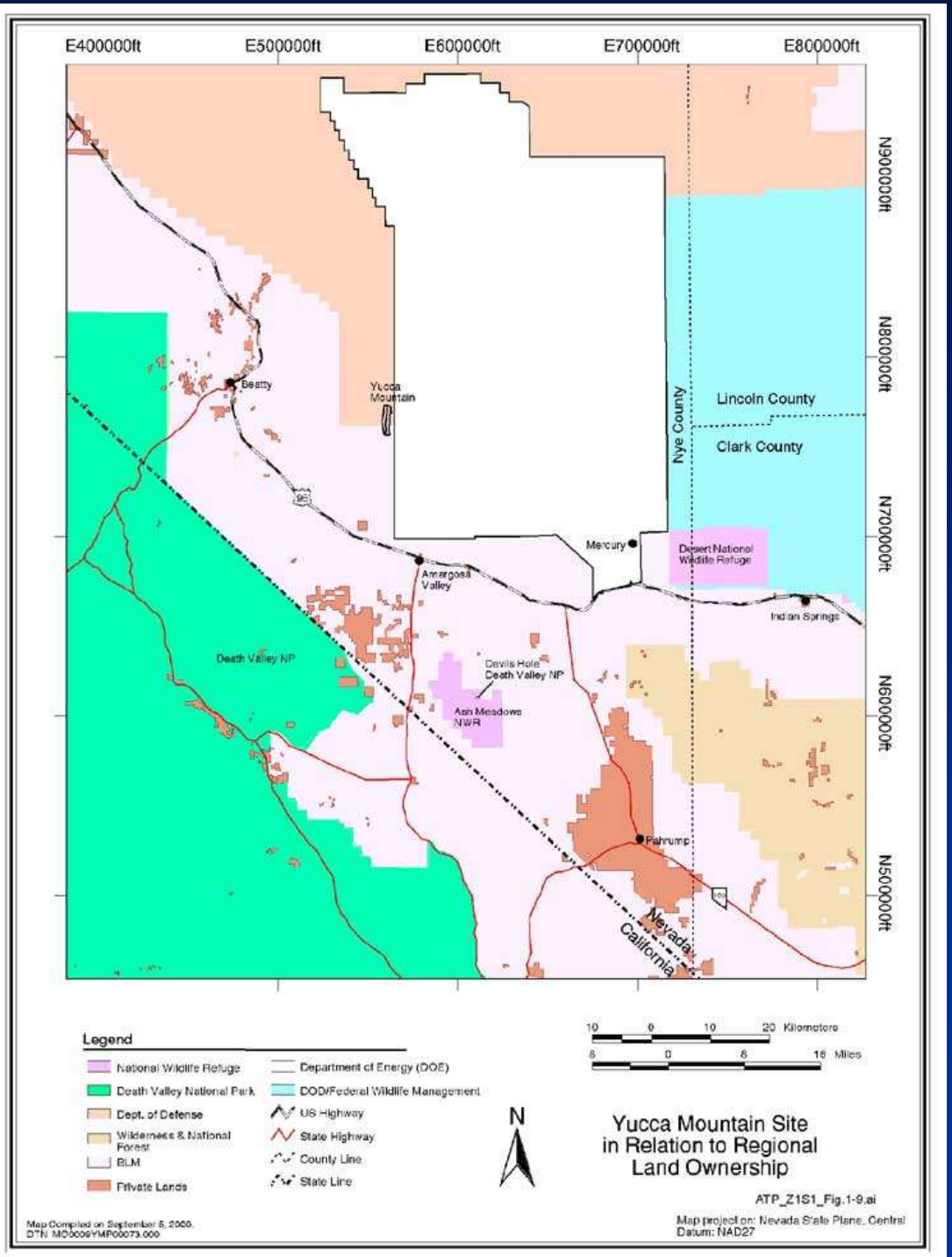
of Yucca Mountain

- approximately 100 miles northwest of Las Vegas, Nevada





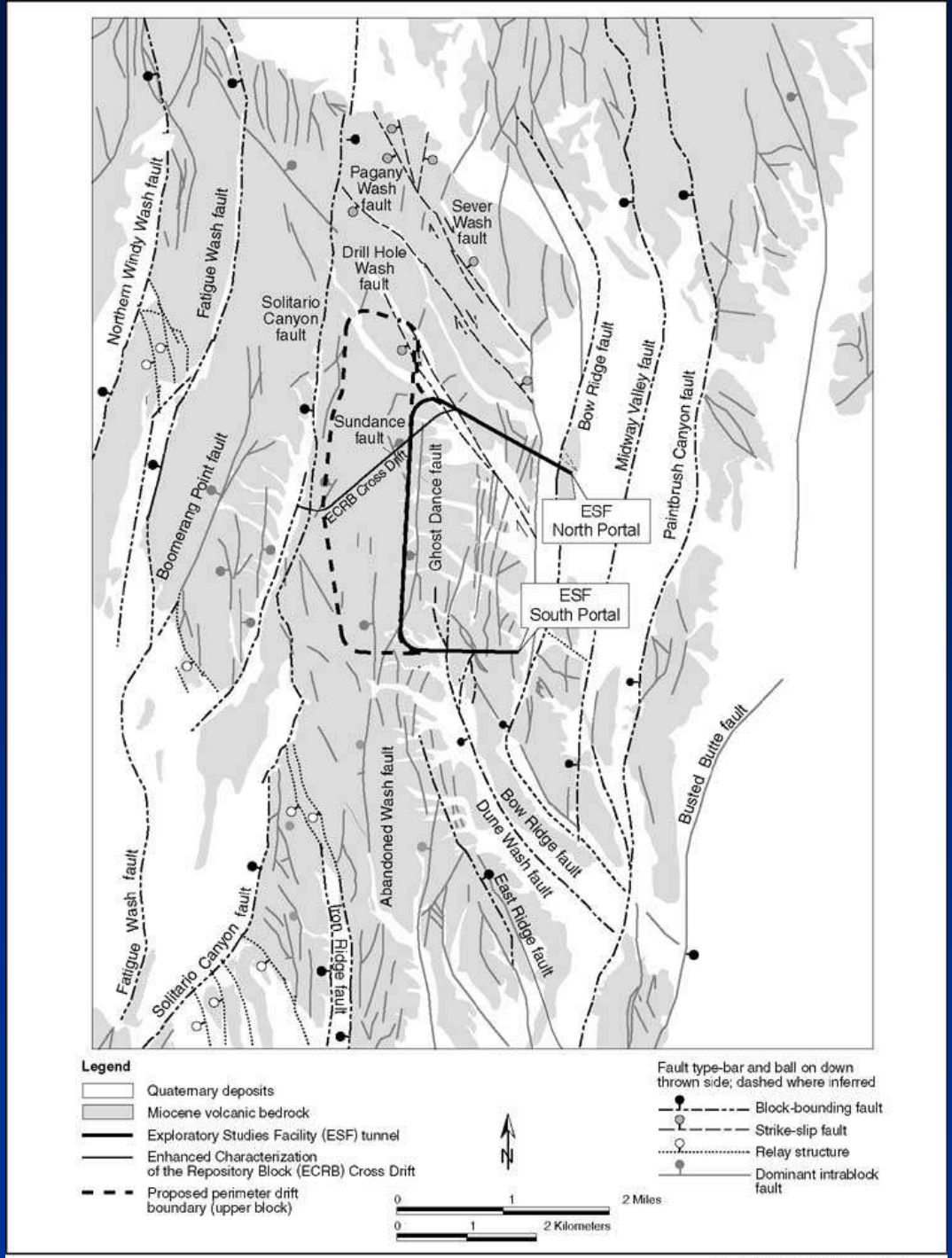
Location – 90 miles NW of Las Vegas – surrounded by Nevada Test Site and Nellis Air Force Base



Land Ownership in the vicinity of the Nevada Test Site

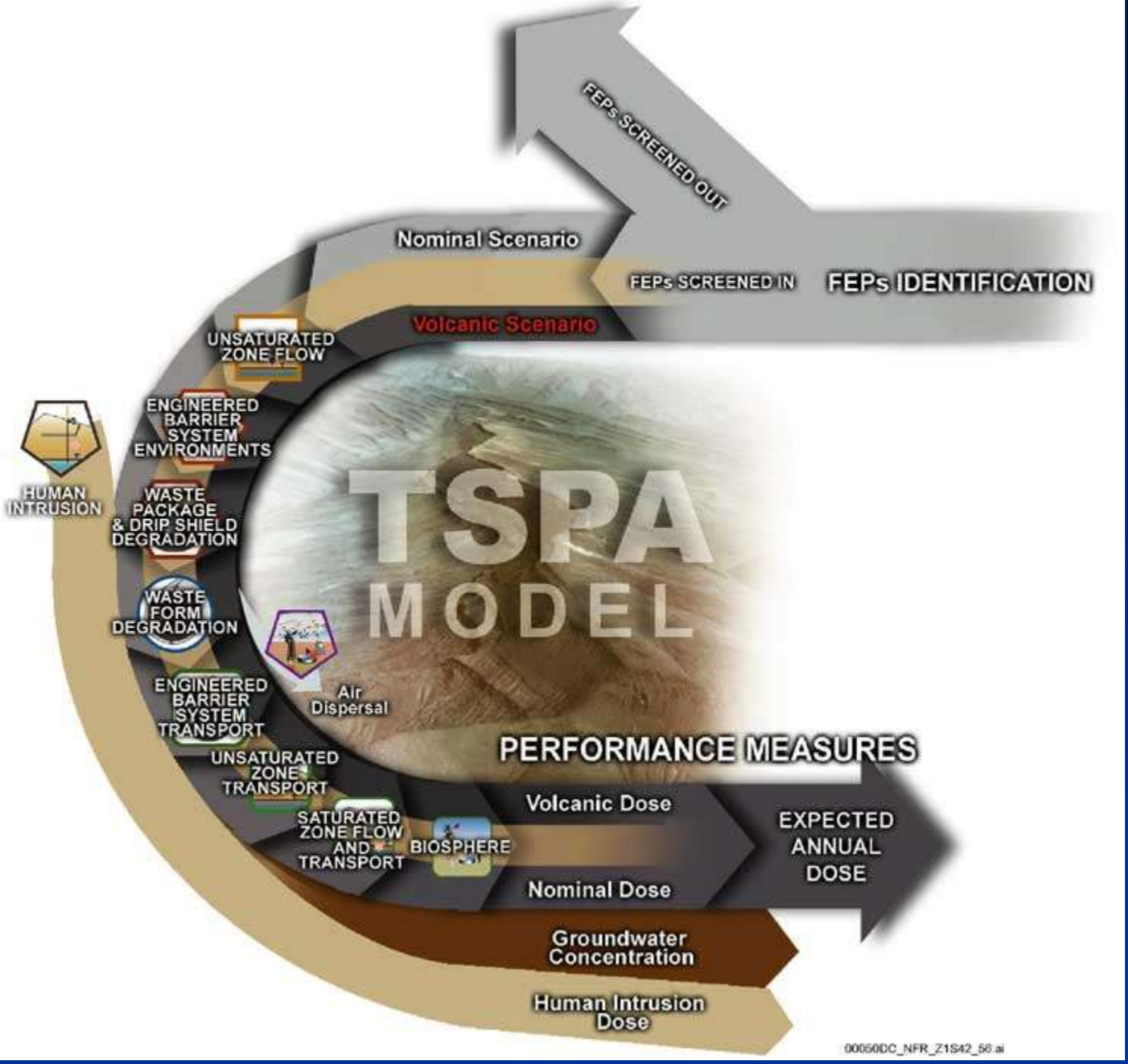
Air photo of Nevada Test Site (outlined in thin yellow line)

Yucca Mtn. is in lower left corner



Location of tunnel, proposed repository, and major faults and drainages

Looking South over Yucca Mountain



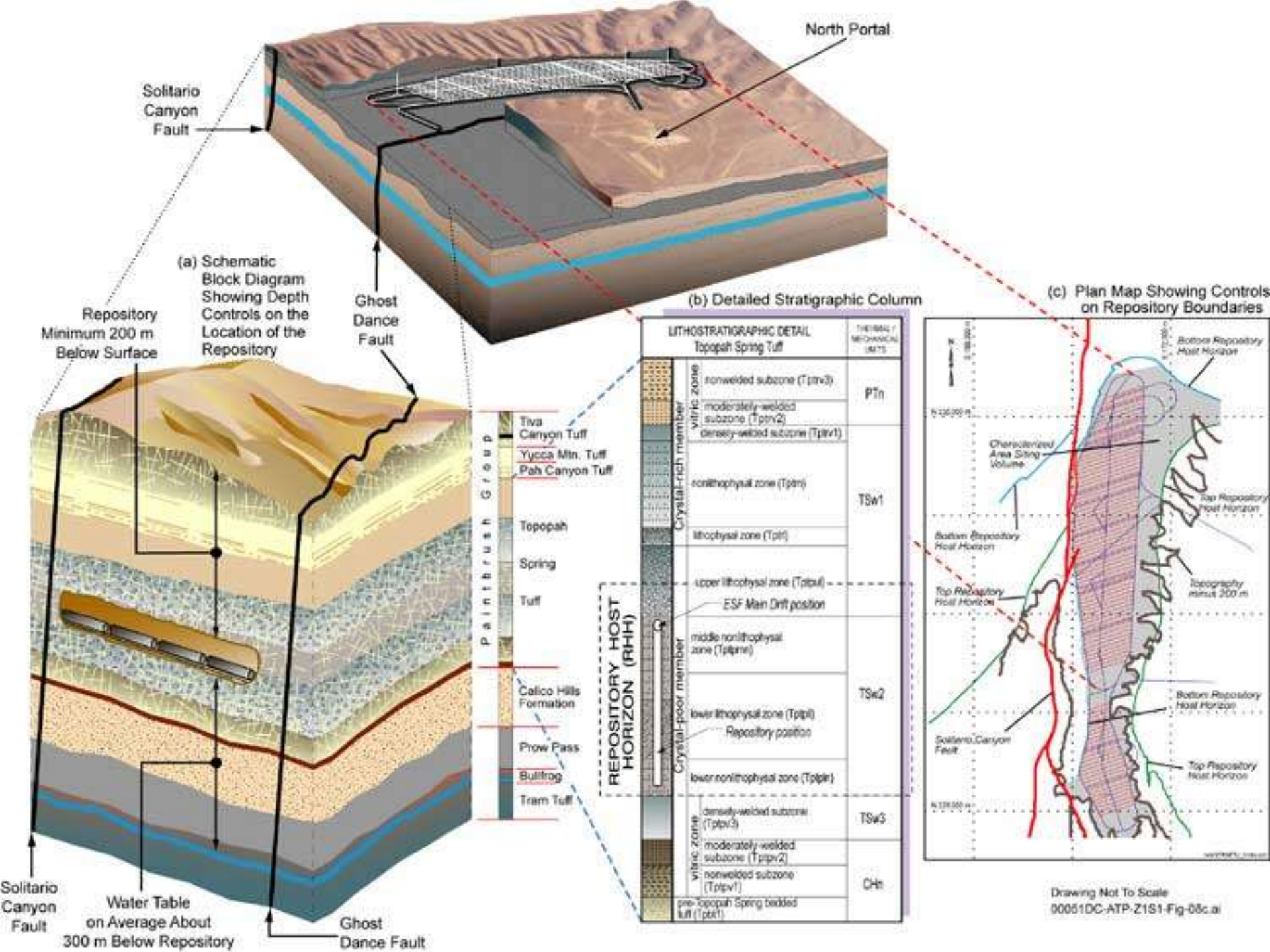
Total System Performance Assessment

Review Process

- Department of Energy
- Nucear Regulatory Commission (NRC)
- Nuclear Waste Technical Review Board
- U.S. Geological Survey
- State of Nevada, Nye County, etc.
- Scientific peer review
- International Atomic Energy Agency

Positive Features of Yucca Mountain

- Repository would be in unsaturated zone
- Desert environment – 7.5 “/yr precipitation
- Zeolite minerals present
- Remote location – isolated from population centers
- Natural barriers to supplement engineered barriers
- Closed hydrologic basin


North Portal
Solitario Canyon Fault
Ghost Dance Fault
(a) Schematic Block Diagram Showing Depth Controls on the Location of the Repository
Repository Minimum 200 m Below Surface
Solitario Canyon Fault
Water Table on Average About 300 m Below Repository
Ghost Dance Fault
Paintbrush Group
Tiva Canyon Tuff
Yucca Mtn. Tuff
Pah Canyon Tuff
Topopah Spring Tuff
Calico Hills Formation
Prow Pass
Bullfrog
Tram Tuff
(b) Detailed Stratigraphic Column
LITHOSTRATIGRAPHIC DETAIL
Topopah Spring Tuff
THERMAL/MECHANICAL UNITS
vitric zone
nonwelded subzone (Tptrv3)
moderately-welded subzone (Tptrv2)
densely-welded subzone (Tptrv1)
PTn
Crystal-rich member
nonlithophysal zone (Tptm)
lithophysal zone (Tptl)
TSw1
upper lithophysal zone (Tptpul)
ESF Main Drift position
REPOSITORY HOST HORIZON (RHH)
middle nonlithophysal zone (Tptpmn)
Crystal-poor member
lower lithophysal zone (Tptpll)
Repository position
TSw2
lower nonlithophysal zone (Tptpln)
densely-welded subzone (Tptpv3)
TSw3
vitric zone
moderately-welded subzone (Tptpv2)
nonwelded subzone (Tptpv1)
CHn
pre-Topopah Spring bedded tuff (Tpbt1)
(c) Plan Map Showing Controls on Repository Boundaries
Bottom Repository Host Horizon
Characterized Area Siting Volume
Top Repository Host Horizon
Bottom Repository Host Horizon
Topography minus 200 m
Top Repository Host Horizon
ESF Main Drift
Repository Outline
Solitario Canyon Fault
Bottom Repository Host Horizon
Top Repository Host Horizon
Drawing Not To Scale
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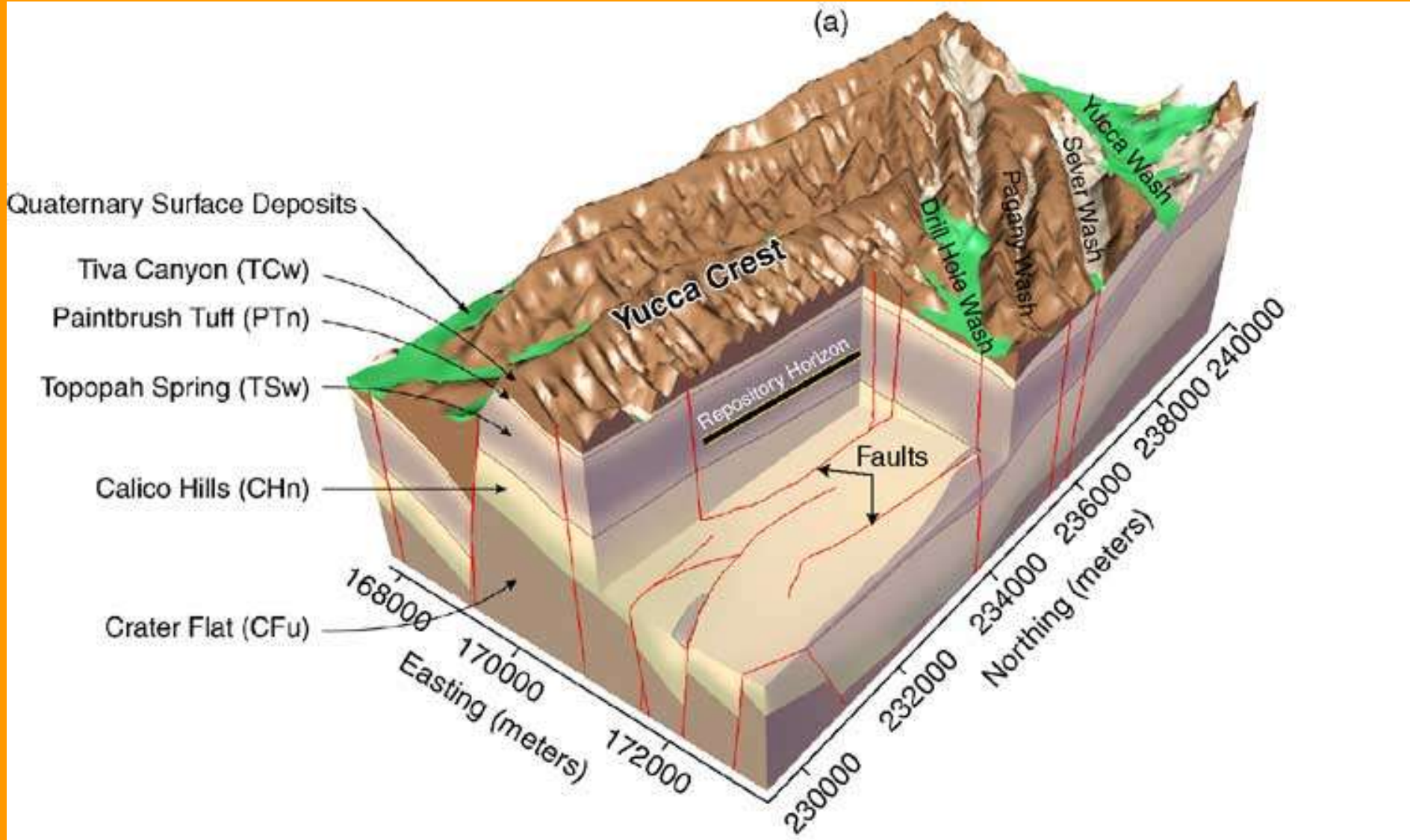
Geologic studies

