Preliminary Interpretation of Water Chemistry and Groundwater Levels in the Eastern San Agustin Plains and Upper Alamosa Creek, New Mexico

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AQUIFER MAPPING PROGRAM

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ABSTRACT

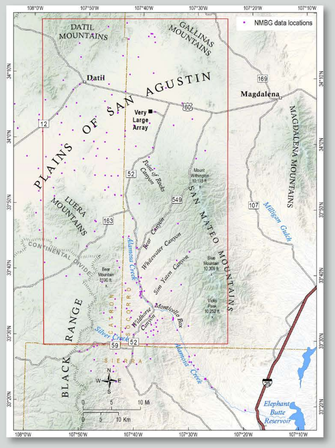
We present a compilation of water chemistry and groundwater level measurements from the eastern San Agustin Plains and the upper Alamosa Creek, NM. The San Agustin Plains forms a closed surface water basin with poorly constrained connections to other basins. The eastern San Agustin Plains are surrounded by the Datil Mountains to the northwest, the Gallinas Mountains to the northeast, Tres Montosa to the east and the northern San Mateo Mountains to the southeast. The C-N embayment of the eastern San Agustin Plains extends the between Luera and northern San Mateo Mountains. A low surface water divide separates the C-N embayment and the upper Alamosa Creek drainage. We define upper Alamosa Creek from its headwaters at the surface divide with the C-N embayment to just beyond the Monticello Box upstream of the village of Monticello.

Both the eastern San Agustin Plains and upper Alamosa Creek occupy normal-fault bounded basins. The uppermost units of the San Agustin Plains consist of sandy basin fill, with thick playa-lacustrine deposits in the C-N embayment. The Alamosa Creek aquifers are in alluvium. Uplands surrounding these basins are underlain by ignimbrites, volcaniclastic sediment and lava flows associated with the Mogollon-Datil volcanic field, which may have high transmissivity fractured zones. Overlapping calderas exist at the boundary of the C-N embayment and upper Alamosa Creek

We sampled groundwater levels, major ion and trace element chemistry, and environmental tracers including O and H isotopes, carbon-14 and tritium. Groundwater levels have low gradients in the eastern San Agustin Plains. Between the C-N embayment and upper Alamosa creek, there is a steep groundwater gradient. The upper Alamosa Creek groundwater levels mimic topography. The steep gradient between the upper Alamosa Creek and the C-N embayment suggests a very low transmissivity zone.

Trace element and major ion chemistry suggests there is little connection between the San Agustin Plains and Alamosa Creek. Major ion chemistry results have dominant Ca to Na and HCO_3 to SO_4 concentrations with slightly lower Ca and higher Na concentrations in the eastern San Agustin Plains, relative to the Alamosa Creek drainage. Concentrations of trace elements appear to be correlated with faults and caldera margins in the both areas. Trace elements are zoned by underlying structures and geology.

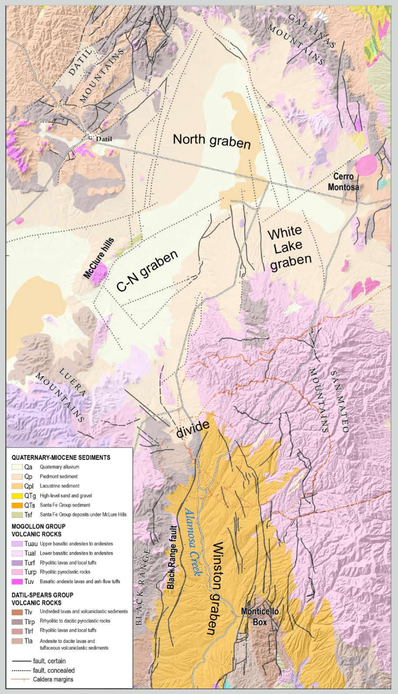
The ^{14}C groundwater ages show relatively "old" water (>10,000 years on average) in the eastern San Agustin Plains, while upper Alamosa Creek samples are mostly younger. These ages are supported by the presence of tritium (groundwater ages <50 y) in the Alamosa Creek waters and the lack of tritium in the eastern San Agustin Plains. The isolation of aquifers of the eastern San Agustin Plains from Alamosa Creek is also supported by lighter $\delta^{18}O$ values in the San Agustin Plains groundwater, and heavier $\delta^{18}O$ values in the Alamosa Creek groundwater.



