INTRODUCTION

The Denver ground-water basin underlies a 6,700-square-mile area extending from Greeley in the north to Colorado Springs in the south, and from the Front Range in the west to near Limon in the east. The four major bedrock aquifers that occur in the basin are the Laramie-Fox Hills aquifer (the deepest aquifer), the Arapahoe aquifer, the Denver aquifer, and the Dawson aquifer (the uppermost aquifer). The Arapahoe aquifer, which is the subject of this report, underlies an area of about 4,300 square miles in east-central Colorado (index map, fig. 1) and is a primary source of water for residents in the Denver suburban area and in the rural areas of central Adams and El Paso Counties, eastern Elbert County, and parts of Arapahoe County. About 90 percent of the estimated 3,200 wells completed in the aquifer supply water to residents and livestock. The remaining wells supply water for commercial and industrial use and limited irrigation of commercial crops.

The continuing increase in population in rural communities and suburban areas near Denver has produced increasing demands for ground-water supplies. As a result, the number of wells obtaining water from the Arapahoe aquifer has steadily increased and the increased pumpage has caused local water-level declines in the aquifer. In sparsely populated areas, water-level declines have not been significant; however, near some more urbanized areas, the average rate of water-level decline has exceeded 15 feet per year. Continued increases in population will likely cause increasing demands for water from the Arapahoe aquifer and will continue the water-supply problems faced by residents who depend on this bedrock aquifer for water.

This study was undertaken to better define the water-supply potential of the four major bedrock aquifers in the Denver basin. The Arapahoe aquifer is one of the deeper aquifers in this group. Findings related to the Arapahoe aquifer made during the first 2 years of the investigation are presented in this report to provide water users with timely ground-water-resources information that can be used to better manage and develop the water supply of the aquifer. Similar reports for the Dawson aquifer and the Denver aquifer have been completed (Robson and Romero, 1981). The hydrologic data used in preparing these reports are available in Major and others (1981), Hillier and others (1978), McConaghy and others (1964); and in the Colorado District Office of the U.S. Geological Survey in Lakewood, Colo. Study results pertaining to the Laramie-Fox Hills aquifer are being compiled.

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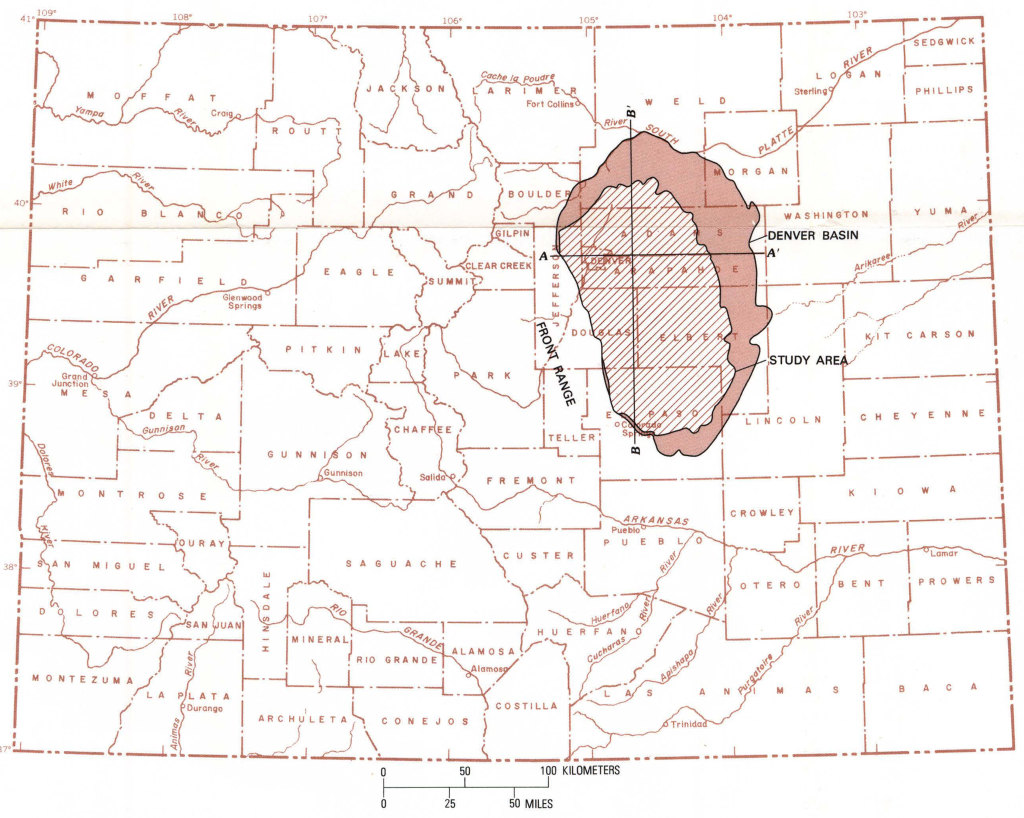

