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Groundwater conditions in the Grande Prairie — Beaverlodge area, Alberta

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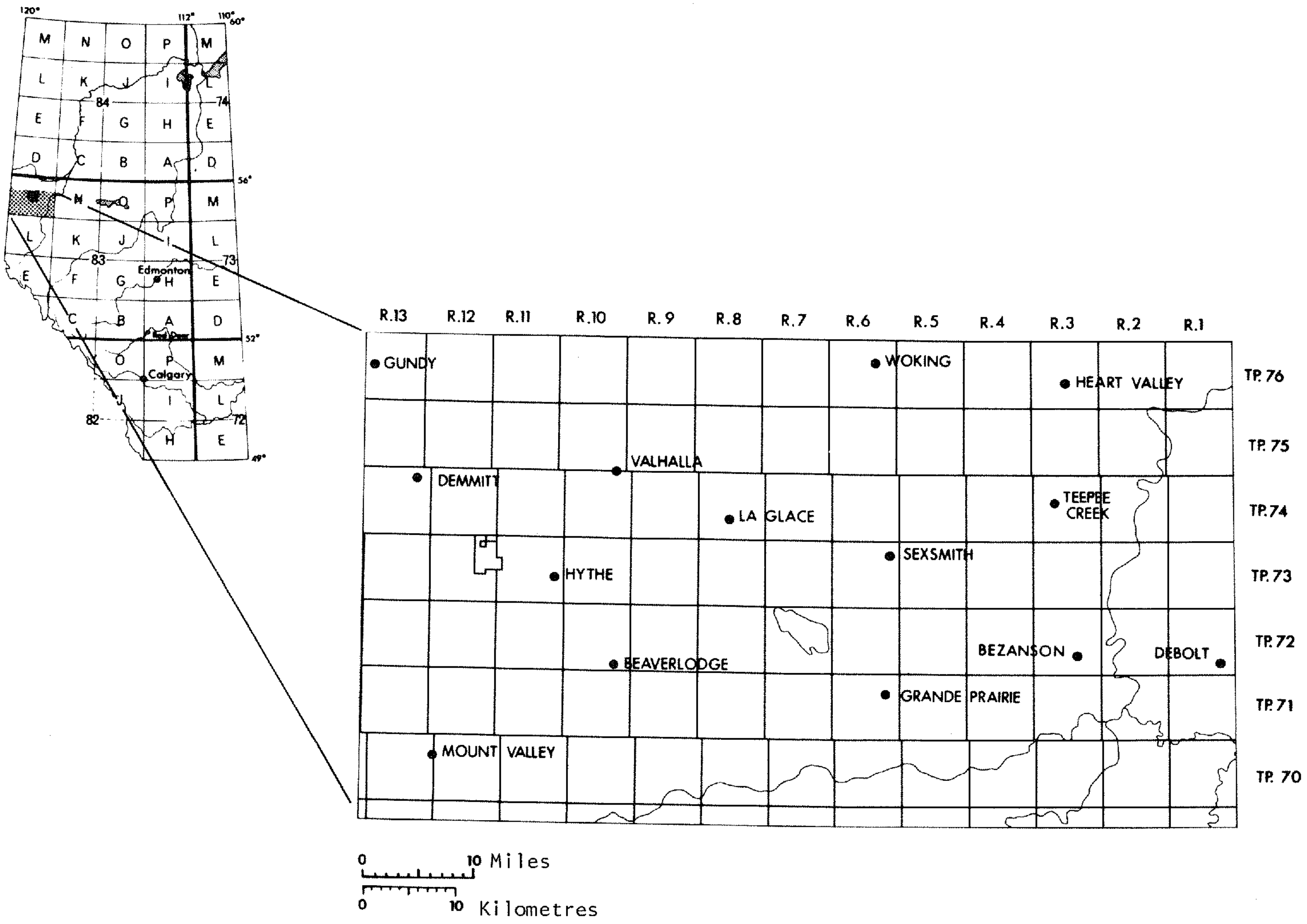

FIGURE 1. Location of area and population centers

GROUNDWATER CONDITIONS IN THE GRANDE PRAIRIE-BEAVERLODGE AREA, ALBERTA

ABSTRACT

The Grande Prairie area is located in west-central Alberta between longitudes 118° and 120° west and latitudes 55° and 55°40' north. It covers approximately the southern two thirds of the Canadian National Topographic System map area 83M — Grande Prairie, Alberta.

Groundwater chemical information is divided into glacial drift- or bedrock-derived (the latter consisting of Upper Cretaceous Wapiti Formation and Smoky Group). The bedrock source is further subdivided into depth intervals of 0 to 150 ft (0 to 46 m), 150 to 300 ft (46 to 91 m), and 300 to 450 ft (91 to 137 m). The data did not warrant explicit investigation to greater depths.

Maps showing the distribution of total dissolved solids, calcium, magnesium, hardness, sodium, potassium, carbonate, bicarbonate, alkalinity, sulfate, chloride, and fluoride are presented for each of the four subdivisions. Maps presenting chemical equivalent as a percent of anions or cations are also presented for pertinent ions in all intervals.

Over most of the study area groundwater to a depth of 450 ft (137 m) is of fairly good quality. Total dissolved solids contents are generally less than 1500 mg/l. Groundwater is of the sodium bicarbonate type with a tendency to calcium bicarbonate type in areas of thick glacial drift.

In the northeastern portion of the area groundwater is of poor quality due to the proximity of the Smoky Group shales. Groundwater in the glacial drift is expected to be of the calcium sulfate type with total dissolved solids concentrations greater than 2000 mg/l. Groundwater in the bedrock is of the sodium sulfate type and total dissolved solids contents are greater than 2000 mg/l.

Maps are presented showing distribution of hydraulic head for various depth intervals down to 600 ft (183 m). Horizontal components of groundwater flow are directed to the south and east. Vertical components of flow show a complicated pattern hypothesized to be related to the lenticular nature of the Wapiti Formation.

INTRODUCTION

This report presents a detailed discussion of groundwater flow and chemistry for a portion of the Grande Prairie hydrogeological map area (Hackbarth, in prep.). Only a portion of the latter area is covered by this report due to the lack of data north of Tp 76.

The purpose of this publication is two-fold: 1) to present available groundwater information in a manner readily usable by nonscientists in order to assist them in selecting suitable water supplies, and 2) to document systematically the groundwater chemistry of the area in order that the information may be accessible for use in environmental health studies. Freedman (1977) has noted that a major problem in environmental health studies is "...getting the information already available into the hands of the general public and the practitioners of medical and dental services."

The study area is located between longitudes 118° and 120° west and latitudes 55° and 55°40' north. It covers Tps 69 (northern one third) through 76 and Rs 1 through 14, west of the 6th meridian. The area covers approximately the southern two thirds of the Canadian National Topographic System map area 83M — Grande Prairie, Alberta. Figure 1 shows the location of the area and its population centers.

The hydrochemistry information presented here is derived mainly from numerous domestic water wells in the area. About 400 water samples were collected in one summer of field work to supplement the 450 available water chemistries in the files of the Groundwater Division. The distribution of data points is shown on all water level and water chemistry maps. In general data become sparse in Tps 75 and 76 in the north, in Rs 12 and 13 in the west and in Rs 1 and 2 in the east.

Information presented on all maps except figures 1, 2, 3, 9, 10, and 11 was analyzed according to a procedure developed by Newton (1973) and employed by Hackbarth (1974, 1975). The procedure is, in brief, a statistical probability analysis of a field of randomly scattered data with subsequent contouring by computer procedures. The contoured information was examined to determine whether hydrogeologic principles had been violated and if so was manually recontoured.

ACKNOWLEDGMENTS

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PHYSIOGRAPHY AND CLIMATE

The surface of the area slopes southward from the Saddle Hills (Fig. 2) where elevations as high as 3200 ft are reached. Minor local highs occur at Kleskun and Saskatoon Hills. Aside from these highs, the area has a gently rolling topography.

The Wapiti, Smoky, and Simonette Rivers have deeply incised valleys. Tributaries have deep valleys within a few miles of these three major rivers.

Mean annual precipitation is about 475 mm. The average annual temperature is about 1°C (Canada Department of Transport). Potential evapotranspiration (Thornthwaite and Mather, 1957) is about 483 mm while evaporation (Bruce and Weisman, 1967) is slightly less than 635 mm annually.

GEOLOGY

SURFICIAL GEOLOGY

The most widespread deposits of the area according to Jones (1966) are glaciolacustrine in origin. These deposits are, in fact, quite thin and overlie glacial till. Sand dunes cover the surface of much of the area within a few miles of the Wapiti River. The Saddle Hills, Saskatoon Hill, and Kleskun Hill are covered with thin till. Carlson and Hackbarth (1974) show most of the area covered by 50 to 150 ft (15 to 46 m) of glacial drift. Areas with drift thicker than 150 ft (46 m) are indicated in figures 26 through 39.

The Bezanson valley (Carlson and Hackbarth, 1974), a major preglacial valley, crosses the southeastern portion of the area (Fig. 3). Two tributaries to this feature in the map area are the Wembley (Jones, 1966) and Grande Prairie valleys. These buried valleys contain varying amounts of gravel or sand or both and may be locally important sources of water.

BEDROCK GEOLOGY

The Upper Cretaceous Smoky Group is the oldest bedrock unit of interest to this study. This unit has limited subcrop in the northern portion of the area (Fig. 3). Due to its low hydraulic conductivity and consequent poor water quality, exploration in this unit for potable water supplies is not warranted.

The major bedrock unit of the map area is the Upper Cretaceous Wapiti Formation which thickens and dips southward (Fig. 3). Near Grande Prairie the Wapiti Formation is about 1500 ft (460 m) thick and over most of the area is the only bedrock source of domestic or industrial water supplies.

The following descriptions are from Green (1972):

Wapiti Formation: gray, feldspathic clayey sandstone; gray bentonitic mudstone; bentonite; scattered coal; nonmarine.

Smoky Group: dark gray shale and silty shale, nodules and thin beds of concretionary ironstone; marine.

HYDROGEOLOGY

GROUNDWATER FLOW

Water levels in wells 0 to 150 ft (0 to 46 m), 150 to 300 ft (46 to 91 m), 300 to 450 ft (91 to 137 m), and 450 to 600 ft (137 to 183 m) deep are shown in figures 4 through 7 respectively. Areas in which higher hydraulic heads are observed in the immediately underlying interval are indicated. It is likely that groundwater is moving upward from the underlying interval within these areas in response to the hydraulic head gradient. This upward movement does not imply that flowing wells will occur within the designated areas — flowing wells will occur only where the water levels are above the land surface. Topographic surface contours are also presented in figures 4 through 7 for the purpose of indicating whether flowing conditions are likely to occur at a certain location.

Water levels in wells 0 to 150 ft (0 to 46 m) deep (Fig. 4) are an approximate expression of the water table. The water table is basically very similar to topography, and regional groundwater flow is towards the southeast. Local highs occur around Saskatoon (Tp 72, R 9) and Kleskun Hills (Tp 72, R 4). The Wembley and Grande Prairie valleys (Fig. 3), which contain materials of relatively high hydraulic conductivity compared to the Wapiti Formation, may act as regional groundwater drains; the contours (where data are sufficiently dense to define them well) show that flow tends to concentrate towards these features.

Extensive groundwater discharge features were observed in the valley of Kleskun Creek (Tp 73, Rs 3 through 5); these include: 1) an extensive man-made drainage network; 2) soap holes; 3) springs; 4) infertile ground; 5) localized salt deposits; and 6) flowing wells. Note that the hydraulic head in the interval from 0 to 150 ft (0 to 46 m) (Fig. 4) is above the land surface in this area indicating that these features are related to groundwater discharge. This supports hypotheses put forward by Tóth (1966, 1971).

Water level contours for wells 150 to 300 ft (46 to 91 m) deep (Fig. 5) present a much more subdued replica of topography than in the overlying interval. Flow continues to be southeastward.

An area of upward flow from the underlying interval is noted north of Bear Lake and extends to the nose of the Saddle Hills to the east. This probably results from groundwater flow systems originating in the Saddle Hills.

The influence of high hydraulic conductivity materials in the Wembley valley is indicated by a minor reentrant of the 2400 ft water level contour. The Grande Prairie valley appears to have an influence on the flow pattern in its upper reaches.

Figure 6 presents contours of water levels in wells 300 to 450 ft (91 to 137 m) deep. Flow continues to be toward the southeast with the contour pattern still reflecting topography. Some minor influence of the Wembley valley continues to be evident on the 2200 ft contour. Influence of the Grande Prairie valley on flow at this depth is minor. Upward flow from the underlying interval takes place in the valley of Kleskun Creek and in the southwest corner of the area.

Figure 7, presenting contours of water levels in wells 450 to 600 ft (137 to 183 m) deep, shows the same southeast direction of groundwater flow. Water level contours are fairly regular and reflect only very general topographic trends.

A review of the water level maps (Figs. 4 through 7) reveals that flowing wells from depths up to 600 ft (183 m) might be expected in the major river valleys. Only a few wells have been drilled in these valleys; most are shallow and completed in river alluvium. These do not flow and reflect water levels in the adjacent river. One well 1100 ft (335 m) deep was drilled in the Wapiti River valley south of Grande Prairie and did encounter hydraulic heads above land surface. However, evidence of major groundwater discharge in the valleys of the Smoky, Wapiti, and Simonette Rivers was not found even though extensive field work was carried out in these areas. It is concluded that major amounts of groundwater do not discharge in these valleys.

Generally, the water level contour maps are subdued replicas of topography. The pattern of horizontal flow in all layers presented is quite simple at the scale of analysis.

On the other hand, vertical patterns of groundwater flow are not quite so simple as the horizontal. The complex, lenticular, and possibly fractured nature of the Wapiti Formation appears to strongly control vertical components of groundwater flow. A schematic representation of vertical groundwater flow patterns is presented in figure 8. The lateral and vertical distribution of more permeable zones, which may be connected by fractures, causes groundwater to flow upward or downward following paths of greatest hydraulic conductivity.

Jones (1966) cited the great variability in calculated 20-year safe yields as evidence for fracture permeability in the Wapiti Formation. This author concurs with that opinion.

Wells of drastically different short-term yield are observed close to each other. The overall long-term yield will be determined by the average regional permeability.

Figures 9 and 10 present the average hydraulic conductivity of aquifers in the intervals 150 to 300 ft (46 to 91 m) and 300 to 450 ft (91 to 137 m). Basically these maps show the hydraulic conductivity of portions of the Wapiti Formation, since the glacial drift is less than 150 ft (46 m) thick over most of the area. An hydraulic conductivity map for the interval 0 to 150 ft (0 to 46 m) was not constructed because transmissivities in the glacial drift are too variable to have any regional significance.

Figures 9 and 10 can be used to calculate the expected yield of a well 150 to 450 ft (46 to 137 m) deep. An example follows:

1. Well location: 1-73-6 W 6th Mer
2. Surface elevation: 2300 ft (701 m) (Fig. 6)
3. Open portion of well: 300 to 400 ft (91 to 122 m)
4. Expected water level elevation (from figure 6 in this case): 2200 ft (671 m)
5. Drawdown to 300 ft (91 m) in 20 years is desired, therefore available drawdown is 200 ft (61 m) - from 2200 ft to 2000 ft (671 to 610 m) (top of open interval)
6. Hydraulic conductivity is 1 igpd/ft^2 (5.7 x 10^{-5} cm/sec) minimum and 10 igpd/ft^2 (5.7 x 10^{-4} cm/sec) maximum (Fig. 10)
7. Calculate the transmissivity by multiplying the limits of the range of hydraulic conductivity by the length of the open portion of the well (100 ft): 1 x 100 to 10 x 100 igpd/ft (1.5 m^2/day to 15 m^2/day)
8. By use of figure 11, with the two transmissivity values and an available drawdown of 200 ft (61 m), the 20-year safe yield is predicted as between 8 and 80 igpm (0.6 to 6 l/sec).

It should be pointed out that the 20-year safe yield is the rate at which the well can be pumped continuously for 20 years to cause a predetermined drawdown. This drawdown is usually considered to be the top of the pump or top of the open interval. Also, a continuous yield of 1 igpm (0.076 l/sec), although seemingly small, gives 1440 igpd (6551 l/day). This yield is more than sufficient for household use.

Persons wishing to drill wells within the map area should try to select a target depth where high values of hydraulic conductivity are documented; however, the selection of well depth should not be based on hydraulic conductivity alone. It may, in some cases, be advantageous or necessary to select a low hydraulic conductivity zone in order to obtain water of good chemical quality.

GROUNDWATER CHEMISTRY

About 850 chemical analyses of groundwater from the area were available from two sources:

1) samples submitted to the Provincial Pollution Control Laboratory by well owners;
2) samples collected during 1973 specifically for the purposes of this study.

In order to demonstrate the chemical differences among groundwaters from different source materials and depths, the samples were divided into four groups:

1) groundwater from wells 0 to 200 ft (0 to 61 m) deep that terminate in glacial drift (Figs. 12 through 25)
2) groundwater from wells 0 to 150 ft (0 to 46 m) deep that terminate in bedrock (Figs. 26 through 39)
3) groundwater from wells 150 to 300 ft (46 to 91 m) deep that terminate in bedrock (Figs. 40 to 53)
4) groundwater from wells 300 to 450 ft (91 to 137 m) deep that terminate in bedrock (Figs. 54 through 66).

Areas where the glacial drift is greater than 150 ft (46 m) thick are outlined on the maps for the bedrock interval 0 to 150 ft (0 to 46 m) deep (Figs. 26 through 39). The boundaries of these thick drift areas are taken directly from the bedrock topography map of the area (Carlson and Hackbarth, 1974). The area underlain by drift thicker than 300 ft (91 m) is quite restricted and is not shown on the maps for the two underlying bedrock intervals.

Maps of iron concentration are not presented. Water samples intended for iron analysis require special treatment upon collection; none of the samples available for this study were so treated and thus any reported values are misleading.

Maps showing calcium, magnesium, carbonate, bicarbonate, alkalinity, and hardness are presented even though the samples were not analyzed in the field. During the time between collection and laboratory analysis, calcium and magnesium carbonates precipitate out in quantities dependent upon the amount of carbon dioxide loss and temperature increase experienced by the sample. As a result, values of the above parameters will be lower than in the freshly sampled groundwater. This is not a serious deficiency, considering the regional nature of the study and the scale of presentation of the data.

Maps of equivalents per million (epm) percent are also presented for calcium plus magnesium, sodium plus potassium, sulfate, carbonate plus bicarbonate, and chloride (where percentages were significant). The percentages are calculated on the basis of total cations or total anions, not total ions. These maps indicate relative concentration of a particular constituent regardless of changes in absolute concentrations. Either a calcium plus magnesium or a sodium plus potassium epm percent map is presented for every depth interval.

Table 1 presents current drinking water standards. This table may be used as a basis for judging the potability of groundwater.

Groundwater from Glacial Drift from 0 to 200 ft (0 to 61 m) below the Land Surface

Over much of the area the total dissolved solids content of waters in this interval (Fig. 12) is between 1000 and 1500 mg/l. Values of this parameter rise rapidly in Tp 76 north of the Saddle Hills.

Calcium and magnesium have similar distribution patterns (Figs. 13 and 14). Calcium is usually less than 80 mg/l while magnesium is commonly less than 40 mg/l. Values of both parameters increase rapidly north of the Saddle Hills in the Saddle River valley near Woking and Heart Valley. Another area of relatively high values occurs west of Hythe.

Figure 15 shows hardness to be less than 400 mg/l (as $CaCO_3$) over most of the area. Values increase markedly near Woking and west of Hythe. The increases are due to higher calcium content of the groundwater in these areas.

Figure 16, presenting epm percent of calcium plus magnesium, shows that the areas of higher calcium and magnesium noted previously are not areas of higher percentages of calcium plus magnesium relative to sodium plus potassium. In fact, sodium and potassium (Figs. 17 and 18) increase in concentration more than does calcium or magnesium.

The two areas of higher calcium and magnesium concentrations are apparently groundwater discharge areas. The area west of Hythe seems to be a local system as it is not reflected in the hydrochemistry of deeper intervals. The area near Woking is reflected in water chemistry to a depth of at least 300 ft, and probably results from discharge of intermediate flow systems.

Higher values of calcium and magnesium both in absolute terms and relative to sodium plus potassium are observed in the buried valleys.

Sodium and potassium are less than about 400 mg/l and 4 mg/l (Figs. 17 and 18) respectively throughout much of the area. These two constituents together represent about 60 to 80 epm percent of cations over most of the area. Both absolute and ion percent values of these two constituents are quite high compared to usual values in the glacial drift of Alberta. Pawluk and Bayrock (1969) found that large amounts of silt and clay-sized particles are present in the drift which is largely derived from bentonite-rich Smoky Group shales which

Table 1. Drinking Water Standards

Parameter	Acceptable (mg/l)	Maximum Permissible (mg/l)
Total dissolved solids	500	1000
Calcium (Ca^{++})	200	ND
Magnesium (Mg^{++})	<50	150
Hardness (as $CaCO_3$)	<120	ND
Sodium (Na^+)	ND	300
Potassium (K^+)	ND	2000
Bicarbonate (HCO_3^-)	ND	625
Alkalinity (as $CaCO_3$)	ND	500
Sulfate ($SO_4^=$)	250	500
Chloride (Cl^-)	<250	250
Fluoride (Fl^-)	<1.5	1.5
Nitrate ($NO_3^=$)	<45	45

ND: value not defined

Sources:

1. Canada Department of National Health and Welfare (1969).
2. McKee and Wolf (1971).

crop out to the north and east of the area. The abundance of bentonite in the drift results in high values of sodium and potassium relative to calcium and magnesium.

Bicarbonate concentrations (Fig. 19) are less than 1200 mg/l over much of the area. Carbonate ion concentrations are not significant and a map is not presented. Figure 20 presents the epm percent carbonate plus bicarbonate in the drift and shows that these are the dominant anions present in the drift except in the Heart Valley-Woking area.

The distribution of alkalinity (as mg/l $CaCO_3$) is shown in figure 21. Alkalinity is less than 600 mg/l in groundwater from the drift nearly everywhere in the study area.

The sulfate content of drift waters is highly variable over most of the map area (Fig. 22). Sulfate concentrations exceeding the standard of 250 mg/l are likely in the west-central and northeastern parts of the area. The high values in the Woking area are probably due to oxidation of pyrite in the glaciolacustrine deposits there. The high values of sulfate in the west-central region are related, for the most part, to the local high known as Saskatoon Hill. The high sulfate is again probably due to the oxidation of pyrite-rich till, derived from the Smoky Group, which was deposited around this bedrock high by overriding glacial ice. Examination of the epm percent sulfate map (Fig. 23) shows that both of the mentioned areas of high sulfate are also areas where sulfate occurs in high concentrations relative to other anions.

