Integration of Carbon-14 and Oxygen-18 as a Basis for Differentiating between Pleistocene and Post-Pleistocene Ground-Water Ages along Flow Paths in Two West Texas Bolson Aquifers

Bruce K. Darling
Hydrogeologist/Geochemist
Bastrop, TX

Barry J. Hibbs
Department of Geosciences
California State University – Los Angeles

John M. Sharp, Jr.
Jackson School of Geosciences
The University of Texas at Austin

A Modest Addition to Today's Topic

Regional Hydrogeology
and
Interbasin Flow of Groundwater

Closely Related
to Estimation of Groundwater Age

Basin and Range Physiographic Province

Basin and Range Physiographic Province of North America and location of Trans-Pecos Subprovince. Source: Bedient and others (1985).

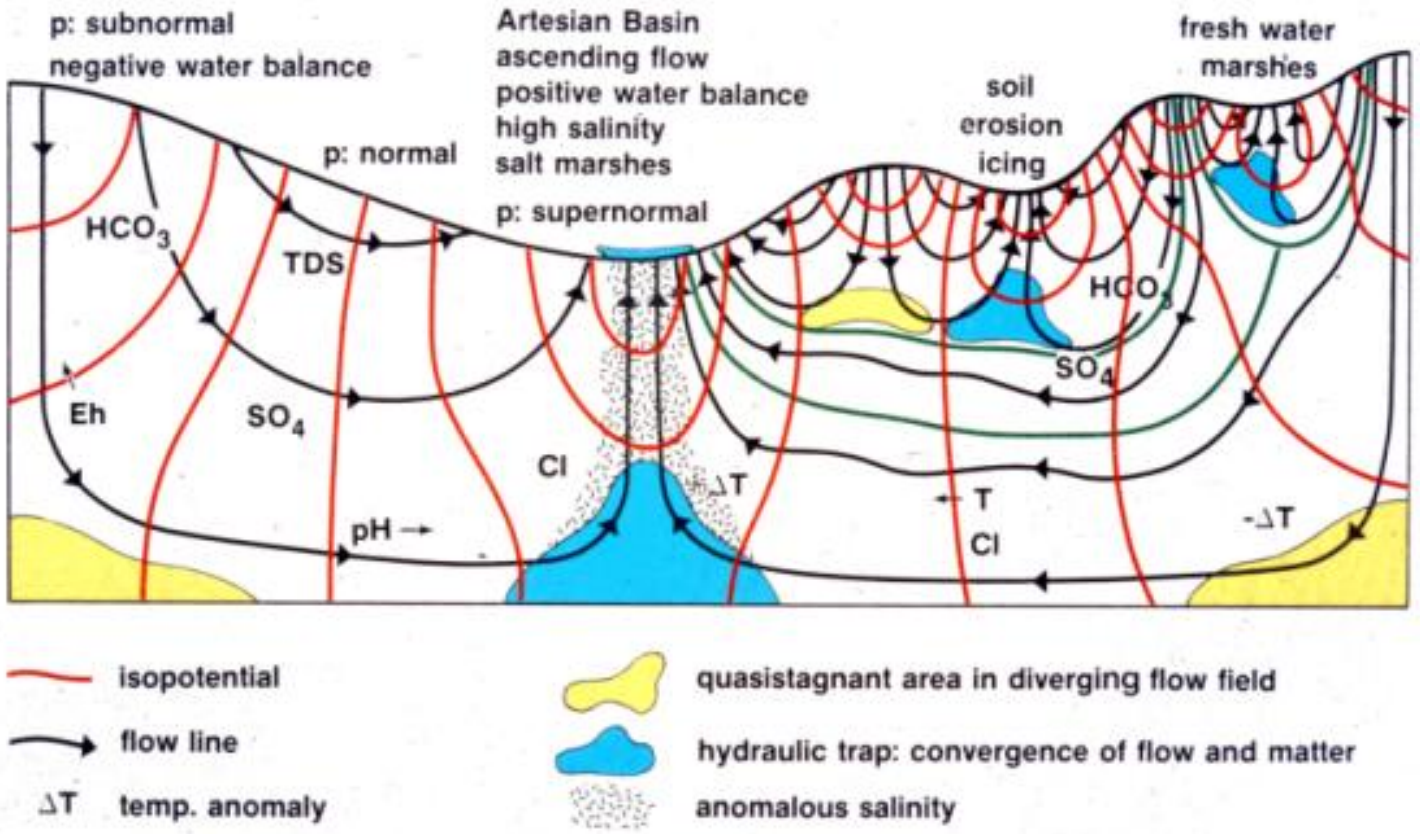
Interbasin Movement of Ground Water at the Nevada Test Site

Isaac J Winograd

US Geological Survey

TEI-807

1962



Hydrological effects of the regional gravity flow of groundwater (Toth, 1980)

Tothian Flow Model

Areas of the Basin and Range have been studied for ~70 yrs for disposal of radioactive waste

The Nevada Test Site has been the location of above-ground and below-ground tests of nuclear weapons

So there is concern regarding the potential for contamination and regional flow of ground water

739 above-ground weapons tests in Yucca Flat and Frenchman Flat

828 below-ground weapons tests

High-level radioactive waste disposal at Yucca Mountain, Nevada (suspended)

Nevada National Security Site: Low-Level and Mixed Low-Level Rad Waste

Waste Isolation Pilot Plant (Carlsbad, NM)

Hudspeth County, TX (Fort Hancock and Sierra Blanca

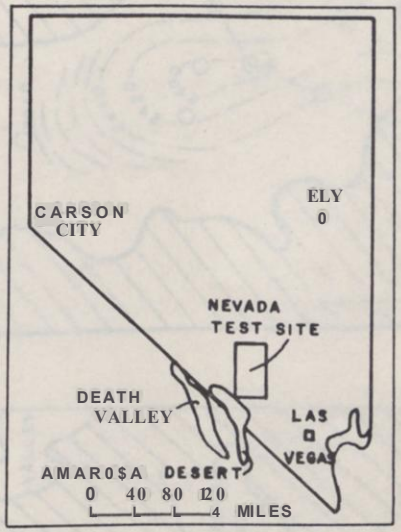


Figure 1.--Index map showing Nevada Test Site, Death Valley, and Amargosa Desert.

GW depth is 700 to 1700 ft inYucca Flat and Frenchman Flat

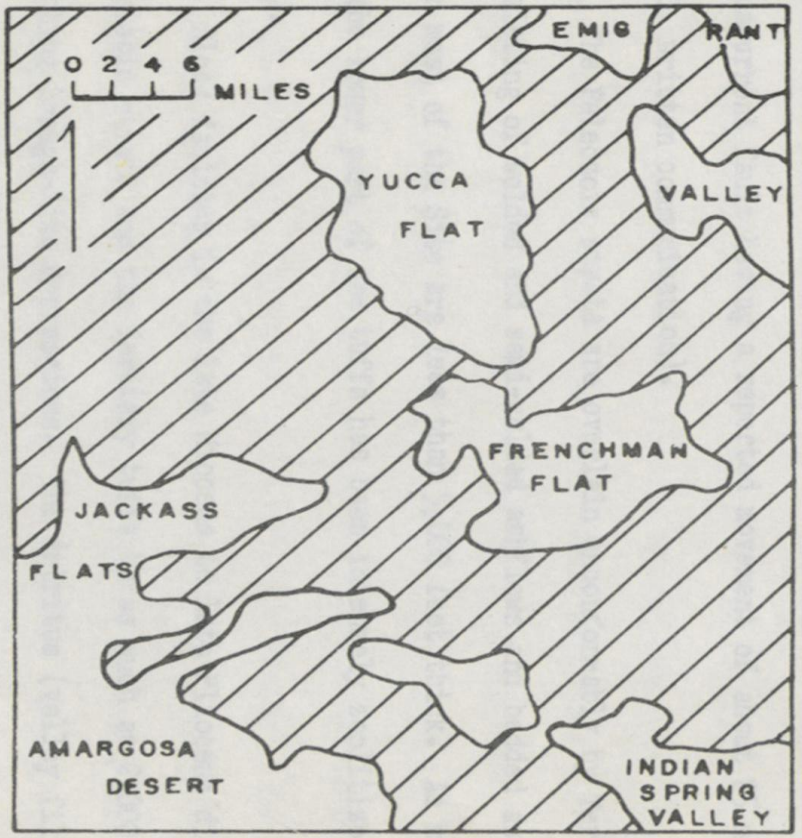


Figure 2.--Major intermontane basins at Nevada Test Site.

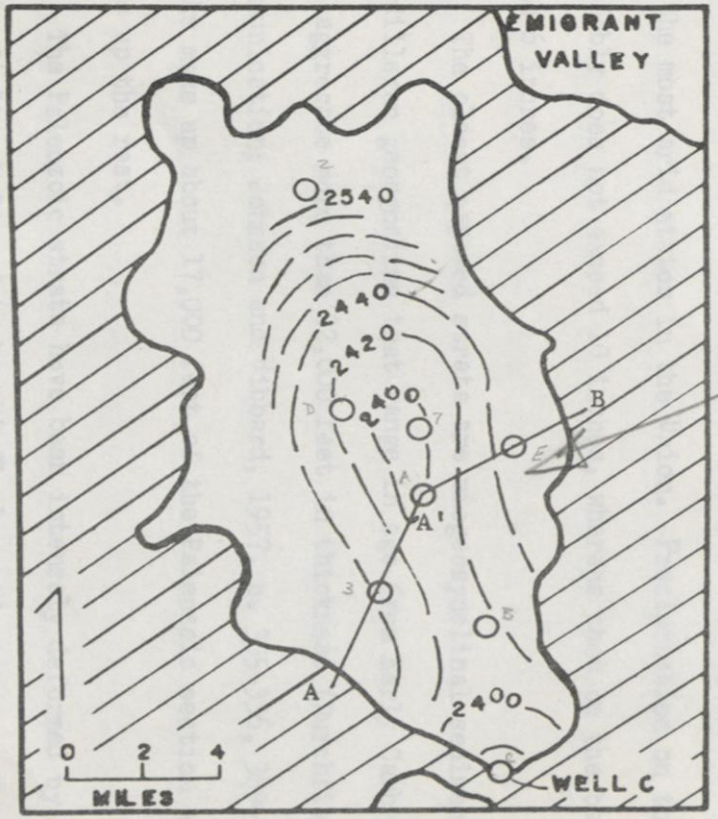


Figure 3.--Configuration of potentiometric surface, Yucca Flat, Nevada Test Site. A-A'-B, line of cross section, figure 4.

