Atlas of chemical-quality data for irrigation waters of western Kansas

by
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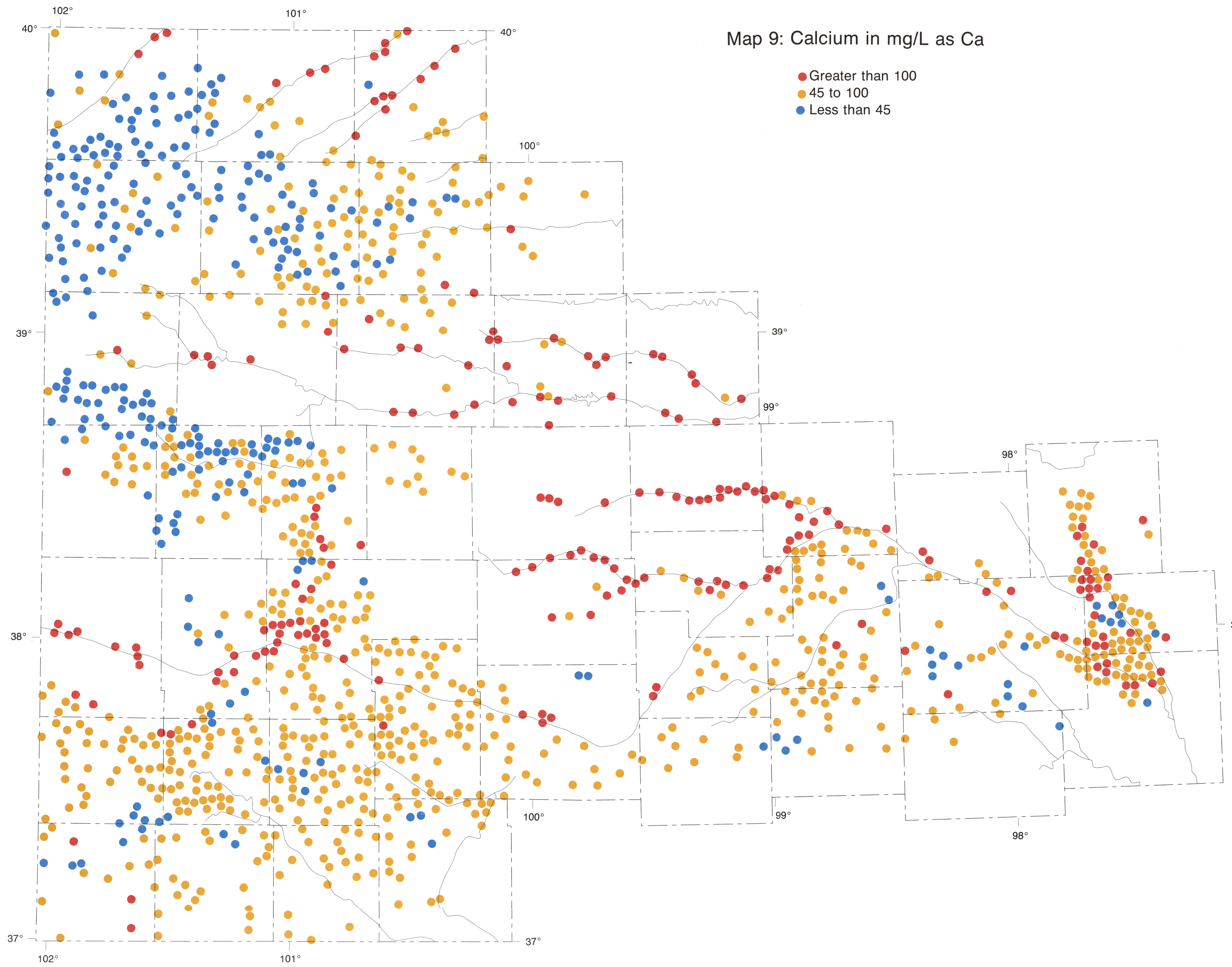
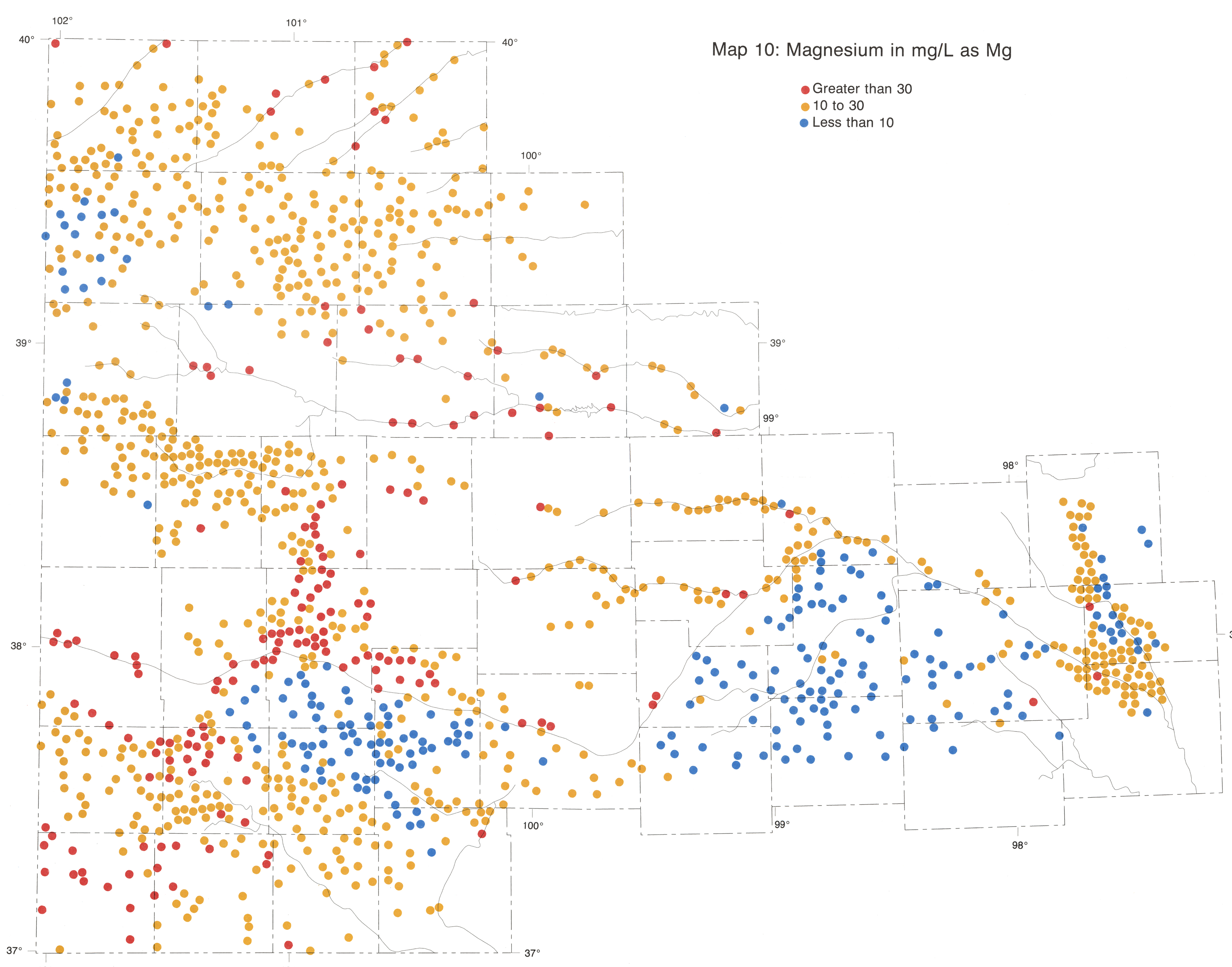
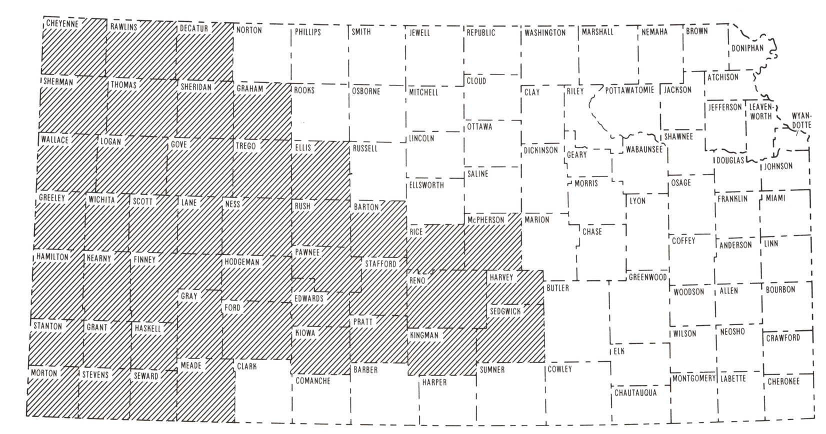
Kansas Geological Survey
1985



