INITIAL FINDINGS OF SYNOPTIC SNOWPACK SAMPLING IN THE COLORADO ROCKY MOUNTAINS

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Samples of the high-elevation Colorado snowpack collected in 1991 and 1992 indicate increased concentrations of sulfate and nitrate east of the Yampa River valley in northwestern Colorado. Slightly smaller concentrations are present in the Front Range in the vicinity of Rocky Mountain National Park. The snowpack in the Rocky Mountains is a widespread, natural collector of atmospheric deposition. Further, the snowpack provides most of the water and solutes, such as sulfate and nitrate, to high elevation lakes and streams.

To determine whether synoptic sampling of the seasonal snowpack was feasible in the Rocky Mountains, sampling was done during March through April of 1991 and 1992 at about 20 sites in Colorado (figs. 1 and 2). The sites were selected to coincide with long-term monitoring of snow-water-equivalent at snowpack telemetry (SNOTEL) sites operated by the U.S. Soil Conservation Service. Samples representing the full depth of the snowpack were collected by compositing snow core samples or by excavation and subsampling of snowpits.

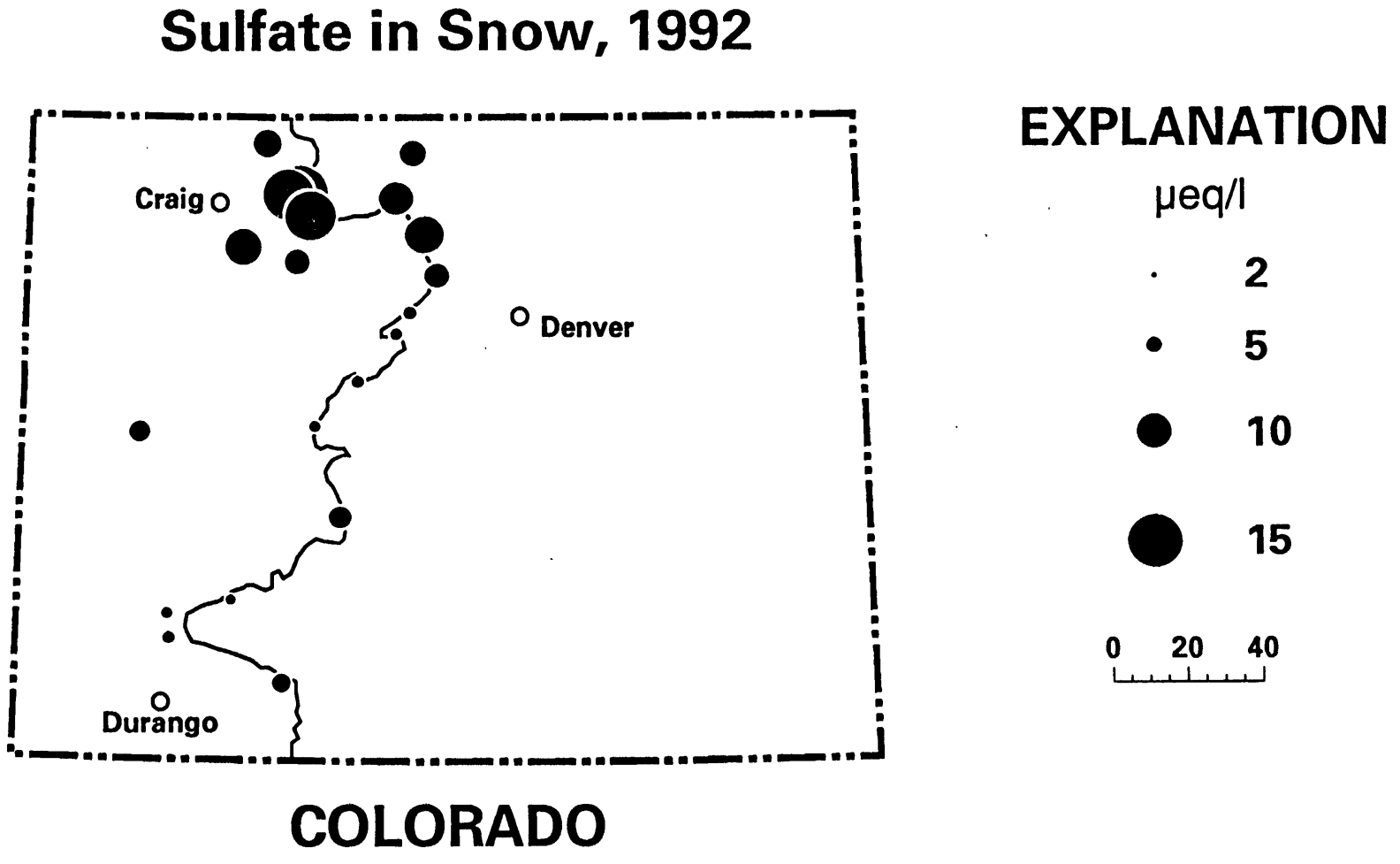

Figure 1.--Concentrations of sulfate at snowpack sample sites in Colorado, 1992.

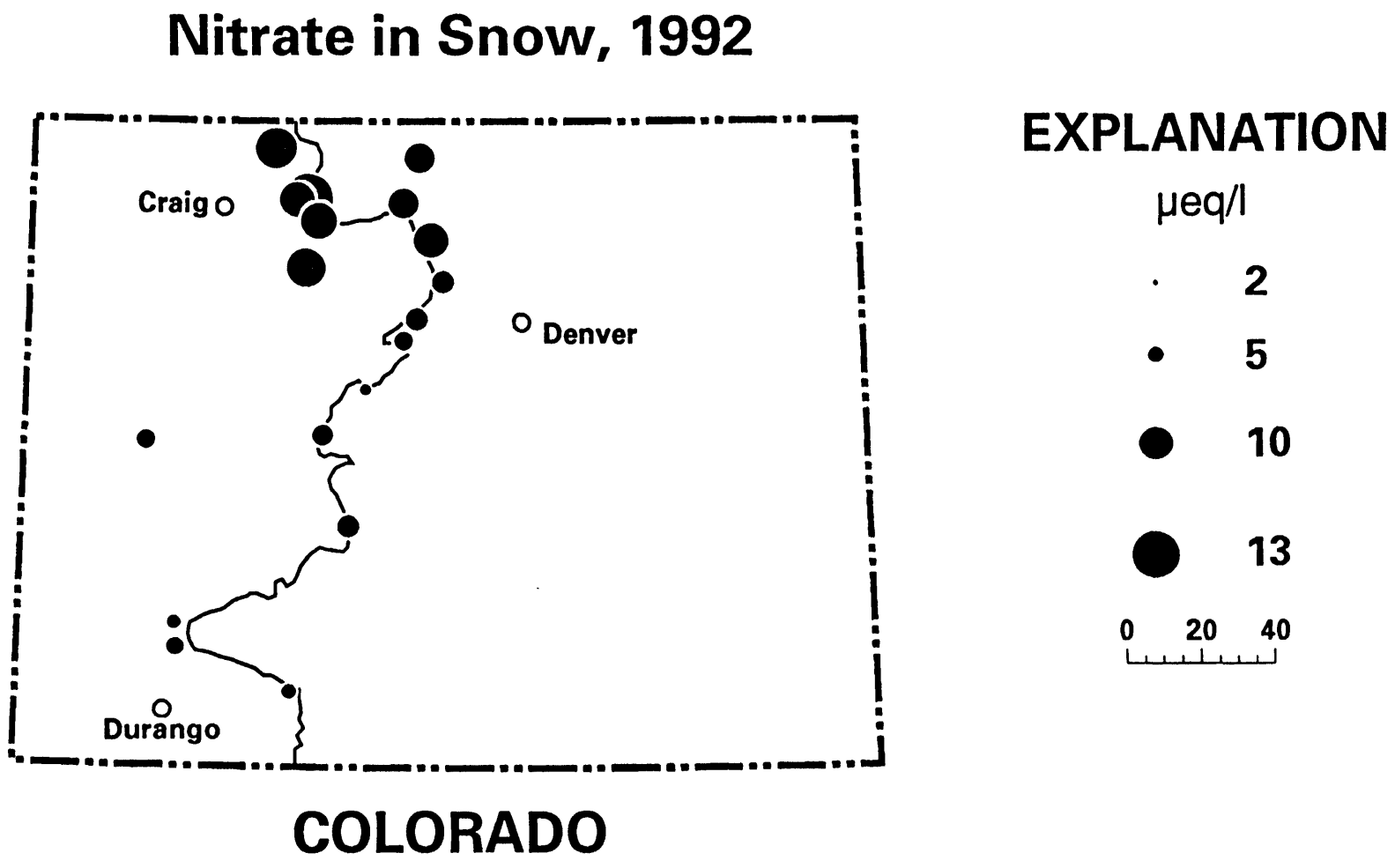

Figure 2.--Concentrations of nitrate at snowpack sample sites in Colorado, 1992.