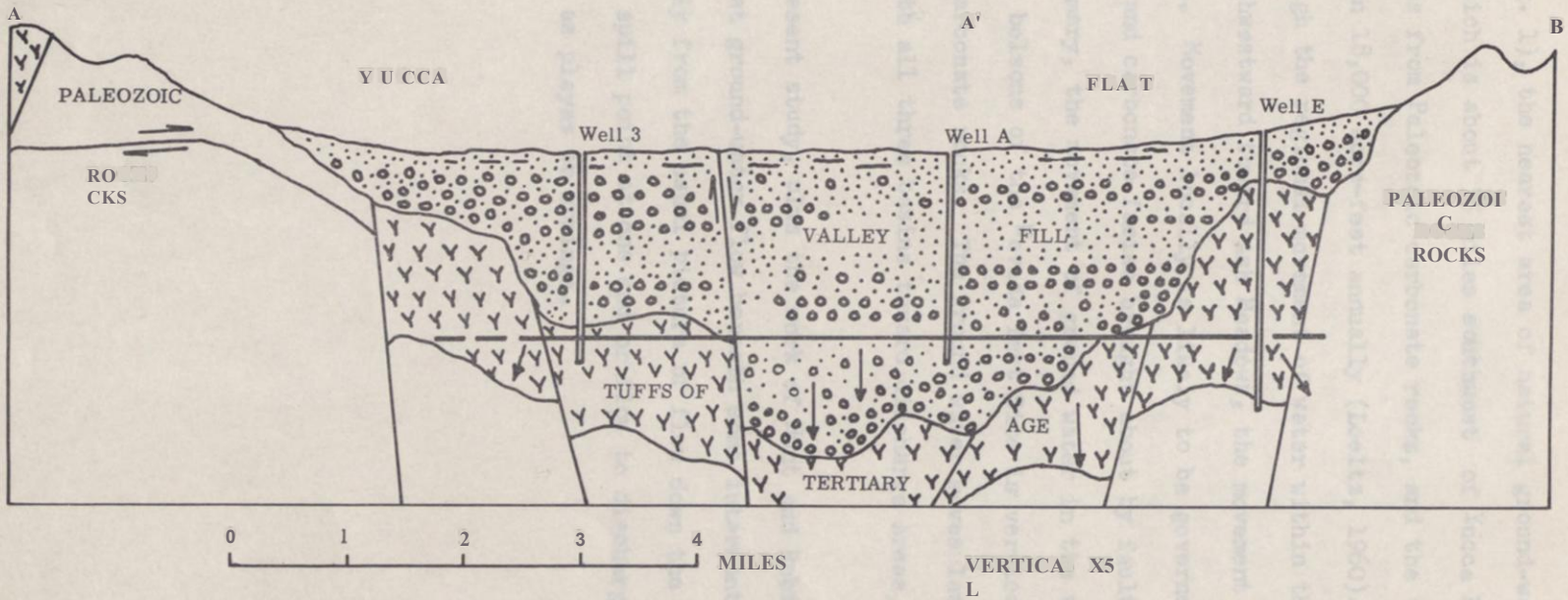
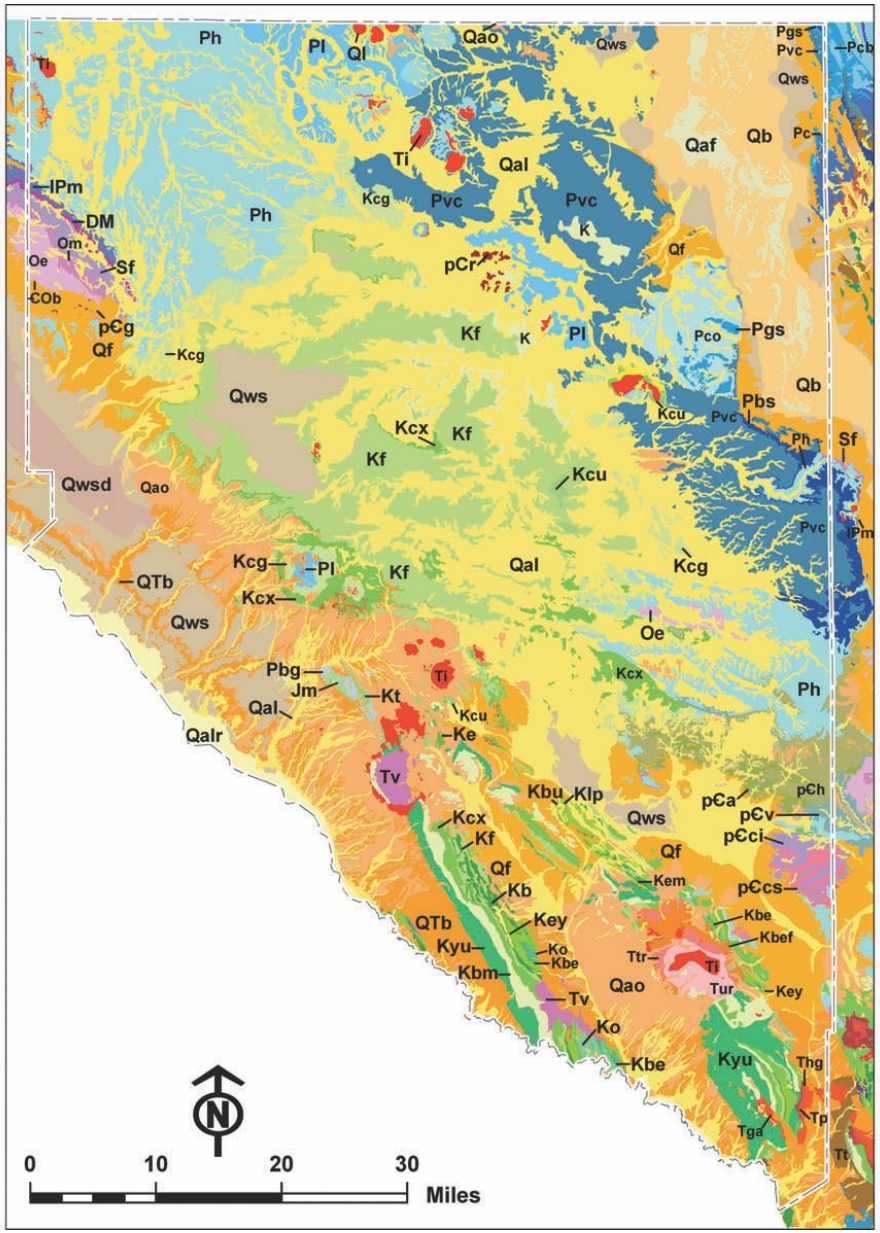


Figure 4. Diagrammatic geologic section across southern Yucca Flat. Line of section shown on figure 3.

Trans-Pecos Sub-Province of Basin and Range Province

Source: Bedinger, et al., 1985

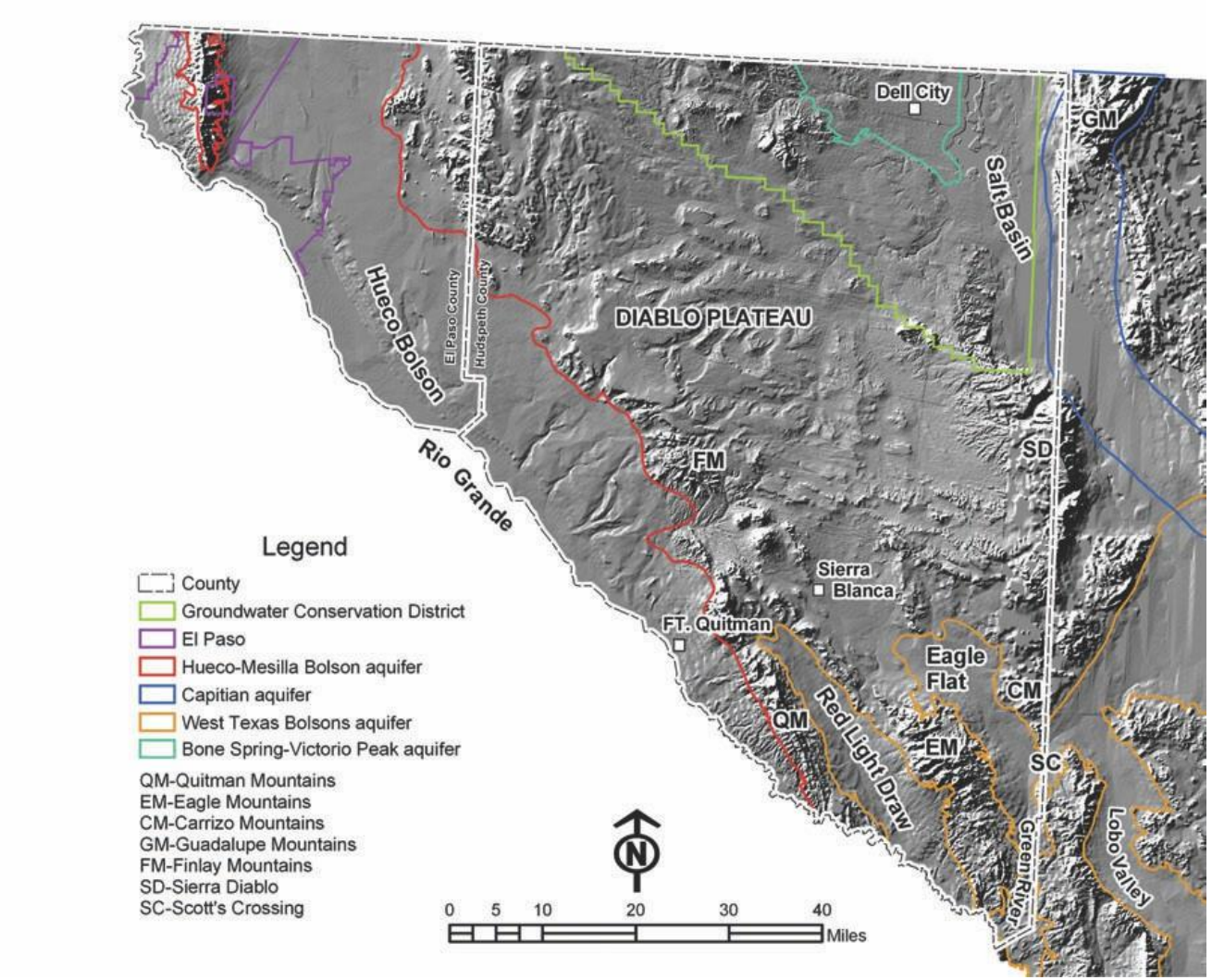
Area: 4,572 mi^2
(11,851 km^2)



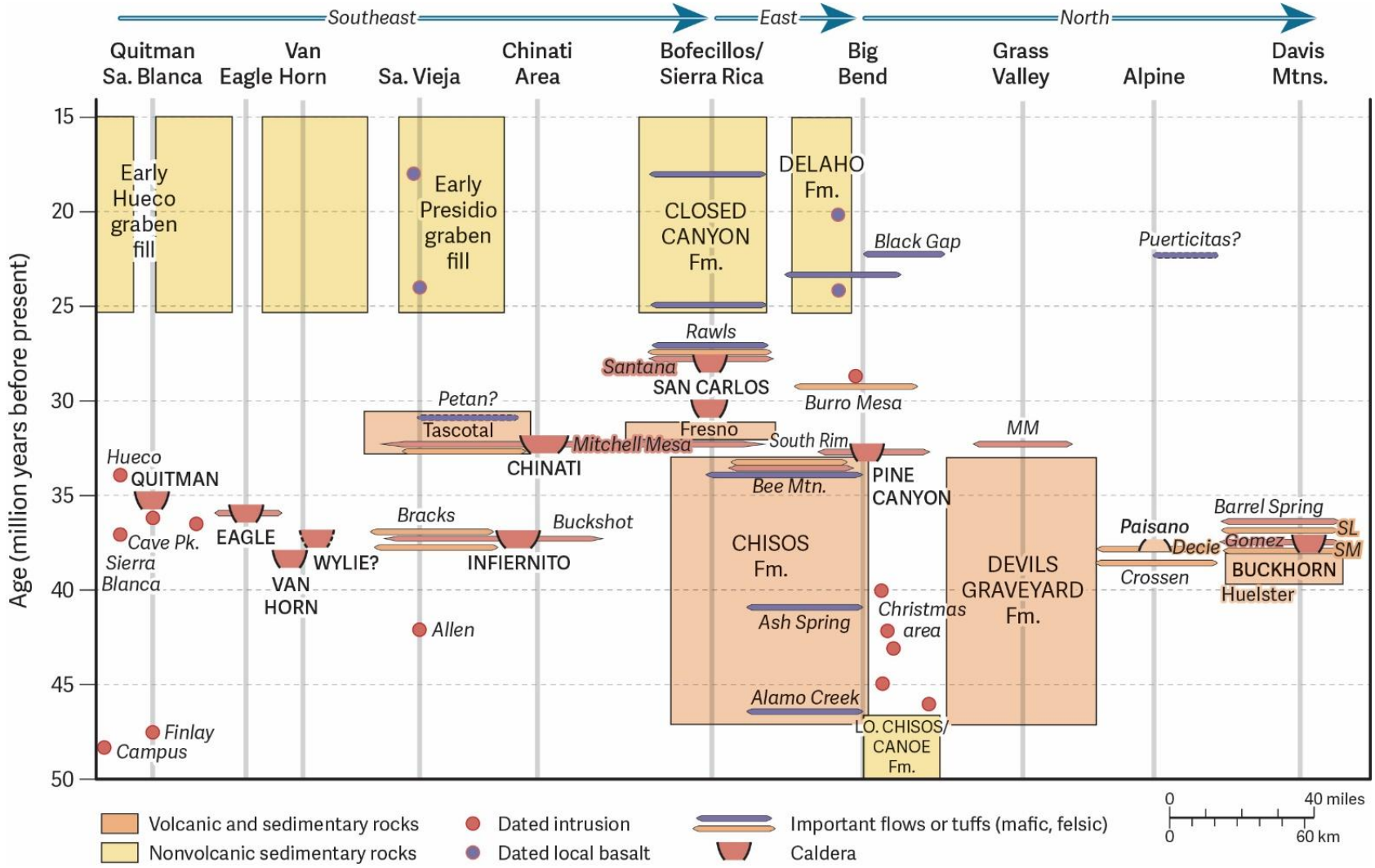
Hudspeth County – Geological Atlas of Texas
(Van Horn – El Paso Sheet)