Map 9: Calcium in mg/L as Ca



Map 10: Magnesium in mg/L as Mg



Index map of study area.

Calcium (Ca), magnesium (Mg), and strontium (Sr) are all members of the same chemical family of elements, the alkaline earths. The relative abundance of these elements in sediments which make up the aquifer systems of the study area is Ca > Mg > Sr. The relative mass and molar concentrations in ground water normally are in the same order. Cations of these three alkaline-earth elements usually are associated with bicarbonate (HCO_3) or sulfate (SO_4) anions in ground water, contributing to the water's carbonate and noncarbonate hardness, respectively. The three alkaline-earth sulfates are more soluble than the corresponding carbonates, with the general solubility order for both being Mg > Ca > Sr. Thus abundance in the sediment seems to be the primary factor in determining relative amounts of the ions in ground water.

Map 9 presents calcium concentrations in ground water from the study area. Two features stand out in this map and are reflected also in Map 2 (total residue). First is the concentration of <45 ppm values in the northwestern part of the study area where the ground water exhibits little if any noncarbonate hardness. Second is the concentration of >100 ppm values in ground water from areas associated with shallow water-table conditions, drainageways, and sites subjected to oil-brine contamination where considerable noncarbonate hardness exists. Map 9 differs from the total residue map (Map 2) in that it does not display a well-developed low-concentration zone south of the Arkansas River.

The distribution of magnesium concentrations in ground water (Map 10) shares some features of the total residue map (Map 2) but also exhibits some differences. Comparison of Map 10 and Map 9 indicates that magnesium and calcium may show similar behavior of build-up in areas associated with drainageways or restricted surface drainage and shallow water-table conditions as in central Scott and Finney counties. An increase in sulfate concentration (Map 17) also is typical of such areas. However, these two alkaline earths differ in the concentration patterns noted in portions of the upland area.

The low-magnesium zone in the northwestern part of the study area is less pronounced than comparable zones on Map 2 (total residue) or Map 9 (calcium). This may indicate a leachable source of magnesium in the sediments of this part of the study area. South of the Arkansas River the low-magnesium zone is well established, especially in the eastern half of the study area where magnesium levels of 5 ppm or less are noted for a number of well sites. This points to an effective removal of source materials from sediments of the aquifer in this region.

In the southwest corner of the study area, magnesium levels may exceed 30 ppm. Some wells in this area produce ground water which has a Mg/Ca mole ratio that is greater than 1.0. Enrichment of magnesium in these waters may be the result of calcium removal through calcite ($CaCO_3$) precipitation. Water from a number of these wells also exhibits fluoride (F) concentrations (Map 16) in excess of 2 ppm.

Strontium is a minor constituent in most ordinary rocks, sediment, and natural waters. Its behavior in the surface and near-surface hydrogeochemical environment is expected to be much like that of calcium. However, a comparison of the distribution of strontium-concentration values in Map 11 with the patterns for calcium (Map 9) and magnesium (Map 10) indicates that strontium is more closely aligned with magnesium in ground water of the study area.

Statistical analysis of water-quality data for ground water from wells in Greeley, Wichita, Scott, Lane, Hamilton, Kearny, Finney, southern Wallace, and northern Gray counties showed, after correction for common correlation with total residue, that strong correlations exist among uranium, silica (SiO_2), fluoride, magnesium, potassium (K), and strontium. Thus, several lines of evidence point to a source of the constituents such as the volcanic ash which is distributed within the body of aquifer sediment in the western half of the study area. Alluviation of these sediments during Pleistocene times may have produced a distribution of the source material which now operates in concert with geologic factors such as bedrock geology and present drainage features to produce the distribution patterns noted in some maps of this atlas.

