Geologic and hydrologic controls on spring, stream, and groundwater chemistry in the Big Chico Creek Watershed and Butte Basin, California

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Comparisons of creek, spring, and groundwater chemistry can provide insight to the hydrologic processes of groundwater recharge and can increase understanding of interactions between the geology and hydrology of the surface and groundwater systems. Big Chico Creek (BCC) at the southwestern extent of the Cascade Range, traverses deformed strata that are assumed to be the principal recharge zone for the Butte Basin aquifer. Annual precipitation ranges from 24–80" with most rainfall occurring November through April. Six perennial springs were characterized based on elevation, distinct lithologies, and water chemistry. Spring water chemistry analyzed in March and July 2005 shows significant variations corresponding to bedrock lithology but little seasonal variation. Creek discharge and major chemical constituents were measured by the USGS at a site east of the groundwater basin for the period 1953 through 1971. Creek water chemistry shows seasonal variations with a strong meteoric component and lower concentrations at high discharge. Dilute creek water is similar to spring water emerging from the Tuscan Formation rocks in the BCC Watershed. Creek water concentrations in base flow during the dry season correspond to greater input of Chico Formation spring water. Reported concentrations for Butte Basin well water are similar to creek water under low discharge conditions. These concentrations appear to require a contribution of Chico Formation water as a recharge source.

Typical Spring Water Chemistry (mg/L)

Lithology	Cl	SO4	Na	Ca	Mg	K
Chico Formation	59.5	93.8	83	54	17	2
Tuscan Formation	1.45	1.48	5	21	8	1

Mineralogical changes in oil shale from hydrous retorting

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The mineralogies of oil shale samples from the Green River Formation (Piceance Basin) were analyzed before and after a series of hydrous pyrolysis experiments conducted over a temperature range of 310 to 350 ºC and pressures from 1600 to 2685 psig. The original shales are carbonate rich (~50%), dominated by ankerite (~25-30%). Other major phases include potassium feldspar, analcime (~15%), quartz (10%), illite (~5%) and plagioclase, in decreasing order of abundance.

Powder x-ray diffraction analyses show that the hydrous pyrolysis results in the near-total loss of analcime and the majority of ankerite. The release of silica and aluminum from analcime and magnesium and iron from ankerite promote the formation of smectite, as evidenced by the appearance of a 12.5-Å peak, indicative of a Na-smectite, which shifts to 17.0 Å after glycol solvation. Non-basal diffractions (e.g., 4.51 and 1.52 Å) indicate the phase is the trioctahedral smectite saponite. Illite peak intensities were unchanged. Quartz peaks show a slight loss of intensity (~2%), which is to be expected under the high temperature conditions and could provide additional silica for saponite formation. We estimate that saponite constitutes 5-10% of the post-pyrolysis samples. Chemical analysis of the post-pyrolysis water show significant sodium concentrations (>1,800 mg/L), consistent with loss from analcime. Calcium concentrations were surprisingly low (<100 mg/L). Calcium and carbonate lost from dissolution of ankerite and aragonite form additional calcite, clearly evident in the increased XRD peak intensities (to >50% of sample composition) for all calcite peaks. These results could have important implications for production of shale oil from the Green River Formation.