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# An investigation of vertical mixing between two carbonate aquifers using a multiport monitor well, central Texas

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## 1. INTRODUCTION

- Edwards and Trinity aquifers are two carbonate aquifers that are important groundwater resources for south-central Texas providing for human and ecological needs.
- The Trinity aquifer is increasingly being developed as an alternative to the Edwards aquifer.
- Currently, the Edwards aquifer is being overdrawn and the Trinity is being developed to alleviate demand on the Edwards. It is commonly assumed that there is limited interflow from the Trinity to the Edwards, but there is limited scientific evidence to support this understanding.
- **Research Question:** Is there a hydraulic connection between the Trinity and Edward aquifers?
- This question was addressed by monitoring head pressure and water compositions (major ions and Sr isotopes) in two multiport wells that access the Edwards and Trinity aquifers in similar locations.
- **Key Findings:** Vertical communication is possible between the uppermost units of the Trinity and Edwards aquifers suggested by the presence of distinct hydrochemical facies and water level variations.

## 2. STUDY SITE

- The two multiport wells are located in the Recharge and Confined zones of the Edwards aquifer and sample similar hydrostratigraphic units (Fig. 1a).
- Faulting can allow vertical communication between aquifers and offset units of the Edwards and Trinity possibly resulting in lateral communication (Fig. 1b).

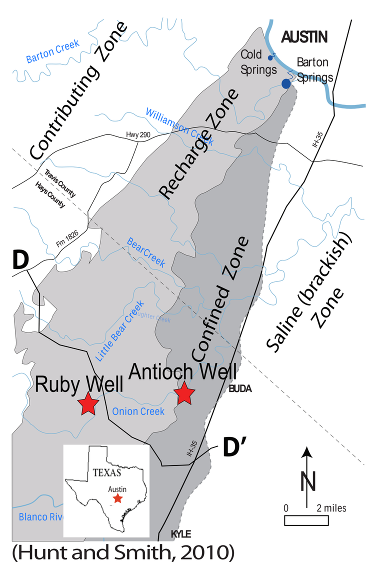


Figure 1a. Location of the Antioch and Ruby Ranch multiport wells.

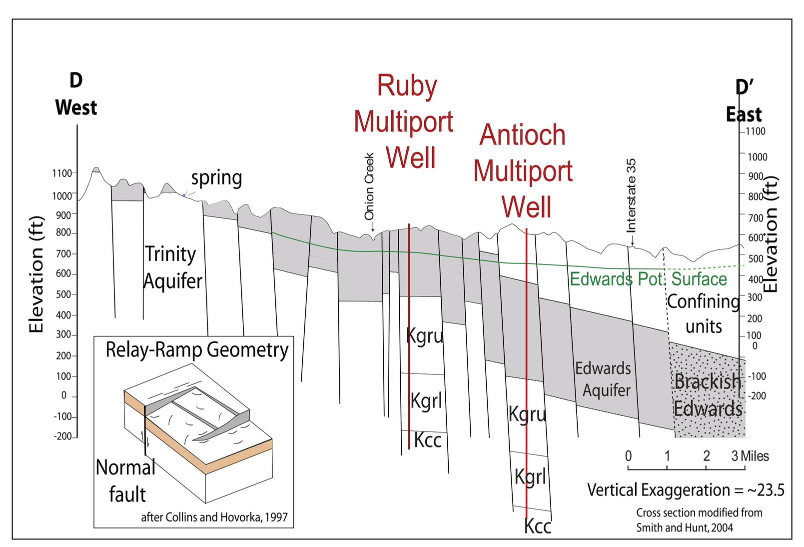


Figure 1b. Crossection from D-D' of the Antioch and Ruby Ranch Westbay wells. Kgrl and Kgru are Glen rose units. The ramp schematic illustrates how zones could be in lateral communication.