Figure 24 presents the chloride content of glacial drift groundwaters. Concentrations rarely exceed 10 mg/l except in the northeastern and eastern areas. High values around Woking and Heart Valley are the result of longer residence time of groundwater in the lacustrine clays. The area of relatively high chloride in Tps 72 and 73, R 3 is probably related to groundwater discharge in the Kleskun Creek valley (Fig. 4). An epm percent map for chloride is not presented as the values never exceed 10 percent.

Fluoride concentrations (Fig. 25) can be expected to be less than 1.0 mg/l over most of the area. A localized area of high fluorides occurs southeast of Beaverlodge and is probably related to upward groundwater flow which is taking place from a depth of at least 450 ft.

The distribution of chemical constituents for groundwater in the drift to a depth of 200 ft can be generally characterized as follows:

1) High values of all constituents, except fluoride, are noted in the Woking-Heart Valley area. Concentrations in this area are generally greater than drinking water standards. Sodium tends to exceed the standard of 300 mg/l; alkalinity tends to exceed the standard of 500 mg/l; and sulfate likely exceeds the standard of 250 mg/l.

2) Calcium and magnesium show a tendency toward higher values, both in absolute terms and relative to sodium and potassium, in the deposits of the buried valleys.

3) Outside of the Woking-Heart Valley area groundwater tends to be of the sodium bicarbonate type. Sodium sulfate type dominates in the Woking-Heart valley area.

Groundwater from Bedrock from 0 to 150 ft (0 to 46 m) below the Land Surface

Figure 26 presents the total dissolved solids content of water from this interval. Values are less than 1500 mg/l except in the Woking and Heart Valley areas which coincide roughly with the area of Smoky Group shale subcrop. The location of these units of marine origin plays a strong rôle in the distribution of chemical parameters in this interval.

The patterns of calcium and magnesium ion concentration are shown in figures 27 and 28 respectively. The distribution patterns and concentrations are not significantly different from those presented for the glacial drift (Figs. 13 and 14), which is to be expected since groundwater flows back and forth readily between these two stratigraphic units.

Hardness values (Fig. 29) of waters in this interval are generally less than 400 mg/l. The average hardness in this interval is somewhat less than in the overlying drift interval even though higher values are observed in the northeast area. The Wembley valley, in Tps 70 and 71, Rs 8 and 9, causes higher values of calcium and magnesium and hence of hardness than might otherwise be expected in the bedrock. This is due to downward movement of groundwater. Except in the northeast, softer water will be encountered by completing wells in the upper bedrock rather than in the glacial drift, due to ion exchange in the sodium-rich shales of the bedrock.

The concentrations of sodium and potassium (Figs. 30 and 31) are approximately the same as in the overlying drift (Figs. 17 and 18). Concentrations of sodium less than 600 mg/l can be expected, with even lower values common in areas of thick drift in the south. Lower values of epm percent sodium plus potassium are evident along the Bezanson and Wembley valleys (Fig. 32). This decline is, of course, complemented by an increase in calcium and magnesium. This indicates that water of greater than average hardness will be found at shallow depths in bedrock in the areas overlain by thick drift.

The pattern of bicarbonate distribution (Fig. 33) is quite similar to that of the overlying drift. Highest values occur in the northeast and in the vicinity of Grande Prairie. The epm percent of carbonate plus bicarbonate (Fig. 34) shows that the highest concentrations relative to other anions are found near Grande Prairie.

The alkalinity of water in this interval is presented in figure 35. The pattern is nearly the same as that for bicarbonate except where more data allows the distribution to be better defined.

Concentrations of sulfate are shown in figure 36. Higher values are observed in the northeast where the pyrite in the Smoky Group shales influences the water chemistry. The average value for sulfate concentration in this interval is approximately the same as in the overlying drift interval (Fig. 22); however, the distribution seems to be much more even, with concentrations generally less than 400 mg/l over much of the area. The northeast and the southwest areas tend to have waters exceeding the provincial drinking water standard for sulfate. Figure 37 shows the epm percent of sulfate for this interval. Sulfate values increase both in absolute and relative terms in the northeast and the southwest.

Chloride concentration and distribution in this interval (Fig. 38) differ little from those in the overlying drift. As in the drift, higher values tend to be observed in the northeast. However, all values are still well below drinking water standards. An epm percent map for chloride is not presented as chloride constitutes an insignificant proportion of the total anions.

Fluoride (Fig. 39), for the most part, is not expected to exceed 1.0 mg/l in the area. Concentrations are below the standard of 1.5 mg/l.

Generally, the distribution of chemical constituents in groundwater from bedrock at depths of 0 to 150 ft (0 to 46 m) can be characterized as follows:

1) High concentrations of all constituents, except fluoride, are noted in the Woking-Heart Valley area.

2) Calcium and magnesium tend to occur in greater concentrations and relative abundance near buried valleys.

3) Alkalinity and sulfate tend to exceed drinking water standards. Sodium tends to exceed the standard in the central and northeastern areas.

4) Except in the Woking-Heart Valley area and near areas of thick drift, groundwater tends to be of the sodium bicarbonate type. The Woking-Heart Valley area has water of the sodium sulfate type.

Groundwater from Bedrock from 150 to 300 ft (46 to 91 m) below the Land Surface

The distribution of total dissolved solids for this interval is shown in figure 40. As in overlying intervals, higher than average values occur in the Woking-Heart Valley area;

however, the maximum observed concentrations are less than those observed in the drift or overlying bedrock by about several thousand milligrams per litre. Concentrations are expected to be less than about 1500 mg/l for most of the area.

Calcium values (Fig. 41) are high below the Wembley valley and in the northeast area, as in the overlying interval (Fig. 27). The high values in the northeast are the result of the generally higher levels of dissolved solids. Along the Wembley valley calcium-rich waters move downward into the bedrock from the relatively thick drift section. The distribution pattern of magnesium values (Fig. 42) is about the same as in the overlying interval (Fig. 28) but values are somewhat lower.

Hardness values (Fig. 43) are very high in the northern part of the area and are exceptionally high considering the depth into bedrock. Normally by this depth extensive exchange of calcium for sodium would have occurred in the bedrock shales. Two factors may be acting to give high hardness in the northern part of the area:

1) In the Woking-Heart Valley area the increases in calcium, magnesium, and hardness are the result of a large increase in dissolved material in the groundwater due to the low permeability of the Smoky Group shales.

2) The coincidence of the high values with topographic highs indicates a strong downward component of groundwater movement in these areas. Evidently this flow carries large volumes of relatively calcium-rich water downward quite rapidly, so most available exchange sites have been occupied by calcium with the result that hardness does not decline with depth.

Sodium and potassium (Figs. 44 and 45) show very much the same pattern of concentrations as observed in the overlying bedrock interval. Sodium is expected to be about 400 mg/l or less over most of the area while potassium should exceed 2 mg/l only rarely.

The distribution of epm percent sodium and potassium (Fig. 46) shows that sodium is the dominant cation over much of the area, and reflects the fact that calcium and magnesium values are fairly high in the north. The pattern exhibits less variation than that in the overlying interval (Fig. 32), indicating that surface conditions exert little influence at this depth. The dominance of sodium, especially in the south, is due to the long flow paths of groundwater in this interval. In general, water not only moves 150 to 300 ft (46 to 91 m) downward, but also tens of miles laterally, allowing significant exchange of calcium for sodium in the shales.

As with most other parameters, the distribution of bicarbonate in this interval (Fig. 47) is similar to that in the overlying interval. Values less than 1000 mg/l are common. Carbonate values are less than 10 mg/l.

Figure 48 presents the epm percent carbonate plus bicarbonate for this interval. As in the overlying interval bicarbonate is very much the dominant anion.

Alkalinity for this interval is presented in figure 49. Values usually exceed the standard of 500 mg/l.

The distributions of sulfate in absolute terms and relative to other anions are presented in figures 50 and 51, respectively. Figure 50 shows that the pattern of distribution is much the same as in the overlying interval (Fig. 36) with higher maximum values occurring. Compared to the overlying bedrock interval (Fig. 37), epm percent sulfate is generally lower over most of the area.

Chloride values (Fig. 52) are somewhat higher in this interval than in the overlying one; however, chloride is still far from significant anywhere in the area. Comparatively high values occur in the Woking-Heart Valley area due to the general increase in dissolved solids with depth in that area.

Concentrations of fluoride are shown in figure 53. Values in general do not exceed 1.0 mg/l in the eastern and north-central areas. Concentrations of 1.0 mg/l to 2.0 mg/l commonly occur in the south-central and northwest areas.

The chemical constituents in bedrock groundwaters from depths of 150 to 300 ft (46 to 91 m) can be characterized as follows:

1) Higher values of all constituents, except fluoride, are observed in the Woking-Heart Valley area, as in the overlying interval.

2) Total dissolved solids, sodium, and alkalinity generally exceed drinking water standards. Sulfate exceeds standards in the northeast and south-central areas, while hardness may be excessive along the northern boundary of the map area.

3) The dominant water type is sodium bicarbonate with calcium possibly the dominant cation in the far north.

Groundwater from Bedrock from 300 to 450 ft (91 to 137 m) below the Land Surface

The distribution of total dissolved solids for this interval is shown in figure 54. Over much of the south-central portion of the area dissolved solids are less than 1000 mg/l. An area of slightly lower concentrations roughly coincides with the Wembley valley. Total dissolved solids in wells of this depth in the Woking-Heart Valley area likely will exceed 2000 mg/l.

Figure 55 shows that calcium is less than 20 mg/l over most of the area. As a result, hardness values (Fig. 56) are quite low. The distribution of magnesium is not presented — the average value is 4 mg/l in this interval.

The distribution of sodium is shown in figure 57. The pattern is much the same as in the overlying bedrock interval (Fig. 44) with perhaps more area having less than 400 mg/l. Sodium is virtually the only cation present in any significant quantities. Figure 58 shows that sodium is by far the dominant cation. A slight tendency for lower sodium percentage (higher calcium percentage) may be hypothesized for the areas of thick drift in the southeast. A potassium distribution map is not presented, as the average value for the constituent is only 2 mg/l.

The distribution of bicarbonate ion (Fig. 59) is also not significantly different from that in the overlying interval (Fig. 47). Carbonate (Fig. 60) shows a pattern of distribution which reflects bedrock topography — high values tend to occur below portions of the Bezanson and Grande Prairie valleys. However, the epm percent carbonate plus bicarbonate (Fig. 61) indicates very little correlation of relative concentrations of these two anions with bedrock topography except perhaps southwest of the Wembley valley.

The pattern of alkalinity distribution (Fig. 62) is, as with other constituents, similar to that in the overlying interval (Fig. 49). Values exceed the drinking water standard of 500 mg/l at all locations.

Sulfate concentrations (Fig. 63) tend to be less than in the overlying interval in most areas (Fig. 50). A band of higher values extends generally from La Glace to Mount Valley. This feature is also reflected on the epm percent map (Fig. 64) but is interrupted by the Wembley valley. This band also occurs on the sulfate (Fig. 50) and epm percent sulfate (Fig. 51) maps for the overlying interval but shifted slightly southeast. These higher values of sulfate may be due to localized gypsum concentrations in the Wapiti Formation. Except for the band of higher values, sulfate concentrations in this interval are below drinking water standards.

Chloride values (Fig. 65) are relatively insignificant both in absolute and relative terms.

Fluorides (Fig. 66) are less than 1.5 mg/l over most of the area except for a band of values up to 3.0 mg/l extending from Hythe to Beaverlodge and south and from Beaverlodge to Grande Prairie.

The chemical constituents in groundwater of the bedrock from depths of 300 to 450 ft (91 to 137 m) may be characterized as follows:

1) Data are nonexistent for the Woking-Heart Valley area. High values of all constituents may be expected based on observations from overlying intervals.

2) Total dissolved solids content, sodium, and alkalinity generally exceed drinking water standards.

3) Water in this interval is characterized as sodium bicarbonate.

Groundwater from Depths greater than 450 ft (137 m) below the Land Surface

There were 16 water analyses from depths greater than 450 ft (137 m) available to this study. Most were from depths of 500 to 600 ft (152 to 183 m) and the deepest was from 1105 ft (337 m). The average total dissolved solids concentration in these analyses was 820 mg/l; the highest value was 1800 mg/l and the lowest was 311 mg/l. The chemical character of the water is basically sodium bicarbonate with three wells showing sodium bicarbonate-sulfate.

Analyses of water samples obtained during drillstem tests in the Beaverlodge area indicate total dissolved solids of 5000 mg/l at depths of 2000 to 3000 ft (610 to 915 m). This is surprisingly fresh compared to waters from similar depths in other areas of Alberta and may indicate that reasonably potable water can be obtained from as deep as several thousand feet in the area.

SUMMARY

The Grande Prairie area can be divided into two subregions for purposes of summarizing water quality.

The Woking-Heart Valley area (Tp 76 and part of Tp 75, Rs 1 to 8) is distinguished by high total dissolved solids concentrations in groundwater to depths of at least 300 ft (91 m). Data are insufficient to characterize the waters of greater depths. Calcium sulfate type groundwater dominates in the drift of this subregion, while water of the sodium sulfate type predominates in the bedrock. The poor water quality is due to the combined effects of topography and the slow passage of groundwater through parts of Smoky Group marine shales or lacustrine clays.

The remainder of the project area is characterized by water of fairly good quality, with local exceptions. Total dissolved solids concentrations are generally less than 1500 mg/l and tend to decrease to depths of 450 ft (137 m). Groundwater is of the sodium bicarbonate type with some tendency to calcium bicarbonate type in areas of thick glacial drift.

Limited existing data indicate that groundwater quality may be slightly better at depths greater than those investigated in this study. The average total dissolved solids concentration of 16 samples from depths of 450 to 1105 ft (137 to 337 m) was 820 mg/l — about 115 mg/l less than the average for the 300 to 450 ft (91 to 137 m) interval.

Good yields of groundwater may be expected everywhere in the southern region with excellent yields available from the buried valley deposits. The Wapiti Formation, the only bedrock unit of interest, consists of lenticular sands in a shaly matrix and can be expected to yield a minimum of about 1 igpm (0.076 l/sec).

A significant groundwater discharge area exists north of Kleskun Hill in Tp 73, Rs 3, 4, and 5. Soap holes, infertile ground, flowing wells, springs, and salt deposits are observed there. Extensive surface drainage is necessary just to make the area suitable for grazing.

REFERENCES

Bruce, J. P. and B. Weisman (1967): Provisional evaporation maps of Canada; Canada Department of Transport, Meteorology Branch, 21 pages.

Canada Department of National Health and Welfare (1969): Canadian drinking water standards and objectives; Joint Committee on Drinking Water Standards of the Advisory Committee on Public Health Engineering and the Canadian Public Health Association, Queen's Printer, Ottawa, 39 pages.

Canada Department of Transport (undated): Temperature and precipitation 1941-1970 — Prairie Provinces; Atmospheric Environment Service, Ottawa, 159 pages.

Carlson, V. A. and D. A. Hackbarth (1974): Bedrock topography of the Grande Prairie map area, NTS 83M, Alberta; Alberta Research Council map.

Freedman, J. (1977): Trace-element geochemistry; Geotimes, Vol. 22, No. 1, p. 22-23.

Green, R. (1972): Geological map of Alberta; Research Council of Alberta map.

Hackbarth, D. A. (1974): Total dissolved solids in groundwater of the Wainwright area, Alberta; Ground Water, Vol. 12, no. 4, p. 206-212.

Hackbarth, D. A. (1975): Regional chemistry of groundwater in the Wainwright area, Alberta; Alberta Research Council Report 75-6, 49 pages.

Hackbarth, D. A. (in prep.): Hydrogeology of the Grande Prairie area, Alberta; Alberta Research Council Report 76-4, 17 pages.

Jones, J. F. (1960): Groundwater geology, Beaverlodge District, Alberta; Research Council of Alberta Preliminary Report 59-2, 52 pages.

Jones, J. F. (1966): Geology and groundwater resources of the Peace River District, northwestern Alberta; Research Council of Alberta Bulletin 16, 143 pages.

McKee, J. E. and H. W. Wolf (Editors) (1971): Water quality criteria; California State Water Resources Control Board, Publication 3-A, 548 pages.

Newton, R. (1973): A statistical prediction technique for deriving contour maps from geophysical data; Journal of the International Association of Mathematical Geology, Vol. 5, No. 2, p. 159-189.

Odynsky, W., A. Wynnyk and J. D. Newton (1956): Reconnaissance soil survey of the Grande Prairie and Sturgeon Lake sheets; University of Alberta Bulletin 60, 111 pages.

Odynsky, W., J. D. Lindsay, S. W. Reeder and A. Wynnyk (1961): Reconnaissance soil survey of the Beaverlodge and Blueberry Mountain sheets; University of Alberta Bulletin SS-3, 123 pages.

Pawluk, S. and L. A. Bayrock (1969): Some characteristics and physical properties of Alberta tills; Research Council of Alberta Bulletin 26, 72 pages.

Thornthwaite, C. W. and J. R. Mather (1957): Instructions and tables for computing potential evapotranspiration and the water balance; Drexel Institute of Technology, Laboratory of Climatology, Publications in Climatology, Vol. 10, No 3, 289 pages.

Tóth, J. (1966): Mapping and interpretation of field phenomena for groundwater reconnaissance in a prairie environment, Alberta, Canada; Bulletin of the International Association of Scientific Hydrology, Vol. XI, No. 2, p. 1-49.

Tóth, J. (1971): Groundwater discharge: a common generator of diverse geologic and morphologic phenomena; Bulletin of the International Association of Scientific Hydrology, Vol. XVI, No. 1, p. 7-24.

