Abstract 208316: Isotopic evidence for the origin and evolution of CO_2-rich volatiles from Oligocene to Miocene mantle magmas, southwestern Colorado and northwestern New Mexico

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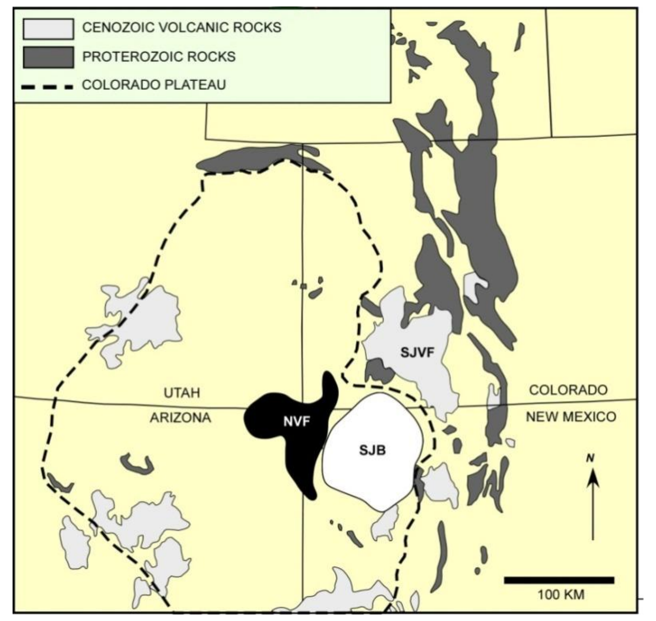
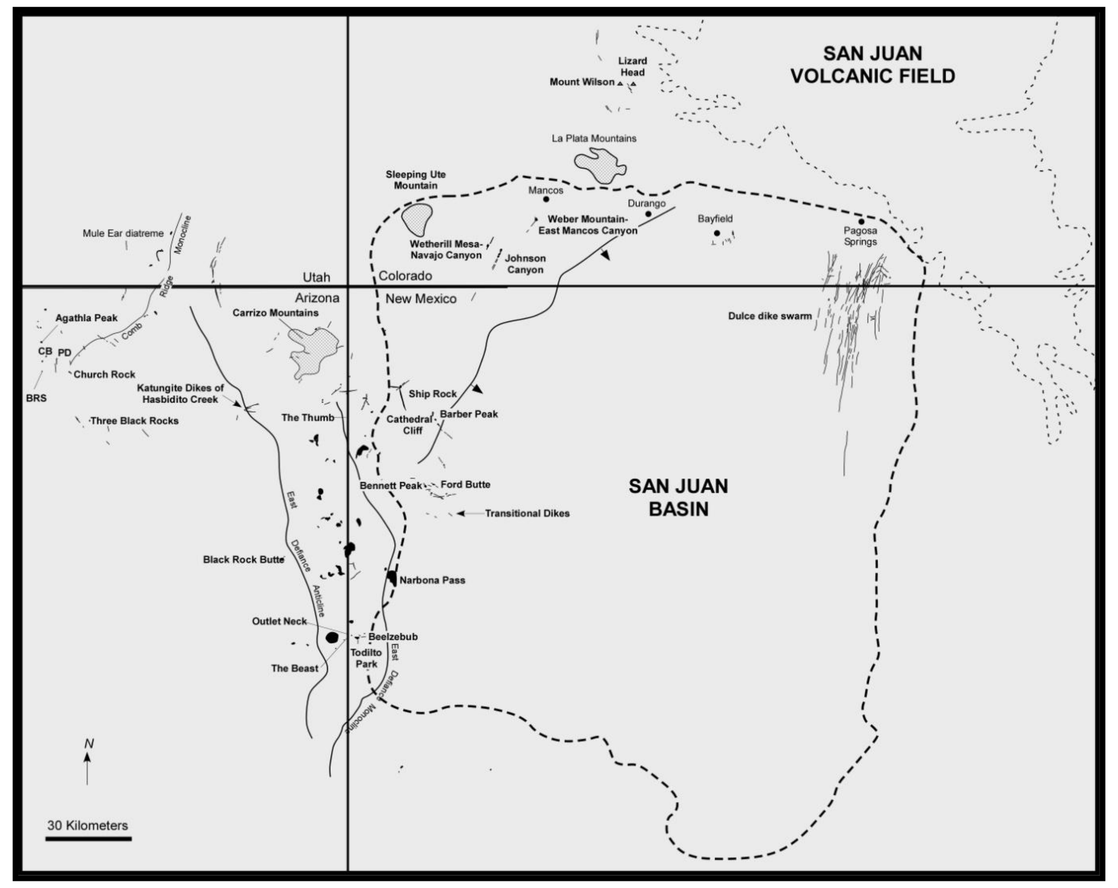
Widespread emplacement of alkaline-subalkaline mantle magmas on the northeastern edge of the Colorado Plateau from 30-5 Ma is expressed by numerous dikes, plugs, and diatremes (NVSJ). Exsolution of carbonated fluorine-rich volatiles from silicate melts crystallized calcite ± fluorite assemblages in vugs, veins, and breccias. New O, C and Sr isotope signatures of bulk carbonate samples plus field and petrologic observations provide: 1) insight into sources of volatiles; 2) clues to processes that influenced the isotopic signatures; and 3) further constraint on the magmatic and external processes during emplacement and crystallization of magmas.