| Hydrologic Function | Group, Formation | | Member | Lithology |
|---|---|---|---|---|
| Confining Unit | Edwards Group | | Buda Limestone | hard nodular limestone |
| | | | Del Rio Clay | clay, fossiliferous |
| | | | Georgetown Formation | marly limestone |
| Edwards Aquifer | | Pearson Formation | Leached and Collapsed Members | crystalline limestone, mudstone to grainstone, chert, and collapsed breccia |
| | | | Regional Dense Member | dense argillaceous mudstone |
| | | Kainer Formation | Grainstone Member | mudstone to wackestone, and chert |
| | | | Kirschberg Member | evaporites and crystalline limestone, chalky mudstone, and chert |
| | | | Dolomitic Member | mudstone to grainstone, crystalline limestone, and chert |
| | | | Basal Nodular Member | shaly, nodular limestone, mudstone, and miliolid grainstone |
| Trinity Aquifer | Upper Trinity | | Upper Member Glen Rose Limestone | evaportie beds, thinly bedded limestone and marl |
| | Middle Trinity | | Lower Member Glen Rose Limestone | fossiliferous limestone, dolomite, marl, and shale |
| | | | Hensel Sand | clay, silt, sand, conglomerate, and thin limestone beds |
| | | | Cow Creek Limestone | many fossils, white to gray argillaceous and dolomitic limestone with some shale and sand |
| | | | Hammett Shale | fossiliferous, dolomitic shale |

Figure 2. Detailed stratigraphy of the Anitoch multiport well adapted from Maclay and Small,1986 and Ashworth, 1983.

## 3. METHODS

- Advanced well technology was used in this study, because it is difficult to determine the existence and extent of connectivity between distinct hydrostratigraphic units using typical well placements (Fig. 3).
- Groundwater was sampled from each zone and water levels were measured over a two week interval from May to June 2011 for the Antioch Well.
- This groundwater was analyzed for major ions and strontium isotopes ($^{87}Sr/^{86}Sr$), which have application to tracing groundwater sources.
- Sr isotopes were measured in the Department of Geological Sciences using a Triton Thermal Ionization Mass Spectrometer.
- The values obtained were compared to values from the the Ruby Ranch Well that were collected from 2009-2011.

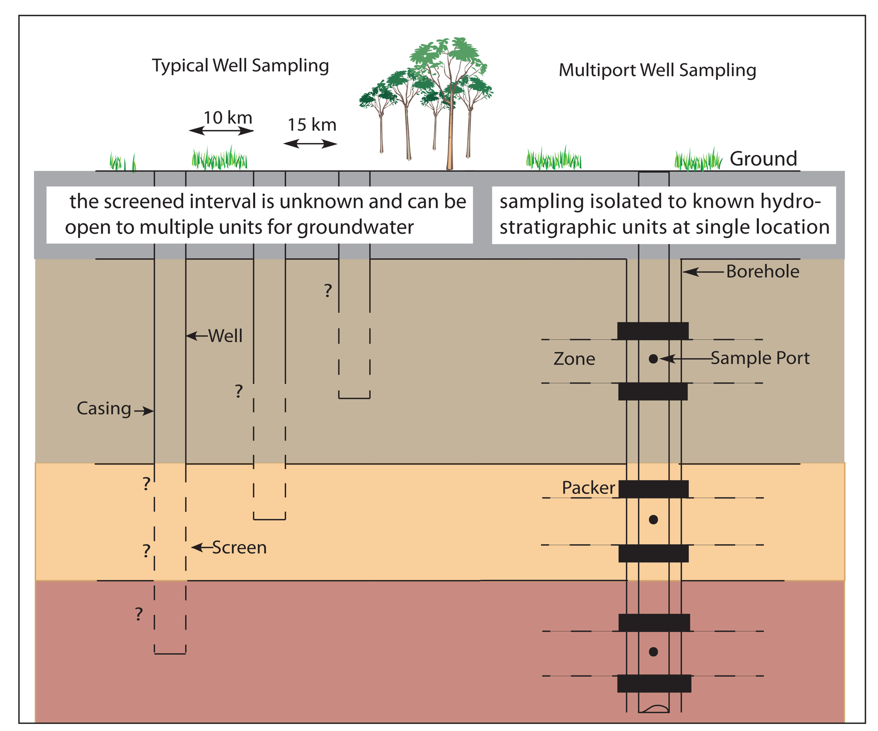


Figure 3. Illustrates how typical well sampling occurs at multiple wells and from various unknown units. Multiport Well Sampling uses a single location with isolated units (zones) to sample groundwater.