PHYSIOGRAPHY

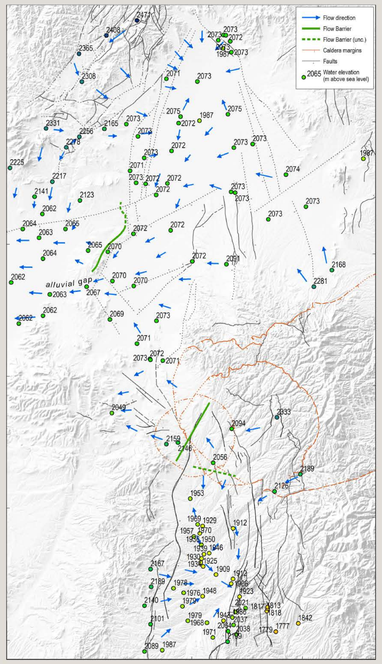
- Study area encompasses the eastern Plains of San Agustin as well as upper Alamosa Creek. The former is a topographically closed basin, whereas the latter drains southeastward into Elephant Butte Lake.
- Alamosa Creek is ephemeral except for a perennial reach in the Monticello Box, which is in a structural high underlain by low-permeability volcanic rocks.
- The perennial reach is fed by fault-controlled warm springs just west of the Box, as well as from basin-fill seeps immediately west (up-gradient) of the structural high.

GEOLOGY



- The eastern San Agustin Plains is underlain by three fault-bounded structural grabens, which are labeled above.
- Being about 3,600–3,800 ft deep, the C-N graben and the western part of the North graben are the structuraly deepest parts of the eastern San Agustin Plains.
- The upper Alamosa Creek drainage has developed in the west-tilted, northern Winston half-graben, whose basin-fill thickens westward towards the Black Range fault. This basin was probably closed throughout the Miocene, and playa deposits are observed northwest of the Monticello Box.
- Volcanic rocks underlie the Monticello Box, and a fault system extends north from the Monticello Warm Springs towards the caldera margins.
- The volcanic rocks of the Monticello Box and the mountains surrounding the study area belong to the Mogollon-Datil field.
- Lower volcanic strata consist primarily of tuffaceous, very low-permeability volcaniclastic rocks interbedded with intermediate volcanic flows (38–37 Ma).
- Middle volcanic strata generally consist of regionally extensive ignimbrites and volcaniclastic strata (36–32 Ma).
- Overlying a regional unconformity, upper volcanic strata are dominated by high-silica ignimbrites, volcaniclastic sediment, and bimodal volcanic flows of basalt-basaltic andesite + rhyolite (29–25 Ma).
- The topographic divide between eastern San Agustin Plains and upper Alamosa Creek coincides with three overlapping caldera margins. Ferguson et al. (2012).

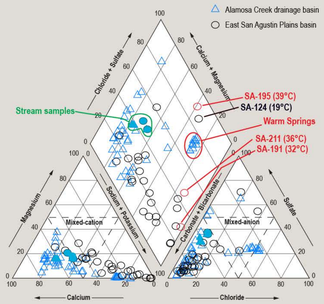
GROUNDWATER FLOW



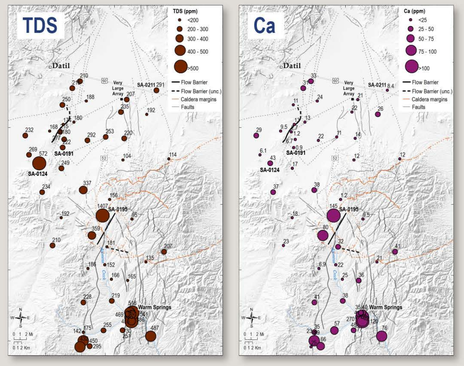
- Eastern San Agustin Plains have generally low groundwater gradients and reflect subsurface structural controls.
- Upper Alamosa Creek groundwater flow mostly reflects surface topography. Possible ancillary fault-controlled path along eastern boundary with outflow at Warm Springs.
- High groundwater elevation gradients exist at boundary between C-N subbasin and the headwaters of upper Alamosa Creek, with divergence of flow directions. This suggests underlying caldera complexes act as flow barrier.
- Eastern San Agustin Plains generally drain to the west. Flow is funneled through shallow alluvium with fault controlled divide in the west-central region, and possibly along faults and fractured volcanics in the west-southerly region.