The snowpack samples from both years indicate greater concentrations of sulfate and nitrate in northern Colorado than in southern Colorado. In northern Colorado, the winds during winter blow primarily from west to east (based on measurements in the Flat Tops Wilderness Area, which is south of Craig). The greatest concentrations of sulfate and nitrate are downwind (east) from Craig, in the Yampa River valley. Concentrations of sulfate and nitrate in snowpack samples collected downwind from the Yampa River valley are twice the mean concentrations of those at remaining snowpack sample sites. In this survey, the concentration of sulfate in the area of greatest concentration is about 13 microequivalents per liter compared to 6 microequivalents per liter in samples from other Colorado snowpack sites. Similarly, the nitrate concentration in the area of greatest concentration is about 12 microequivalents per liter compared to 6 microequivalents per liter in samples from other Colorado snowpack sites. Because of differences in the atomic weight of chemicals, scientists often report concentrations in microequivalents per liter, in which a microequivalent per liter of any single constituent equals the same ability as a microequivalent per liter of any other constituent to undergo a chemical reaction.

Greater concentrations of calcium and other alkaline ions are present in southern Colorado snowpack than in northern Colorado snowpack. Small concentrations of alkaline ions are present in areas that have the greatest concentrations of sulfate and nitrate in the snowpack. Thus, sites with the greatest potential to release acid that may be associated with the source of sulfate and nitrate have the least amount of alkaline ions to neutralize this acidity. The relative proportions of sulfate, nitrate, and alkaline ions affect the pH of the samples. The acid content, as measured by pH, downwind from the Yampa River valley is about two and one-half times the mean acid content in the remaining samples. This increased acid content could cause acidification of lakes and streams as the snow melts in spring.

Downwind from the area of greatest concentration of sulfate and nitrate in the snowpack is an area of lesser, but still greater than average concentration of these constituents. This area is within the Front Range of Colorado, and the concentration may result from either dilution of sulfate and nitrate from upwind sources or from sources within the Front Range. Snowpack sample sites in the Front Range nearest Denver and other major population centers have lesser concentrations of sulfate and nitrate than do those sites most directly downwind from the Yampa River valley. Thus, sulfate and nitrate from the Yampa River valley or upwind sources may affect Front Range sites about 75 kilometers distant.

The samples also were analyzed for stable-sulfur isotope ratios. Stable-sulfur isotope ratios can be used to distinguish among possible sources of sulfate. Most samples had ratios with values of about +4 to +6 in the units commonly used for reporting isotope ratios; however, the samples collected downwind from the Yampa River valley had values from +7 to +9. In contrast to concentrations, isotope ratios are considered important even if they differ by small numbers. The data for this survey indicate great differences in the source of sulfate for the area downwind from the Yampa River valley compared to the other snowpack sample sites in Colorado. Thus, the greater concentrations of sulfate downwind from the Yampa River valley have an isotopically different sulfate than the sulfate from other sources that is present in the rest of the Colorado snowpack.

Samples also were collected from lakes downwind from the Yampa River valley. Maximum concentrations of sulfate and isotopically heaviest sulfate occur in lakes nearest the greatest concentrations of sulfate and isotopically heaviest sulfate in the snowpack. Therefore, the sources of sulfate deposited in the snowpack seem to affect lake chemistry as well. This effect extends into the southern part of the Mt. Zirkel Wilderness Area (MZWA), which is protected from significant deterioration of air quality and water quality by the Clean Air Act and the Wilderness Act. The greatest concentrations of sulfate and nitrate are south of the MZWA in an area for which few data exist on the chemistry and sensitivity of lakes and no data exist for headwater streams.

At this time it is impossible to determine the cause of the observed differences in snowpack chemistry and isotopic composition. The differences in concentration of sulfate and nitrate at the sites indicate a localized effect primarily east of the Yampa River valley; however, the source of the increased concentrations could be in the Yampa River valley or farther west. The U.S. Geological Survey is proposing a study to determine the source.

This report is the result of several studies conducted by the U.S. Geological Survey, in cooperation with the Colorado Department of Health, the U.S. Forest Service, and the U.S. Environmental Protection Agency.