Combined use of physico-chemical parameters and isotopic composition to characterize groundwater flow systems and their response to intensive extraction

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With the support of

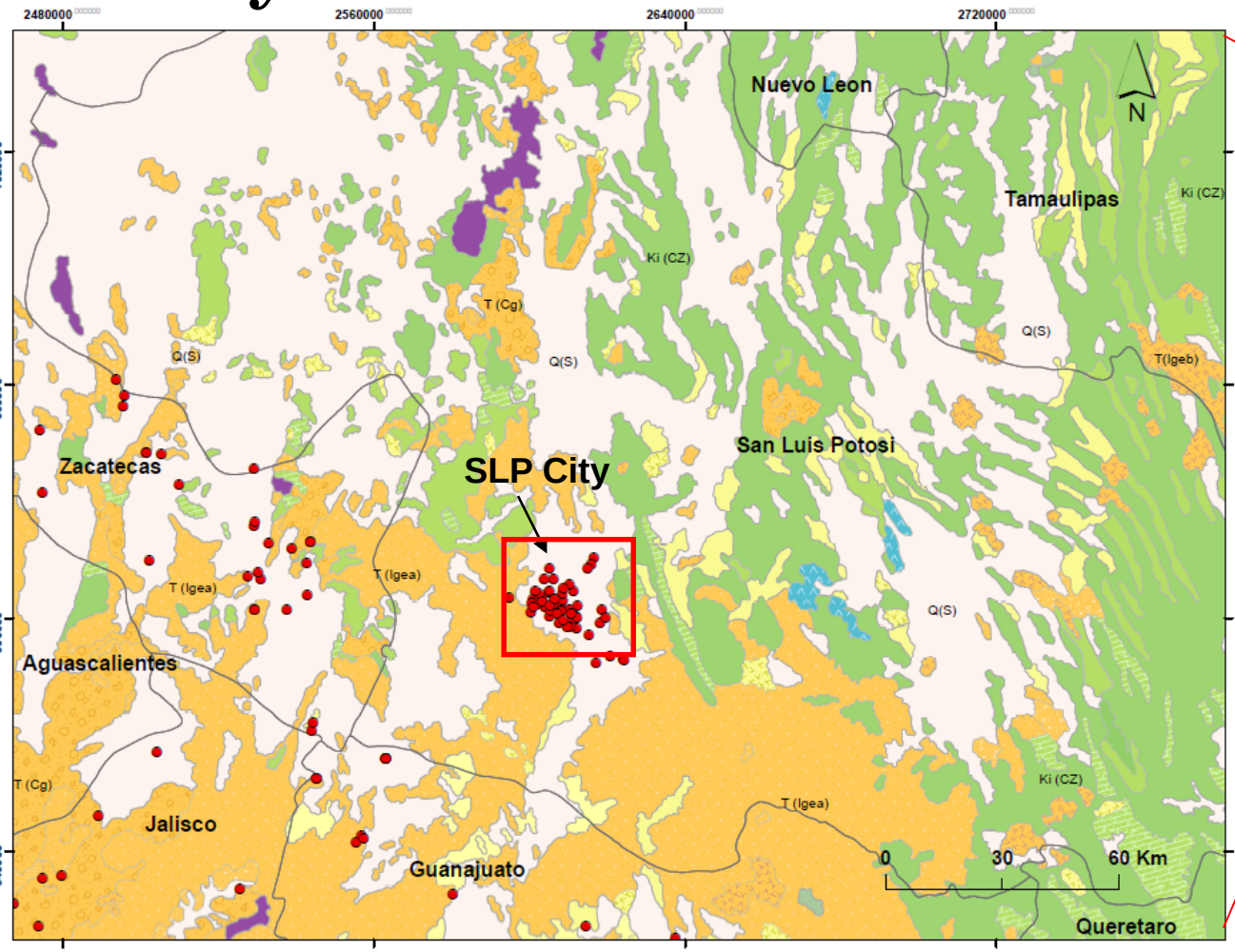
Issues

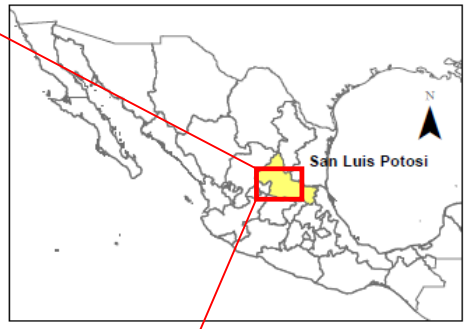
- Increase of chemical and physical caracteristics of GW as result of intensive extraction (*20 years of investigation);*
- Natural increase of fluoridated waters (44% of supplied waters contain 3 to 4 mg/l of F) → *GW quality change is linked to its extracted volume*
- Land subsidence (urban areas < 5 cm/y);
- The water balance has often being the main objective; however, this does not suffice to gain an understanding of groundwater functioning;
- The management of deep aquifer in Mexico is not considered;
- Studies usually ignore vertical ascending flow, it is often claimed that it is unimportant.

Goals

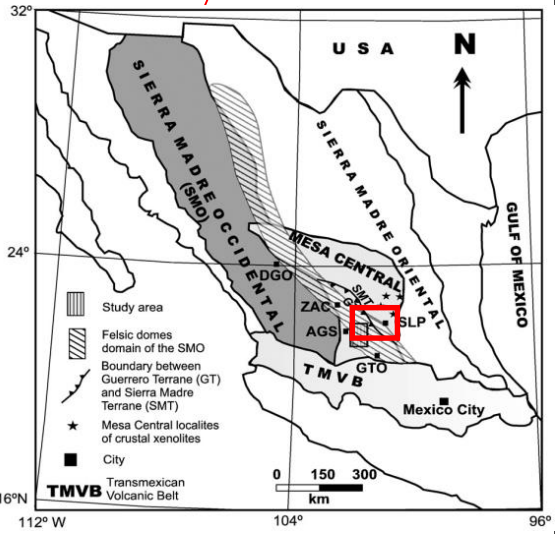
- Evaluation of GW flow patterns using environmental isotopes tracers in parallel with hydrogeological and chemical characteristics evaluation
- Select natural tracers considering **GW flow systems hierarchy**
- Define fluoride functioning in abstracted groundwater
- Investigate possible natural fluoride controls
- Test the reliability of Li, F and temperature as tracer for deep groundwater inflow and intensive extraction.