MAJOR ION CHEMISTRY

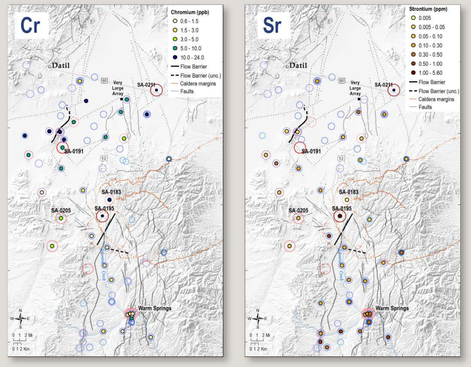
- There does not appear to be increasing ion concentrations along inferred groundwater flow paths.
- Patterns of concentrations of major ion constituent such as Total Dissolved Solids (TDS), calcium (Ca), sodium (Na), and sulfate (SO_4) contrast between the east San Agustin Plains region and the Alamosa Creek drainage.
- The notable differences in major ion chemistry concentrations between the east San Agustin Plains region and the Alamosa Creek drainage suggest these two regions are not well-connected via shallow groundwater flowpaths.
- Locations of high major ion content, such as SA-0211, SA-0195, and the Warm Springs cluster, are correlated structural influences on the groundwater source, potentially indicating warm deeper brines traveling upwards along faults or caldera margins.



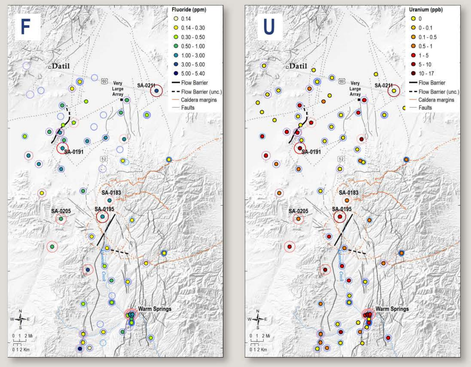
- Piper diagram shows higher calcium concentrations in the Alamosa Creek, with higher sodium concentrations in the east San Agustin Plains. This may reflect the occurrence of clays within the east San Agustin Plains region in playa and distal alluvial fan deposits. Bicarbonate is the dominant anion for most of the sampled waters. Structure-influenced and warm waters have higher chloride and sulfate concentrations.



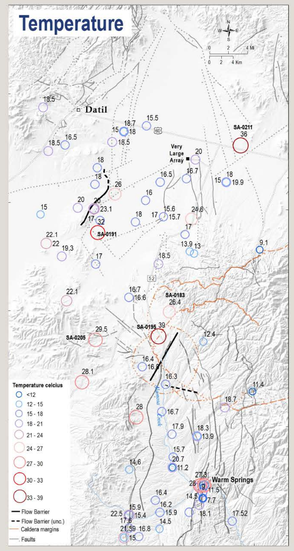
TRACE CHEMISTRY



- Chromium: Very low concentrations (1 ppb) found in Alamosa Creek, highest found at caldera margins and flow-impeding faults in San Agustin Plains. Away from structures in San Agustin Plains, intermediate concentrations found (5–10 ppb).
- Strontium: Moderate values found in Alamosa Creek, highest located near caldera margins. Lowest values found away from structures in San Agustin Plains. Supports higher sorption of cations in San Agustin Plains relative to Alamosa Creek.



- Fluoride: Highest concentrations found near caldera margins and flow-effecting faults. Otherwise, shows increases in concentration with flow path. Supports flow paths and may highlight recharge in fractured rocks.
- Uranium: Highly variable concentrations found throughout, with highest concentrations located in or around shallow volcanic rocks, caldera margins or fault zones.



- Temperatures greater than 30°C are found at
  - The junction of three calderas (SA-0195),
  - The transfer zone of basin bounding faults of the western and the eastern San Agustin Plains (SA-0191),
  - Along eastern boundary of the eastern San Agustin Plains (SA-0211)
- Temperatures between 25°C and 30°C are found at
  - Northern caldera margins (SA-0183), and
  - The northern Black Range and Luera Mountains (SA-0205).
- The San Agustin Plains, groundwater temperatures are
  - Close to uniform (16-18°C) in the central basin, and
  - With higher temperatures along southwestern, western and southern boundaries.
- Temperatures greater than 30°C are found at
  - The junction of three calderas (SA-0195),
  - The transfer zone of basin bounding faults of the western and the eastern San Agustin Plains (SA-0191), and
  - Along eastern boundary of the eastern San Agustin Plains (SA-0211).