The dissolving of carbon dioxide (CO_2) or dissolution of carbonate minerals introduces inorganic carbon into natural waters in the form of carbonic acid (H_2CO_3), bicarbonate ion (HCO_3^-), or carbonate ion (CO_3^{2-}). The distribution of carbon among the three forms is controlled by the pH of the water, which ranges from 7.0 to 8.0 for most ground water in the study area. In this pH range, bicarbonate is the prevalent form of inorganic carbon and the dominant factor in the alkalinity of the ground water. Carbonate-mineral solubility relationships, especially those for calcite, are expected to exert a limiting effect upon the bicarbonate concentration of ground water in the study area.

The bicarbonate map (Map 12) displays some characteristics of both the calcium map (Map 9) and the magnesium map (Map 10). Like calcium, a low-concentration region exists in the northwestern part of the bicarbonate map. The occurrence of high-bicarbonate concentrations in areas associated with drainageways, restricted surface drainage, and shallow water-table conditions resembles more the distribution of high levels of calcium than the pattern of high-magnesium values. The low-bicarbonate concentration areas south of the Arkansas River extend westward of the general location of the corresponding low-magnesium zone.

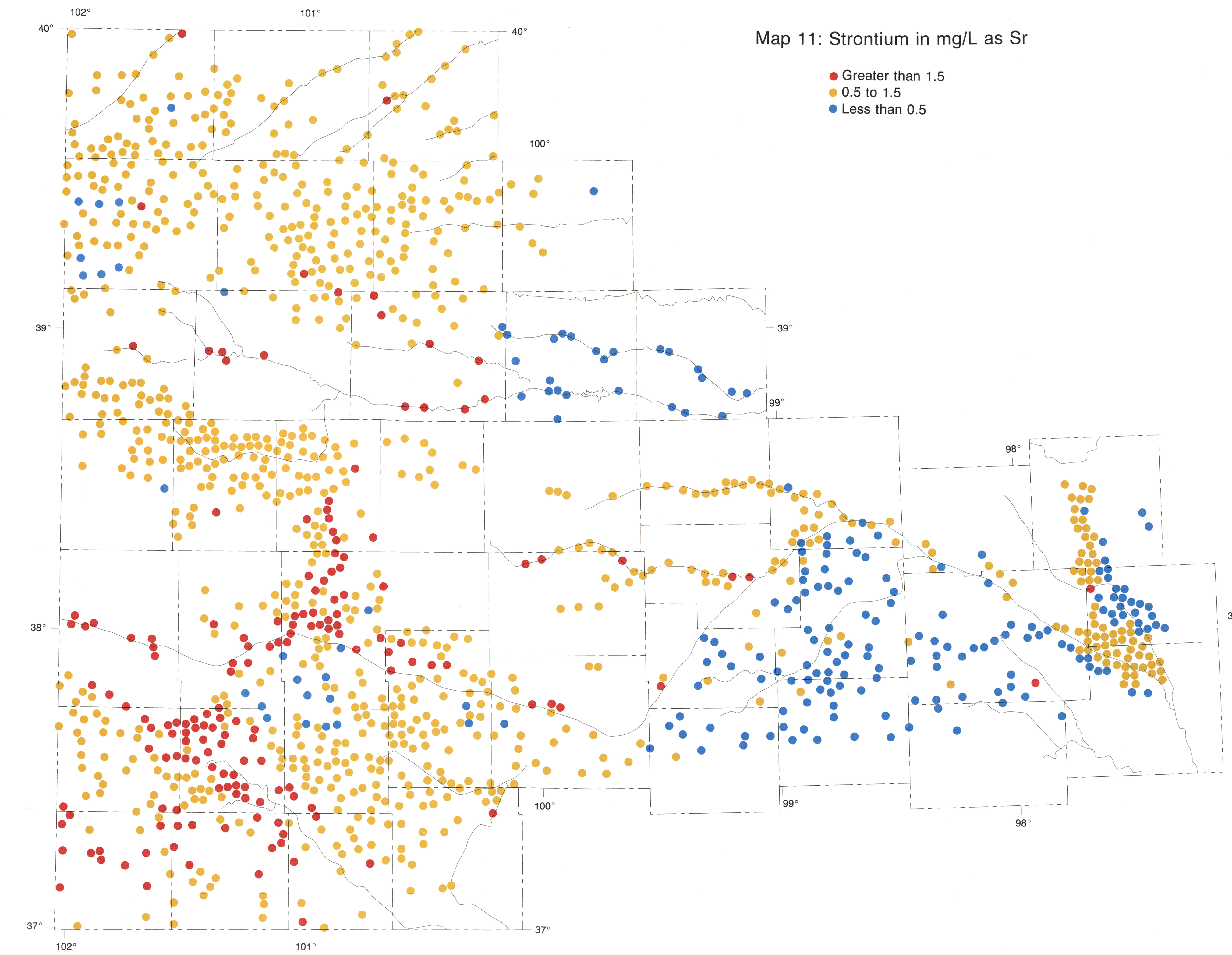
Preliminary analysis of the chemical-quality data for Kearny and Finney counties suggests that ground water north of the Arkansas River in areas that have been irrigated with river water are at saturation with respect to calcite solubility. Ground water from sandy areas south of the river seems to be unsaturated. Thus, low values in this region seem to arise from two different causes. Higher bicarbonate levels in alluvial deposits may result from processes such as greater solubility of carbonate minerals in waters with higher dissolved-solids loads, increased carbon-dioxide levels from respiration and decay, and oxidation of pyrite (FeS_2) in the presence of carbonate-containing sediments or bedrock. The high bicarbonate levels noted in McPherson and Harvey counties near the eastern edge of the study area may reflect the action of anaerobic bacteria and reducing conditions in the aquifer. Ammonium ion and elevated levels of iron (Fe), manganese (Mn), and phosphate (PO_4) are present in ground water of this area.