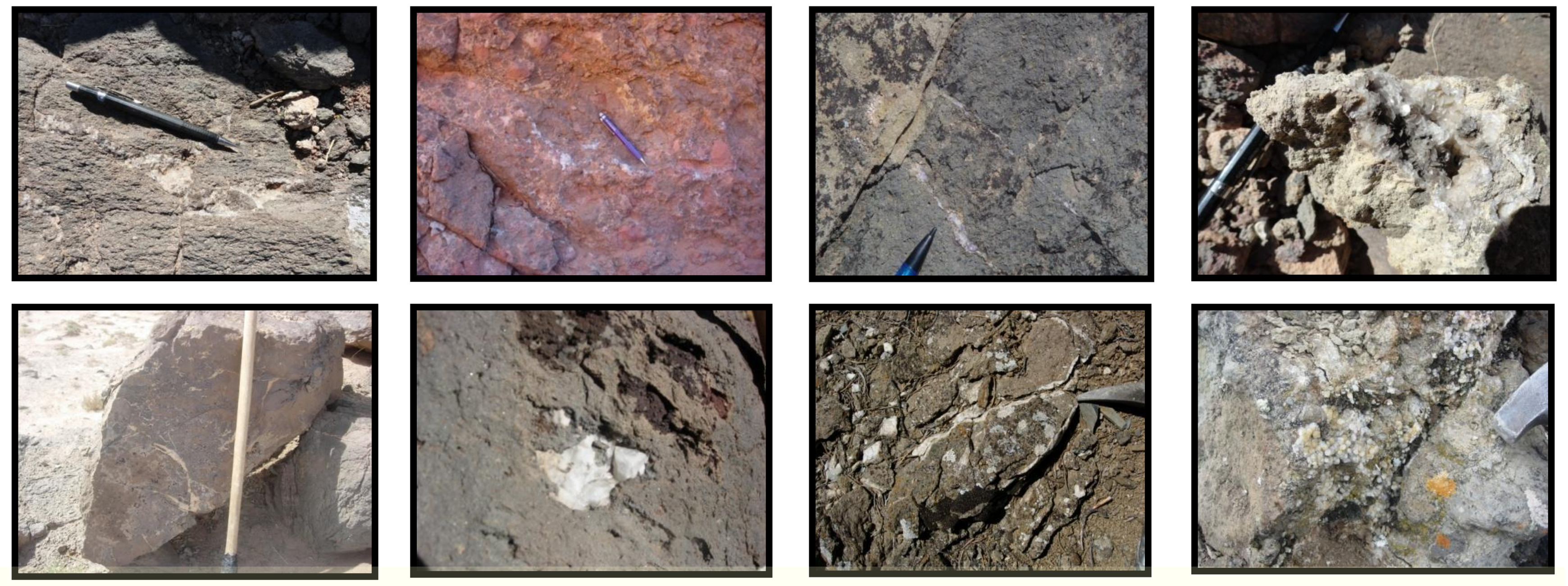




diatremes

dikes/sills

plugs



Calcite veins, breccias, and vugs in outcrops of NVSJ mafic-ultramafic rocks. The ubiquitous presence of late-stage carbonate and fluorite in these rocks reveals that magmas were rich in CO_2 and F. Bulk-rock chemistry and minerals (apatite, phlogopite) also indicate magma with high fluorine contents.