FIGURE 1.—INDEX MAP SHOWING LOCATION OF DENVER BASIN, STUDY AREA, AND GENERALIZED GEOLOGIC SECTIONS

GEOLOGIC CHARACTERISTICS

The geologic formations containing the four aquifers of the Denver basin are the Fox Hills Sandstone, the Laramie and the Arapahoe Formations of Late Cretaceous age, and the Denver Formation of Late Cretaceous and early Tertiary age, and the Dawson Arkose of Tertiary age (Romero, 1976). These formations occur in a sequence of layers as shown by the generalized geologic sections drawn from west to east and from south to north through the basin (fig. 2). The northern, eastern, and southern parts of the basin form a shallow bowl, the sides of which dip gently toward the west-central part of the basin. Along the western edge of the basin, sedimentary formations are upturned along the Precambrian crystalline rocks of the Front Range and dip steeply to the east as a result of faulting and the gradual upward movement of the Rocky Mountains. The Pierre Shale of Late Cretaceous age underlies the Fox Hills Sandstone and is considered to be the base of the major bedrock-aquifer system due to its great thickness (as much as 8,000 feet) and its minimal permeability.

The Arapahoe Formation consists of a 400- to 700-foot thick series of interbedded conglomerate, sandstone, siltstone, and shale. Shale tends to be more prevalent in the northern one-third of the formation. In some areas the formation can be subdivided into an upper and lower part. The upper part commonly consists of 200 to 300 feet of shale with some conglomerate and sandstone beds, while the lower part consists of 200 to 300 feet of sandstone and conglomerate with less prevalent beds of shale. The conglomerates, sandstones, and siltstones normally are light to medium gray with local very light gray and grayish green beds. These colors are generally darker in the upper 100 to 200 feet of the formation near its boundary with the overlying Denver Formation. Shales are normally medium gray and silty. The larger proportion of conglomerate and sandstone with respect to shale, the absence of significant carbonaceous beds, and a generally lighter color distinguish the Arapahoe Formation from the underlying Laramie Formation and the overlying Denver Formation. In most of the outcrop area along the margins of the aquifer, the formation is exposed at the surface or buried under a thin layer of soil. Near the South Platte River and many of the smaller streams crossing the outcrop area, the formation is buried under 20 to 100 feet of sand and gravel deposited in the stream valleys.

Individual conglomerate and sandstone beds in the Arapahoe Formation are commonly lens shaped and range in thickness from a few inches to 30 or 40 feet. The beds may be so closely spaced that they form a single hydrologic unit that is 200 to 300 feet thick in some areas. The conglomerate and sandstone generally are only moderately consolidated and are much more coarse grained than the siltstone and shale. This allows ground water to flow through the void spaces between the grains of gravel and sand in the conglomerate and sandstone while little or no water is able to flow through the siltstone and shale. The aquifer thus consists of a complex pattern of interconnected beds of permeable and relatively impermeable sediments that differ in their ability to store water and to transmit water from one area to another.