Study area





San Luis Potosi Catchment



Legend

QUATERNARY
- Q(S) Soil
- Q(Igeb) Igneous extrusive basic rocks
- Q(cg) Conglomerates

CENOZOIC

NEOGENE
- TS (Cg) Conglomerates

PALEOGENE
- Te (Lu-ar) Shales-Sandstones
- Tpal (Lu-ar) Shales-Sandstones
- Tpal (Lu) Shales
- T (Cg) Conglomerates
- T(Igeb) Igneous extrusive basic rocks
- T(Igia) Igneous intrusive acid rocks
- T (Igea) Igneous extrusive acid rocks

MESOZOIC

CRETACEOUS
- KS (Cz-Lu) Limestones-Shales
- KS (CZ) Limestones
- KS (Lu) Shales
- Ki (CZ) Limestones
- K(Cz) Limestones

JURASSIC
- J (lu-ar) Shales-Sandstones
- J(CZ) Limestones
- J(Y) Gypsum
- J(E) Schistes

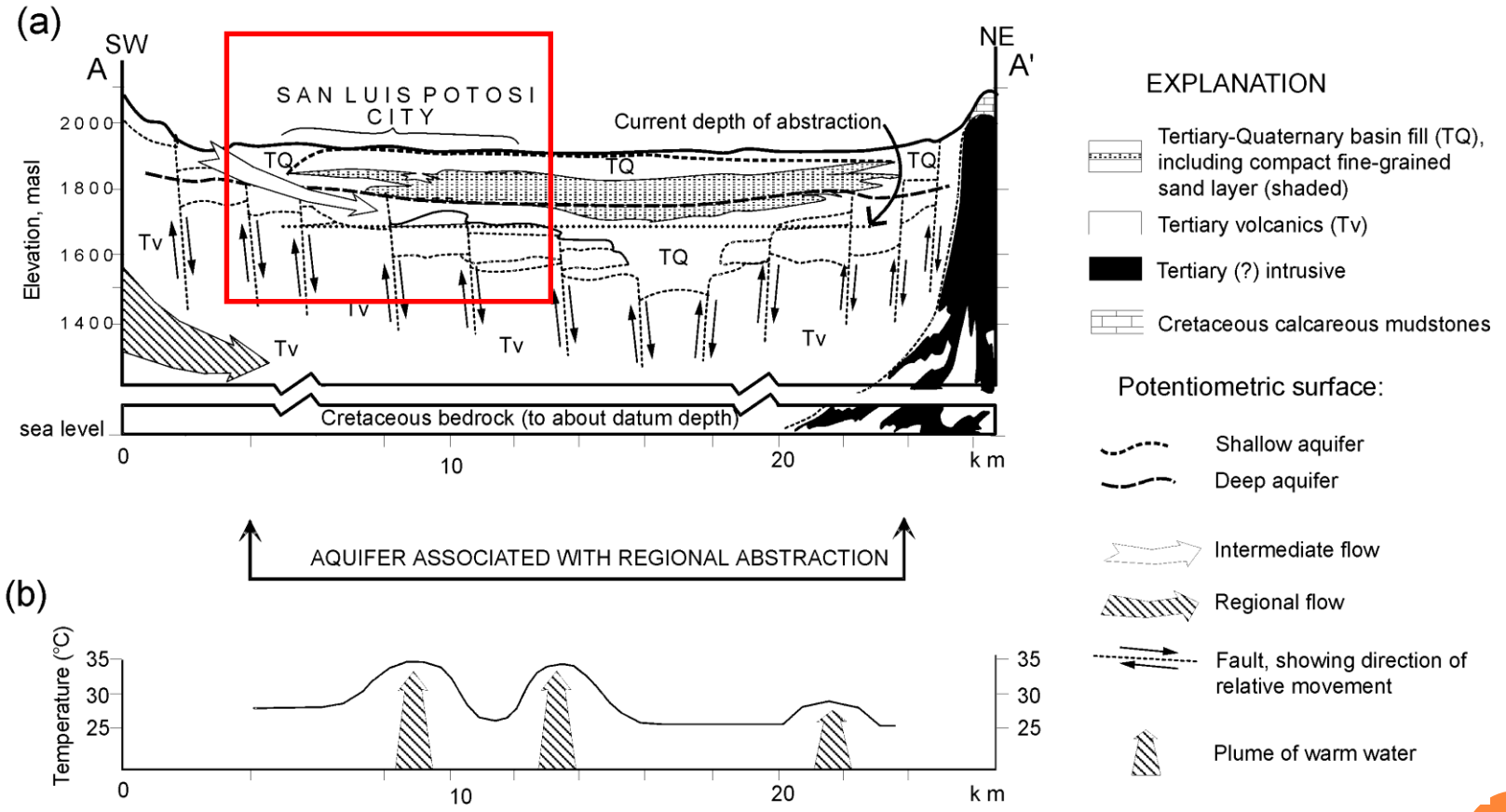
TRIAS
- TR (lu-ar) Shales-Sandstones
- TR(E) Shales
- TR(cg) Conglomerates

PALEOZOIC

PERMIAN
- Pe(lu-ar) Shales-Sandstones

- Domestic, Industrial Wells
- States borders

BACKGROUND


(a)
SW
A
NE
A'
SAN LUIS POTOSI CITY
Current depth of abstraction
TQ
Tv
Elevation, masl
2000
1800
1600
1400
sea level
Cretaceous bedrock (to about datum depth)
0
10
20
k m
AQUIFER ASSOCIATED WITH REGIONAL ABSTRACTION
(b)
Temperature (°C)
35
30
25
EXPLANATION
Tertiary-Quaternary basin fill (TQ), including compact fine-grained sand layer (shaded)
Tertiary volcanics (Tv)
Tertiary (?) intrusive
Cretaceous calcareous mudstones
Potentiometric surface:
Shallow aquifer
Deep aquifer
Intermediate flow
Regional flow
Fault, showing direction of relative movement
Plume of warm water