ACKNOWLEDGMENTS

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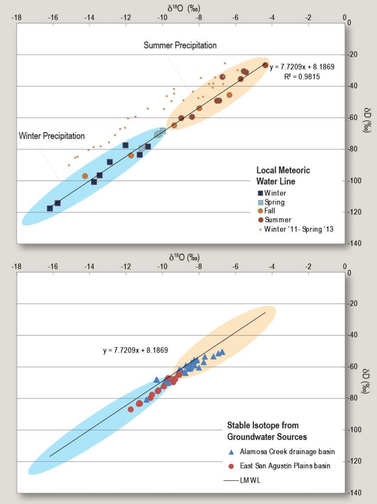
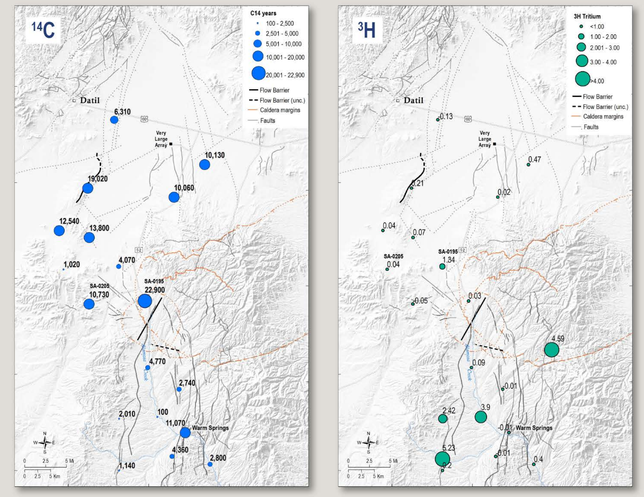
STABLE ISOTOPES

- Precipitation
  A local meteoric water line was plotted.
  - Collected precipitation samples from five sites from fall '09 through 2014.
  - Scattered around study area at different elevations.
  - Amalgamated samples analyzed every three months, coinciding with the changing of seasons.
  - Anomalous trend recorded from Winter '11- Spring '13.
- San Agustin Plains and Alamosa Creek drainage basin show two trends.
- Alamosa Creek drainage basin
  - Isotopic composition indicate warmer recharge.
  - Evidence of some evaporation.
- San Agustin Plains
  - Isotopically lighter, more negative values of δD and $\delta^{18}O$.
  - Plots where modern precipitation would indicate cold recharge.
  - Likely indicates recharge from colder periods (Younger Dryas and uppermost Pleistocene).
  - No evaporation trend.



GROUNDWATER AGE

- Carbon 14, ^{14}C: (50–50,000 years) uncorrected ages
  - Average Alamosa Creek apparent age: 3,840 ybp.
  - Average San Agustin Plains apparent age: 11,000 ybp
    - *Oldest sample ~23,000 ybp.*
    - *Older samples at flow barriers (caldera margins and faults).*
- Tritium, ^{3}H: (0–50 years)
  - Presence of tritium indicates younger water.
  - Alamosa Creek drainage basin: highest ^{3}H values.
    - *Young, recent recharge.*
  - San Agustin Plains: little or no ^{3}H detected.
    - *Recharge not occurring near sample sites.*



CONCLUSIONS

- Shallow aquifers of eastern San Agustin Plains and upper Alamosa Creek show distinct and separate patterns of
  - Groundwater flow directions,
  - Major ion chemistry,
  - Trace element chemistry,
  - Stable isotopes, and
  - Distribution of groundwater ages.
- Caldera margins and some fault/transfer zones are
  - Barriers to shallow lateral flow, and
  - Pathways for upward-flowing warm waters.
- Caldera margins are associated with the oldest waters, high water temperatures, high major ion concentrations, and high trace element (Sr, F, U) concentrations.
- The fault bounding the north-western C-N graben focus flow through alluvial gap, and has high water temperatures and high trace element (Cr, F, somewhat U).
- Some faults in Alamosa Creek and along southwestern San Agustin Plains (due west of caldera complexes) may focus lateral flow to the south and west, respectively.
- Major ion chemistry concentrations and Sr concentrations are consistent with greater sorption by clay minerals in San Agustin Plains than in Alamosa Creek.

Eastern San Agustin Plains and Alamosa Creek show little subsurface connectivity. Boundaries for lateral flow are structural features (caldera margins and basin-bounding faults). These features also serve to focus lateral flows within each basin.

In eastern San Agustin Plains significant evidence exists for westward flow out of the basin in the alluvium, through the Luera Mountains. Most recharge likely occurred during snow-dominated wet periods at 10 ka and earlier. Proportionally little modern recharge indicated by water chemistry or flow paths.

In Alamosa Creek, groundwater is less saline and younger. Groundwater flow is topographically controlled, with some possible structural controls indicated in upland valleys. Groundwater flow in center of valley is likely shallow and relatively fast.

ArcGIS, illustrations and design by Brigitte Felix