Tectonic Development and Structural Geology

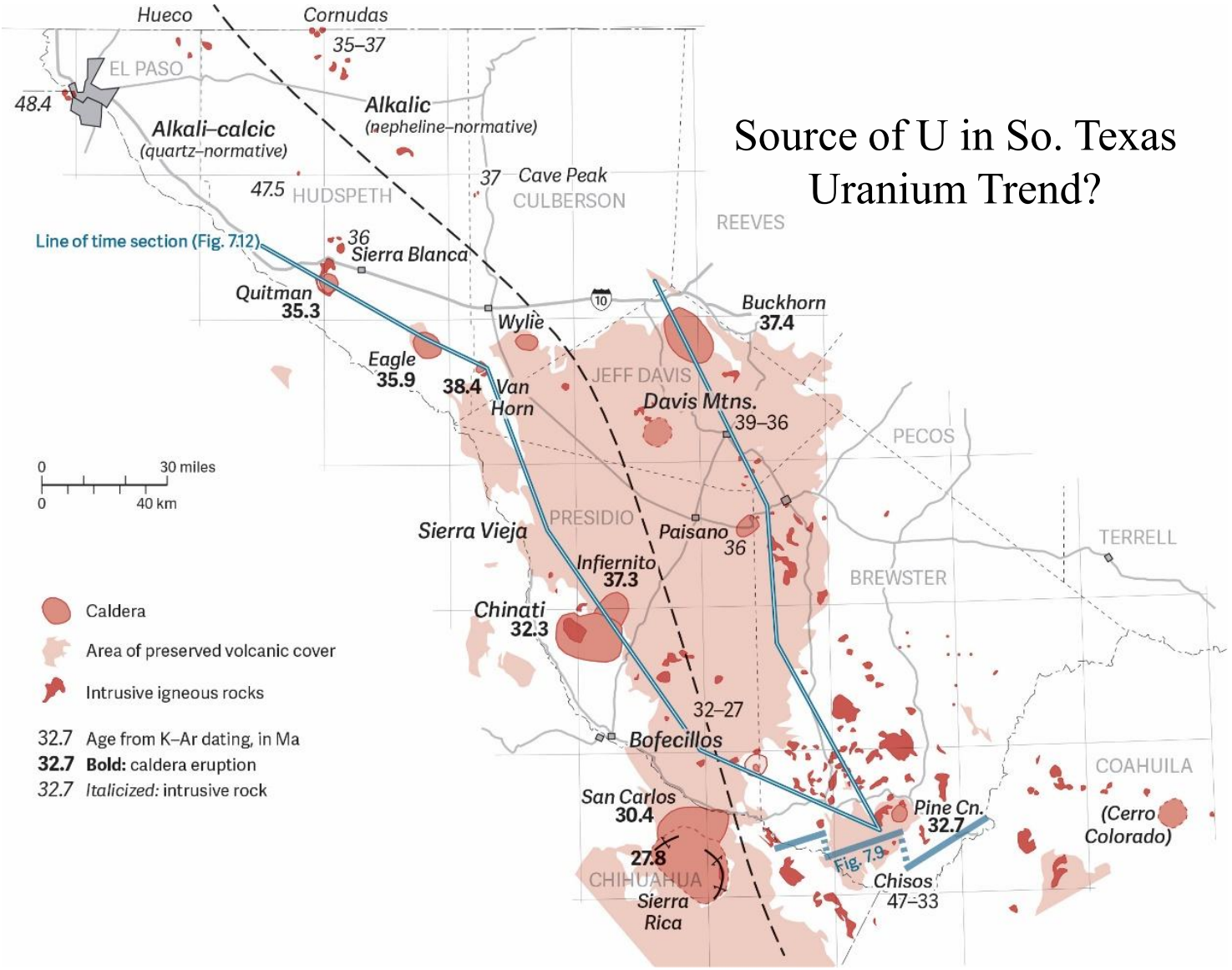
- Grenville Orogeny (1.3 – 1.0 Ga)
- Ouachita/Marathon Orogeny (Late Pn – Early Pm)
- Laramide Orogeny (75 – 35 Ma)
- Tertiary Volcanism (48 – 17 Ma)
- Basin-and-Range Tectonism
  - 31 – 24 Ma (Beginning)
  - 23 Ma (Most Active Faulting)



Physiographic features of El Paso, Hudspeth, and Westernmost Culberson counties

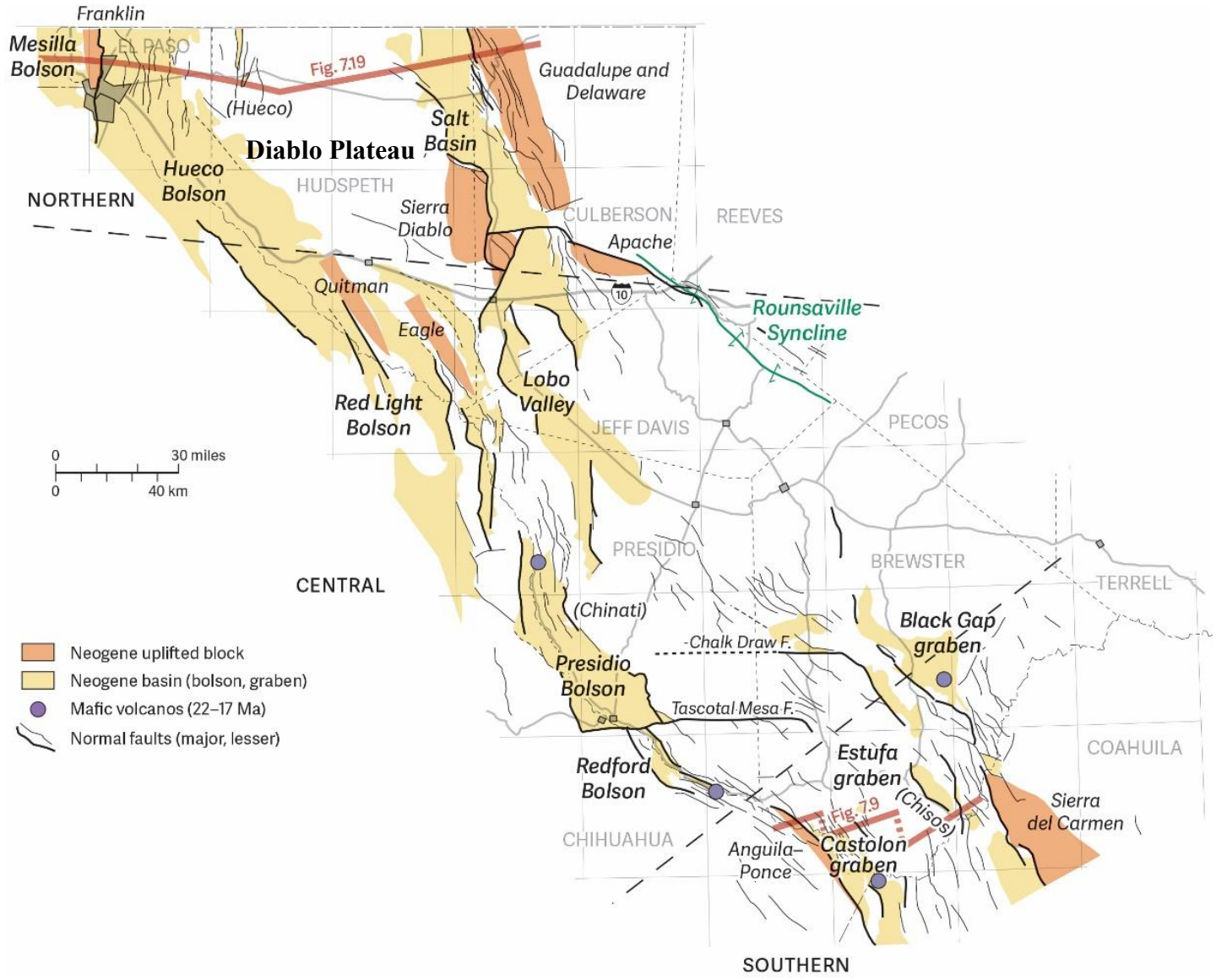


Time section of volcanic activity, formation of bolsons and calderas. Source: Ewing (2016)

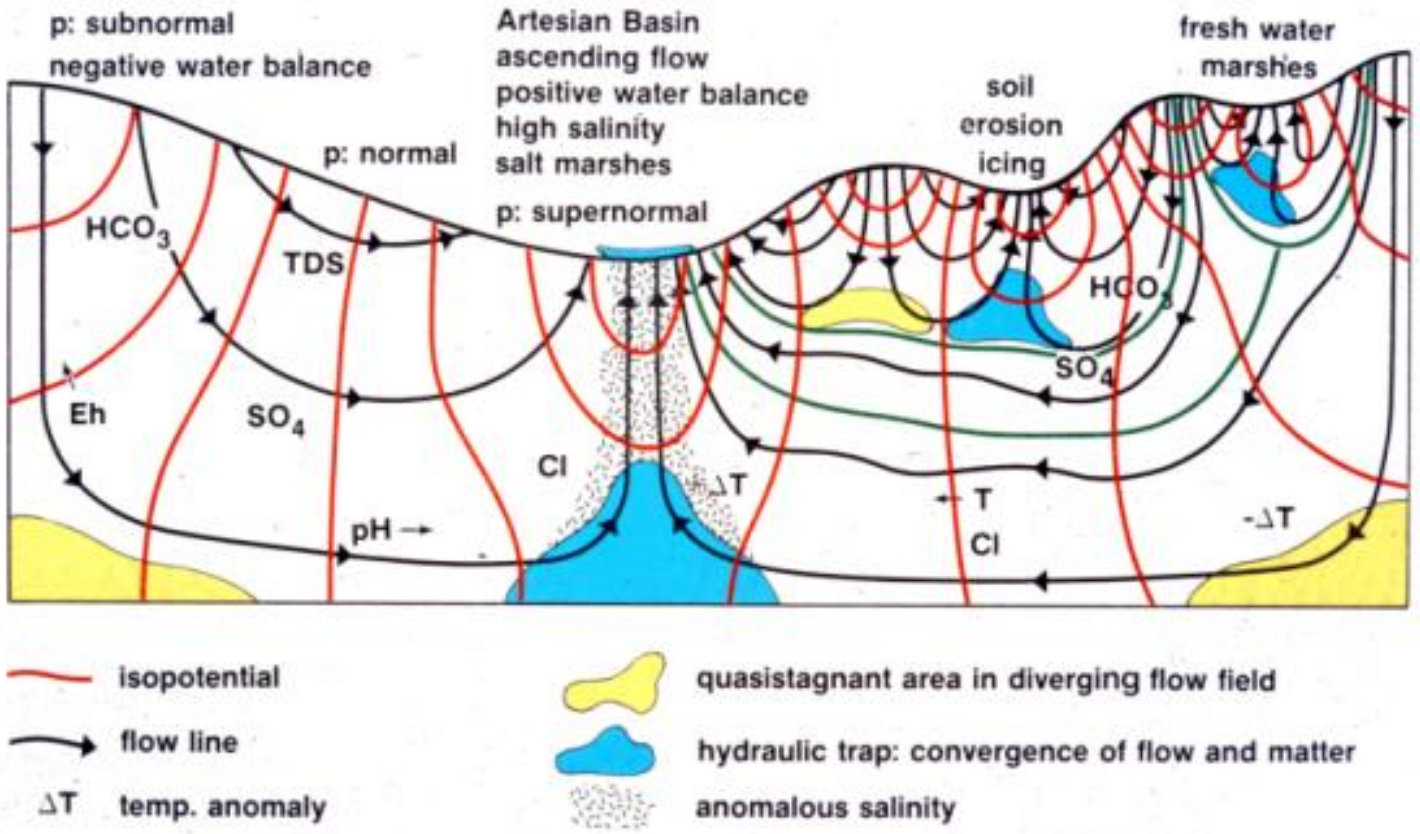


Source of U in So. Texas Uranium Trend?

Eruptive centers, calderas, extent of volcanic deposits, and radiometric dates. Source: Ewing (2016), modified from Henry and Price (1985)



Tertiary Rift Basins of Trans-Pecos Texas. Source: Ewing (2016), modified from Henry and Price (1985)

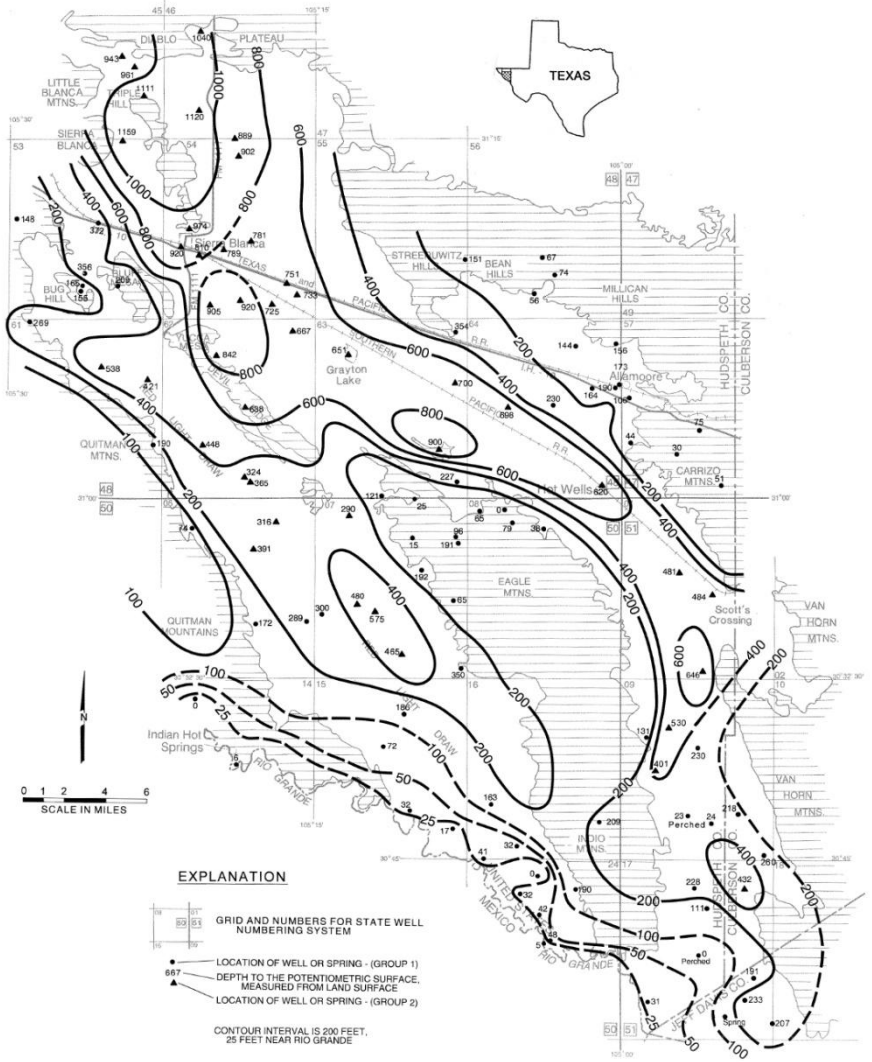


Hydrological effects of the regional gravity flow of groundwater (Toth, 1980)