- Geologic studies
- Geologic mapping – rocks and faults
- Boreholes, trenches, core, samples
- Geophysical studies – mag., gravity, etc.
- Geochemical studies

Major Geologic Issues Investigated

- Rocks - Stratigraphy and Engineering Characteristics
- Hydrology - water depth and flow
- Effect of heat at repository horizon
- Geochemistry of rocks and radionucleides
- Potential for Volcanism
- Potential for Earthquakes
- Potential for Human Interference - Mining

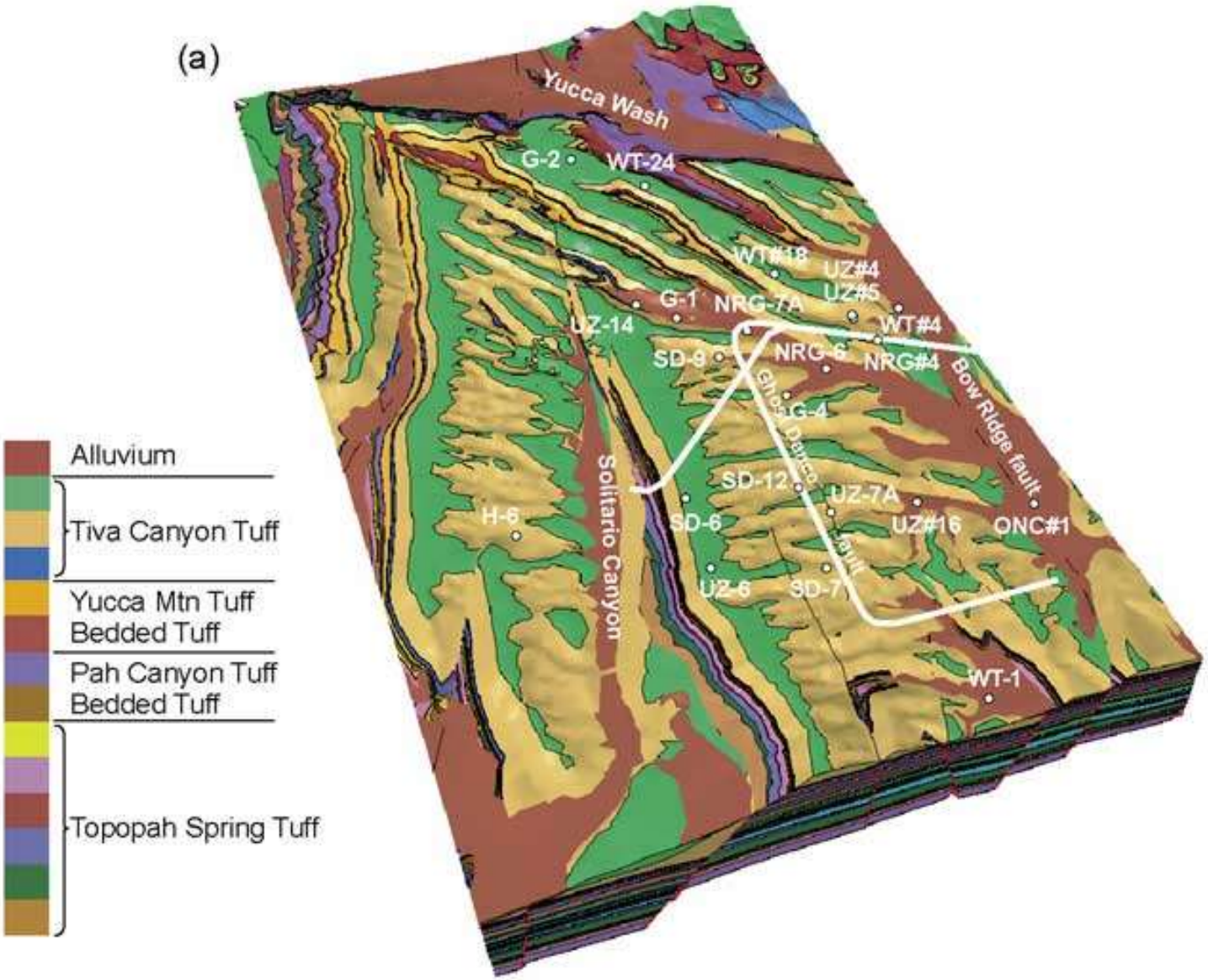
Block Diagram of Yucca Mountain

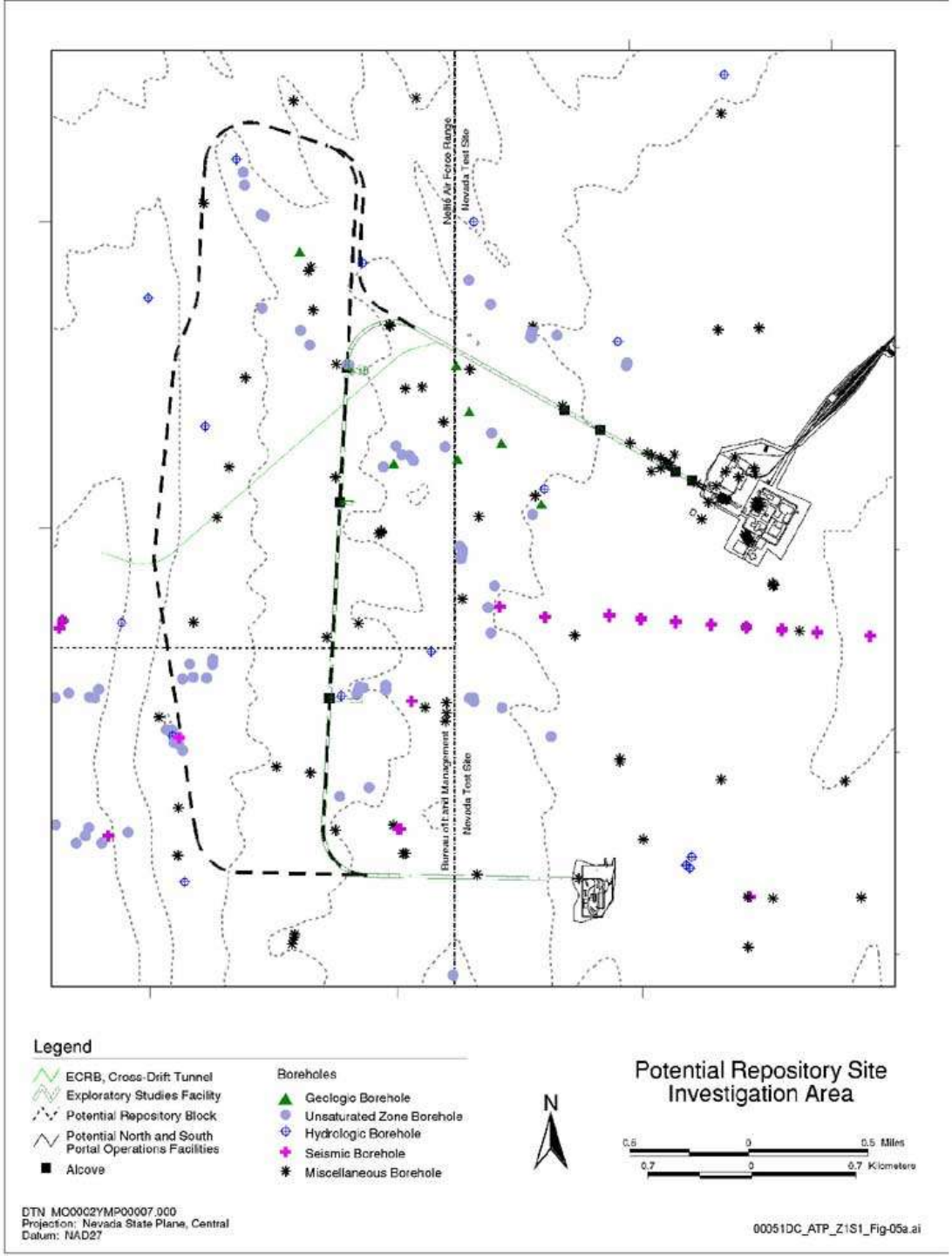


LM-300 Drill Rig

air circulating

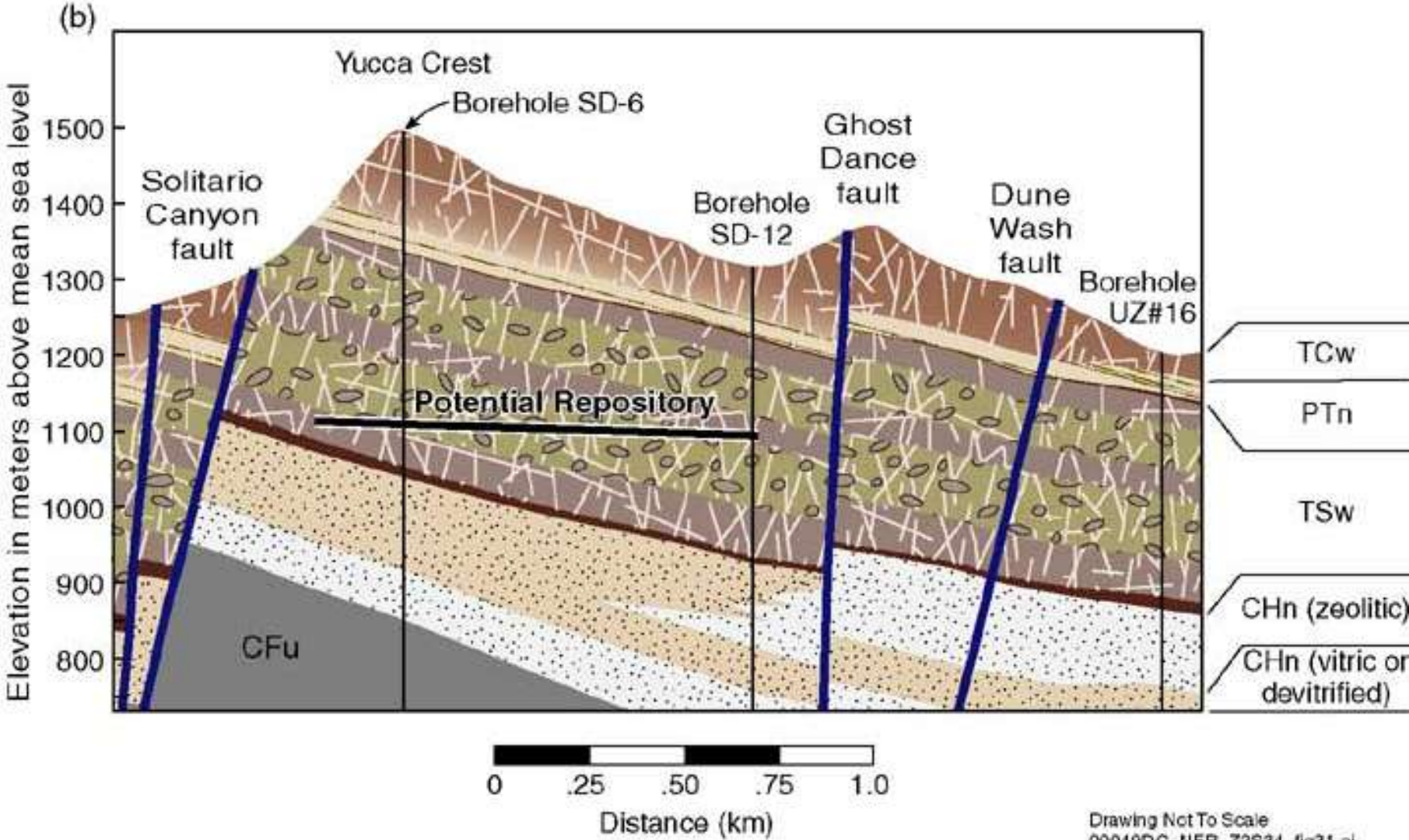
Location of major stratigraphic and hydrologic boreholes





Bore-holes at Yucca Mtn

Cross-section of Yucca Mountain



(a) Drilling of Borehole SD-6 on the Crest of Yucca Mountain

(b)

Objectives:

- Determine lithology and structural features of tuff units.
- Evaluate distribution of fractures and faults.

Approaches:

- Map features on bedrock, in trenches, and along Exploratory Studies Facility drifts.
- Conduct geophysical logging along boreholes.
- Deploy geophysical tomographic imaging techniques on the surface and in underground drifts.

Results:

- Refined geological maps of bedrock, washes, and faults.
- Improved geological framework of tuff layers and fault offsets.
- Detailed line surveys and full peripheral maps along drifts.
- Interpreted fracture density distributions between surface and underground drifts.

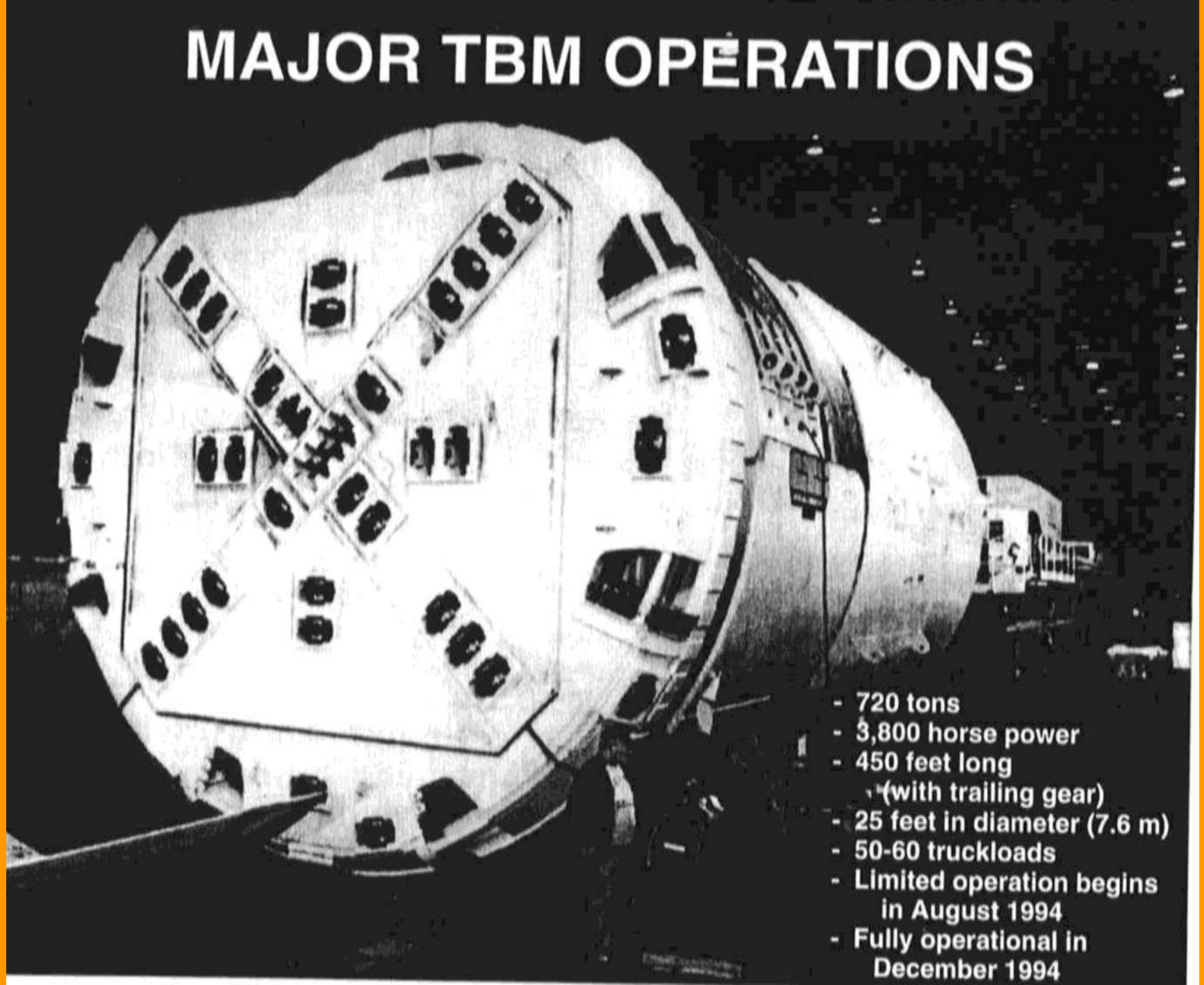
Ghost Dance Fault Mapping

Clearing Pavement For Detailed Fracture analysis

Engineering Studies

- Tunnel – Tunnel Boring Machine - TBM
- Alcove tests
- Large Block and other heater tests
- Tested mechanical,chemical, and hydrologic properties of rock samples
- Examined engineered materials for corrosion resistance

