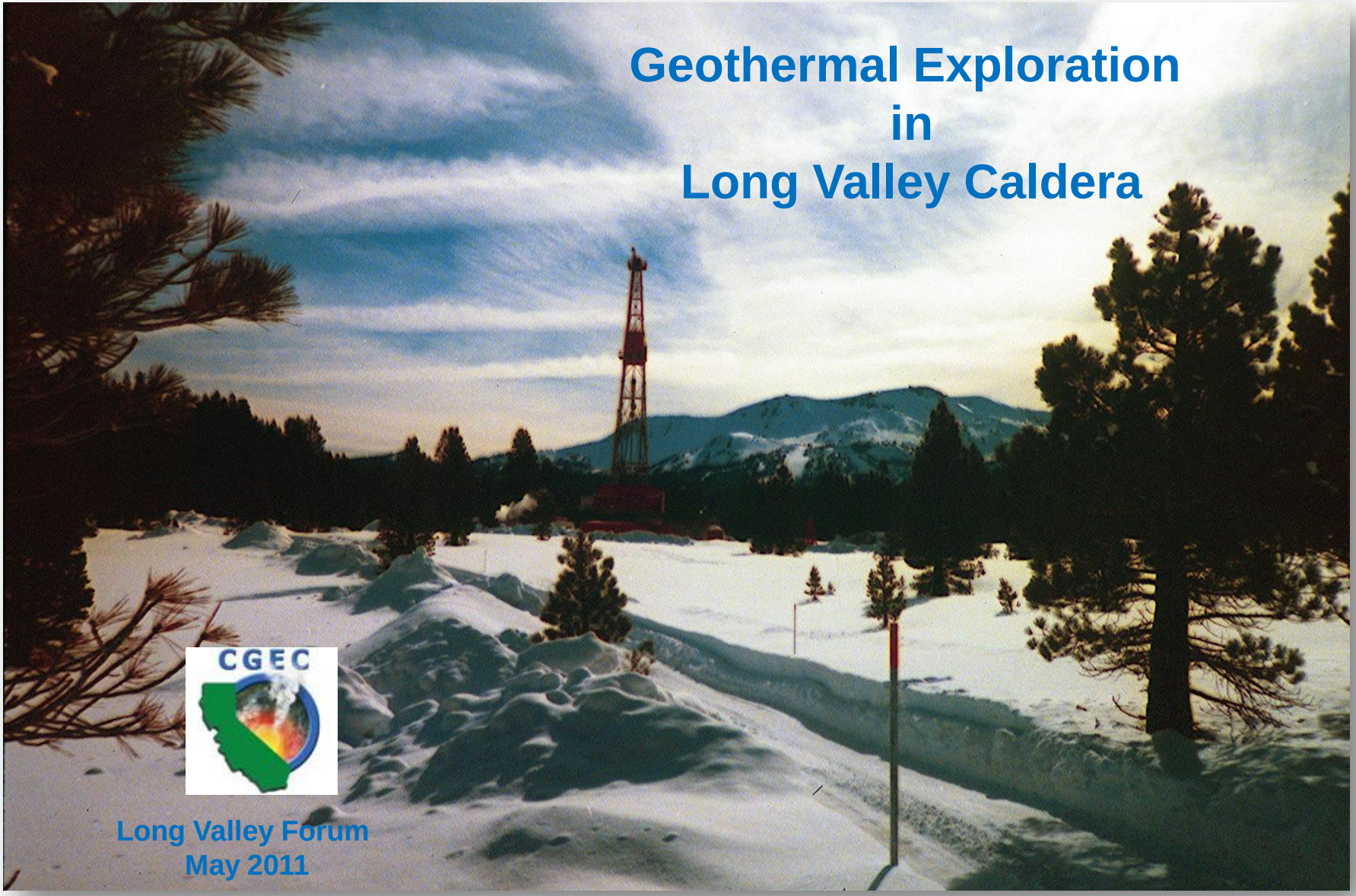
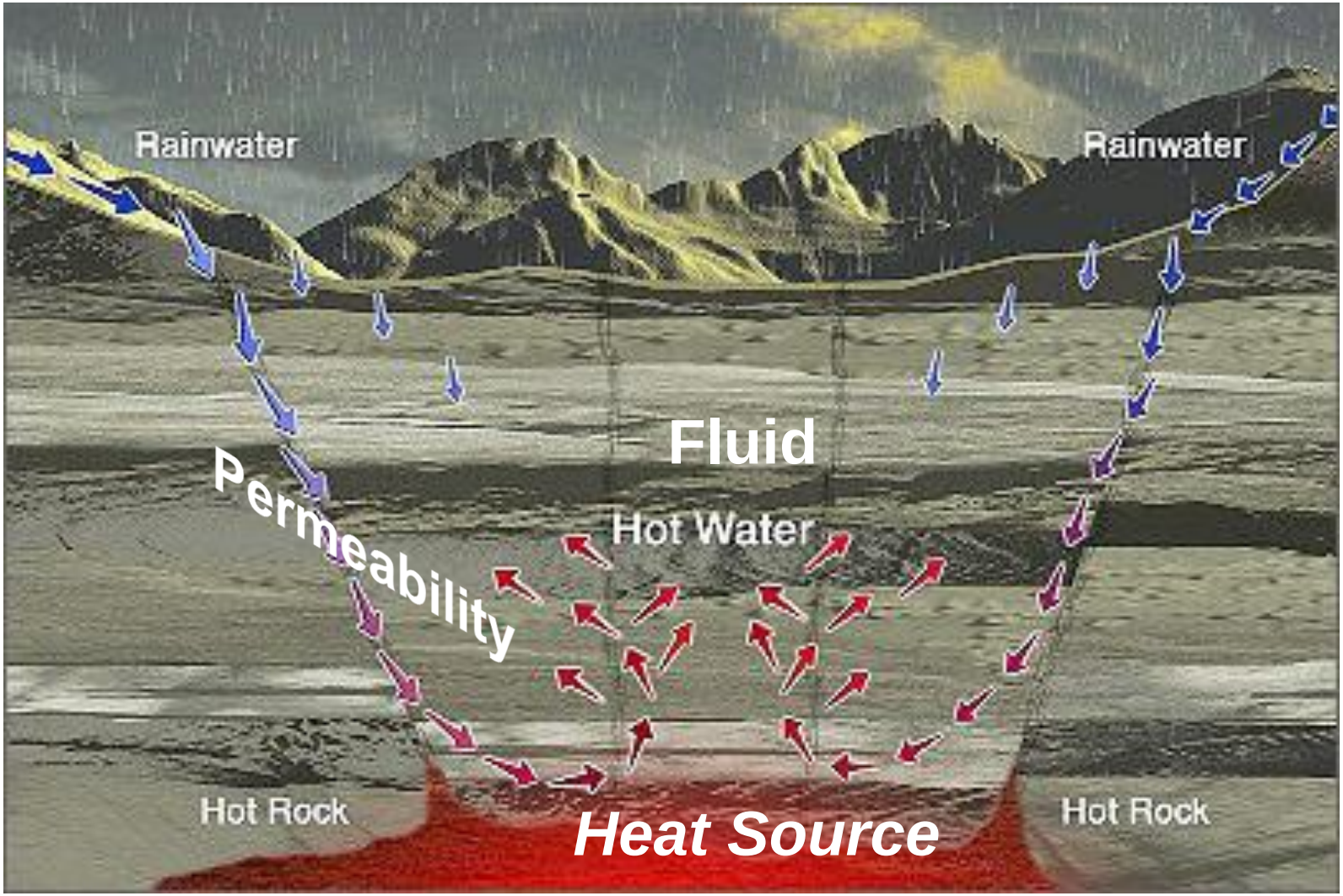


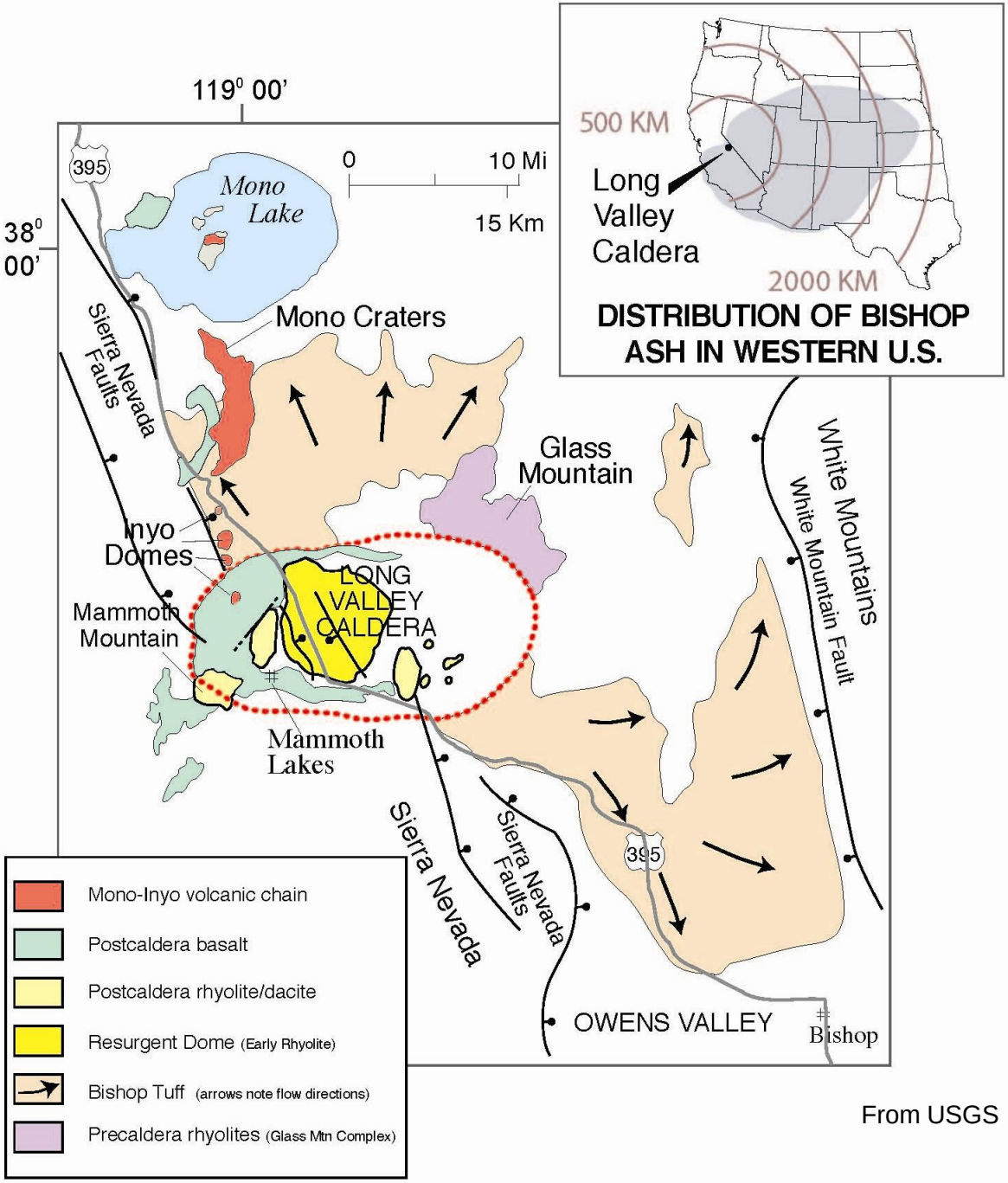
Geothermal Exploration in Long Valley Caldera