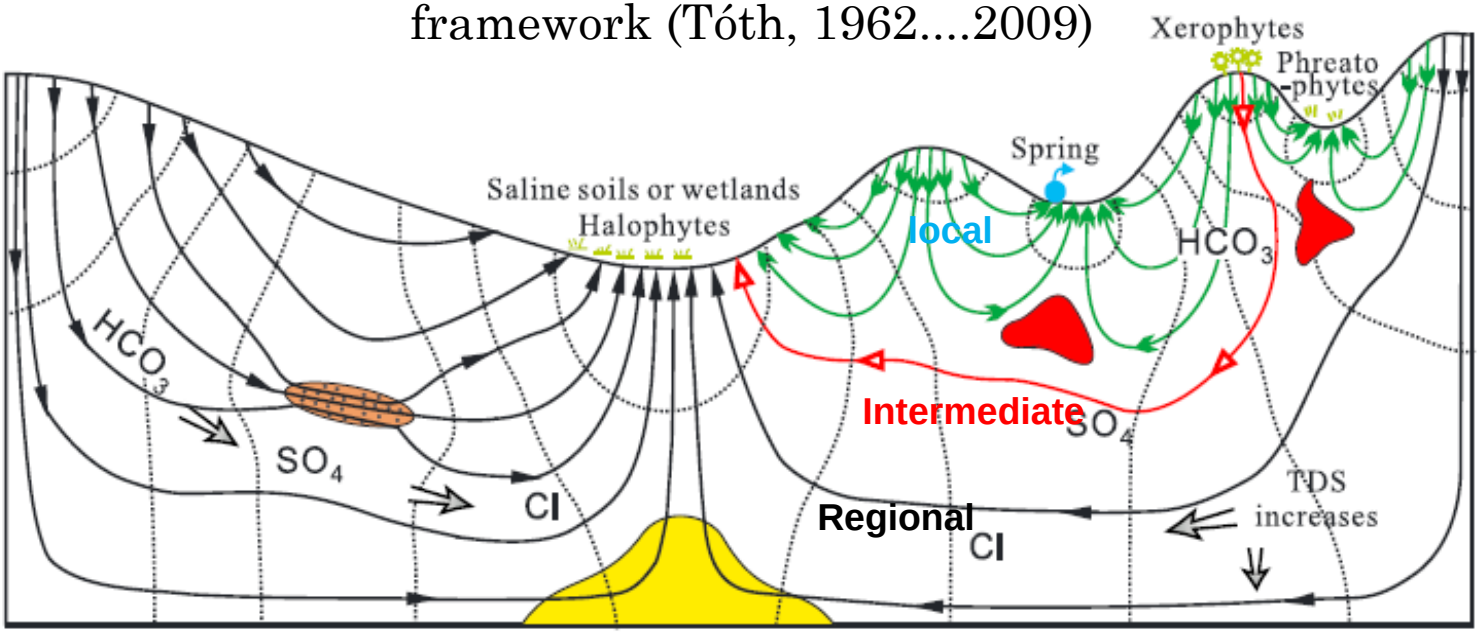
SCIENTIFIC REFERENCES

Chemical tracers as supportive indicators of flow patterns and groundwater residence-time:

Chebotarev, 1955; Kamensky, 1955; Schwartz and dominico, 1973;Wallick and Tóth, 1975 ; Edmunds et al., 1984; Elliot et al., 1999; Edmunds et al., 2004; Edmunds and Smedley, 2000; Carrillo-Rivera and Cardona, 2008; among others

Inert tracers	Reactive tracers	Redox sensitive
Halogens (Cl, Br, F, I); NO3,δ18O, δ2H	Sr, Na, Li, Rb, B, Cs, Mg/Ca, 14C	As, U, Se

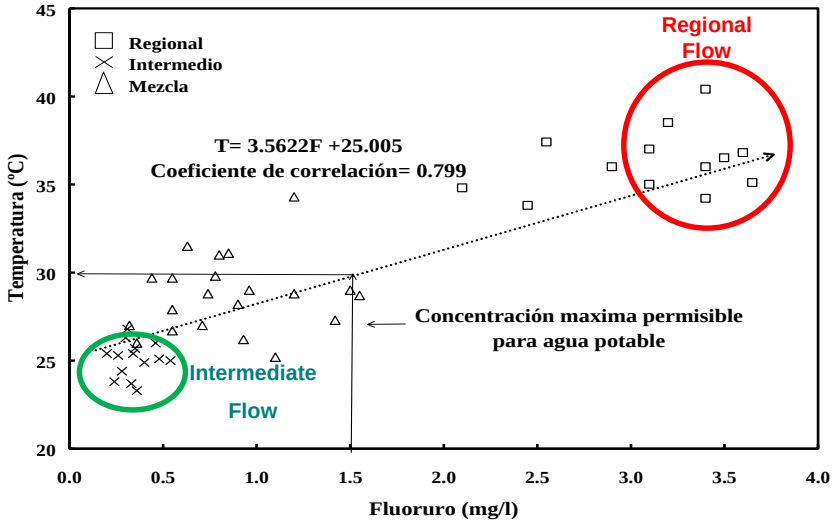
Groundwater Flow System framework (Tóth, 1962....2009)

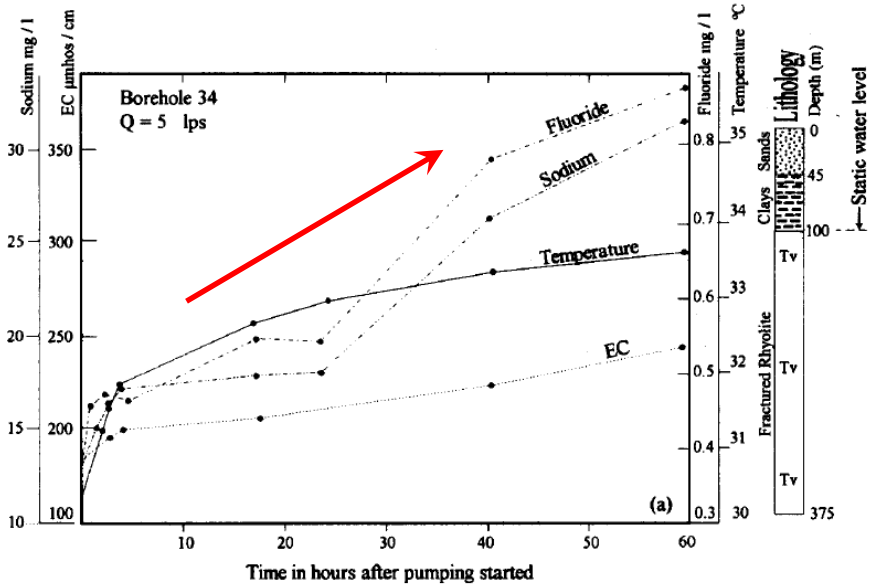


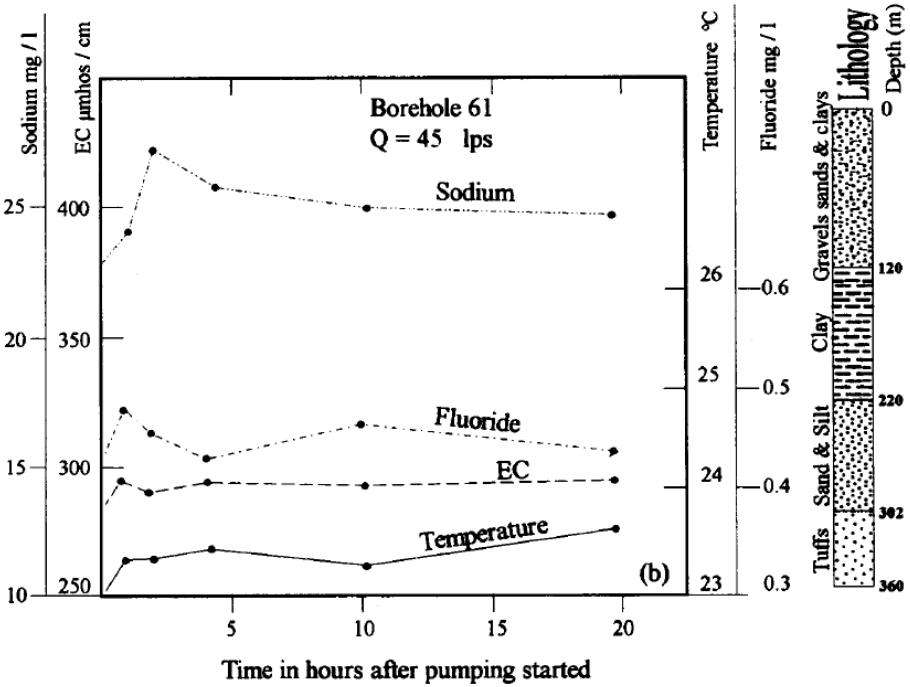
(modified from Tóth, 1999 by Jiang et al. 2014)