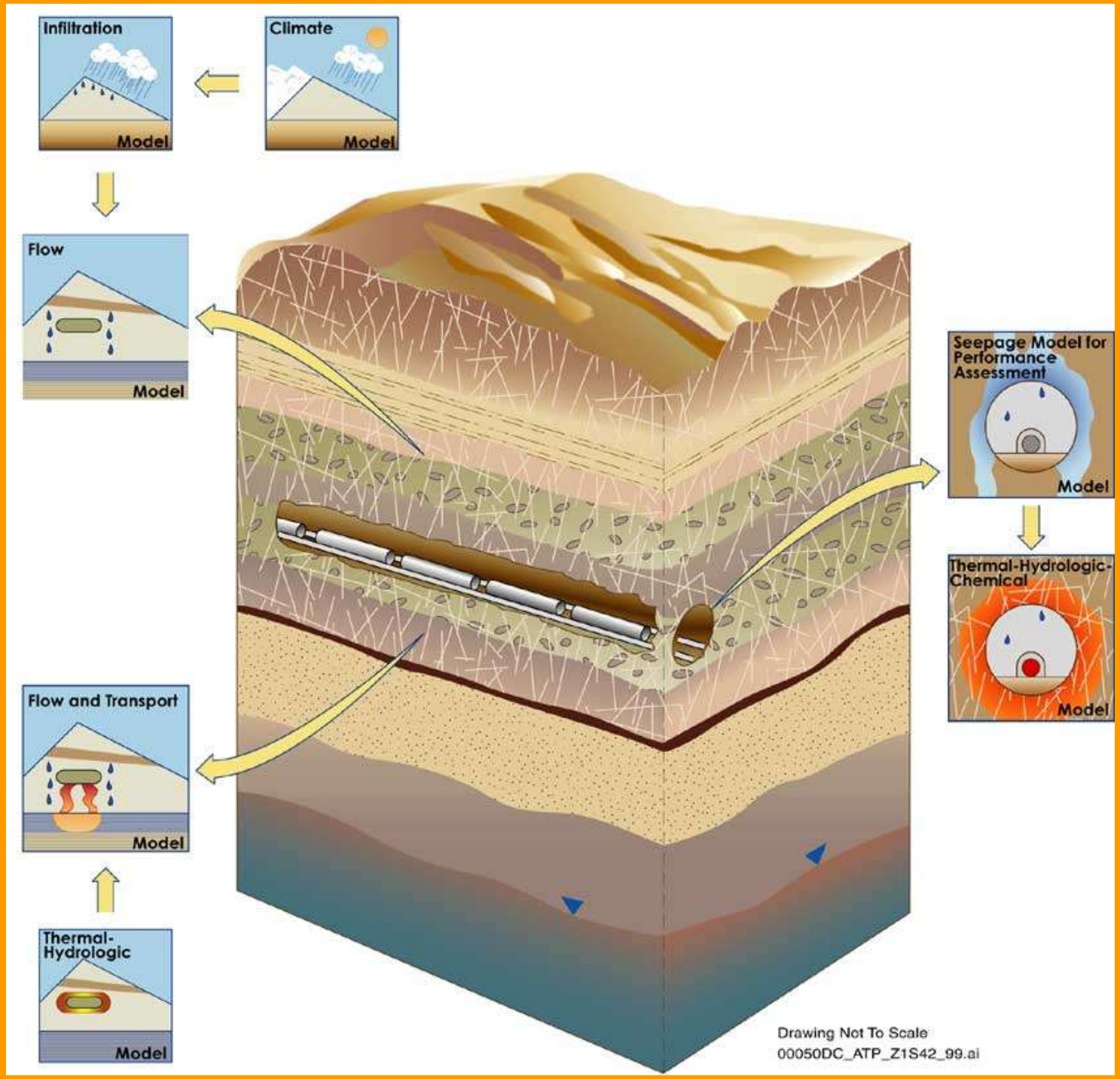
MAJOR TBM OPERATIONS



- 720 tons
- 3,800 horse power
- 450 feet long (with trailing gear)
- 25 feet in diameter (7.6 m)
- 50-60 truckloads
- Limited operation begins in August 1994
- Fully operational in December 1994

Tunnel Boring Machine

The center cutter section of the TBM (A) winds its way down US-95 through Indian Springs, Nevada, en route to the TBM assembly pad at Yucca Mountain. Upon arrival (B&C), the TBM parts were uncrated, assembled and tested.


Infiltration
Model
Climate
Model
Flow
Model
Seepage Model for Performance Assessment
Model
Thermal-Hydrologic-Chemical
Model
Flow and Transport
Model
Thermal-Hydrologic
Model
Drawing Not To Scale
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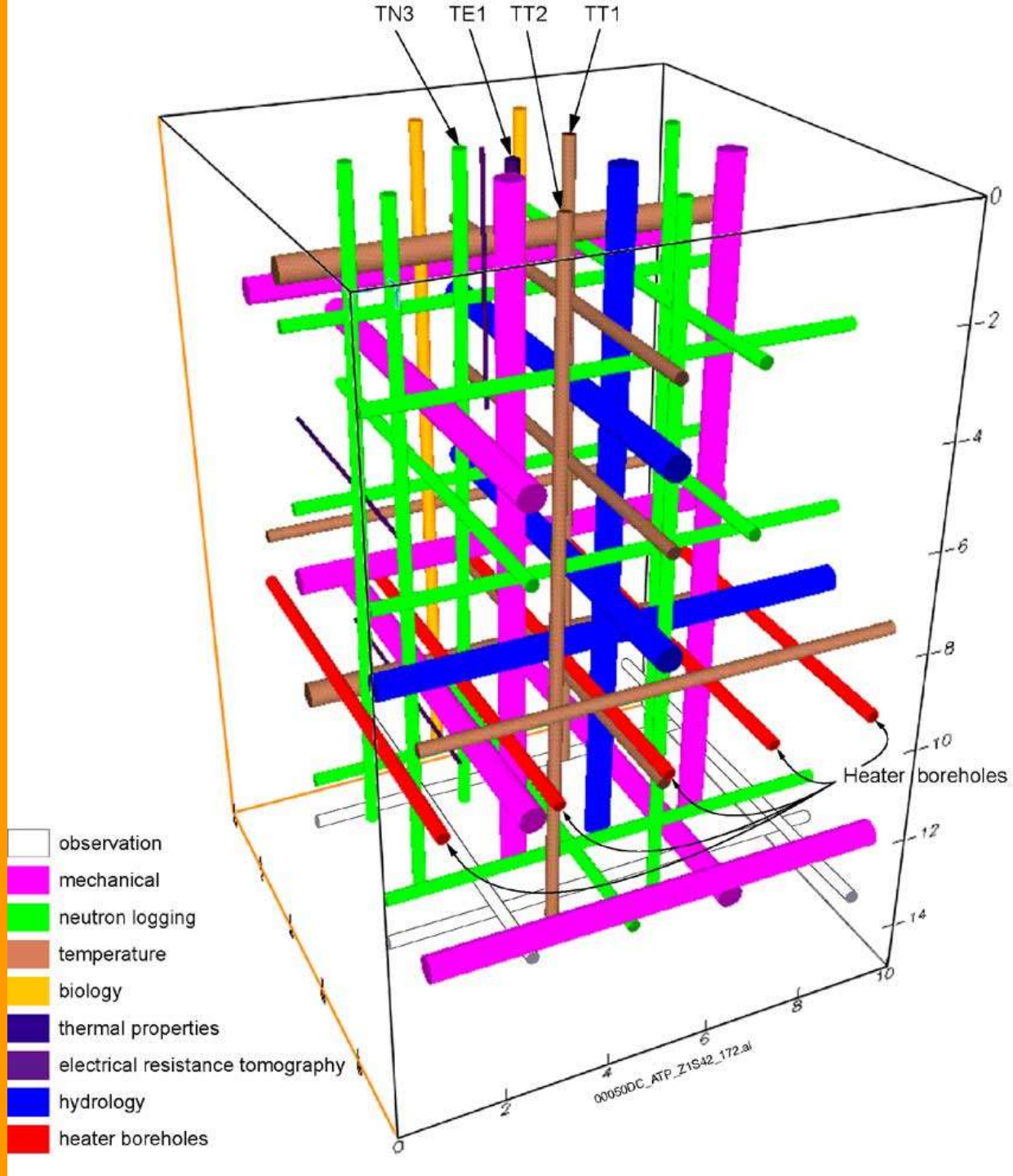
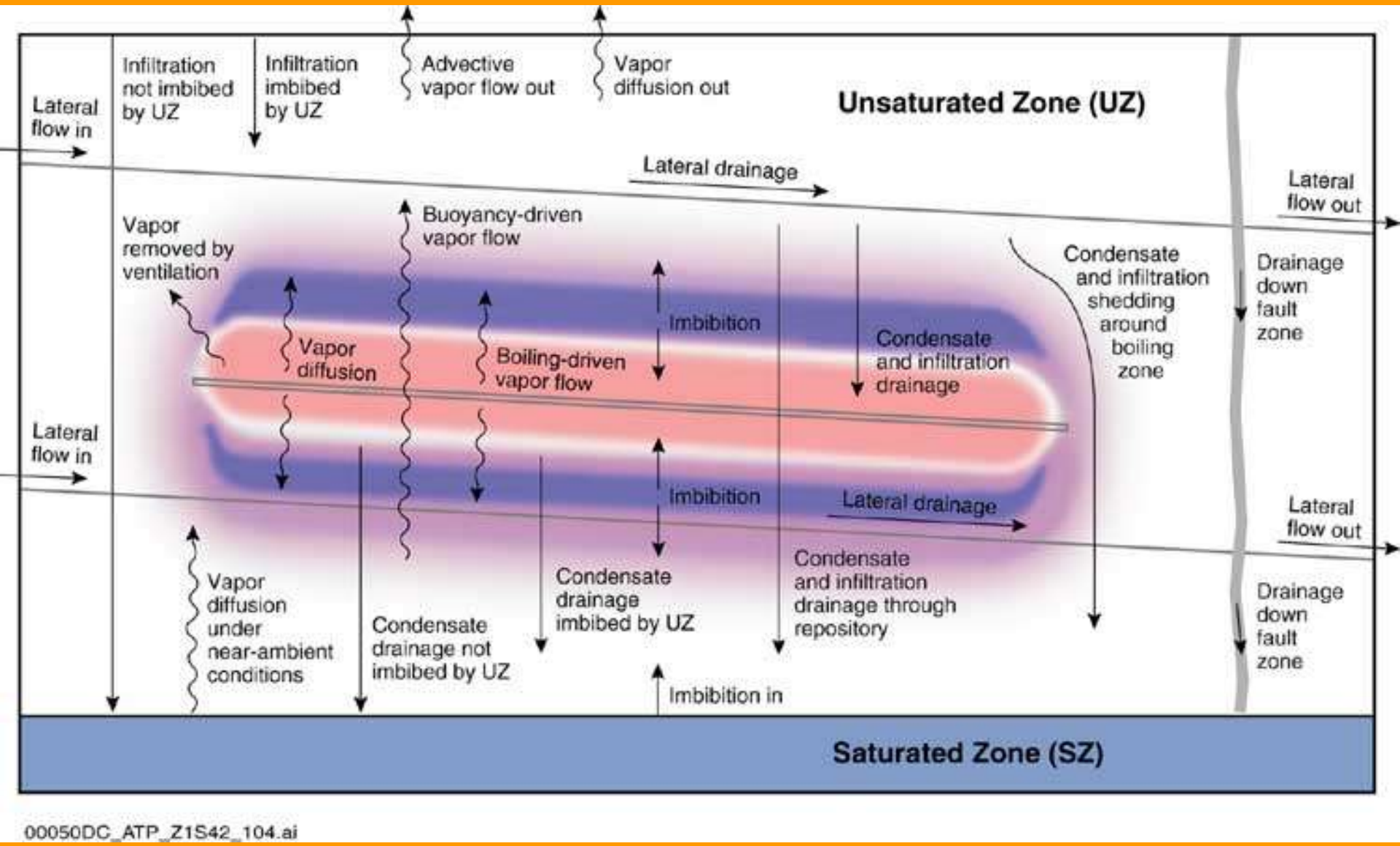
Alpine Miner Excavating the Access Drift

Large Block Heater Test



Large Block Heater Test –

various instrumentation sensors



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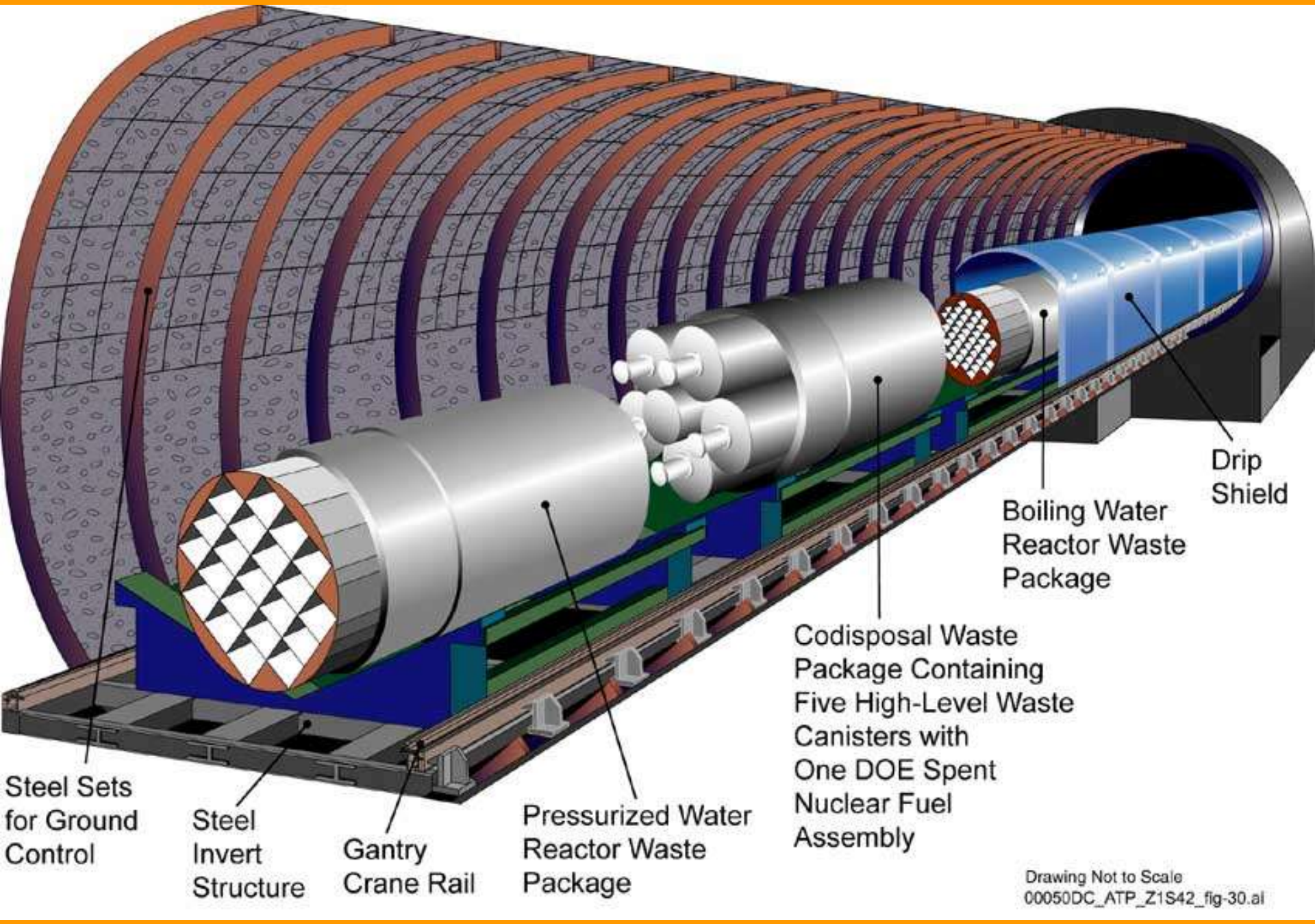
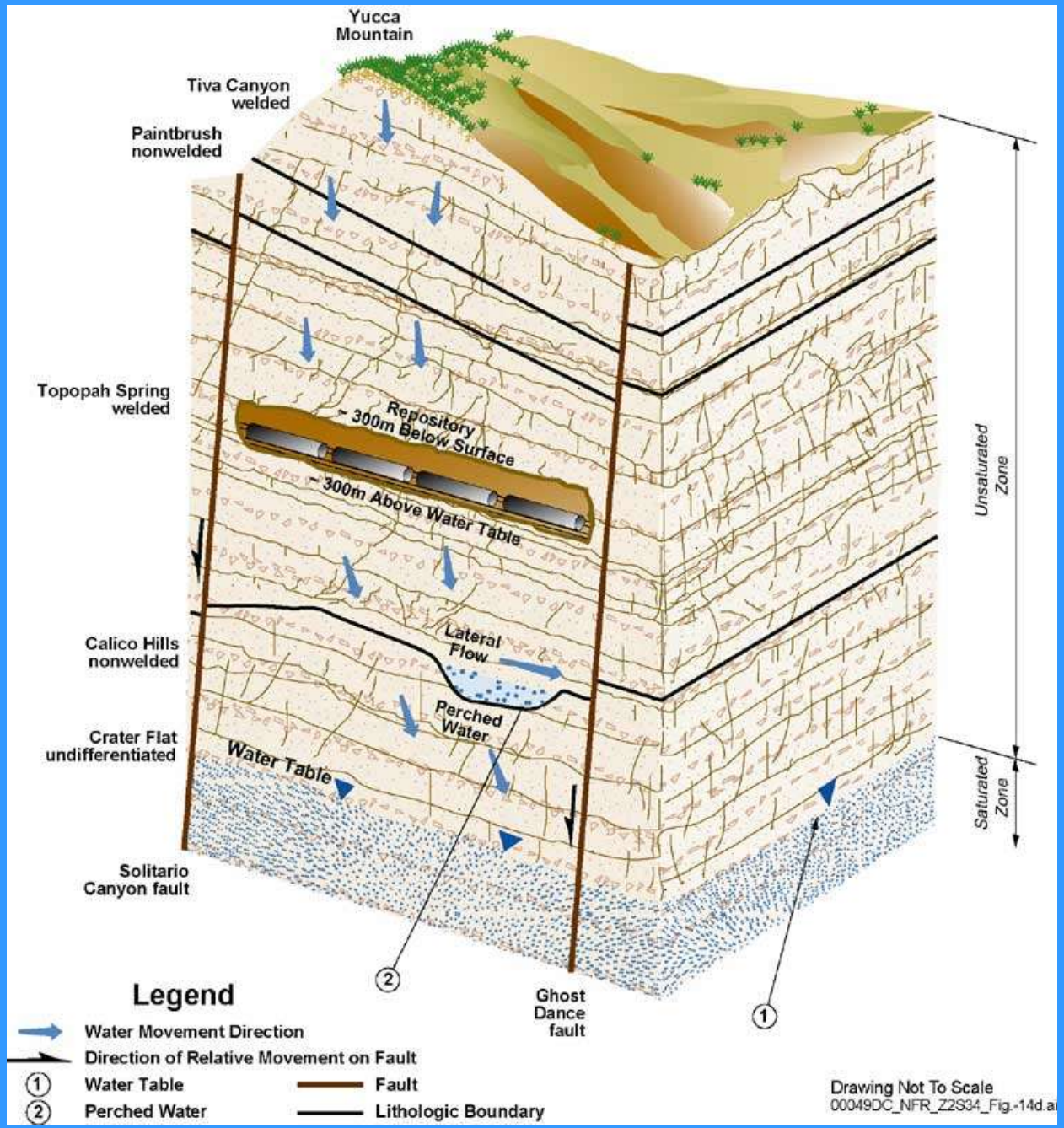
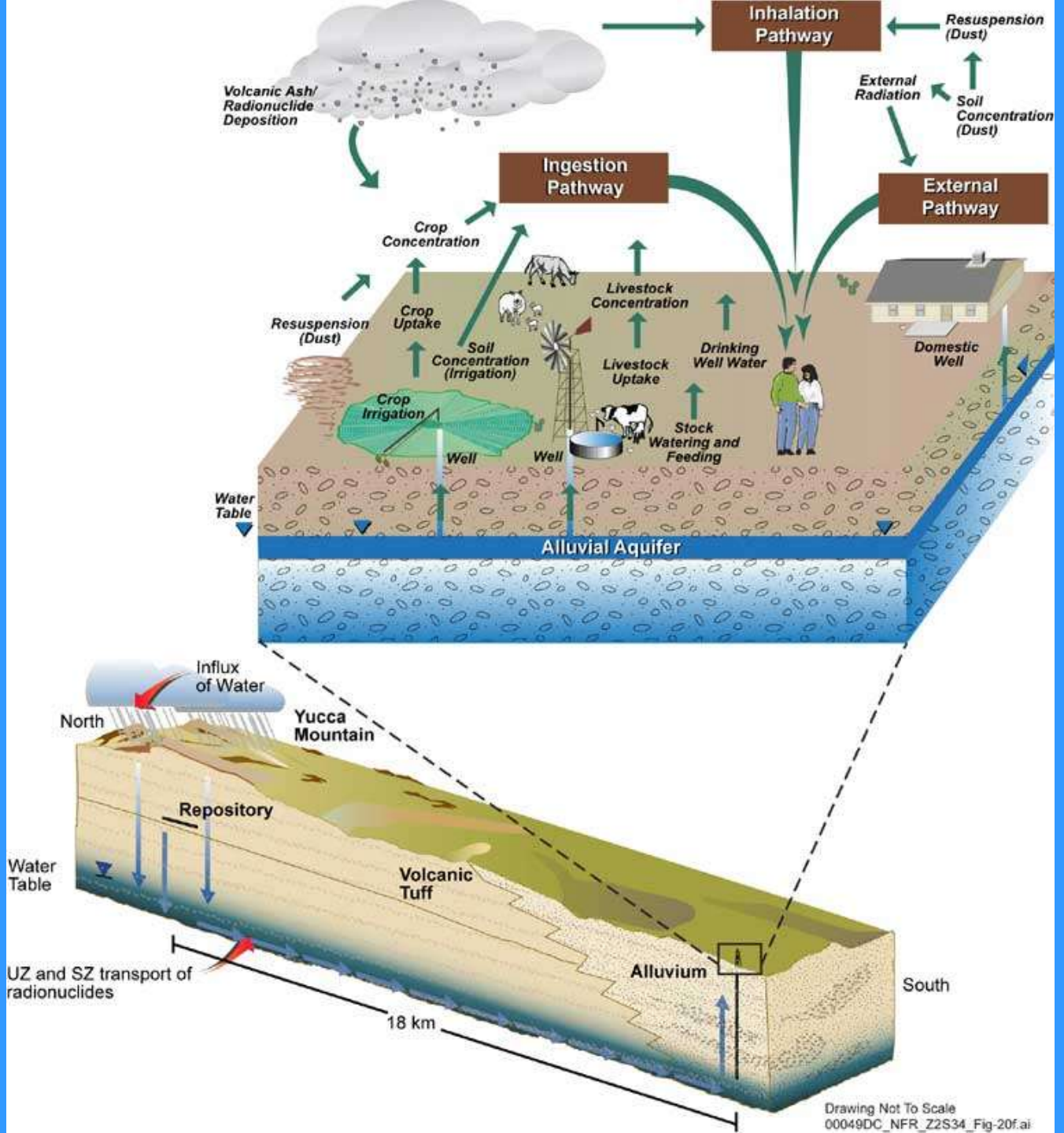
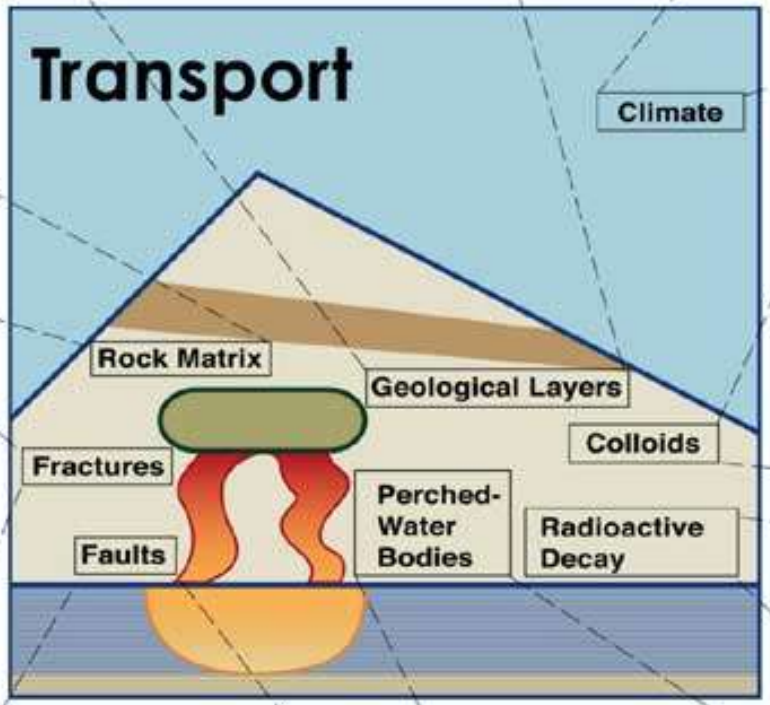