CGEC

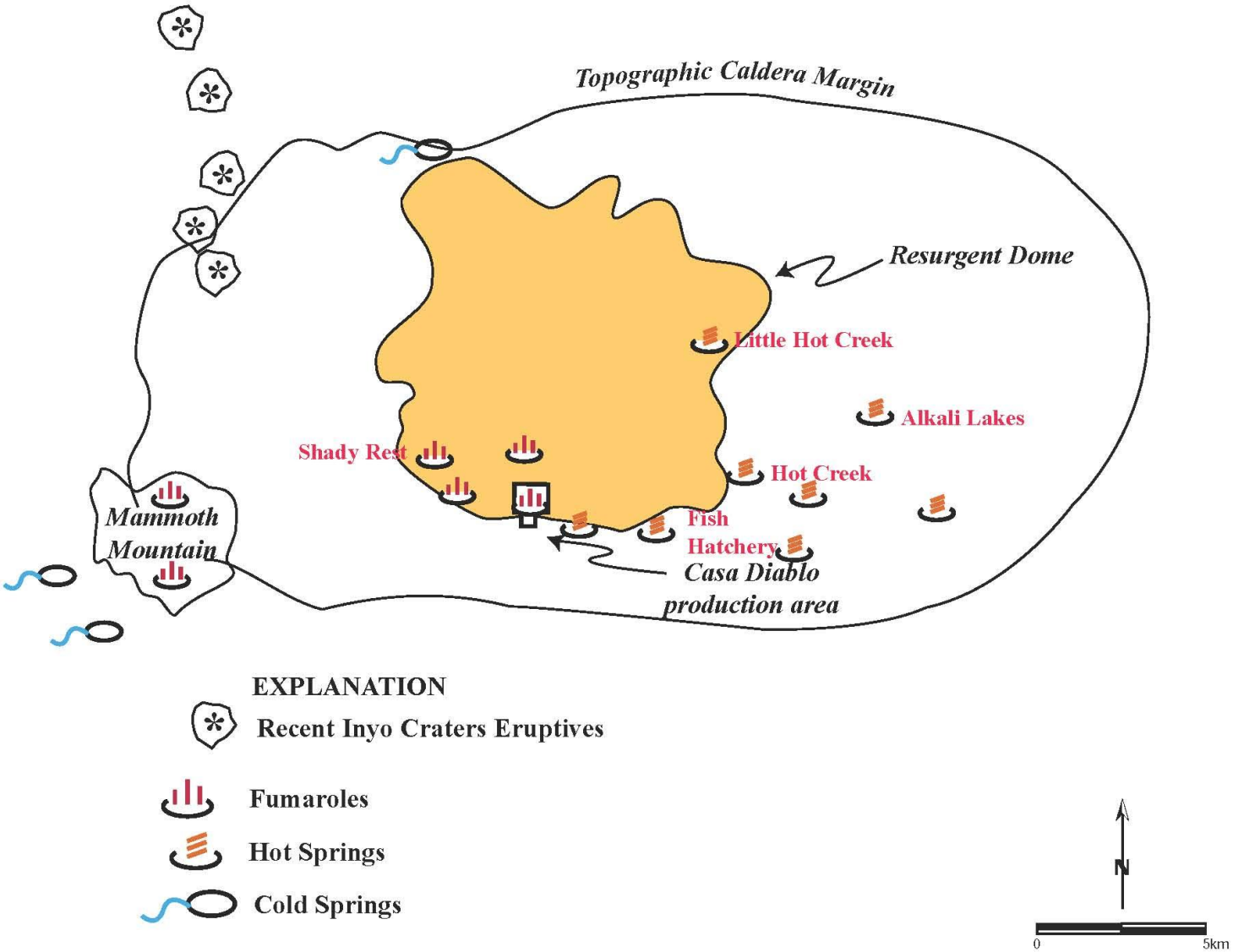
Long Valley Forum
May 2011

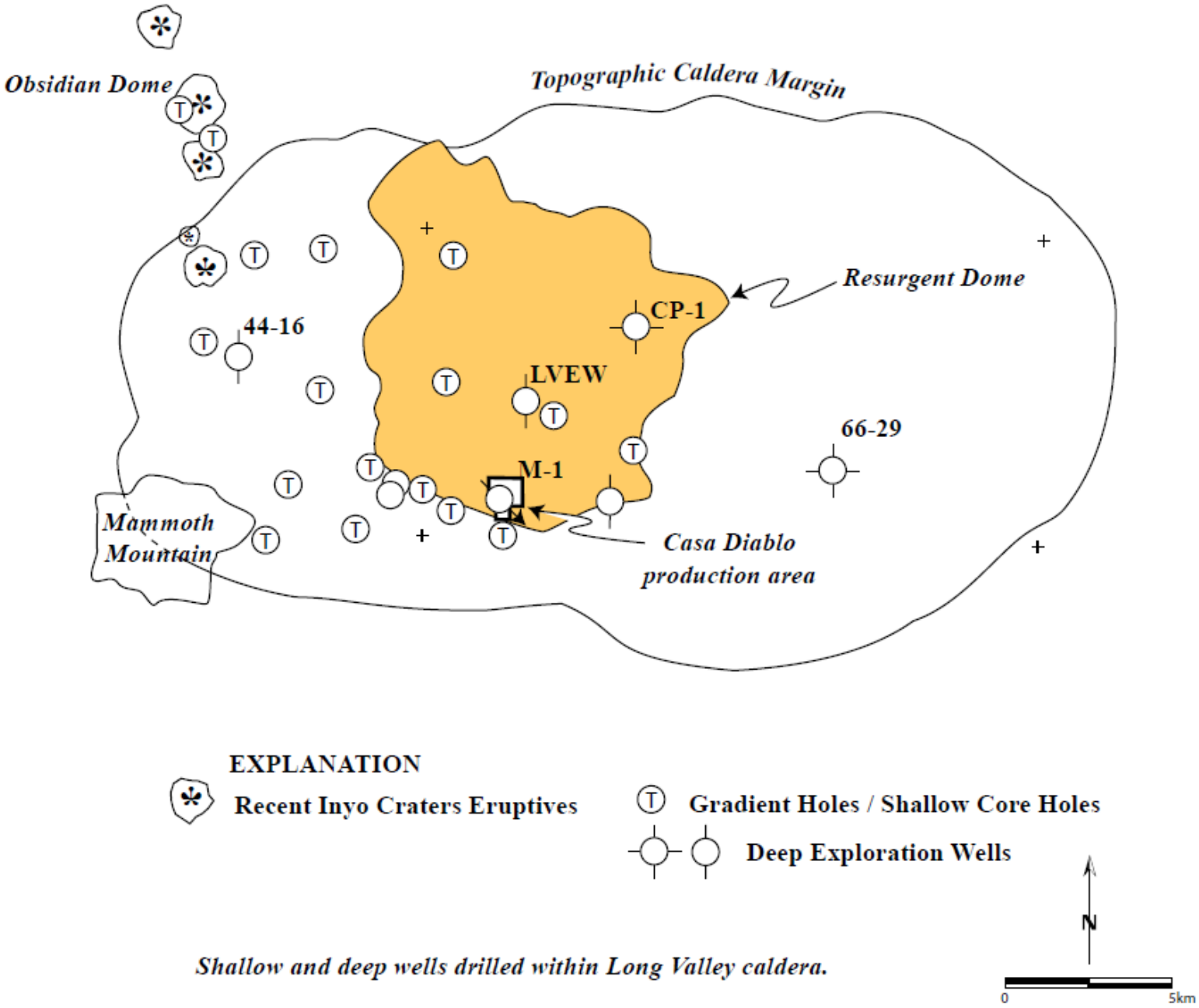
Geothermal System Requirements



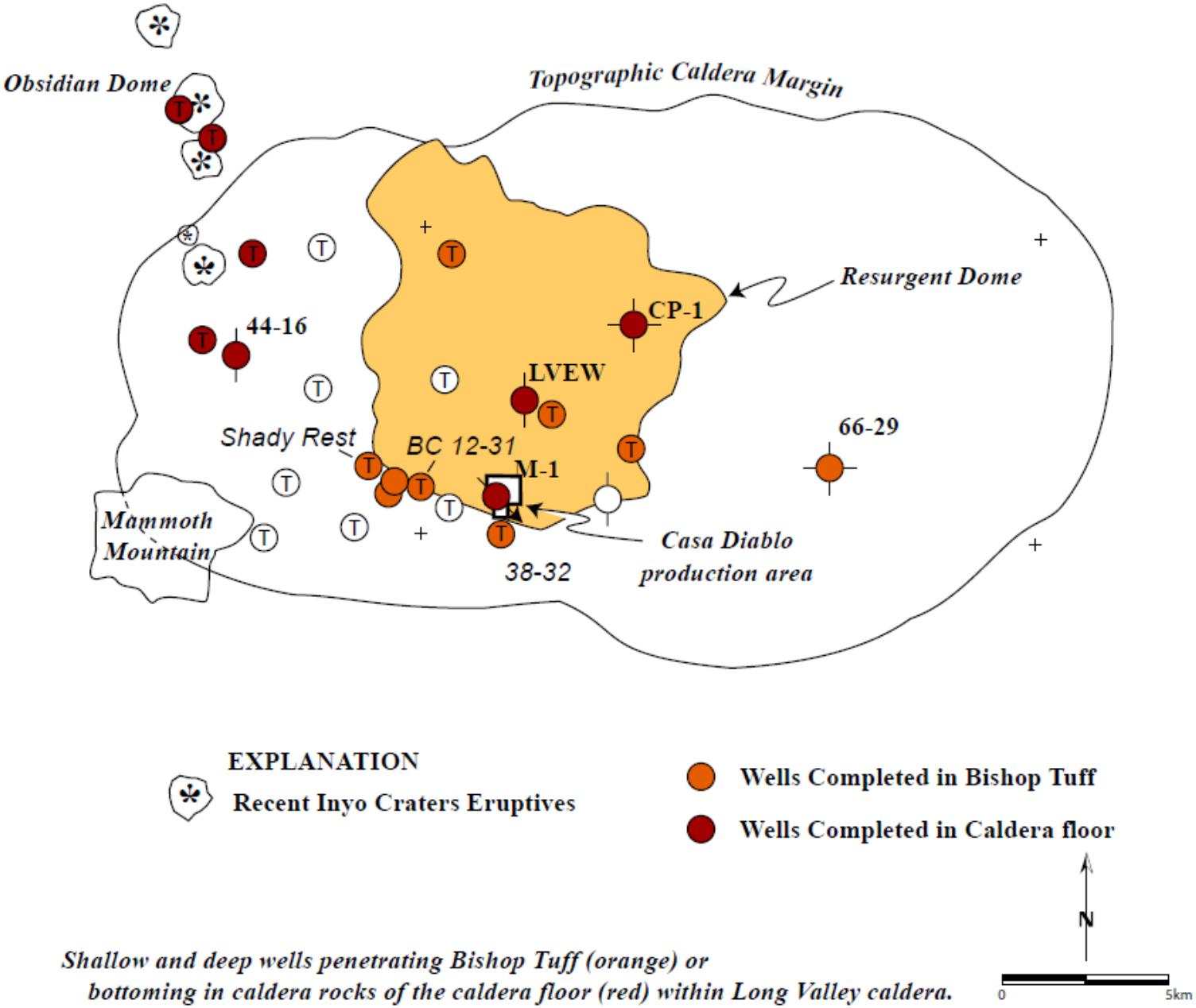

119⁰ 00'
38⁰ 00'
395
Mono Lake
0
10 Mi
15 Km
Mono Craters
Sierra Nevada Faults
Glass Mountain
White Mountains
White Mountain Fault
Inyo Domes
LONG VALLEY CALDERA
Mammoth Mountain
Mammoth Lakes
Sierra Nevada
Sierra Nevada Faults
395
OWENS VALLEY
Bishop
500 KM
Long Valley Caldera
2000 KM
DISTRIBUTION OF BISHOP ASH IN WESTERN U.S.
Mono-Inyo volcanic chain
Postcaldera basalt
Postcaldera rhyolite/dacite
Resurgent Dome (Early Rhyolite)
Bishop Tuff (arrows note flow directions)
Precaldera rhyolites (Glass Mtn Complex)

From USGS

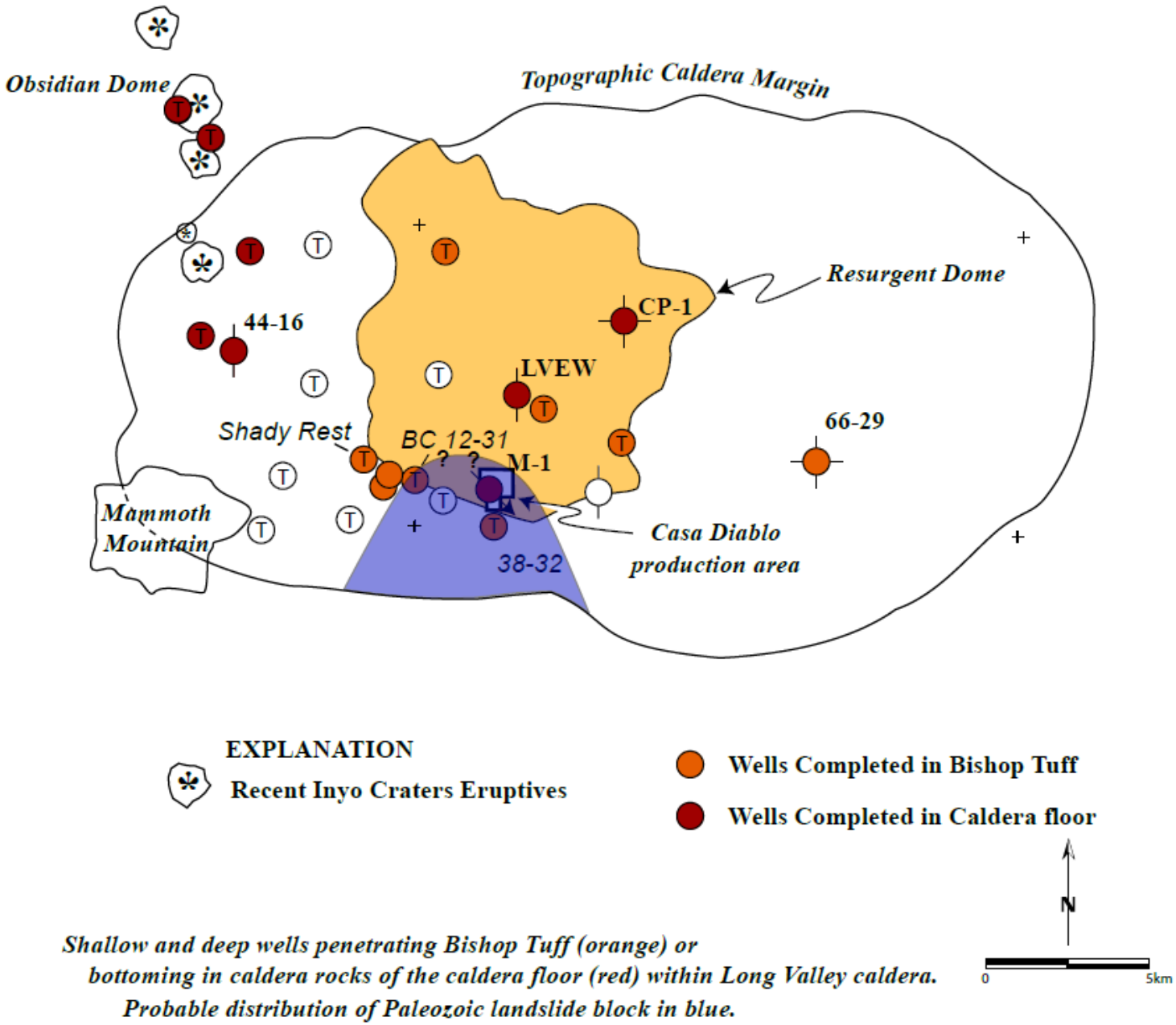

Topographic Caldera Margin
Resurgent Dome
Little Hot Creek
Alkali Lakes
Shady Rest
Hot Creek
Mammoth Mountain
Fish Hatchery
Casa Diablo production area
EXPLANATION
Recent Inyo Craters Eruptives
Fumaroles
Hot Springs
Cold Springs
N
0
5km



