Hydrogeology of the San Agustin Plains, NM

A comprehensive geologic, geochemical and geophysical approach to understanding the hydrology of an enigmatic extensional basin

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22 September 2019
GSA Annual Meeting
Phoenix, AZ

NEW MEXICO TECH
SCIENCE • ENGINEERING • RESEARCH UNIVERSITY

We want to thank

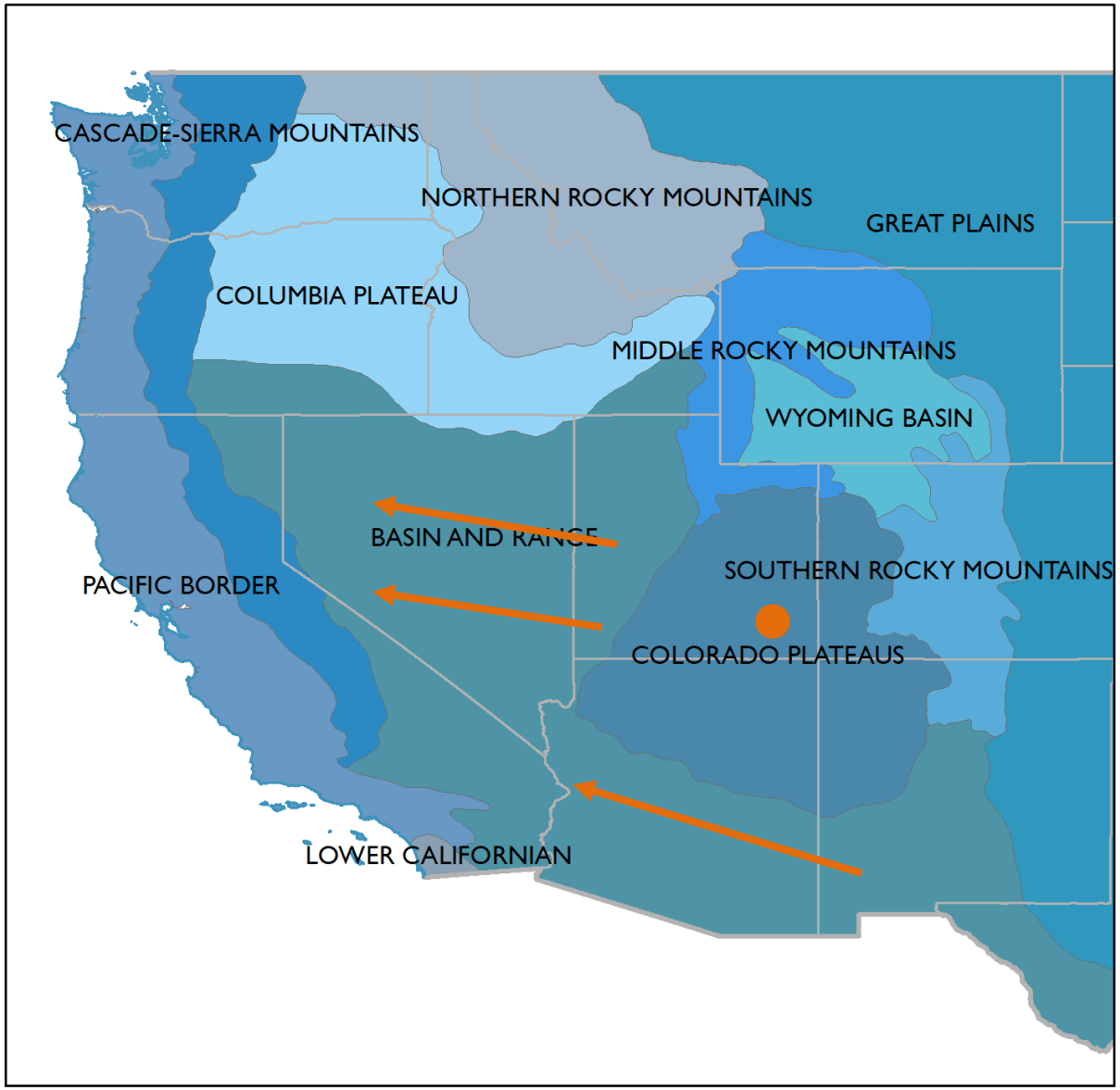
Local land owners and community members for access to wells and springs, and Eileen Dodds, Roy Farr and Carol Coker for paying for some recent analyses.

John Shomaker and Associates with permission from Agustin Plains Ranch LLC for access to well records and logs, and cuttings from pilot wells.

Fred Phillips, David Parkhurst, Trevor Kludt, Scott Christenson, Luna Brett, Brigitte Felix, Kitty Pokorny, Talon Newton and Sara Chudnoff.

Majority of funding provided through the Aquifer Mapping Program under the New Mexico Bureau of Geology state legislative budget, with some support from the Hydrology Bureau (M. Johnson) of the NMOSE.

The San Agustin Plains is in the transition between the Colorado Plateau, the Rio Grande rift, and the Mogollon-Datil Volcanic Field.



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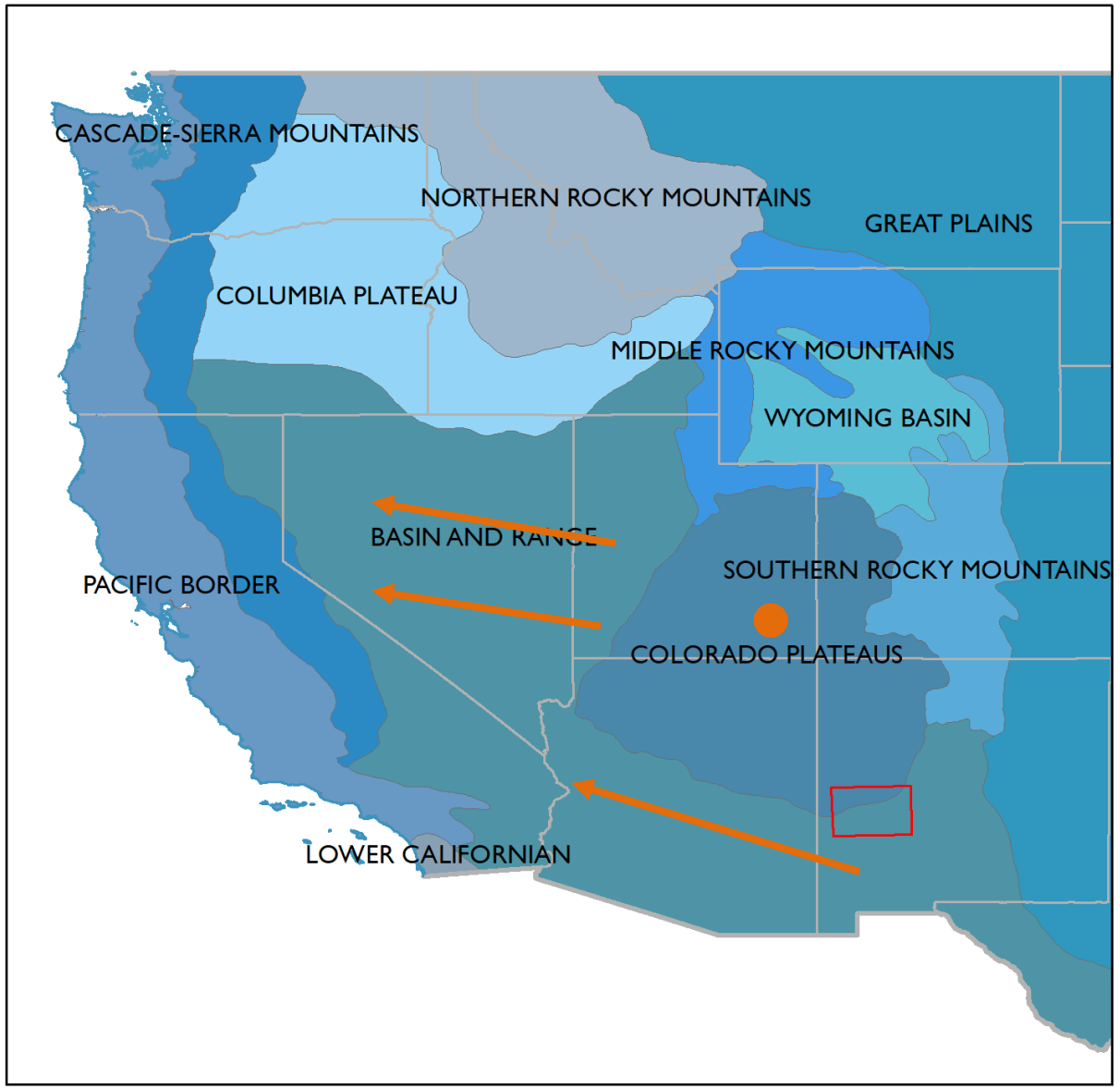


San Agustin Plains and Datil-Mogollon Volcanic Field in general have little previous work.

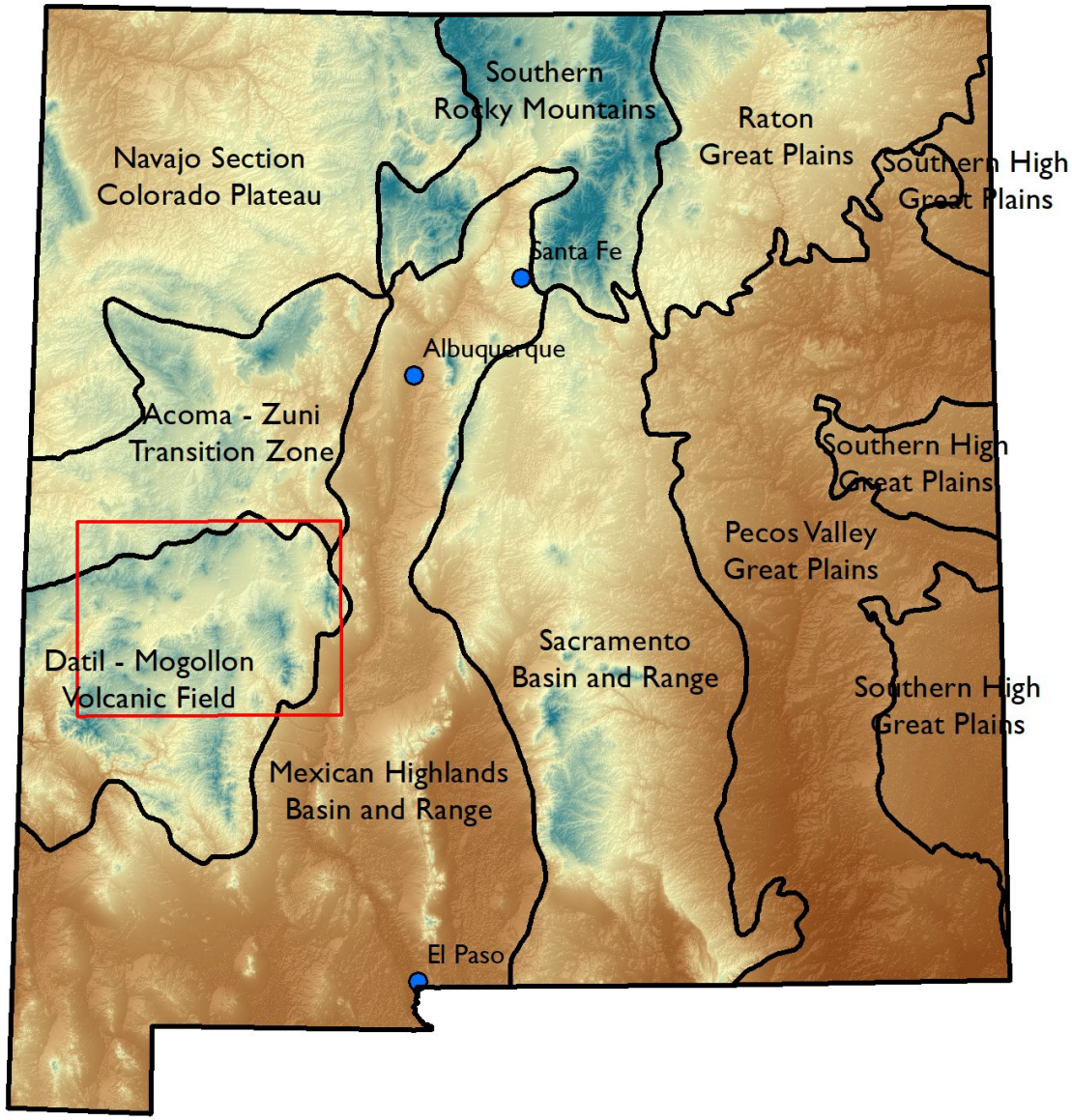
Extensional basin in transition between B&R and Colorado Plateau.

How many sub-basins are there?

What are the aquifers? The connection between the mountain blocks and basin? Between sub-basins?

How quickly is the water moving? What controls the chemistry?

What can the San Agustin Plains and neighboring open basin (Alamosa Creek) tell us about the hydrogeology in the rest of the Datil-Mogollon Volcanic Field?



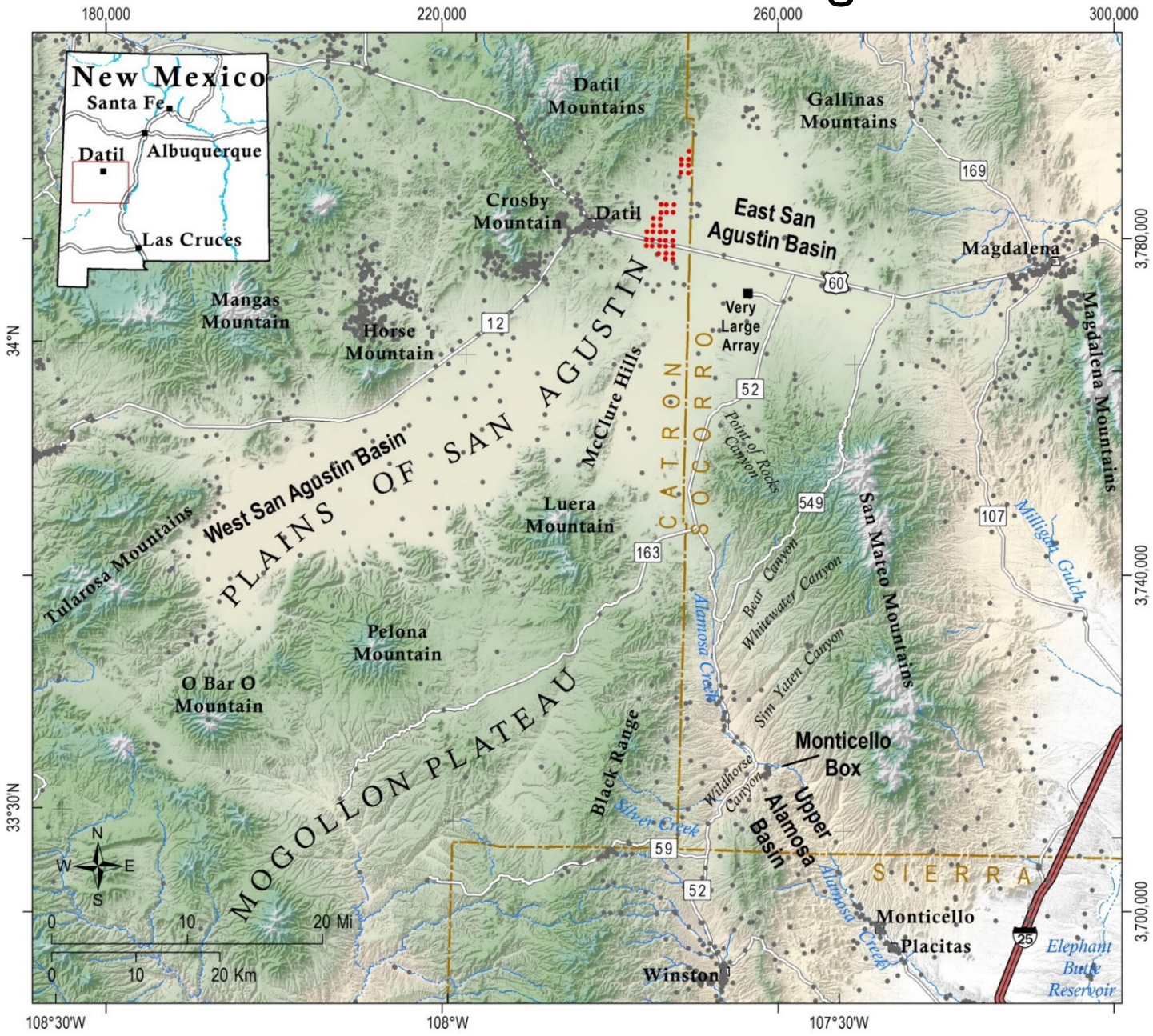
Low-relief semi-arid volcanic and volcaniclastic mountains next to high-elevation extensional basins.