Depth to groundwater
(feet below surface)

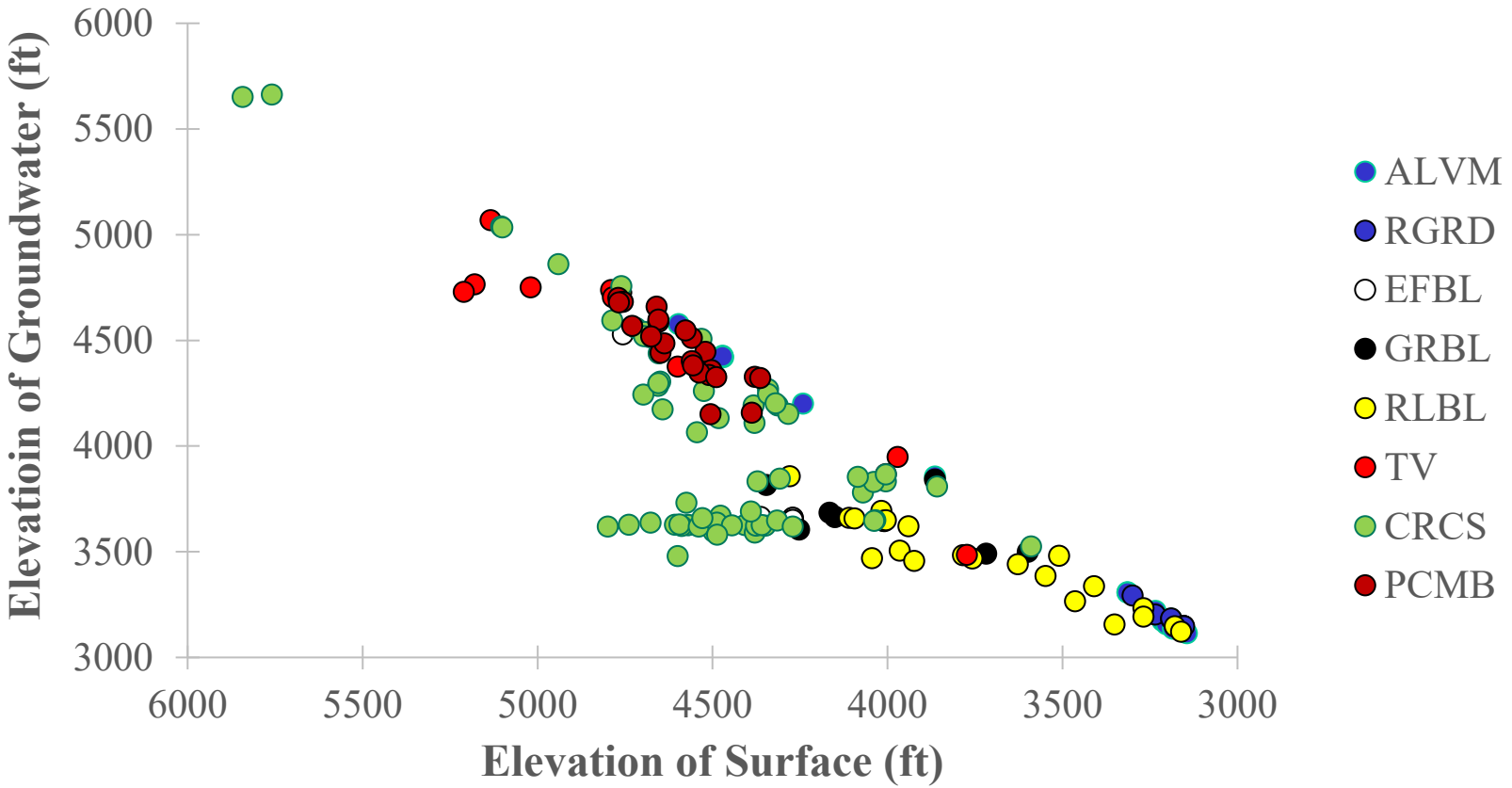
Greatest depths are beneath floor of Eagle Flat Basin (600 to >800 ft) and along the axis of Red Light Draw