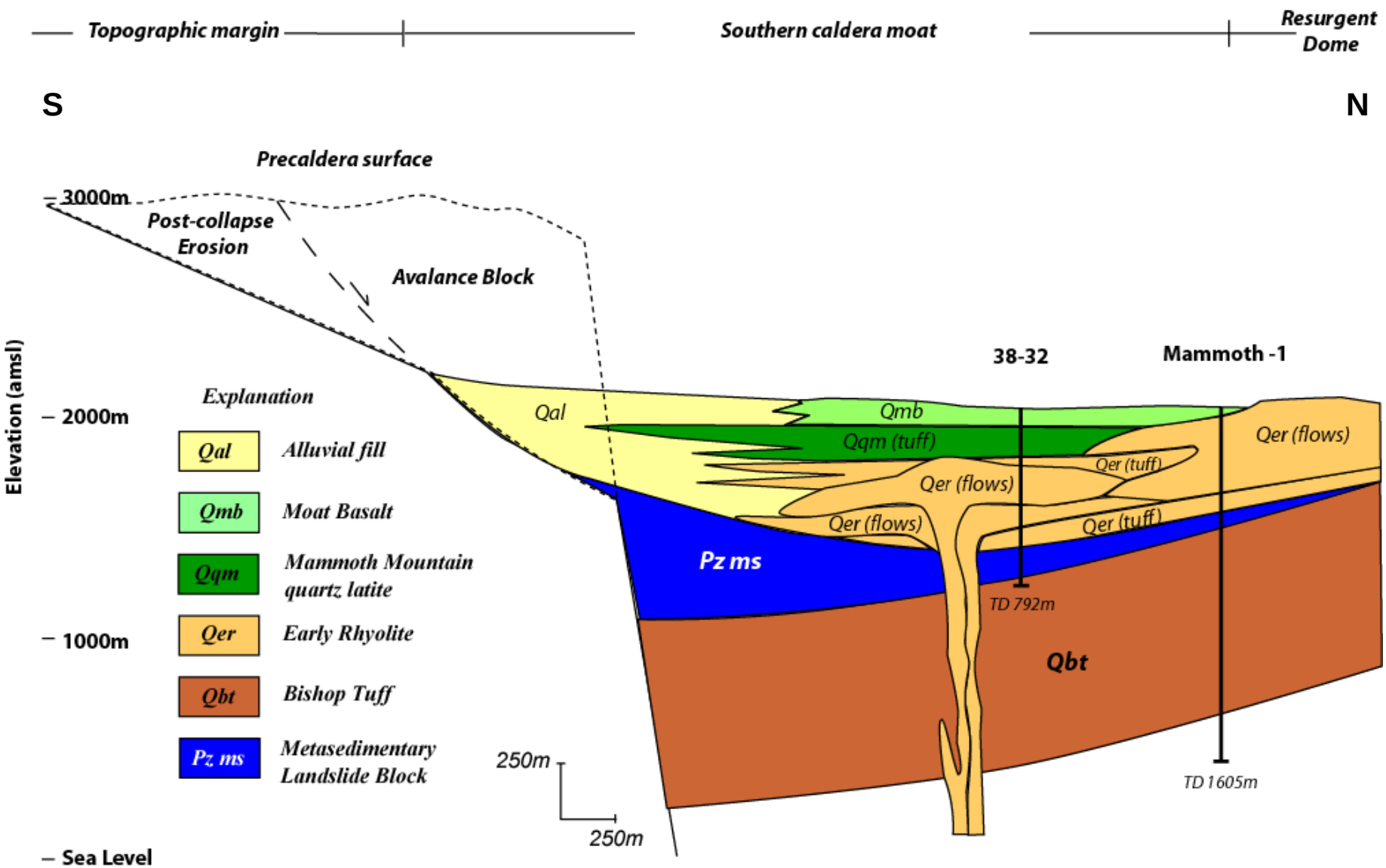
Shallow and deep wells drilled within Long Valley caldera.



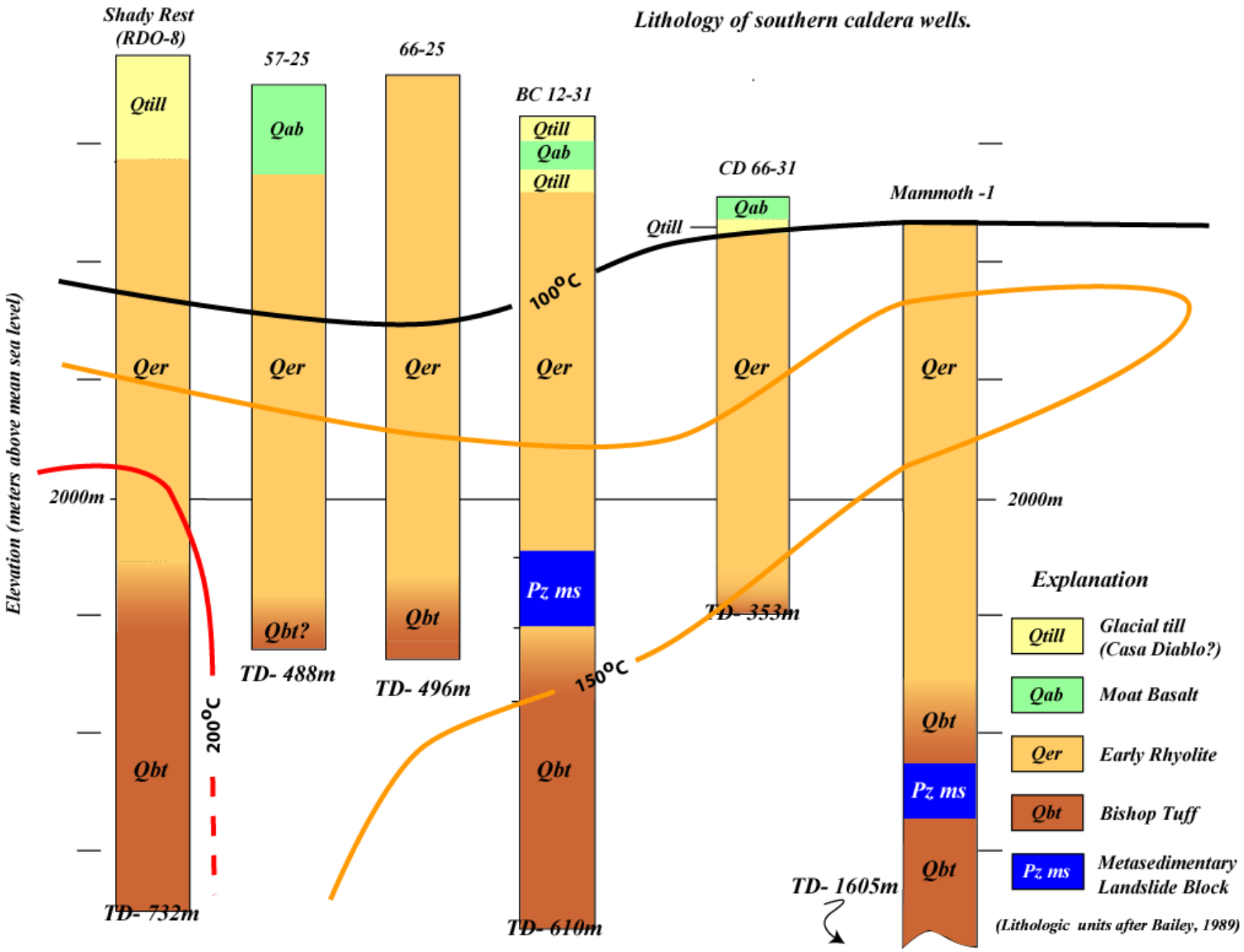
Shallow and deep wells penetrating Bishop Tuff (orange) or bottoming in caldera rocks of the caldera floor (red) within Long Valley caldera.

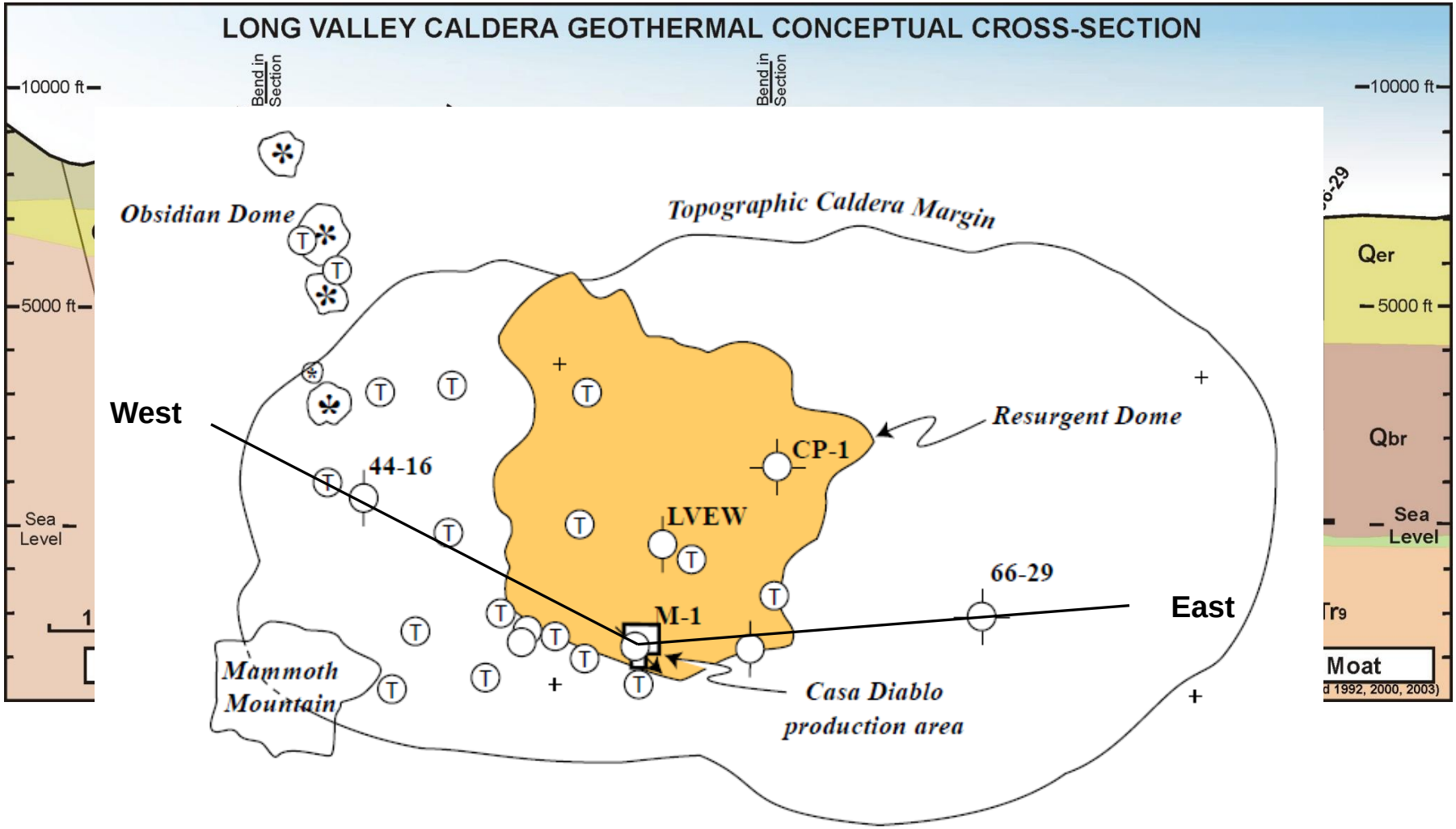


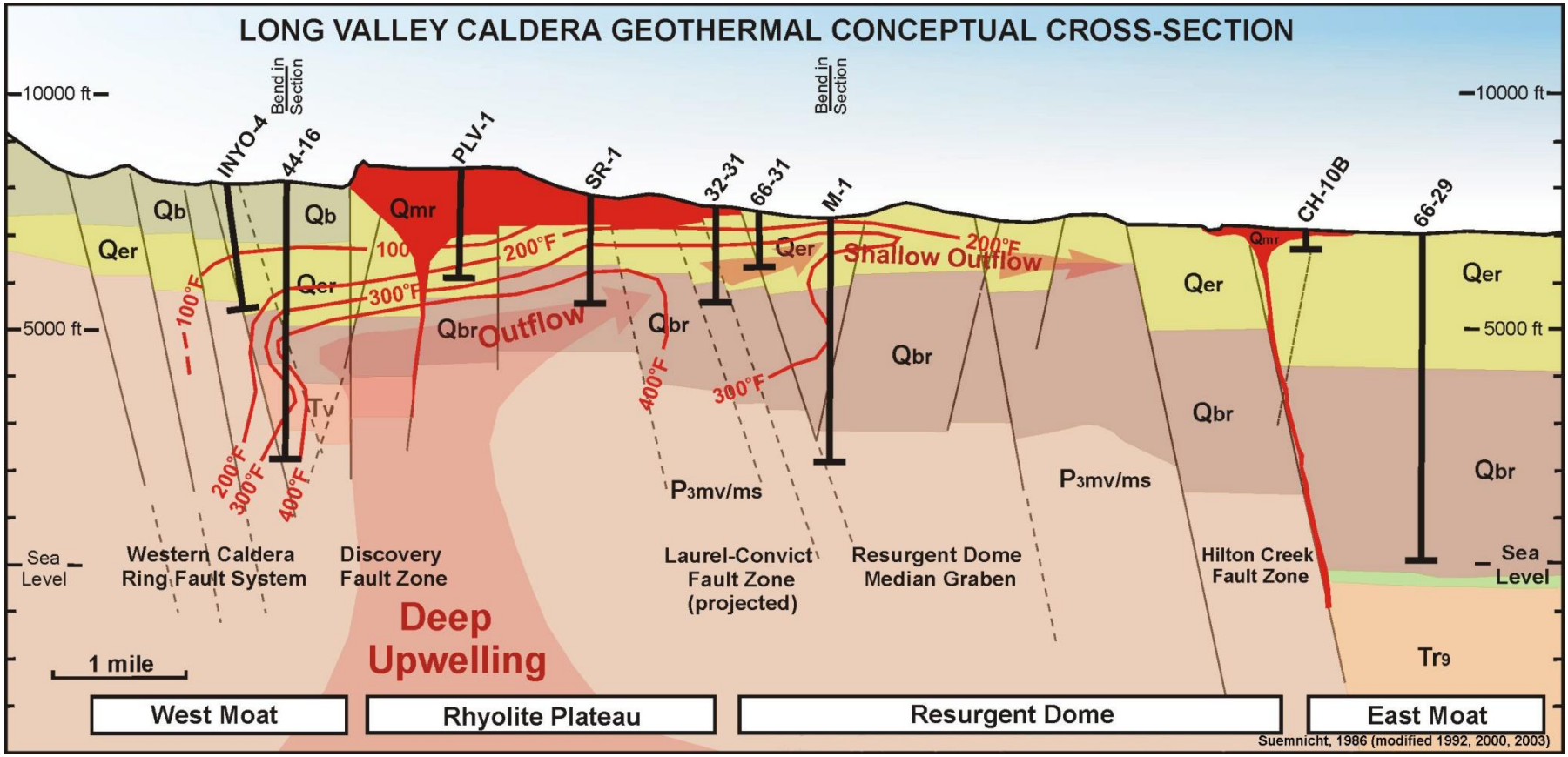
Shallow and deep wells penetrating Bishop Tuff (orange) or bottoming in caldera rocks of the caldera floor (red) within Long Valley caldera. Probable distribution of Paleozoic landslide block in blue.