In valley, 8 to 13 in of precip., 60% as rainfall.

About 15 in precip. in uplands, mostly rainfall.

Basin elevations: 6800 ft amsl (SW corner) to 7000 ft amsl (northern tip).

Most mountain peaks 8500 ft amsl to over 10,000 ft amsl.

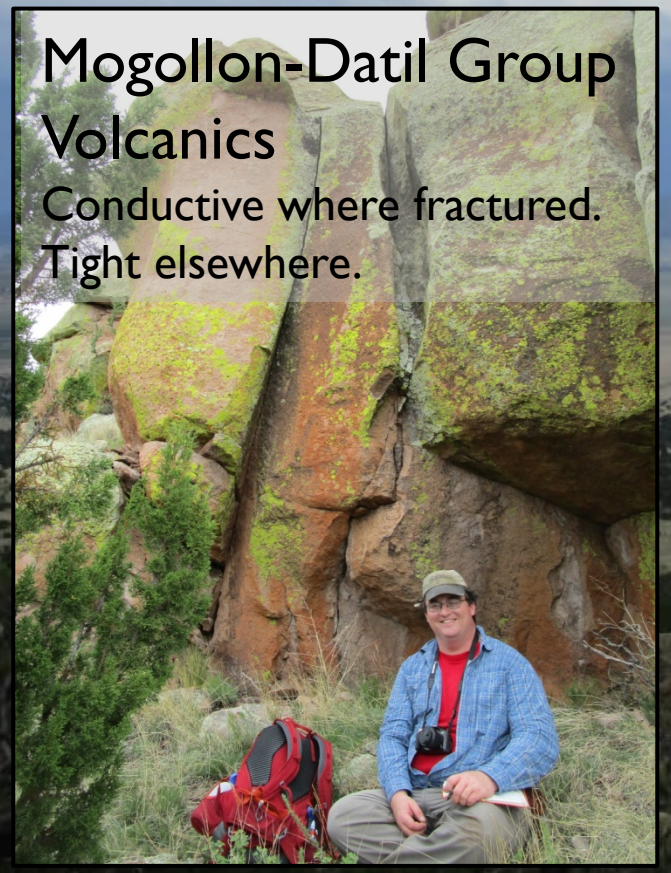


Basin is filled by a Pleistocene fan-delta-lake complex.

Basin-fill underlain by 2k – 5k ft of volcanics (Mogollon-Datil Group, Oligocene) and volcaniclastic (Spears Group, Oligocene) rocks. Mountains made of Mogollon-Datil Group and Spears Group.

Basin is filled by a Pleistocene fan-delta-lake complex.

Basin-fill underlain by 2k – 5k ft of volcanics (Mogollon-Datil Group, Oligocene rhyolitic tuffs and basaltic andesites) and volcaniclastic (Spears Group, Oligocene) rocks. Mountains made of Datil Group and Spears Group.

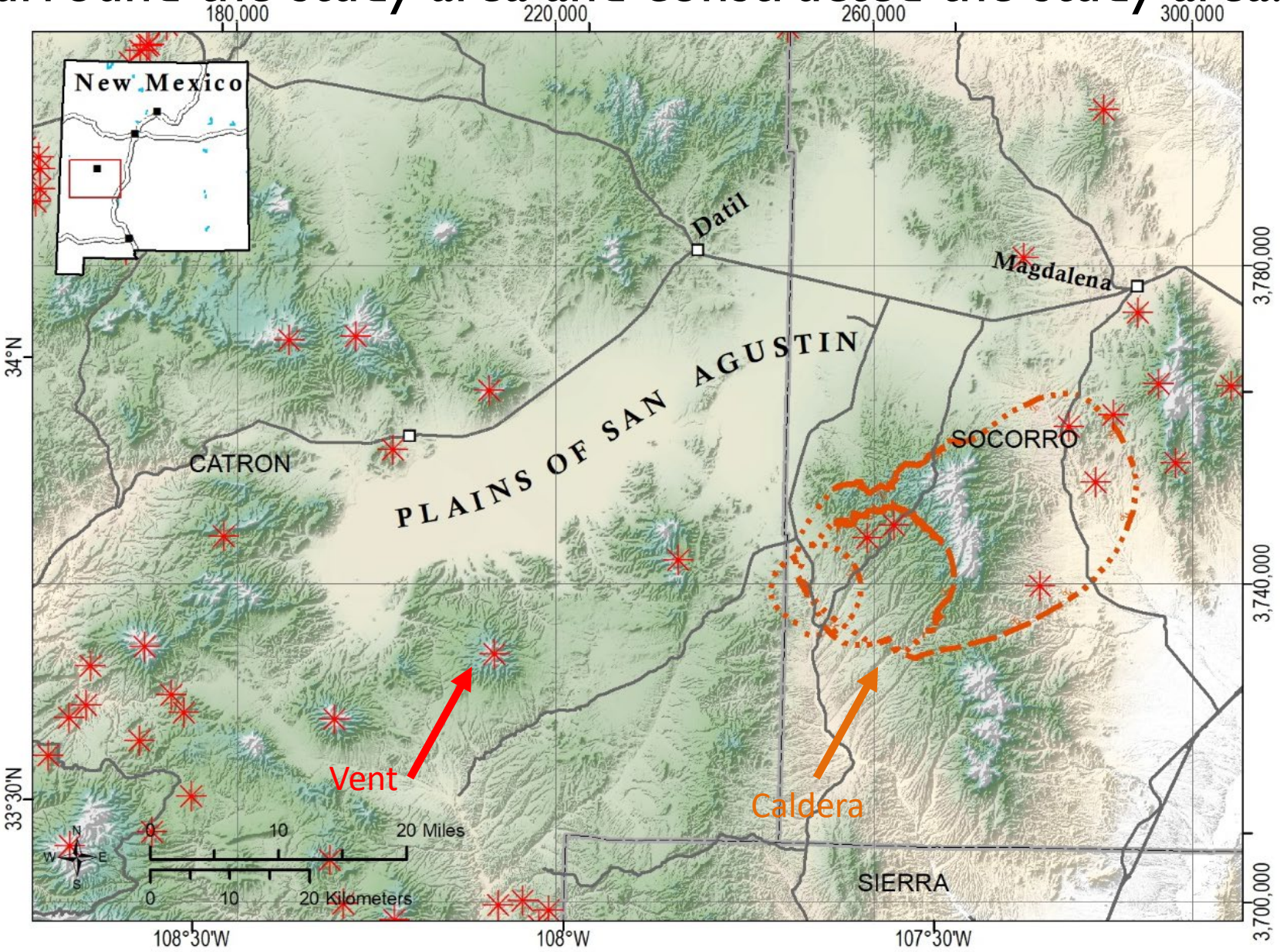


Volcanic features both surround the study area and constructed the study area.

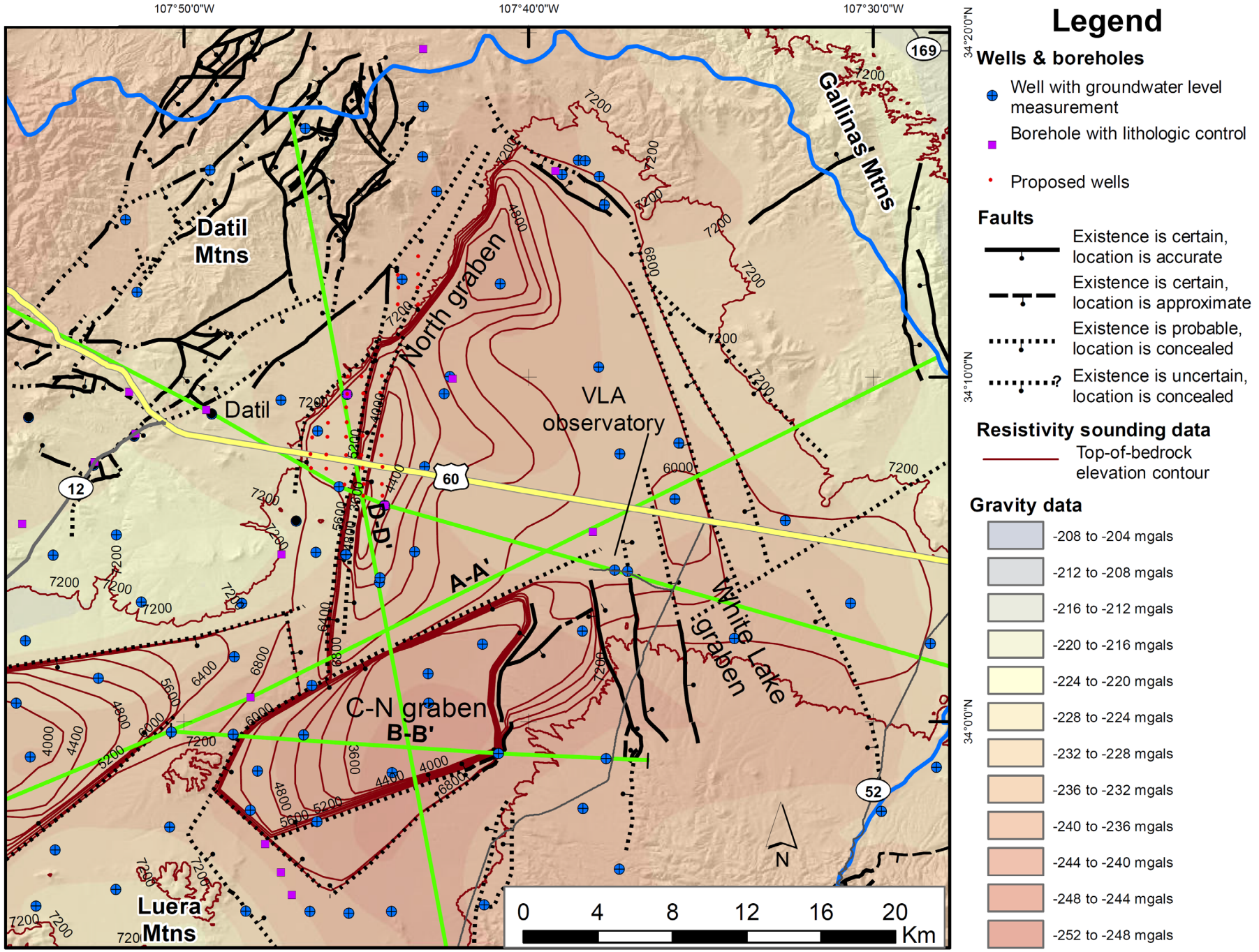
Highest mountains are formed by large Oligocene calderas.

Many small shield volcanoes and other vents scattered across the region, often at the top of current lower mountains.

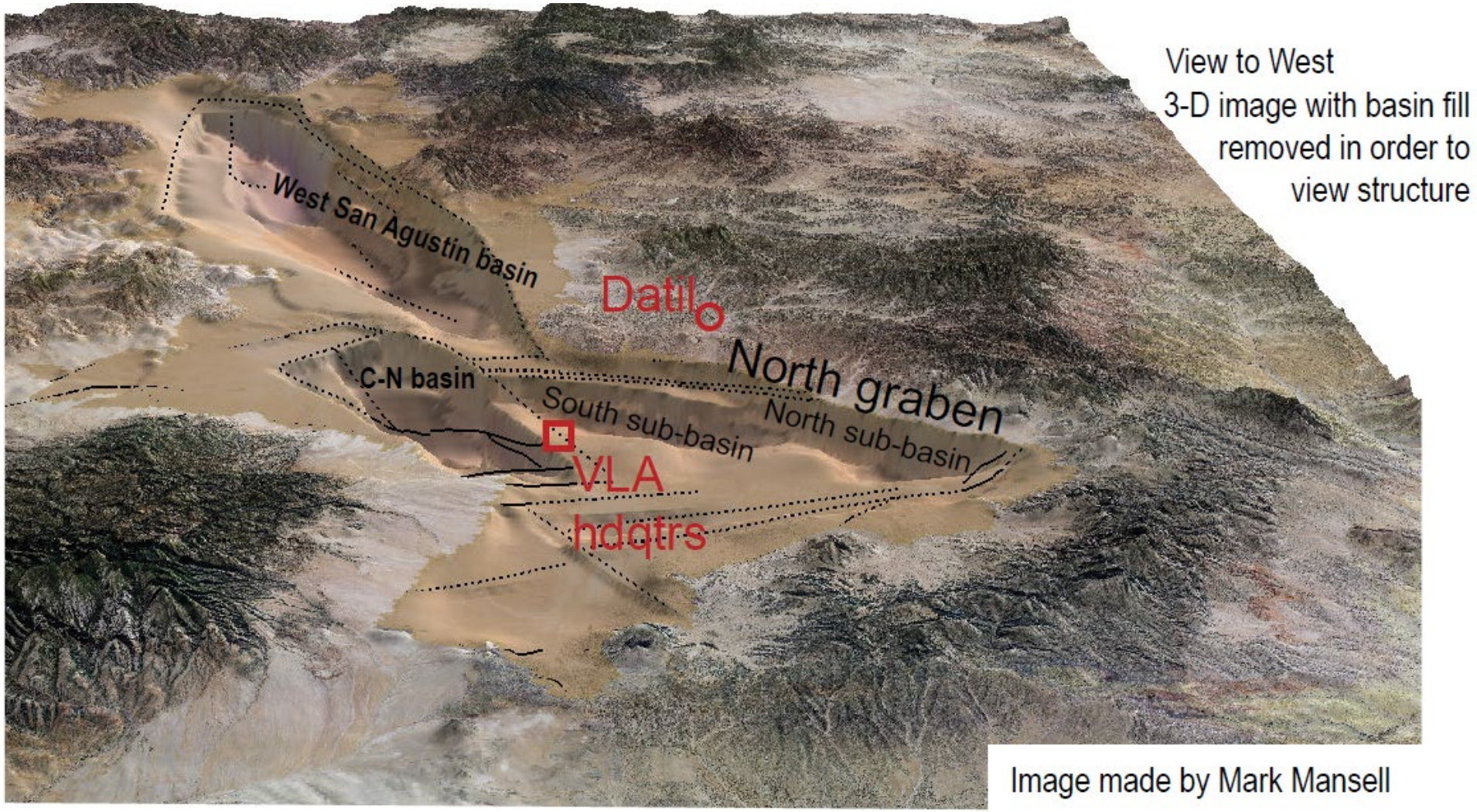
Mountain blocks are interbedded volcanics and volcaniclastics.