FIGURES

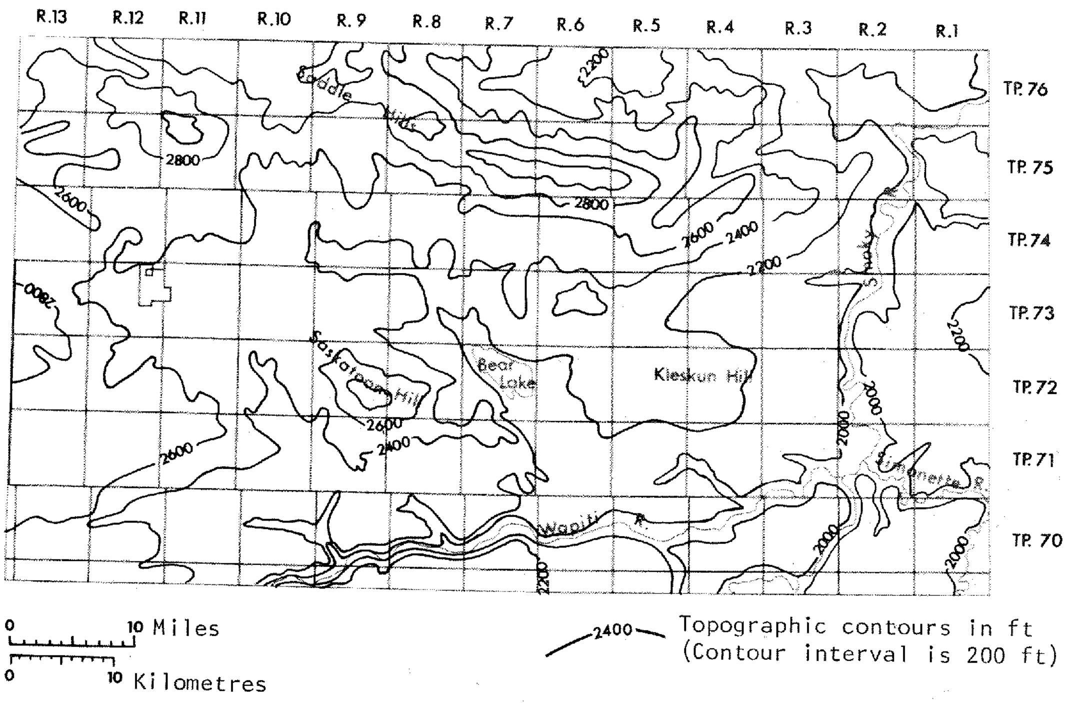

FIGURE 2. Topography and drainage

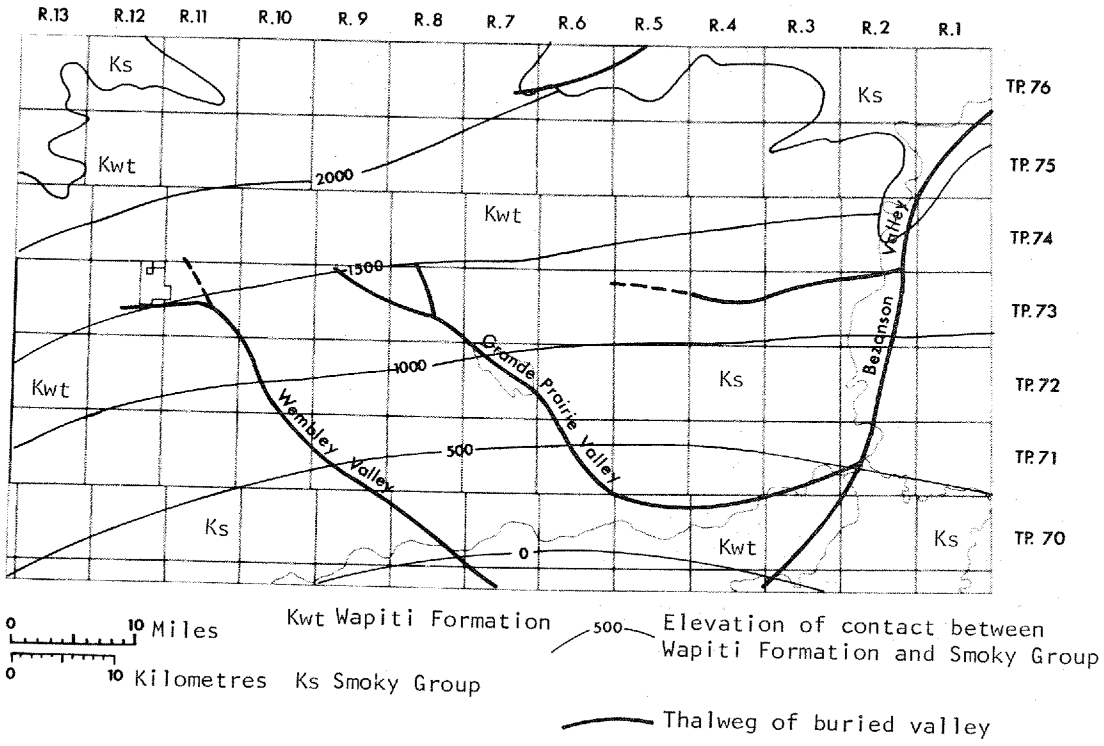

FIGURE 3. Bedrock geology, structure and buried valleys

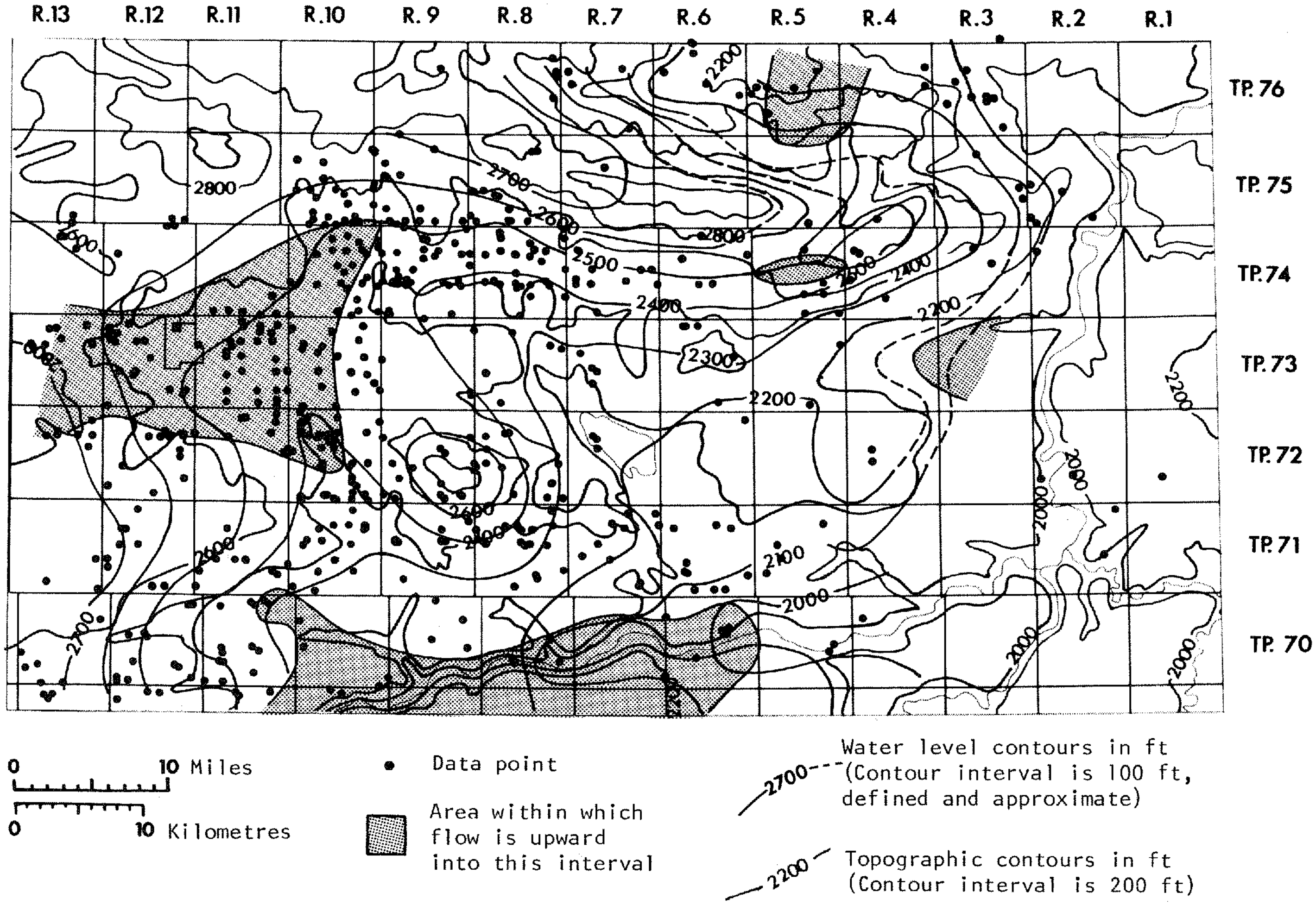

FIGURE 4. Water levels in wells 0 to 150 ft (0 to 46 m) deep

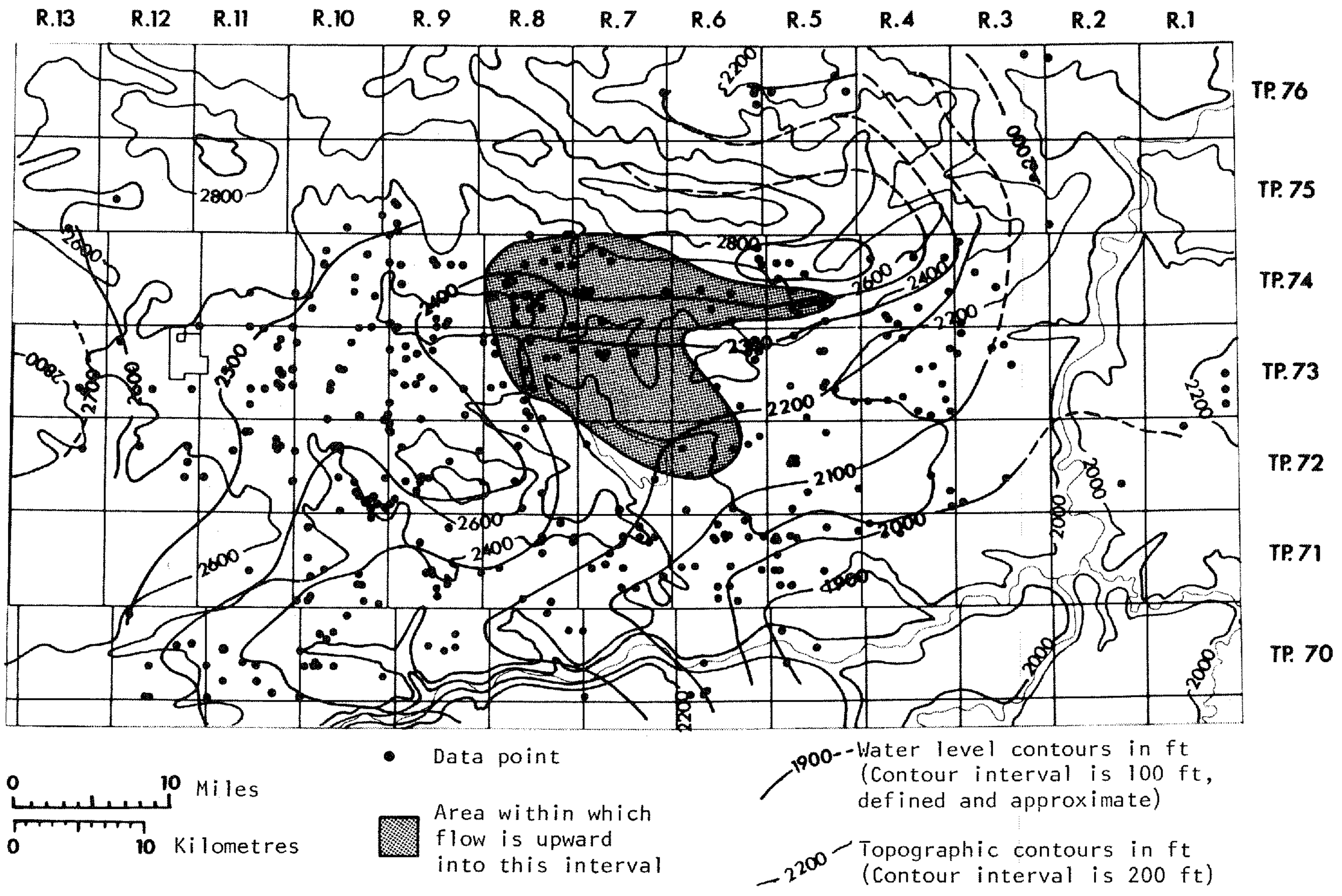

FIGURE 5. Water levels in wells 150 to 300 ft (46 to 91 m) deep

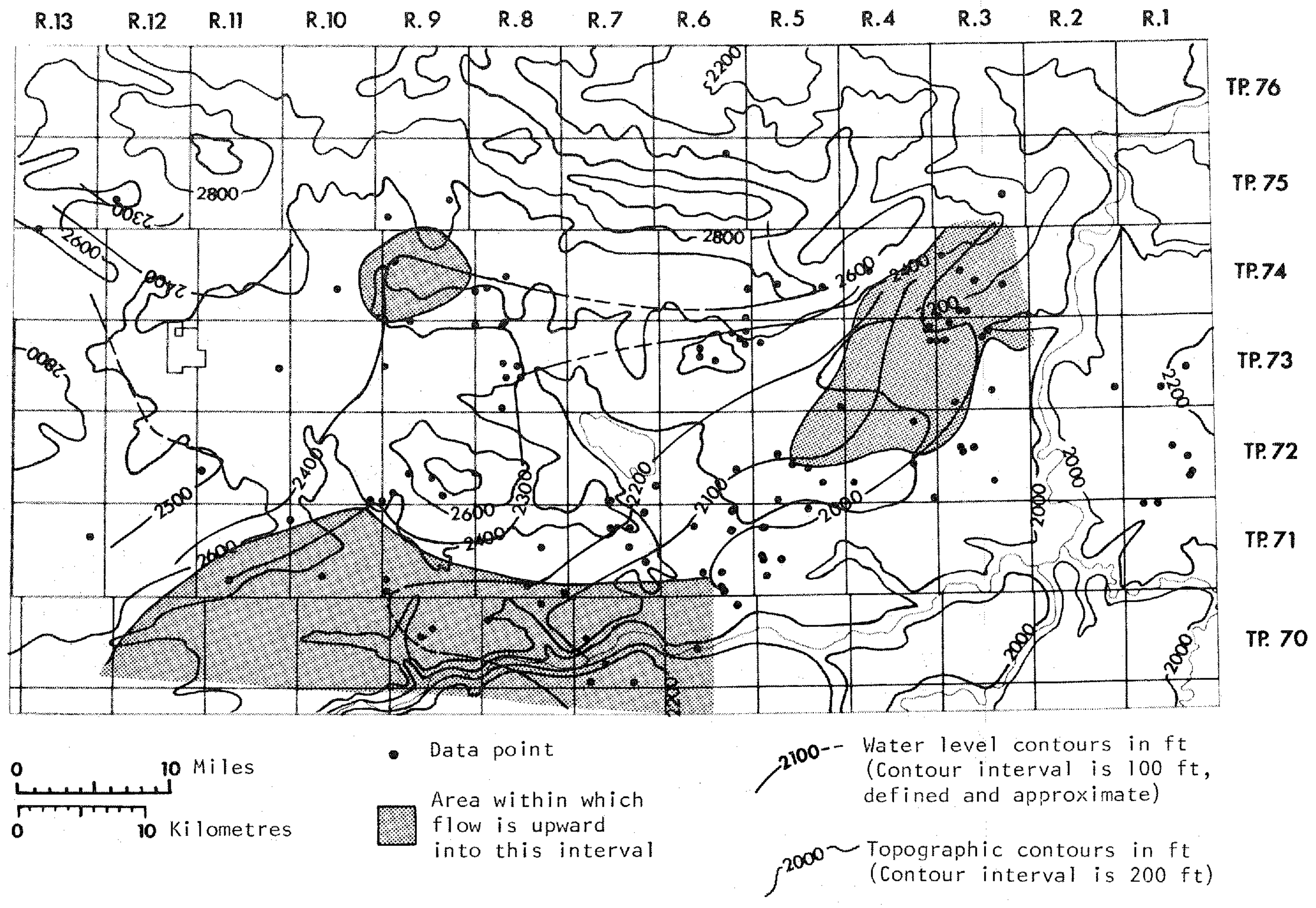

FIGURE 6. Water levels in wells 300 to 450 ft (91 to 137 m) deep

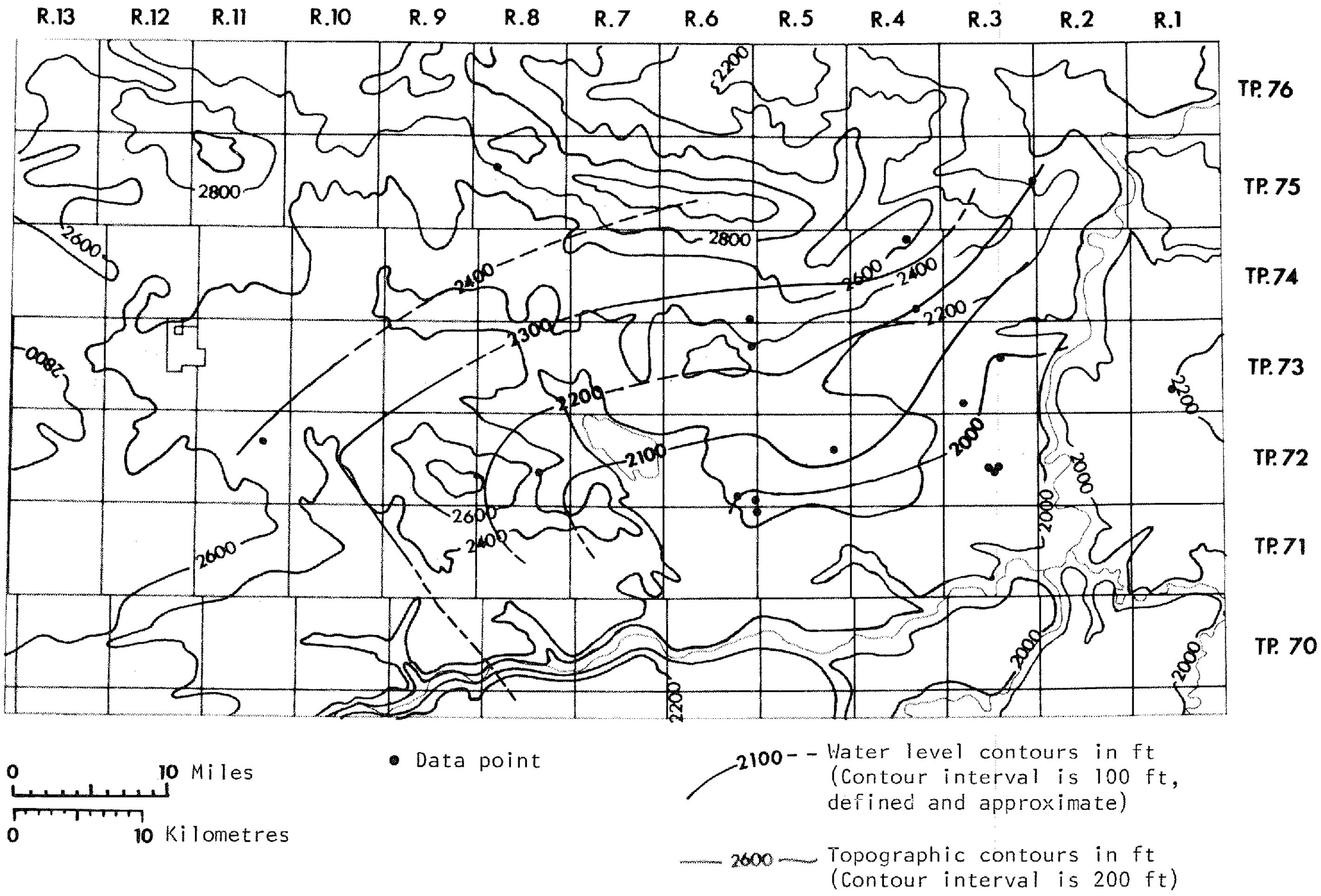

FIGURE 7. Water levels in wells 450 to 600 ft (137 to 183 m) deep

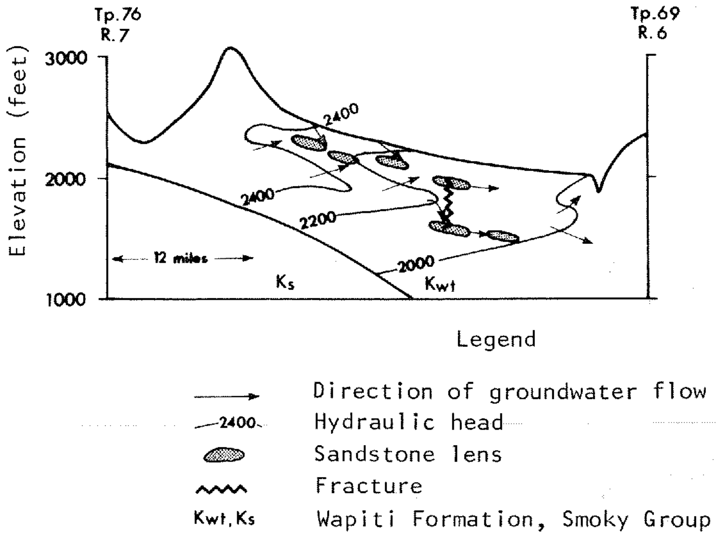

FIGURE 8. Schematic hydrogeologic cross section

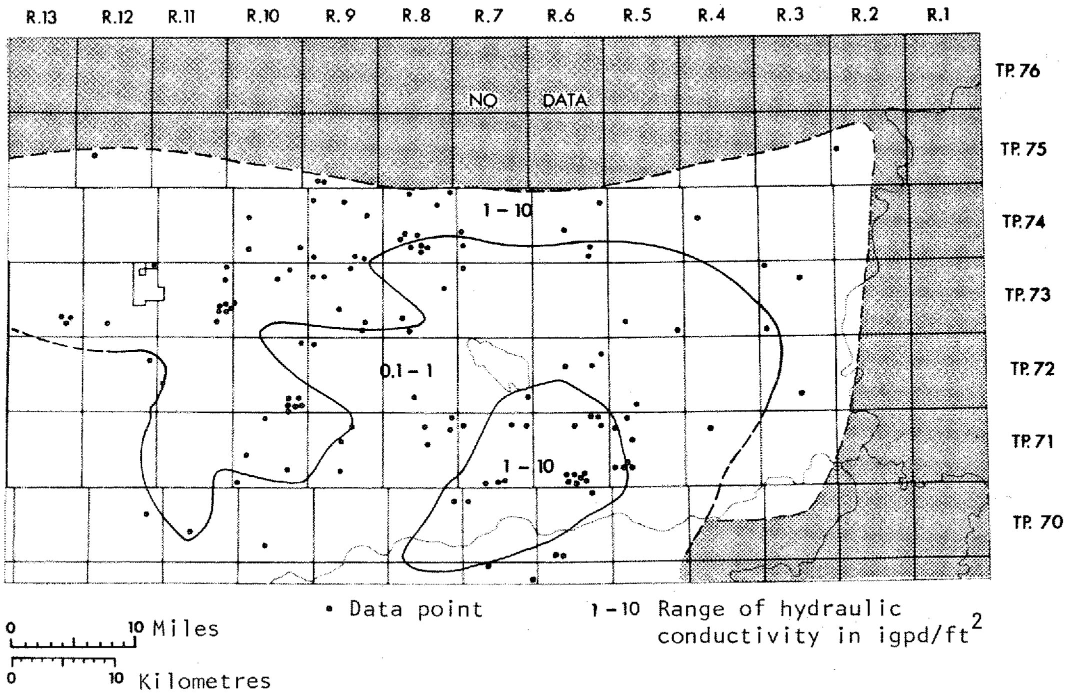

FIGURE 9. Hydraulic conductivity at depths of 150 to 300 ft (46 to 91 m)