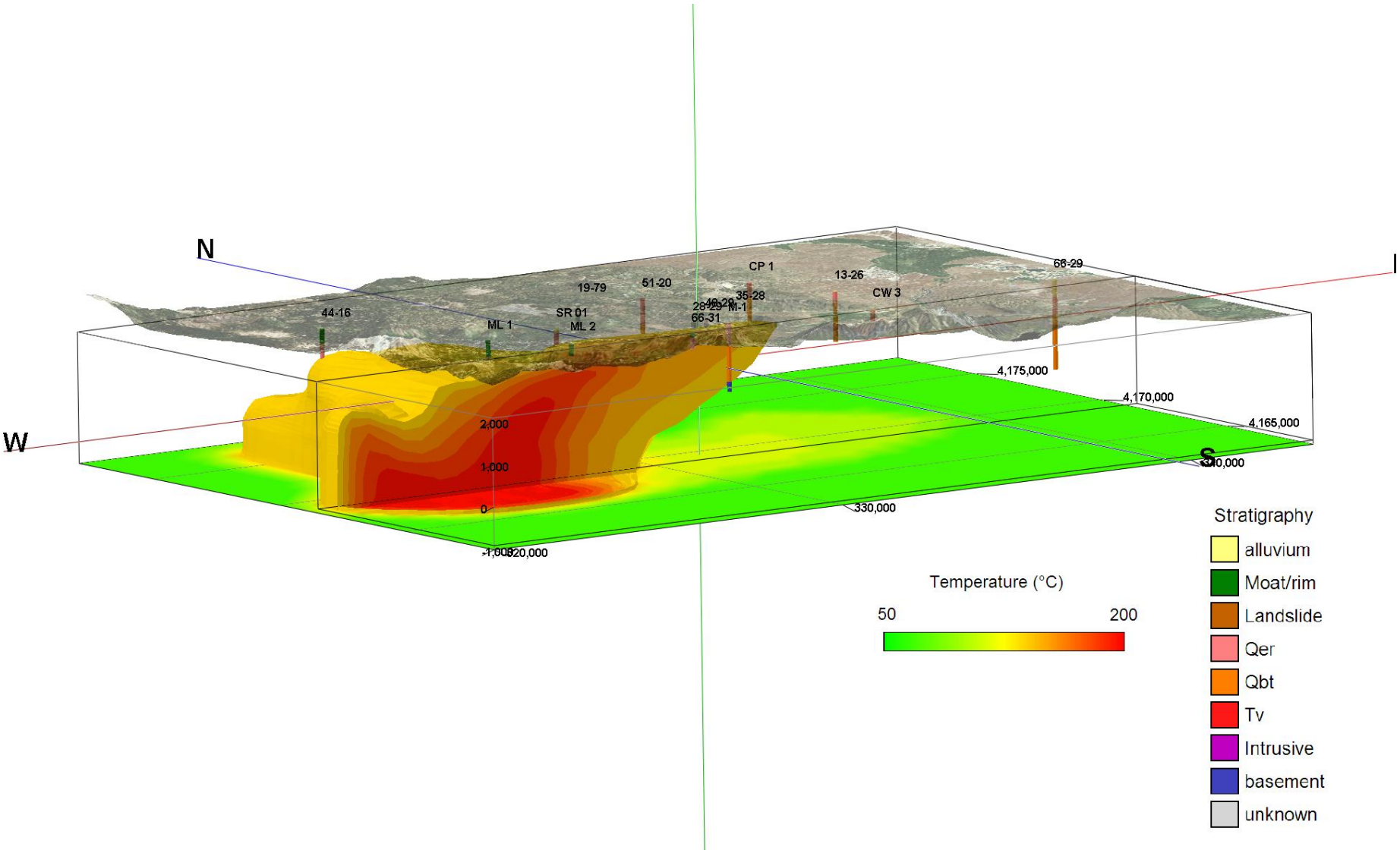


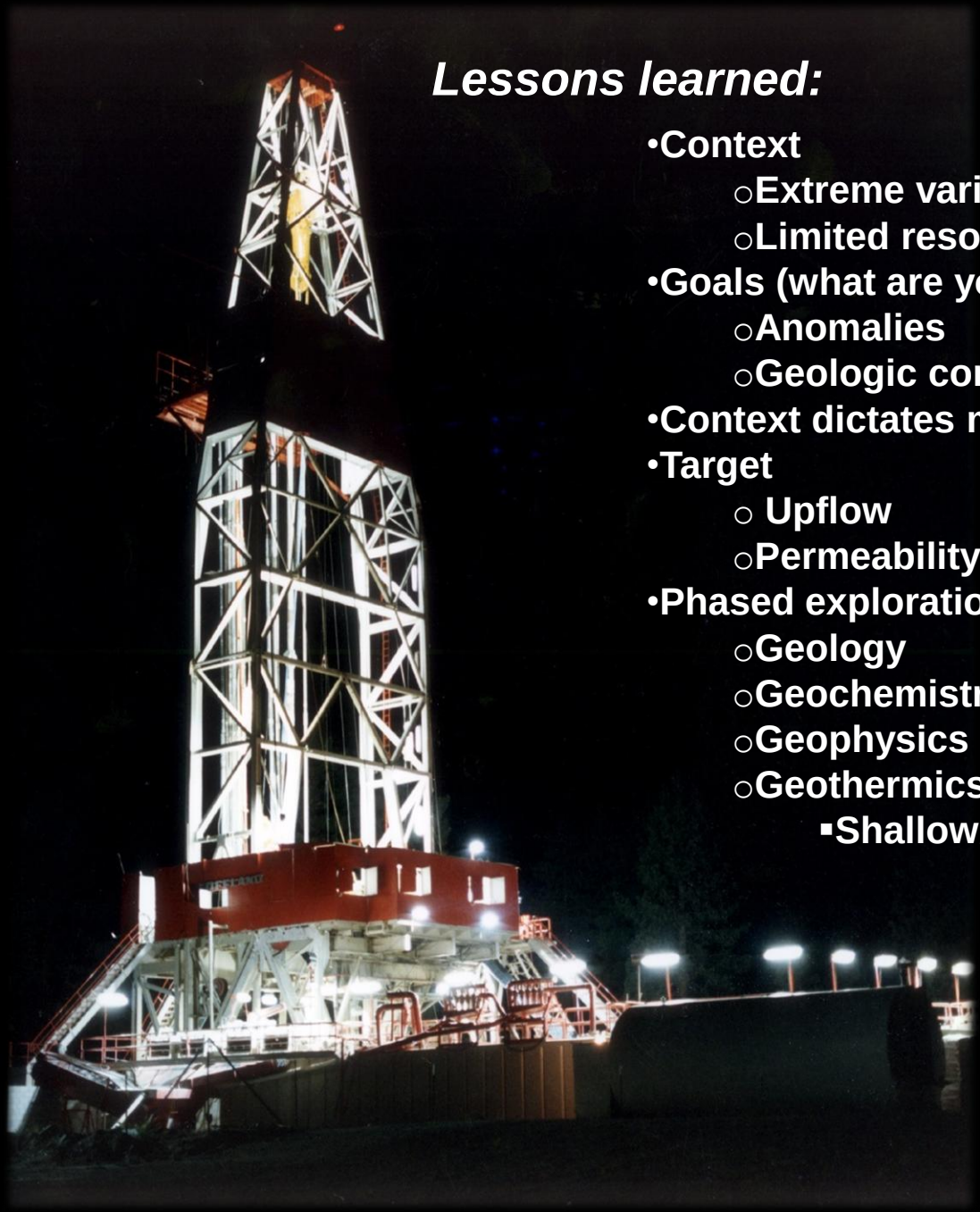
Structural cross-section of southern caldera showing the landslide block encountered in exploration corehole 38-32 and the Mammoth-1 deep test well at Casa Diablo. (after R.A. Bailey 1992)


Lithology of southern caldera wells.
Shady Rest (RDO-8)
57-25
66-25
BC 12-31
CD 66-31
Mammoth -1
Qtill
Qab
Qtill
Qab
Qtill
Qab
Qtill
Qer
Qer
Qer
Qer
Qer
Qer
Qbt
Qbt?
Qbt
Qbt
Qbt
Pz ms
Pz ms
Qbt
Elevation (meters above mean sea level)
2000m
2000m
100°C
150°C
200°C
TD- 732m
TD- 488m
TD- 496m
TD- 610m
TD- 353m
TD- 1605m
Explanation
Qtill Glacial till (Casa Diablo?)
Qab Moat Basalt
Qer Early Rhyolite
Qbt Bishop Tuff
Pz ms Metasedimentary Landslide Block
(Lithologic units after Bailey, 1989)


LONG VALLEY CALDERA GEOTHERMAL CONCEPTUAL CROSS-SECTION
10000 ft
5000 ft
Sea Level
Bend in Section
Bend in Section
Qer
Qbr
Tr9
Moat
Obsidian Dome
Topographic Caldera Margin
West
East
44-16
CP-1
LVEW
M-1
66-29
Resurgent Dome
Mammoth Mountain
Casa Diablo production area

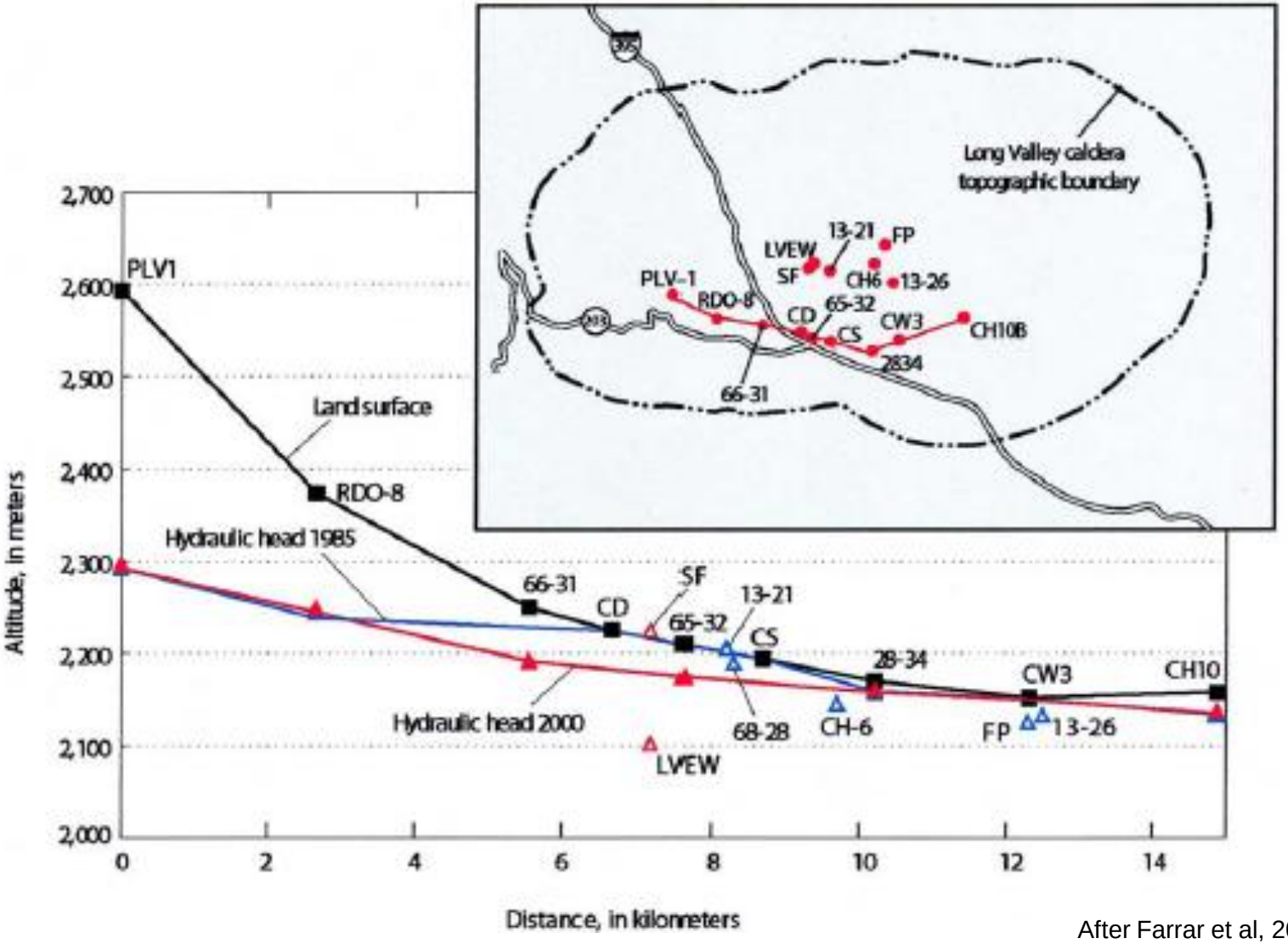

LONG VALLEY CALDERA GEOTHERMAL CONCEPTUAL CROSS-SECTION
10000 ft
5000 ft
Sea Level
Bend in Section
INYO-4
44-16
PLV-1
SR-1
32-31
66-31
M-1
CH-10B
66-29
Qb
Qer
Qmr
Qbr
Tv
P3mv/ms
Tr9
100°F
200°F
300°F
400°F
Outflow
Shallow Outflow
Western Caldera Ring Fault System
Discovery Fault Zone
Laurel-Convict Fault Zone (projected)
Resurgent Dome Median Graben
Hilton Creek Fault Zone
Deep Upwelling
1 mile
West Moat
Rhyolite Plateau
Resurgent Dome
East Moat
Suemnicht, 1986 (modified 1992, 2000, 2003)


N
W
S
E
44-16
ML 1
SR 01
ML 2
19-79
51-20
66-31
CP 1
35-28
M-1
13-26
CW 3
66-29
4,175,000
4,170,000
4,165,000
2,000
1,000
0
-1,000
320,000
330,000
Temperature (°C)
50
200
Stratigraphy
alluvium
Moat/rim
Landslide
Qer
Qbt
Tv
Intrusive
basement
unknown