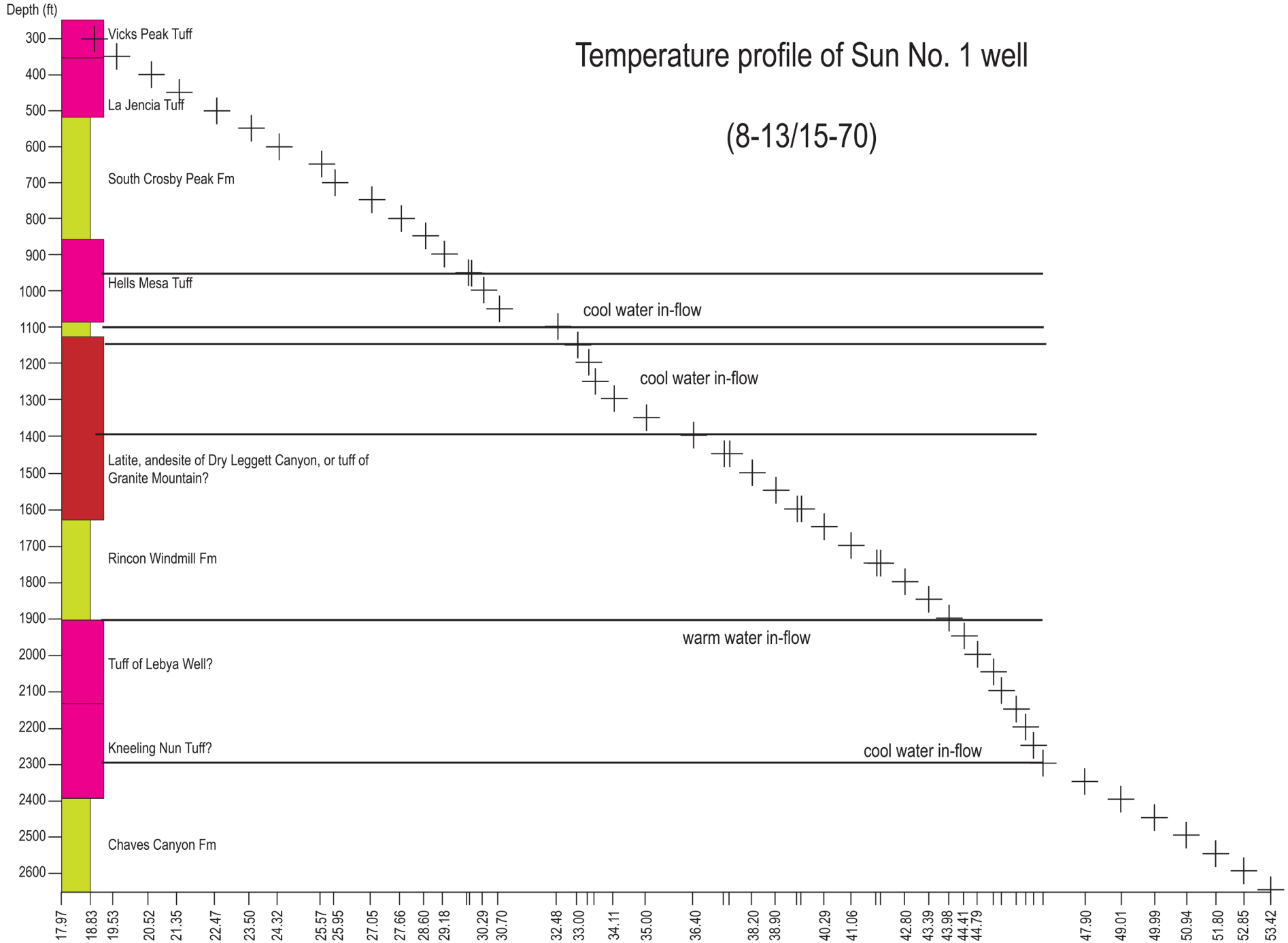


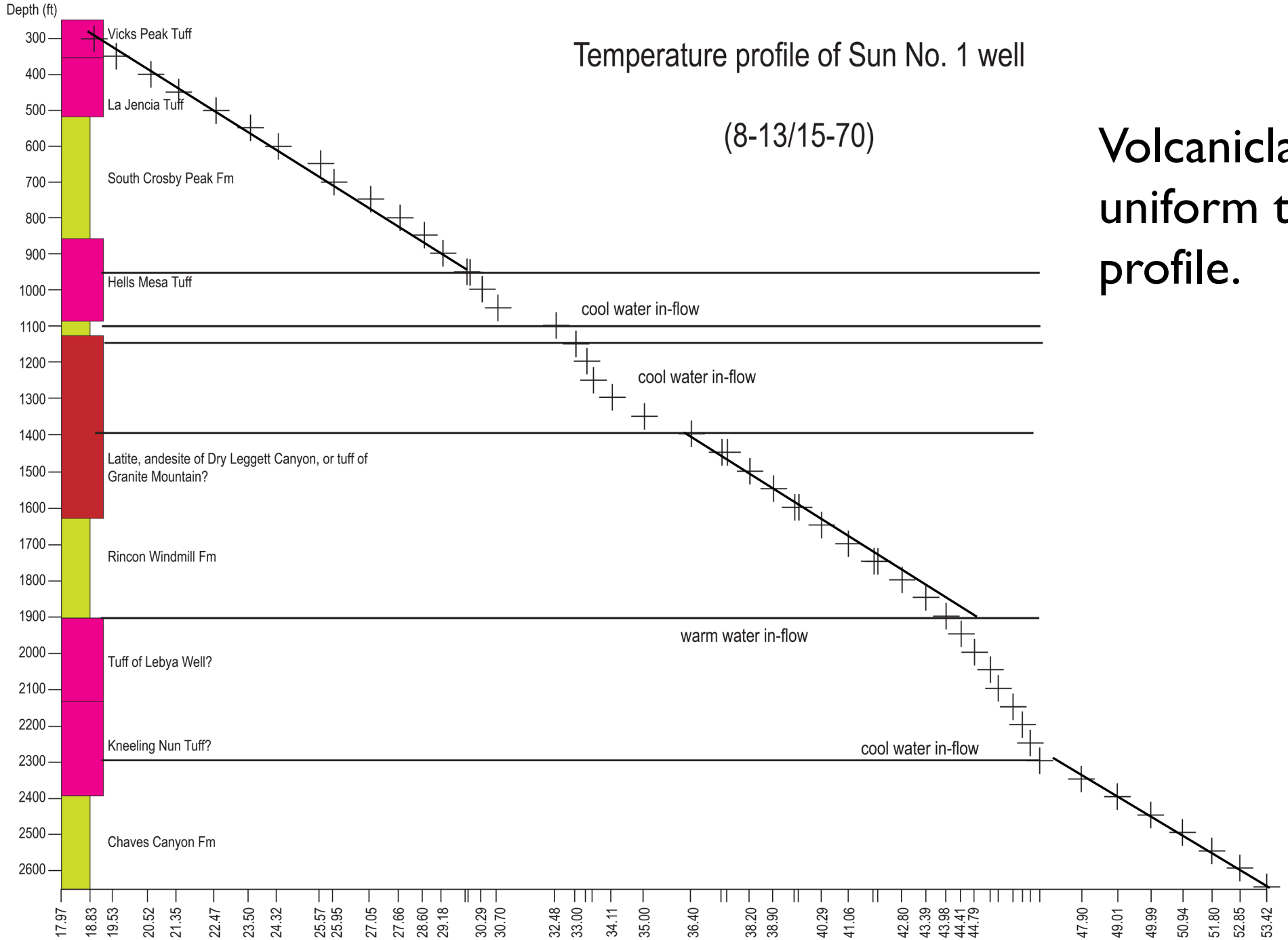
Compilation of mapping, well logs, historical electrical resistivity maps and terrain-corrected Bougeur anomaly.



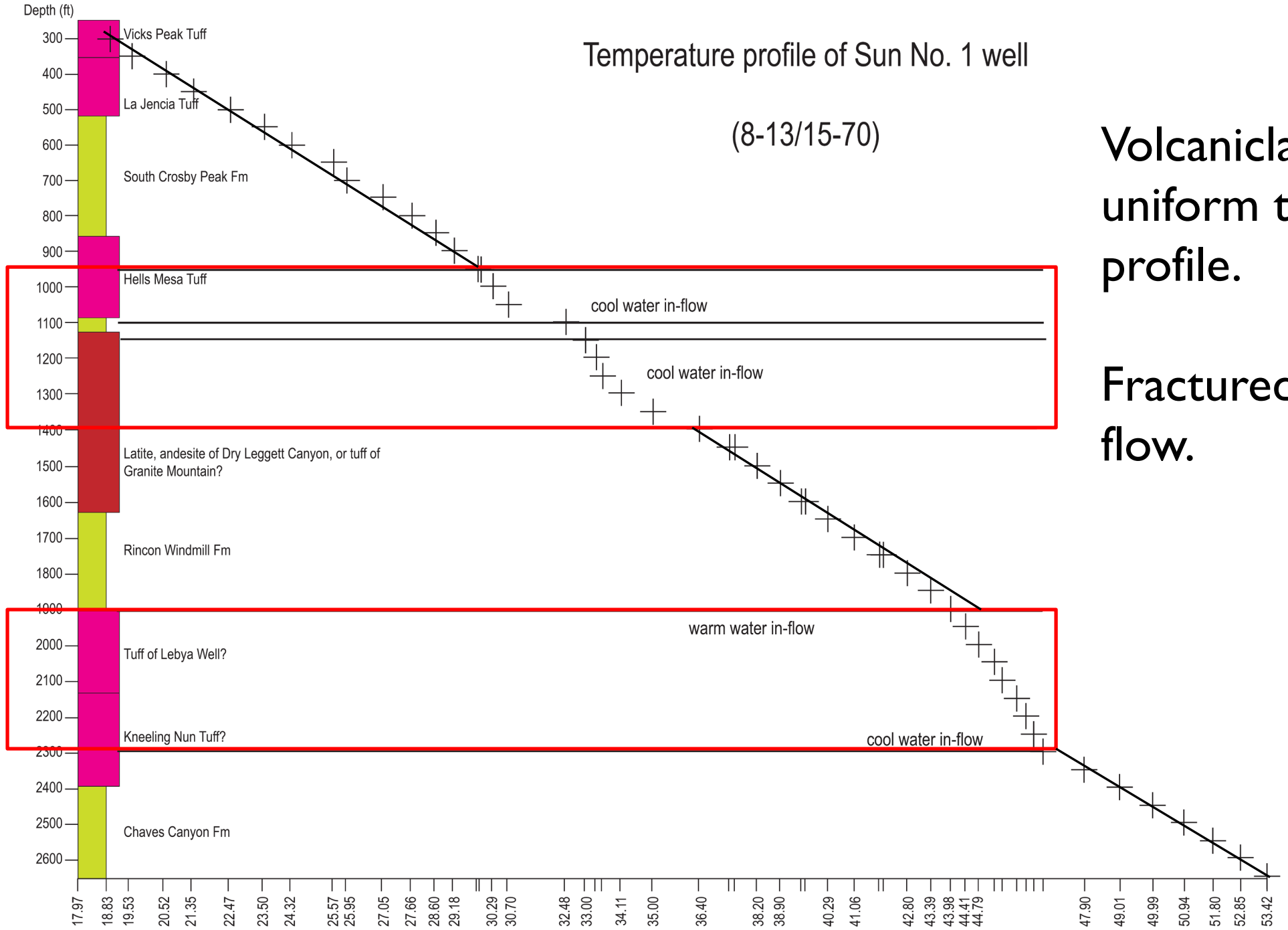
Two surface basins are made of separate three grabens




Temperature profile of Sun No. 1 well
(8-13/15-70)
Depth (ft)
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
Vicks Peak Tuff
La Jencia Tuff
South Crosby Peak Fm
Hells Mesa Tuff
cool water in-flow
cool water in-flow
Latite, andesite of Dry Leggett Canyon, or tuff of
Granite Mountain?
Rincon Windmill Fm
warm water in-flow
Tuff of Lebya Well?
Kneeling Nun Tuff?
cool water in-flow
Chaves Canyon Fm
17.97
18.83
19.53
20.52
21.35
22.47
23.50
24.32
25.57
25.95
27.05
27.66
28.60
29.18
30.29
30.70
32.48
33.00
34.11
35.00
36.40
38.20
38.90
40.29
41.06
42.80
43.39
43.98
44.41
44.79
47.90
49.01
49.99
50.94
51.80
52.85
53.42