Controversy Around Source & Evolution of Volatiles

Competing Hypotheses: Volatiles originated from magmas or were generated by interaction of melts with external fluids (i.e., groundwater). Previously there were no existing data to test either model.

New Data to Test Ideas: Carbon-oxygen and Sr isotope signatures from calcite combined with field observations plus previous and recent geochemical and isotope data from rocks.

Data Summary: δ13C mostly -8‰ to -4‰ similar to primary mantle carbonate. $\delta^{18}O$ are +5‰ to +24‰ consistent with magmatic volatiles that were enriched in ^{18}O at some stage of crystallization. $^{87}Sr/^{86}Sr$ of rock and calcite samples reflect different melt-volatile sources.

Evaluating Possible Mechanisms

Mechanism	Supporting Arguments	Arguments Against
Heterogeneous melt-volatile sources	•Rock chemical models (Nowell, 1993; Carlson & Nowell, 2001). •Xenolith studies (Perkin et al., 2006; Smith et al., 2004). •Range of δO18 from +6‰ to +24‰ •Variable $^{87}Sr/^{86}Sr$ for rock and carbonate samples. •Cl isotopes (Cammack & Gonzales, 2011) •High F concentrations of rocks: magmatic fluids dominant.	None.
Hydrothermal Deuteric Alteration	•OL & BIO phenocrysts show incipient to extensive alteration. •Abundant phlogopite indicate magmas contained water. •High F concentrations of rocks: magmatic fluids dominant.	•Magmas were emplaced rapidly and cooled quickly. •Groundmass assemblages are mostly unaltered (alteration limited).
Limestone Contamination	•Paleozoic-Mesozoic carbonates wall rocks over region. •δO18 of igneous rock overlap field for limestone samples. •Range of δO18 above +14‰.	• Limestone xenoliths are rare. • Mixing model cannot produce Sr isotope trends. • Higher Sr isotope ratios for some calcite in mafic rocks. • Geochemical studies (Nowell, 1993; Carlson & Nowell, 2001; this study). • High Sr in rocks (600-3000 ppm) and carbonate (400-3100 ppm) versus limestone (200-400 ppm). • Lack of low – or low + δC13.
Interaction with Groundwater	Evidence for near-surface explosive eruptions involving aquifers to create maar craters (e.g., Narbona Pass). Range of δO18 above +14‰.	• Magmas emplaced rapidly and cooled quickly limiting water-rock exchange. • Lack of evidence for alteration by external water-rich fluids. • Low percentage of sedimentary xenoliths in diatremes. • Most diatreme samples have low δO18; contradicts external fuel model. • No evidence for extensive rock-water exchange after cooling.

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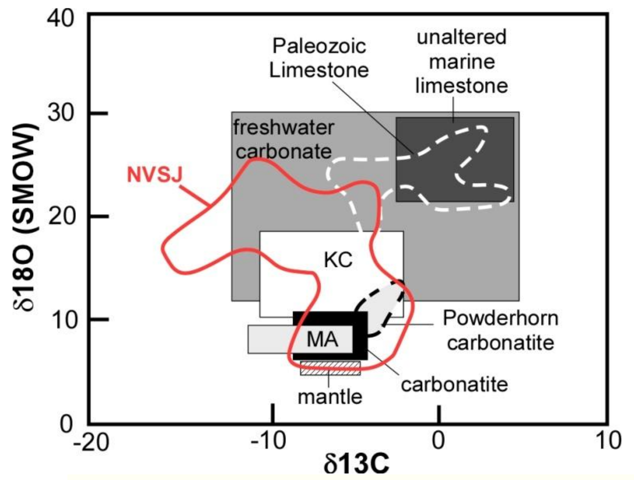
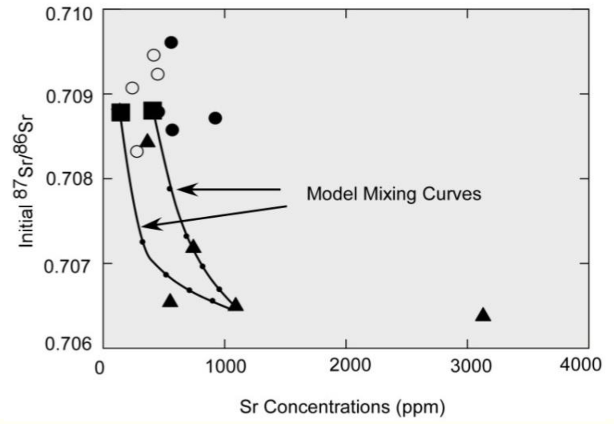
Chlorine Isotope data from phlogopite crystals from mafic rocks yield δ37Cl values of +4 (enriched OIB) to -2 (lithospheric mantle) hinting at different melt sources.