In general, the saturated part of the Arapahoe Formation forms the Arapahoe aquifer. However, because the geologic contact with the overlying Denver Formation is not always easily discernible, the upper limit of the aquifer may not always coincide with the actual location of this contact. In addition, 50 to 100 feet of sediments assigned to the top part of the Laramie Formation have been included in the lower part of the Arapahoe aquifer because water in these sediments appears to function more as a part of the Arapahoe aquifer than the Laramie-Fox Hills aquifer. Near the margins of the aquifer, the ground-water level is below the geologic unit forming the top of the aquifer and the Arapahoe Formation is not fully saturated. In these partially saturated areas, the aquifer is assumed to extend from near the base of the aquifer to the potentiometric surface (a surface that shows the elevation of the standing water levels in wells completed in the aquifer). Because of these qualifications, the size, shape, and thickness of the Arapahoe aquifer does not necessarily correspond to the size, shape, and thickness of the Arapahoe Formation.

The map showing the elevation and configuration of the base of the Arapahoe aquifer (fig. 3) indicates that the base is bowl shaped and ranges in elevation from a high of about 6,300 feet near Colorado Springs to a low of about 4,000 feet near Parker. The aquifer limit shown on the map is the approximate extent of saturated sediments in the Arapahoe aquifer. Beyond this limit, it is unlikely that a well completed in the Arapahoe Formation would yield usable quantities of water, although adequate quantities of water may be found in deeper bedrock aquifers.

The depth to the base of the aquifer may be determined by subtracting the elevation of the base of the aquifer from the elevation of the land surface. The depths shown on the adjacent map (fig. 4) were calculated for each section (1 square mile) of land in the area using average land-surface and structural elevations in each section. The depth to the base of the aquifer is as much as 2,600 feet near Table Rock and is in excess of 1,000 feet throughout much of the west-central part of the aquifer. This map provides a quick means of estimating the depth to the base of the aquifer but is somewhat generalized due to the use of average elevations. If, for example, a water well is to be drilled into the Arapahoe aquifer, this map shows the approximate well depth required to fully penetrate the aquifer. A more accurate depth estimate can be made by subtracting the elevation of the base of the aquifer at the well site from the land-surface elevation at the well site.

The extent, elevation, and configuration of the geologic structure at the top of the Arapahoe aquifer is shown on the accompanying map (fig. 5). The top of the aquifer has a bowl shape similar to the base of the aquifer and ranges in elevation from about 6,500 feet near Colorado Springs to about 4,600 feet in the area between Castle Rock and Aurora. The thickness of the aquifer can be determined by one of two methods depending on the location of the point of interest. If the point of interest is (1) within the limit of the geologic structure forming the top of the aquifer, the thickness is the difference between the elevations of the top and base of the aquifer. If the point of interest is (2) located in the partially saturated zone, the difference between the elevation of the potentiometric surface (fig. 8, shown on the second map sheet) and the elevation of the base of the aquifer must first be determined. If the point of interest is not located over an alluvial aquifer, this difference is the thickness of the Arapahoe aquifer. If the point of interest is over an alluvial aquifer, the thickness of the alluvial aquifer must be subtracted from the above difference to determine the thickness of the Arapahoe aquifer. Because alluvial aquifers 20 to 100 feet thick commonly occur in the valleys of larger streams in the area, the thickness of the Arapahoe aquifer under an alluvial aquifer will be 20 to 100 feet less than the above difference.

The bedrock-aquifer thickness calculated by either of the above methods includes the thickness of the water-yielding conglomerate, sandstone, and siltstone, as well as the thickness of the nonwater-yielding shale. Because the thickness of the water-yielding beds is of particular interest, the map of total conglomerate, sandstone, and siltstone thickness (fig. 6) was prepared to show the thickness of only these materials. Near the margins of the aquifer there is less than 50 feet of water-yielding material in the aquifer, but southeast of Castle Rock there is more than 400 feet of conglomerate, sandstone, and siltstone. A comparison of total aquifer thickness to total conglomerate, sandstone, and siltstone thickness within the aquifer indicates that the Arapahoe aquifer contains about 40-percent conglomerate, sandstone, and siltstone and about 60-percent shale. By comparison, the overlying Denver aquifer contains about 30-percent sandstone and siltstone and about 70-percent claystone and shale.