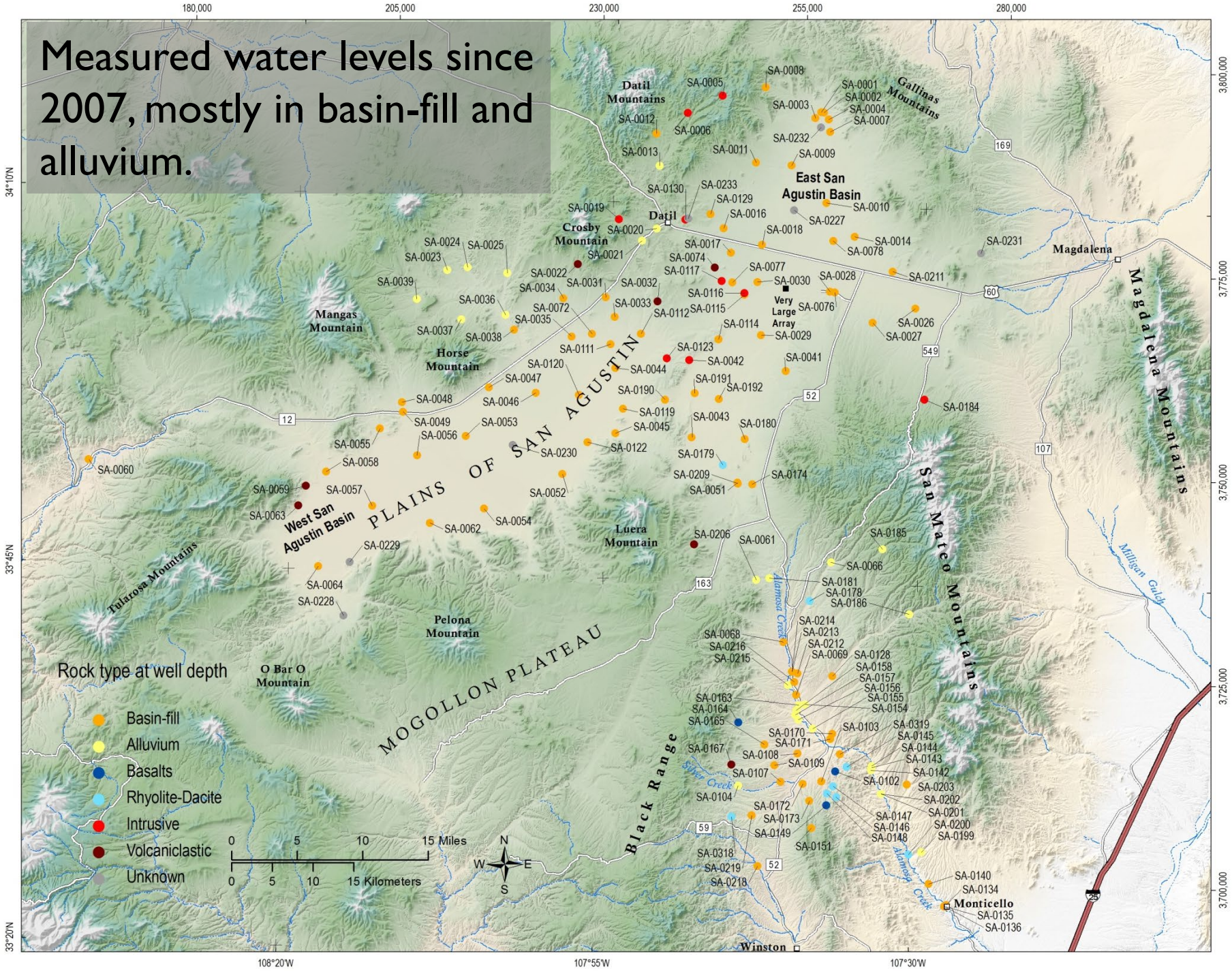


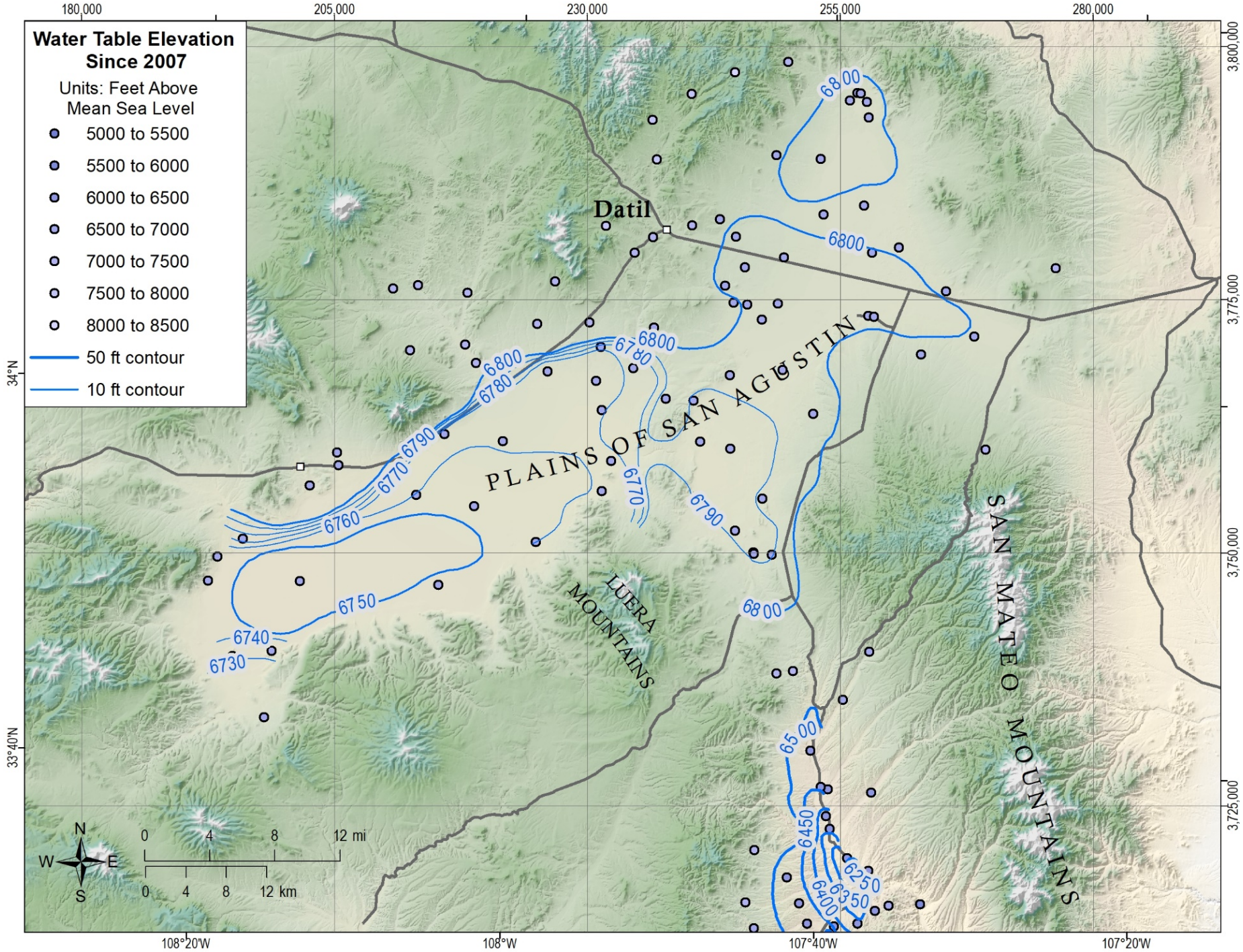
Volcaniclastics have uniform temperature profile.

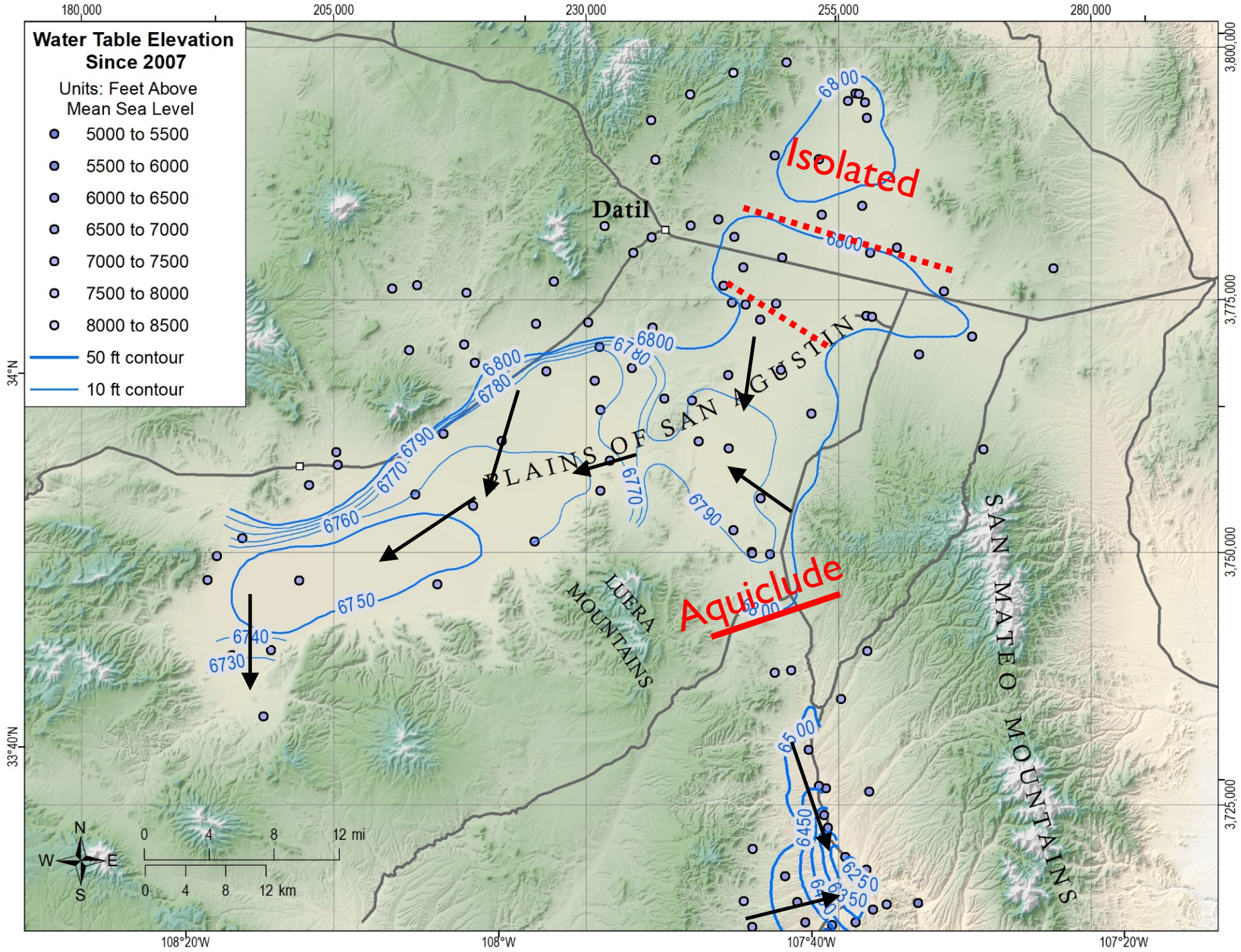


Volcaniclastics have uniform temperature profile.

Fractured tuffs have lateral flow.


Measured water levels since 2007, mostly in basin-fill and alluvium.
180,000
205,000
230,000
255,000
280,000
34°10'N
33°45'N
33°20'N
3,800,000
3,775,000
3,750,000
3,725,000
3,700,000
108°20'W
107°55'W
107°30'W
Datil Mountains
Gallinas Mountains
East San Agustin Basin
Datil
Crosby Mountain
Magdalena
Magdalena Mountains
Mangas Mountain
Horse Mountain
PLAINS OF SAN AGUSTIN
Very Large Array
West San Agustin Basin
Luera Mountain
San Mateo Mountains
Tularosa Mountains
Pelona Mountain
O Bar O Mountain
MOGOLLON PLATEAU
Black Range
Alamosa Creek
Milligan Gulch
Silver Creek
Monticello
Winston
Rock type at well depth
Basin-fill
Alluvium
Basalts
Rhyolite-Dacite
Intrusive
Volcaniclastic
Unknown
0 5 10 15 Miles
0 5 10 15 Kilometers
N
W
E
S


Water Table Elevation Since 2007
Units: Feet Above Mean Sea Level
5000 to 5500
5500 to 6000
6000 to 6500
6500 to 7000
7000 to 7500
7500 to 8000
8000 to 8500
50 ft contour
10 ft contour
Datil
PLAINS OF SAN AGUSTIN
LUERA MOUNTAINS
SAN MATEO MOUNTAINS
6800
6780
6790
6770
6760
6750
6740
6730
6450
6250
6350
6400
180,000
205,000
230,000
255,000
280,000
3,800,000
3,775,000
3,750,000
3,725,000
34°N
33°40'N
108°20'W
108°W
107°40'W
107°20'W
N
W
E
S
0 4 8 12 mi
0 4 8 12 km


Water Table Elevation Since 2007
Units: Feet Above Mean Sea Level
5000 to 5500
5500 to 6000
6000 to 6500
6500 to 7000
7000 to 7500
7500 to 8000
8000 to 8500
50 ft contour
10 ft contour
Datil
Isolated
Aquiclude
PLAINS OF SAN AGUSTIN
LUERA MOUNTAINS
SAN MATEO MOUNTAINS
6800
6780
6790
6770
6760
6750
6740
6730
6450
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6350
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205,000
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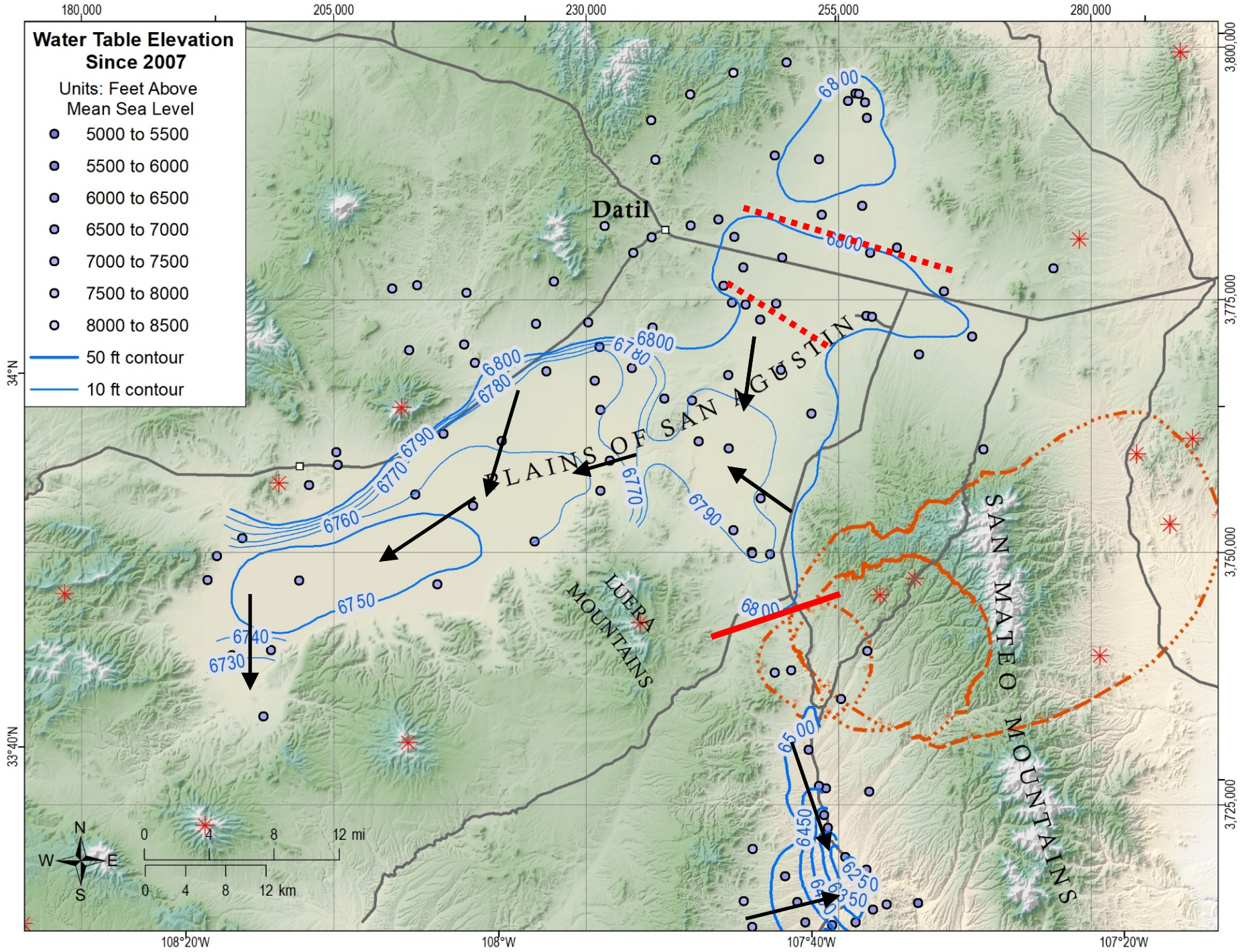
3,800,000
3,775,000
3,750,000
3,725,000
34°N
33°40'N
108°20'W
108°W
107°40'W
107°20'W
N
W
E
S
0 4 8 12 mi
0 4 8 12 km


Water Table Elevation Since 2007
Units: Feet Above Mean Sea Level
5000 to 5500
5500 to 6000
6000 to 6500
6500 to 7000
7000 to 7500
7500 to 8000
8000 to 8500
50 ft contour
10 ft contour
Datil
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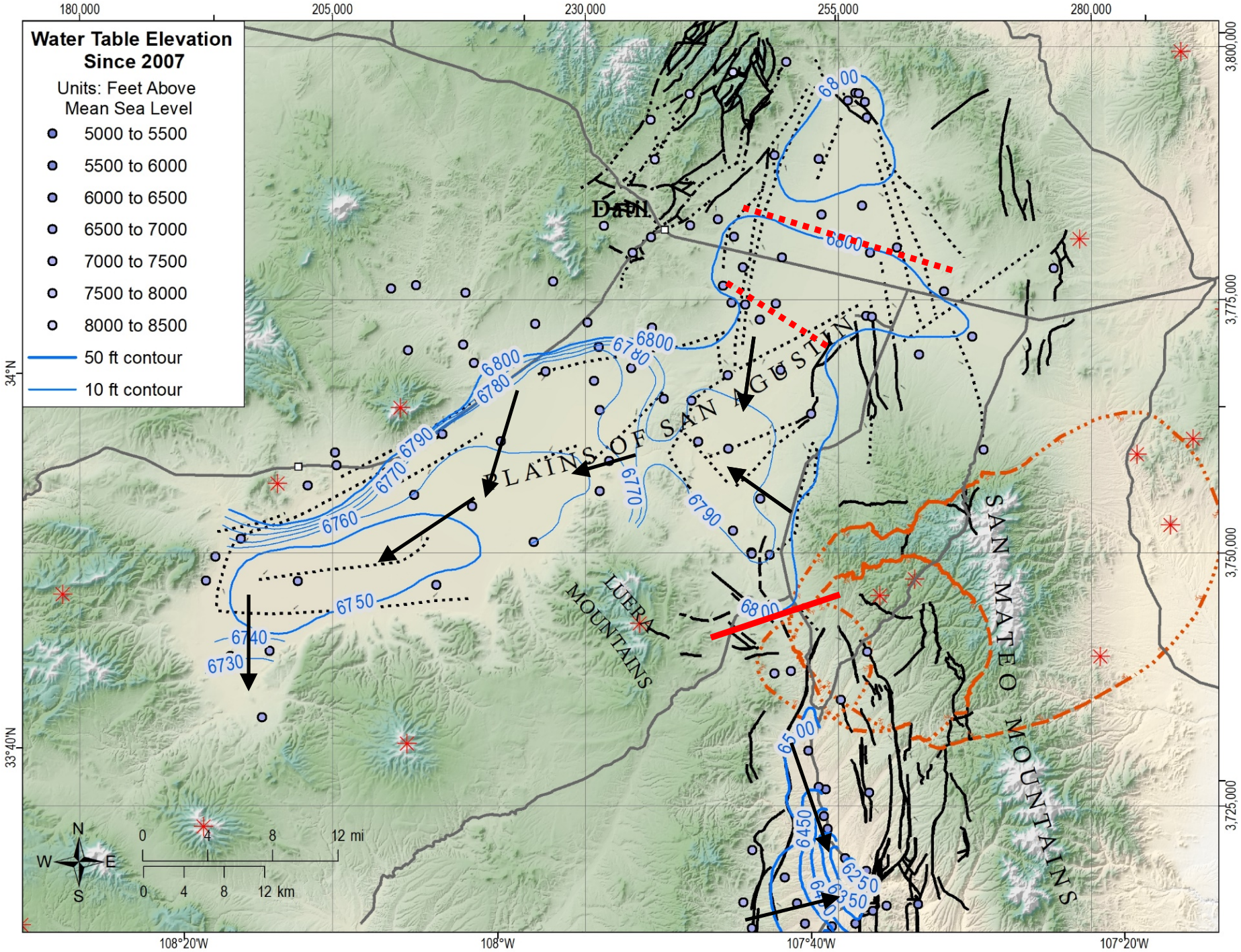
3,750,000
3,725,000
34°N
33°40'N
108°20'W
108°W
107°40'W
107°20'W
N
W
E
S
0 4 8 12 mi
0 4 8 12 km