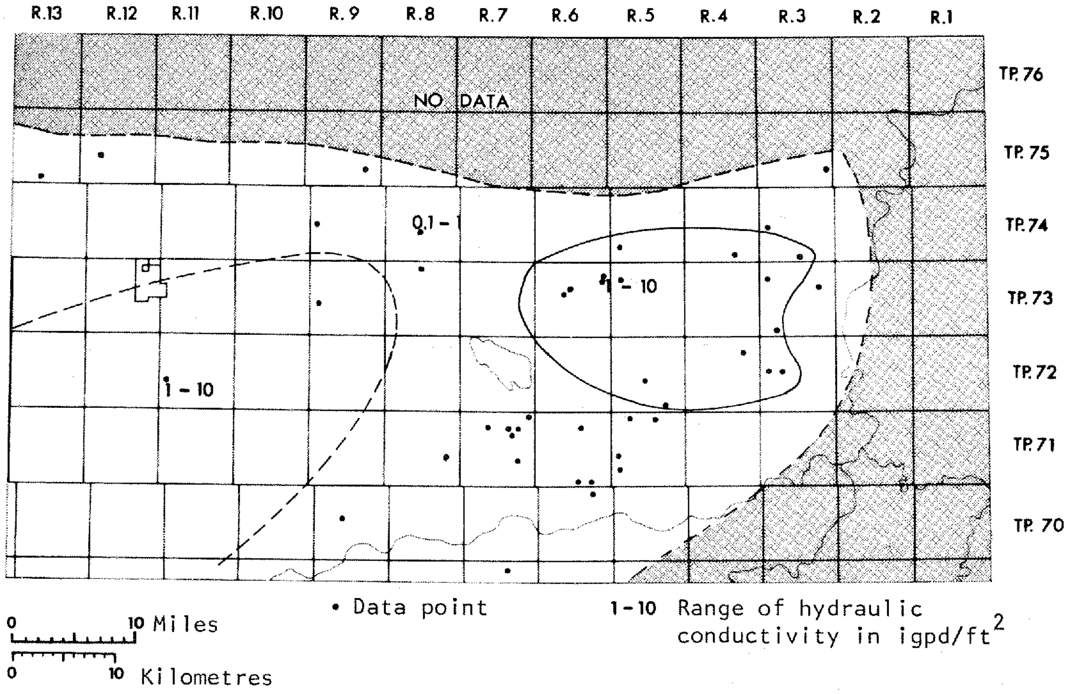

FIGURE 10. *Hydraulic conductivity at depths of 300 to 450 ft (91 to 137 m)*

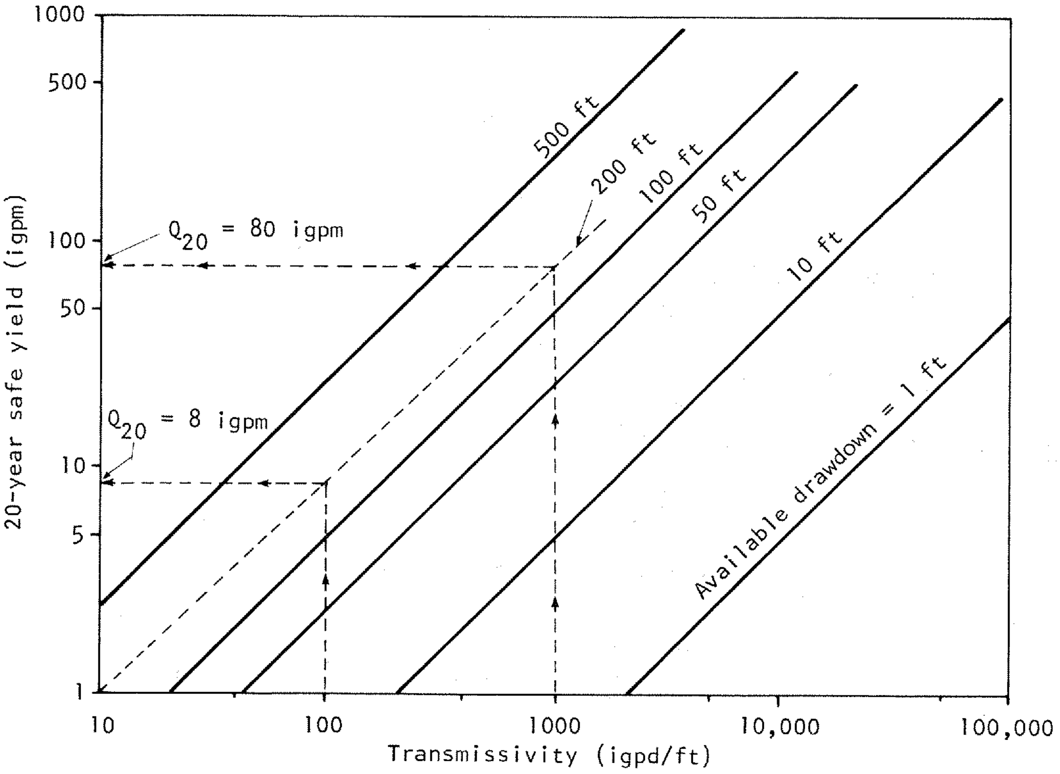

FIGURE 11. *Graph for determining 20-year safe yield*

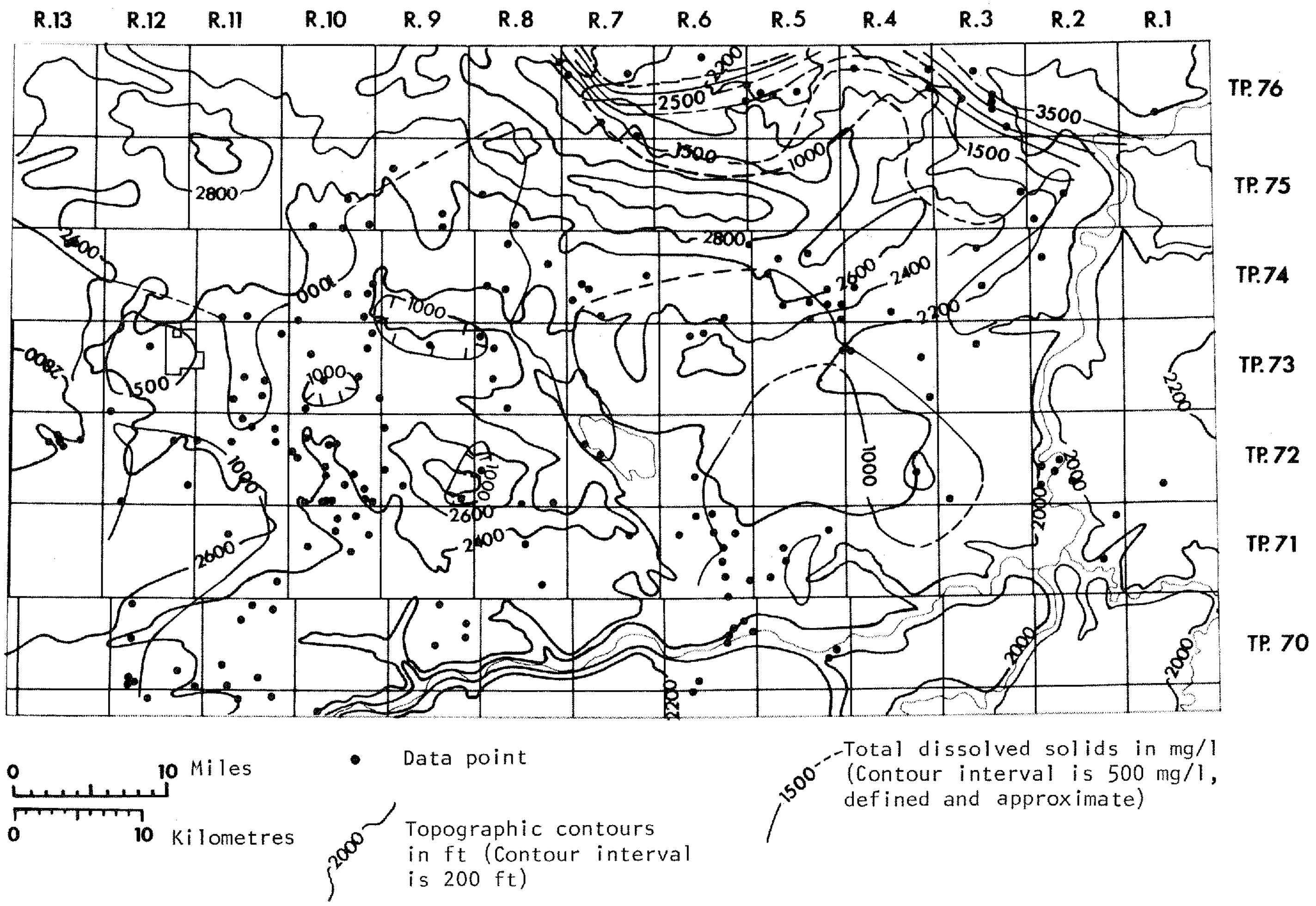

FIGURE 12. Total dissolved solids; drift, 0 to 200 ft (0 to 61 m)

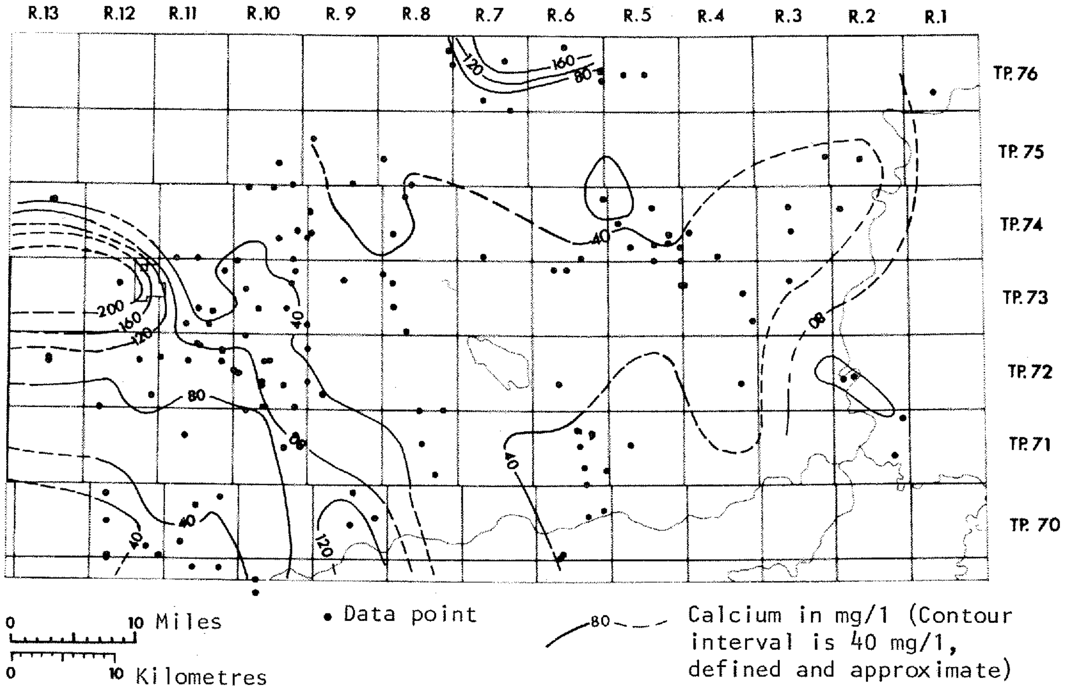

FIGURE 13. Calcium; drift, 0 to 200 ft (0 to 61 m)

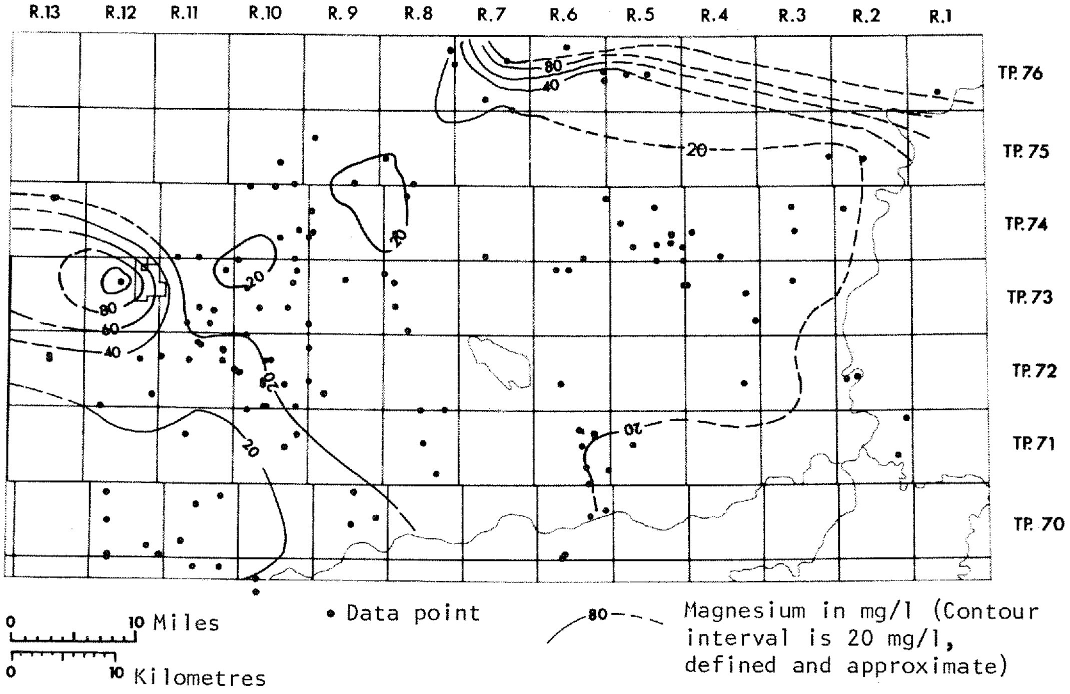

FIGURE 14. Magnesium; drift, 0 to 200 ft (0 to 61 m)

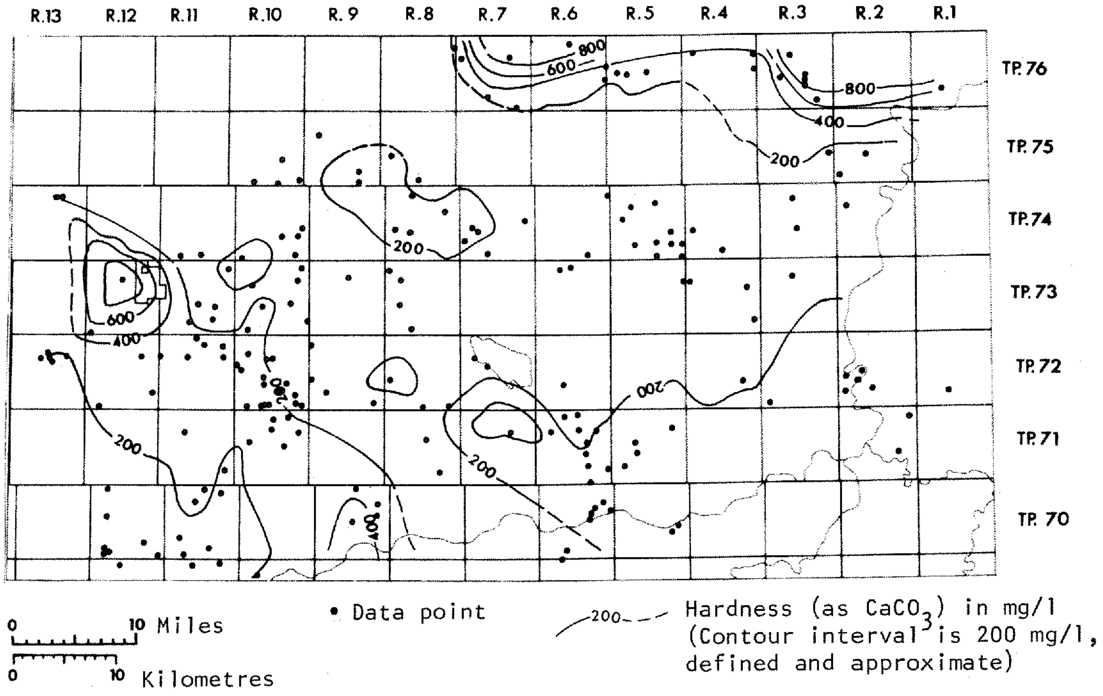

FIGURE 15. Hardness; drift, 0 to 200 ft (0 to 61 m)

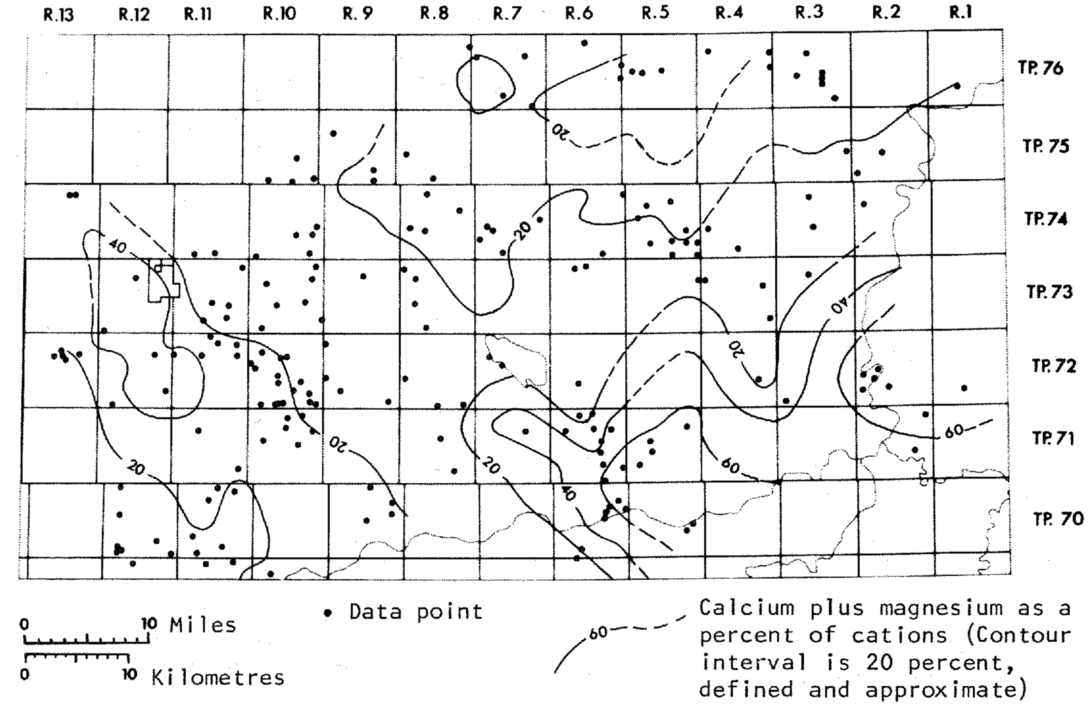

FIGURE 16. Epm percent calcium plus magnesium; drift, 0 to 200 ft (0 to 61 m)

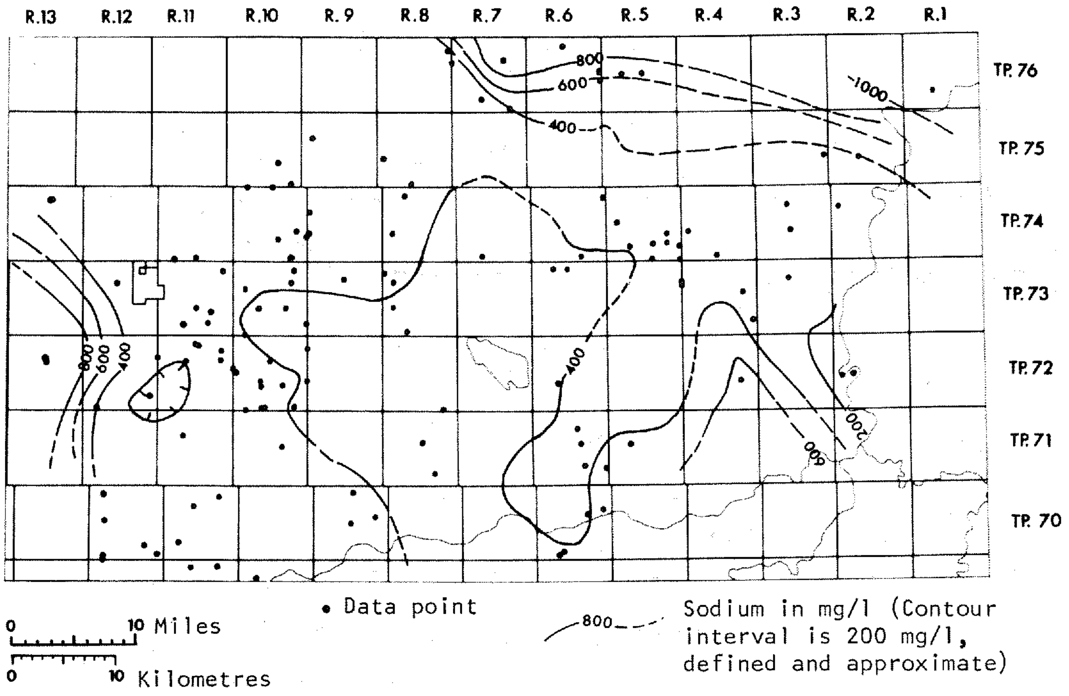

FIGURE 17. Sodium; drift, 0 to 200 ft (0 to 61 m)

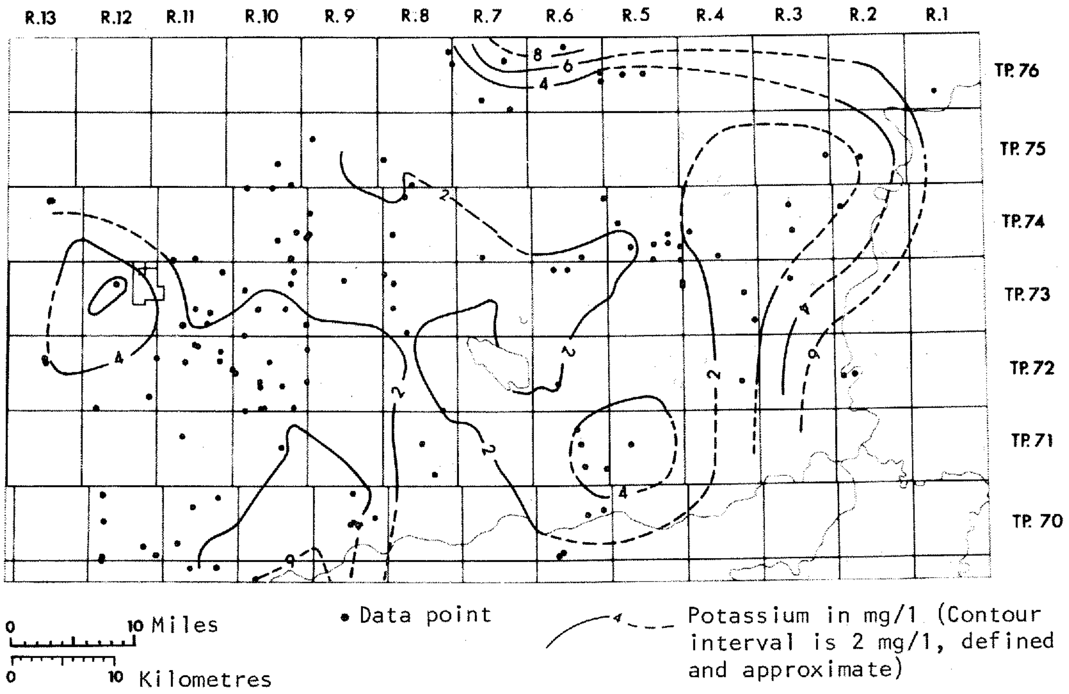

FIGURE 18. Potassium; drift, 0 to 200 ft (0 to 61 m)

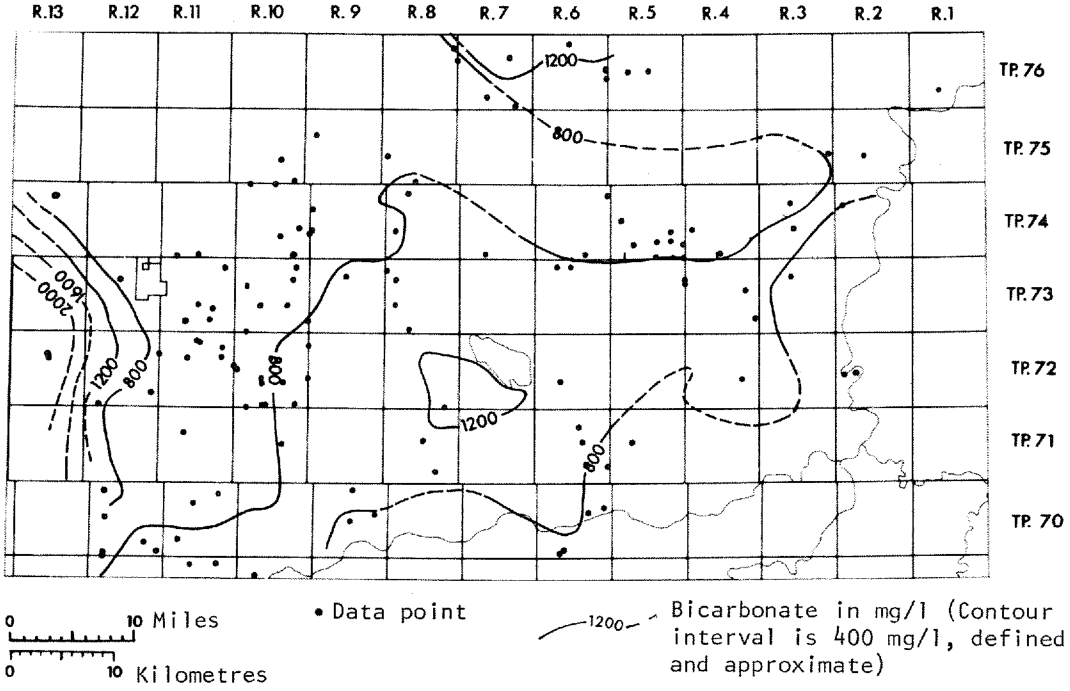

FIGURE 19. Bicarbonate; drift, 0 to 200 ft (0 to 61 m)