Drip Shield
Boiling Water Reactor Waste Package
Codisposal Waste Package Containing Five High-Level Waste Canisters with One DOE Spent Nuclear Fuel Assembly
Pressurized Water Reactor Waste Package
Gantry Crane Rail
Steel Invert Structure
Steel Sets for Ground Control
Drawing Not to Scale
00050DC_ATP_Z1S42_fig-30.ai

Hydrologic Investigations

- Unsaturated zone flow
  - Measure infiltration rate
  - Determine air and water movement properties
- Saturated zone – water table
  - Measure depth to water table
  - Conducted aquifer tests to determine transport and other properties
  - Injection tracer tests


Yucca Mountain
Tiva Canyon welded
Paintbrush nonwelded
Topopah Spring welded
Repository ~ 300m Below Surface
~ 300m Above Water Table
Calico Hills nonwelded
Lateral Flow
Perched Water
Crater Flat undifferentiated
Water Table
Solitario Canyon fault
Ghost Dance fault
Unsaturated Zone
Saturated Zone
Legend
Water Movement Direction
Direction of Relative Movement on Fault
1 Water Table
2 Perched Water
Fault
Lithologic Boundary
Drawing Not To Scale
00049DC_NFR_Z2S34_Fig.-14d.ai


Inhalation Pathway
Resuspension (Dust)
Volcanic Ash/ Radionuclide Deposition
External Radiation
Soil Concentration (Dust)
Ingestion Pathway
External Pathway
Crop Concentration
Livestock Concentration
Resuspension (Dust)
Crop Uptake
Soil Concentration (Irrigation)
Livestock Uptake
Drinking Well Water
Domestic Well
Crop Irrigation
Stock Watering and Feeding
Well
Well
Water Table
Alluvial Aquifer
Influx of Water
North
Yucca Mountain
Repository
Water Table
Volcanic Tuff
Alluvium
South
UZ and SZ transport of radionuclides
18 km
Drawing Not To Scale
00049DC_NFR_Z2S34_Fig-20f.ai



- Fracture vs. Matrix Flow
- Vitric CHn
- Zeolitic CHn

- Infiltration Rates
- Climate Regimes

- Matrix Diffusion and Sorption
- Properties (e.g., K_d, Permeability, Porosity)
- Dispersion

- Colloidal Transport
- Colloid-Facilitated Transport
- Colloid Size
- Size Exclusion
- Filtration Models and Parameters

- Fast Pathways of Transport
- Fracture—Matrix Interactions
- Properties (e.g., Aperture, Frequency)
- Sorption in Fractures
- Dispersion

- Decay Rate
- Fate of Daughter Products

- Fast Pathways of Transport
- Limit Lateral Transport

- Effects on Transport
- Perched-Water Models

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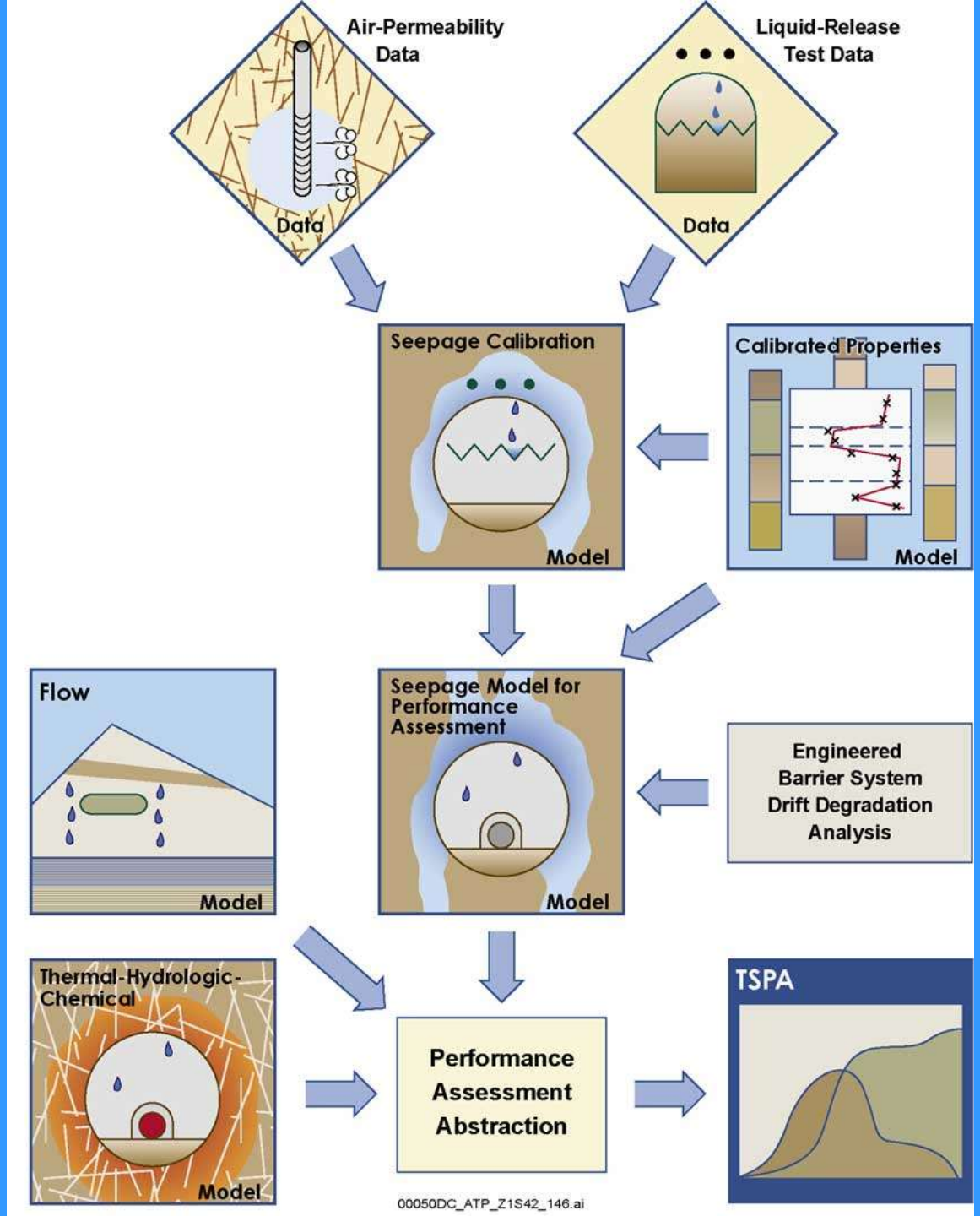
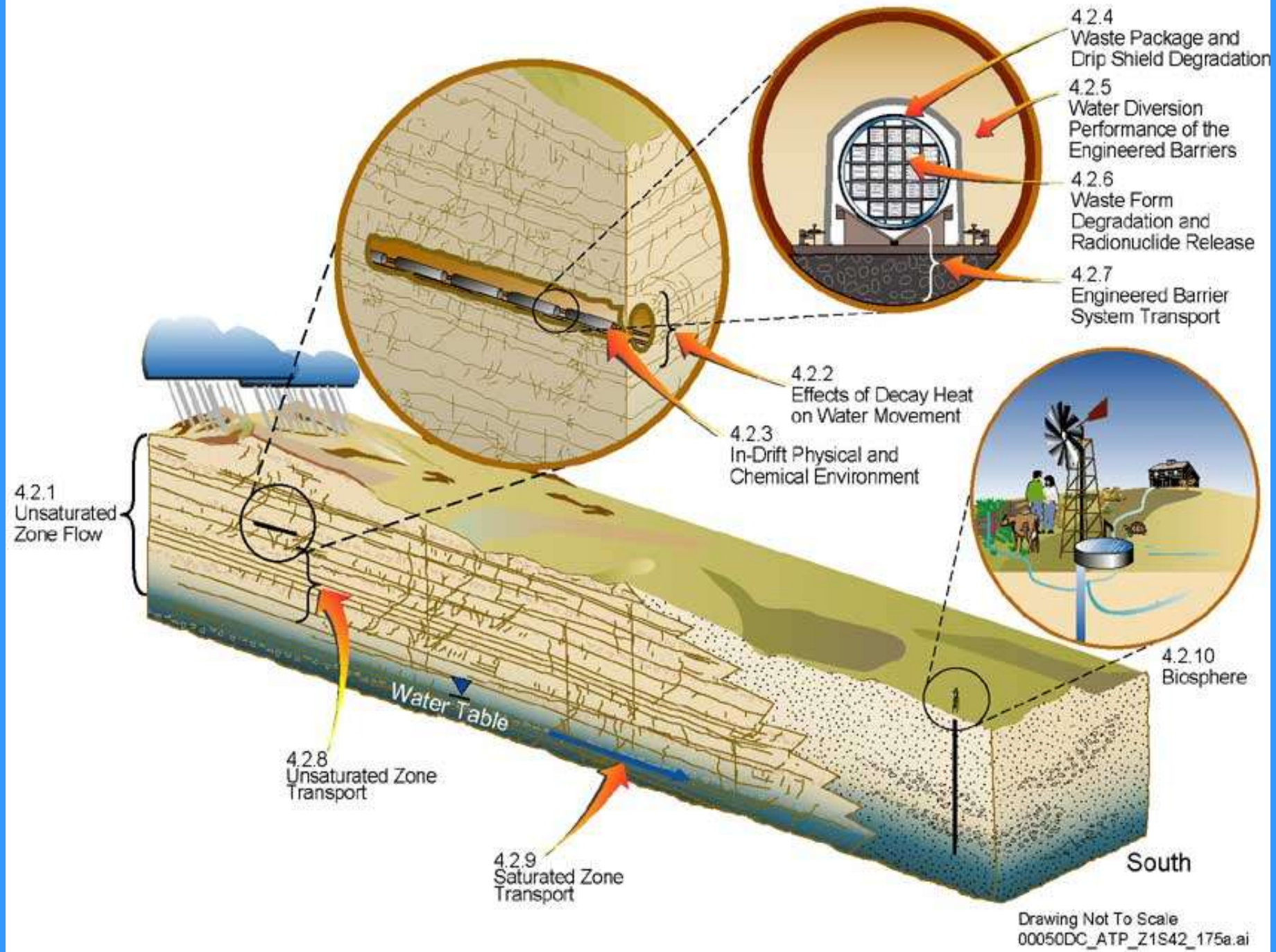

Air-Permeability Data
Data
Liquid-Release Test Data
Data
Seepage Calibration
Model
Calibrated Properties
Model
Flow
Model
Seepage Model for Performance Assessment
Model
Engineered Barrier System Drift Degradation Analysis
Thermal-Hydrologic-Chemical
Model
Performance Assessment Abstraction
TSPA
00050DC_ATP_Z1S42_146.ai


4.2.4
Waste Package and
Drip Shield Degradation
4.2.5
Water Diversion
Performance of the
Engineered Barriers
4.2.6
Waste Form
Degradation and
Radionuclide Release
4.2.7
Engineered Barrier
System Transport
4.2.2
Effects of Decay Heat
on Water Movement
4.2.3
In-Drift Physical and
Chemical Environment
4.2.1
Unsaturated
Zone Flow
4.2.10
Biosphere
Water Table
4.2.8
Unsaturated Zone
Transport
4.2.9
Saturated Zone
Transport
South
Drawing Not To Scale
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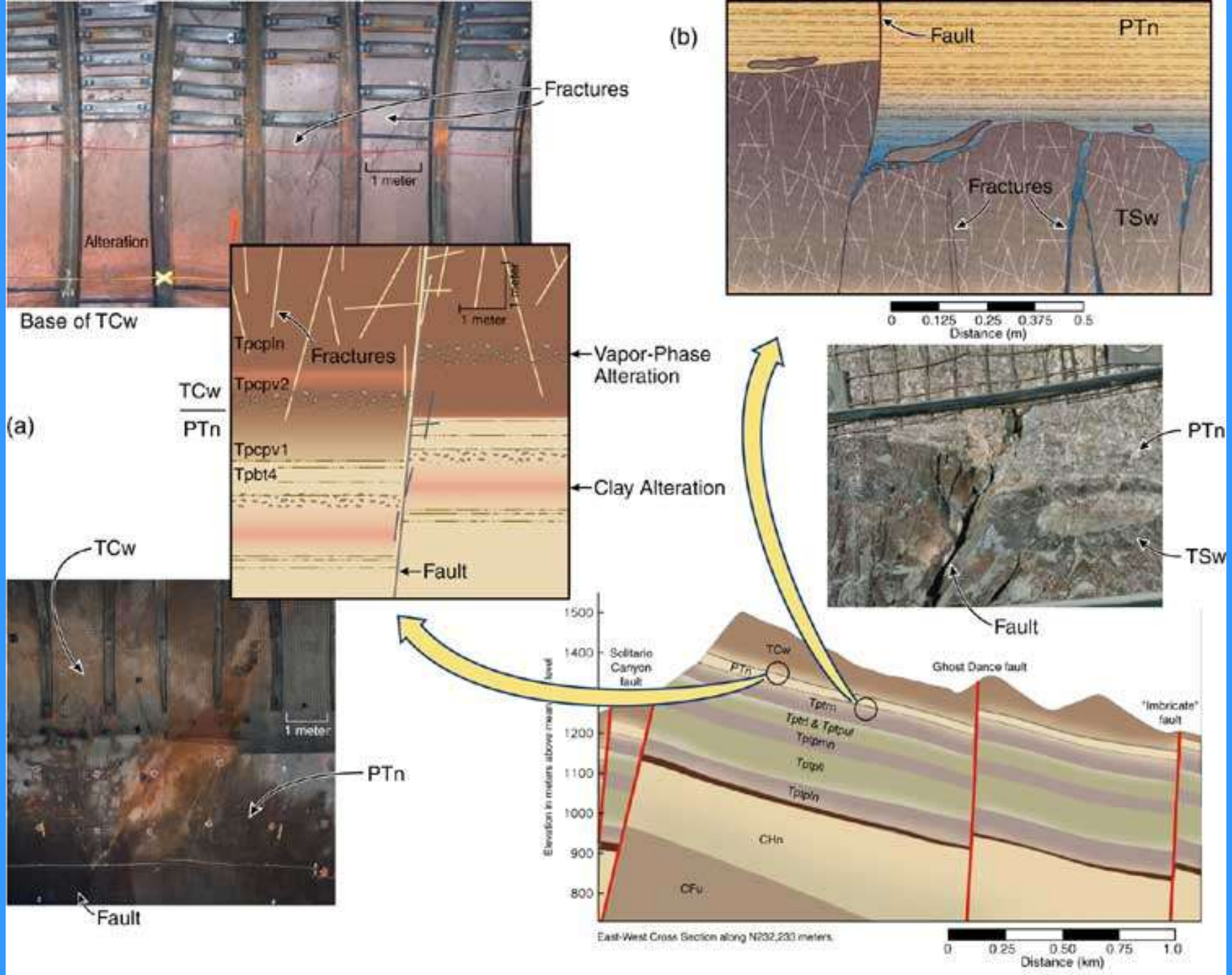