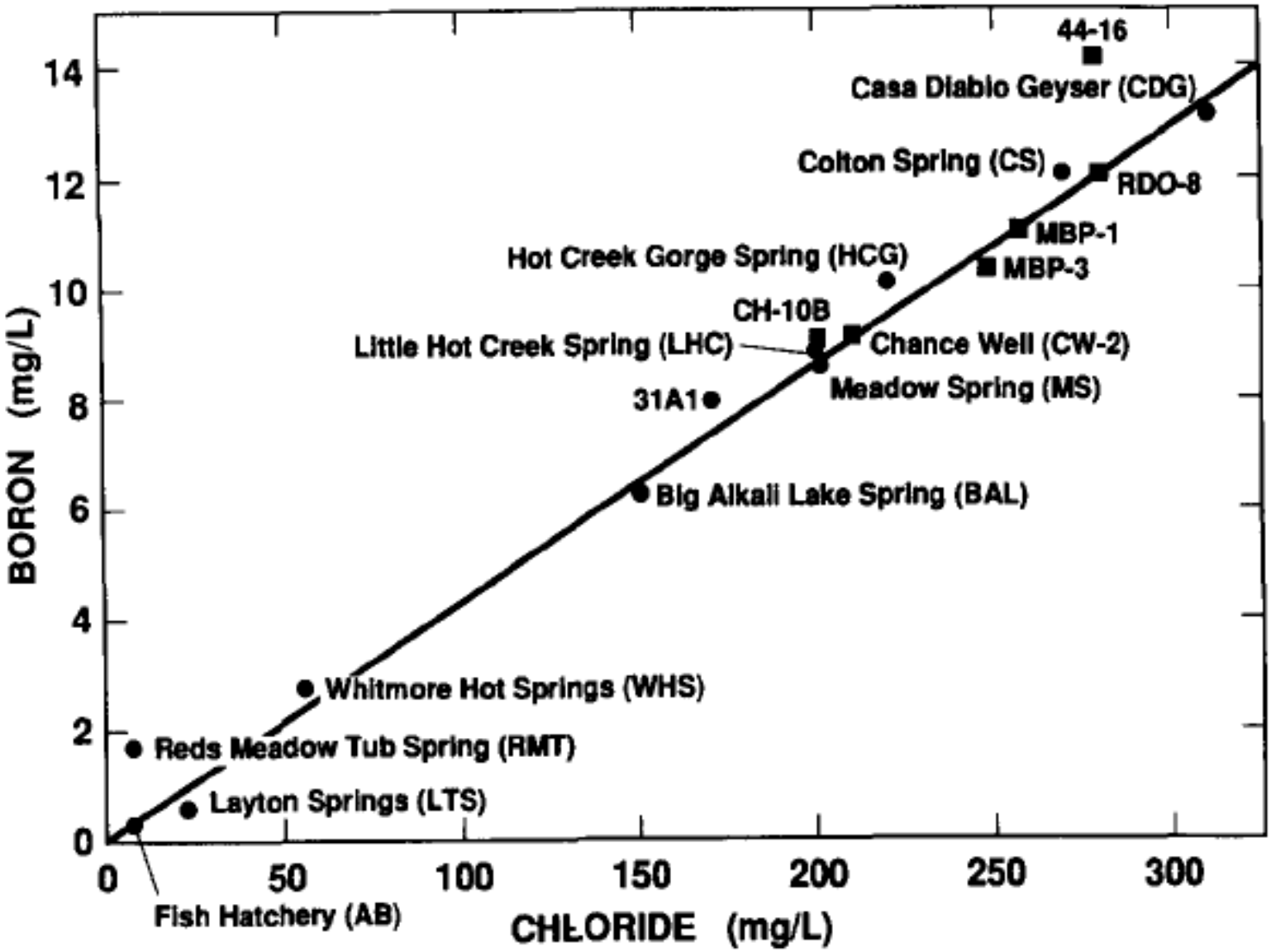


Lessons learned:

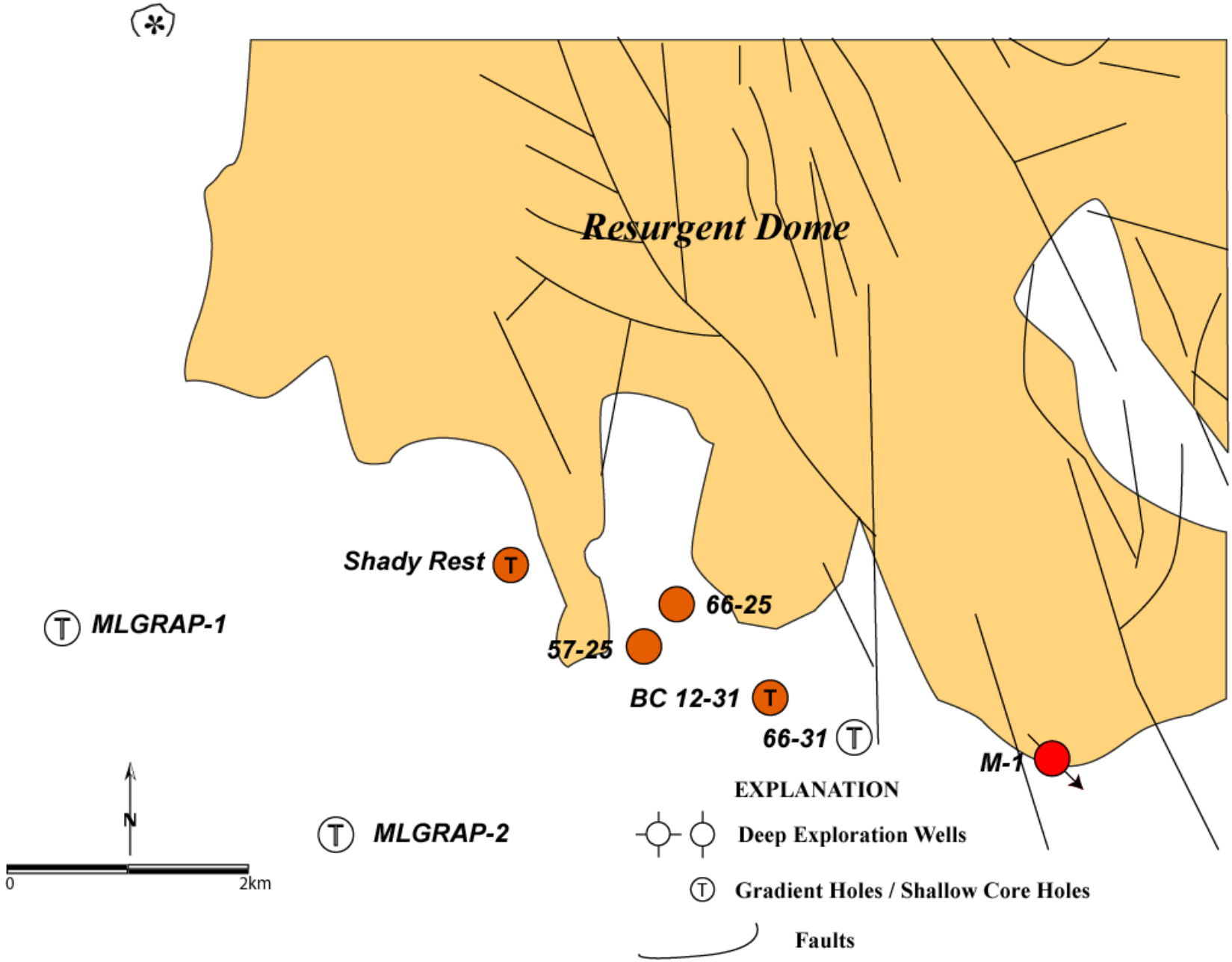
- Context
  - Extreme variability
  - Limited resource models
- Goals (what are you testing?)
  - Anomalies
  - Geologic concepts
- Context dictates methodology
- Target
  - Upflow
  - Permeability control(s)
- Phased exploration
  - Geology
  - Geochemistry
  - Geophysics
  - Geothermics
    - Shallow/Intermediate/Deep