The only area of discharge is in southern Red Light Draw, along the Rio Grande

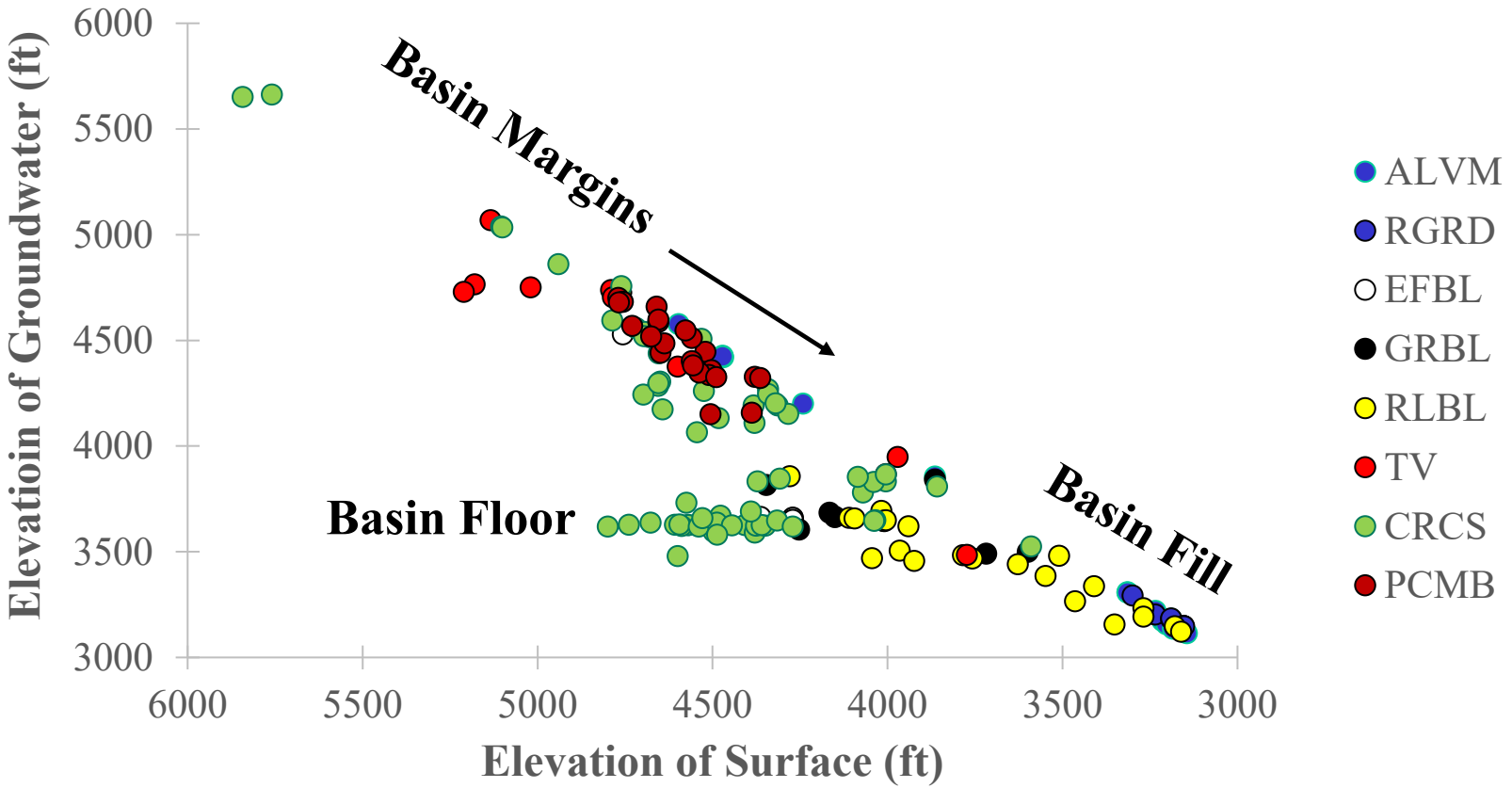


Source: Darling et al, 1994

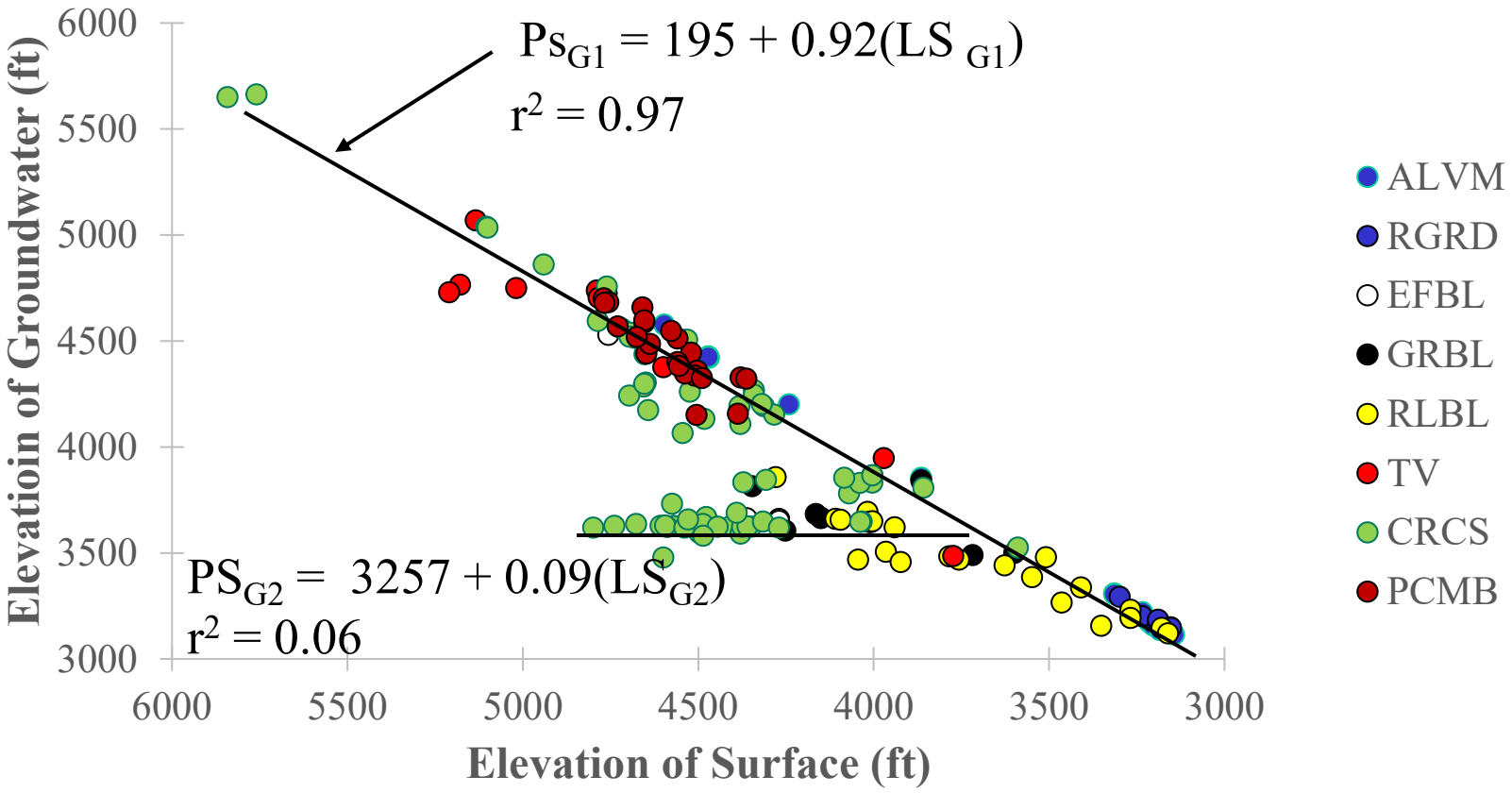
Elevations of land and groundwater



Elevations of land and groundwater



Regression: Elevations of land and ground water

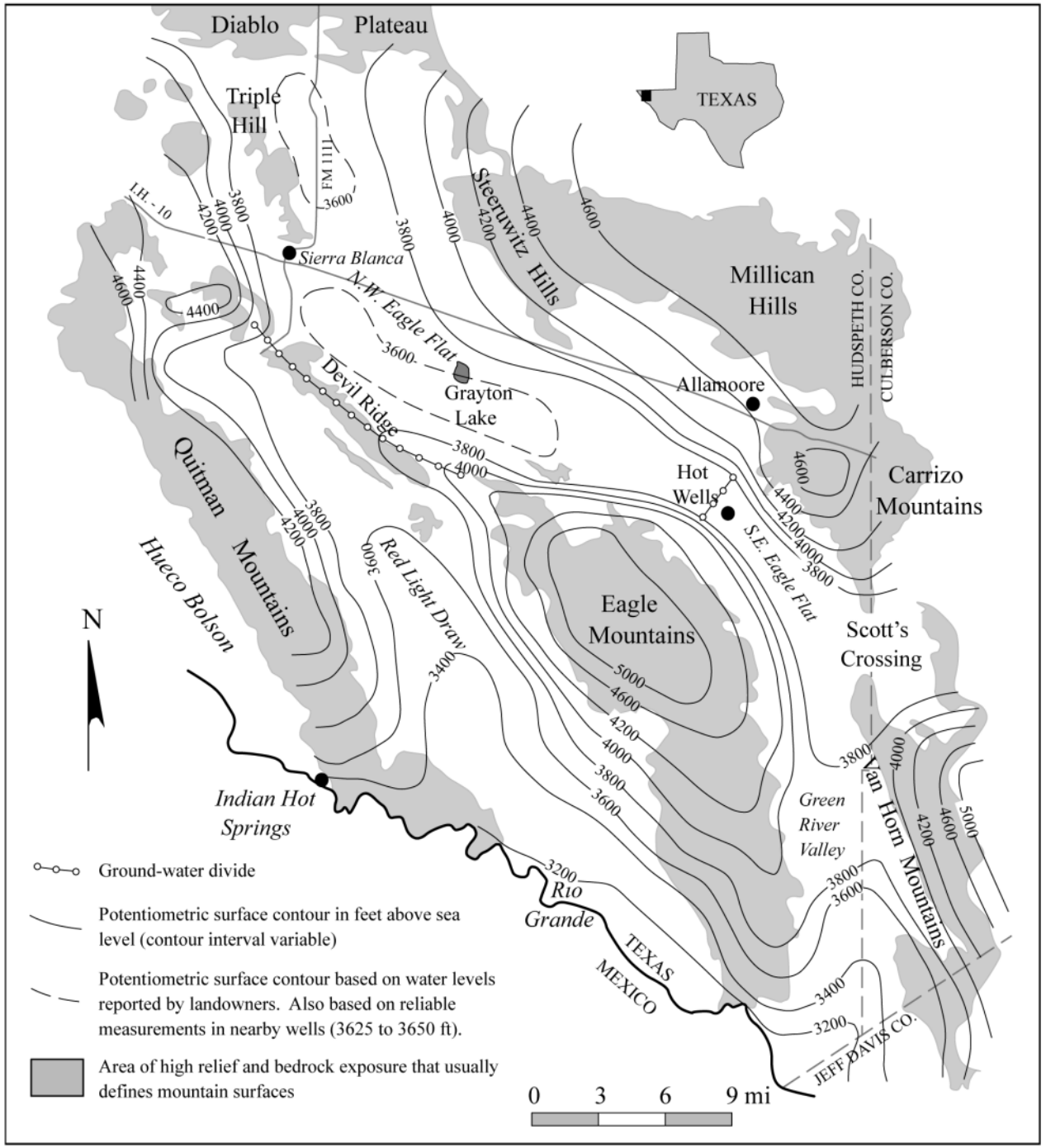


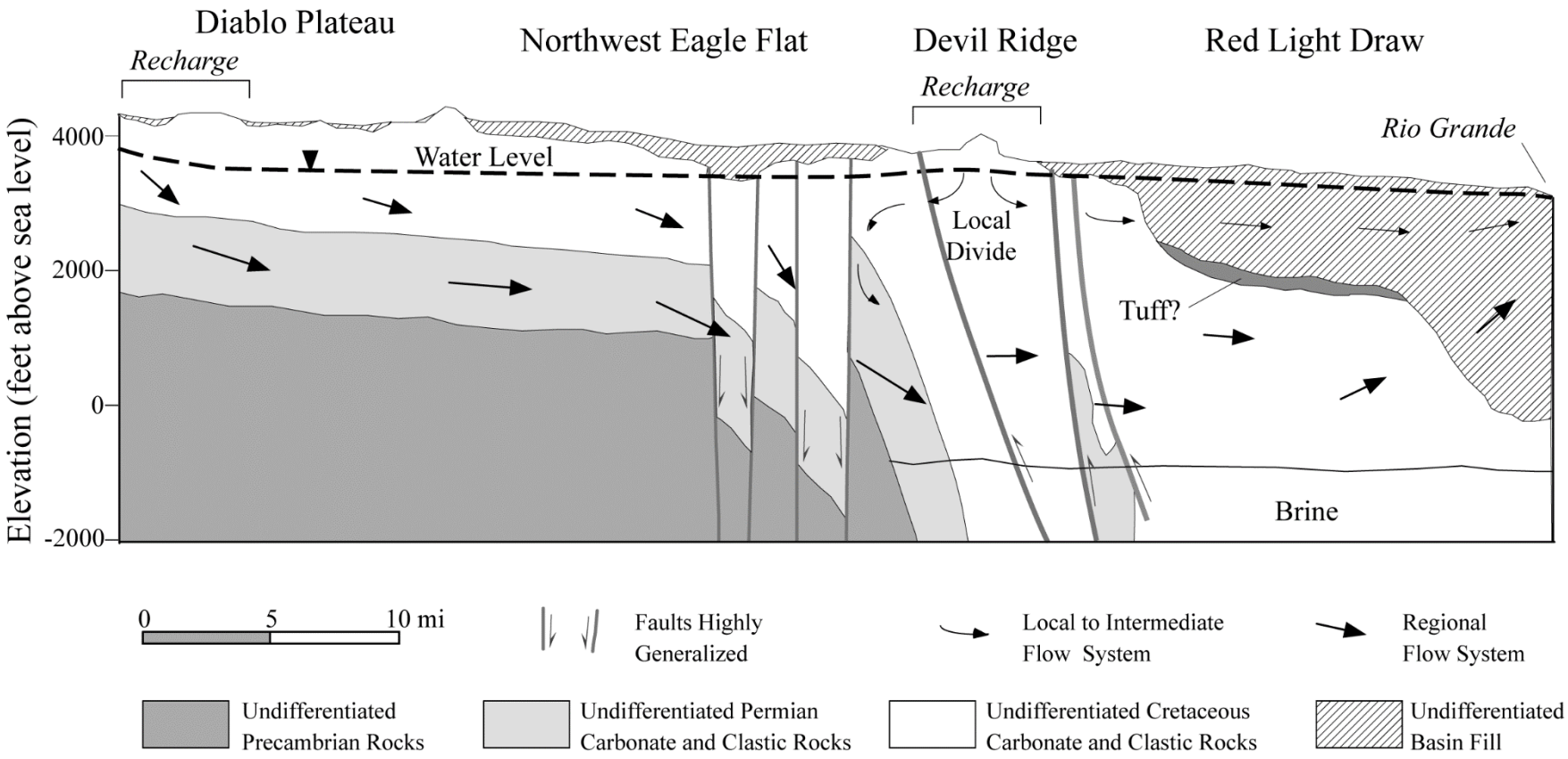
Potentiometric surface water table contours – Eagle Flat, Red Light Draw, Green River Valley and bounding mountains

Closed contours in NW Eagle Flat!

Where does it flow?

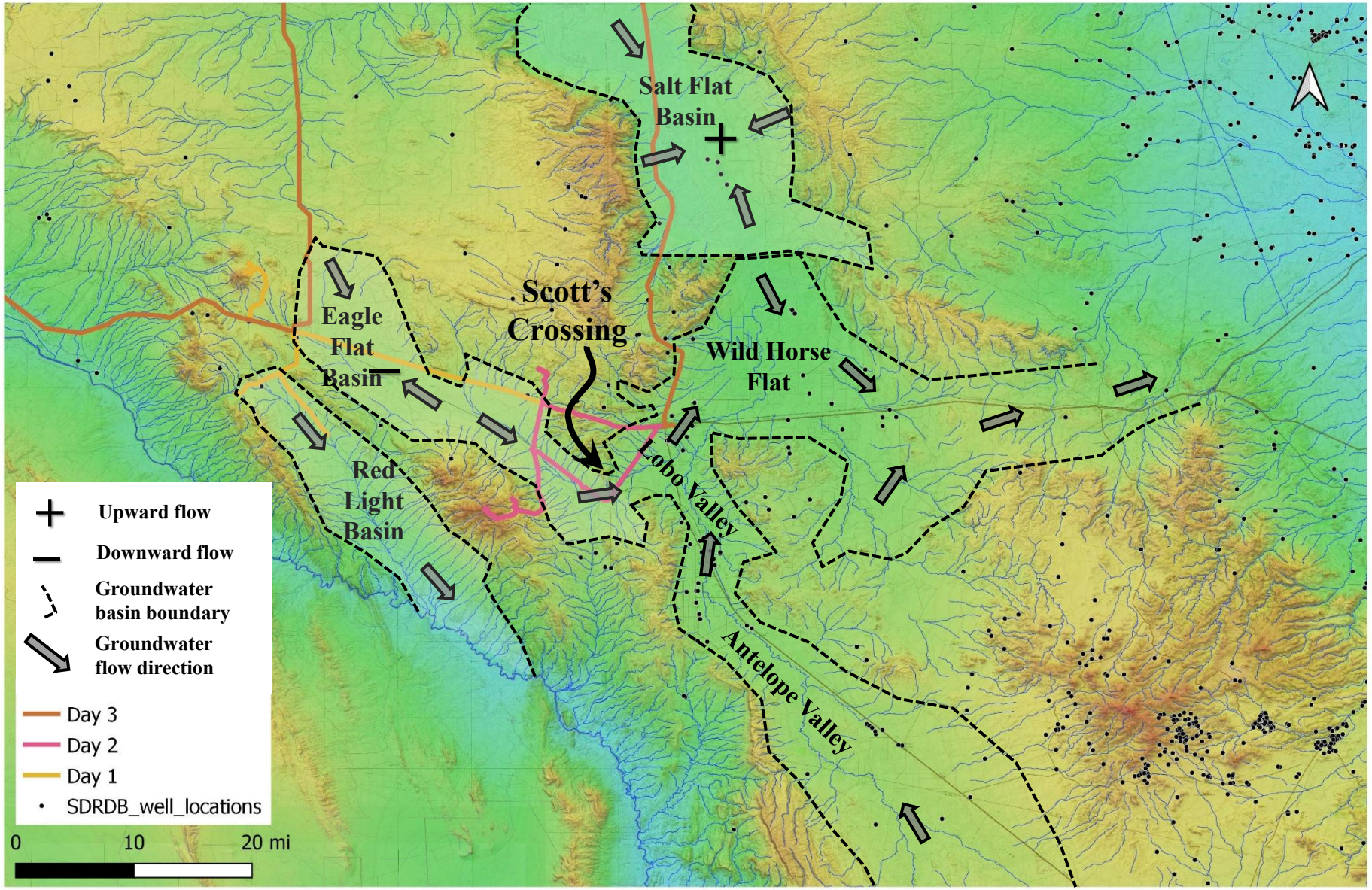
from Darling, 1997, modified from Darling et al., 1994





from Hibbs and Darling, 2004

Regional groundwater flow paths may move underneath local groundwater divides if permeable deposits are found at depth – ***source of recharge to Red Light Draw***


Salt Flat Basin
Scott's Crossing
Eagle Flat Basin
Wild Horse Flat
Red Light Basin
Lobo Valley
Antelope Valley
Upward flow
Downward flow
Groundwater basin boundary
Groundwater flow direction
Day 3
Day 2
Day 1
SDRDB_well_locations
0
10
20 mi

Age-dating Ground Water of Eagle Flat and Red Light Basins

^{14}C – half-life 5730 yrs

Cosmogenic radionuclide
Also generated in nuclear reactors and by detonations of nuclear weapons

Notoriously unreliable as absolute age-dater owing to dilution of ^{14}C signature by dead carbon from carbonate rocks and mixing of ground waters