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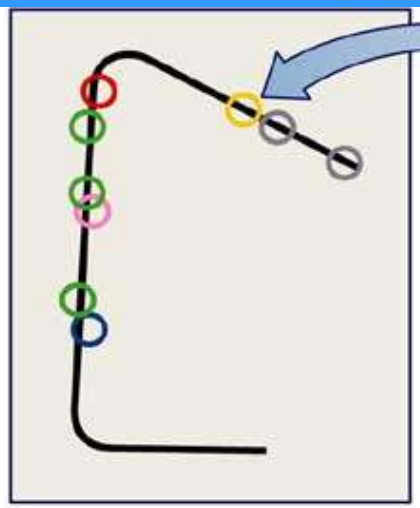
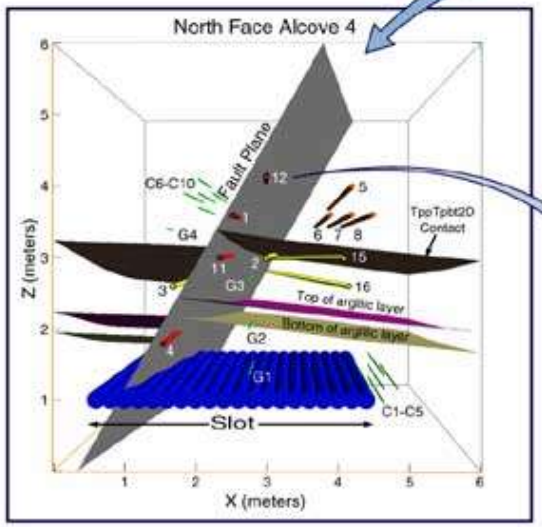
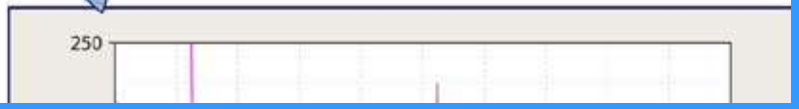


(a) Photograph of Alcove 4 Test Bed



(c) Schematic of Boreholes at Alcove 4

(b) Closeup of Tray on the Left-Hand Side of the Slot



Objectives:

- Evaluate flow mechanism in the Paintbrush nonwelded tuff unit.
- Quantify the damping and lateral diversion processes along a fault and along bedded tuff interfaces.

Approaches:

- Select a test bed containing bedded tuff layers (including an argillic layer), a fault, and a fracture.
- Release water under constant-head conditions to determine the intake rates.
- Monitor wetting front arrivals and measure potential changes in boreholes.

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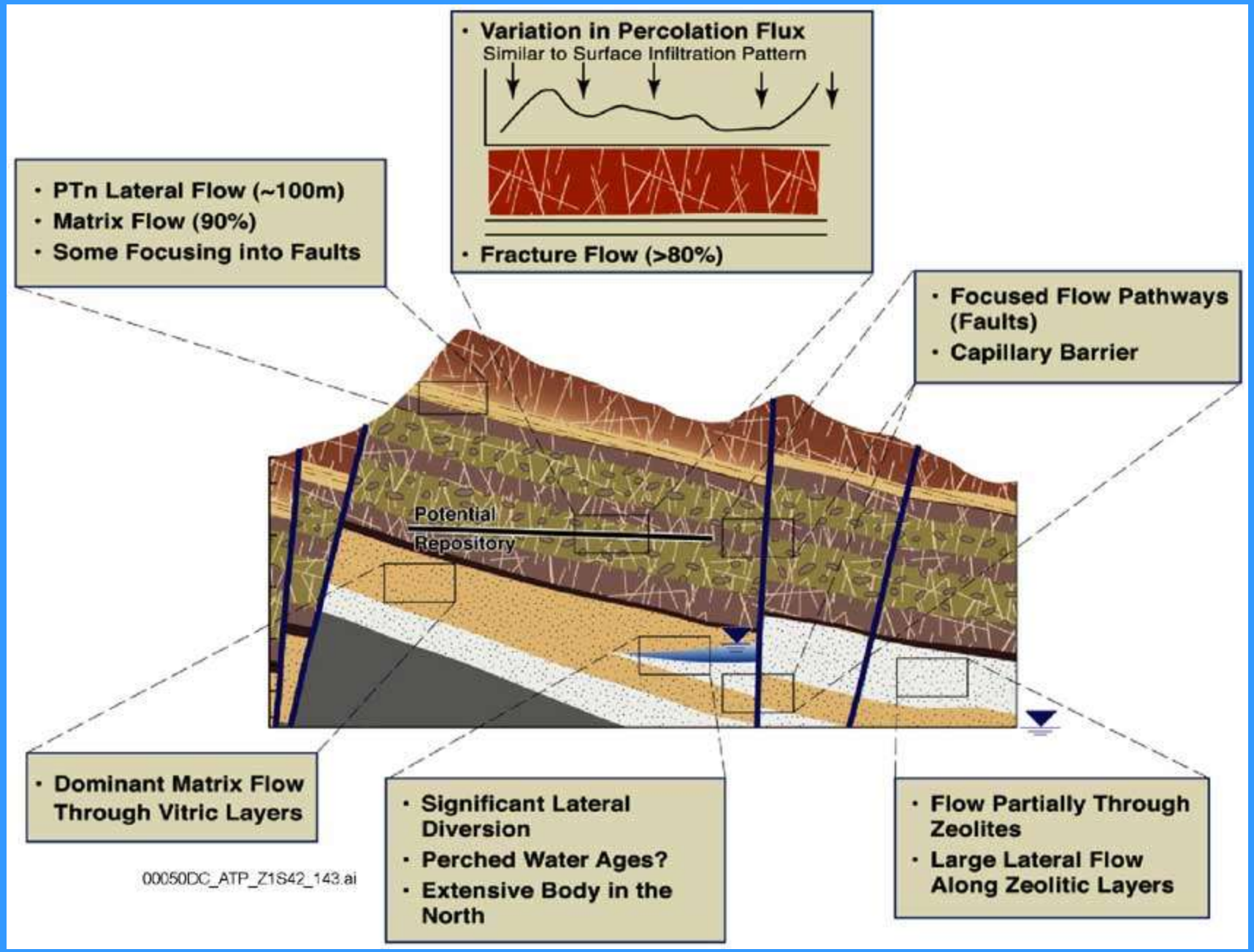
Results:

- Water intake rate in the fault decreased as more water was introduced into the release zone.
- Clay swelling is one mechanism proposed to interpret the field data.
- Detection of downgradient increases in saturation occurred over shorter time intervals with each liquid release test.


• Variation in Percolation Flux
Similar to Surface Infiltration Pattern
• Fracture Flow (>80%)
• PTn Lateral Flow (~100m)
• Matrix Flow (90%)
• Some Focusing into Faults
• Focused Flow Pathways (Faults)
• Capillary Barrier
Potential Repository
• Dominant Matrix Flow Through Vitric Layers
• Significant Lateral Diversion
• Perched Water Ages?
• Extensive Body in the North
• Flow Partially Through Zeolites
• Large Lateral Flow Along Zeolitic Layers
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Objectives:

- Provide isotopic data to define age evolution of water in the unsaturated zone.
- Provide data to delineate flow paths over geological time scales.

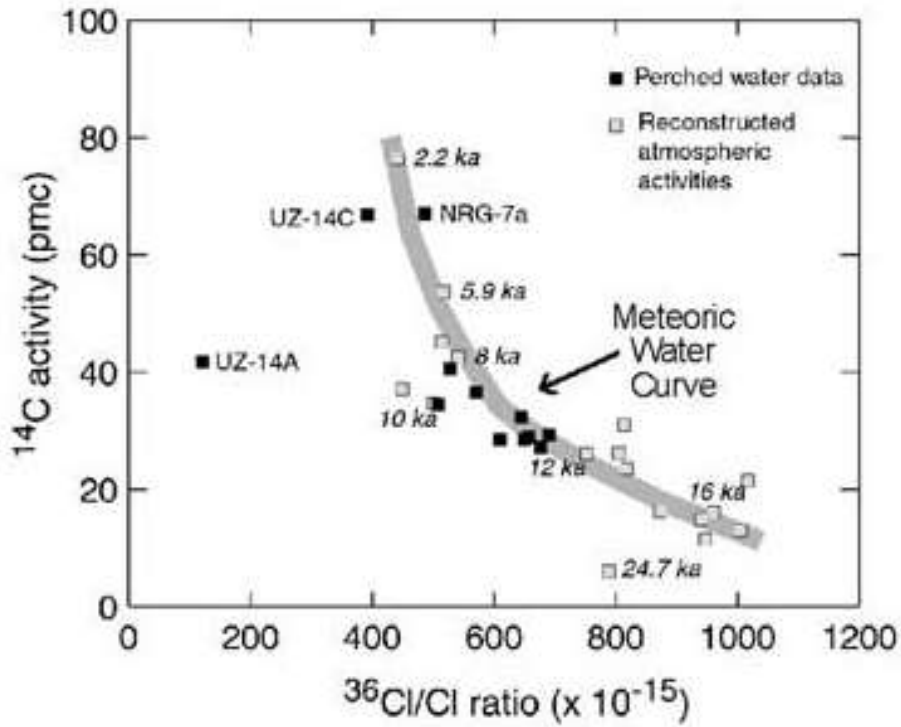
Approaches:

- Leach salts from unsaturated zone cores or cutting for ^{36}Cl and Sr isotopic analyses.
- Extract water for tritium, hydrogen and oxygen stable isotopes, and carbon isotopic analyses.
- Digest mineral samples for analyses of Sr isotope ratios and of U series nuclides.

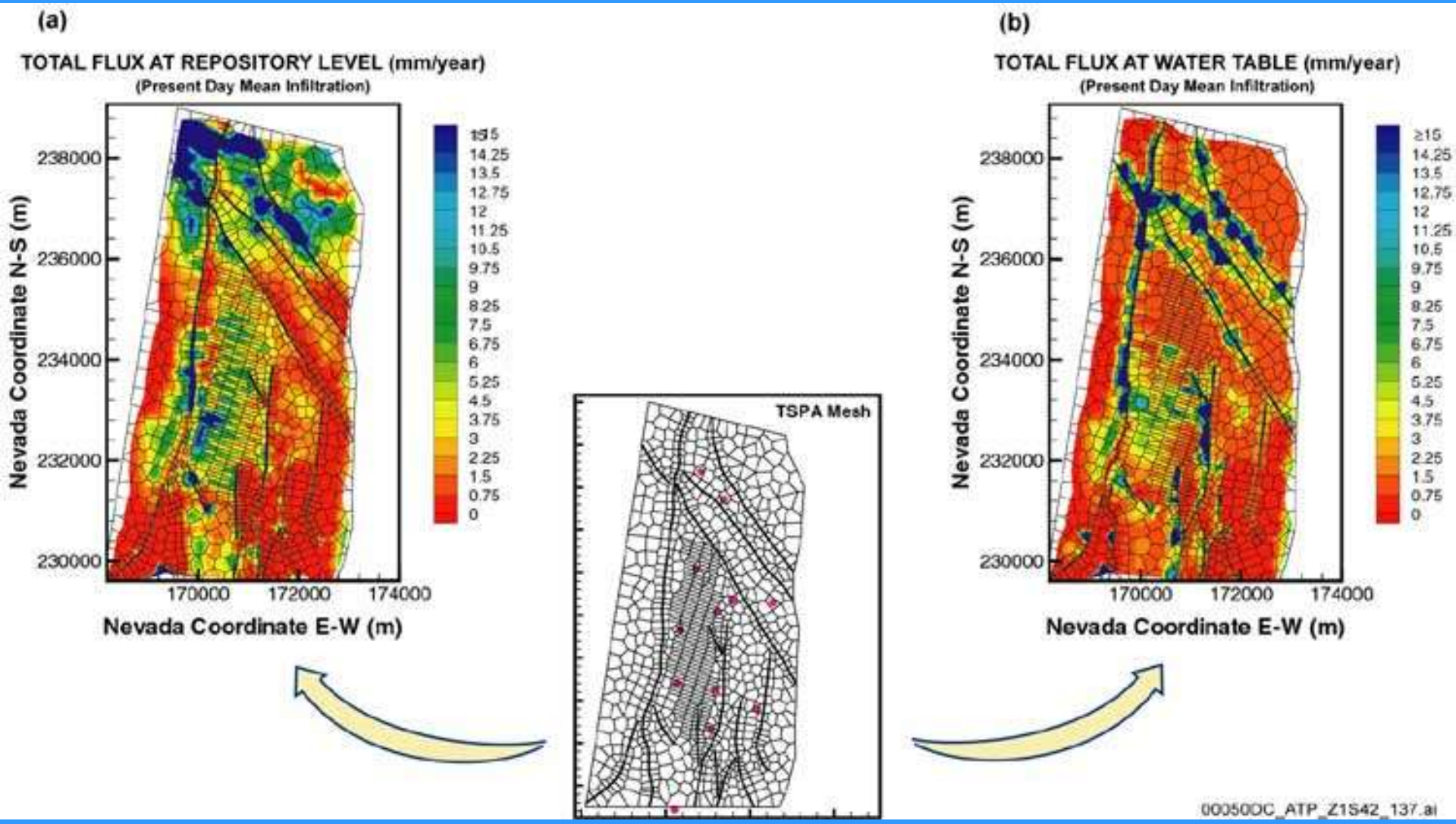
Results:

- Bomb-pulse $^{36}Cl/Cl$ signals are present in the vicinity of some fault zones in the Exploratory Studies Facility
- Detectable levels of tritium are present in ~6% of pore water samples.
- Bomb-pulse $^{36}Cl/Cl$ and tritium signals are not present in perched waters.
- Age of perched waters, mixing between fast and slow flows, climate of recharge are estimated by carbon and stable isotope analyses.
- $^{234}U/^{238}U$ activity ratios indicate recharge through fractures and minimal exchange between pore water and fracture water.

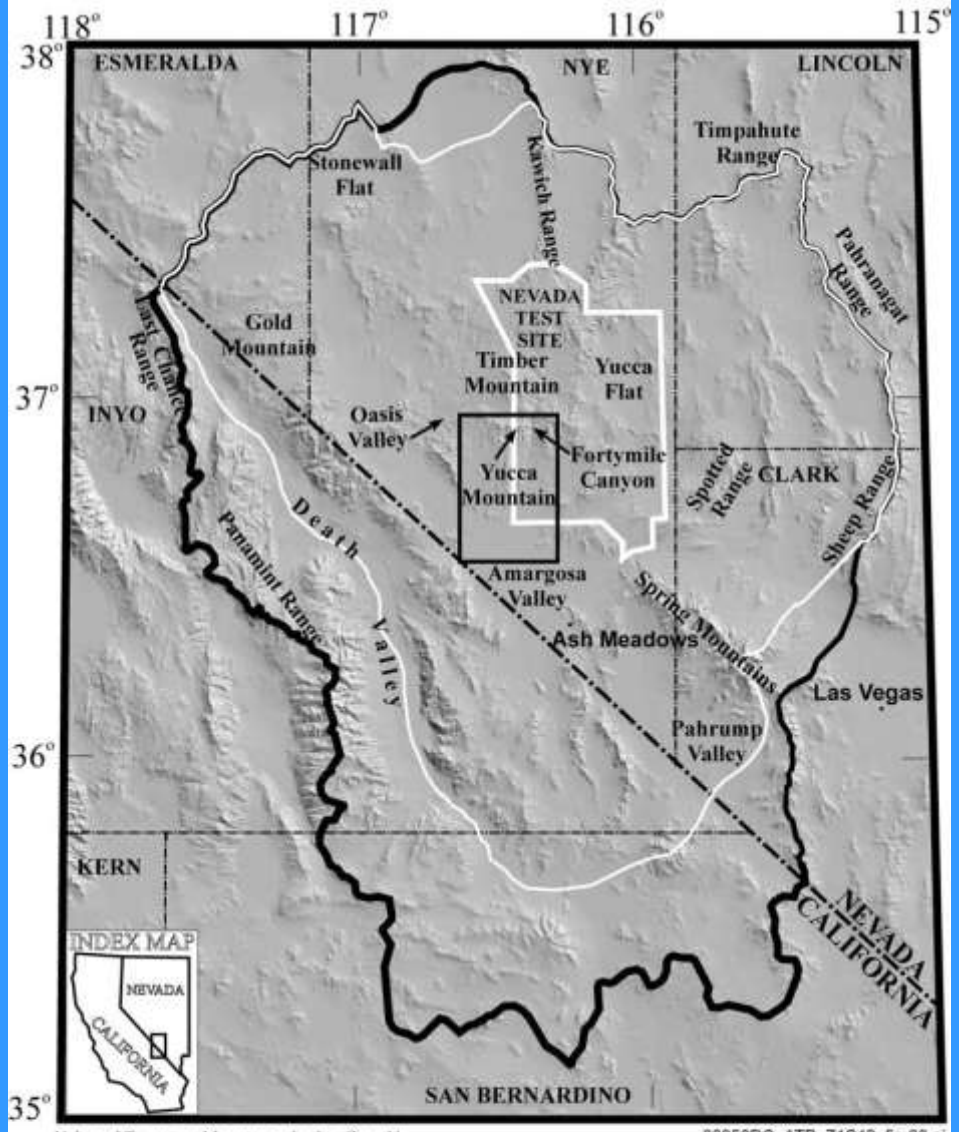
(a) Photograph of a Fracture with Calcite Infill