## 4a. RESULTS

- During drought conditions water levels in the Upper and Middle Trinity decline slightly, except for the uppermost units of the Upper Trinity. Water levels in the Edwards declined drastically, and were lower than those of the Upper and Middle Trinity during drought conditions.

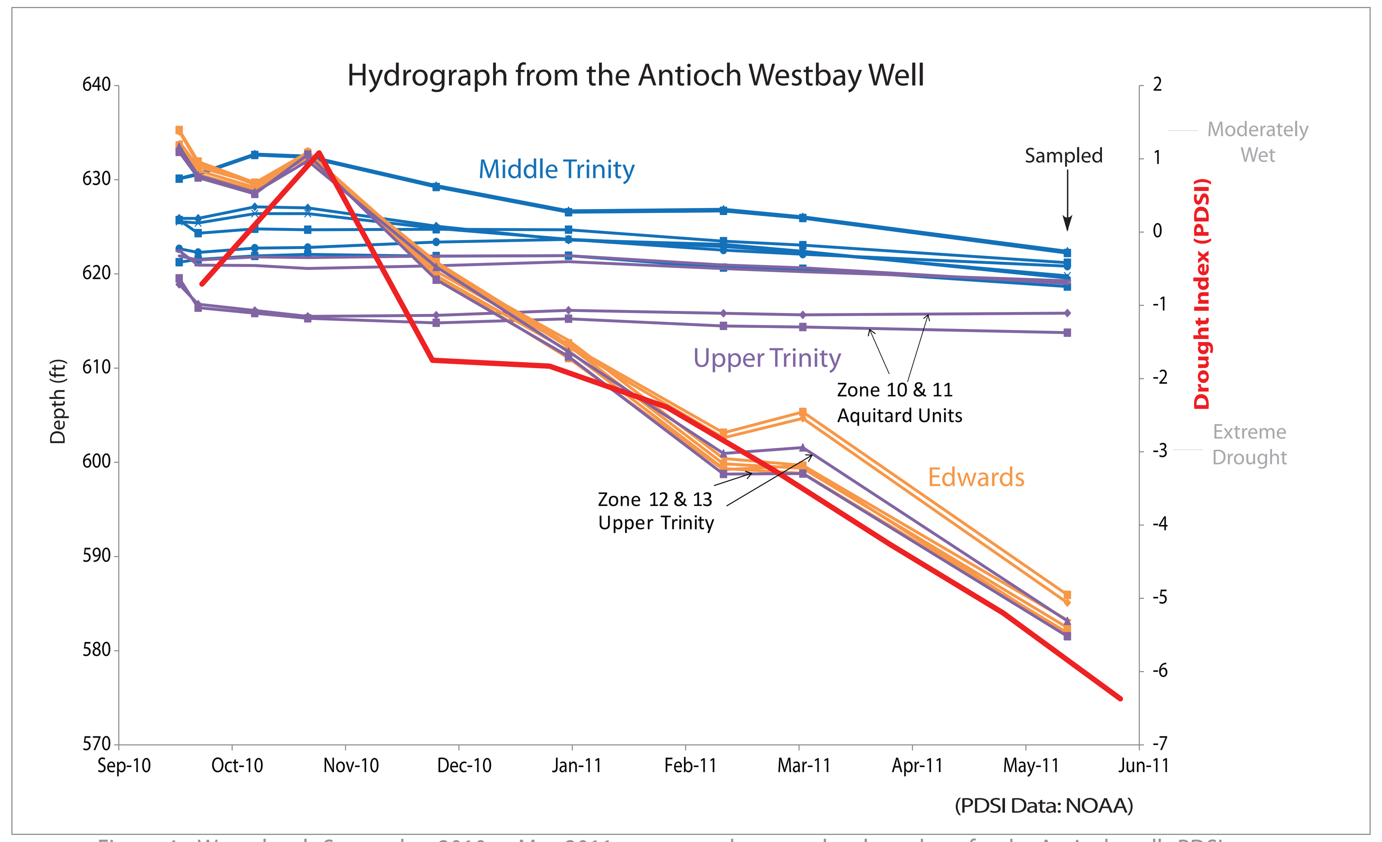


Figure 4. Water levels September 2010 to May 2011 as meters above sea level are show for the Antioch well. PDSI (Palmer Drought Severity Index) indicates the severity of drought.

- Temporal variations in hydrostatic pressure were similar in the Edwards and the upper zones of the Upper Trinity, and distinct from the rest of the Upper Trinity and the Middle Trinity. As drought conditions intensified, hydrostatic head pressure was greater in Middle Trinity units relative to Upper Trinity and Edwards units. This head difference could allow for vertical flow among boundary units in the Edwards and Trinity Aquifers. Some portions of the Trinity behave as an aquitard, providing hydrologic separation between the Edwards and lowermost Trinity units (Fig. 4).

## 4b. RESULTS CONTINUED

- Three geochemical facies were detected: Ca-$HCO_3$ (Edwards), Ca-$SO_4$ (Trinity – Glen Rose), and Ca-$HCO_3$-$SO_4$ (Trinity).
- There are distinct strontium isotope groupings by each aquifer.