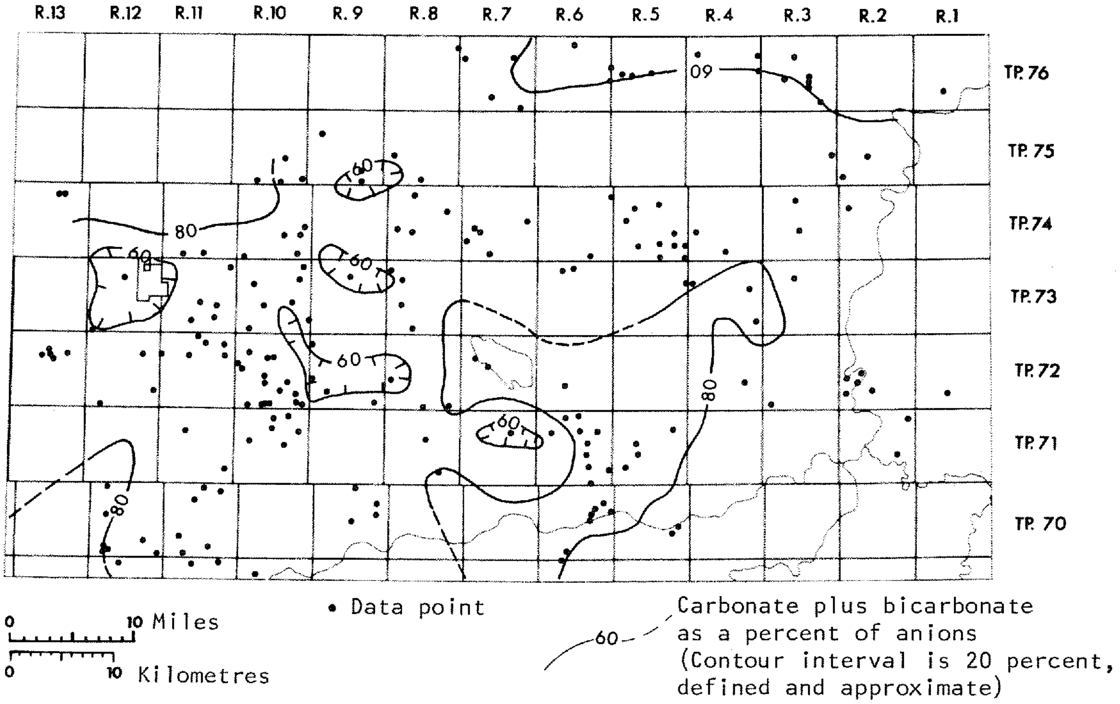

FIGURE 20. Epm percent carbonate plus bicarbonate; drift, 0 to 200 ft (0 to 61 m)

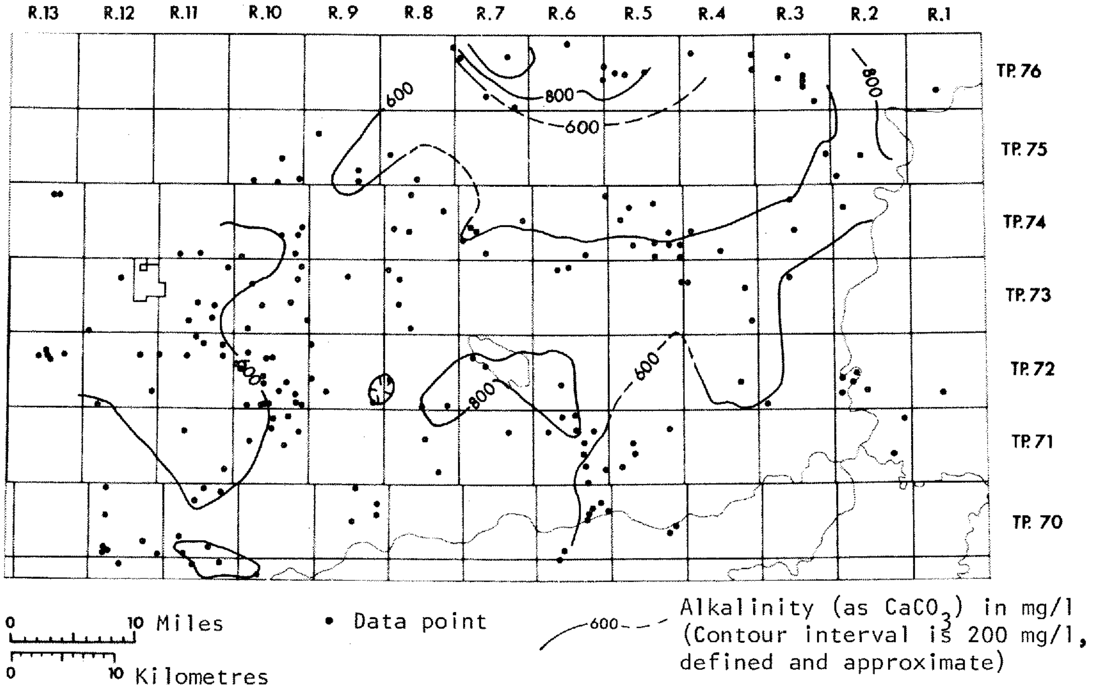

FIGURE 21. Alkalinity; drift, 0 to 200 ft (0 to 61 m)

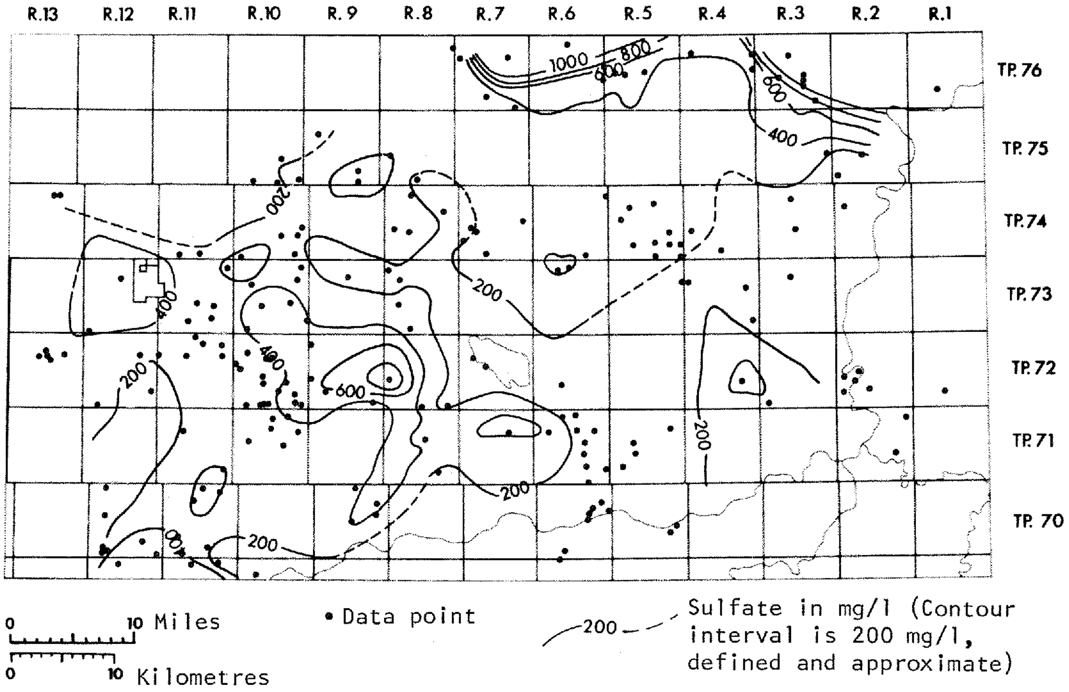

FIGURE 22. Sulfate; drift, 0 to 200 ft (0 to 61 m)

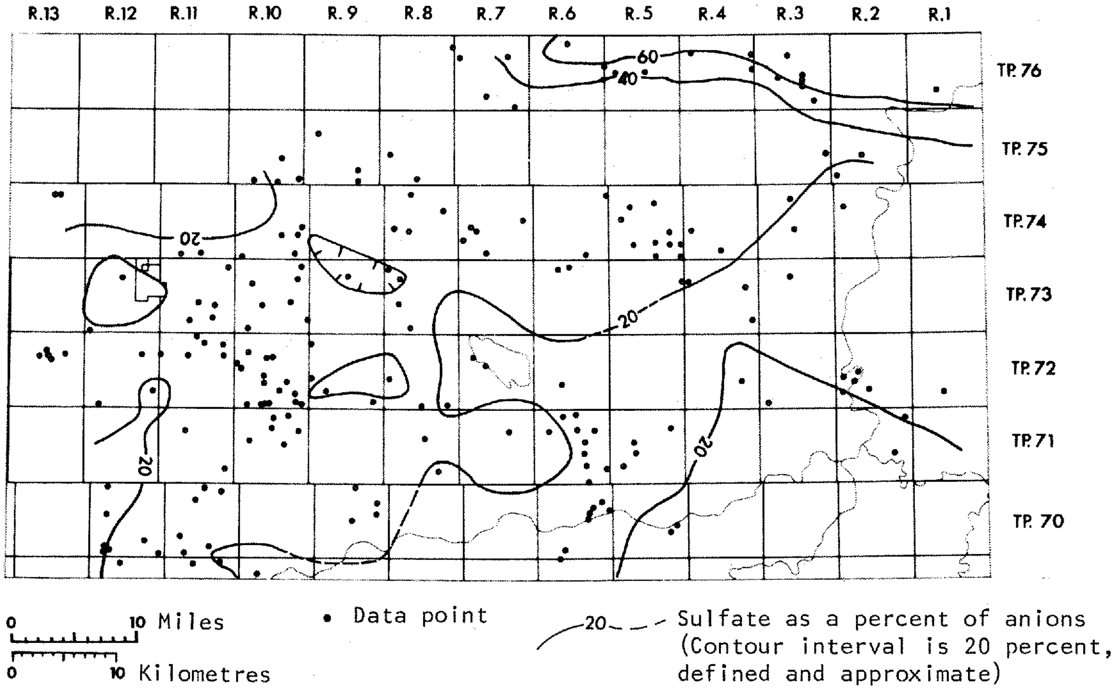

FIGURE 23. Epm percent sulfate; drift, 0 to 200 ft (0 to 61 m)

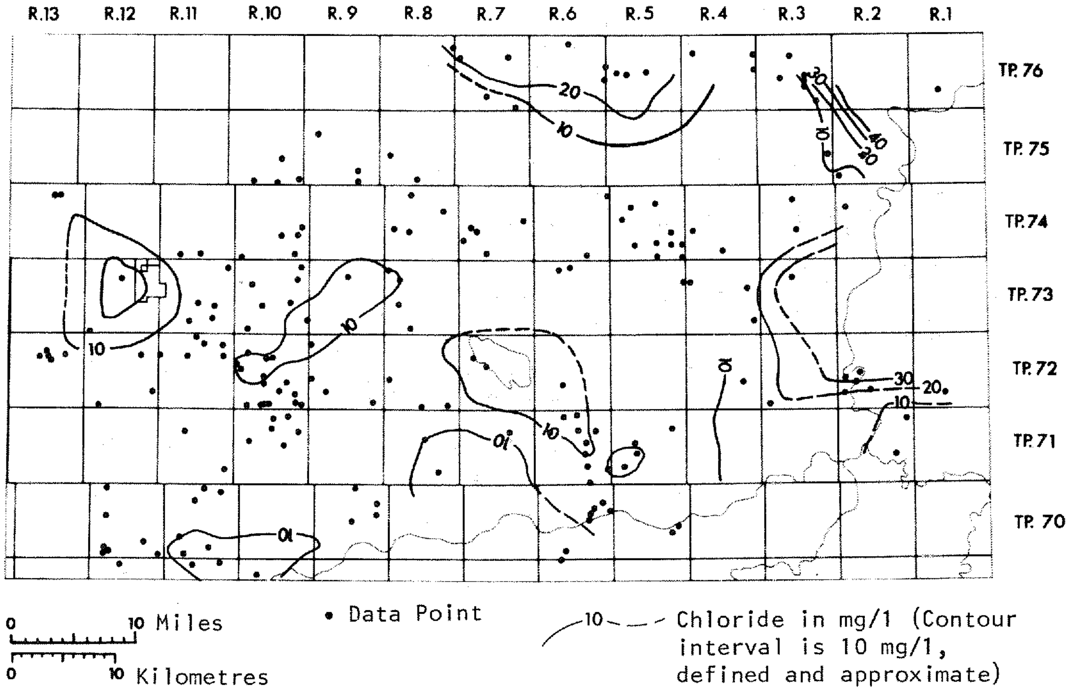

FIGURE 24. Chloride; drift, 0 to 200 ft (0 to 61 m)

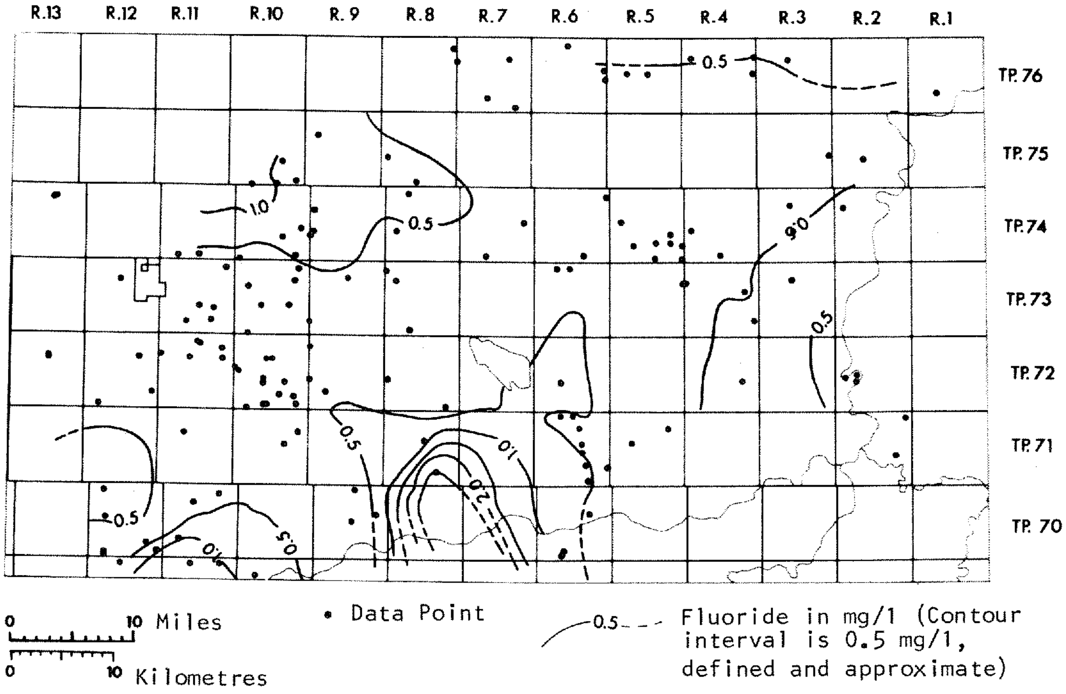

FIGURE 25. Fluoride; drift, 0 to 200 ft (0 to 61 m)

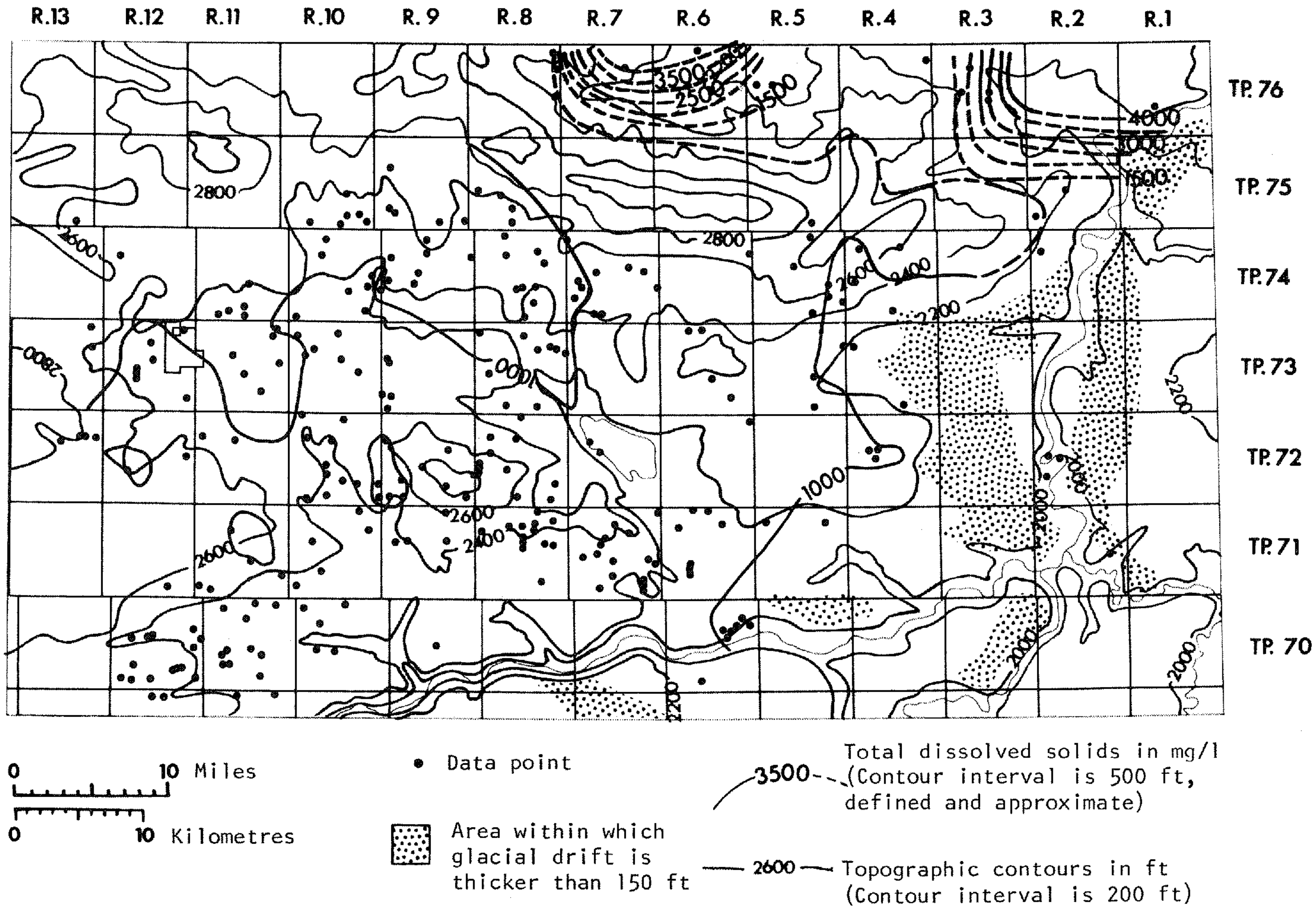

FIGURE 26. *Total dissolved solids; bedrock, 0 to 150 ft (0 to 46 m)*

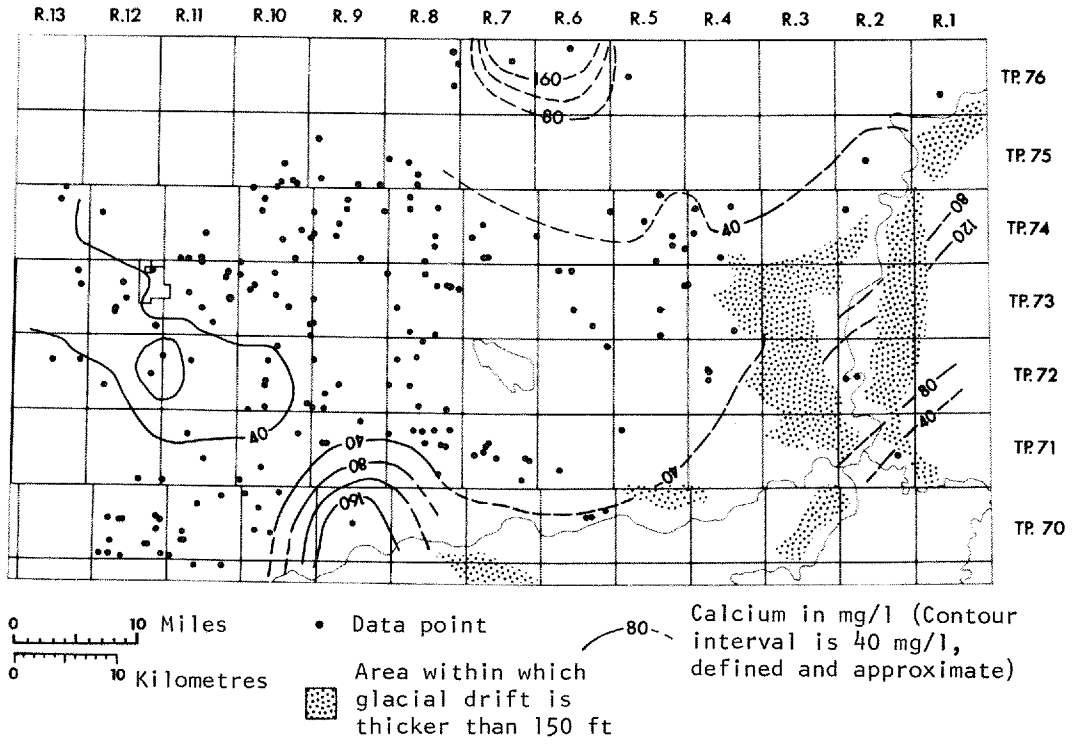

FIGURE 27. Calcium; bedrock, 0 to 150 ft (0 to 46 m)