More reliable as indicator of relative age

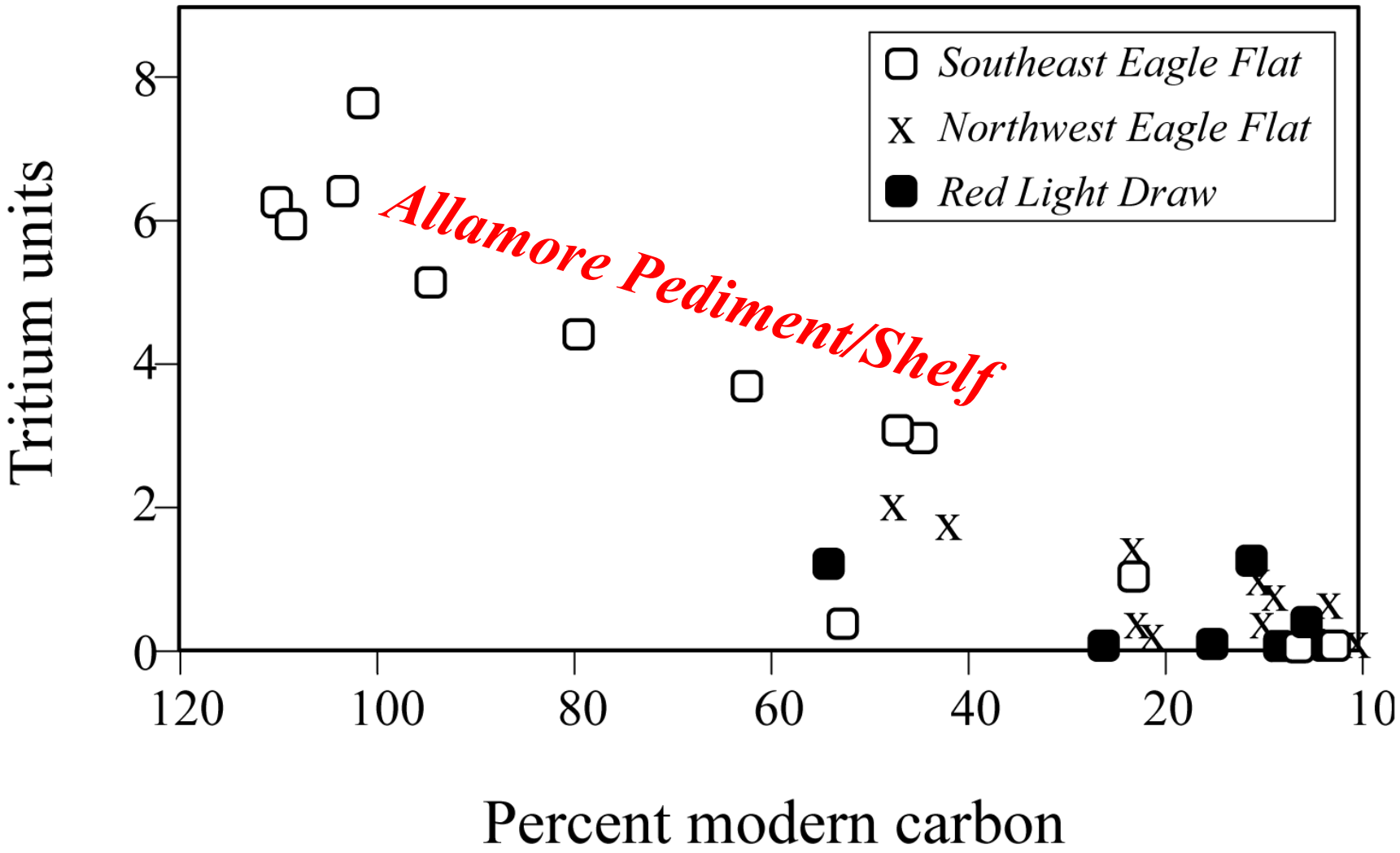
Tritium (^{3}H) – half-life 12.32 yrs

Cosmogenic radionuclide
Also formed in nuclear reactors and detonations of nuclear weapons

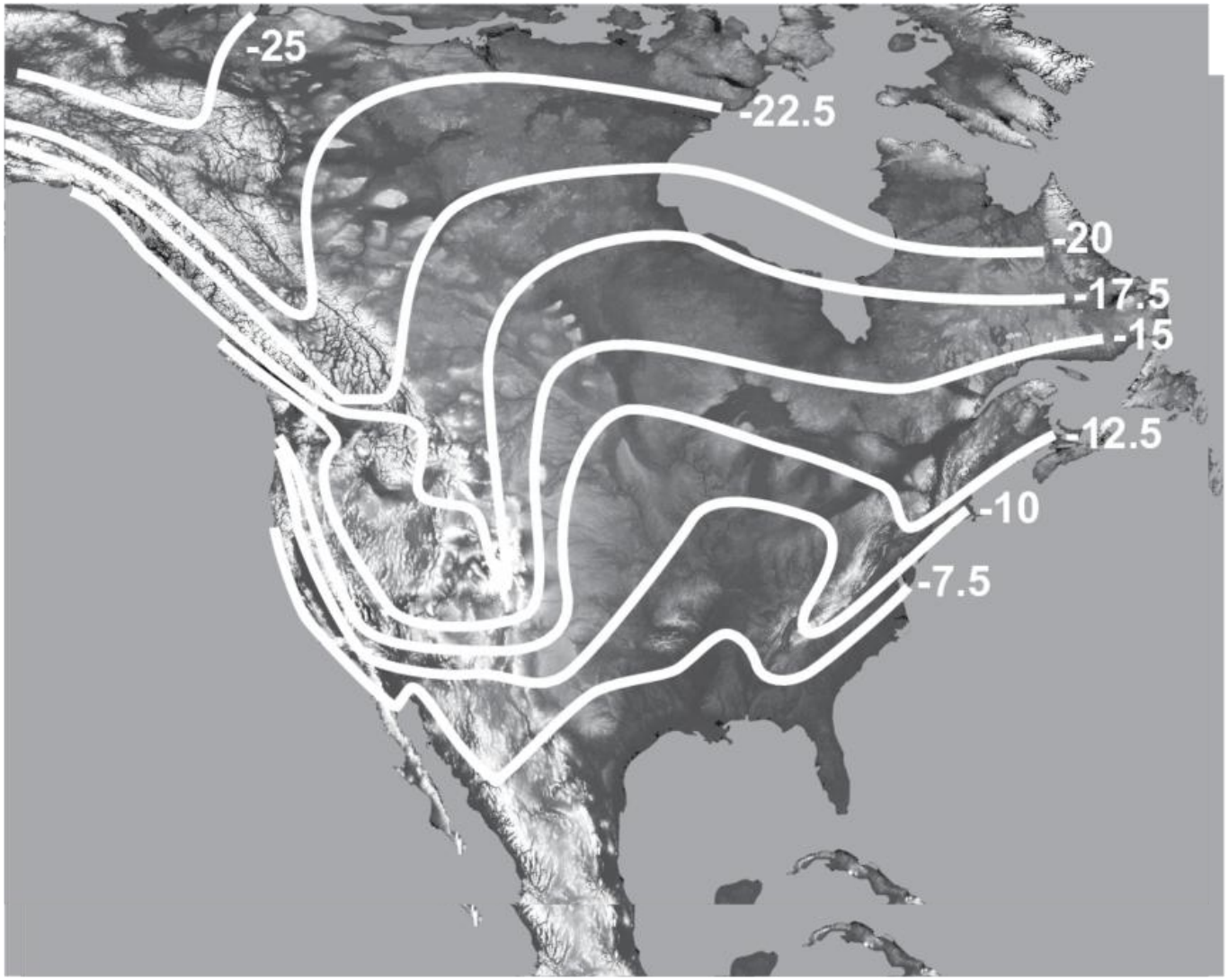
Typically used to trace “young” ground water

Effectiveness can be limited by mixing with different ground waters

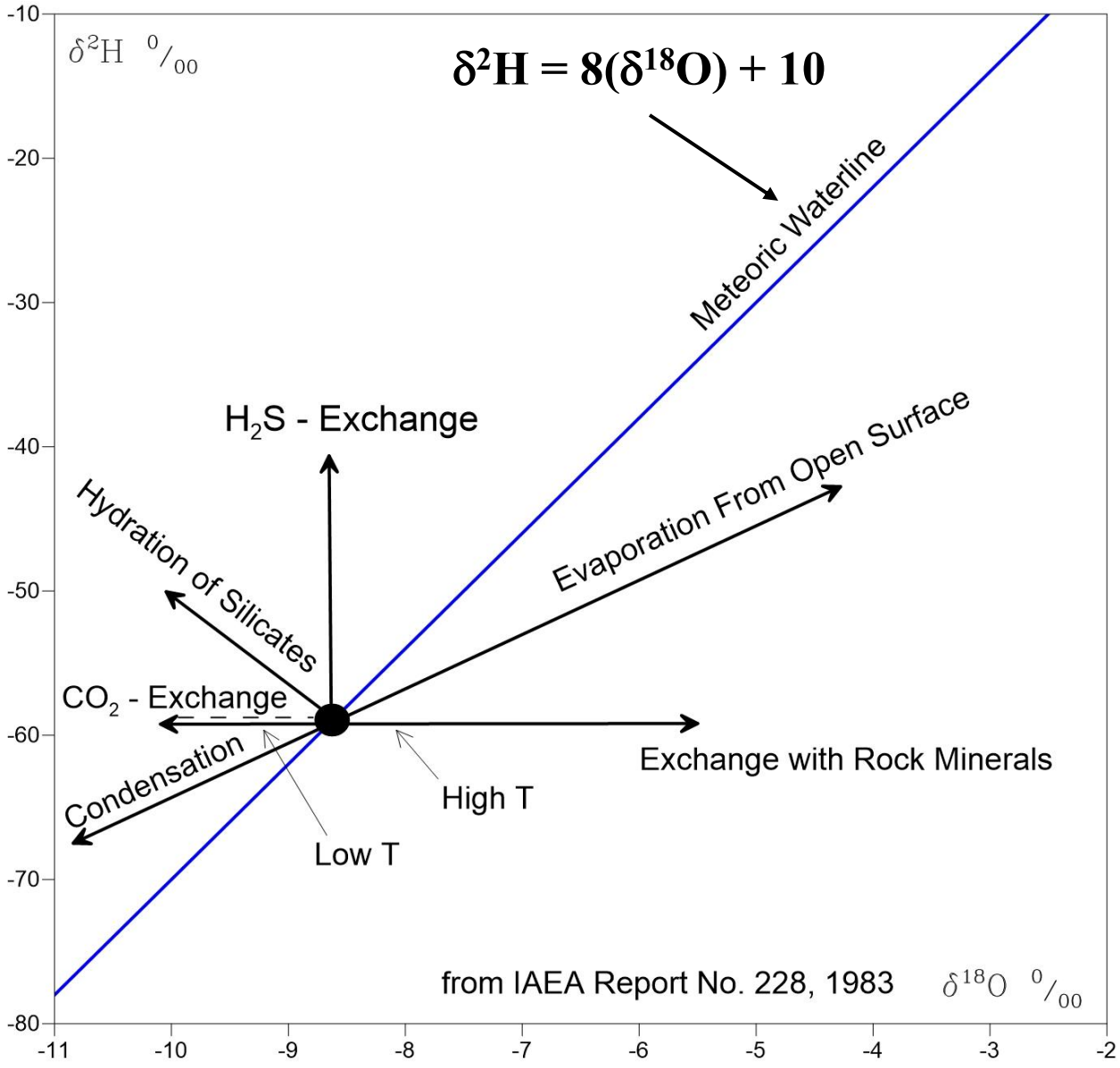
TU = 1 atom of T in 10^{18} atoms of H



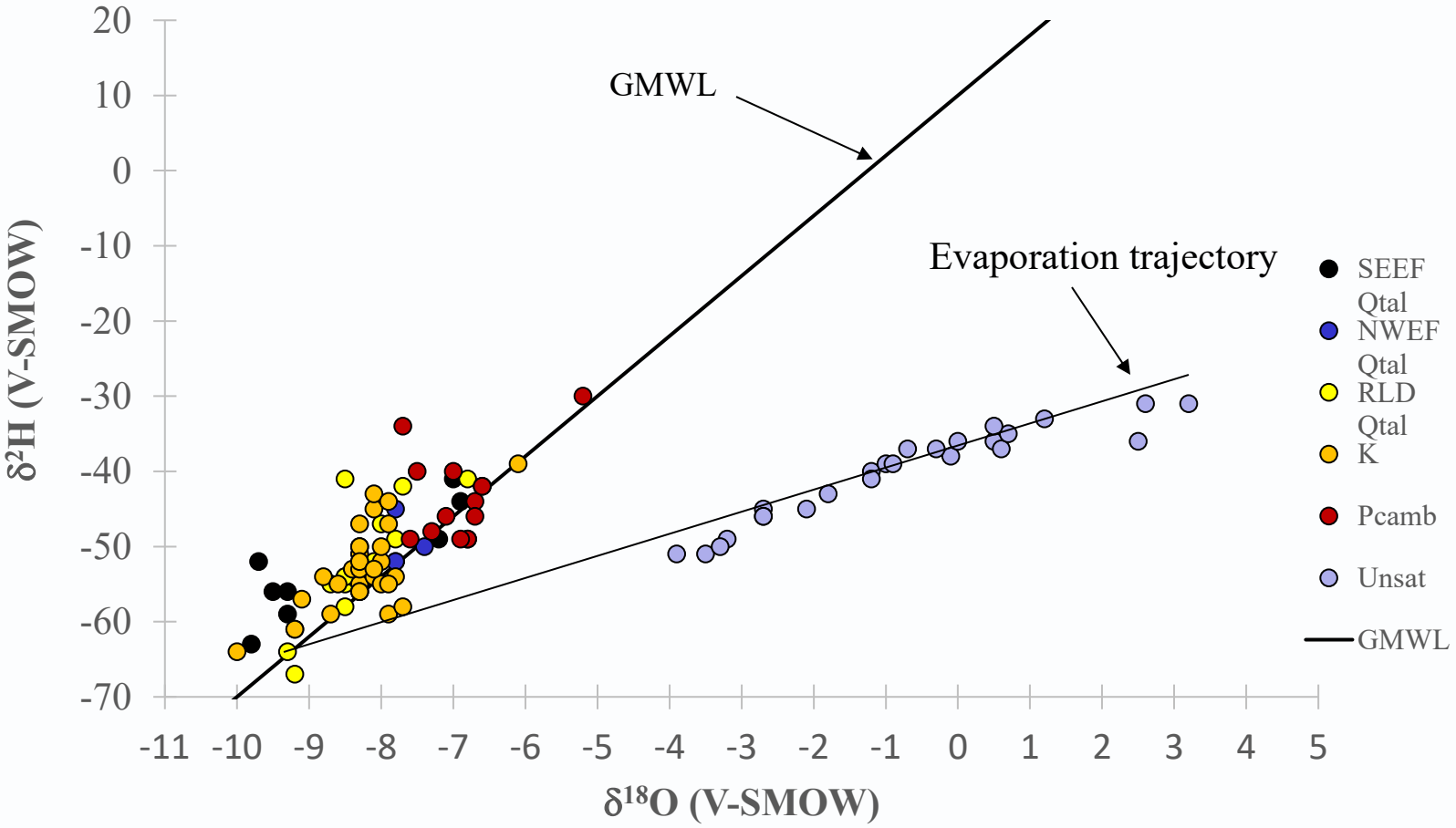
from Darling et al., 1994



Geographic map of North America contoured for $\delta^{18}O$ of precipitation relative to V-SMOW. From Sheppard et al. (1968).