Conclusions

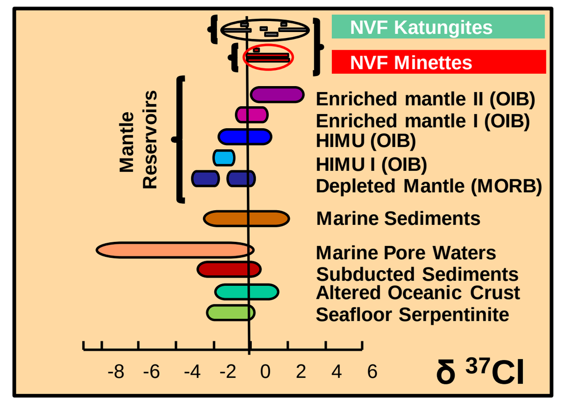
- Volatiles had mantle-magmatic component (C-O signatures and high F).
- Melting of different mantle-magmatic sources produced carbonated-silicate magmas with varied isotopic and chemical "memories" overprinted by incipient to extensive magmatic-hydrothermal alteration.
- Produced variations in $^{87}Sr/^{86}Sr$ signatures and contributed to wide range δ18O values.
- Supports previous melt-production models (Nowell, 1993 and Carlson & Nowell, 2001), oxygen isotope data from mantle xenoliths (Perkin et al., 2006), and variable fluid histories proposed from studies of lithosphere and upper mantle xenoliths (Smith et al., 2004).

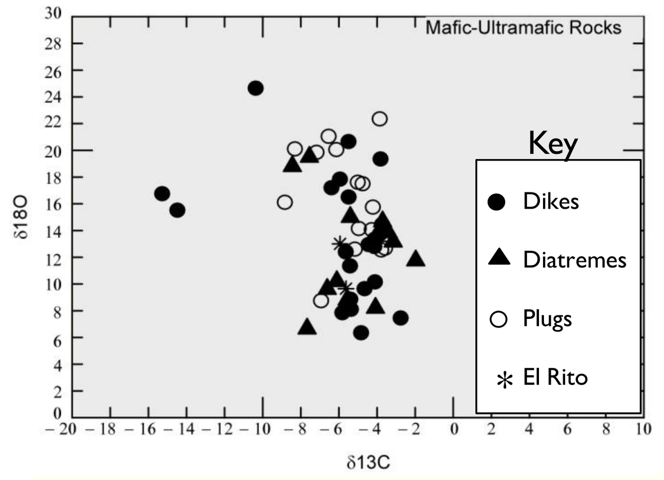


Range of δ18O versus δ13C for NVSJ rocks compared to known fields for various rock types from Rollinson (1993) and Sharp (2007).

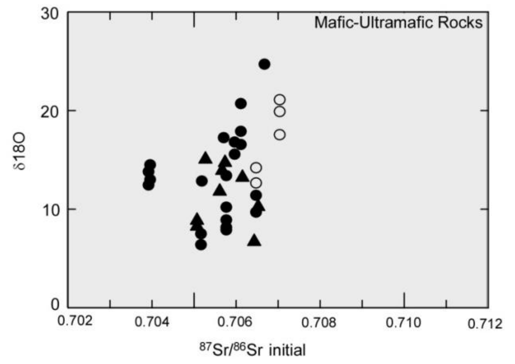


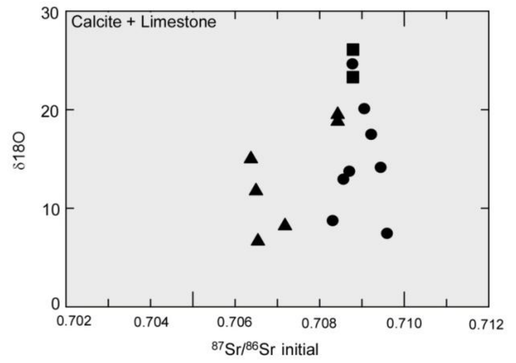
Plot of $^{87}Sr/^{86}Sr_{calcite}$ versus Sr (ppm). The model curves indicate that contamination by limestone (squares) cannot explain the Sr isotope trends in calcite samples.



