

Selected Achievements in the Last 50 Years

Thermodynamic theory/data

- Equilibrium applications
- Limitations: kinetics, reactive surface areas, redox
- Solid-solutions, sorption and trace element processes



Hydrochemical Facies Concept

- Hydrological information in geochemical distributions
- Distinct recharge waters
- Chemical evolution along flow paths



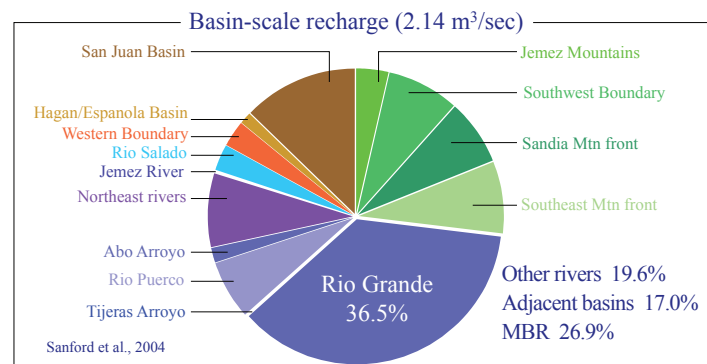
Tracers of flow and reactive processes

- 2H , 18O , Cl , Br , Temp, noble gases...
- Major & trace elements, isotopes of C , N , S , Sr , Ca , B , Fe , Cl , Li ...
- Compound-specific isotopes

Recharge and Flow Modeling: Middle Rio Grande Basin Aquifer System

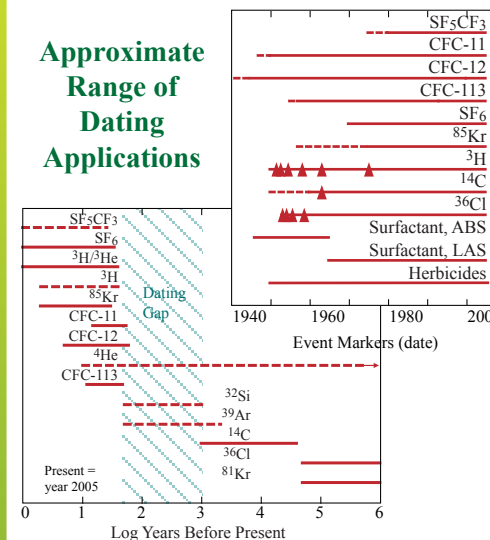
Environmental tracers used to quantify mountain-front recharge, characterize river-aquifer interaction, and improve knowledge of the flow system

- Stable isotopes • Water comp. • ^{14}C data • Dissolved gases



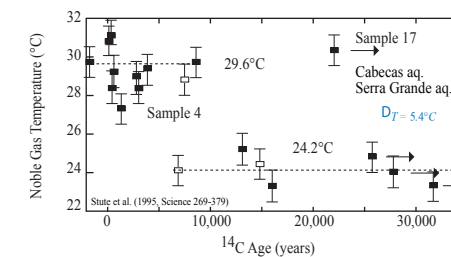
Dating Techniques

Approximate Range of Dating Applications

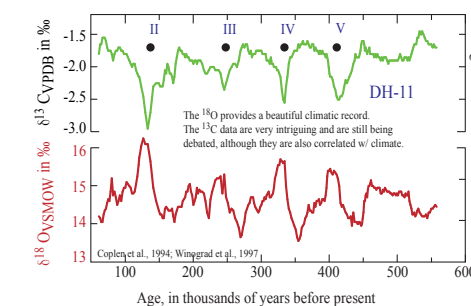


Examples:

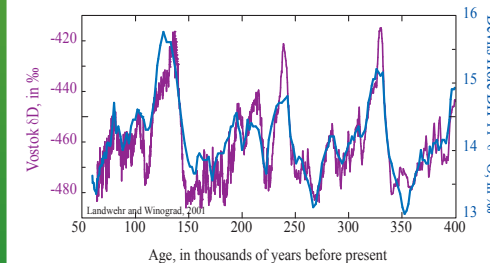
Lowland Brazil ground-waters: noble gas temp. record



Devil's Hole, Nevada, climate record.



Vostok ice core vs. Devil's Hole calcite core



Drivers for Progress

Improvements in Ground-Water Characterization

- Representative sampling, (water, colloids, solids, microbial communities...)
- Need for micro-sampling
- Minimization of dispersion and diffusion effects => more information
- Cheaper sampling and analysis

Advances in measurement capabilities => more data

"Nothing tends so much to the advancement of knowledge as the application of a new instrument."

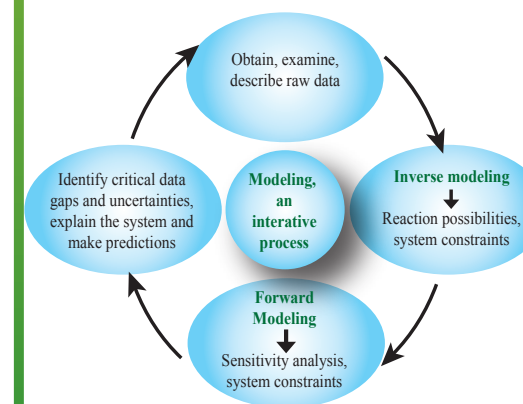
--- Sir Humphrey Davy 1778-1829

Advances in computer technology and availability => data storage and analysis.