BACKGROUND

Carrillo-Rivera et al., 1996; 2008

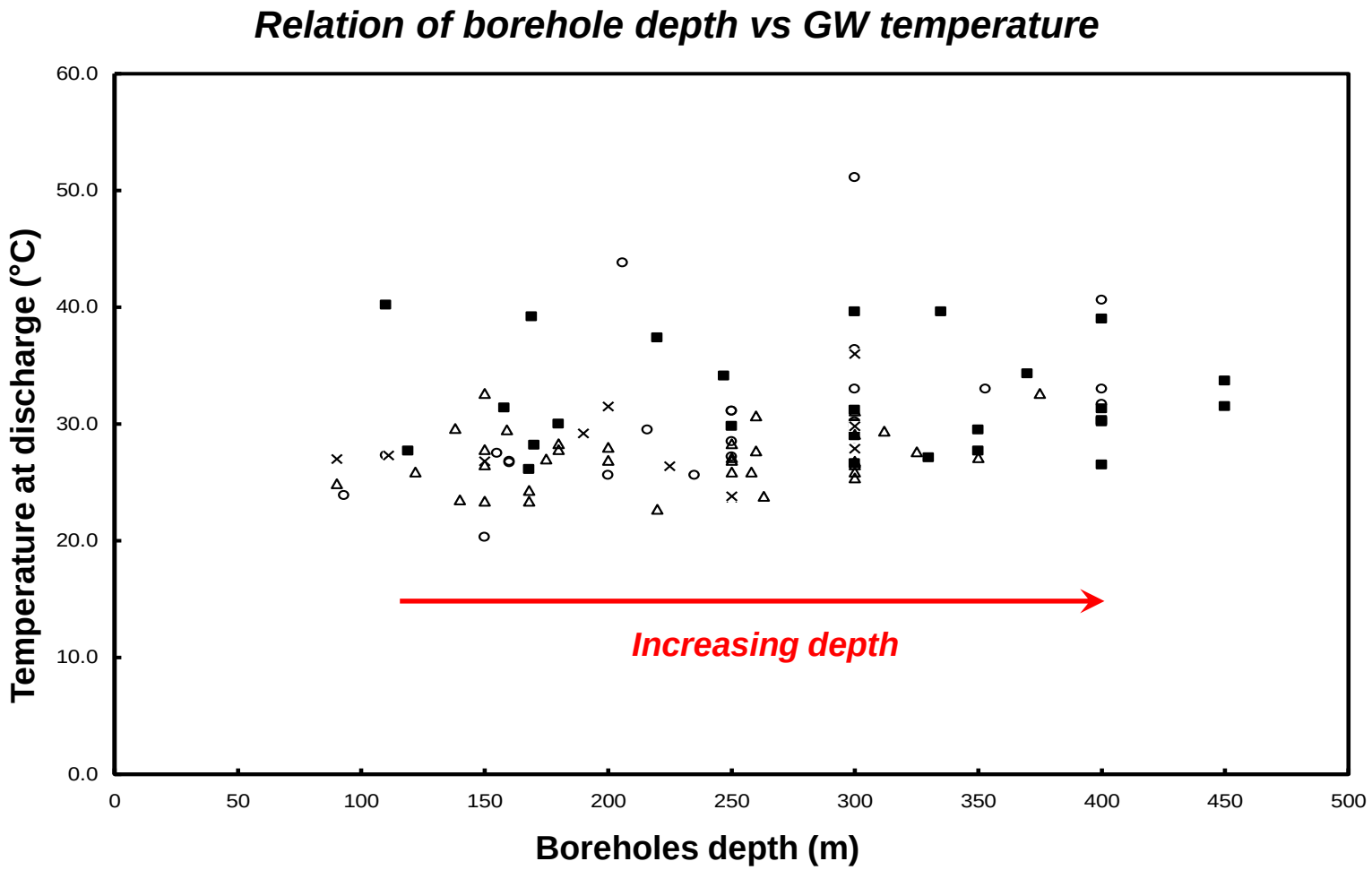




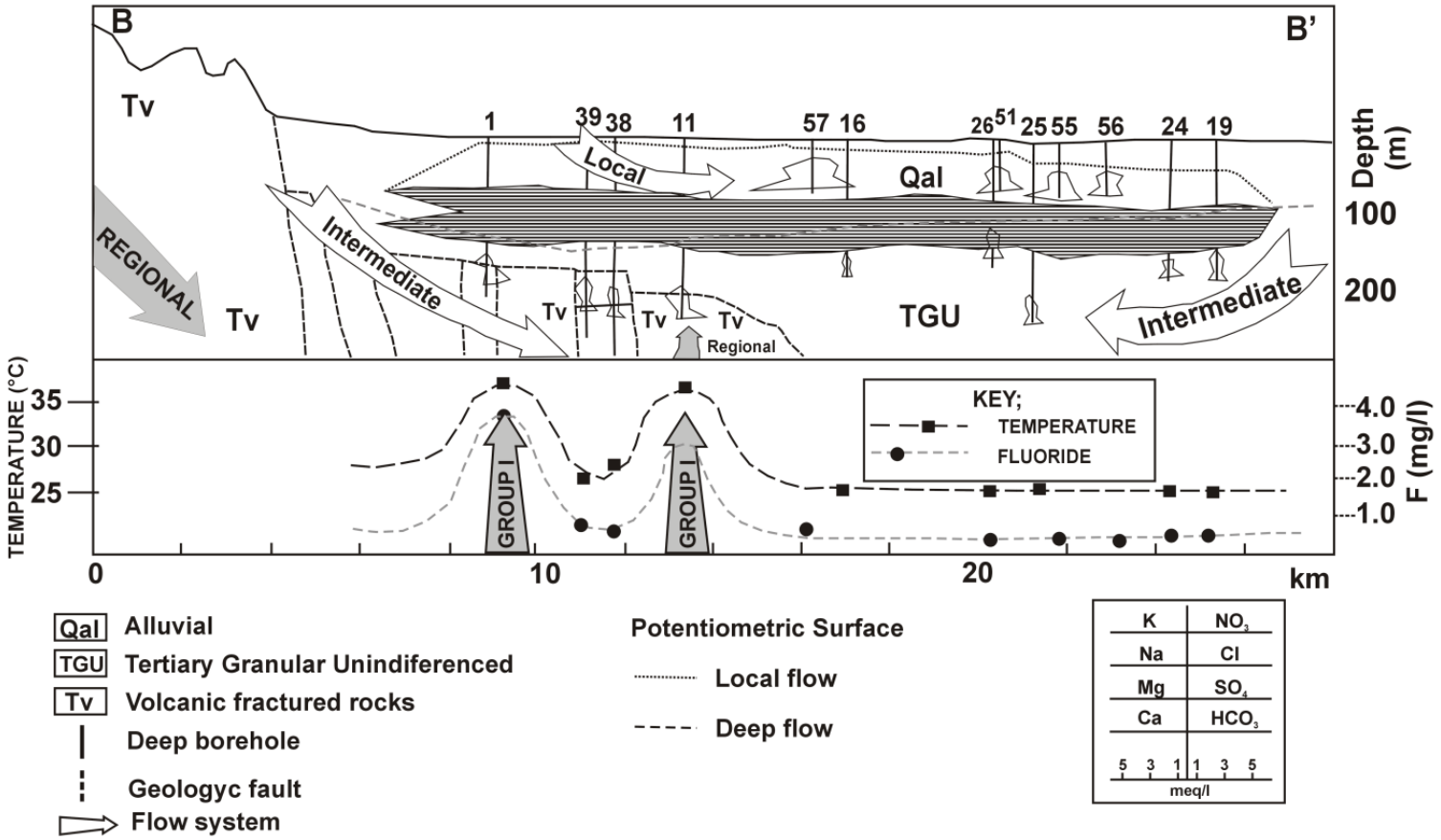


Physical and chemical response of water quality with extraction time (Carrillo-Rivera et al., 1996; 2008)

BACKGROUND


Relation of borehole depth vs GW temperature
Temperature at discharge (°C)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
50
100
150
200
250
300
350
400
450
500
Boreholes depth (m)
Increasing depth