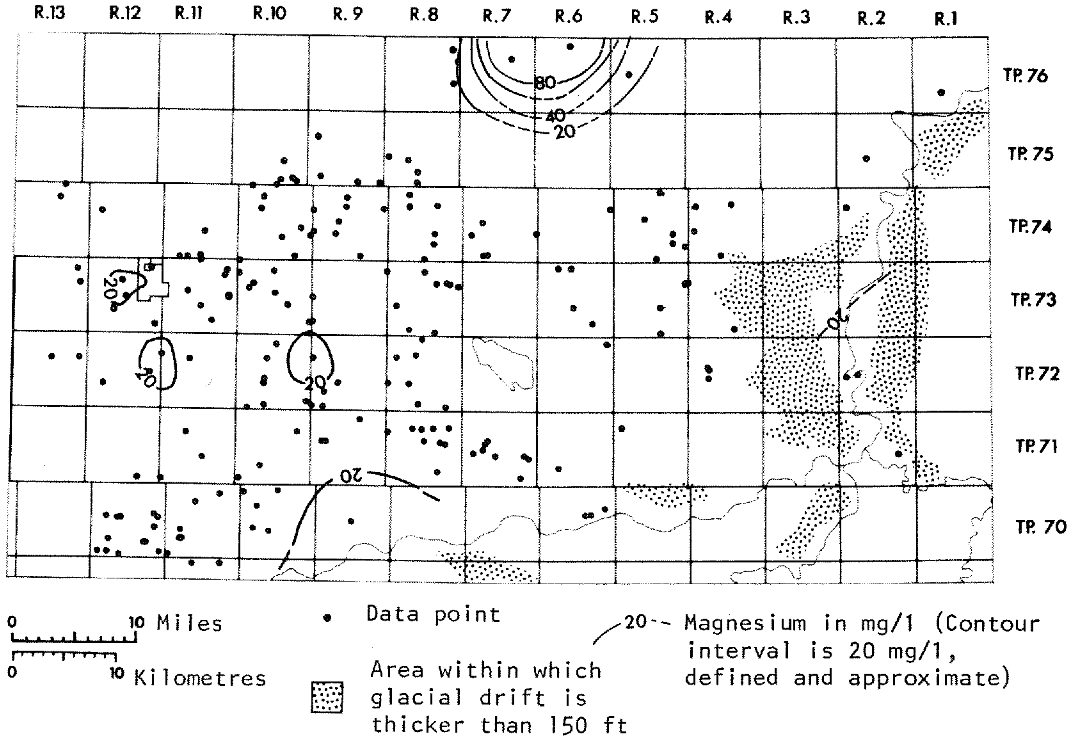

FIGURE 28. Magnesium; bedrock, 0 to 150 ft (0 to 46 m)

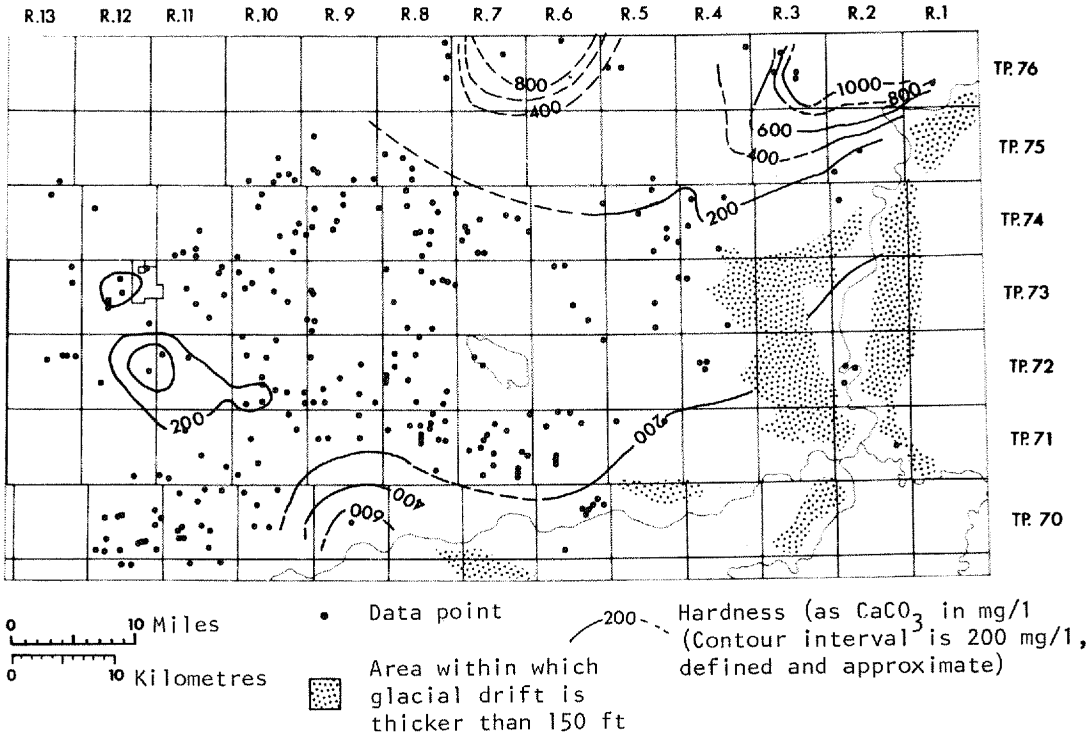

FIGURE 29. *Hardness; bedrock, 0 to 150 ft (0 to 46 m)*

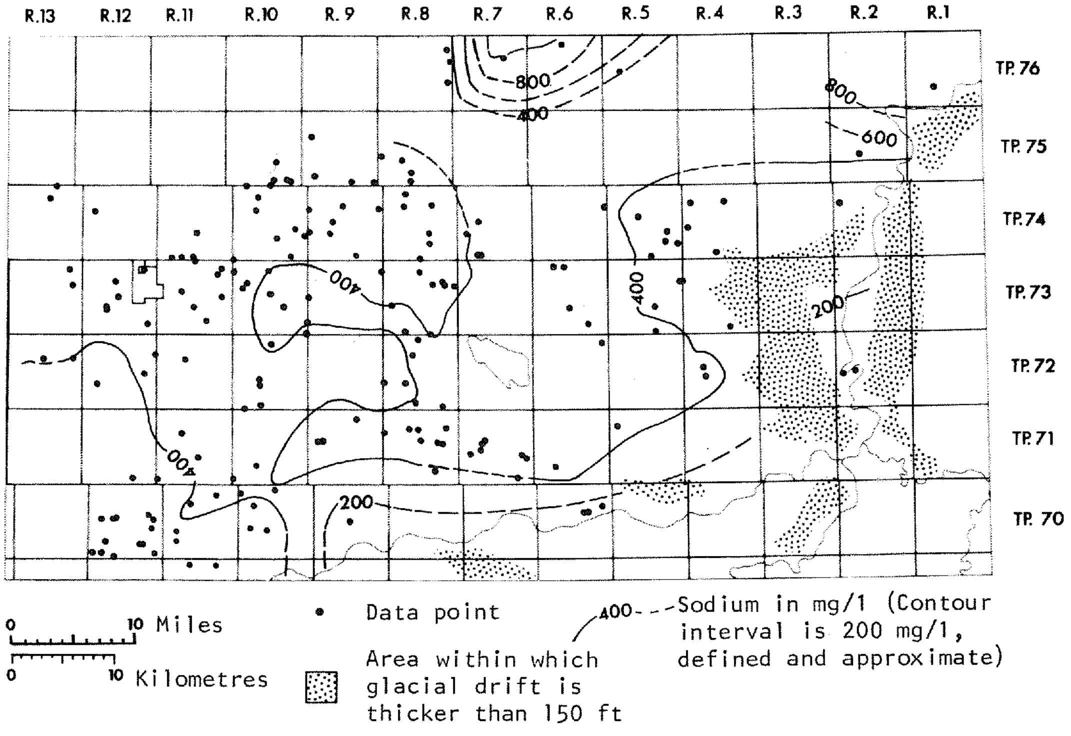

FIGURE 30. *Sodium; bedrock, 0 to 150 ft (0 to 46 m)*

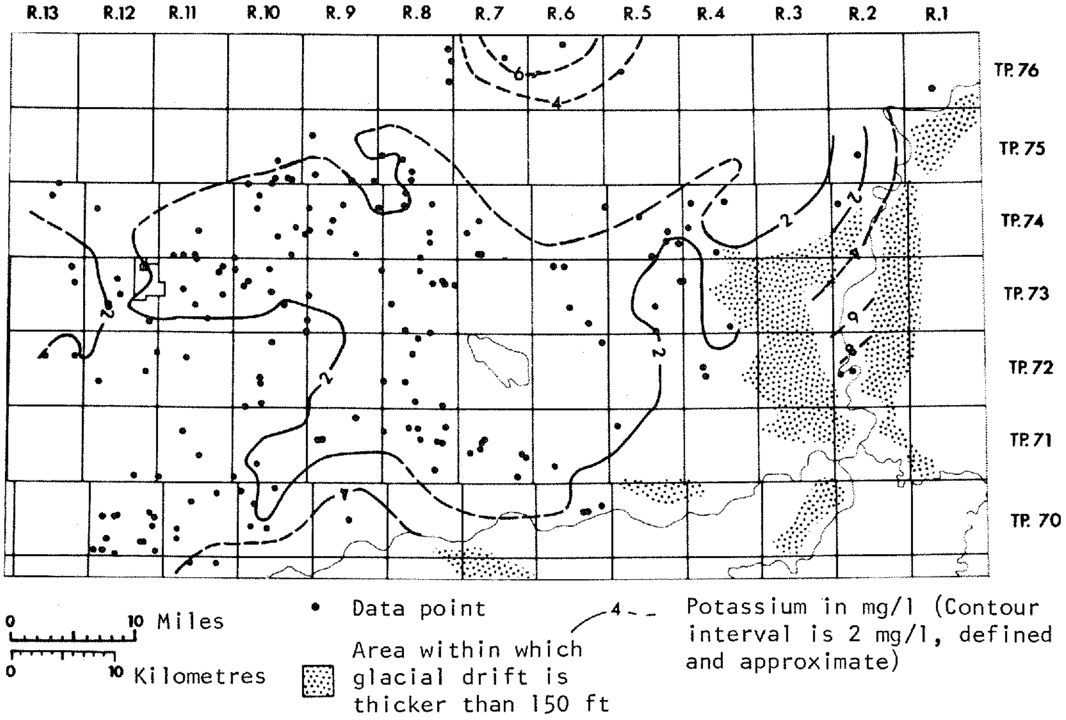

FIGURE 31. Potassium; bedrock, 0 to 150 ft (0 to 46 m)

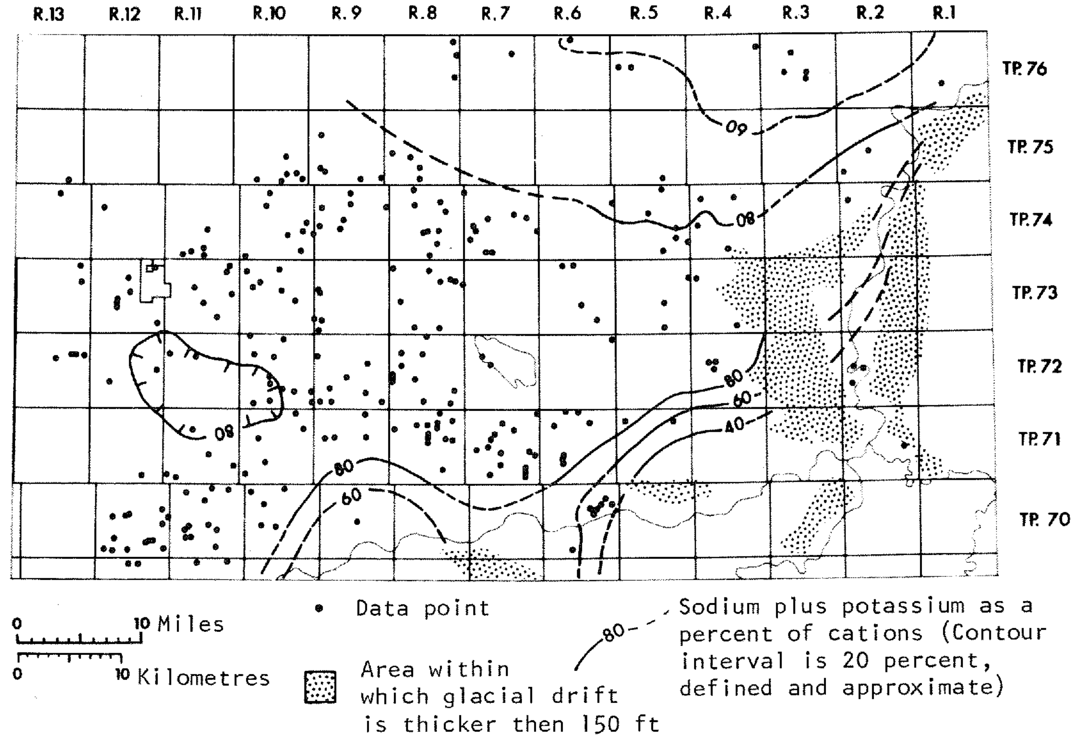

FIGURE 32. Epm percent sodium plus potassium; bedrock, 0 to 150 ft (0 to 46 m)

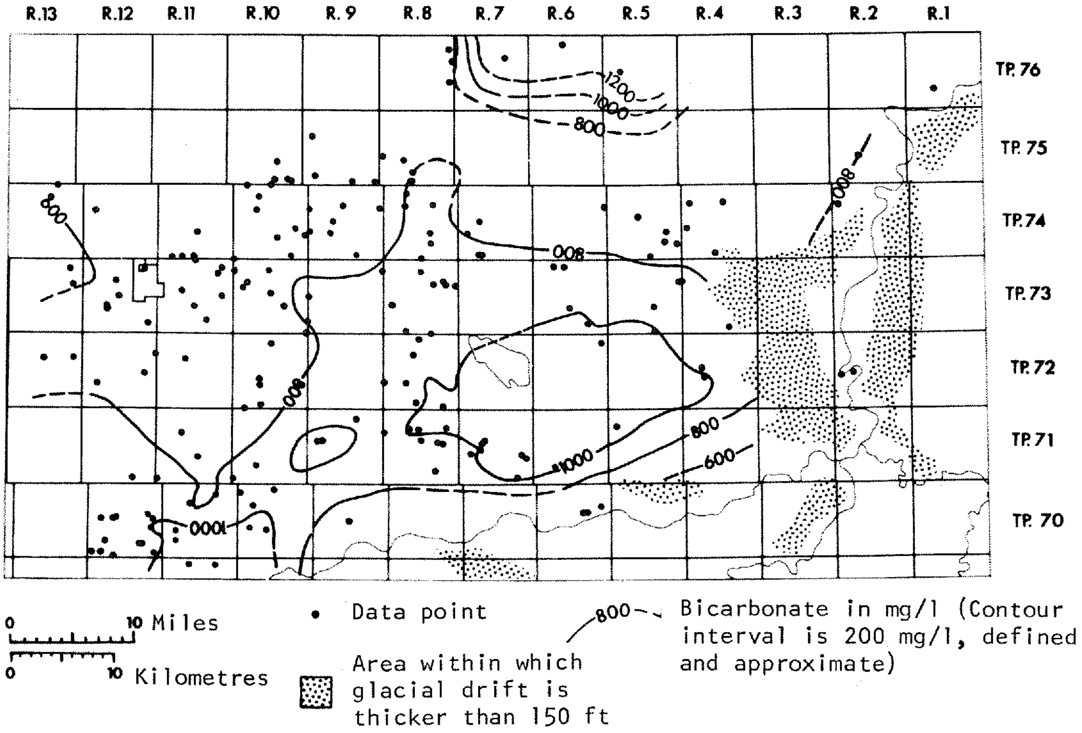

FIGURE 33. Bicarbonate; bedrock, 0 to 150 ft (0 to 46 m)

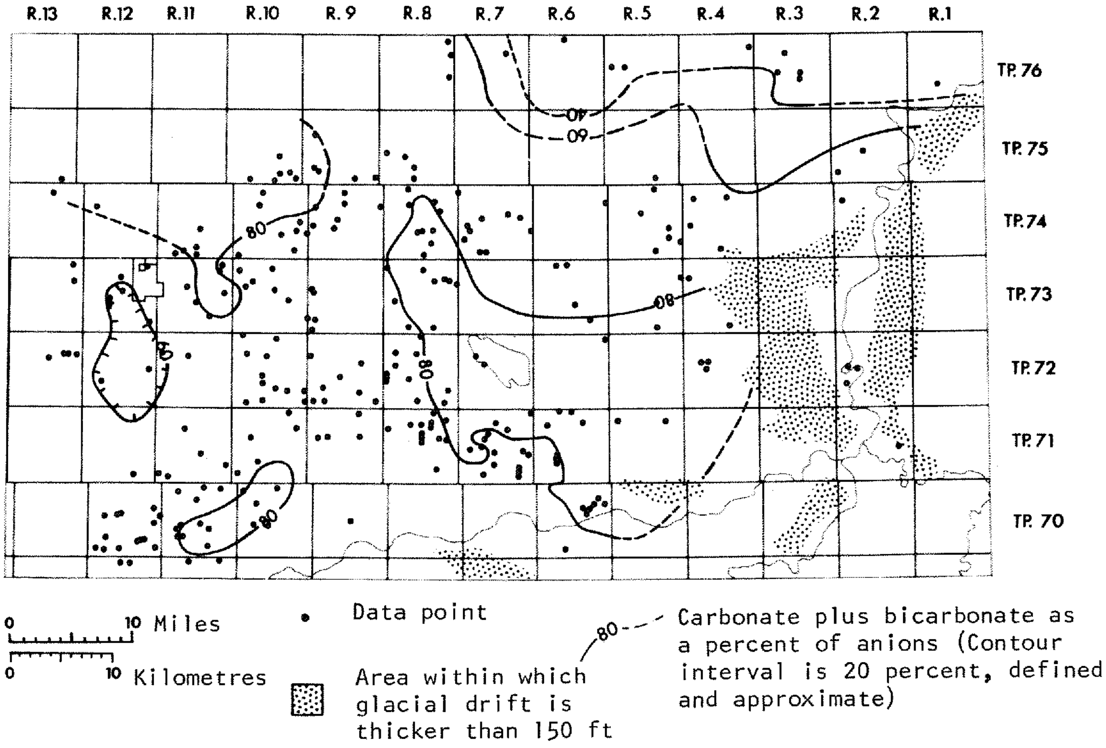

FIGURE 34. Epm percent carbonate plus bicarbonate; bedrock, 0 to 150 ft (0 to 46 m)

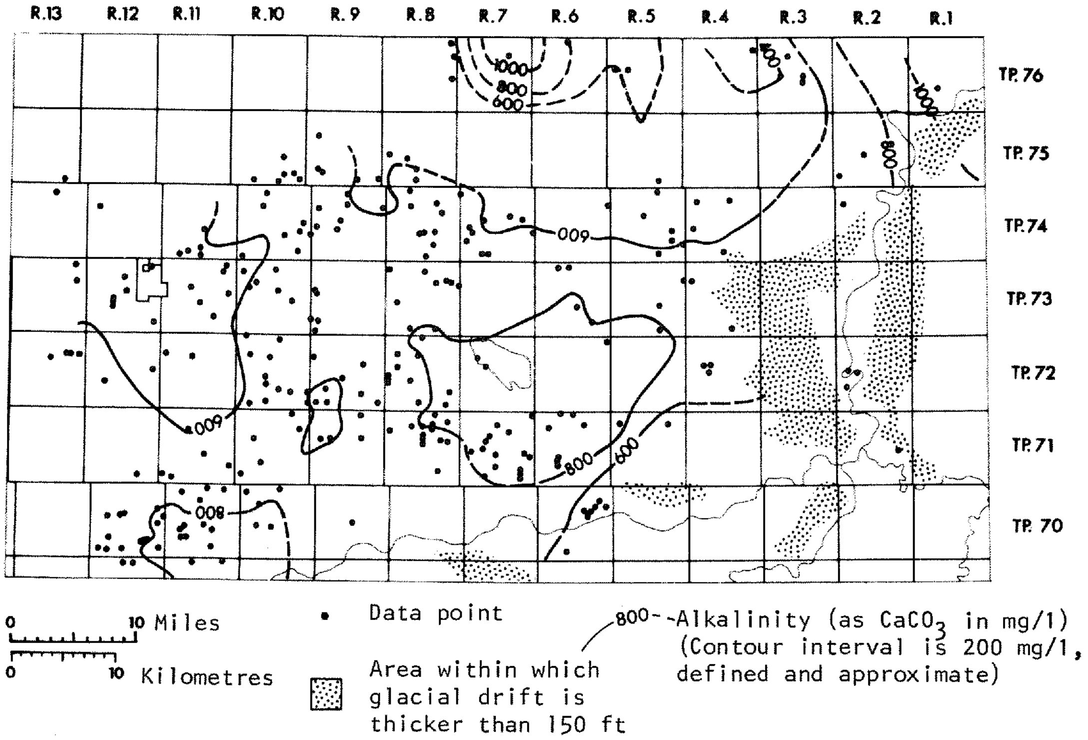

FIGURE 35. Alkalinity; bedrock, 0 to 150 ft (0 to 46 m)

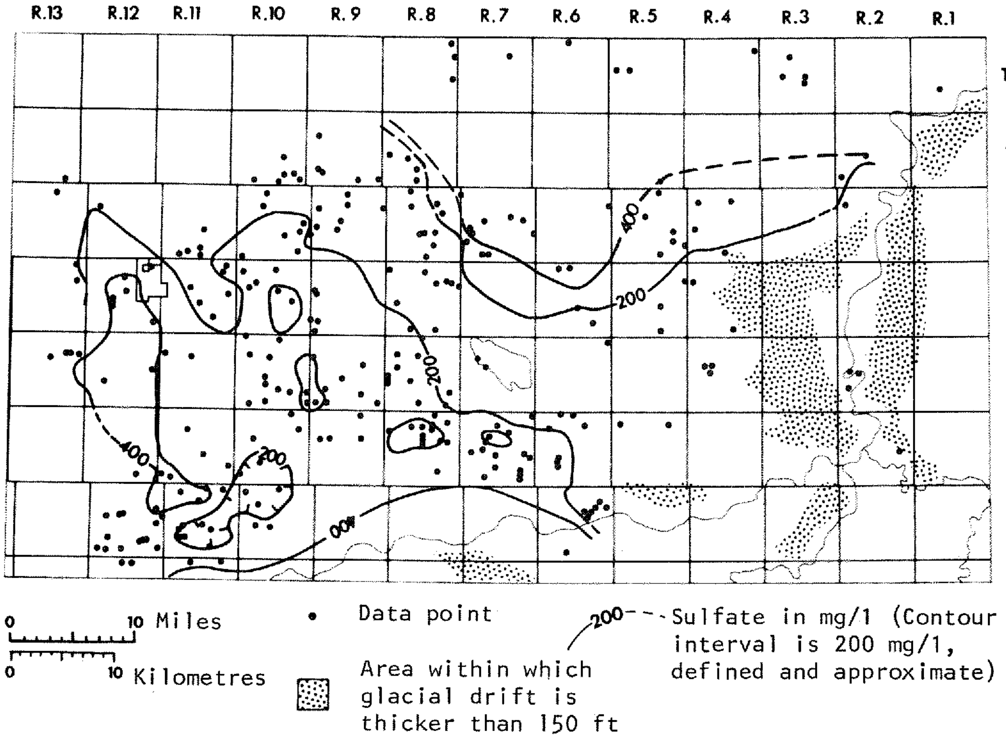

FIGURE 36. Sulfate; bedrock, 0 to 150 ft (0 to 46 m)