"I think there's a world market for 5 computers"

--- T. Watson Sr., 1943

Advanced analysis and synthesis of data and theories => Modeling.



Example of modeling and data analysis. Pinal Creek Basin: site of acidic metal contamination. Glynn and Brown, 1996

Future of Ground-Water Chemistry

Some Needed Research Areas:

- Advances in sampling and in analytical techniques
- GW/SW/G&ST coupling and reactions
- Heat, fluid-flow and chemical coupling
- Unsaturated zone geochemistry
- Reaction kinetics
- Compound specific isotopes; noble gas isotopes
- Microbes and geochemistry
- Charact. of organics, incl. natural proteins, hormones, enzymes and degradates
- Colloids (formation, transport & decay)

"Special Need" Hydrogeologic Environments:

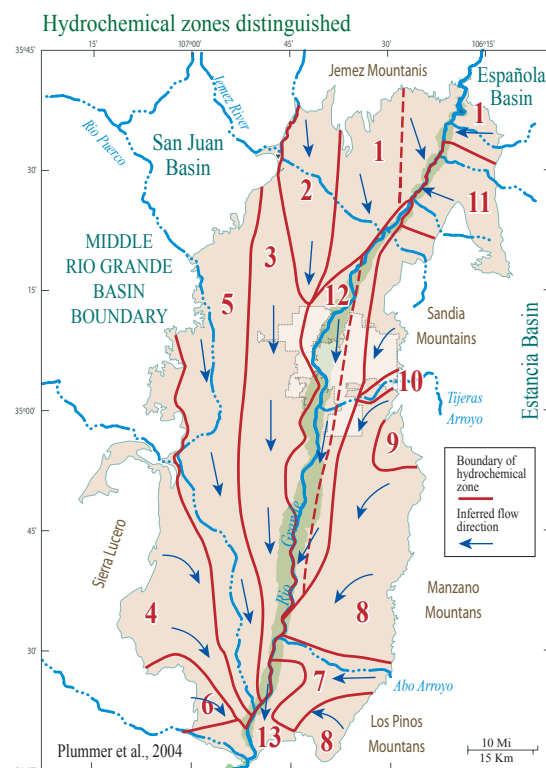
=> Greater process understanding and new techniques

- Fractured rocks and karst
- Aquitards and confining units
- Deep ground-waters
- Geothermal
- Permafrost
- Subglacial
- Coastal
- Submarine
- Extra-terrestrial

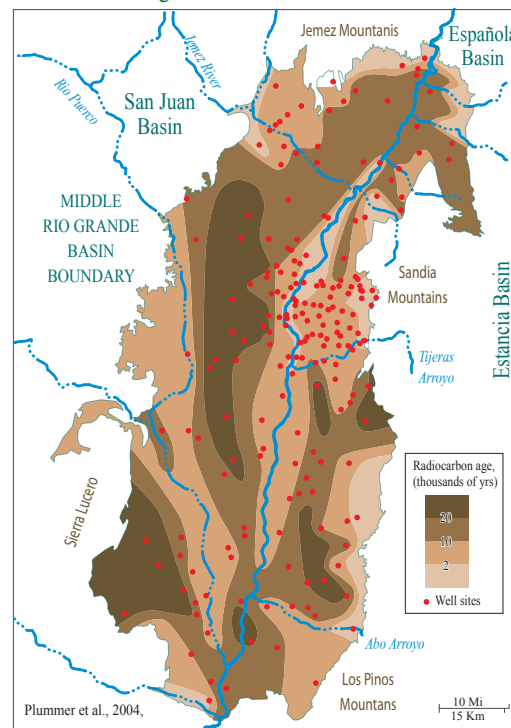
The Thermodynamic System Solution

Description of mass and energy fluxes:

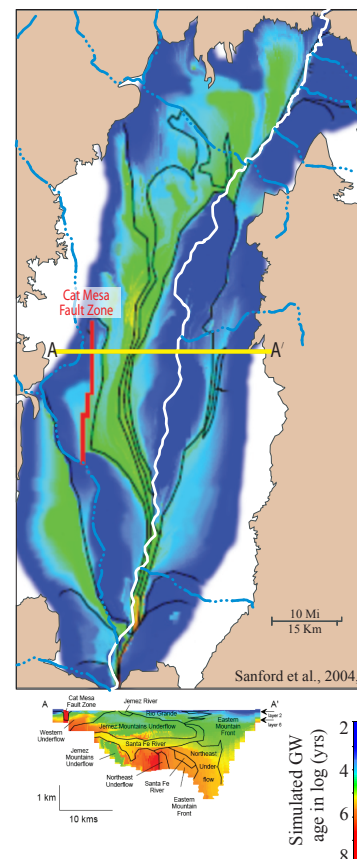
- Comparison of different processes (hydrologic, chemical, biologic, tectonic...)
- Comparison across spatial and temporal scales
- Information synthesis
- Analysis of open-system thermodynamics and dissipative structures (order and pattern creation, destruction, regeneration...)



Observed ^{14}C Ages



Simulated flow-model ages (50 to 100 m below the water table: productive part of the aquifer.)



The 250 uncorrected ^{14}C ages are reliable because MRGB is a siliciclastic system with little dilution by dead carbon.