Water Table Elevation Since 2007
Units: Feet Above Mean Sea Level
5000 to 5500
5500 to 6000
6000 to 6500
6500 to 7000
7000 to 7500
7500 to 8000
8000 to 8500
50 ft contour
10 ft contour
180,000
205,000
230,000
255,000
280,000
3,800,000
3,775,000
3,750,000
3,725,000
34°N
33°40'N
108°20'W
108°W
107°40'W
107°20'W
Dam
PLAINS OF SAN AGUSTIN
LUERA MOUNTAINS
SAN MATEO MOUNTAINS
6800
6780
6790
6770
6760
6750
6740
6730
6450
6250
6350
N
W
E
S
0
4
8
12 mi
0
4
8
12 km

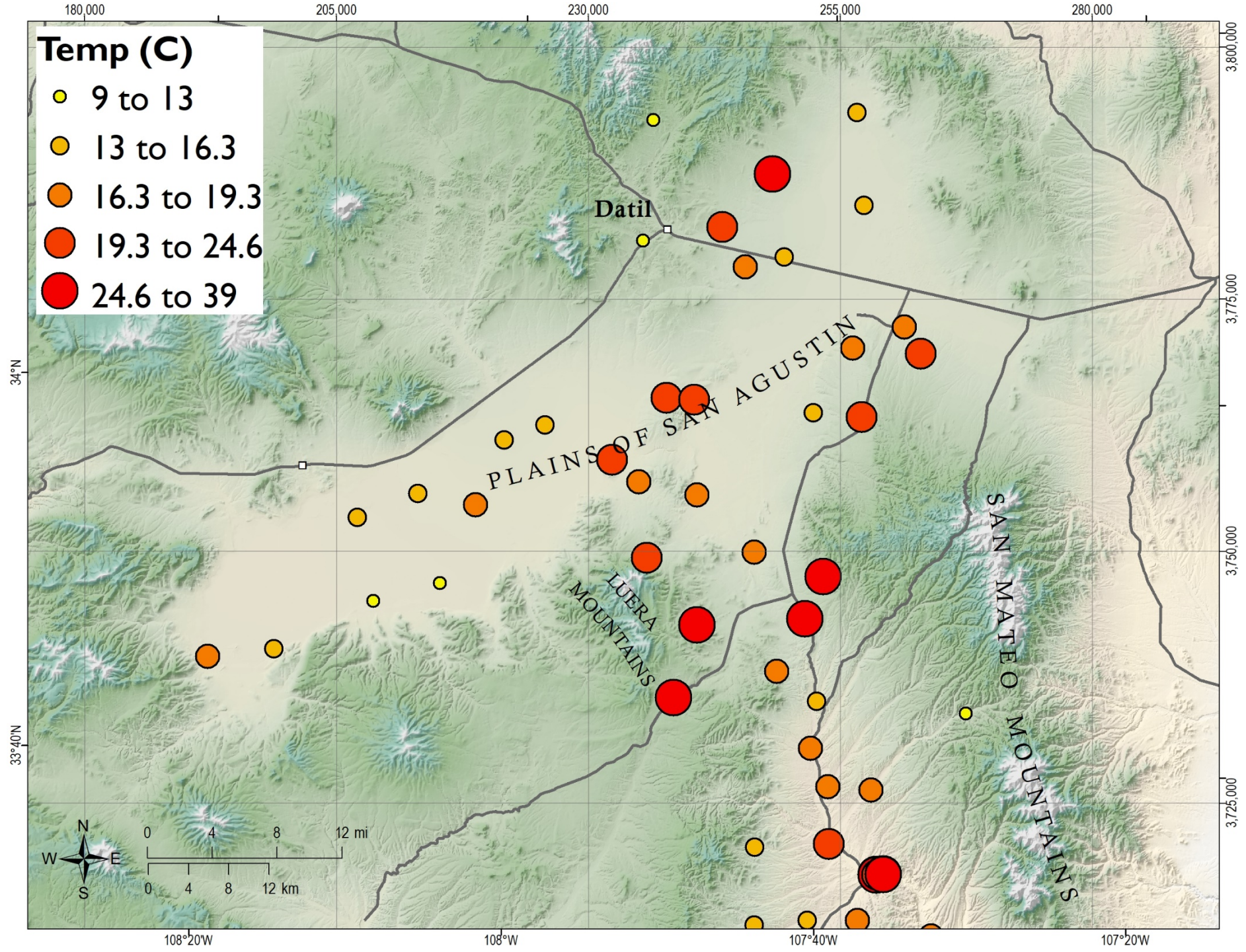
Water levels reflect the grabens, faulting + recharge/discharge.

Basin is at steady state.

Extensional structure + calderas + vents restrict flow out of San Agustin Plains
Mountain block flow is in fractured tuffs.

Stream valley recharge > mountain block recharge. Both significant volumes.

What will the chemistry data reveal?


Temp (C)
9 to 13
13 to 16.3
16.3 to 19.3
19.3 to 24.6
24.6 to 39
Datil
PLAINS OF SAN AGUSTIN
LUERA MOUNTAINS
SAN MATEO MOUNTAINS
180,000
205,000
230,000
255,000
280,000
3,800,000
3,775,000
3,750,000
3,725,000
34°N
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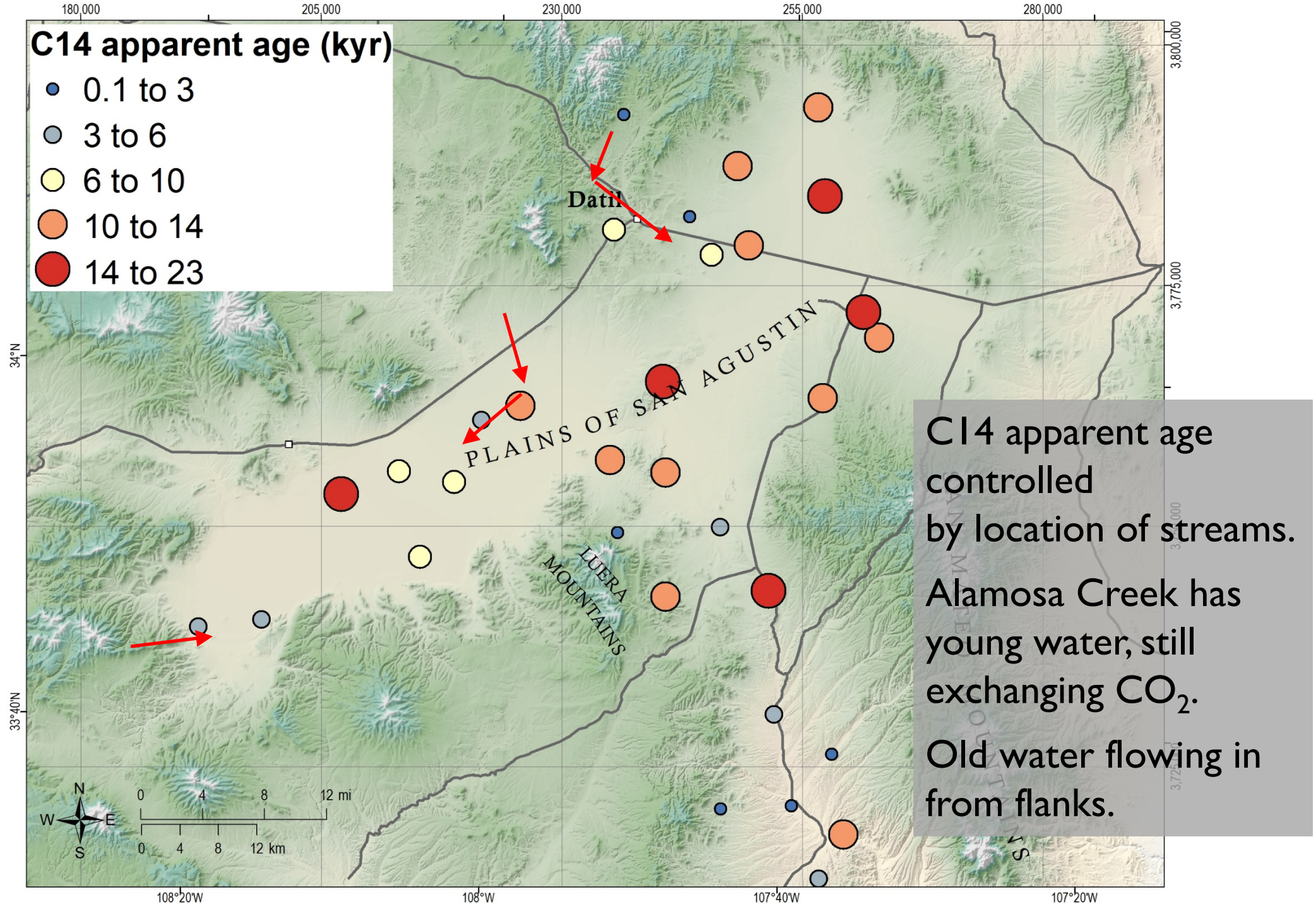
108°W
107°40'W
107°20'W
N
W
E
S
0 4 8 12 mi
0 4 8 12 km

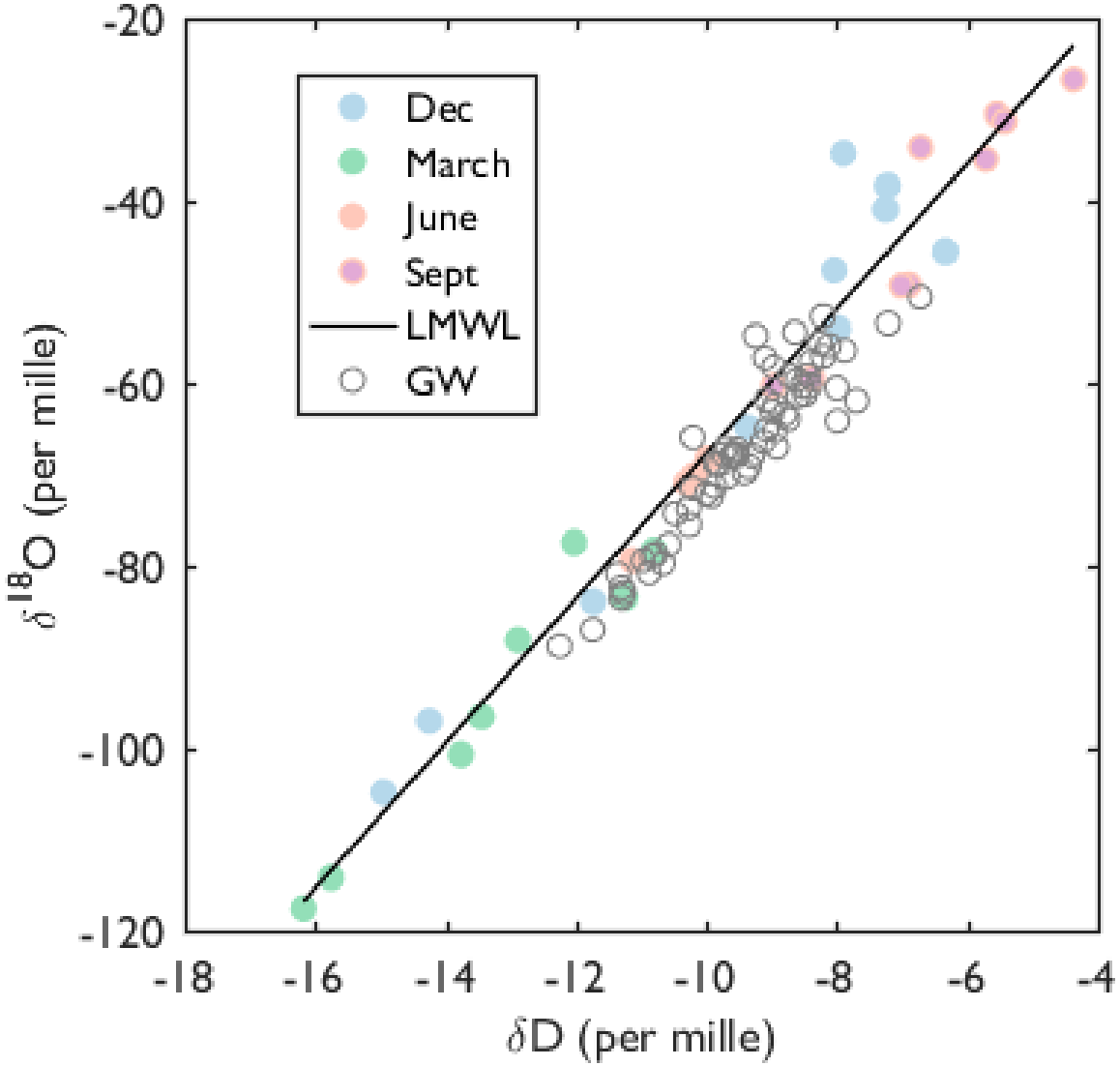


C14 apparent age controlled by location of streams.

Alamosa Creek has young water, still exchanging CO_2.

Old water flowing in from flanks.

All groundwater isotopes are near local meteoric water line, but do not extend toward 'Ice Age' values found in San Juan Basin, northern Rio Grande ($\delta D < -90$ per mille SMOW).