**Vertical Representation of Sr isotopes and Geochemical Facies**

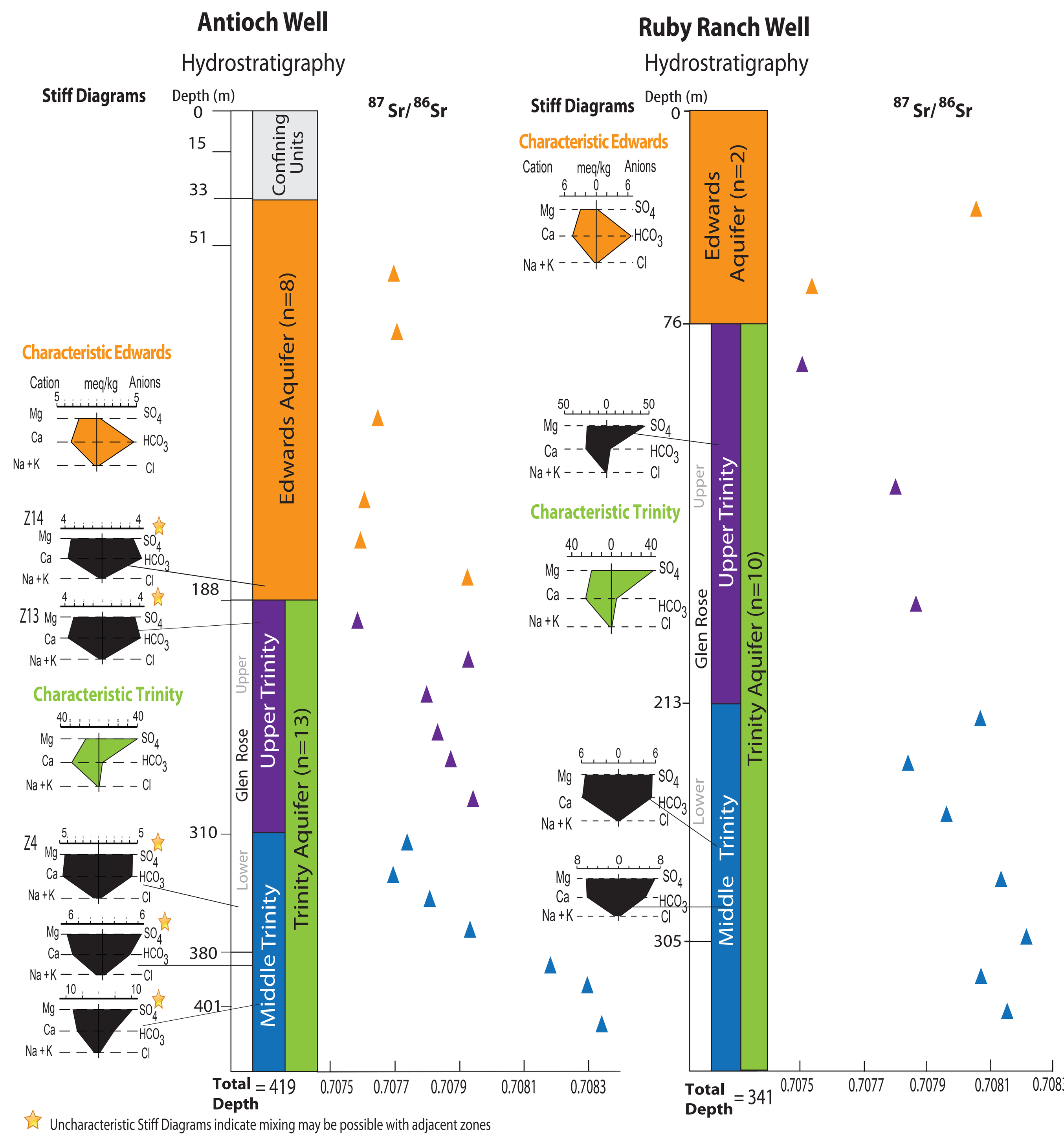


Figure 5. Hydrostratigraphic units of the Antioch well and Rudy Ranch well are shown with Sr isotopes values and major ion compositions represented as stiff diagrams.

- Results from geochemical data are consistent between the two multi-port wells, which suggests that hydrologic and geochemical characteristics of the units are spatially consistent (Fig. 5).
- Stiff diagrams indicate mixing between the lower most member of the Edwards with lower Trinity Units, as they are uncharacteristic of the Edwards and Trinity facies (Z14 &13) (Fig. 5). The stiff diagrams also show that there are characteristic Edwards and Trinity facies.