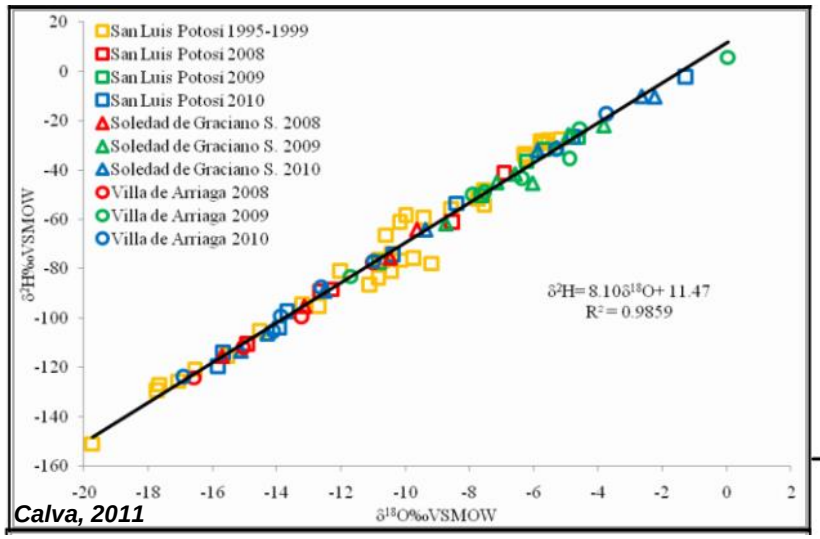
Background



Conceptual model for hydrogeological functionning in San Luis Potosi (Carrillo-Rivera and Cardona, 2008)

Achievements

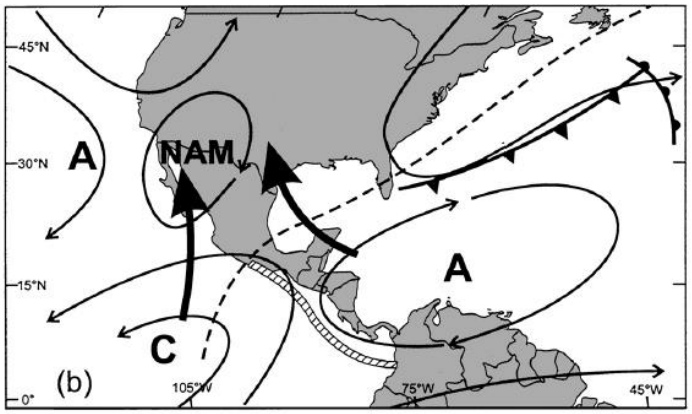
Definition of Recharge: δ18O, δ2H in rainfall

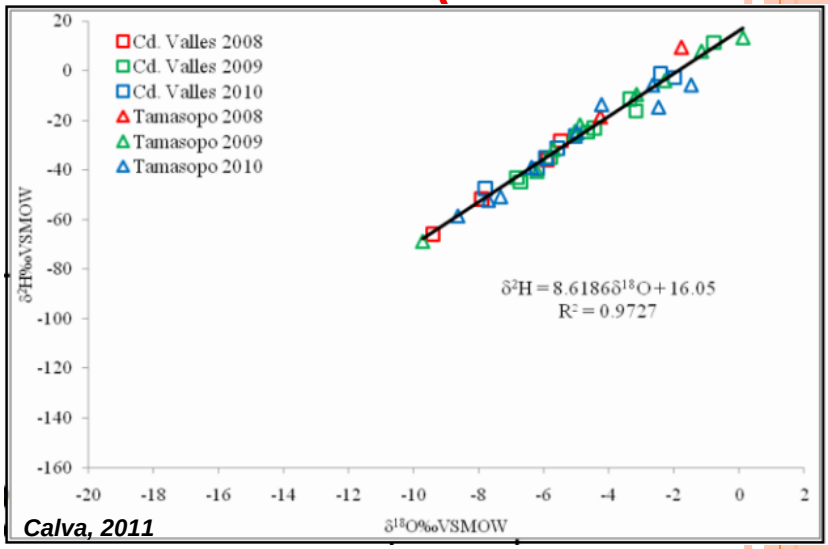


Depleted values towards the west

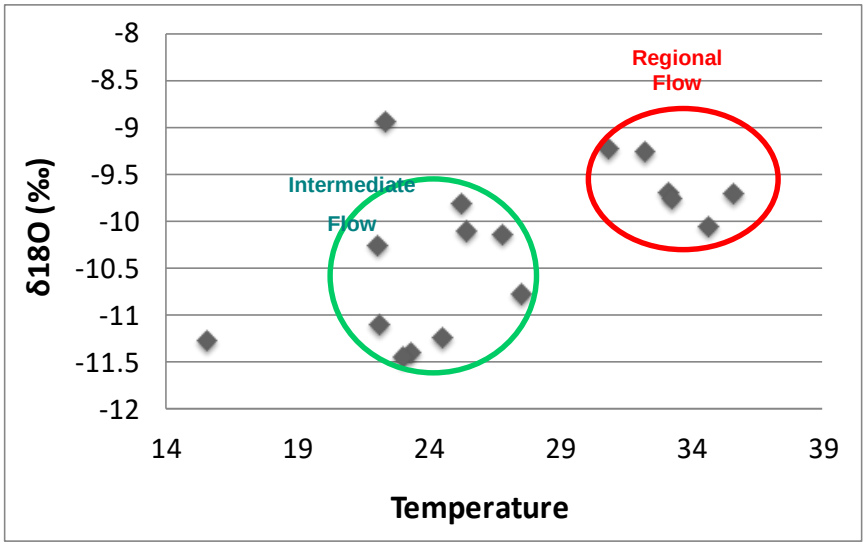
Major features of atmospheric circulation over Mexico (summer) (Metcalfe et al., 2000)