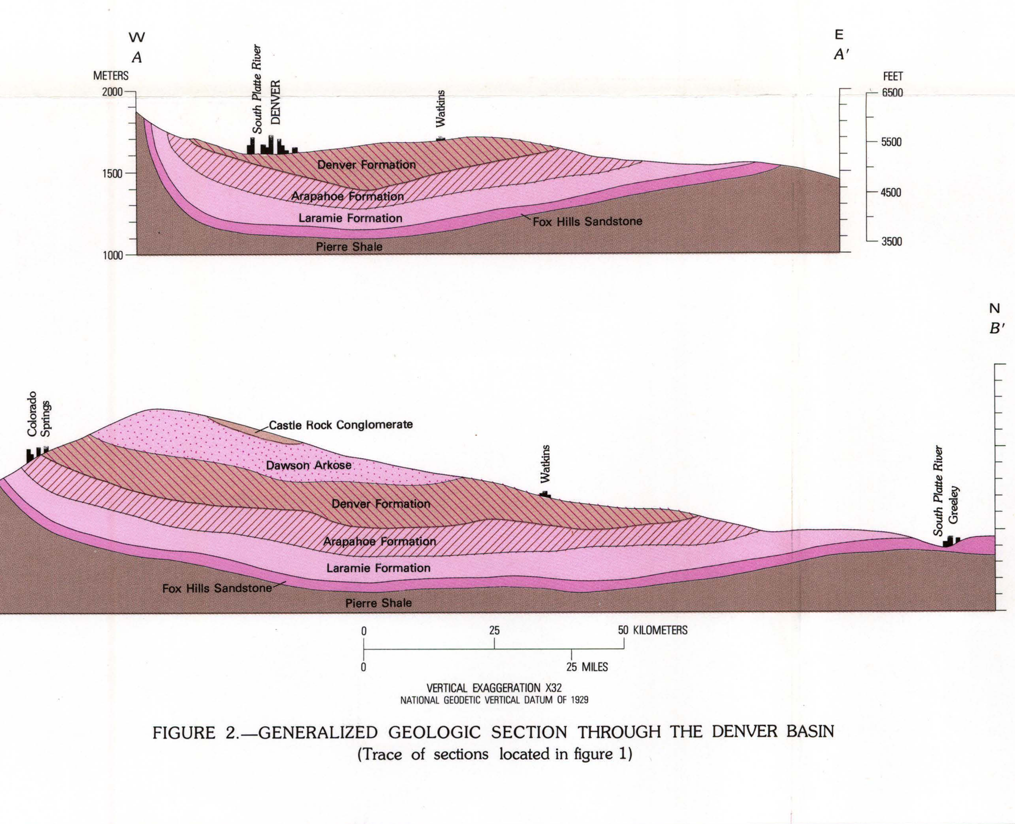

FIGURE 2.—GENERALIZED GEOLOGIC SECTION THROUGH THE DENVER BASIN
(Trace of sections located in figure 1)