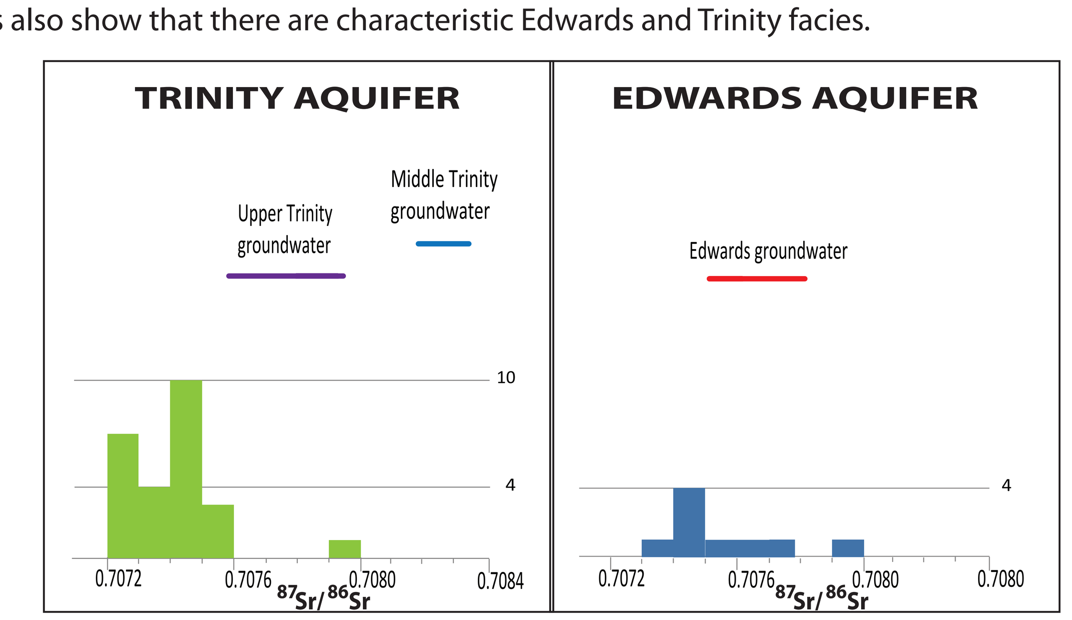


Figure 6. A histogram of Sr isotope values measured for the Edwards and Trinity bedrock are shown along with the range of values measured in groundwater. Sr isotope values in groundwater from the Edwards and Upper Trinity are consistent with those measured in the bedrock, whereas values in groundwater from the Middle Trinity are high relative to the bedrock. Bedrock Sr isotope data was compiled from Musgrove and Banner (2004), Koepnick et al. (1985), Christian et al. (2011), and Wong et al. (2010).

- The histograms from the Edwards and Trinity aquifers show that rock values are similar in the Edwards, and Upper Trinity and cannot account for the difference in $^{87}Sr/^{86}Sr$ values between the two aquifers (Fig. 6).
- Higher $^{87}Sr/^{86}Sr$ values occur in the Middle Trinity possibly due to an increased silisticlastic component in these host units (Hensel Sand and Hammett Shale. Fig. 2), further investigation of the Sr isotope composition of Trinity bedrock units would be necessary to test this hypothesis.

## 4c. RESULTS CONTINUED

- There is a positive linear trend between groundwater $^{87}Sr/^{86}Sr$ values and Sr and $SO_4$ concentrations between the Edwards and some units of the Middle Trinity, which can be accounted for by a two-end-member mixing model. This suggests that groundwater from the Edwards and Middle Trinity are mixing.
- The $^{87}Sr/^{86}Sr$ values from the Glen Rose are consistent with the values of evaporites recovered from the unit. This suggests that $^{87}Sr/^{86}Sr$ values and Sr and $SO_4$ concentrations result from evaporite dissolution.