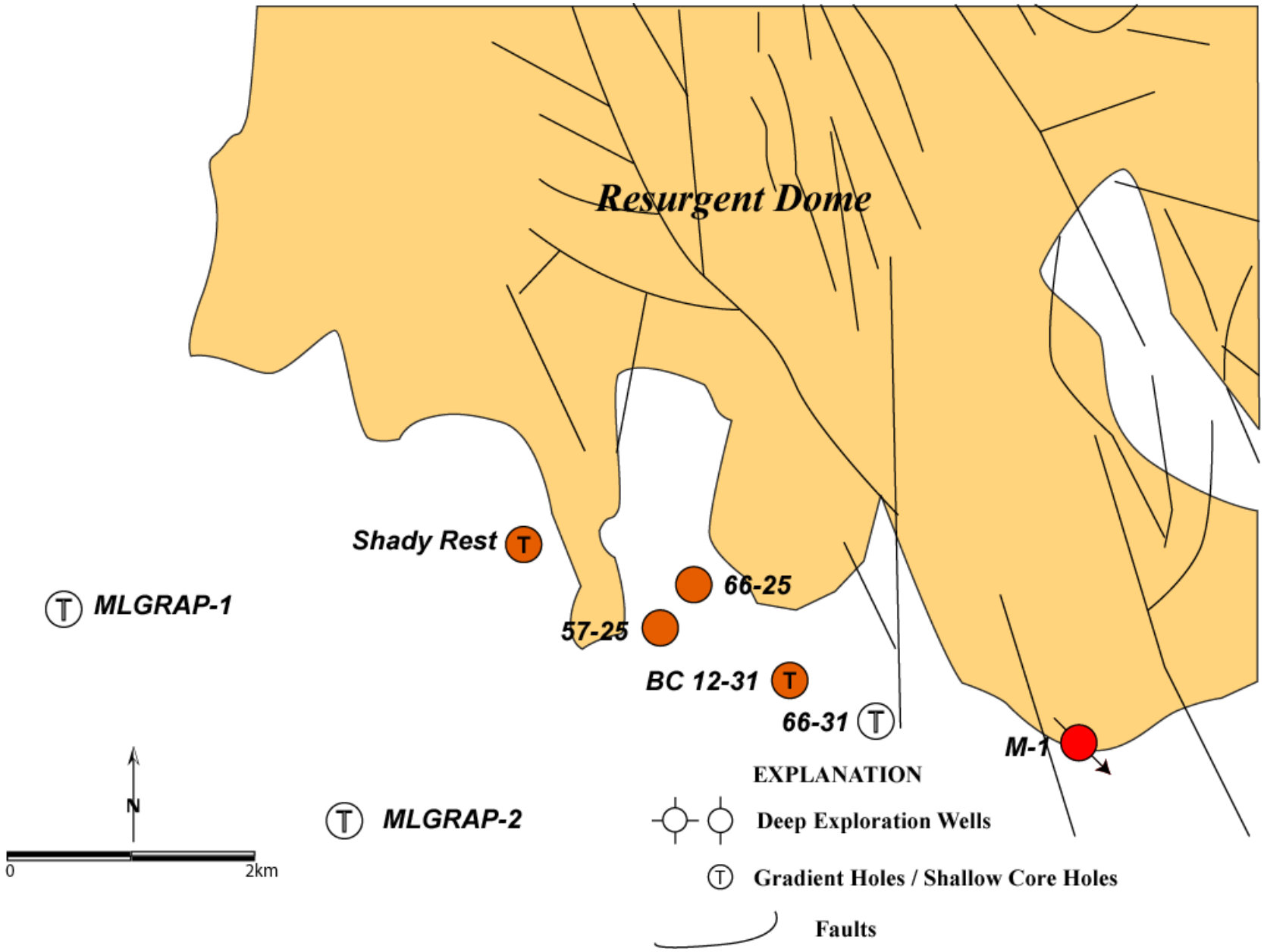
After Farrar et al, 2003

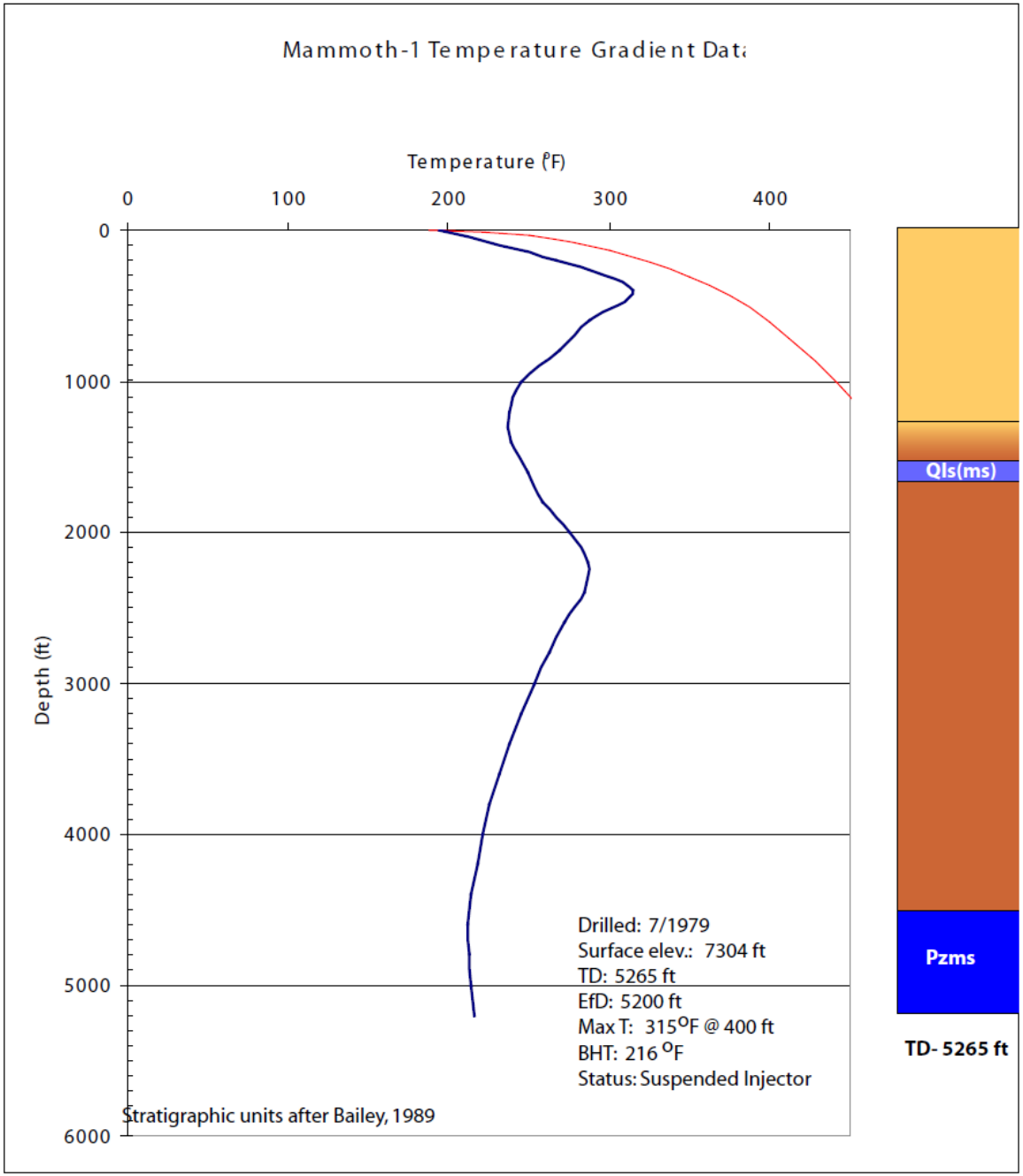


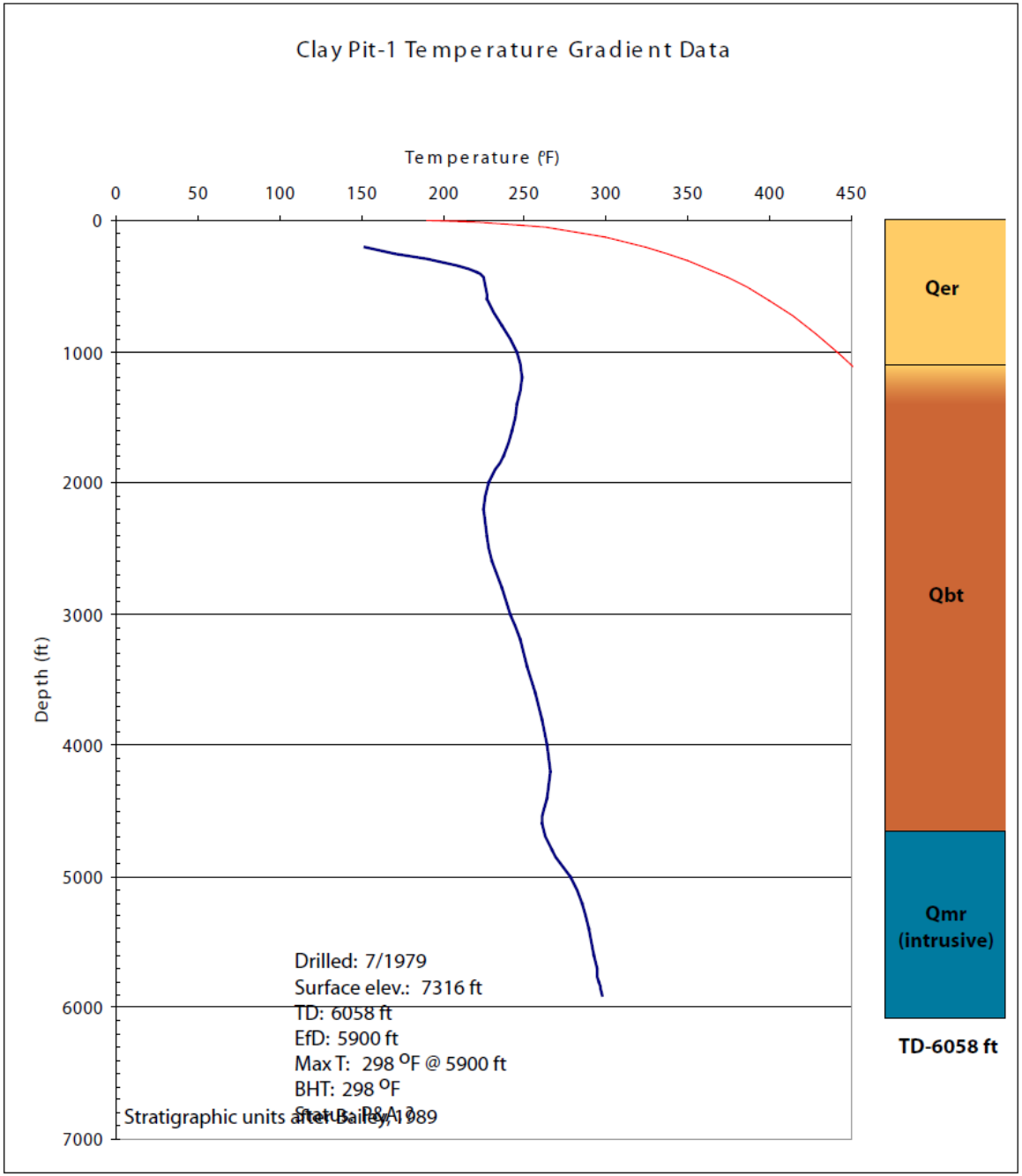
After Sorey et al, 1991

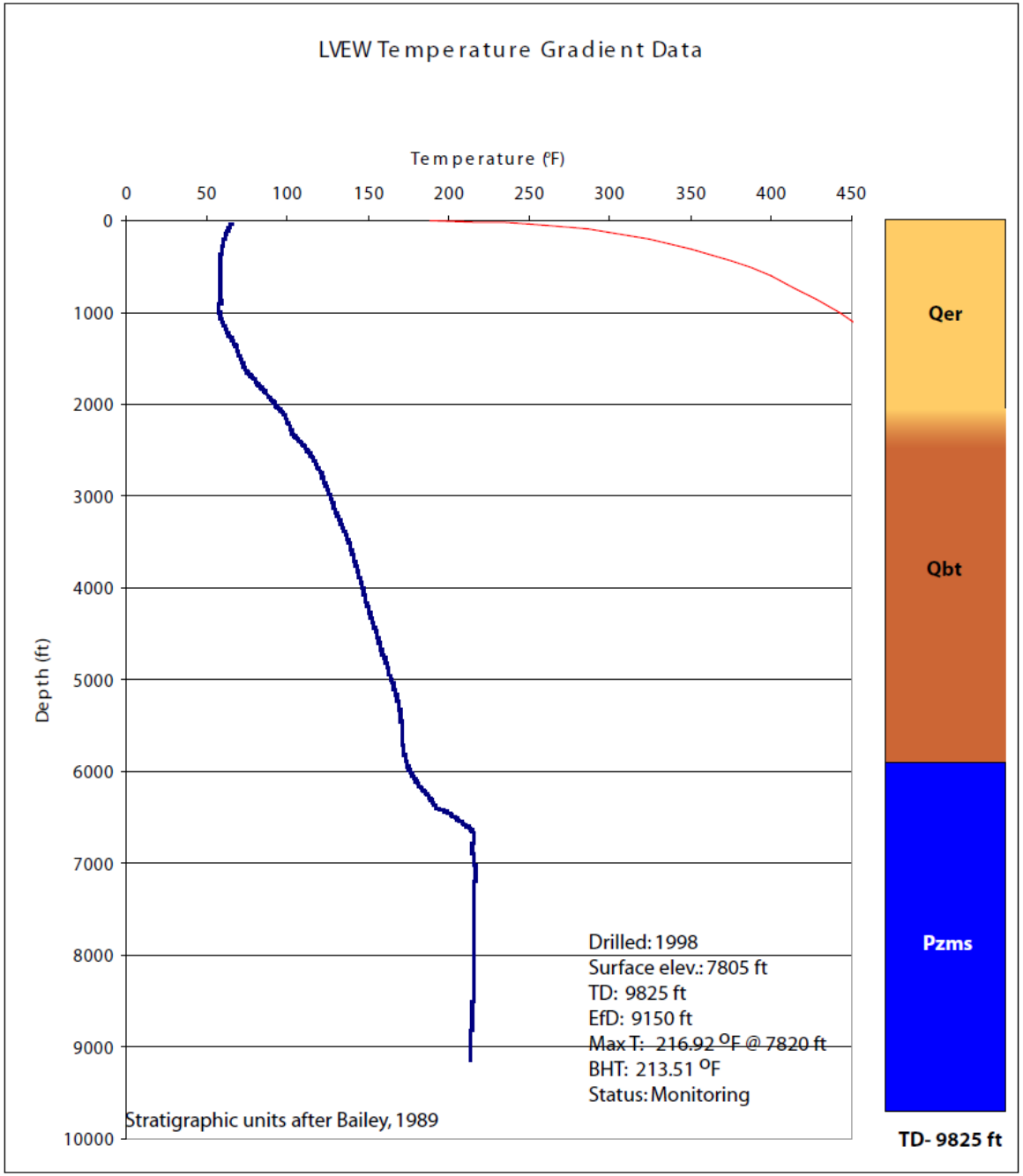


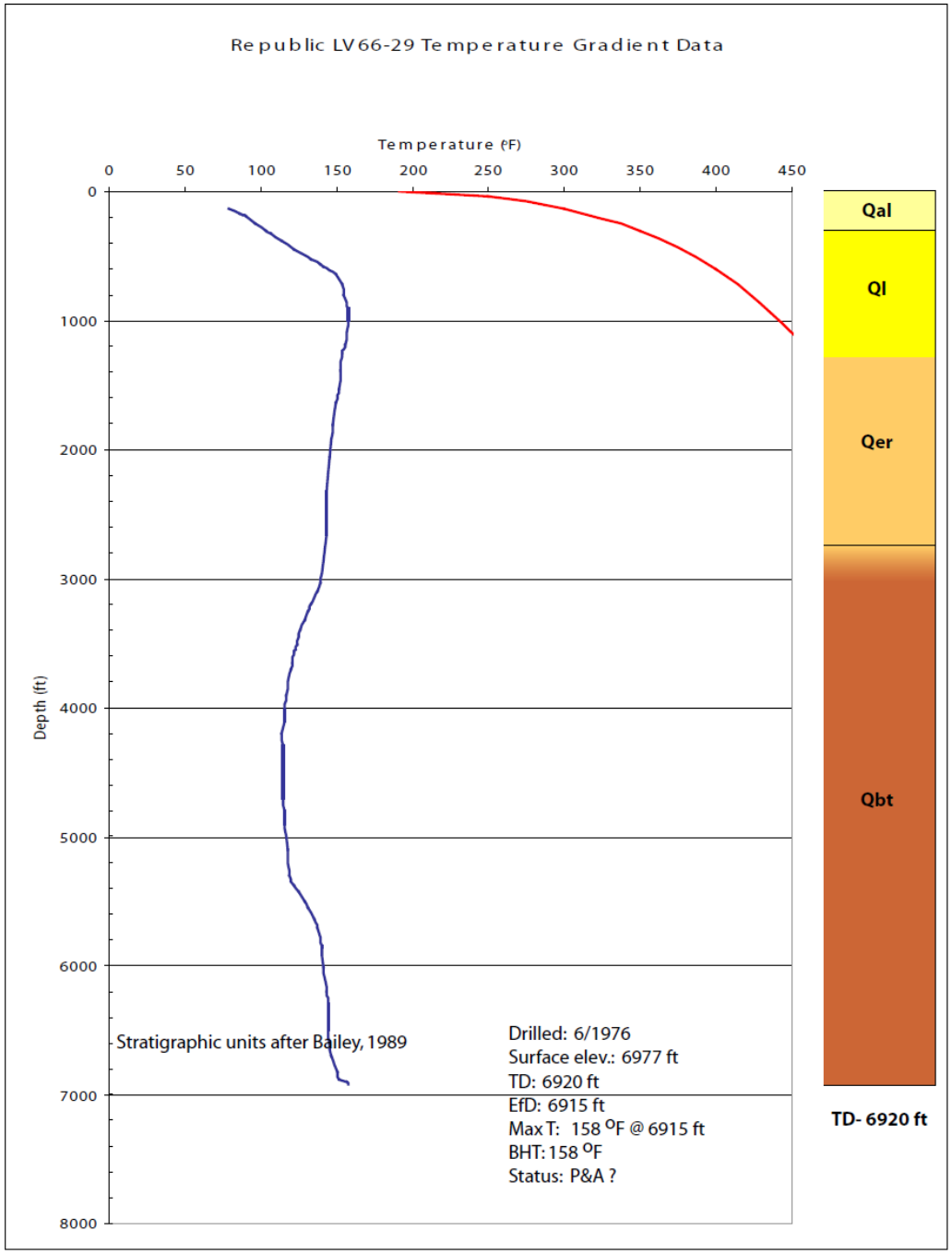
Long Valley wells penetrating Bishop Tuff (orange) or the caldera floor (red).

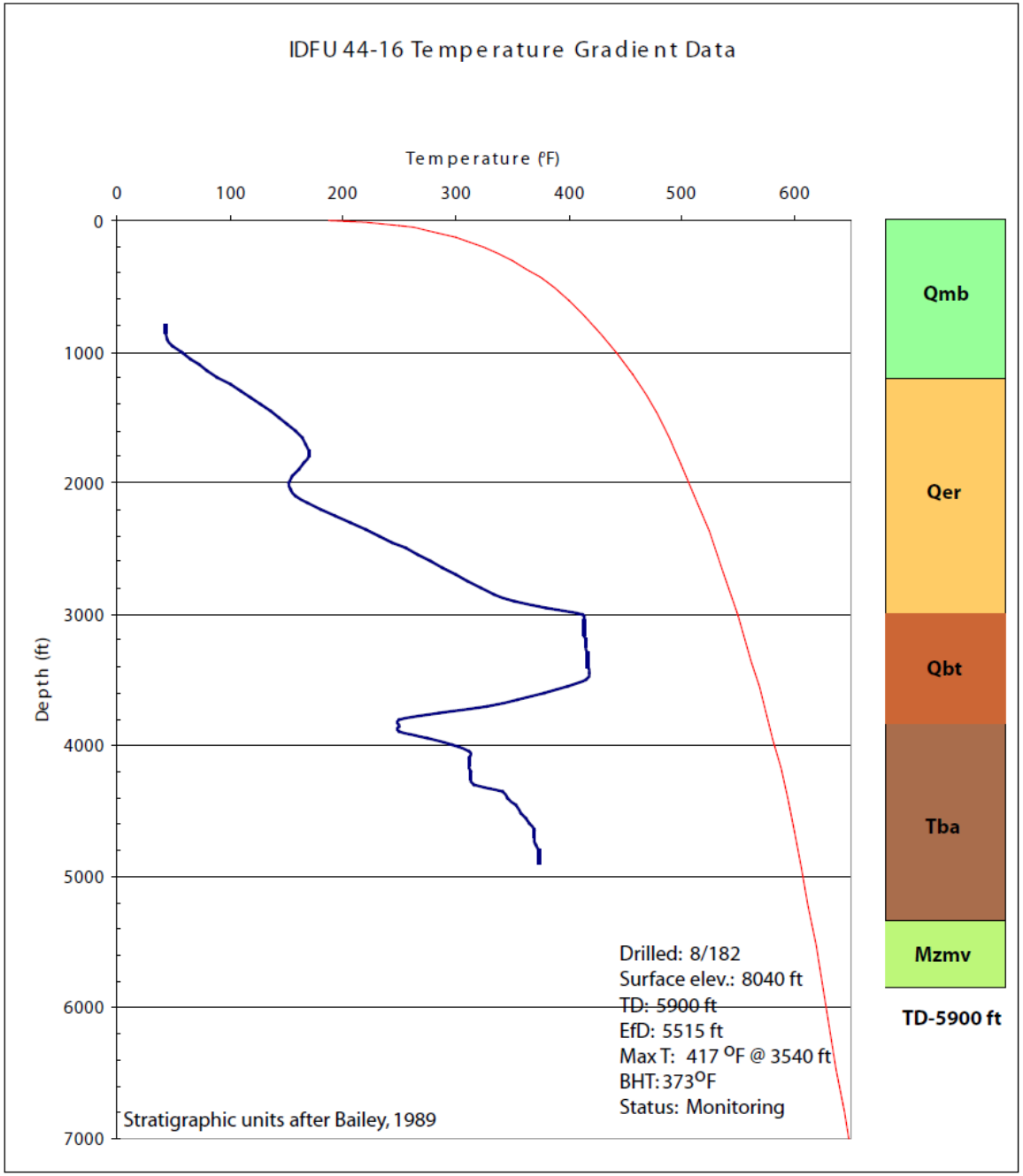

Resurgent Dome
Shady Rest
66-25
57-25
BC 12-31
66-31
M-1
MLGRAP-1
MLGRAP-2
N
0
2km
EXPLANATION
Deep Exploration Wells
Gradient Holes / Shallow Core Holes
Faults