) Perched Water Ages Determined by ^{14}C and $^{36}Cl/Cl$ Data


(a)
TOTAL FLUX AT REPOSITORY LEVEL (mm/year)
(Present Day Mean Infiltration)
Nevada Coordinate N-S (m)
238000
236000
234000
232000
230000
170000
172000
174000
Nevada Coordinate E-W (m)
≥15
14.25
13.5
12.75
12
11.25
10.5
9.75
9
8.25
7.5
6.75
6
5.25
4.5
3.75
3
2.25
1.5
0.75
0
TSPA Mesh
(b)
TOTAL FLUX AT WATER TABLE (mm/year)
(Present Day Mean Infiltration)
Nevada Coordinate N-S (m)
238000
236000
234000
232000
230000
170000
172000
174000
Nevada Coordinate E-W (m)
≥15
14.25
13.5
12.75
12
11.25
10.5
9.75
9
8.25
7.5
6.75
6
5.25
4.5
3.75
3
2.25
1.5
0.75
0
00050DC_ATP_Z1542_137.ai


Glass
Glass
Kapt



Universal Transverse Mercator projection, Zone 11.
Shaded-relief base from 1:250,000-scale Digital Elevation Model;
sun illumination from northeast at 30 degrees above horizon

00050DC_ATP_Z1S42_fig-93.ai

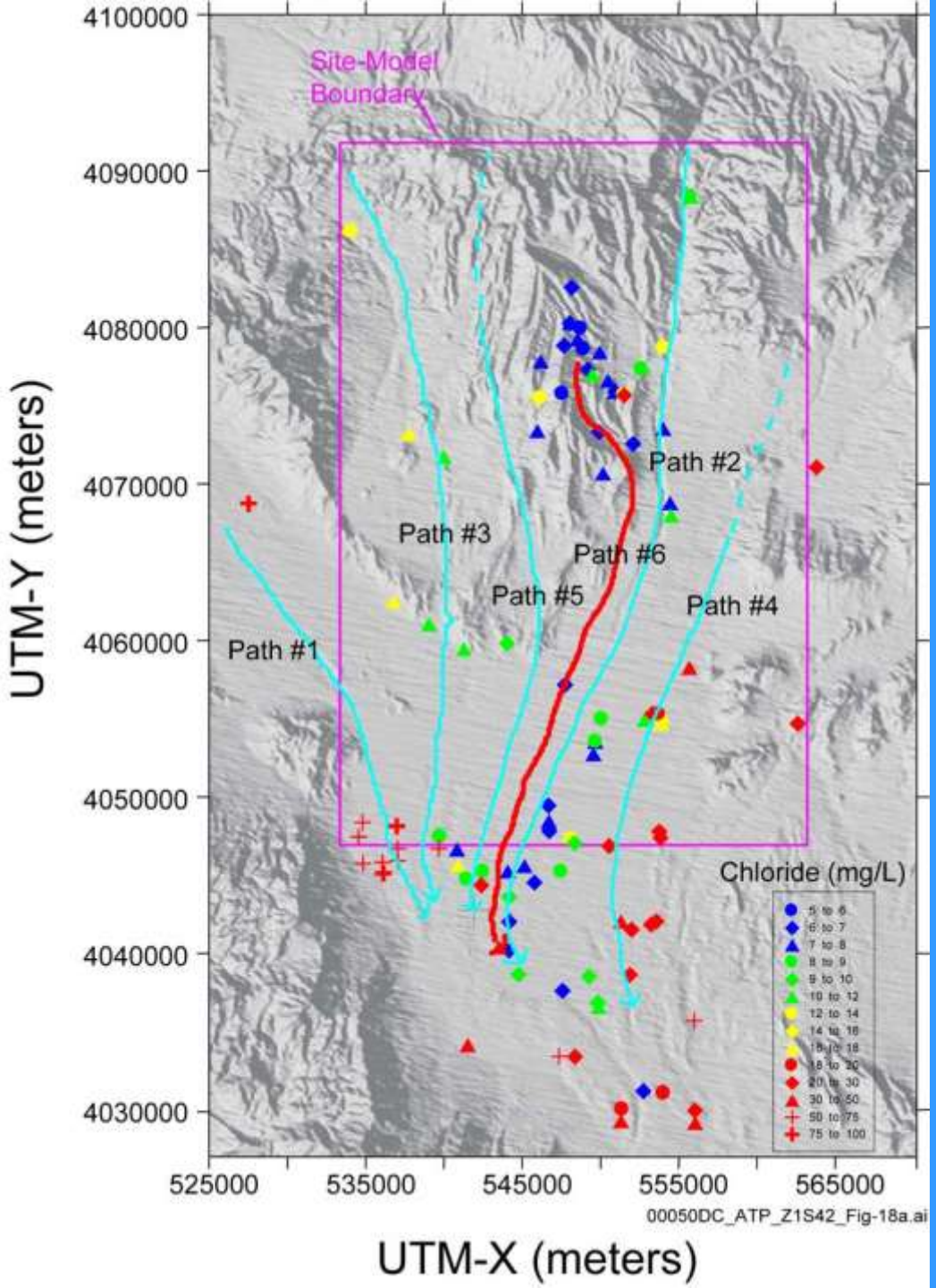
25 0 25 50 KILOMETERS

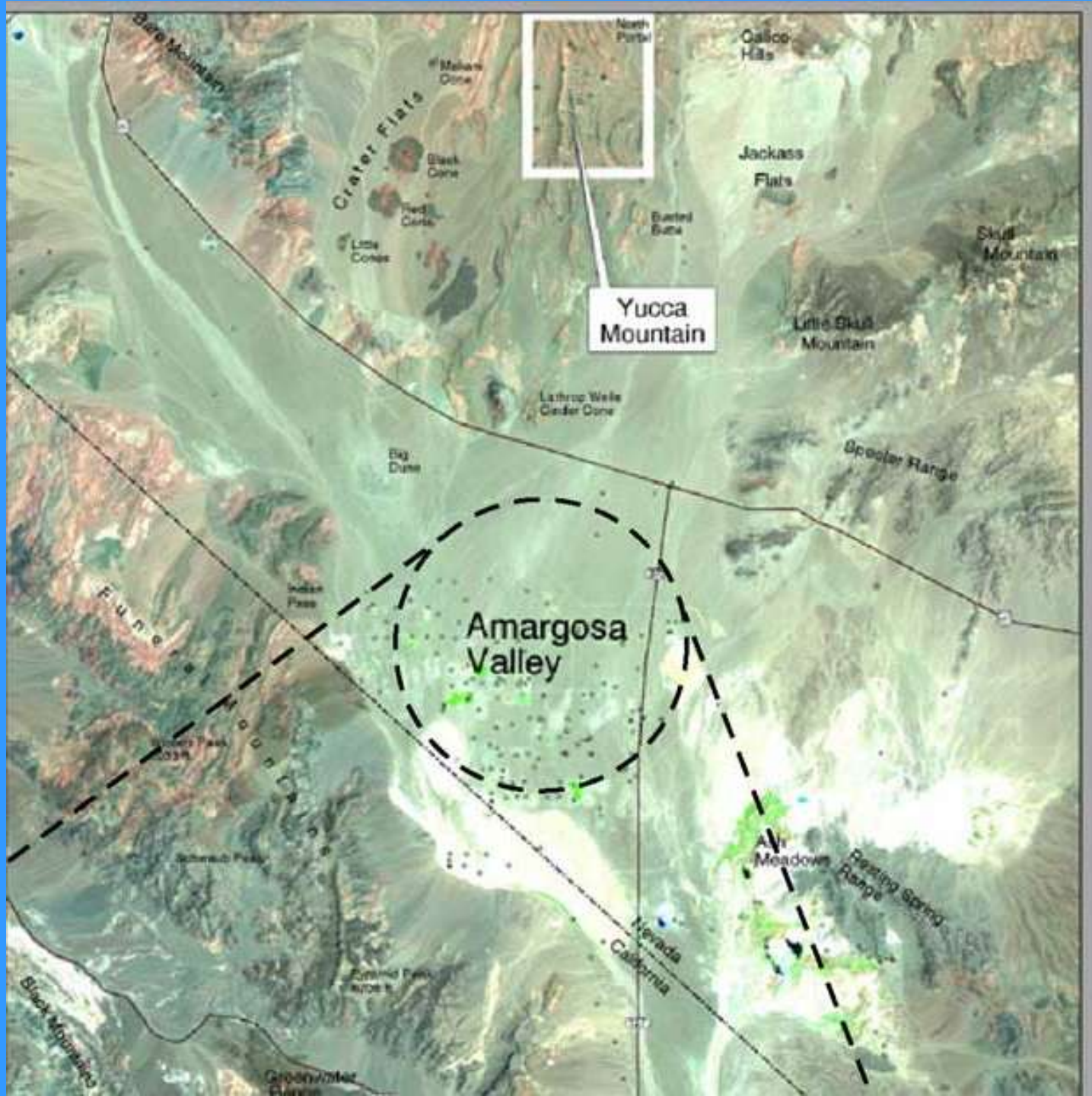
25 0 25 50 MILES

N

EXPLANATION

- Death Valley Regional Flow System Boundary
- Subregion Boundary
- Site-scale Saturated Zone Flow and Transport Model Boundary

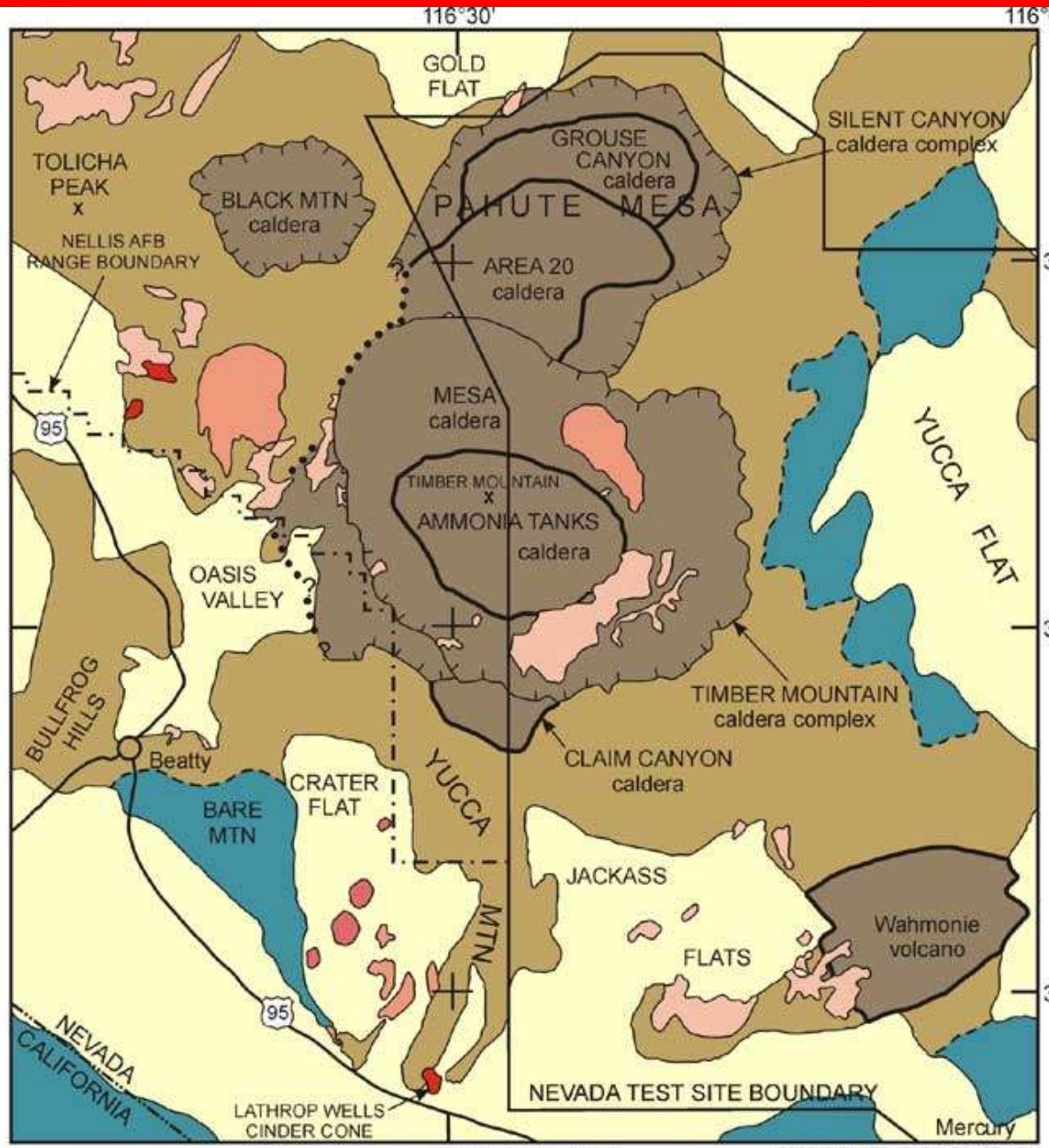

Site-Model Boundary
Path #1
Path #2
Path #3
Path #4
Path #5
Path #6
Chloride (mg/L)
5 to 6
6 to 7
7 to 8
8 to 9
9 to 10
10 to 12
12 to 14
14 to 16
16 to 18
18 to 20
20 to 30
30 to 50
50 to 75
75 to 100
4100000
4090000
4080000
4070000
4060000
4050000
4040000
4030000
525000
535000
545000
555000
565000
UTM-Y (meters)
UTM-X (meters)
00050DC_ATP_Z1S42_Fig-18a.ai


Yucca Mountain
Amargosa Valley
Crater Flats
Jackass Flats
Calico Hills
Skull Mountain
Little Skull Mountain
Spooner Range
Big Dune
Lathrop Wells Cinder Cone
Black Cone
Red Cone
Little Cones
Buried Butte
North Portal
Bare Mountain
Funeral Mountains
Nevada
California
Ash Meadows
Resting Spring Range

Potential for Volcanism

- Three periods of volcanism in last 40 Ma
  - Mid-Tertiary volcanism = 17 - 7 MA
  - Basin & Range volcanism = post-7 MA
  - Recent Volcanism – Crater Flats Cinder Cones = 1 MA – waning & moving westward
- Chance for a volcano disrupting a repository is virtually nonexistent
- Chance = 1 in 70,000,000 or 0.0000014% per year

Simplified Geologic Map



EXPLANATIO

Caldera topographic walls

Caldera structural margins

Inferred caldera margins

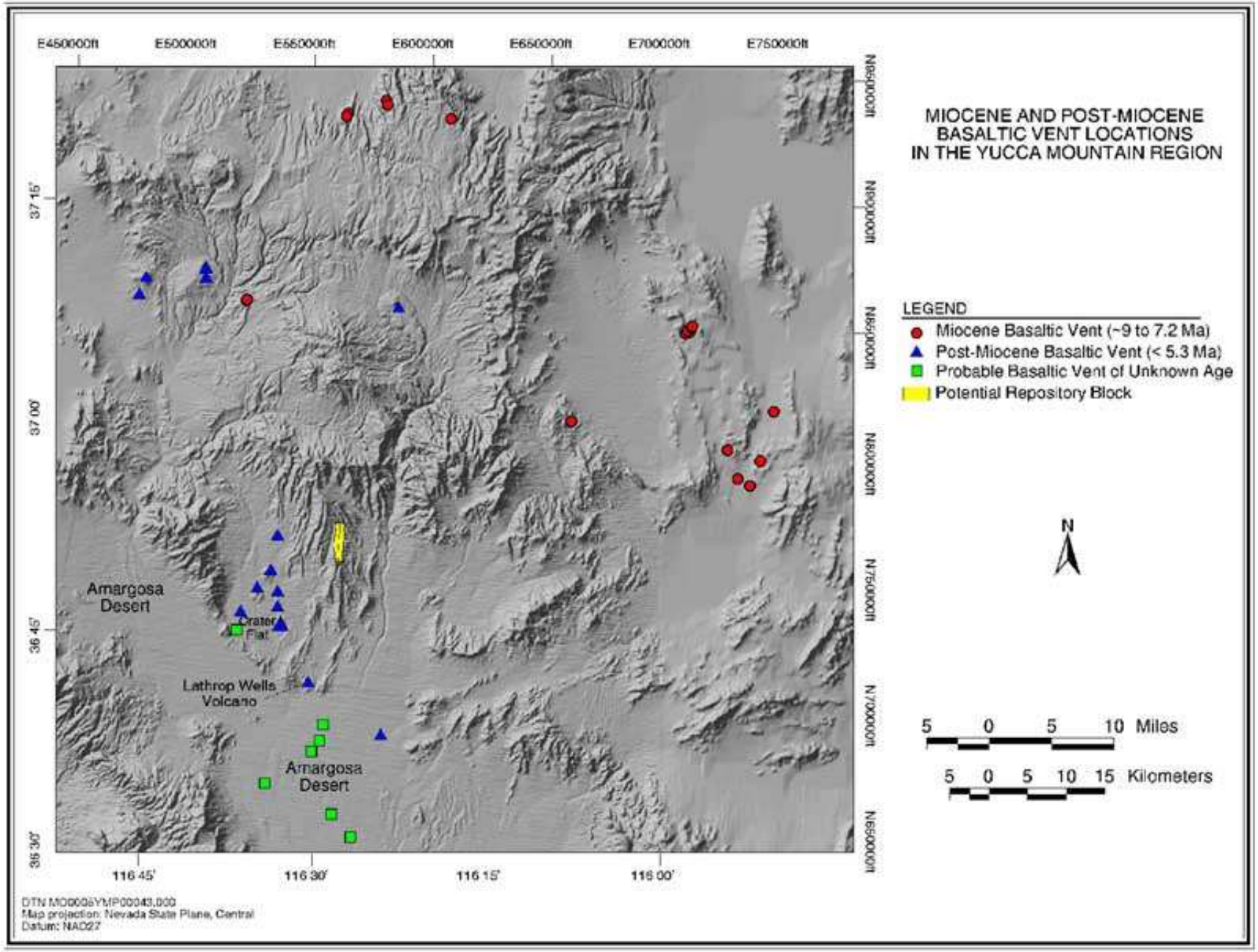
Contacts between geologic units, dashed where approximate

0 15 km

0 10 mi

Qa	Quaternary (less than 2 million years old) deposits of alluvium and other sedimentary deposits
Qby	Late Quaternary basaltic volcanic rocks, less than about 770,000 years in age
Qbo	Early Quaternary basaltic volcanic rocks, ranging from about 1.6 to 0.77 million years in age
Typ	Late Tertiary (Pliocene) basaltic volcanic rocks, ranging from about 5.0 to 1.6 million years in age
Tyb	Tertiary (Miocene) basaltic volcanic rocks, greater than 5 million years in age
Tv	Tertiary volcanic rocks of Miocene age (ranging from about 15 to 7.5 million years in age), including welded and nonwelded silicic ash-flow tuff deposited outside of the caldera margins
Tvc	Tertiary volcanic rocks of Miocene age (ranging from about 15 to 7.5 million years in age), including welded and nonwelded silicic ash-flow tuff deposited within the caldera margins
	Older pre-Tertiary bedrock. Rock types include mostly Paleozoic (approximately 225 to 570 million year old) quartzite, limestone, dolomite, shale, siltstone, and sandstone.