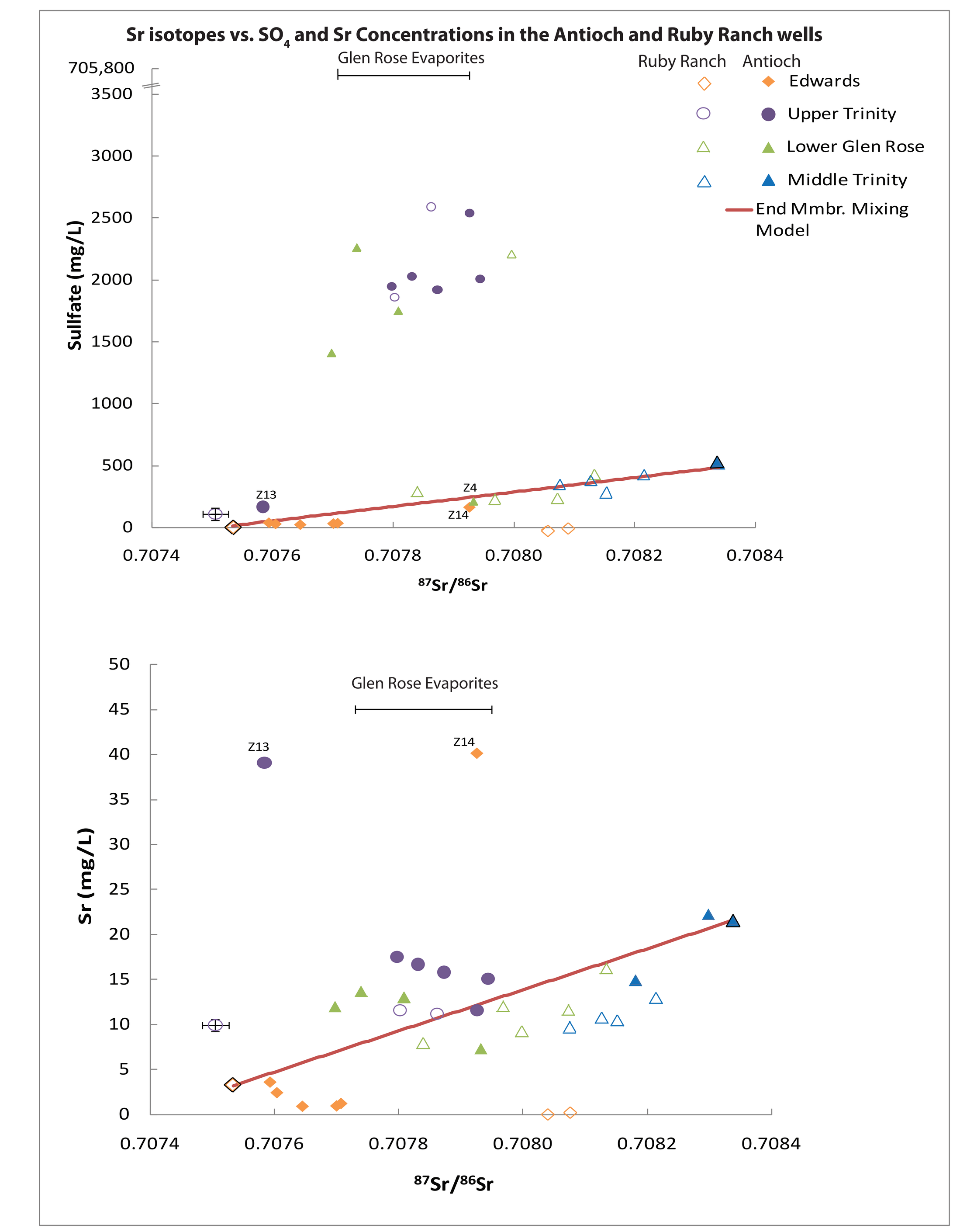


Figure 7. The Glen Rose evaporite line represent Sr isotope values in the evaporites recovered from the Antioch well. A fluid mixing model line (red line) was constructed with the Edwards and Middle Trinity as end members (black outline).

- Covariation of $SO_4$ (and Sr) concentrations and Sr isotopes in groundwater from the Edwards and Middle Trinity suggest that groundwater from these units are mixing. Alternatively, this trend might be a consequence of different processes controlling groundwater $^{87}Sr/^{86}Sr$ values in each aquifer such as: i) groundwater from the Edwards might be a reflection of interaction with Edwards bed rock, ii) evaporite dissolution in the Upper and Lower Glen Rose likely dictates Sr isotope ratios in groundwater from these units, and iii) it is possible that silisticlastic units in the Middle Trinity are responsible for higher Sr isotope ratios of groundwater from the Middle Trinity.

## 5. CONCLUSIONS

- Water-level variations and the presence of distinct hydrochemical facies suggest that vertical flow between the Edwards and Trinity is limited to the uppermost units of the Trinity.
- Covariation of $SO_4$ (and Sr) concentrations and Sr isotopes in groundwater from the Edwards and Middle Trinity suggest that groundwater from these units are mixing by varying extents of the same process. Alternatively, this trend might be the result of groundwater interaction with different bedrock compositions (i.e. Edwards bedrock with lower $^{87}Sr/^{86}Sr$ values and $SO_4$ and Sr concentrations than Trinity bedrock with higher $^{87}Sr/^{86}Sr$ values and $SO_4$ and Sr concentrations associated with silisticlastic components and evaporite minerals, respectively).
- It is critical to understand the extent of interflow from the Trinity to the Edwards before further development of the Trinity. Preliminary results from this study indicate that communication between the aquifers is likely limited to the lower Edwards and upper Trinity, and suggest that independent management of the two aquifers might be possible.

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