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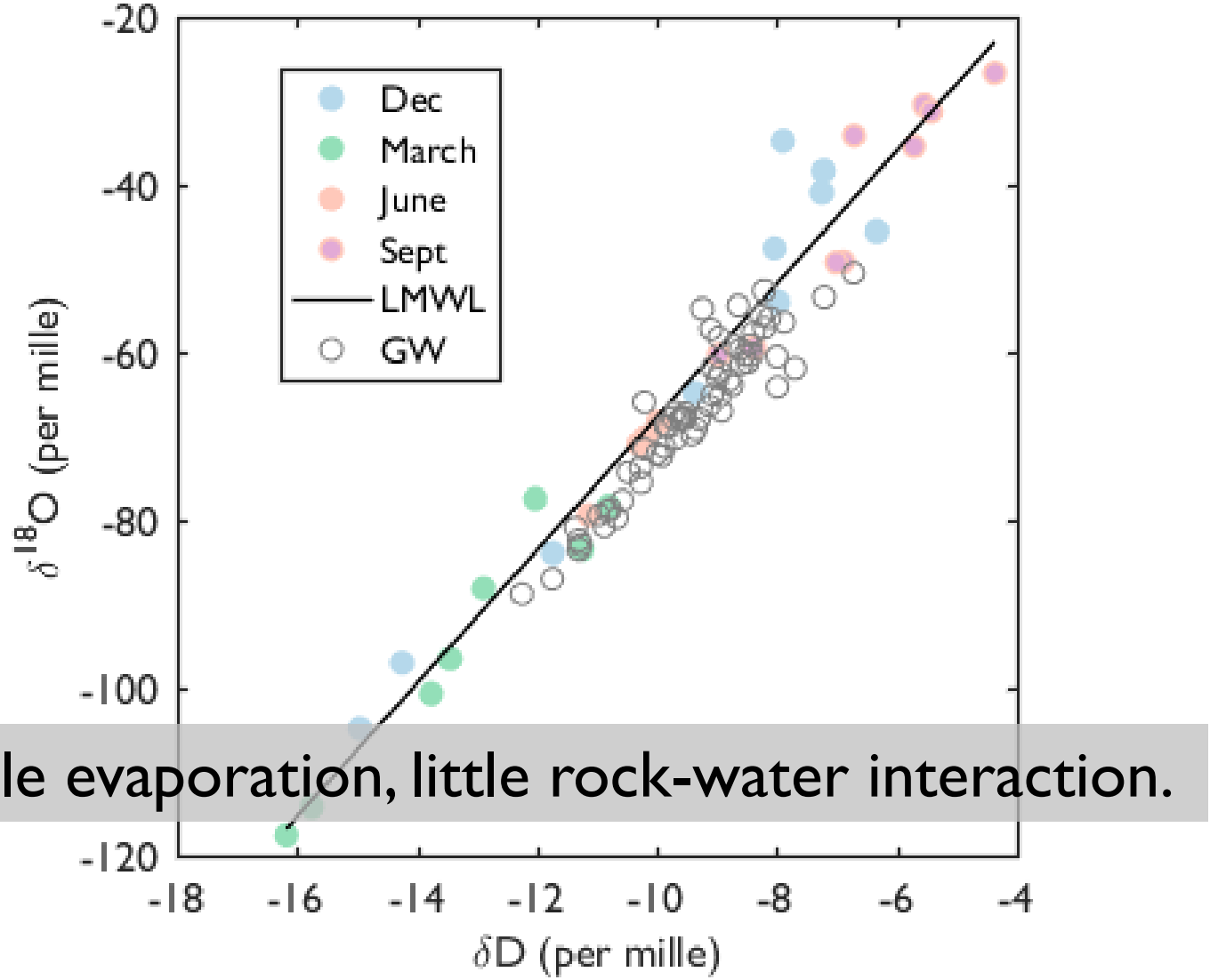
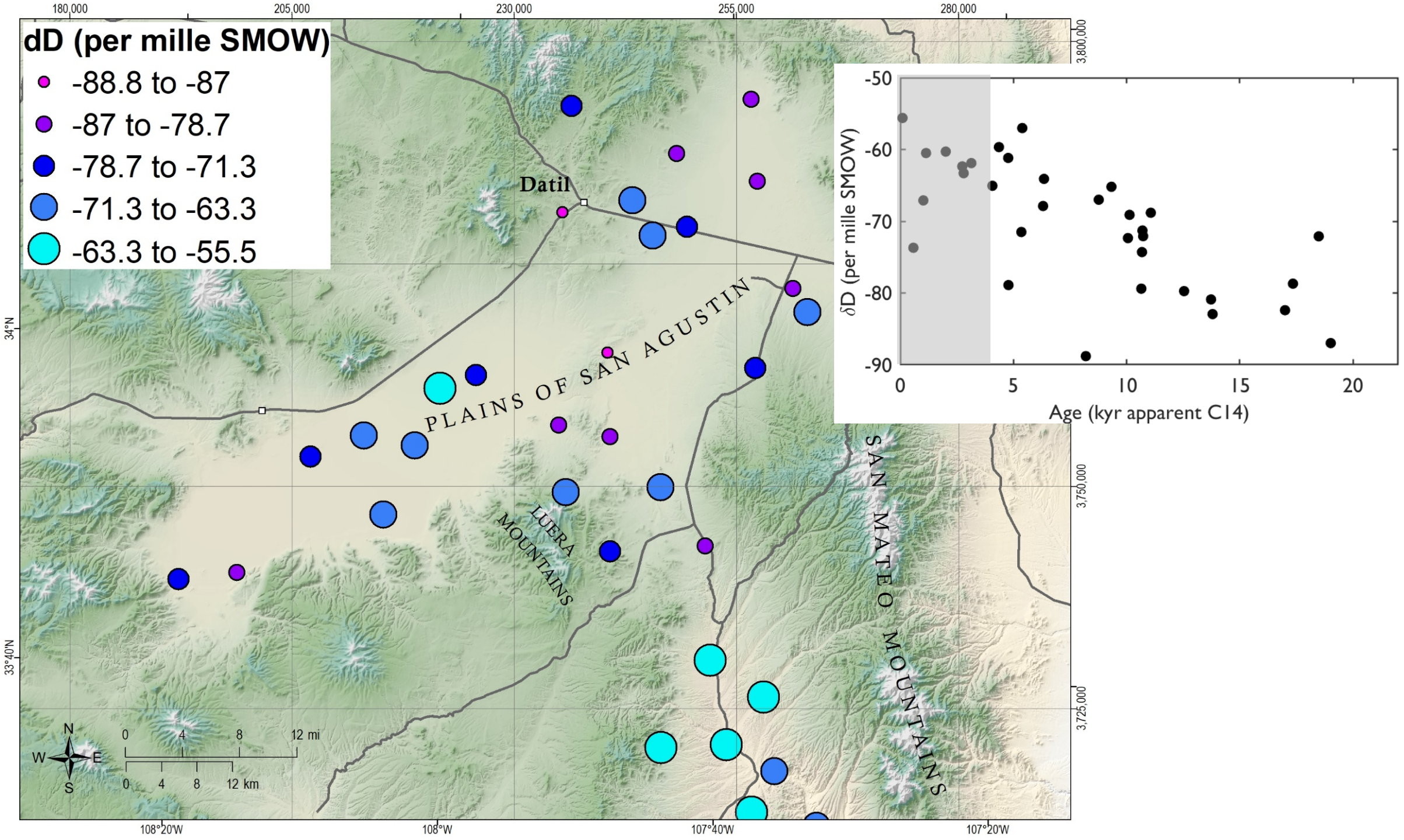


Little evaporation, little rock-water interaction.


dD (per mille SMOW)
-88.8 to -87
-87 to -78.7
-78.7 to -71.3
-71.3 to -63.3
-63.3 to -55.5
Datil
PLAINS OF SAN AGUSTIN
LUERA MOUNTAINS
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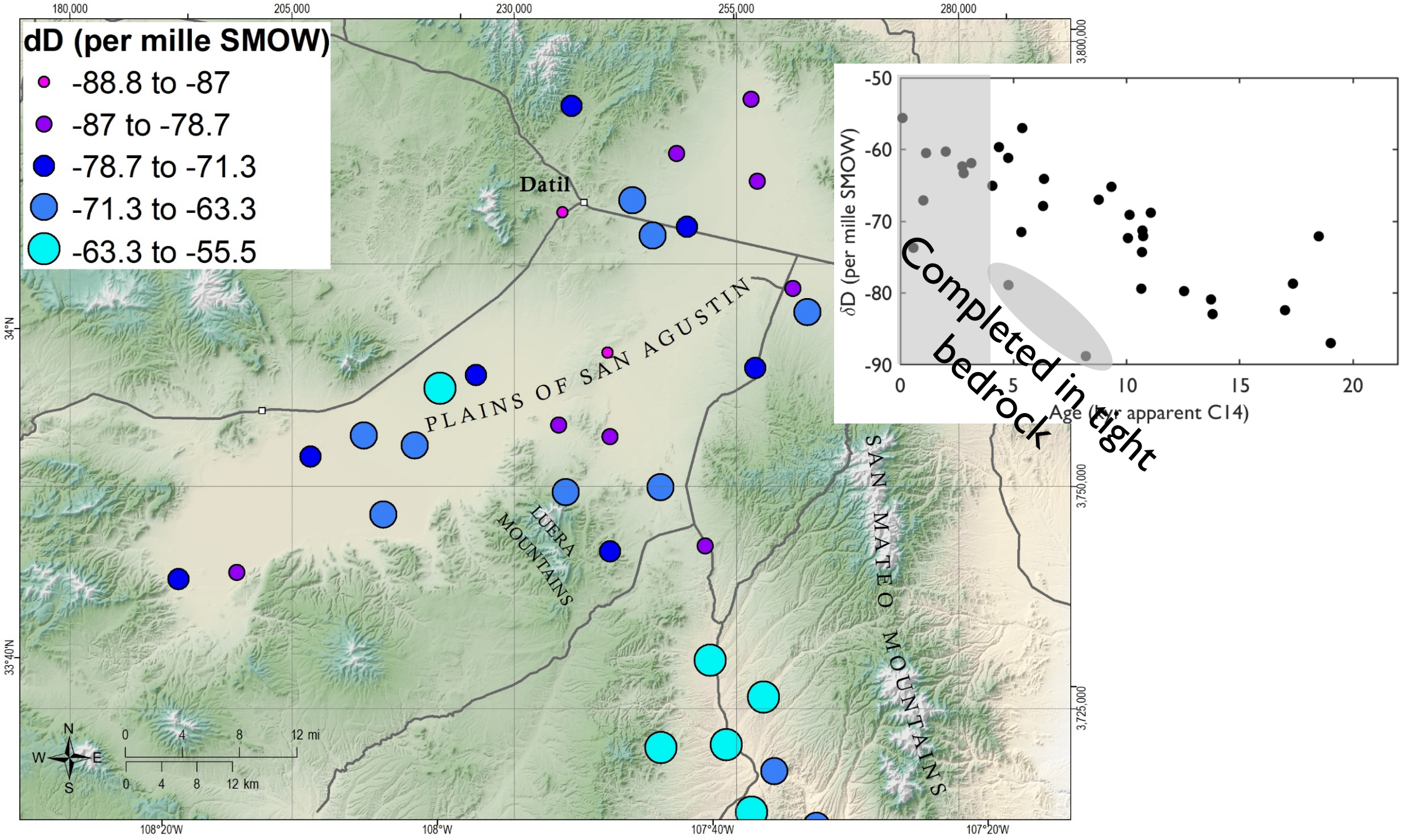
3,725,000
34°N
33°40'N
108°20'W
108°W
107°40'W
107°20'W
N
W
E
S
0 4 8 12 mi
0 4 8 12 km
δD (per mille SMOW)
-50
-60
-70
-80
-90
0
5
10
15
20
Age (kyr apparent C14)


dD (per mille SMOW)
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-87 to -78.7
-78.7 to -71.3
-71.3 to -63.3
-63.3 to -55.5
Datil
PLAINS OF SAN AGUSTIN
LUERA MOUNTAINS
SAN MATEO MOUNTAINS
180,000
205,000
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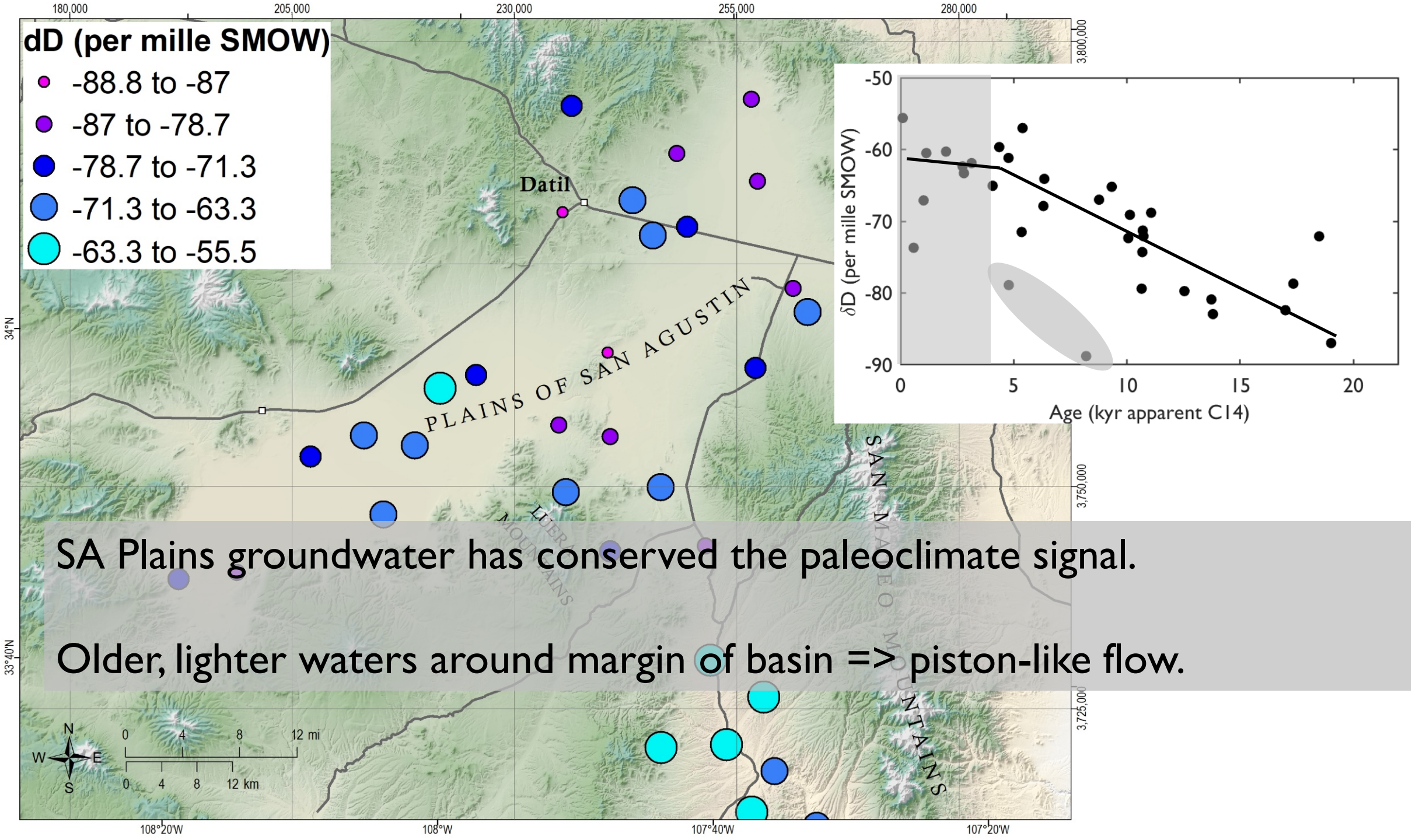
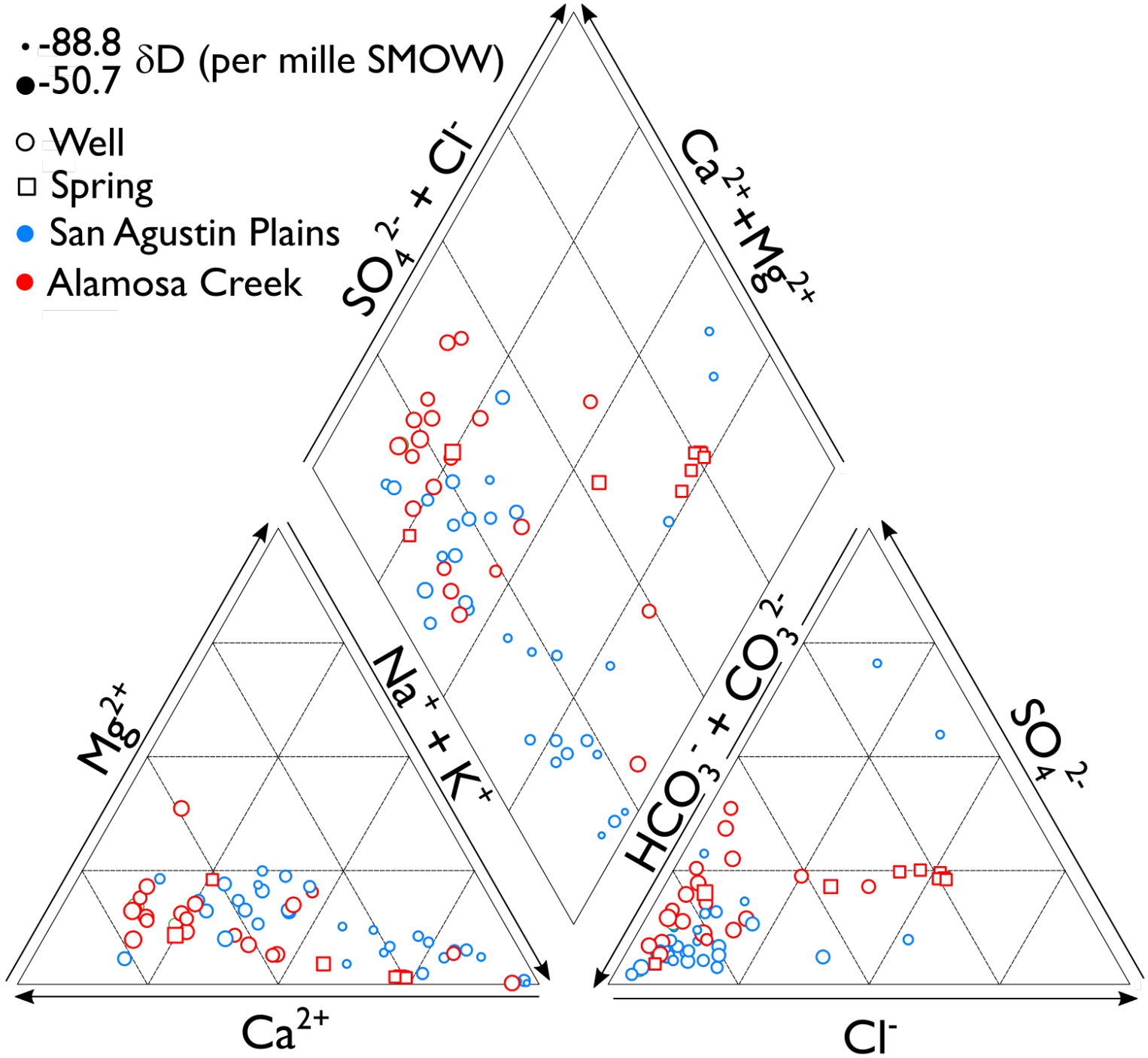
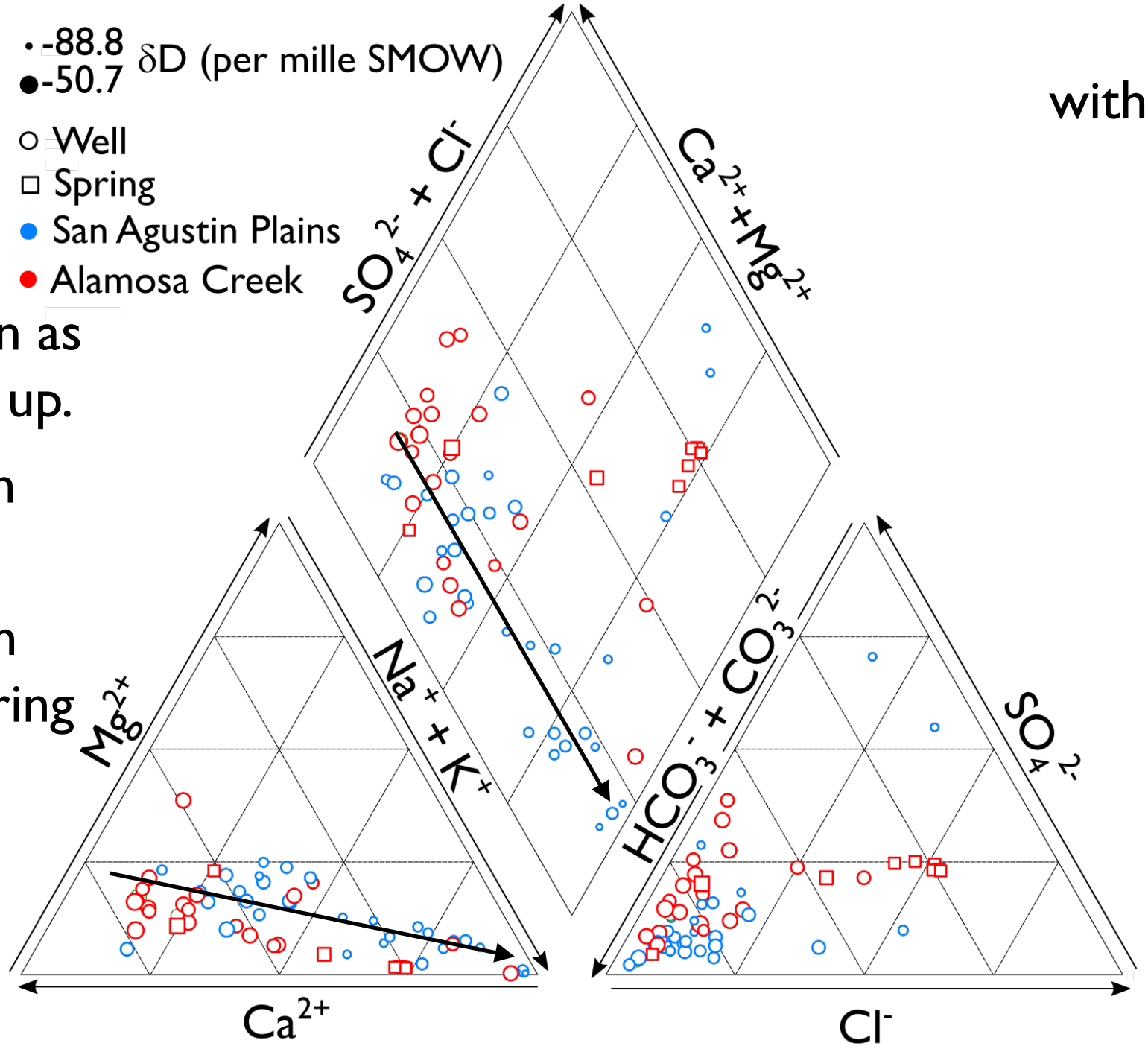
34°N
33°40'N
108°20'W
108°W
107°40'W
107°20'W
N
W
E
S
0 4 8 12 mi
0 4 8 12 km
δD (per mille SMOW)
-50
-60
-70
-80
-90
0
5
10
15
20
Age (kyr apparent C14)
Completed in tight bedrock