main moisture sources

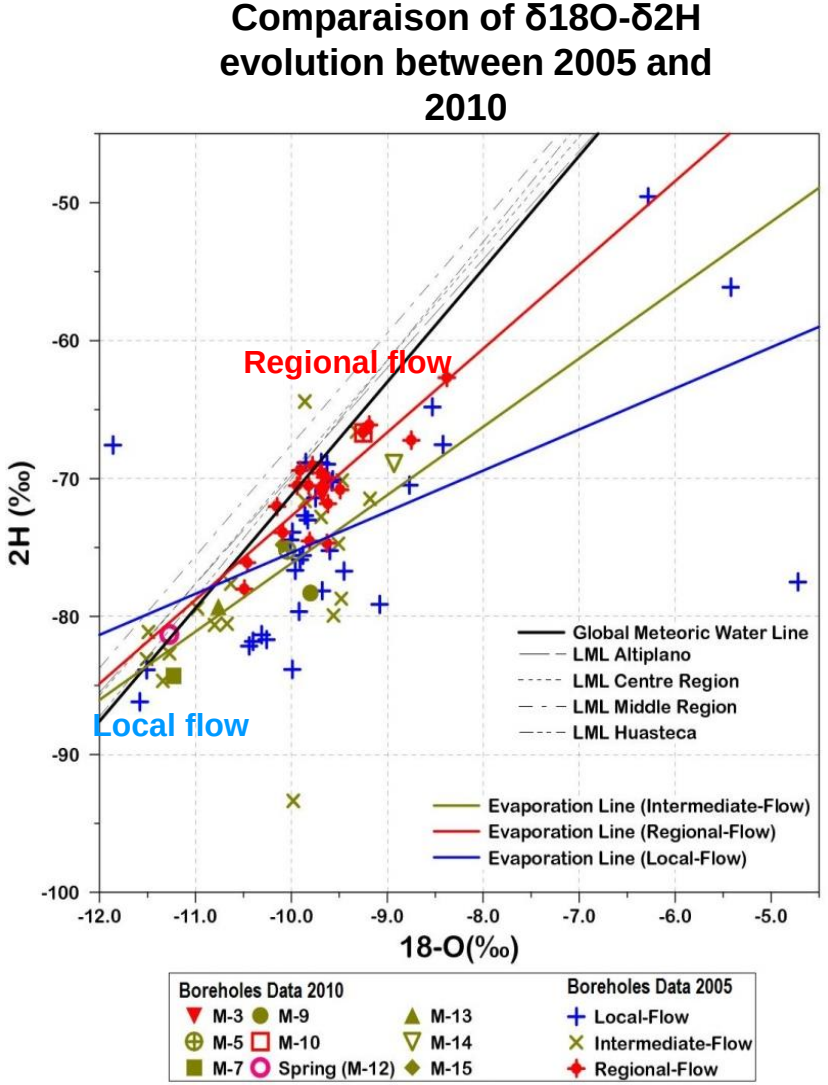




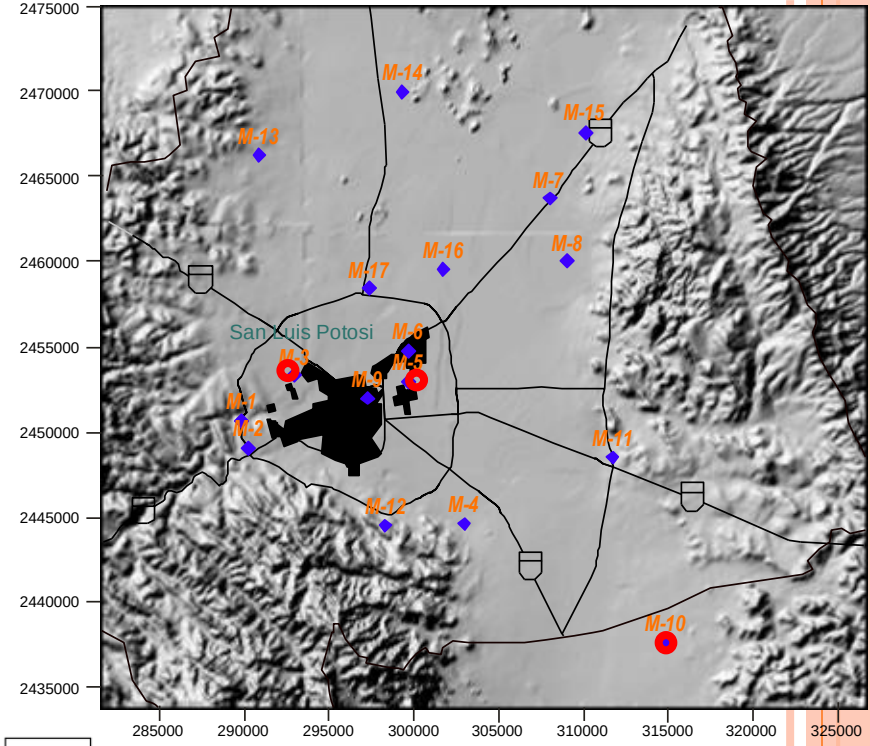
DEFINITION OF RECHARGE: Stable isotopes in GW