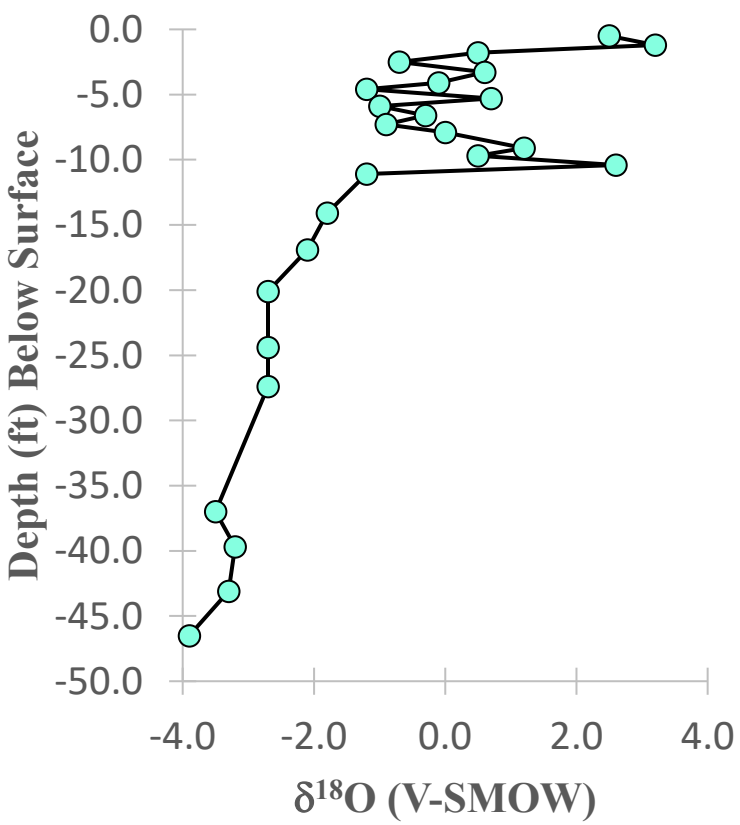

δ^2H $^0/_{00}$
$\delta^2H = 8(\delta^{18}O) + 10$
Meteoric Waterline
H_2S - Exchange
Evaporation From Open Surface
Hydration of Silicates
CO_2 - Exchange
Condensation
Exchange with Rock Minerals
High T
Low T
from IAEA Report No. 228, 1983
$\delta^{18}O$ $^0/_{00}$
-10
-20
-30
-40
-50
-60
-70
-80
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2

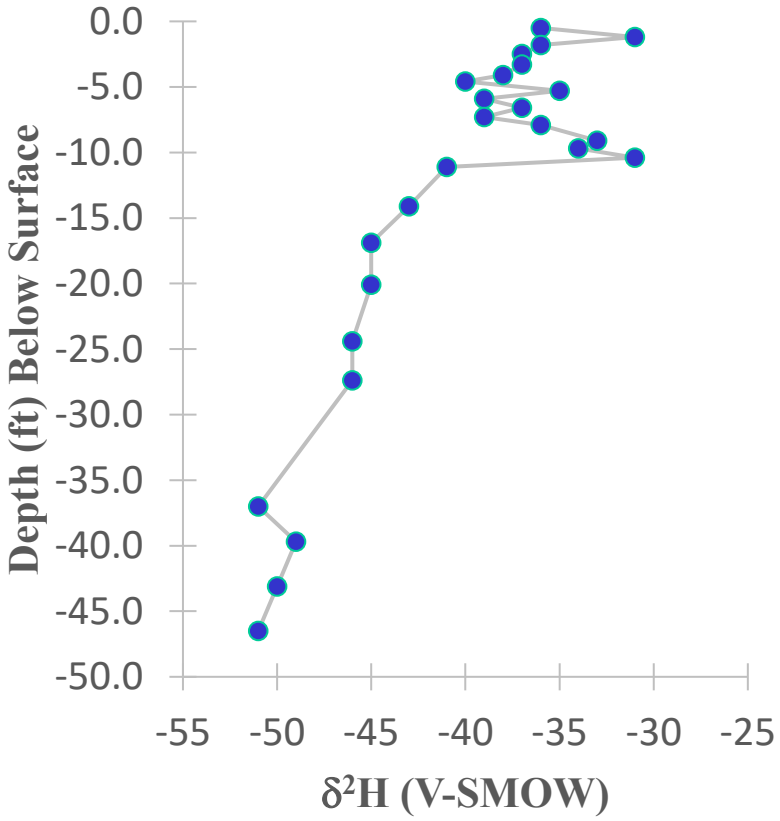
$\delta^{18}O$ and $\delta^{2}H$ – ground water and unsaturated zone



Source: Darling et al., 1994; Scanlon et al., 1993

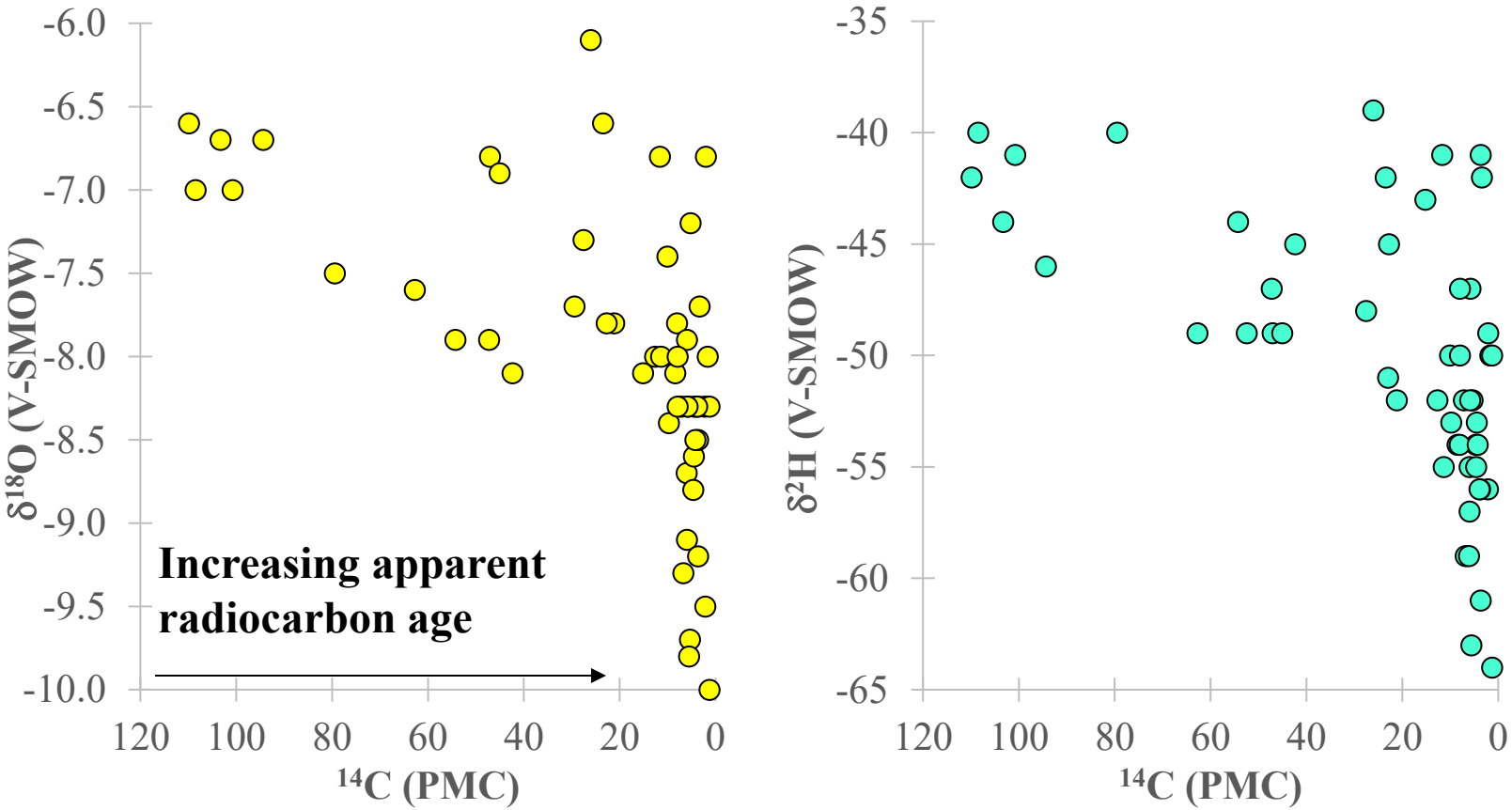
Unsaturated zone profiles of $\delta^{18}O$ and $\delta^{2}H$ – Eagle Flat Basin