SA Plains groundwater has conserved the paleoclimate signal.

Older, lighter waters around margin of basin => piston-like flow.


-88.8
-50.7
δD (per mille SMOW)
Well
Spring
San Agustin Plains
Alamosa Creek
SO4 2- + Cl-
Ca2+ +Mg2+
Mg2+
Na+ + K+
HCO3 - + CO3 2-
SO4 2-
Ca2+
Cl-



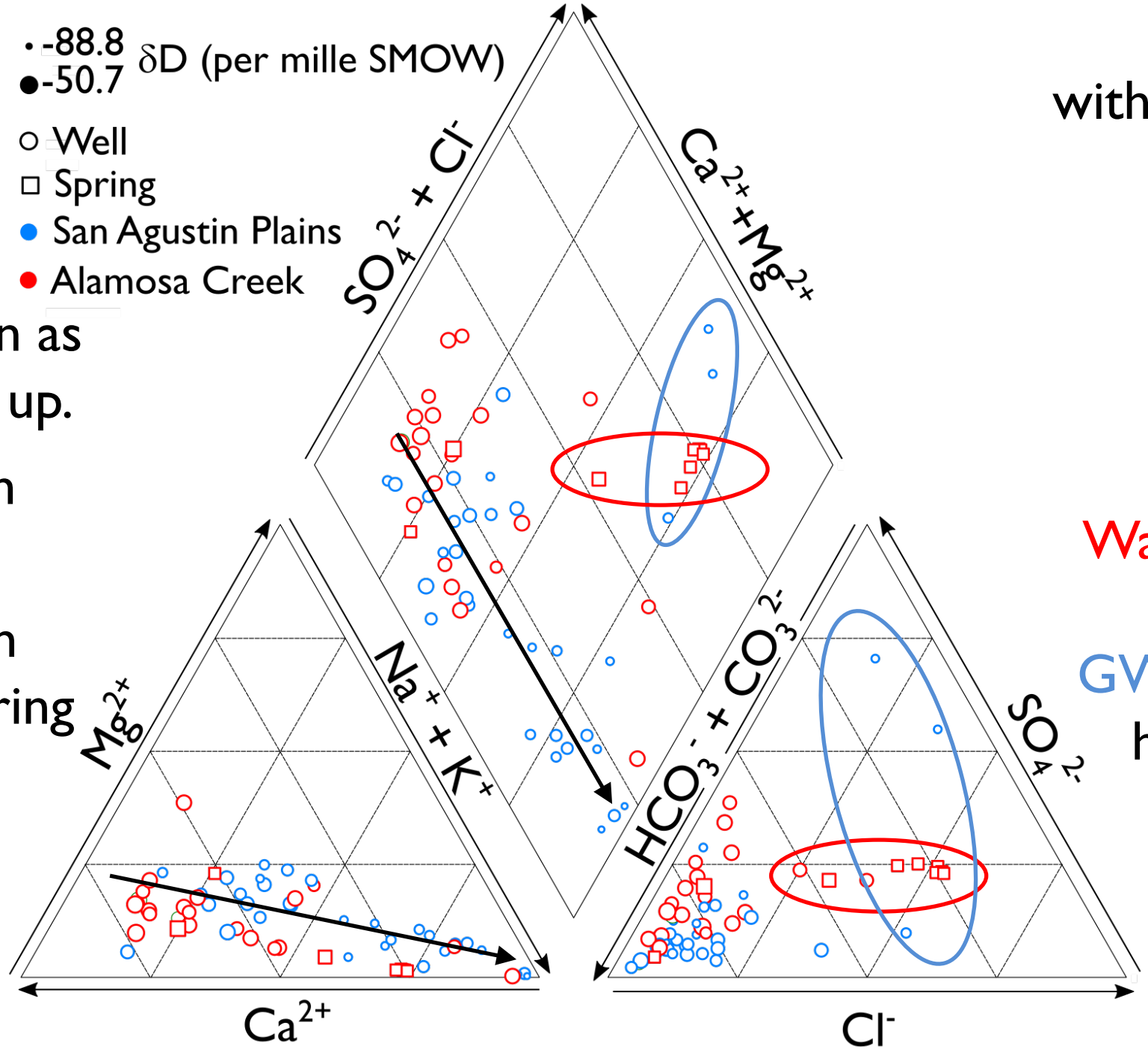
Ca^{2+} goes down as $(Na^+ + K^+)$ goes up.

Lighter δD with lower Ca_{2+}

Consistent with silicate weathering sequence.

Supersaturated with kaolinite, silica, clay minerals.

Strongly undersaturated with feldspars, carbonates.



Ca^{2+} goes down as $(Na^{+}+K^{+})$ goes up.

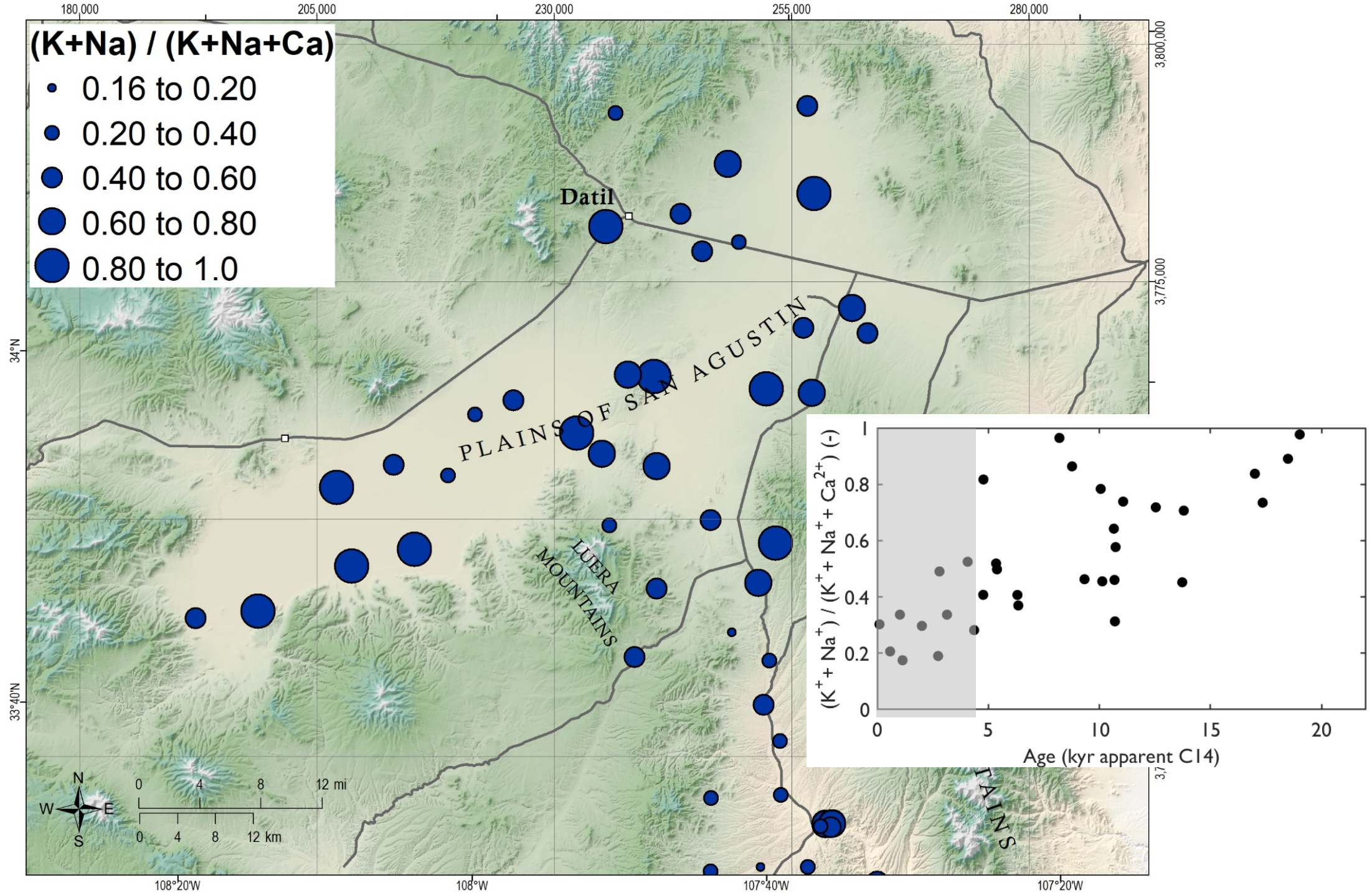
Lighter δD with lower Ca_{2+}

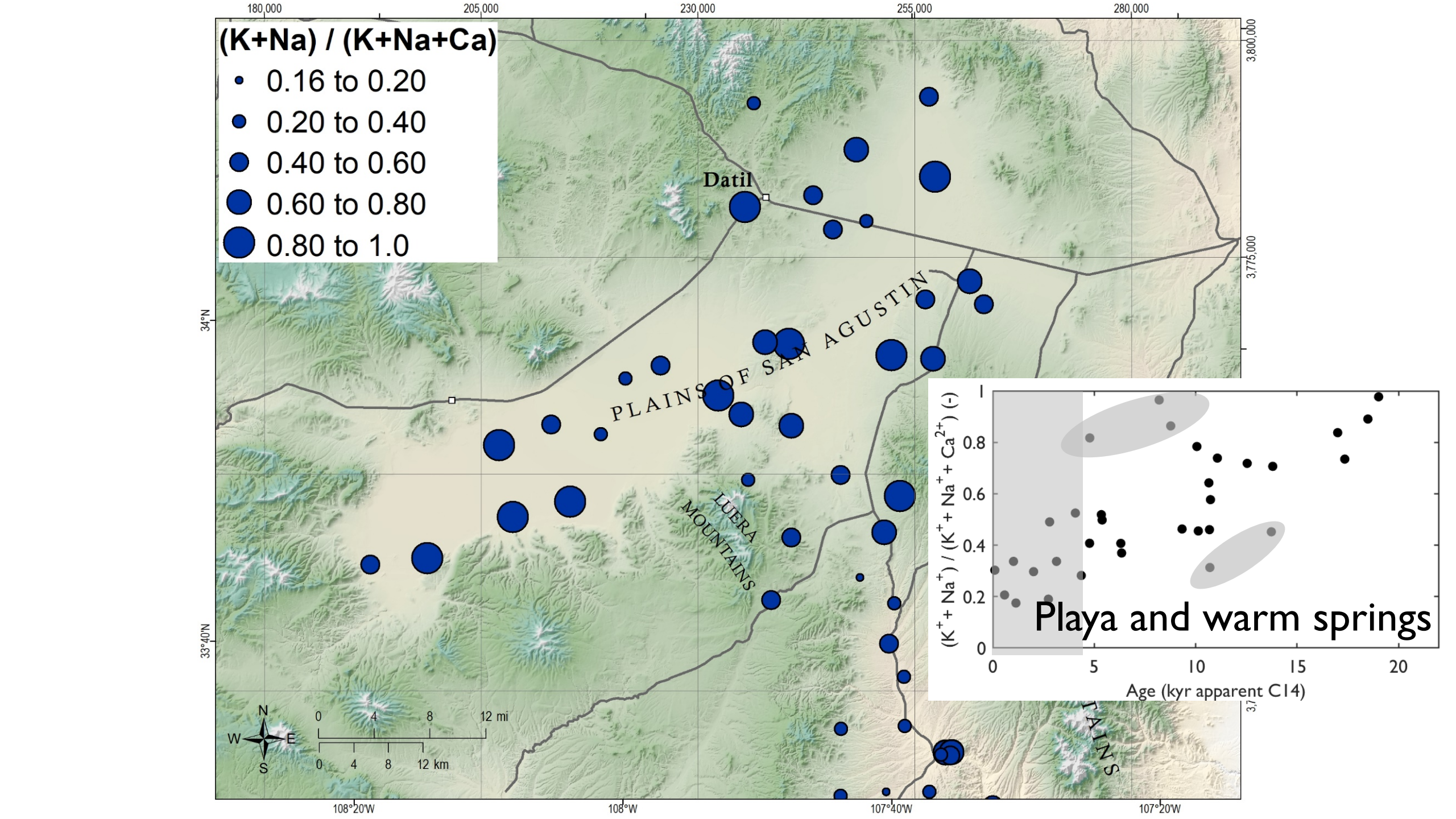
Consistent with silicate weathering sequence.