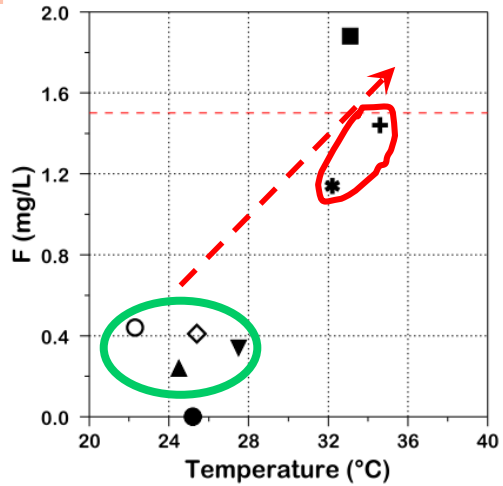


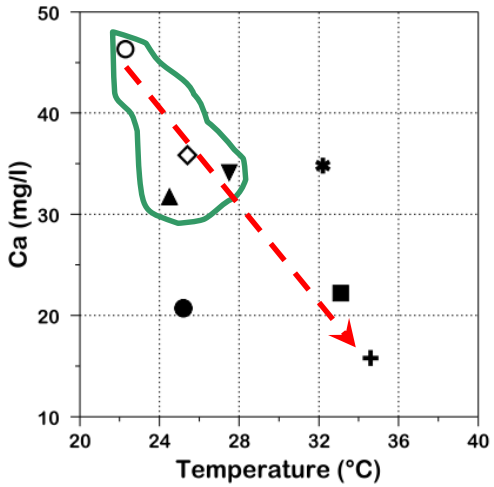
Peñuela-Arévalo, 2013

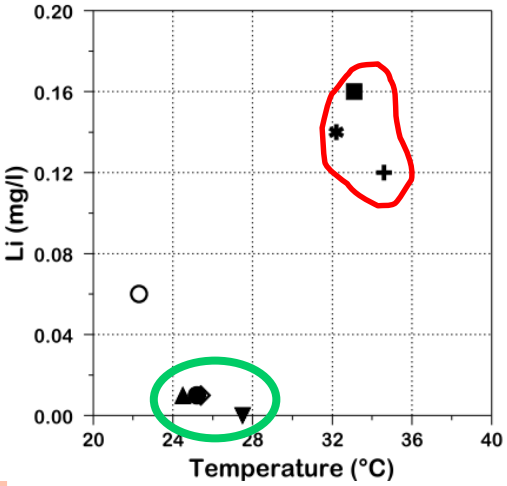


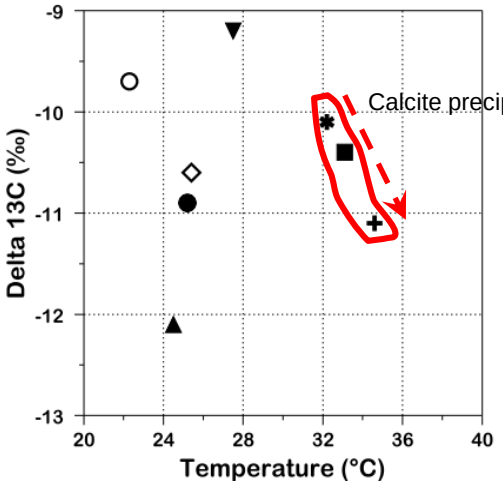
Physico-chemical patterns



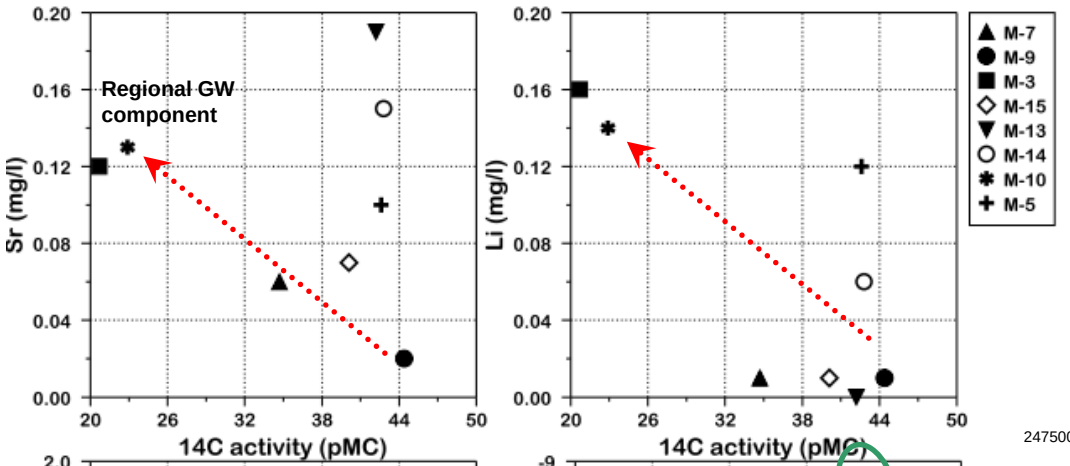


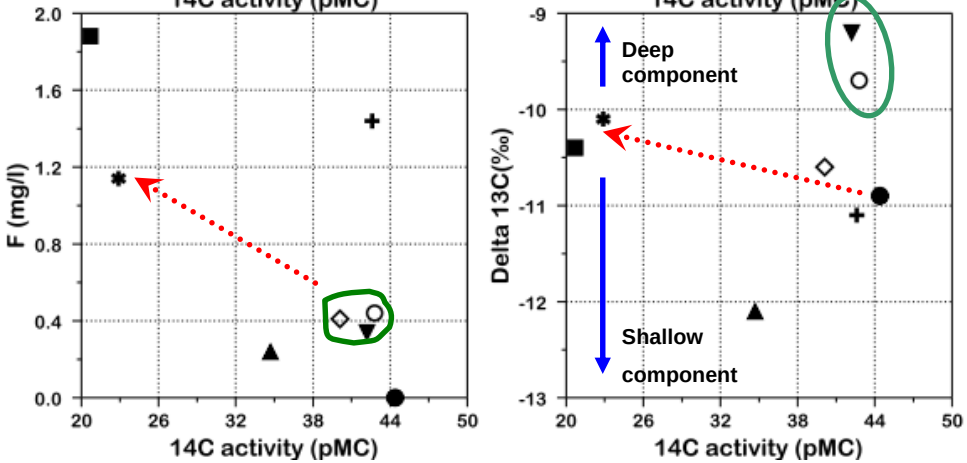


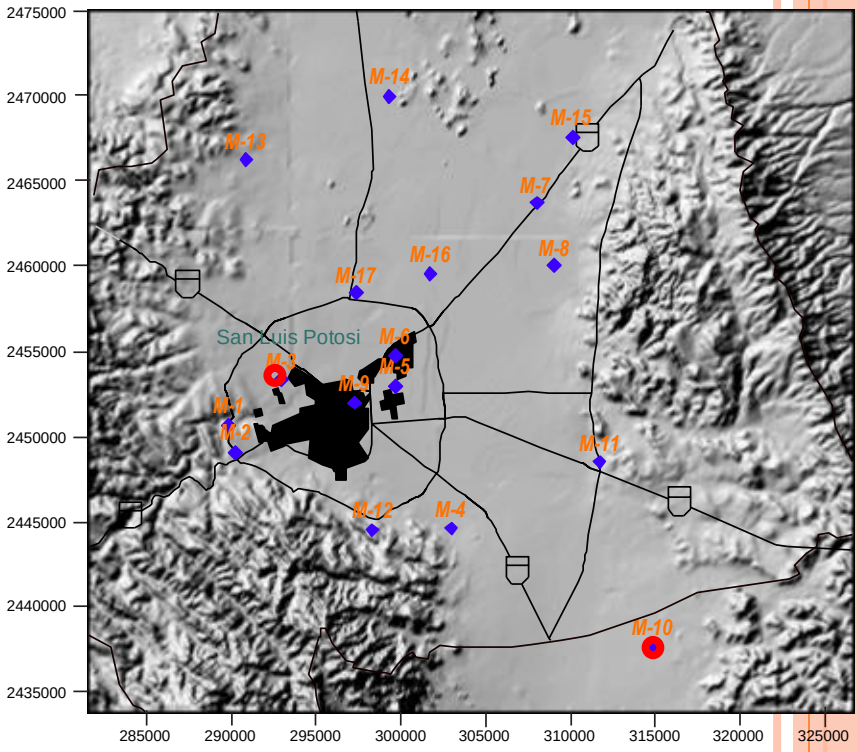




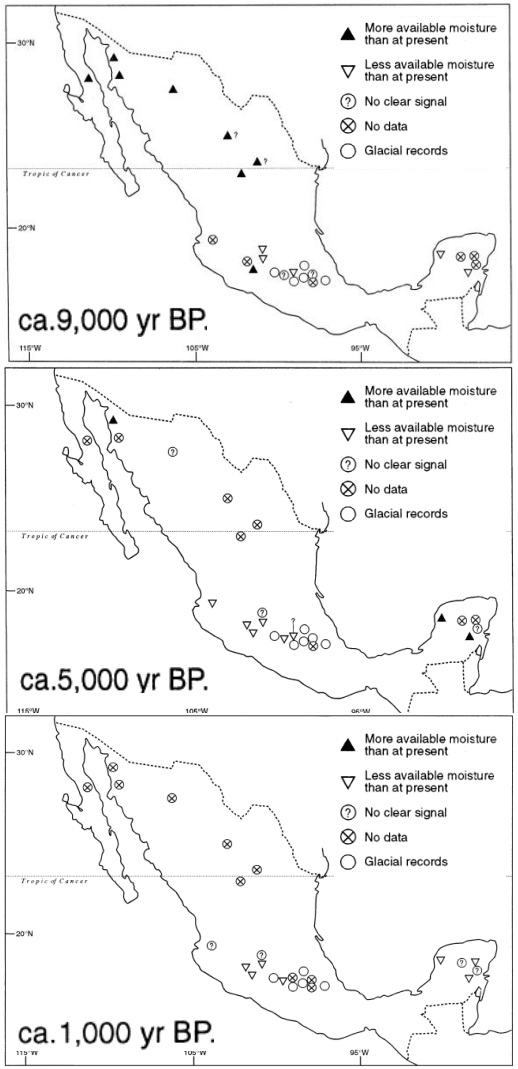
Chemical patterns vs 14C activity



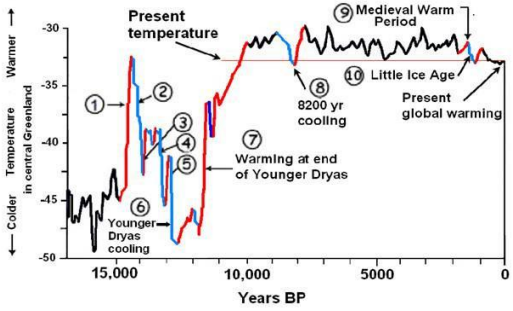


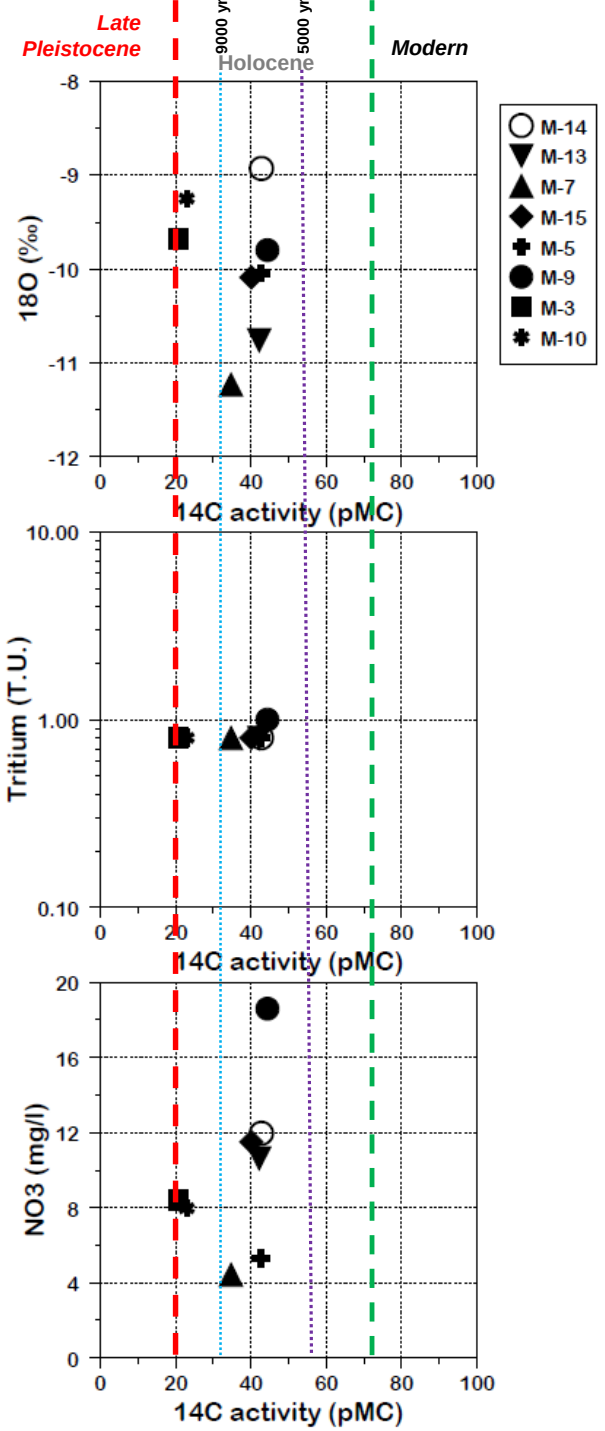


STABLE ISOTOPES VS 14C



Samples	*Corrected age (mixing model)*
M-3	6,496
M-5	1,277
M-7	4,975
M-9	2,074
M-10	5,319
M-13	1,093
M-14	1,400
M-15	2,300





Reconstructed moisture status, wetter or drier than present, time intervals based on uncalibrated 14C (Metcalfe et al., 2000)

CONCLUSION & RECOMMENDATION

✓ **Isotopes analyses (δ18O, δ2H, 3H, 14C, δ13C) have to be used in parallel with geochemical and hydrogeological studies to assist in defining groundwater functioning.**

✓ **Groundwater natural tracers (F, Li, temperature), are recommended as a routine tool for assessing intensive extraction.**

✓ **Reliable groundwater conceptual model (which considers the aquifer units are hydraulically connected) are strongly recommended to be the routinely required tools for assessing intensive groundwater extraction.**

Thank you for your attention

Any question?