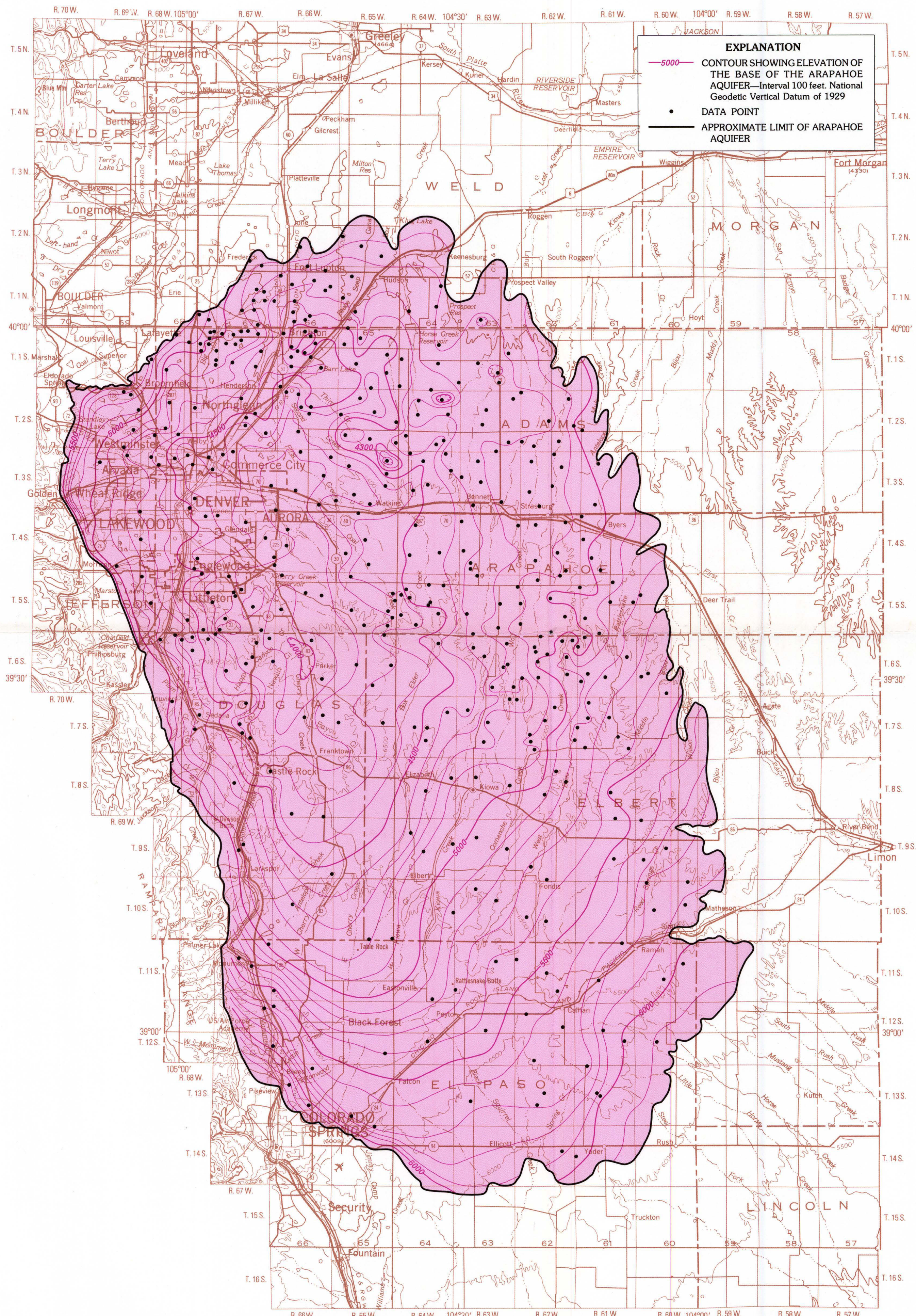

FIGURE 3.—MAP SHOWING ELEVATION AND CONFIGURATION OF THE BASE OF THE AQUIFER

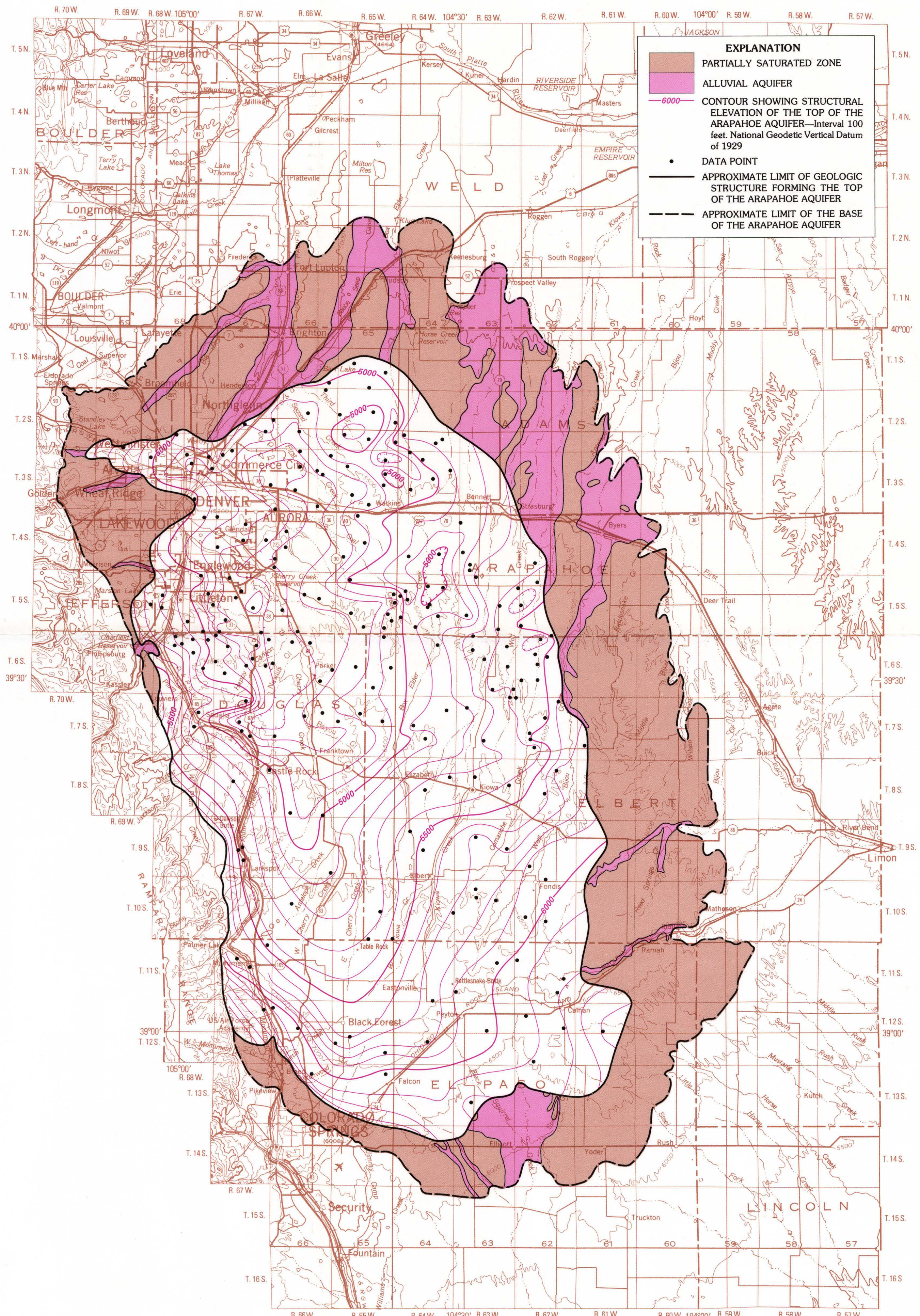

FIGURE 5.—MAP SHOWING ELEVATION AND CONFIGURATION OF THE TOP OF THE ARAPAHOE AQUIFER AND LOCATION OF ALLUVIAL AQUIFERS IN THE PARTIALLY SATURATED ZONE