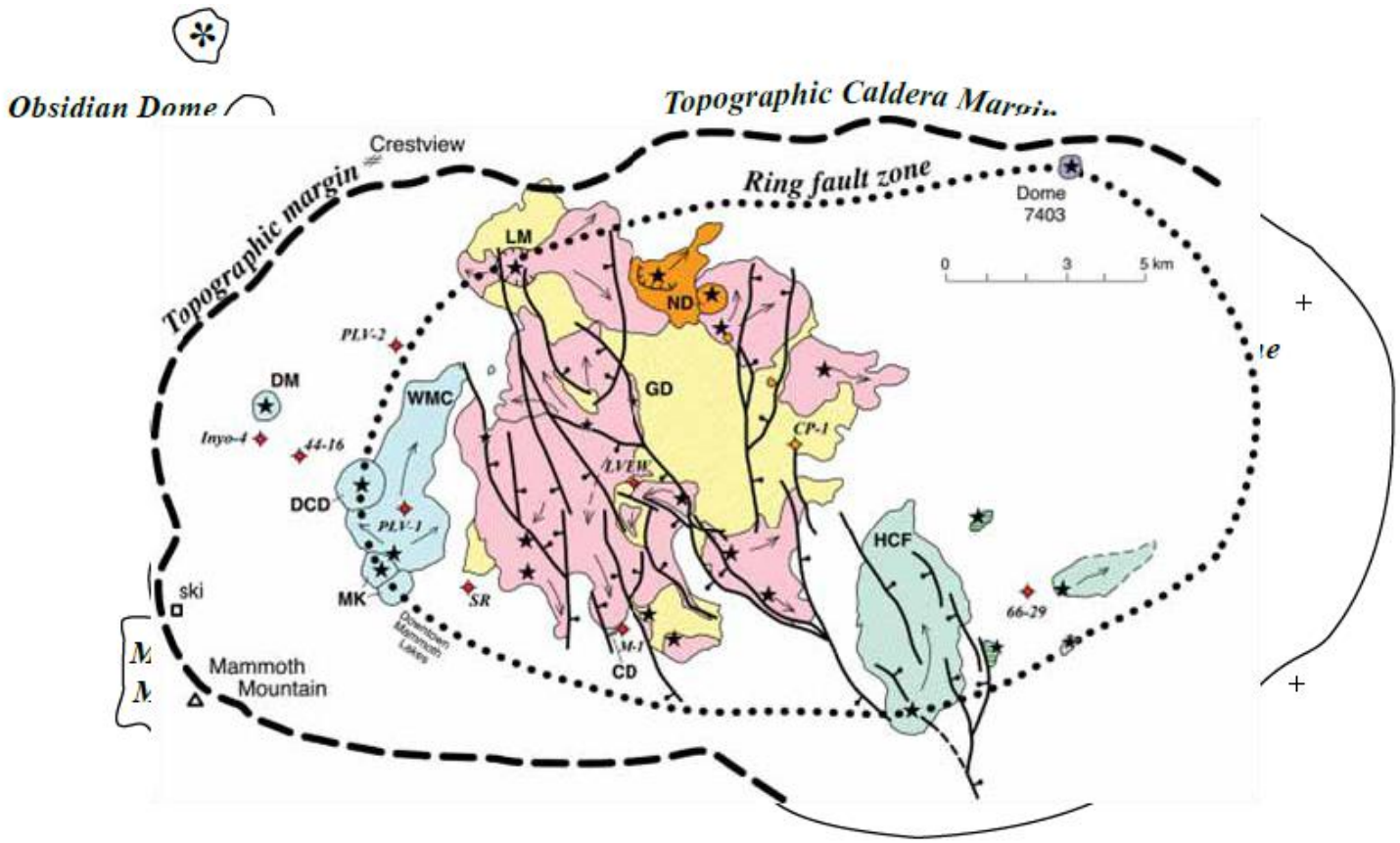

Mammoth-1 Temperature Gradient Data
Temperature (°F)
0
100
200
300
400
Depth (ft)
0
1000
2000
3000
4000
5000
6000
Drilled: 7/1979
Surface elev.: 7304 ft
TD: 5265 ft
EfD: 5200 ft
Max T: 315°F @ 400 ft
BHT: 216 °F
Status: Suspended Injector
Stratigraphic units after Bailey, 1989
Qls(ms)
Pzms
TD- 5265 ft


Clay Pit-1 Temperature Gradient Data
Temperature (°F)
0
50
100
150
200
250
300
350
400
450
Depth (ft)
0
1000
2000
3000
4000
5000
6000
7000
Drilled: 7/1979
Surface elev.: 7316 ft
TD: 6058 ft
EfD: 5900 ft
Max T: 298 °F @ 5900 ft
BHT: 298 °F
Status: P&A 3
Stratigraphic units after Bailey, 1989
Qer
Qbt
Qmr
(intrusive)
TD-6058 ft


LVEW Temperature Gradient Data
Temperature (°F)
0
50
100
150
200
250
300
350
400
450
Depth (ft)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Drilled: 1998
Surface elev.: 7805 ft
TD: 9825 ft
EfD: 9150 ft
Max T: 216.92 °F @ 7820 ft
BHT: 213.51 °F
Status: Monitoring
Stratigraphic units after Bailey, 1989
Qer
Qbt
Pzms
TD- 9825 ft


Republic LV66-29 Temperature Gradient Data
Temperature (°F)
0
50
100
150
200
250
300
350
400
450
Depth (ft)
0
1000
2000
3000
4000
5000
6000
7000
8000
Stratigraphic units after Bailey, 1989
Drilled: 6/1976
Surface elev.: 6977 ft
TD: 6920 ft
EfD: 6915 ft
Max T: 158 °F @ 6915 ft
BHT: 158 °F
Status: P&A ?
Qal
Ql
Qer
Qbt
TD- 6920 ft

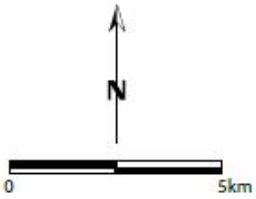

IDFU 44-16 Temperature Gradient Data
Temperature (ºF)
0
100
200
300
400
500
600
Depth (ft)
0
1000
2000
3000
4000
5000
6000
7000
Qmb
Qer
Qbt
Tba
Mzmv
TD-5900 ft
Drilled: 8/182
Surface elev.: 8040 ft
TD: 5900 ft
EfD: 5515 ft
Max T: 417 ºF @ 3540 ft
BHT: 373ºF
Status: Monitoring
Stratigraphic units after Bailey, 1989