Supersaturated with kaolinite, silica, clay minerals.

Strongly undersaturated with feldspars, carbonates.

Warm springs and oldest well and GW in playas have higher Cl^{-}, SO_4^{2-}


(K+Na) / (K+Na+Ca)
0.16 to 0.20
0.20 to 0.40
0.40 to 0.60
0.60 to 0.80
0.80 to 1.0
Datil
PLAINS OF SAN AGUSTIN
LUERA MOUNTAINS
180,000
205,000
230,000
255,000
280,000
3,800,000
3,775,000
34°N
33°40'N
108°20'W
108°W
107°40'W
107°20'W
N
W
E
S
0 4 8 12 mi
0 4 8 12 km
(K+ + Na+) / (K+ + Na+ + Ca2+) (-)
Age (kyr apparent C14)
0
0.2
0.4
0.6
0.8
1
0
5
10
15
20


(K+Na) / (K+Na+Ca)
0.16 to 0.20
0.20 to 0.40
0.40 to 0.60
0.60 to 0.80
0.80 to 1.0
Datil
PLAINS OF SAN AGUSTIN
LUERA MOUNTAINS
180,000
205,000
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280,000
3,800,000
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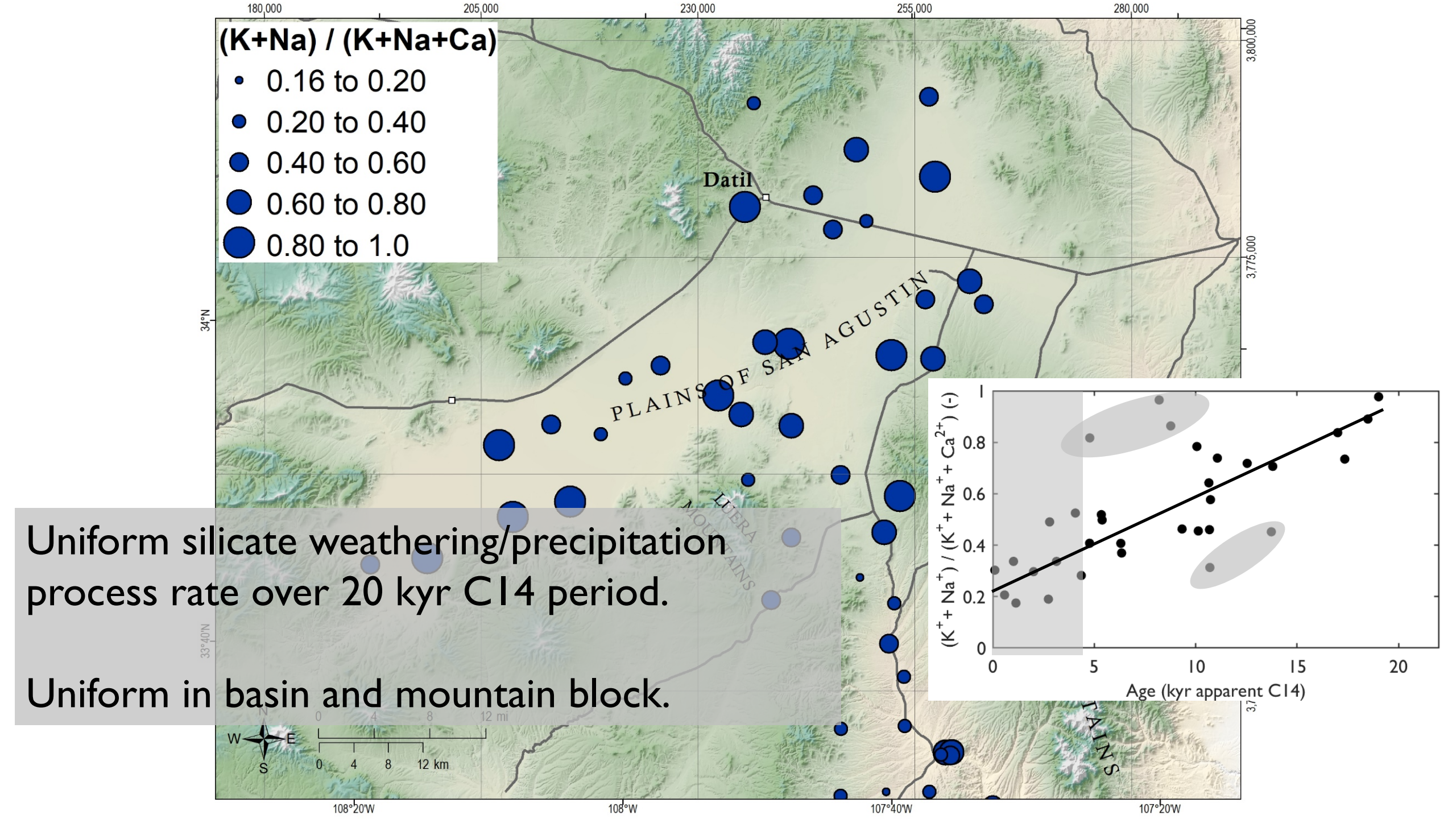
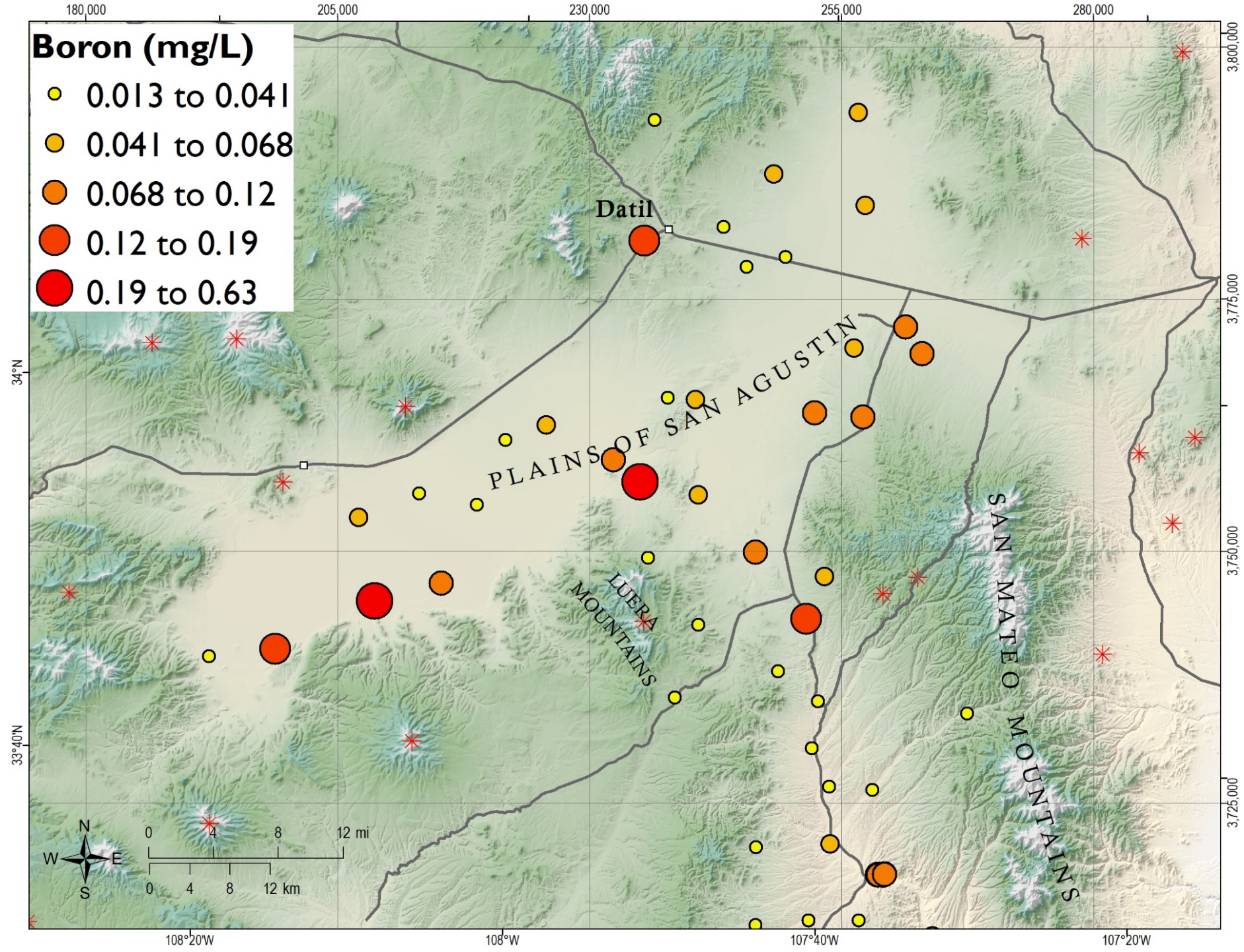
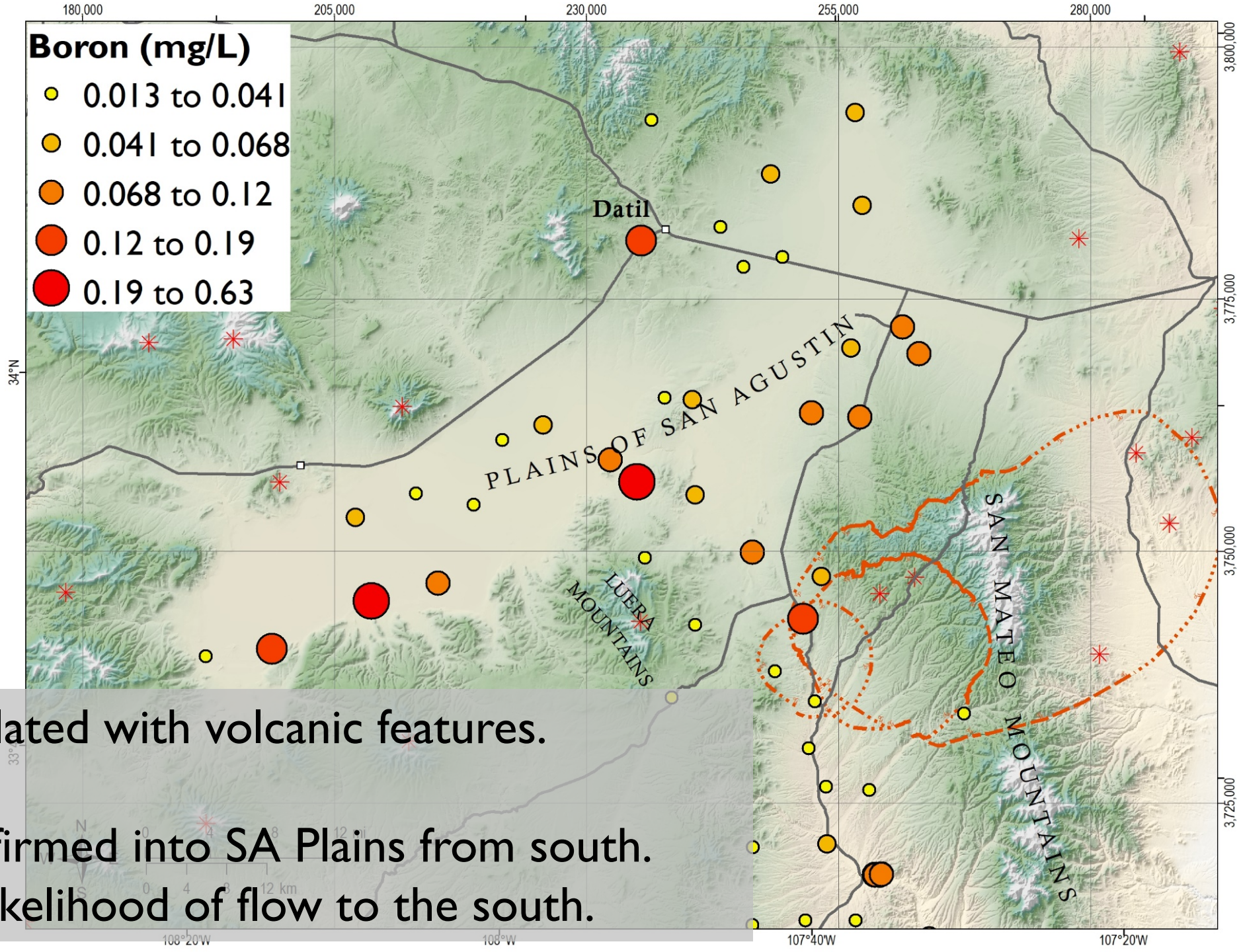
108°20'W
108°W
107°40'W
107°20'W
N
W
E
S
0 4 8 12 mi
0 4 8 12 km
(K+ + Na+) / (K+ + Na+ + Ca2+) (-)
Age (kyr apparent C14)
Playa and warm springs



Uniform silicate weathering/precipitation process rate over 20 kyr C14 period.

Uniform in basin and mountain block.


Boron (mg/L)
0.013 to 0.041
0.041 to 0.068
0.068 to 0.12
0.12 to 0.19
0.19 to 0.63
Datil
PLAINS OF SAN AGUSTIN
LUERA MOUNTAINS
SAN MATEO MOUNTAINS
180,000
205,000
230,000
255,000
280,000
3,800,000
3,775,000
3,750,000
3,725,000
34°N
33°40'N
108°20'W
108°W
107°40'W
107°20'W
N
W
E
S
0
4
8
12 mi
0
4
8
12 km



F, B correlated with volcanic features.

Flow confirmed into SA Plains from south.
Restrict likelihood of flow to the south.

Water levels reflect the grabens, faulting + recharge/discharge.

Basin is at steady state.

Extensional structure + calderas + vents restrict flow out of San Agustin Plains to the south in general.

Mountain block flow is in fractured tuffs.

Stream valley recharge > mountain block recharge. Both significant volumes.

Flow in basin, mountain block occur with little mixing.

Relatively uniform rates of silicate weathering/precipitation over 20 ky C14, everywhere in the basin.

Heightened (but low) F, B concentrations correlate with volcanic features.

Water levels reflect the grabens, faulting + recharge/discharge.

First comprehensive examination of San Agustin Plains and drainage to the south.

Extensional structure + calderas + vents restrict flow out of San Agustin Plains to the south

One of the first (maybe the first) comprehensive look at aqueous chemistry in Mogollon-Datil Volcanic Field.

Stream valley recharge > mountain block recharge. Both significant volumes.

Chemical, physical process interpretation likely transferable into the rest of MDVF.

Relatively uniform rates of silicate weathering/precipitation over 20 ky C14, everywhere in the basin.

Mountain block flow controlled by cooling fractures, faults and volcanic features.

Heightened (but low) F, B concentrations correlate with volcanic features.