Selected readings

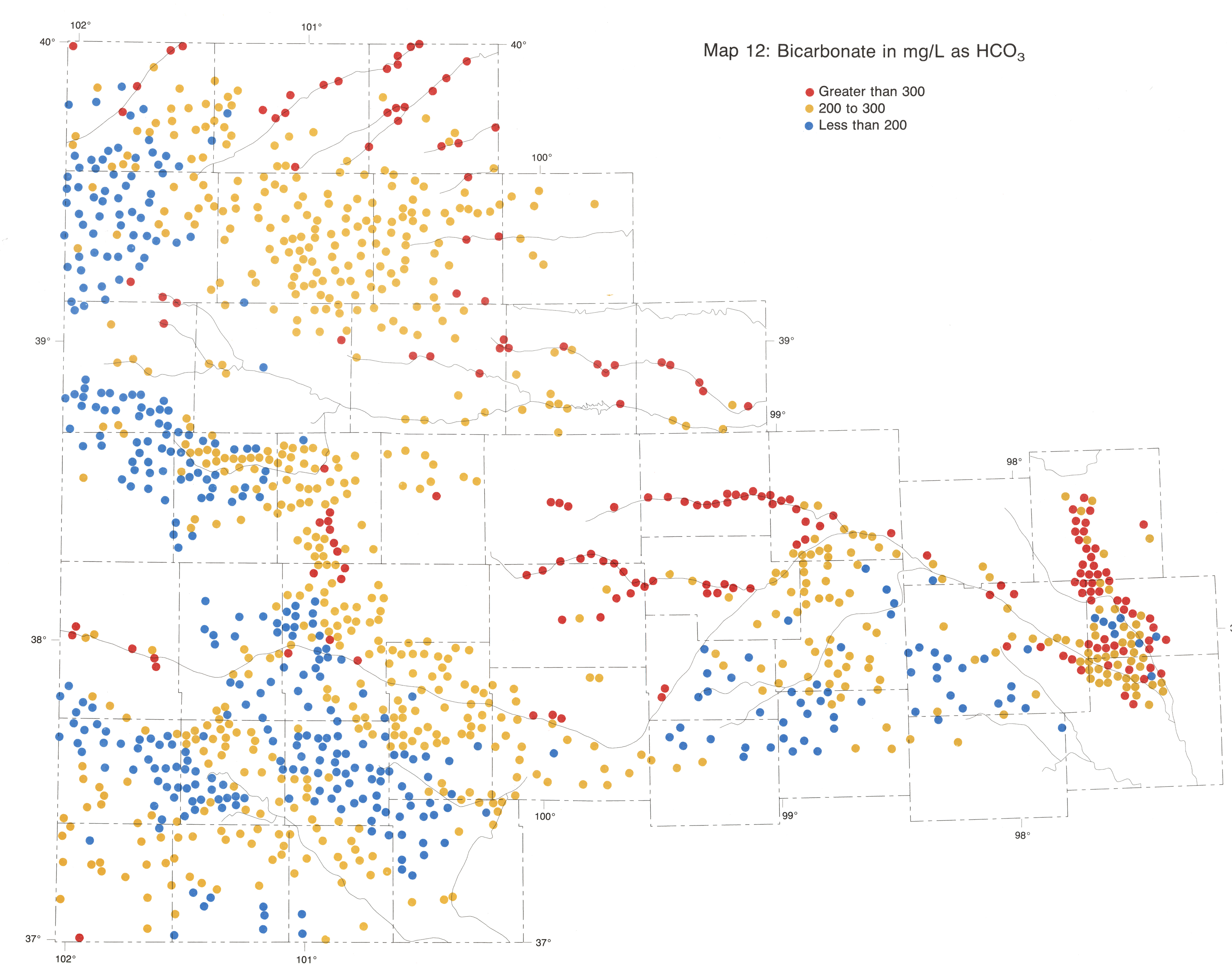
1. Berendsen, P., and Hathaway, L. R., 1981, Uranium in unconsolidated aquifers of western Kansas: Kansas Geological Survey, Mineral Resources Series 9, 43 p.
2. Hathaway, L. R., Carr, B. L., Flanagan, M. A., Galle, O. K., Waugh, T. C., and Dickey, H. P., 1978, Chemical quality of irrigation waters in southwestern Kansas: Kansas Geological Survey, Chemical Quality Series 6, 33 p.
3. Hathaway, L. R., Carr, B. L., Galle, O. K., Magnuson, M. L., Waugh, T. C., and Dickey, H. P., 1977, Chemical quality of irrigation waters in Hamilton, Kearny, Finney, and northern Gray counties: Kansas Geological Survey, Chemical Quality Series 4, 33 p.
4. Hathaway, L. R., and Dickey, H. P., 1978, Soil associations of southwestern Kansas: Kansas Geological Survey, Map M–8A.
5. ———, 1980, Soil associations of northwestern Kansas: Kansas Geological Survey, Map M–8B.
6. ———, 1982, Soil associations of south-central Kansas: Kansas Geological Survey, Map M–8C.
7. Hathaway, L. R., Galle, O. K., Waugh, T. C., and Dickey, H. P., 1978, Chemical quality of irrigation waters in Ford County and the Great Bend Prairie of Kansas: Kansas Geological Survey, Chemical Quality Series 7, 41 p.