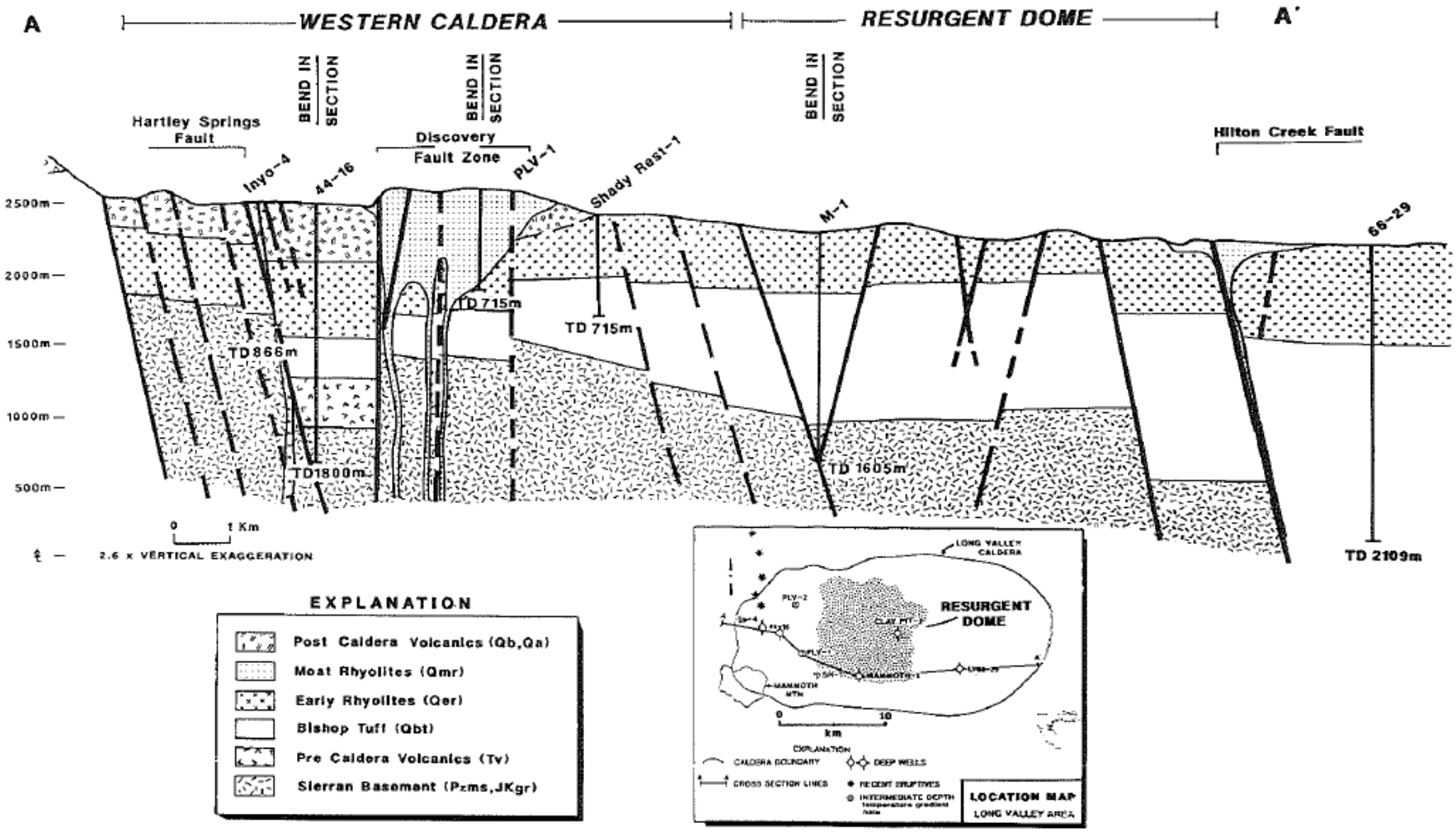


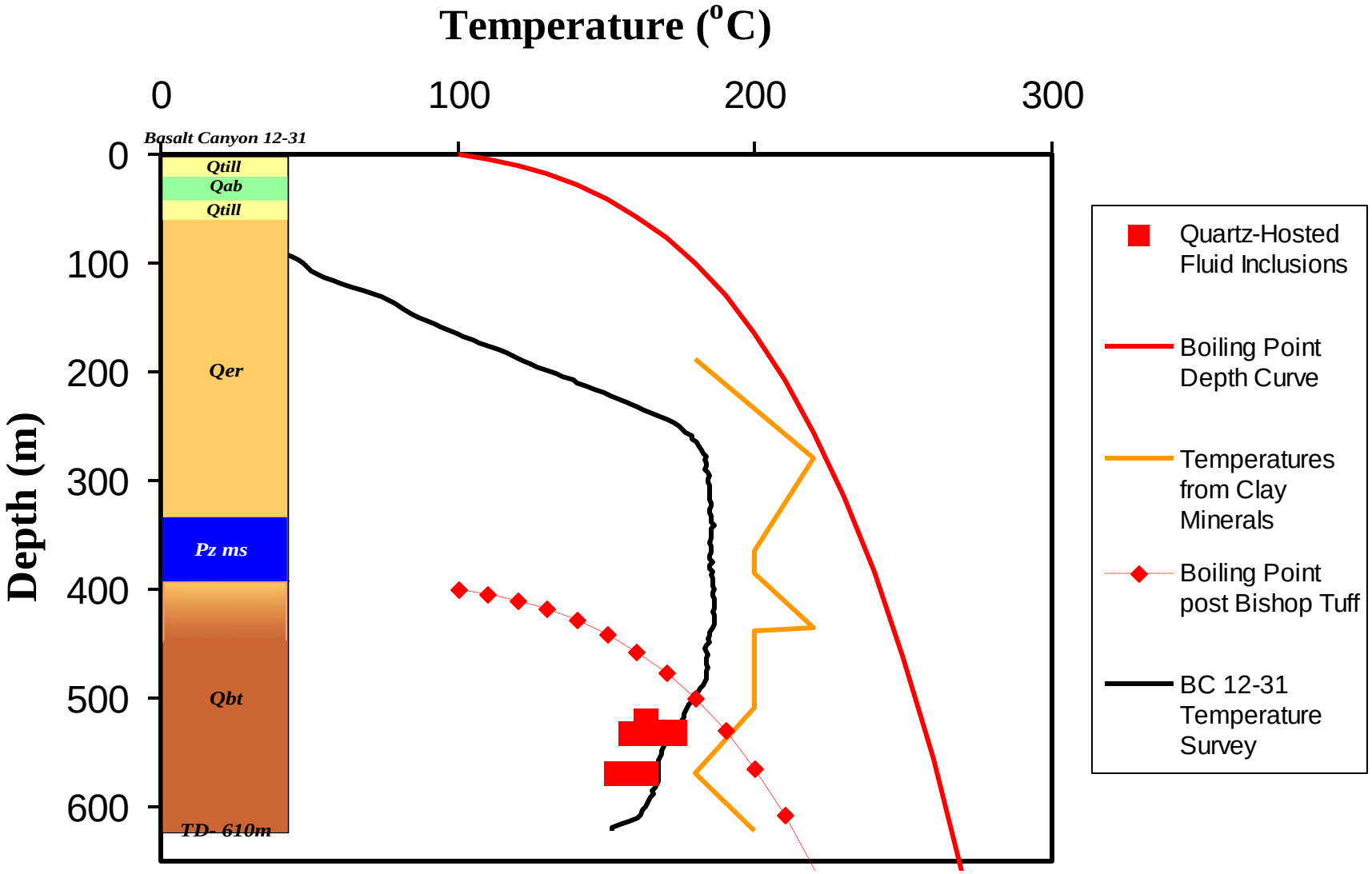
EXPLANATION

Recent Inyo Craters Eruptives

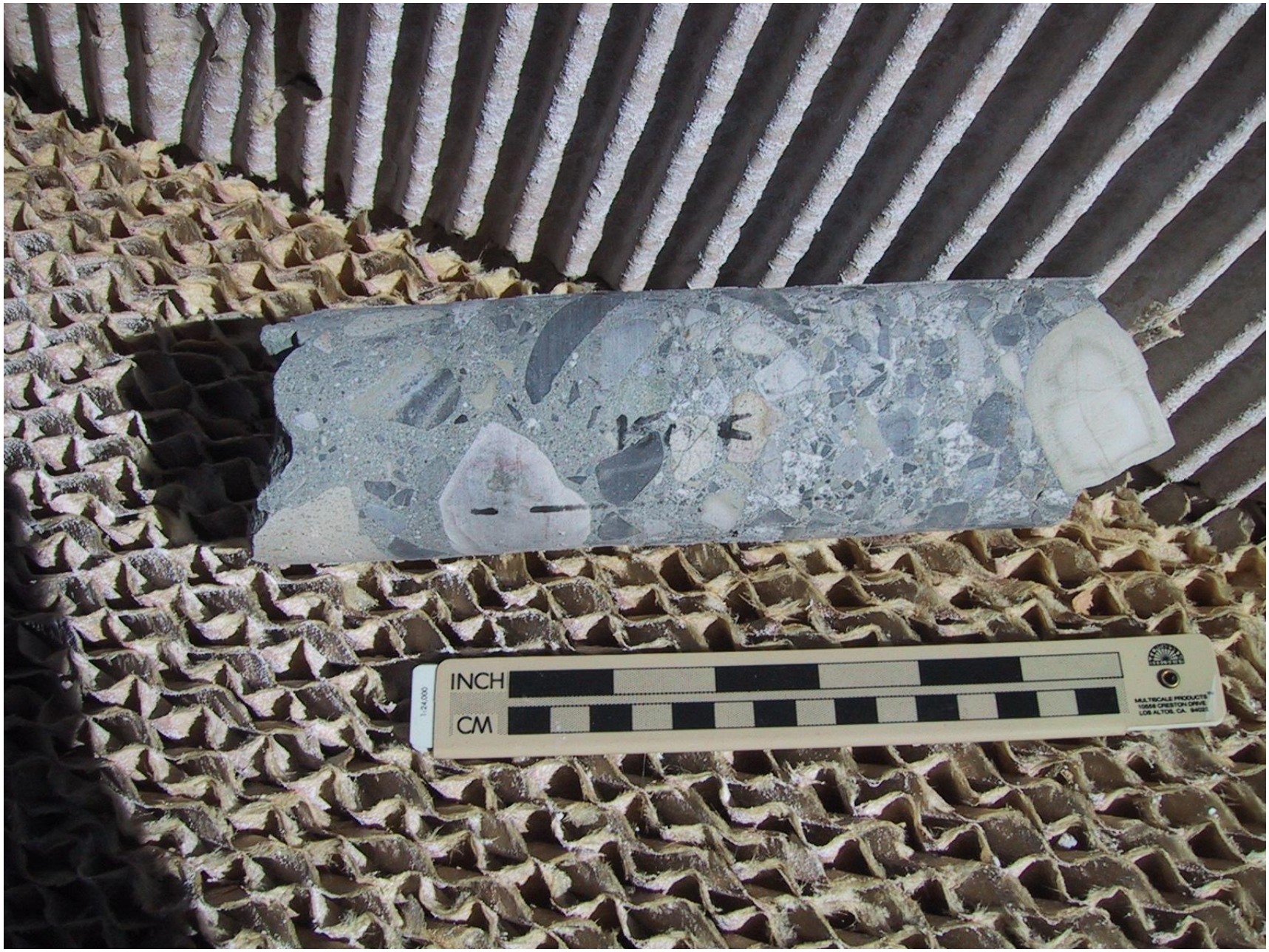
STRUCTURAL CALDERA MARGIN
(AFTER HILDRETH,2004; SUEMNICHT, 2002; BAILEY, 1989)




A
WESTERN CALDERA
RESURGENT DOME
A'
BEND IN SECTION
BEND IN SECTION
BEND IN SECTION
Hartley Springs Fault
Discovery Fault Zone
Hilton Creek Fault
Inyo-4
44-16
PLV-1
Shady Rest-1
M-1
66-29
2500m
2000m
1500m
1000m
500m
TD 715m
TD 715m
TD 866m
TD 1800m
TD 1605m
TD 2109m
0 1 Km
2.6 x VERTICAL EXAGGERATION
EXPLANATION
Post Caldera Volcanics (Qb,Qa)
Moat Rhyolites (Qmr)
Early Rhyolites (Qer)
Bishop Tuff (Qbt)
Pre Caldera Volcanics (Tv)
Sierran Basement (Pzms,JKgr)
LONG VALLEY CALDERA
RESURGENT DOME
MAMMOTH MTN
0 10
km
EXPLANATION
CALDERA BOUNDARY
DEEP WELLS
CROSS SECTION LINES
RECENT ERUPTIVES
INTERMEDIATE DEPTH
LOCATION MAP
LONG VALLEY AREA



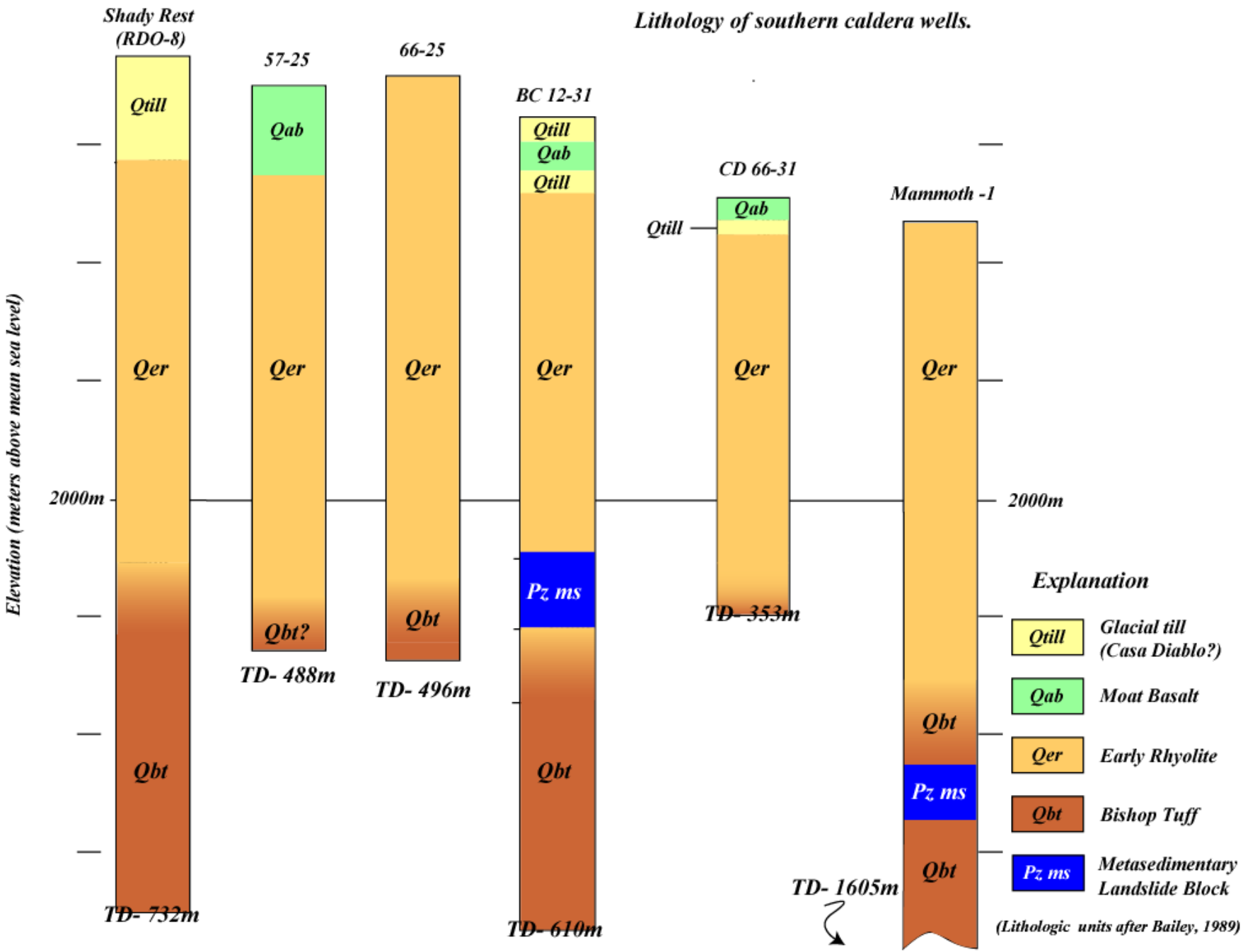
BC 12-31 Fluid Inclusion Data

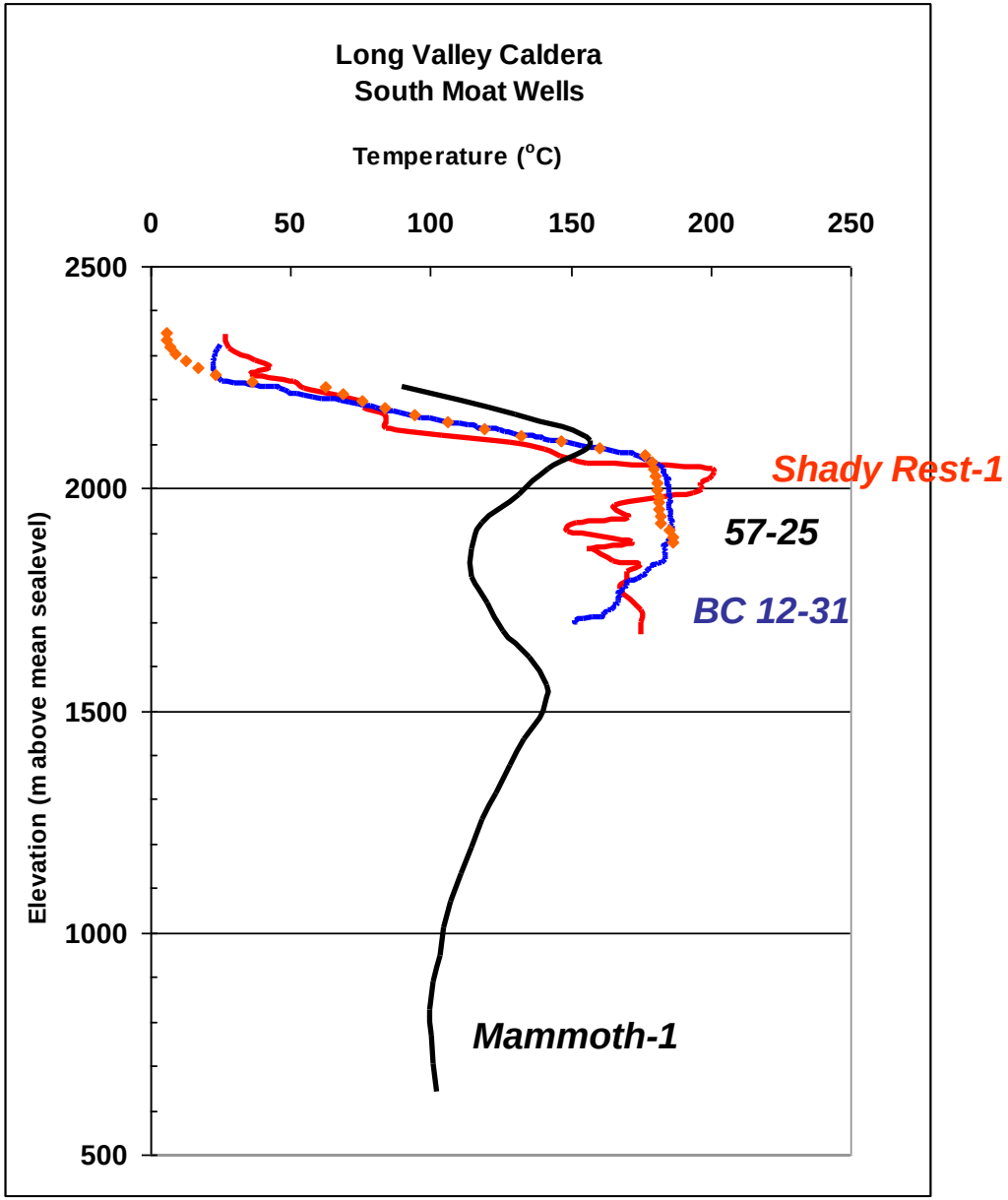

INCH
CM
1:24,000
MULTISCALE PRODUCTS
10668 CRESTON DRIVE
LOS ALTOS, CA. 94022


INCH
CM
1:24,000


INCH
CM


INCH
CM
1:24,000


Lithology of southern caldera wells.
Elevation (meters above mean sea level)
2000m
Shady Rest (RDO-8)
Qtill
Qer
Qbt
TD- 732m
57-25
Qab
Qer
Qbt?
TD- 488m
66-25
Qer
Qbt
TD- 496m
BC 12-31
Qtill
Qab
Qtill
Qer
Pz ms
Qbt
TD- 610m
CD 66-31
Qtill
Qab
Qer
TD- 353m
Mammoth -1
Qer
Qbt
Pz ms
Qbt
TD- 1605m
2000m
Explanation
Qtill
Glacial till (Casa Diablo?)
Qab
Moat Basalt
Qer
Early Rhyolite
Qbt
Bishop Tuff
Pz ms
Metasedimentary Landslide Block
(Lithologic units after Bailey, 1989)


Long Valley Caldera
South Moat Wells
Temperature (°C)
0
50
100
150
200
250
2500
2000
1500
1000
500
Elevation (m above mean sealevel)
Shady Rest-1
57-25
BC 12-31
Mammoth-1