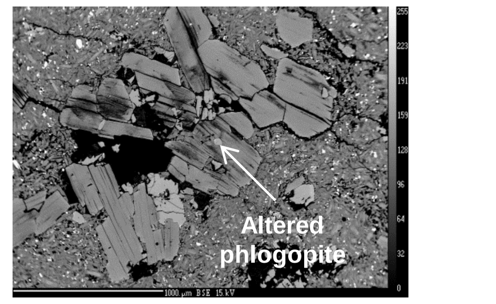


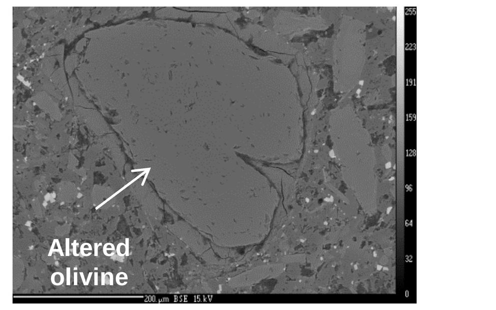
δ18O versus δ13C for NVSJ diatremes, plugs, and dikes. Note the high concentration of points in mantle magmatic (MA) and kimberlite (KC) fields particularly for diatreme samples.



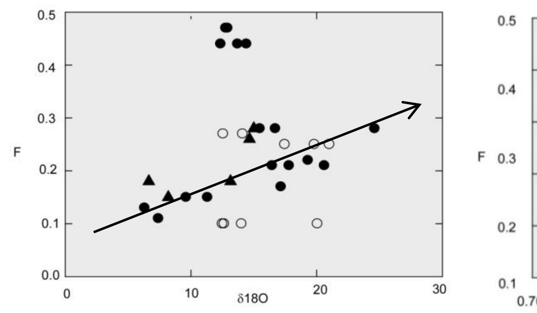


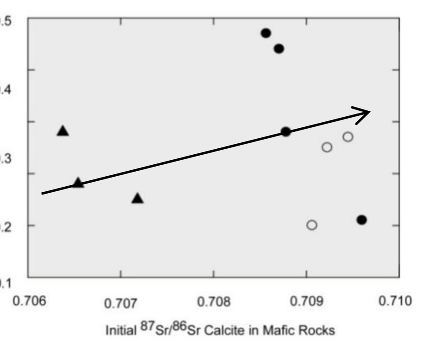
Plots of δ18O versus $^{87}Sr/^{86}Sr_i$ for NVSJ mafic to ultramafic rocks and carbonate samples plus Paleozoic-Mesozoic limestone samples. The solid squares on the lower figure represent limestone samples. The spread of values for both groups is consistent with variations in melt-volatile sources.

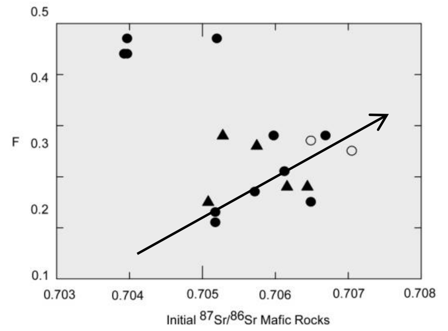




Backscatter images of altered phlogopite and olivine reflecting deuteric alteration. Groundmass is unaltered suggesting that alteration happened in magmas prior to emplacement.







F_{rock} versus $\delta 18O_{calcite}$, $^{87}Sr/^{86}Sr_{calcite}$, $^{87}Sr/^{86}Sr_{irock}$. The general trend (arrow) for minette samples indicate an overall increase in magmatic F with enrichment in 18O and Sr. We interpret this as increased melt contributions from metasomatized F-rich lithospheric mantle. The high fluorine samples are katungite.