Easting

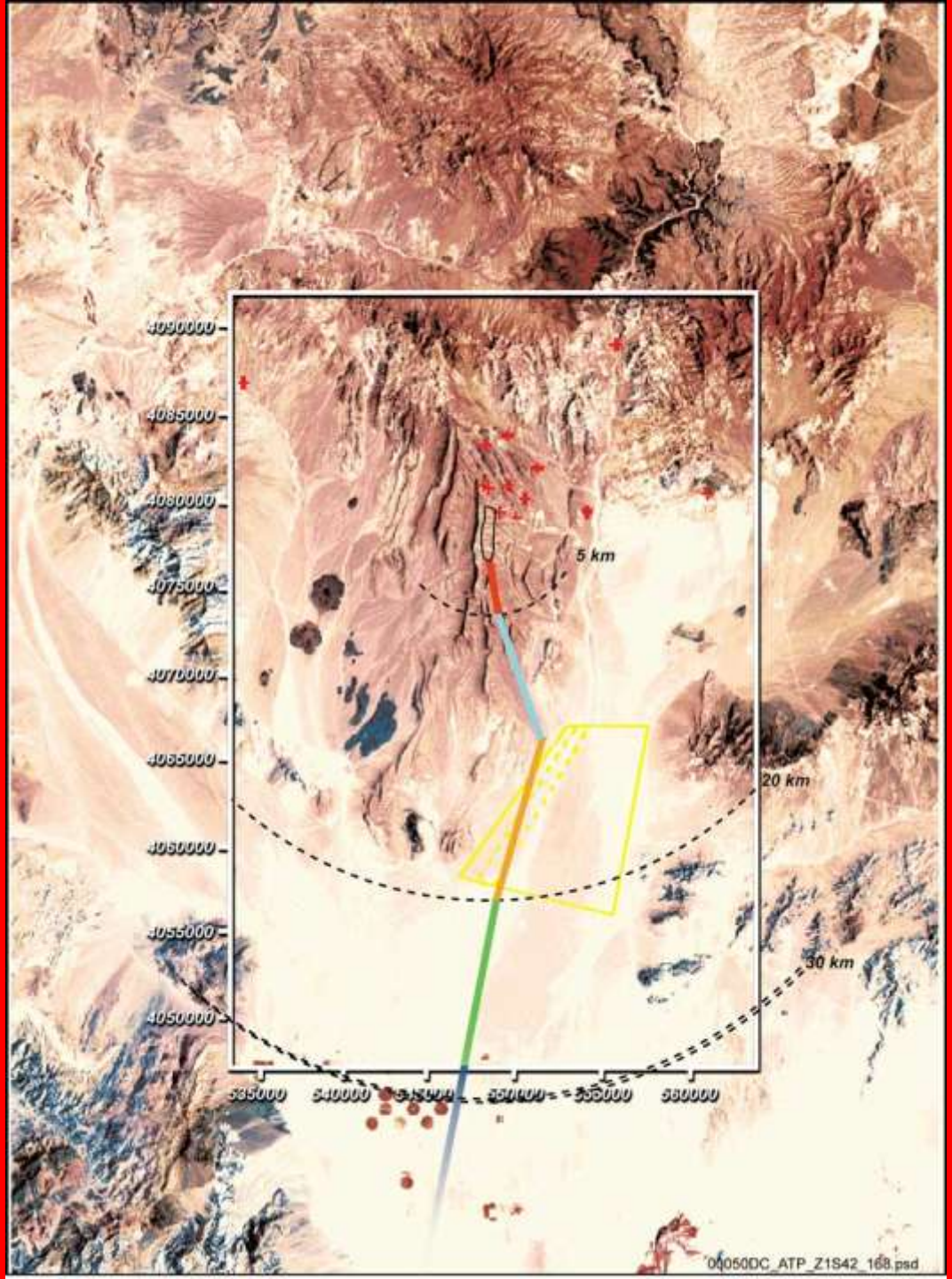


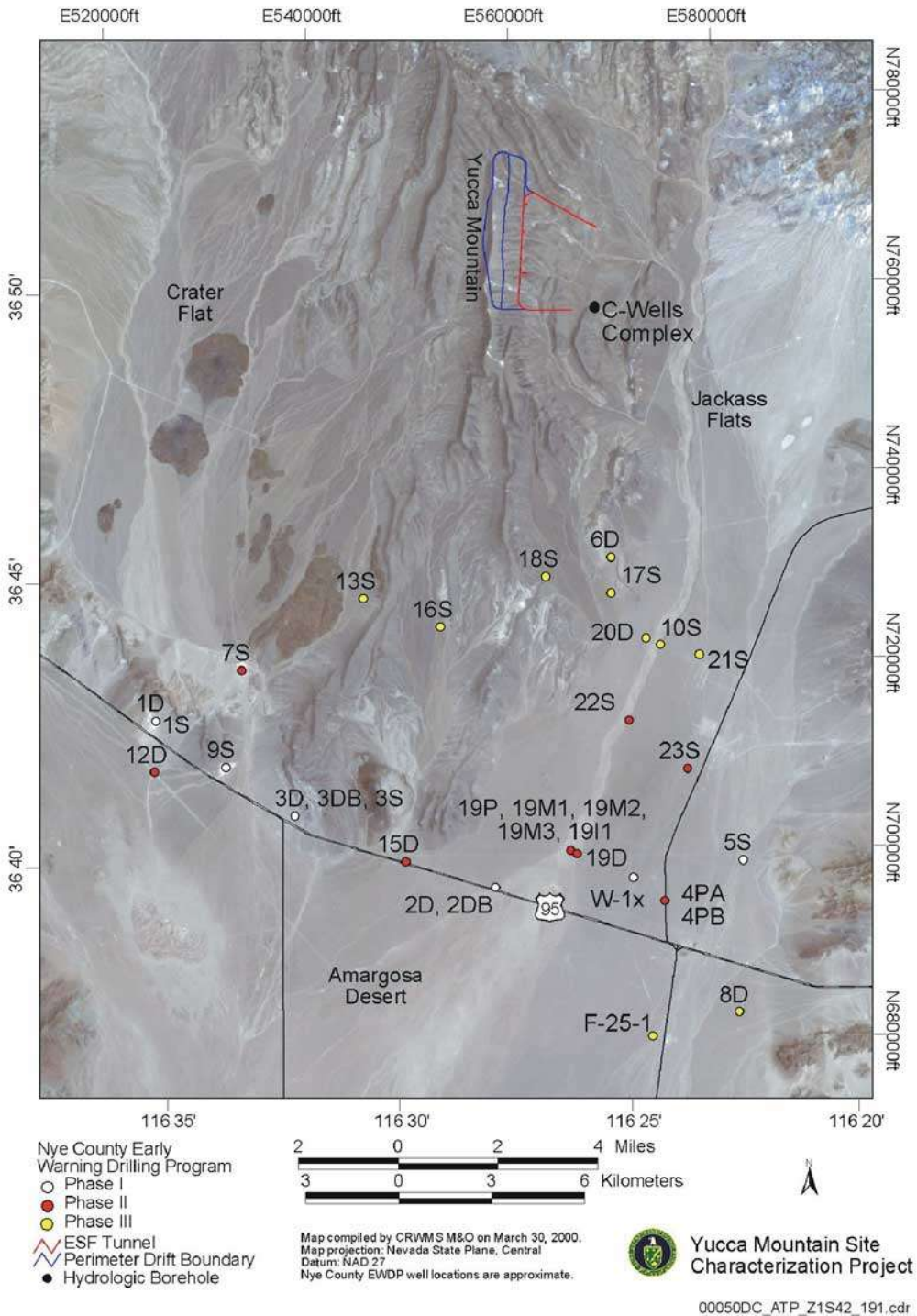
Latitude

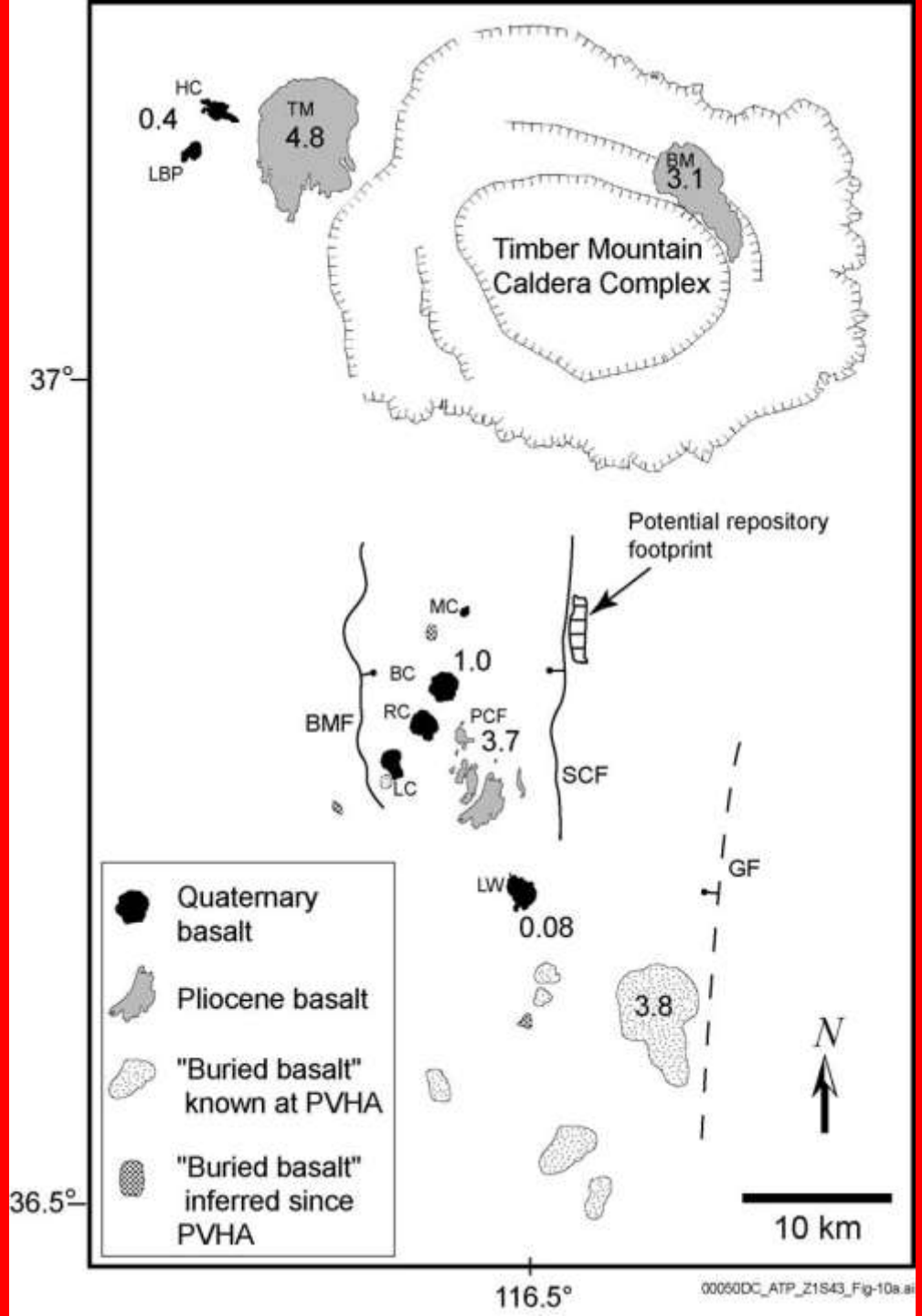
Northing

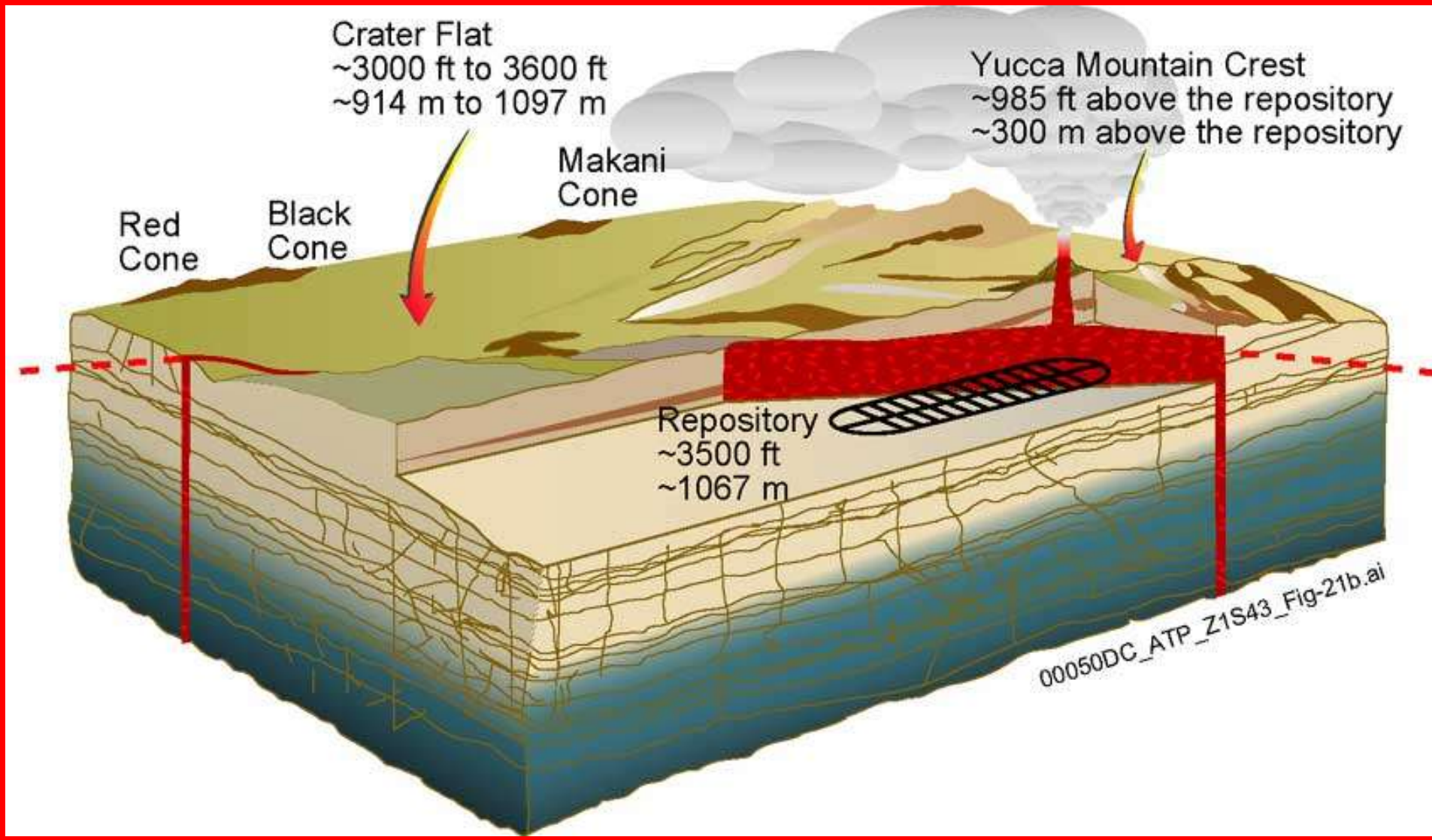
Longitude

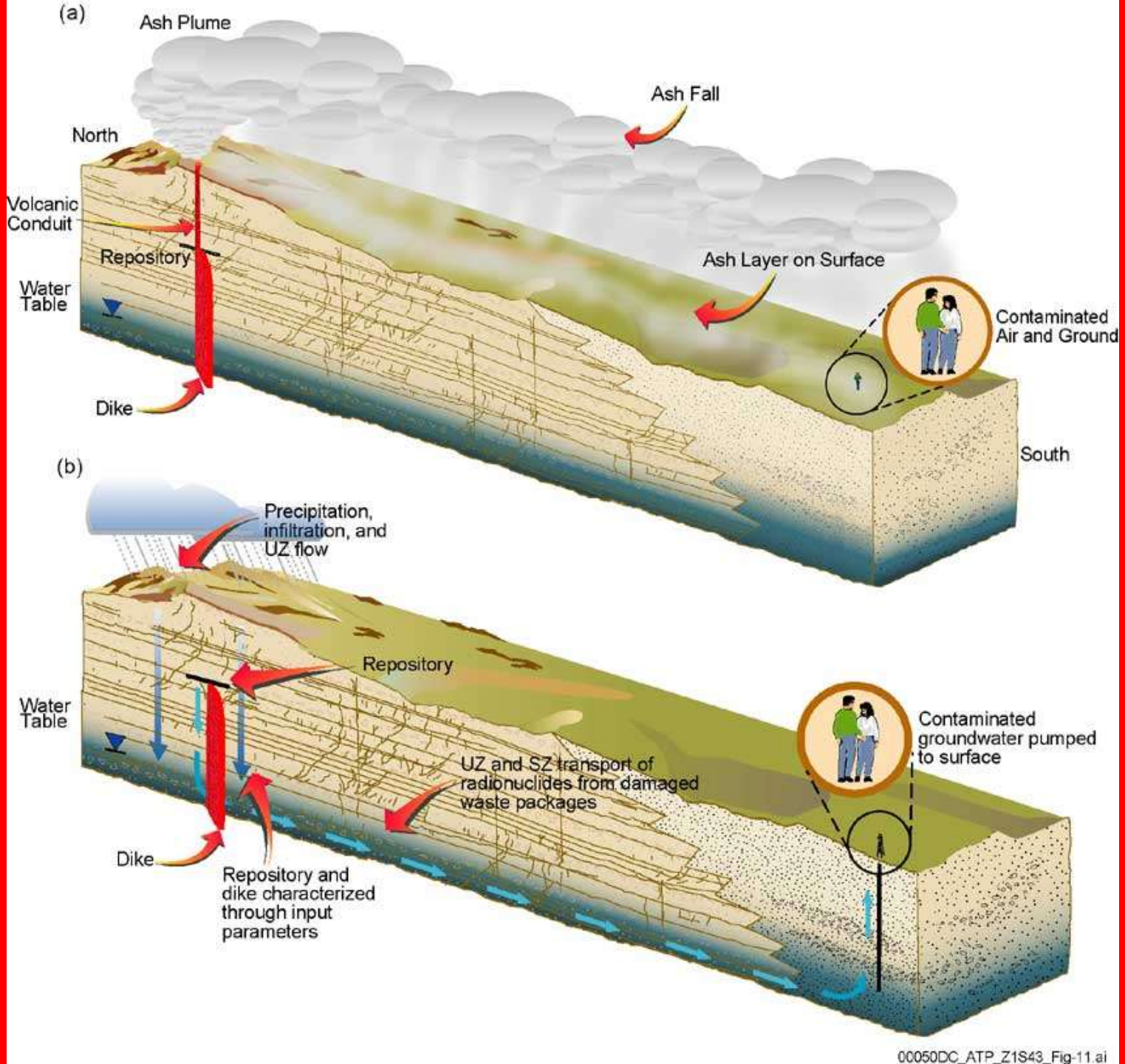
00050DC_ATP_Z1S43_fig.-09.ai


4090000
4085000
4080000
4075000
4070000
4065000
4060000
4055000
4050000
535000
540000
545000
550000
555000
560000
5 km
20 km
30 km
00050DC_ATP_Z1S42_168.psd