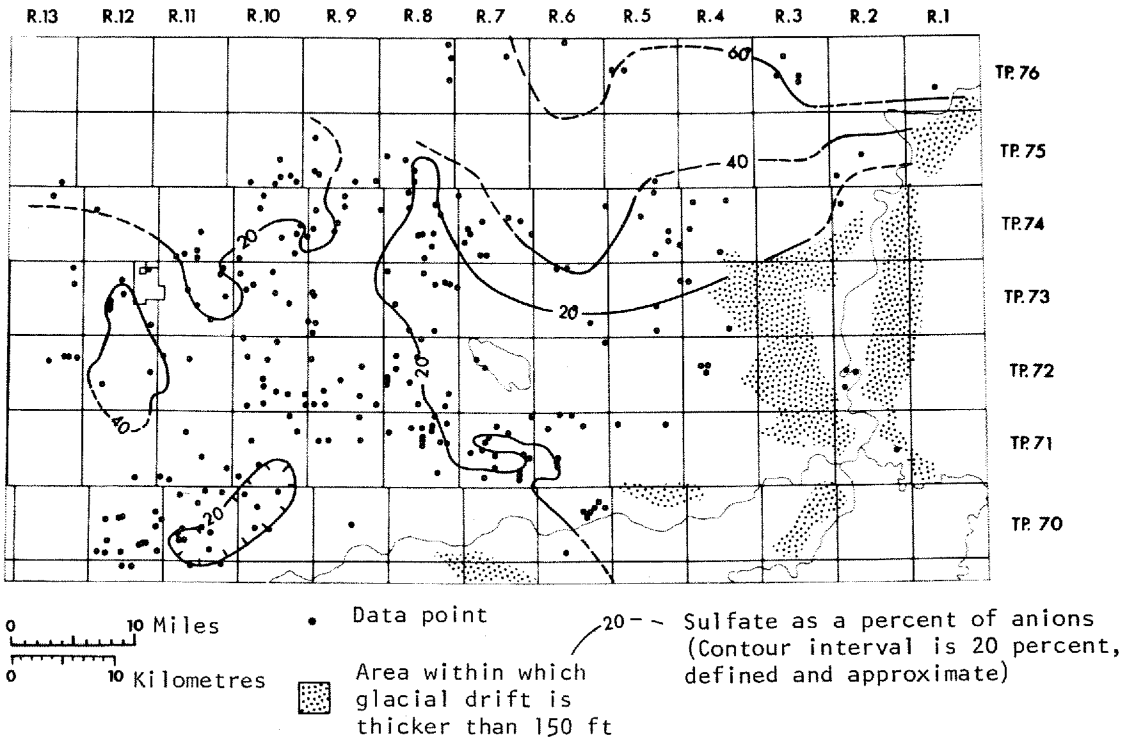

FIGURE 37. Epm percent sulfate; bedrock, 0 to 150 ft (0 to 46 m)

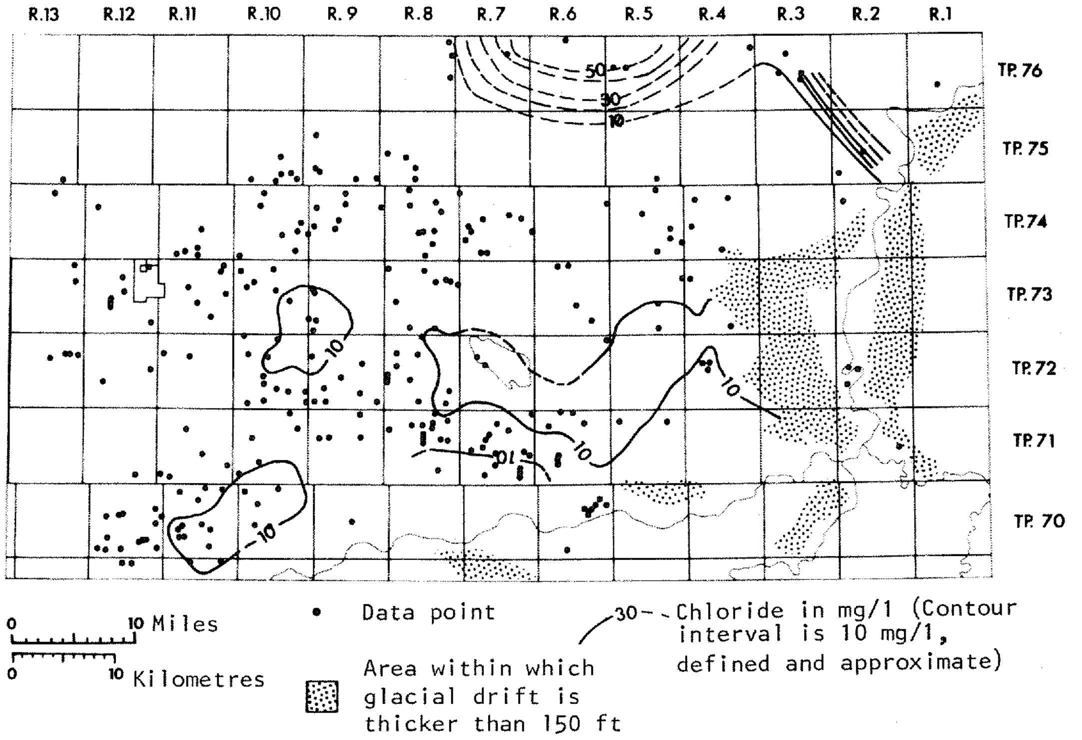

FIGURE 38. Chloride; bedrock, 0 to 150 ft (0 to 46 m)

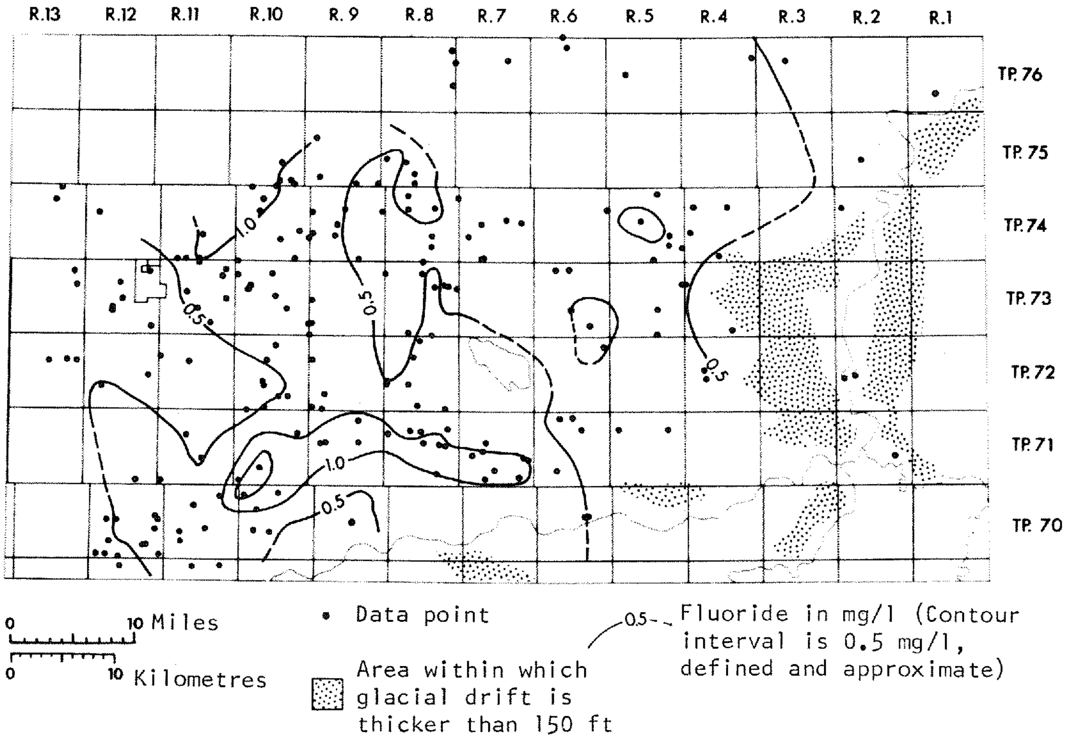

FIGURE 39. Fluoride; bedrock, 0 to 150 ft (0 to 46 m)

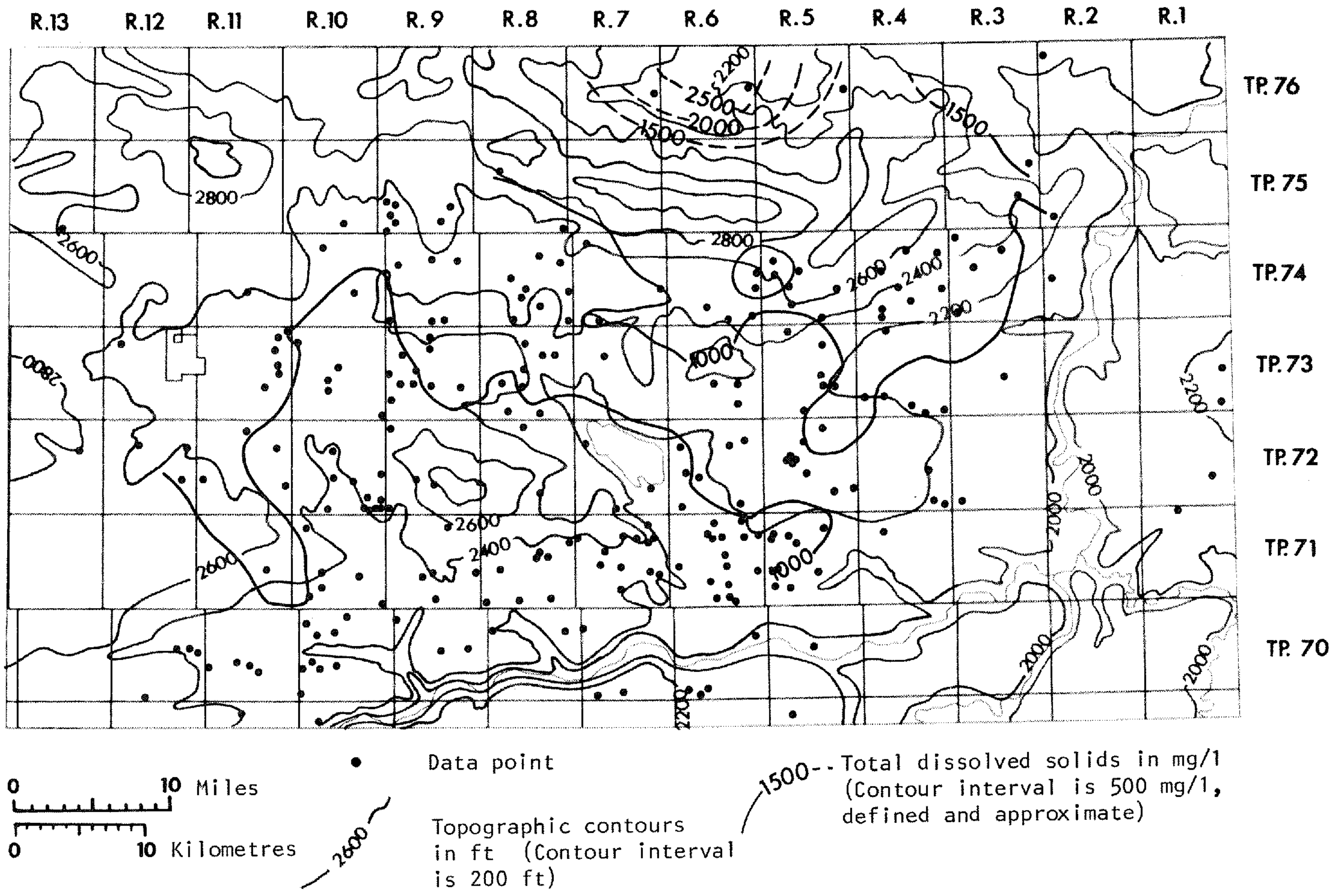

FIGURE 40. *Total dissolved solids; bedrock, 150 to 300 ft (46 to 91 m)*

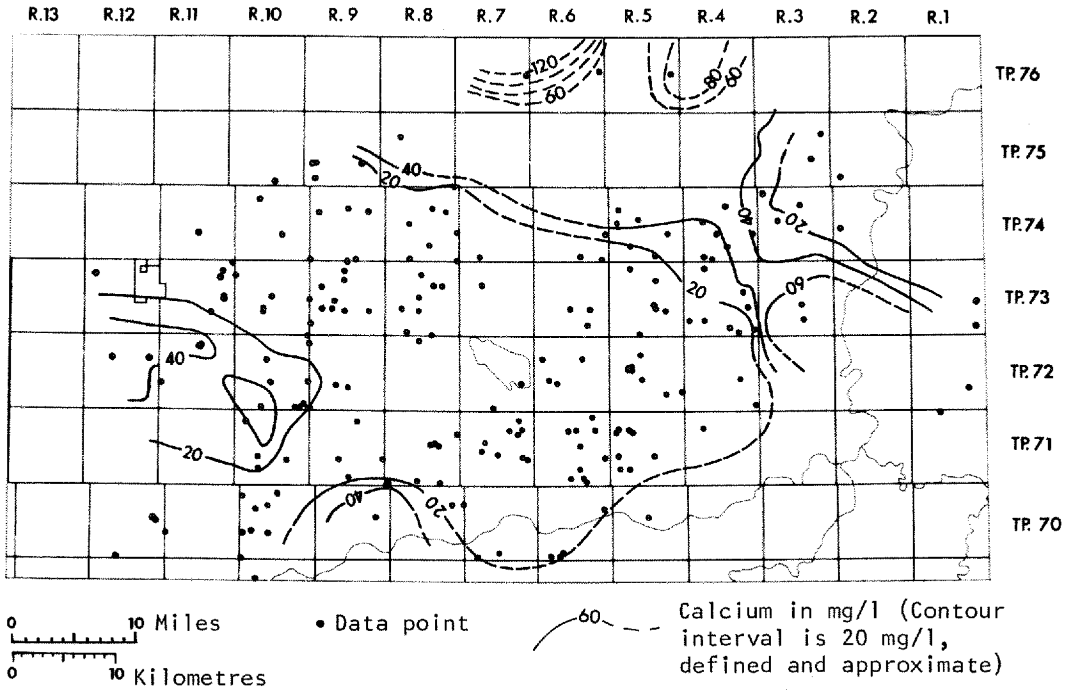

FIGURE 41. Calcium; bedrock, 150 to 300 ft (46 to 91 m)

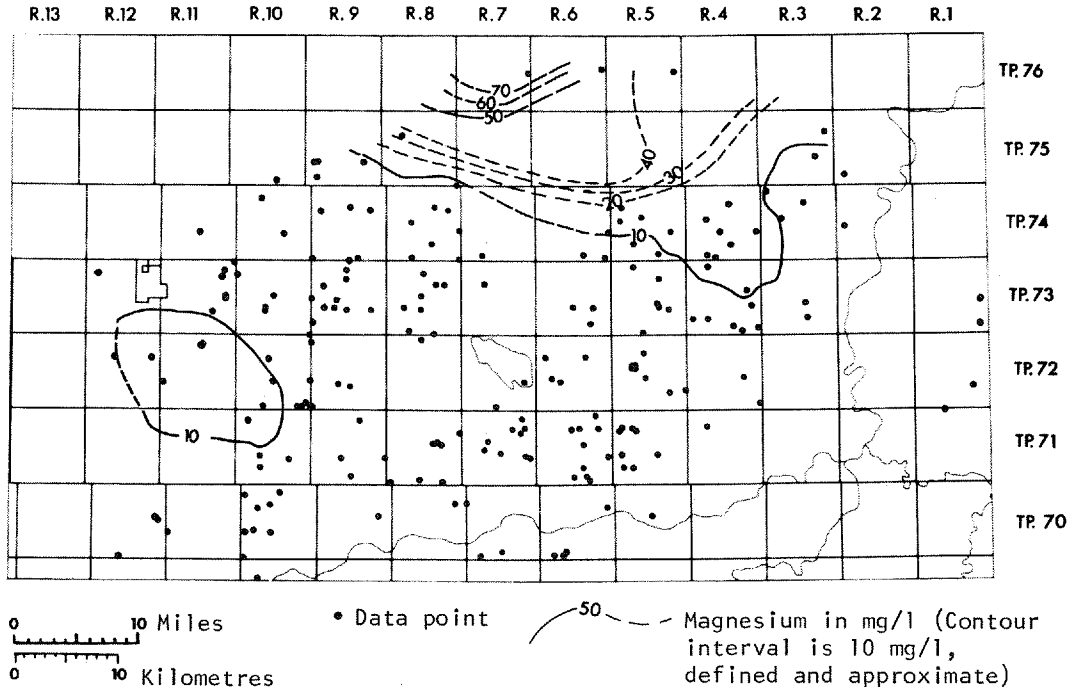

FIGURE 42. Magnesium; bedrock, 150 to 300 ft (46 to 91 m)

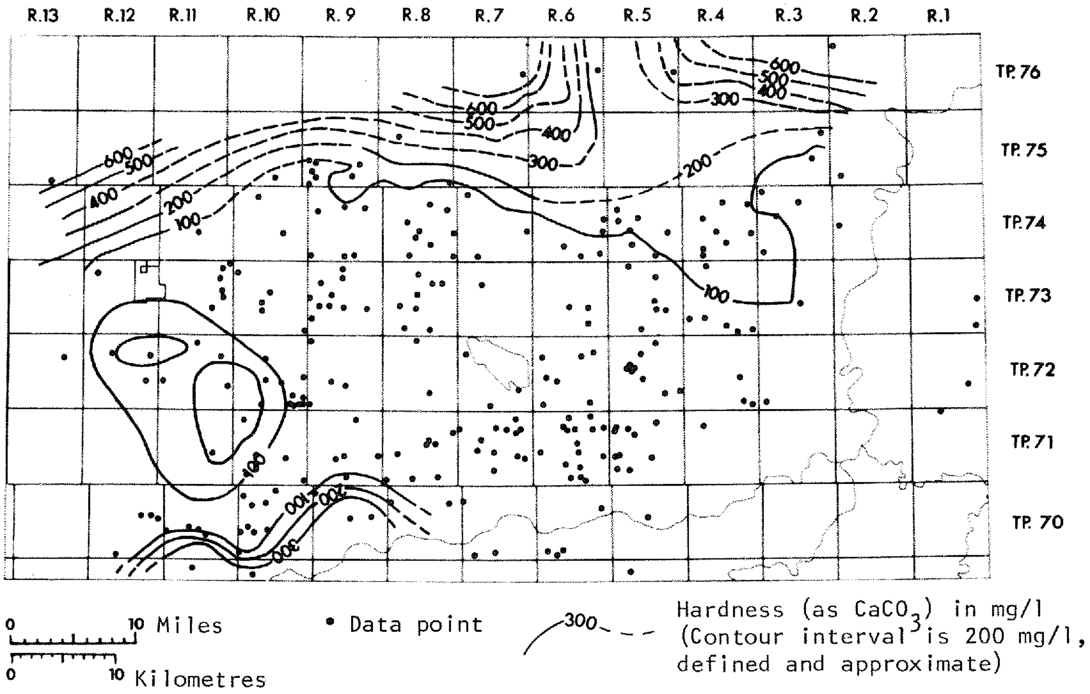

FIGURE 43. Hardness; bedrock, 150 to 300 ft (46 to 91 m)

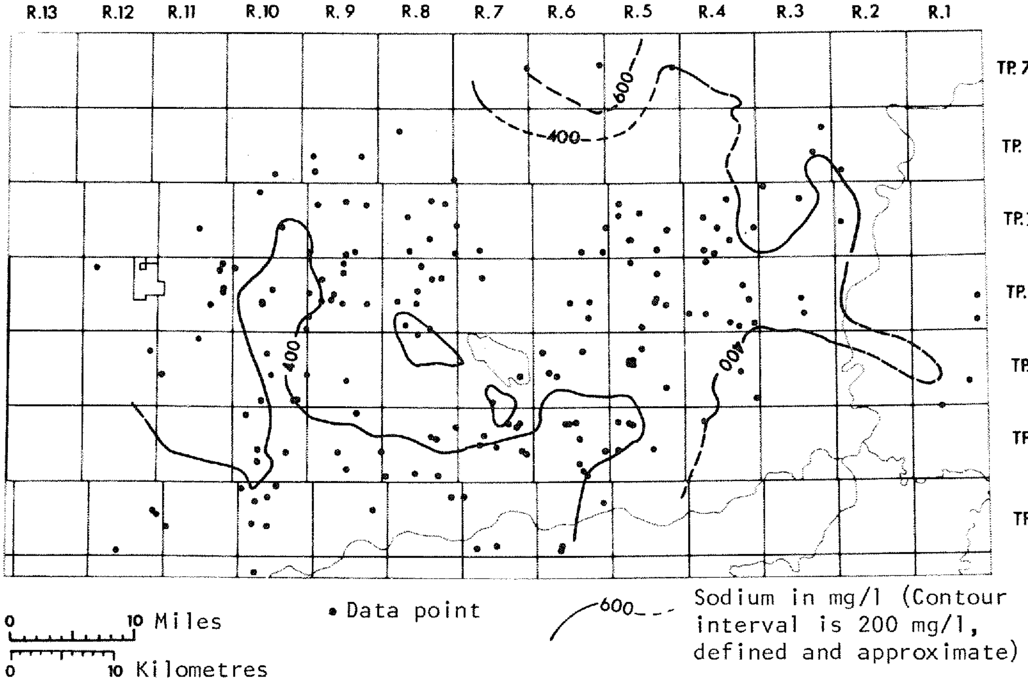

FIGURE 44. Sodium; bedrock 150 to 300 ft (46 to 91 m)