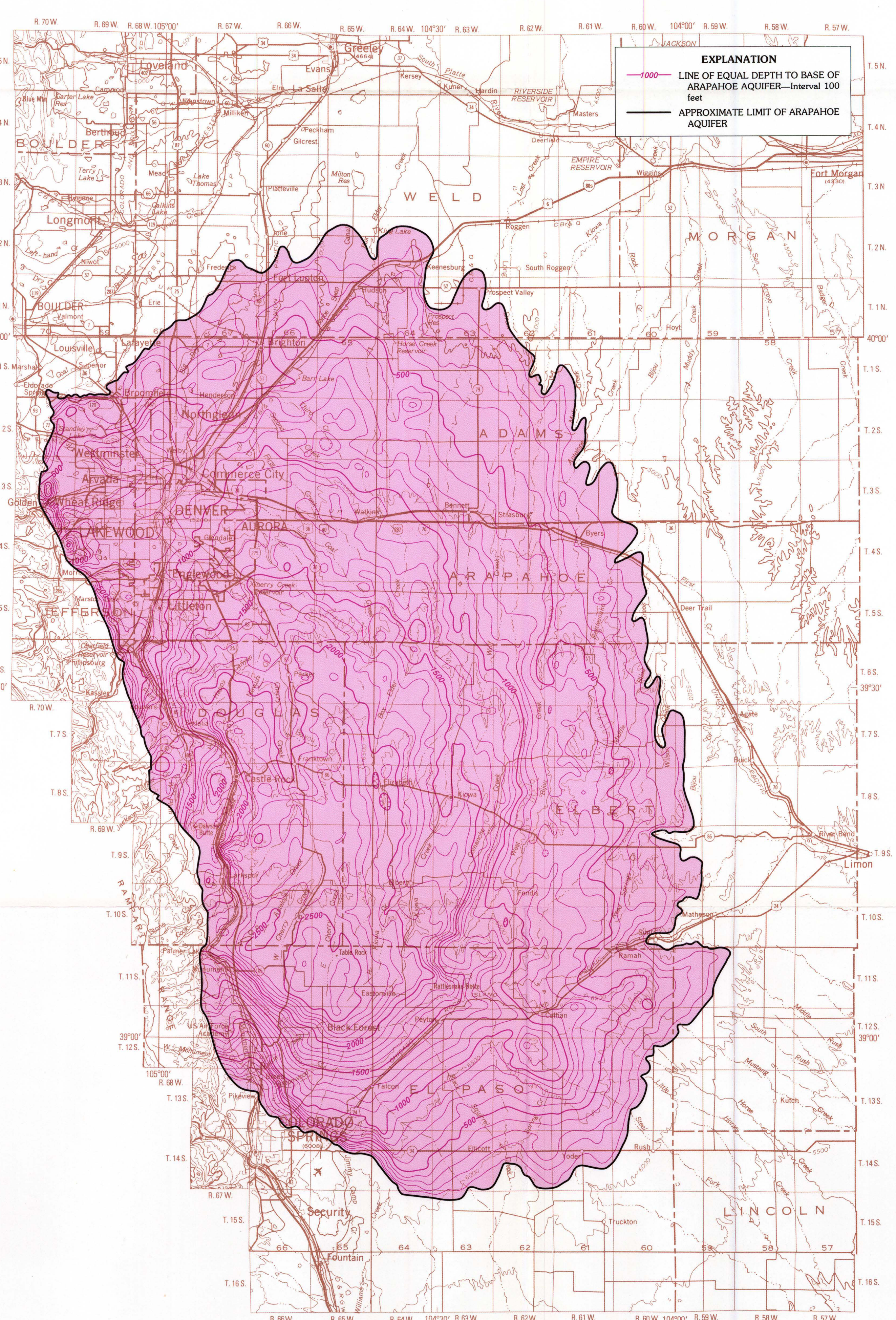

FIGURE 4.—MAP SHOWING DEPTH TO THE BASE OF THE AQUIFER

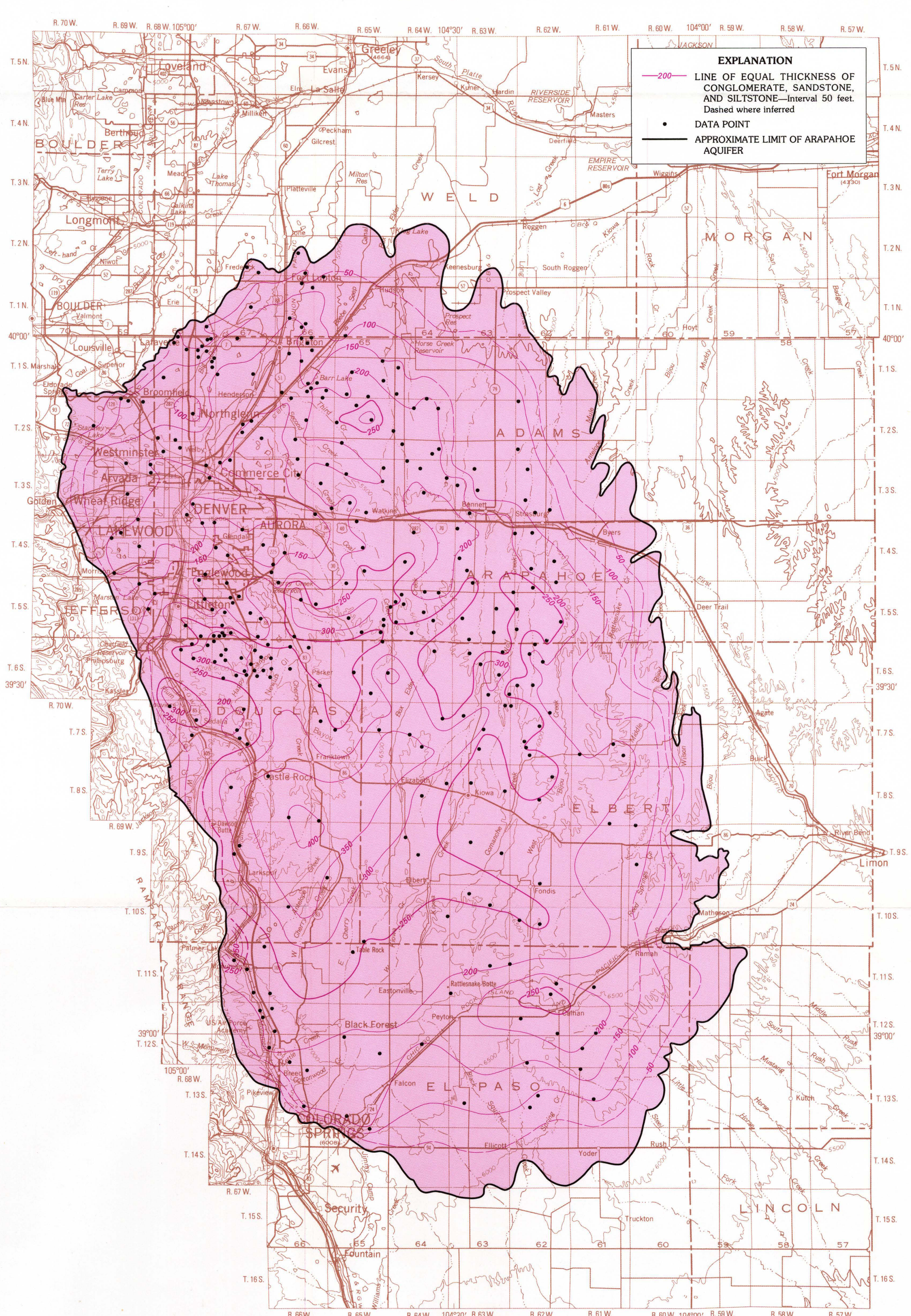

FIGURE 6.—MAP SHOWING TOTAL THICKNESS OF CONGLOMERATE, SANDSTONE, AND SILTSTONE IN THE AQUIFER

Base from U.S. Geological Survey
State base map, 1969

SCALE 1:500 000
10 0 10 20 30 40 50 MILES
10 0 10 20 30 40 50 KILOMETERS
CONTOUR INTERVAL 500 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

GEOLOGIC STRUCTURE, HYDROLOGY, AND WATER QUALITY OF THE ARAPAHOE AQUIFER IN THE DENVER BASIN, COLORADO

By
S. G. Robson, U.S. Geological Survey, and John C. Romero and Stanley Zawistowski, Colorado Division of Water Resources
1981

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