E520000ft
E540000ft
E560000ft
E580000ft
N780000ft
N760000ft
N740000ft
N720000ft
N700000ft
N680000ft
36 50'
36 45'
36 40'
116 35'
116 30'
116 25'
116 20'
Yucca Mountain
Crater Flat
C-Wells Complex
Jackass Flats
Amargosa Desert
6D
18S
17S
13S
16S
20D
10S
21S
7S
22S
1D
1S
12D
9S
23S
3D, 3DB, 3S
19P, 19M1, 19M2, 19M3, 19I1
15D
19D
5S
2D, 2DB
95
W-1x
4PA
4PB
8D
F-25-1
Nye County Early Warning Drilling Program
Phase I
Phase II
Phase III
ESF Tunnel
Perimeter Drift Boundary
Hydrologic Borehole
2 0 2 4 Miles
3 0 3 6 Kilometers
N
Map compiled by CRWMS M&O on March 30, 2000.
Map projection: Nevada State Plane, Central
Datum: NAD 27
Nye County EWDP well locations are approximate.
Yucca Mountain Site Characterization Project
00050DC_ATP_Z1S42_191.cdr

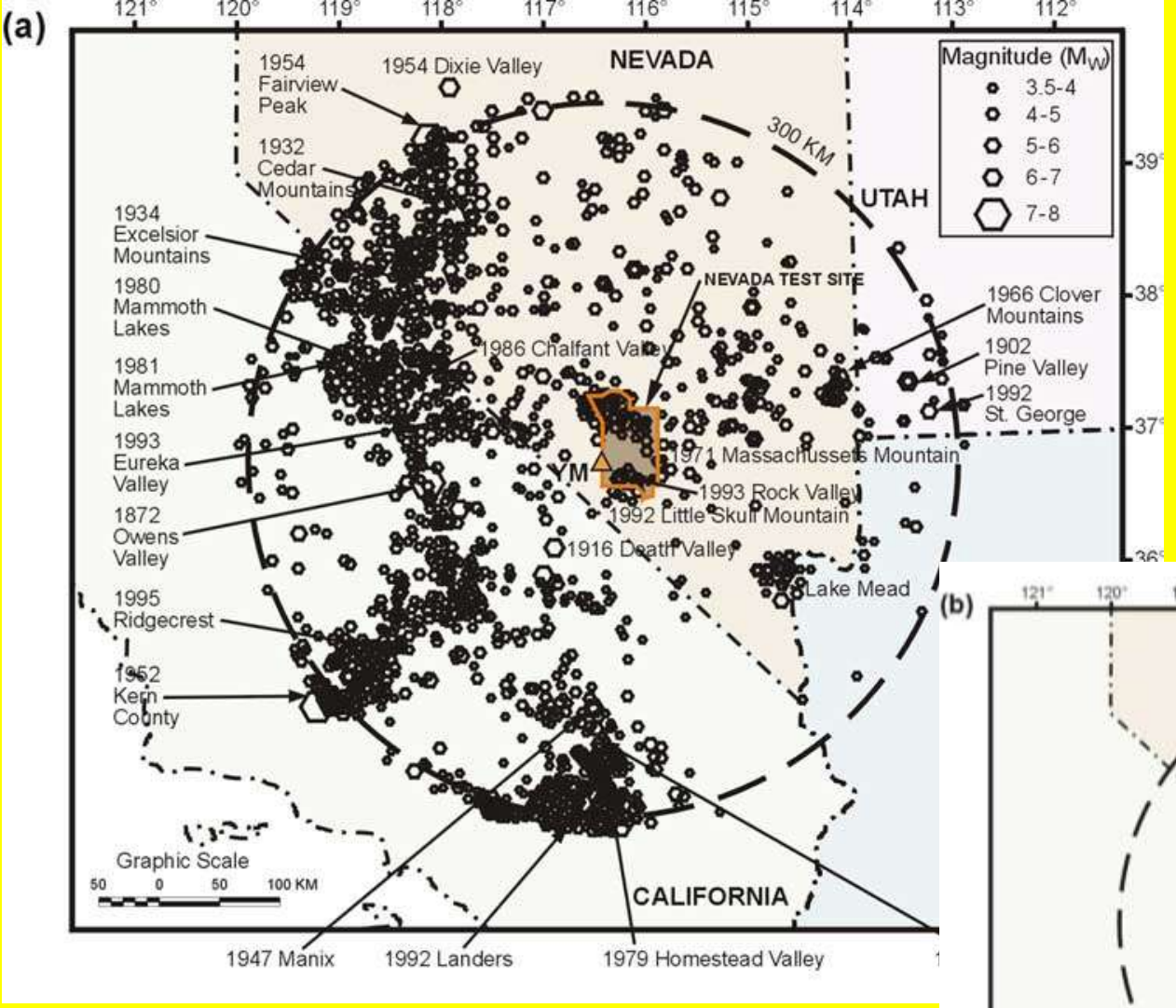

HC
0.4
LBP
TM
4.8
BM
3.1
Timber Mountain
Caldera Complex
37°
Potential repository
footprint
MC
1.0
BC
RC
PCF
3.7
BMF
LC
SCF
GF
LW
0.08
3.8
N
Quaternary
basalt
Pliocene basalt
"Buried basalt"
known at PVHA
"Buried basalt"
inferred since
PVHA
36.5°
10 km
116.5°
00050DC_ATP_Z1S43_Fig-10a.ai

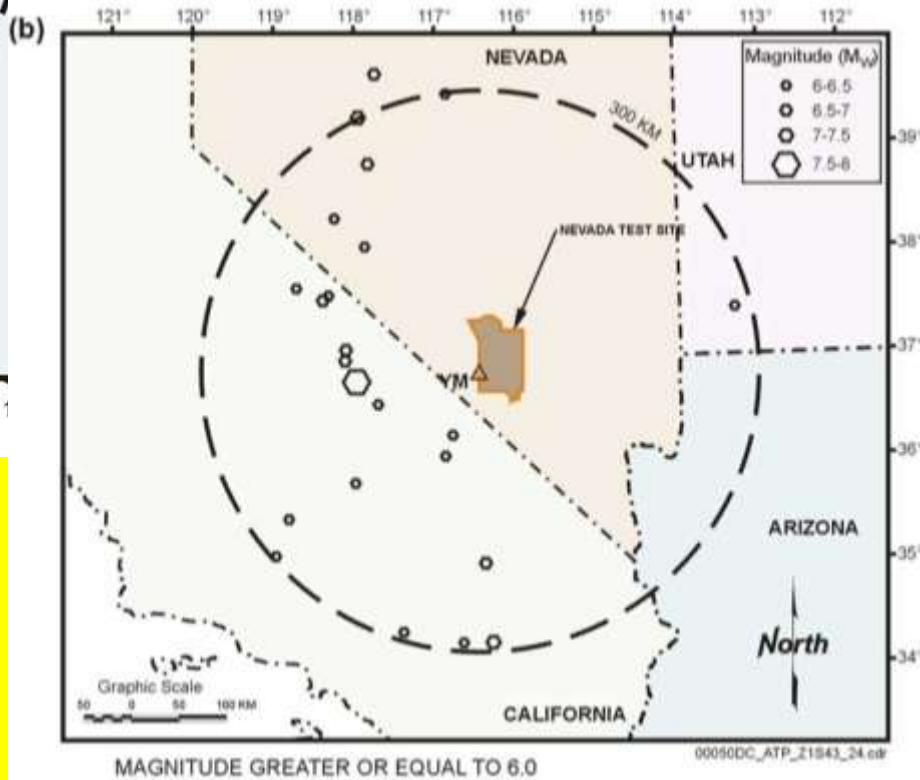

Crater Flat
~3000 ft to 3600 ft
~914 m to 1097 m
Yucca Mountain Crest
~985 ft above the repository
~300 m above the repository
Makani
Cone
Red
Cone
Black
Cone
Repository
~3500 ft
~1067 m
00050DC_ATP_Z1S43_Fig-21b.ai


(a)
Ash Plume
Ash Fall
North
Volcanic Conduit
Repository
Water Table
Dike
Ash Layer on Surface
Contaminated Air and Ground
South
(b)
Precipitation, infiltration, and UZ flow
Repository
Water Table
UZ and SZ transport of radionuclides from damaged waste packages
Contaminated groundwater pumped to surface
Dike
Repository and dike characterized through input parameters
00050DC_ATP_Z1S43_Fig-11.ai

Potential for Earthquakes

- Vibratory ground motion decreases with depth, so earthquakes have less impact underground
- No active faults at the repository site – 140,000 yr.old caliche overlies Bow Ridge fault
- 11 MA volcanics conformably overlie some faults
- Engineers will design the facilities to withstand any severe earthquake considered likely at Yucca Mtn.





MAGNITUDE GREATER OR EQUAL TO 6.0
WITHIN 300 KM OF YUCCA MOUNTAIN.
1868-1996

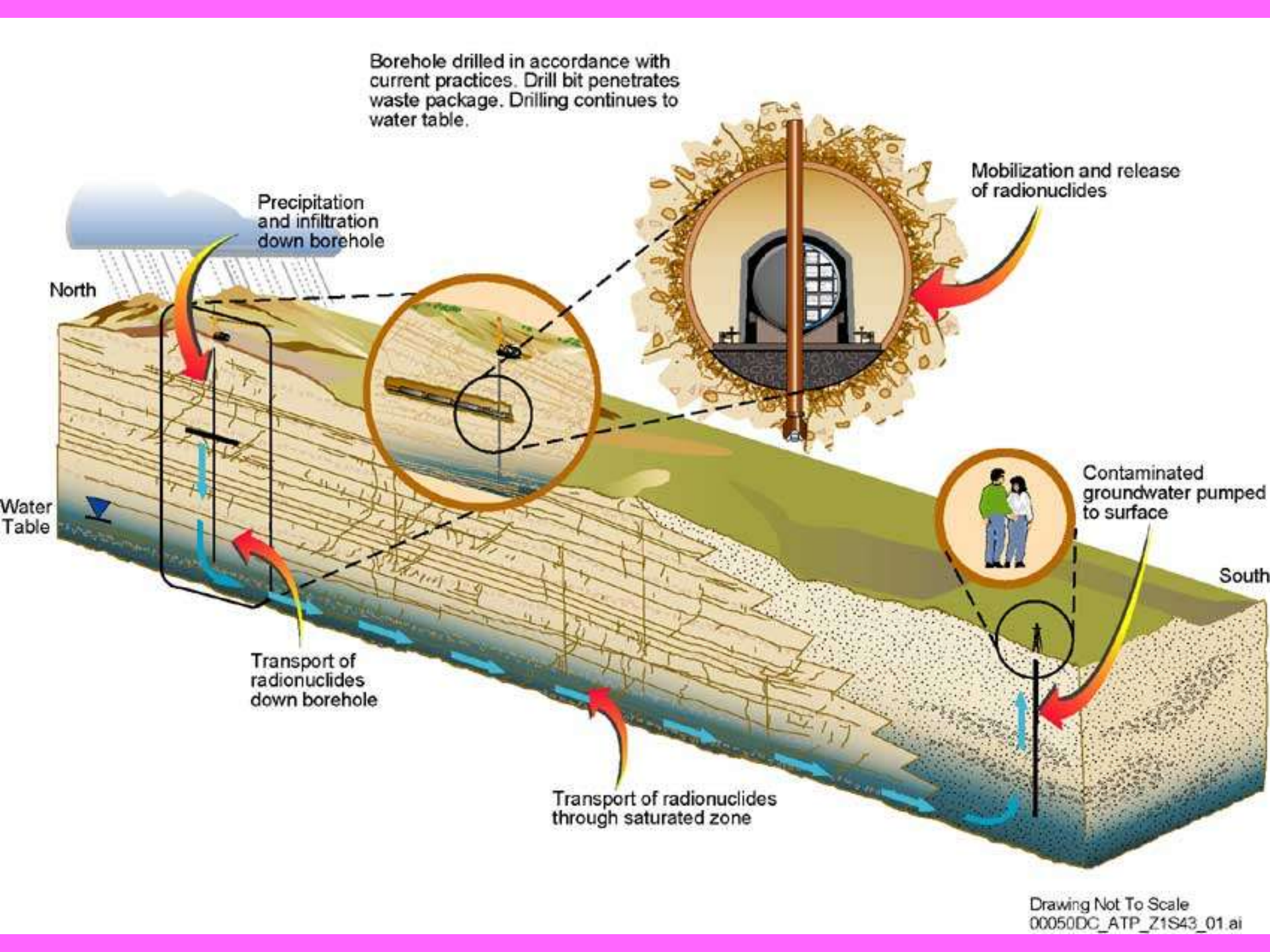
Trench 14

Controversy concerning possibility that this is hydrothermal activity that could penetrate the site.

Additional studies concluded:

- pedogenic (soil-related) caliche layers at the top that conformably overlie the zone are 140,000 years old

- there has been no upward hydrothermal movement since about 11 Ma.


Borehole drilled in accordance with current practices. Drill bit penetrates waste package. Drilling continues to water table.
Precipitation and infiltration down borehole
Mobilization and release of radionuclides
North
Water Table
Contaminated groundwater pumped to surface
South
Transport of radionuclides down borehole
Transport of radionuclides through saturated zone
Drawing Not To Scale
00050DC_ATP_Z1S43_01.ai

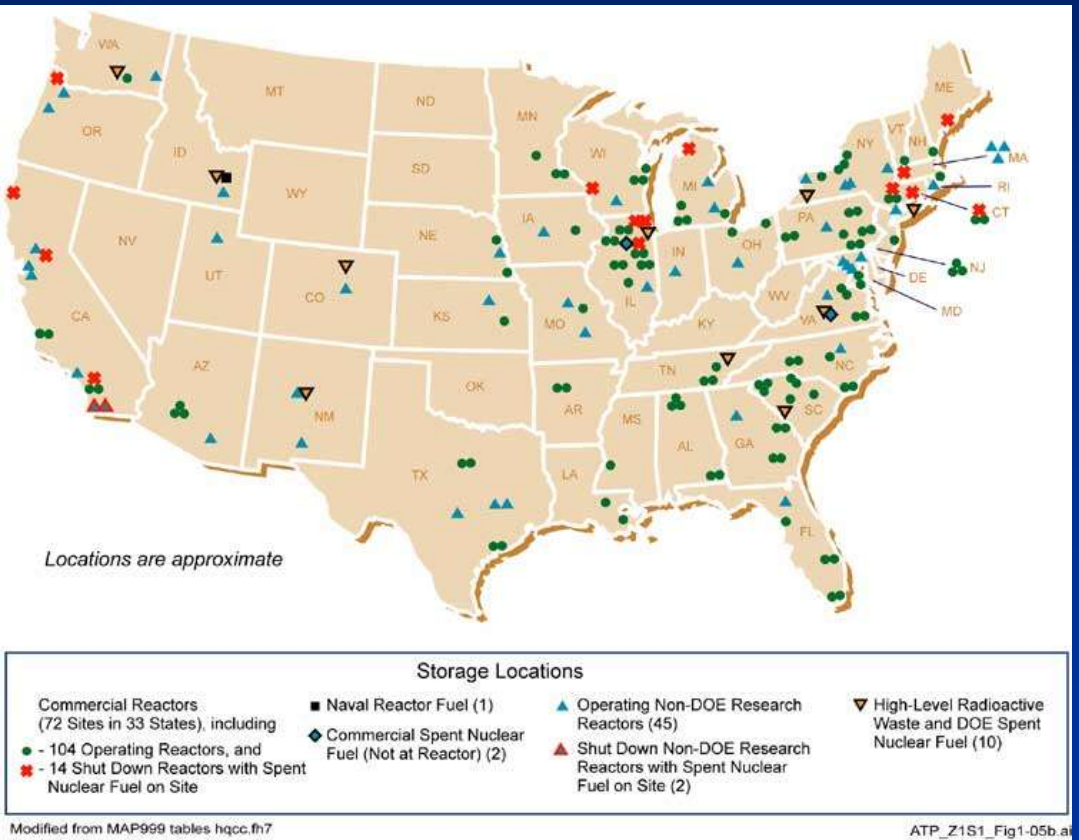
Conclusion

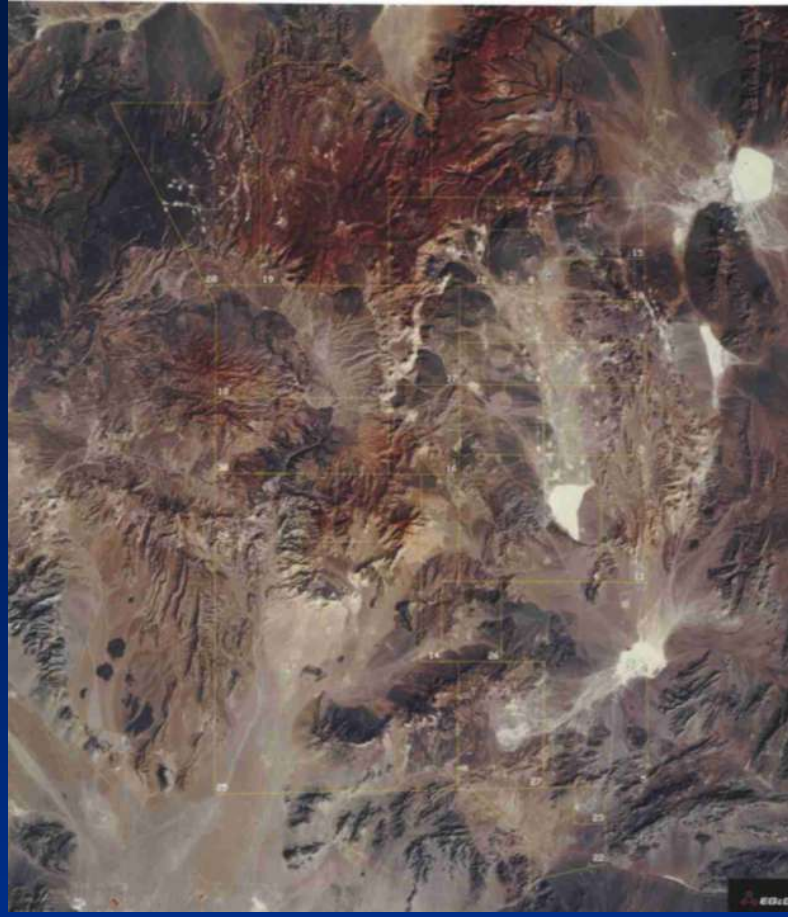
- Geologically Speaking - Is It Safe?
  - Yes!
- Where would you rather have it?
  - At the 131 sites in 39 states?
  - Adjacent to the Nevada Test Site?
- Subject to regulation by NRC
- Continuing monitoring required

Where should we put the high-level radioactive waste?

At the 131 sites in 39 states?

OR





At Yucca Mountain near the Nevada Test Site

For further information

- http://www.ymp.gov
- 1-800-225-6972
- YMP Science Center - Las Vegas – 4101 Meadows Lane = 702-295-1312