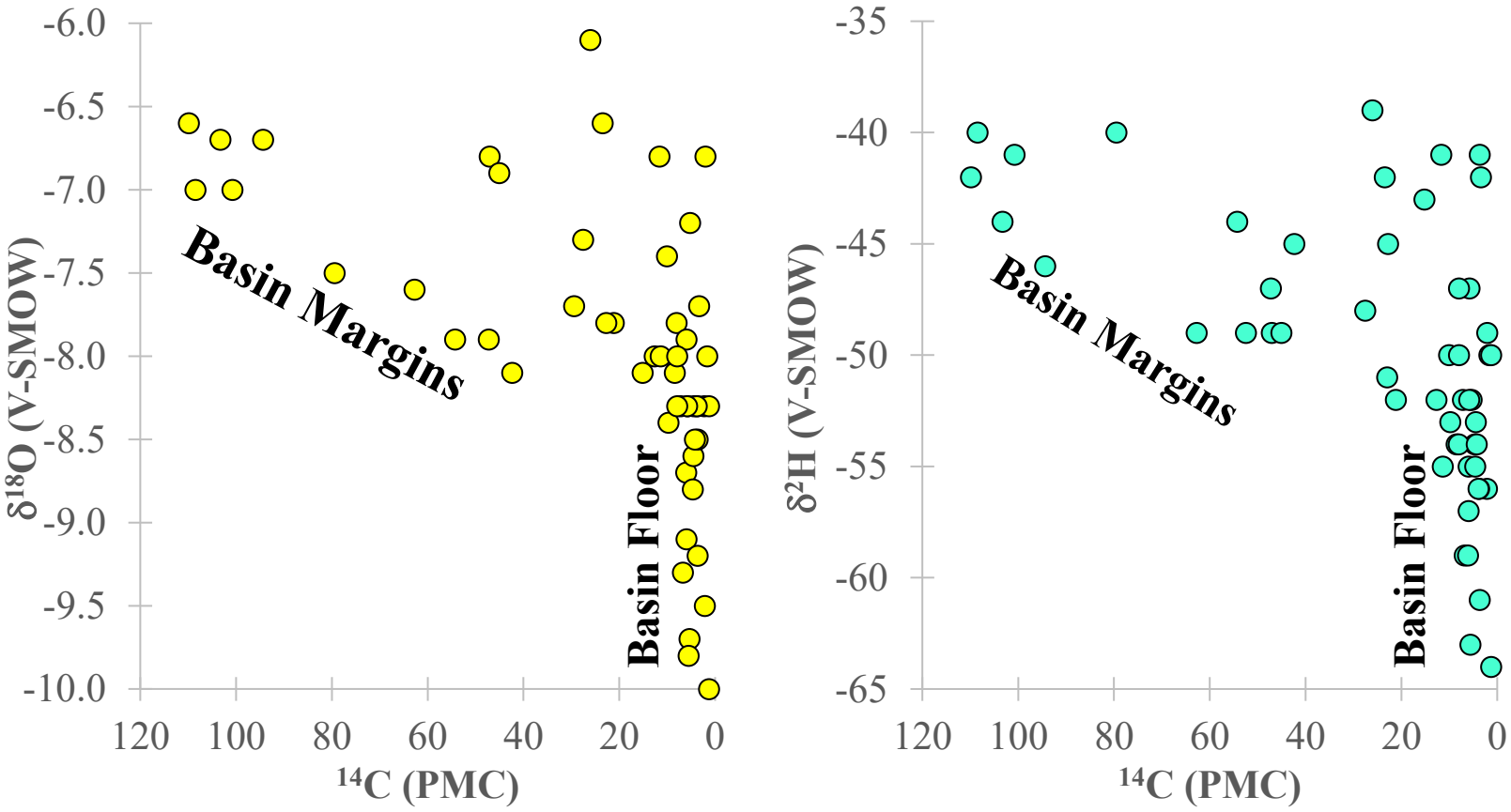
Source: Scanlon et al., 1993

Lower $\delta^{18}O$ and $\delta^{2}H$ ratios with increasing apparent age

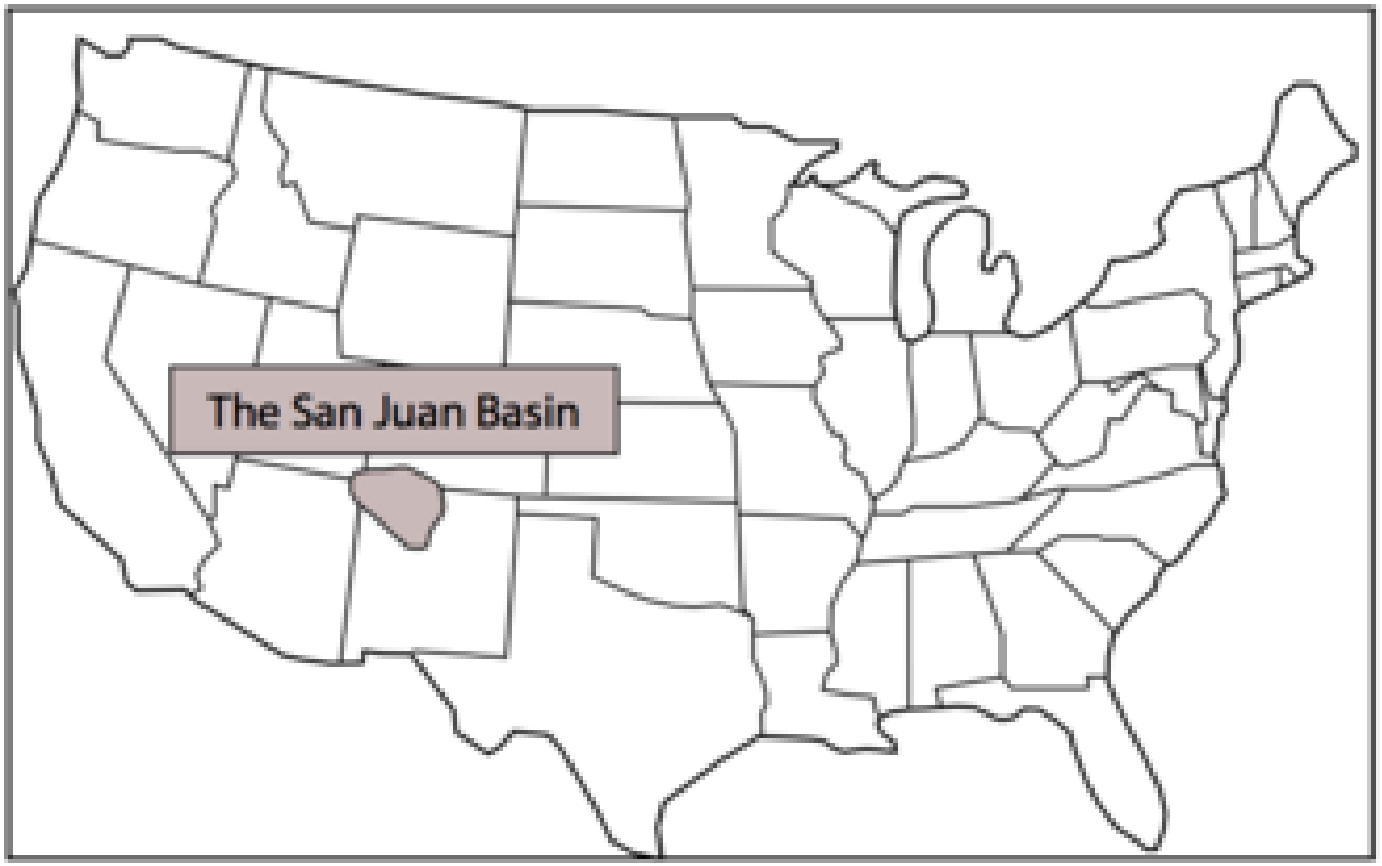


Source: Darling et al., 1994

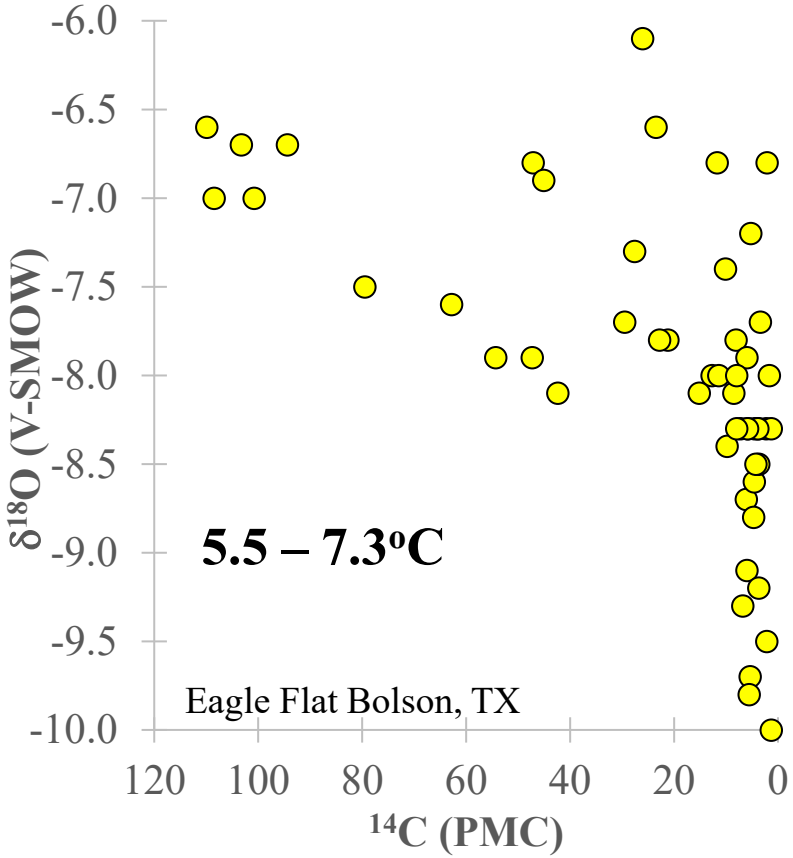
$\delta^{18}O$ and $\delta^{2}H$ v ^{14}C



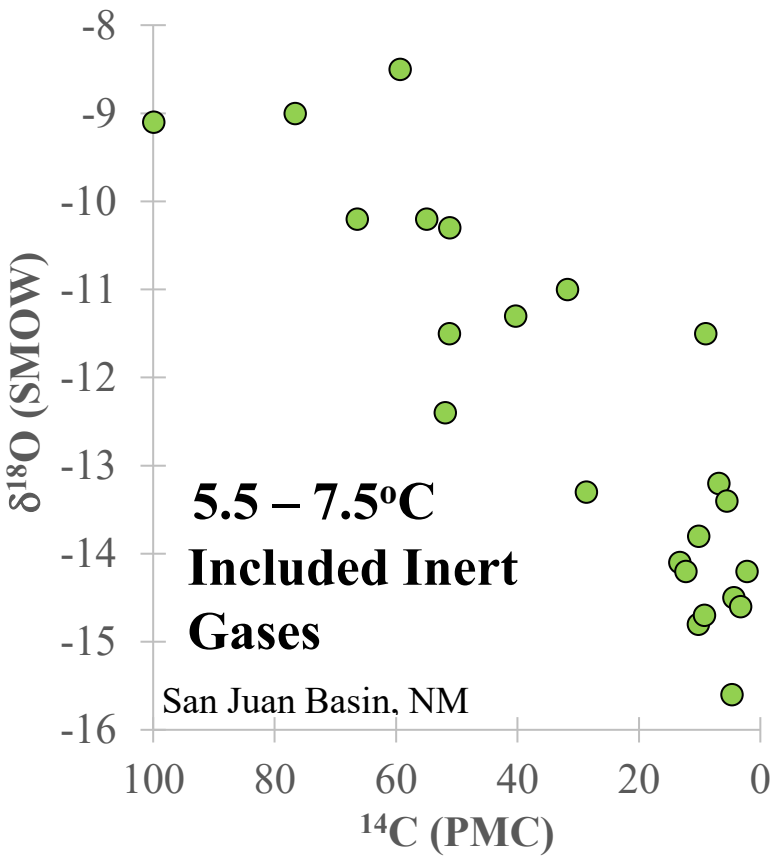
Source: Darling et al., 1994


The San Juan Basin

Similar pattern of decreasing $\delta^{18}O$ vs increasing apparent ^{14}C age observed in San Juan Basin ground water

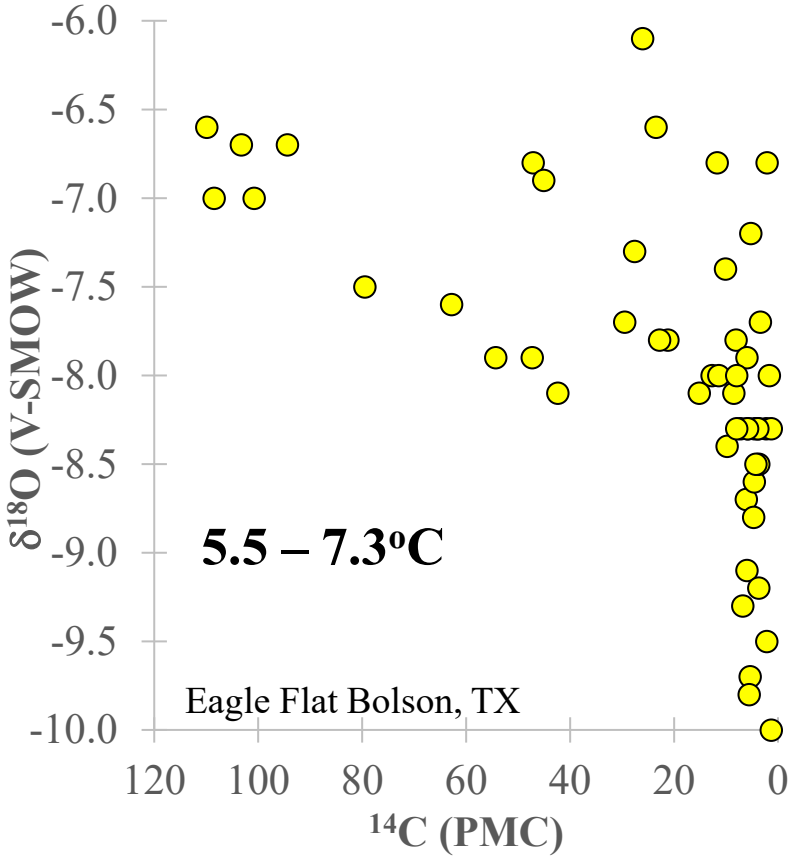


Source: Darling et al., 1994

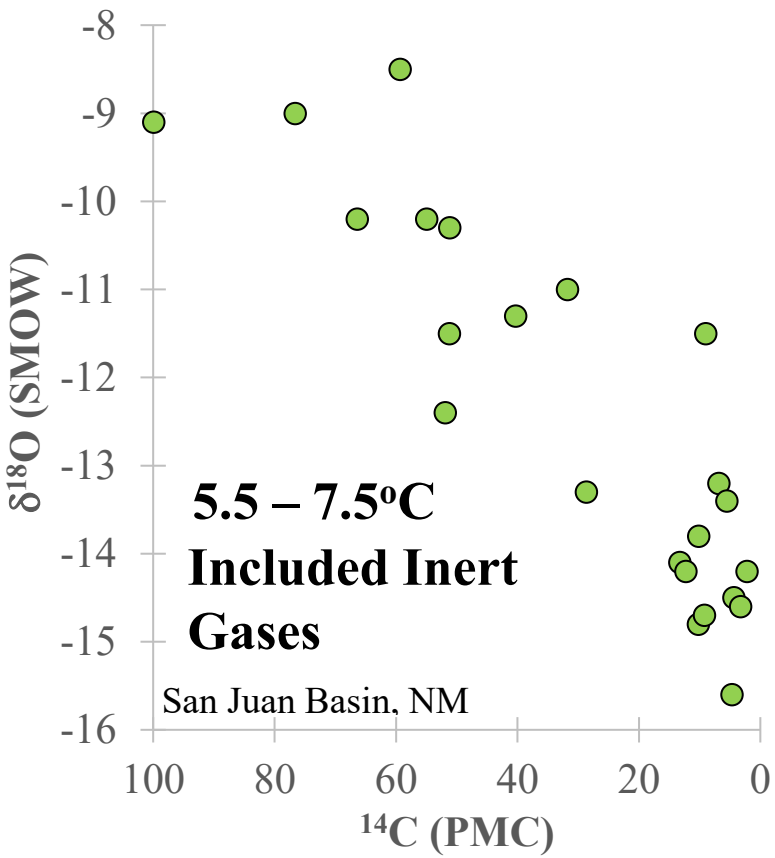


Source: Philips et al., 1986

^{14}C v $\delta^{18}O$ – Eagle Flat Bolson (TX) and San Juan Basin (NM)



Source: Darling et al., 1994



Source: Philips et al., 1986

Other estimates of differences in Late-Pleistocene and Post-Pleistocene temperatures

- Leopold (1951) – 6^{o}C based on relict snowlines

- Dutton (1995) – 5 to 8^{o}C based on differences in $\delta^{18}O$ of unconfined and confined groundwaters of Southern High Plains

- Stute et al (1992) – 5^{o}C based on concentrations of inert gases in the Carrizo aquifer of southern Texas