8. Hathaway, L. R., Magnuson, L. M., Carr, B. L., Galle, O. K., and Waugh, T. C., 1975, Chemical quality of irrigation waters in west-central Kansas: Kansas Geological Survey, Chemical Quality Series 2, 45 p.
9. Hathaway, L. R., Waugh, T. C., Galle, O. K., and Dickey, H. P., 1979, Chemical quality of irrigation waters in northwestern Kansas: Kansas Geological Survey, Chemical Quality Series 8, 45 p.
10. ———, 1981, Chemical quality of irrigation waters in the Equus Beds area, south-central Kansas: Kansas Geological Survey, Chemical Quality Series 10, 45 p.
11. Chemical-quality data for ground waters from the Smoky Hill River, Pawnee River, and Walnut Creek valleys: Kansas Geological Survey, Open-file Report 80–18 (available from L. R. Hathaway).

Scale 1:1,000,000
0 10 20 30 40 mi
0 10 20 30 40 50 km

The county boundaries, streams, contours of saturated thickness shown on Plate 1, and color-separated dot symbols on all five plates were produced by computer in the Automated Cartography Laboratory of the Kansas Geological Survey. Dot symbols were generated from supplied locations. Software used to perform these tasks is a part of GIMMAP (Geodata Interactive Management Map Analysis and Production), a computer-assisted cartography system developed at the Kansas Geological Survey. All other preparation and layout by Renate Hensiek.



Map 11: Strontium in mg/L as Sr



Map 12: Bicarbonate in mg/L as HCO_3