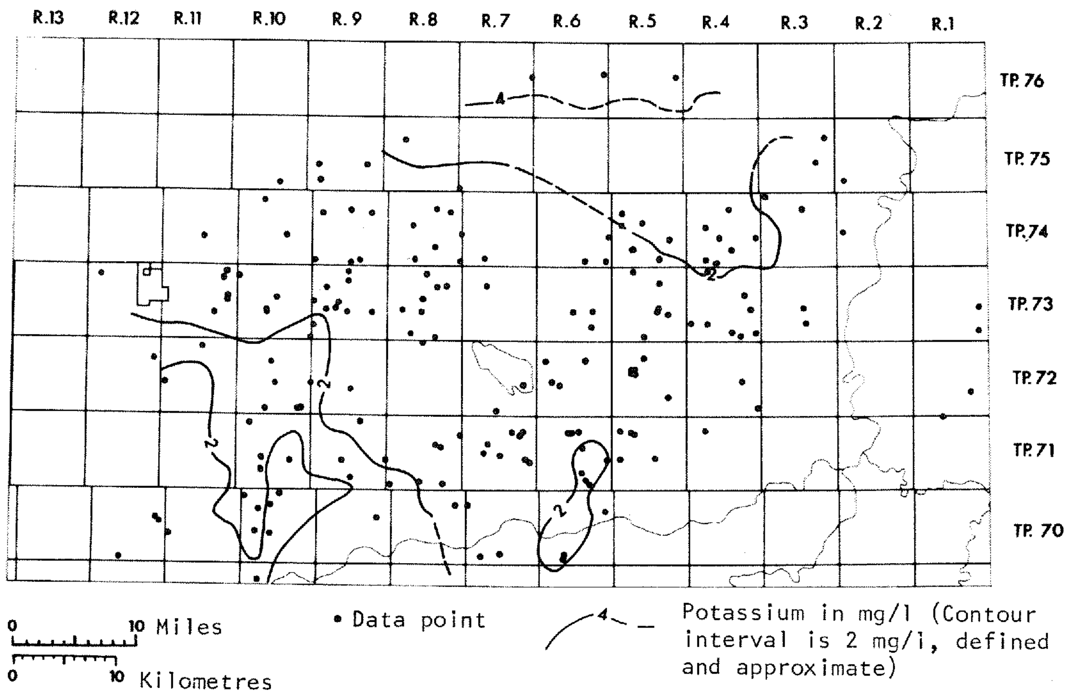

FIGURE 45. Potassium; bedrock, 150 to 300 ft (46 to 91 m)

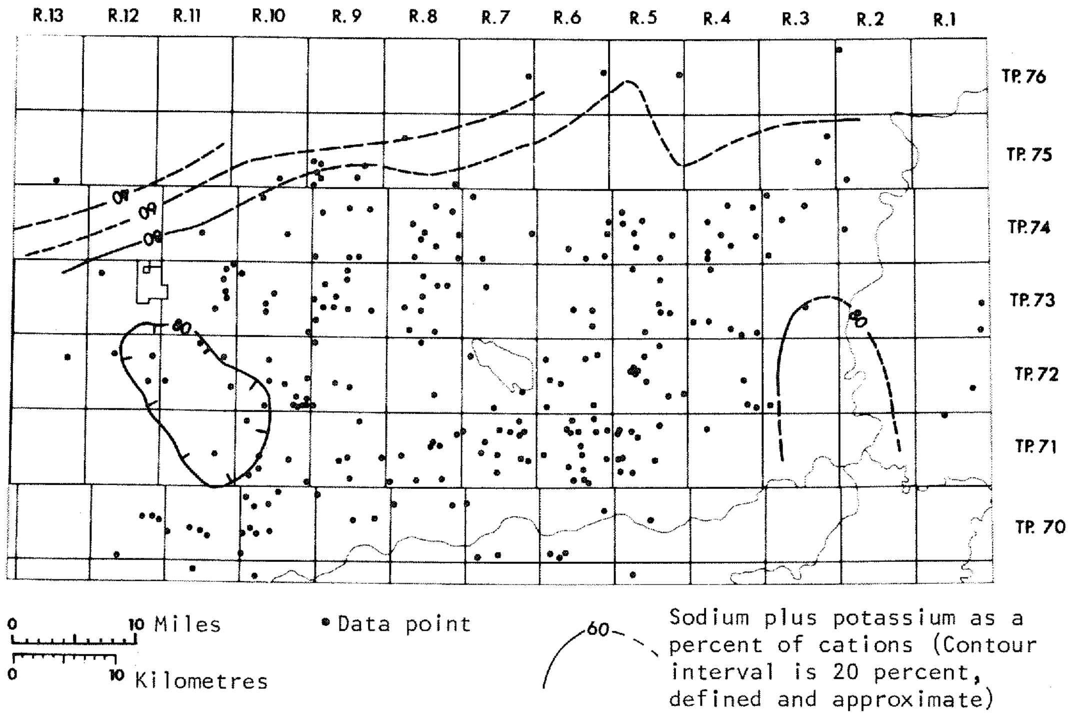

FIGURE 46. Epm percent sodium plus potassium; bedrock, 150 to 300 ft (46 to 91 m)

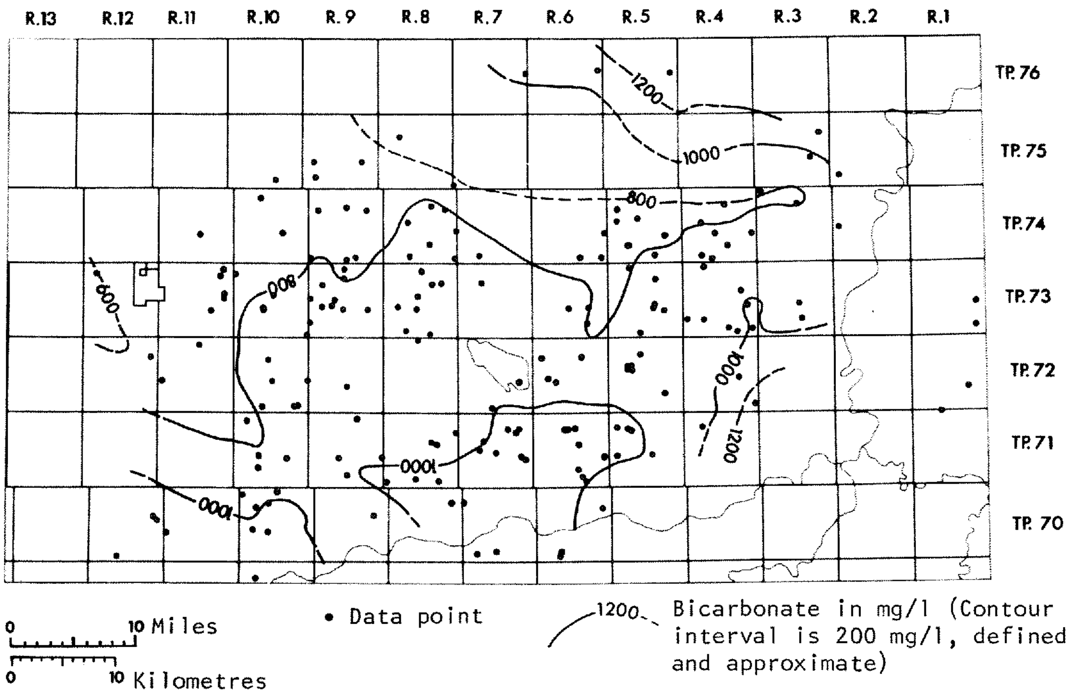

FIGURE 47. Bicarbonate; bedrock, 150 to 300 ft (46 to 91 m)

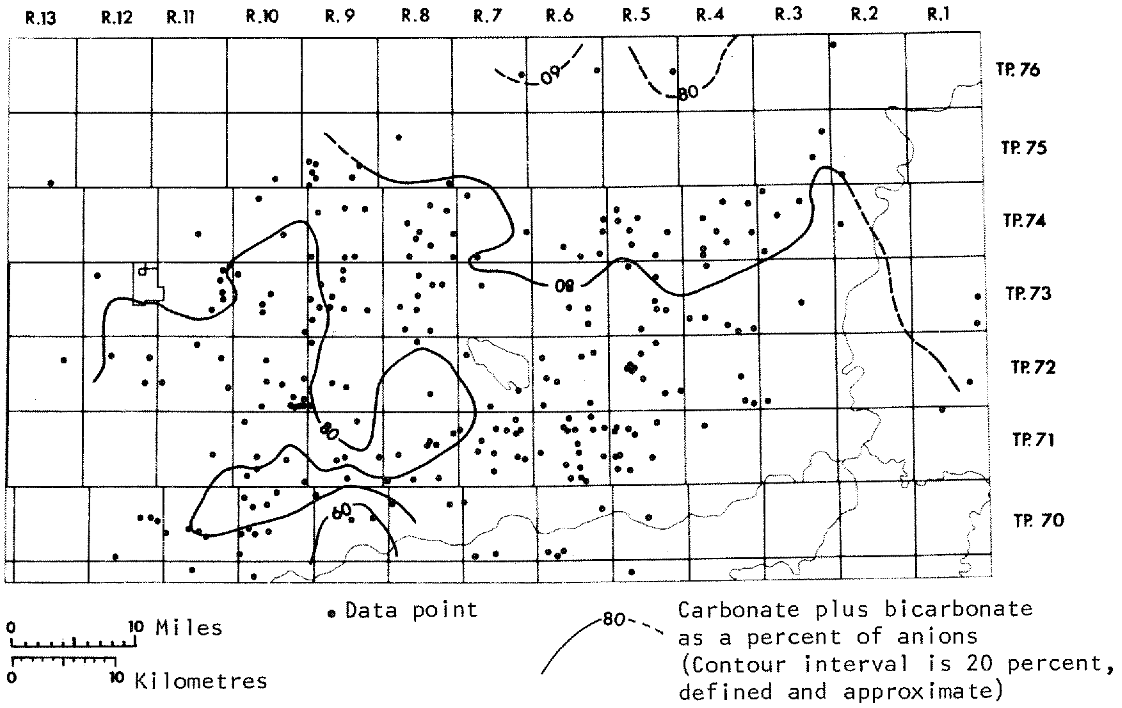

FIGURE 48. Epm percent carbonate plus bicarbonate; bedrock, 150 to 300 ft (46 to 91 m)

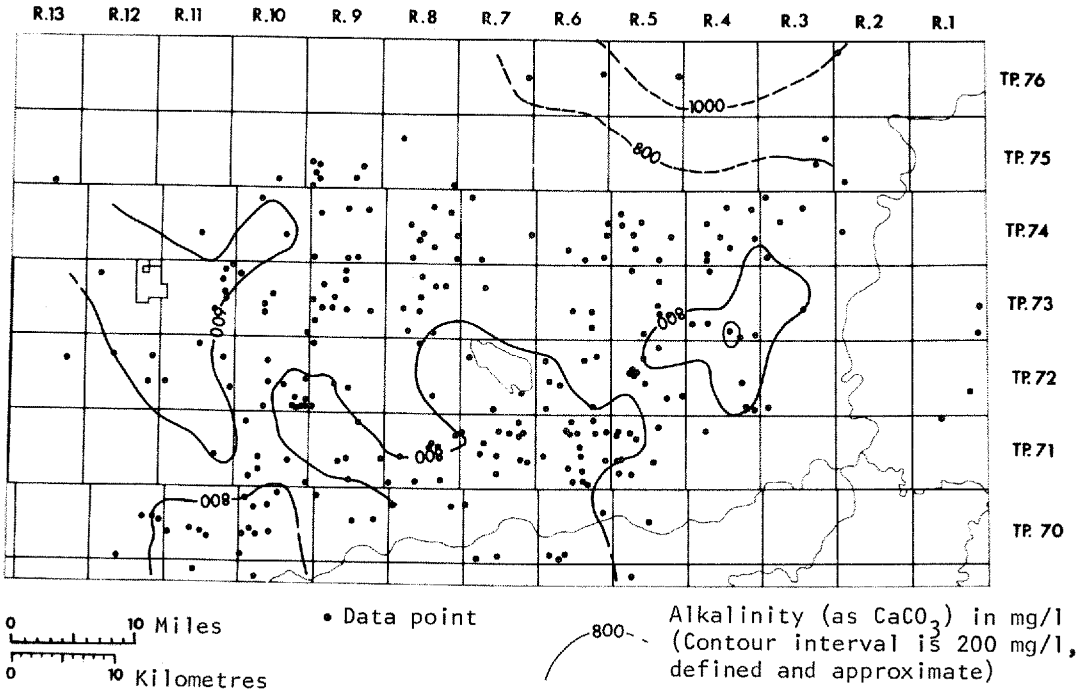

FIGURE 49. Alkalinity; bedrock, 150 to 300 ft (46 to 91 m)

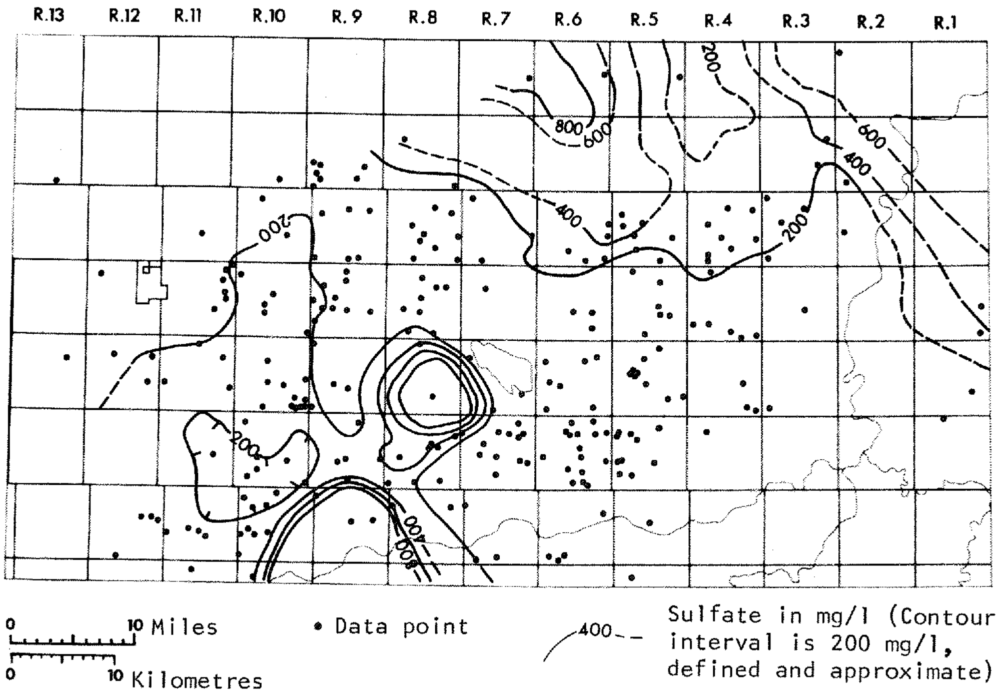

FIGURE 50. Sulfate; bedrock, 150 to 300 ft (46 to 91 m)

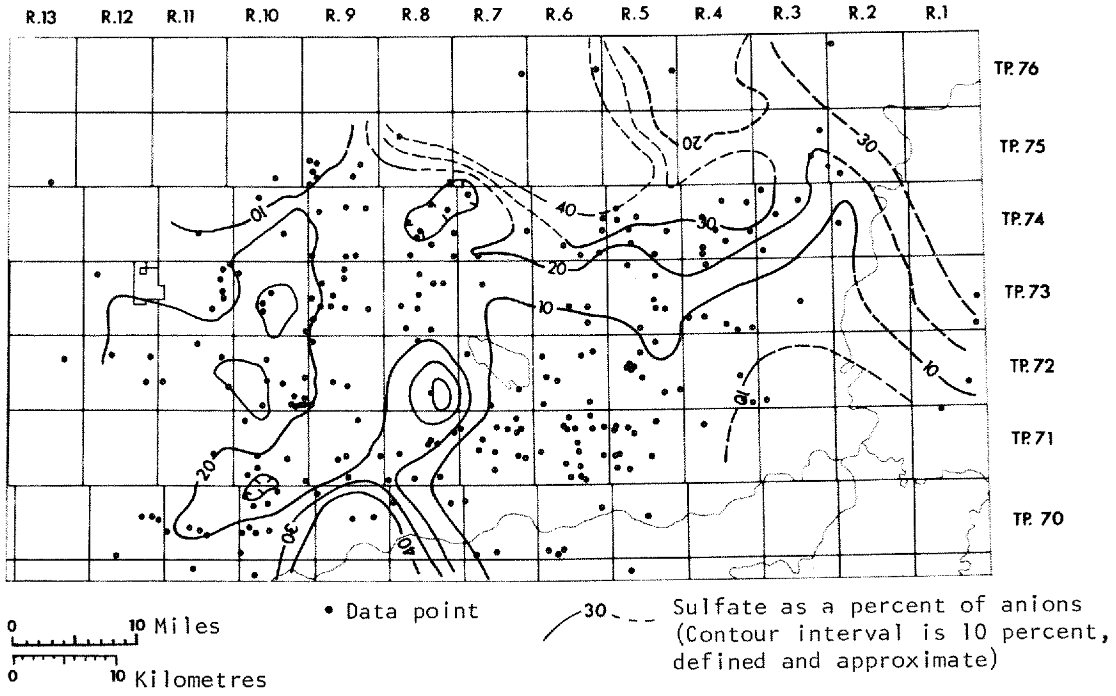

FIGURE 51. Epm percent sulfate; bedrock, 150 to 300 ft (46 to 91 m)

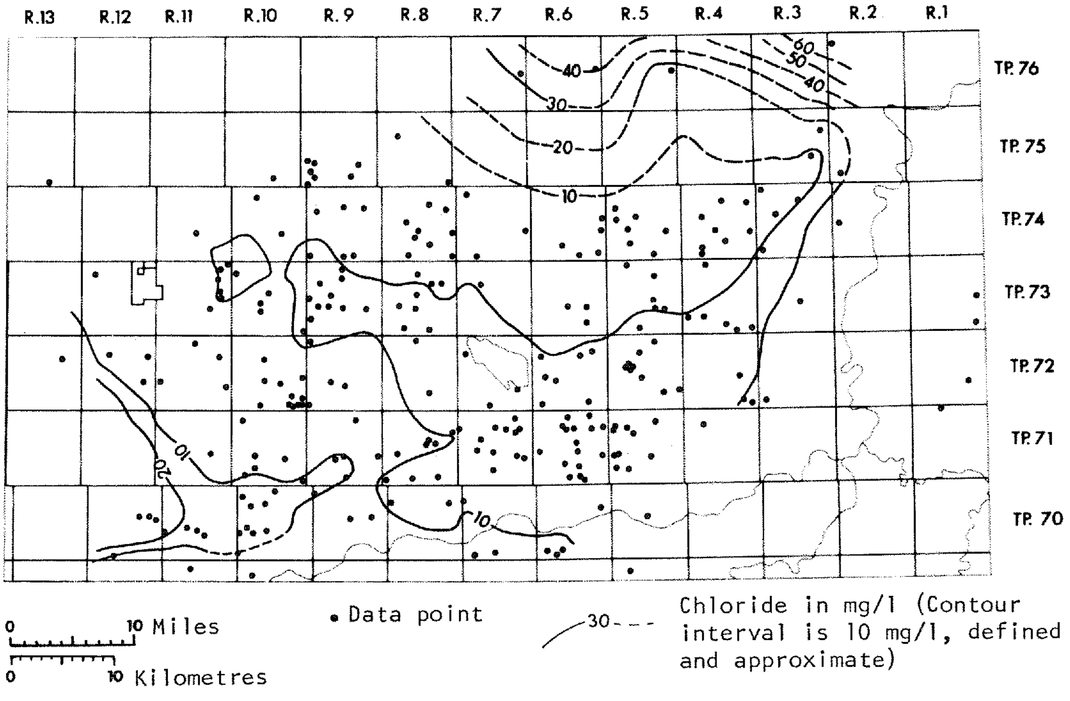

FIGURE 52. Chloride; bedrock, 150 to 300 ft (46 to 91 m)

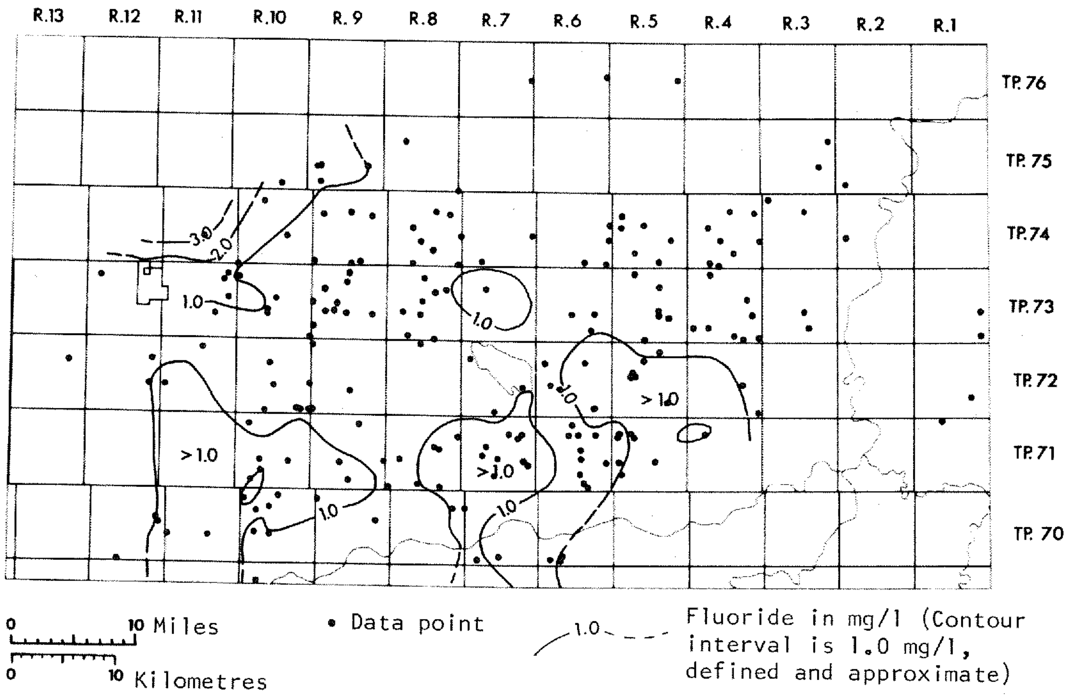

FIGURE 53. Fluoride; bedrock, 150 to 300 ft (46 to 91 m)

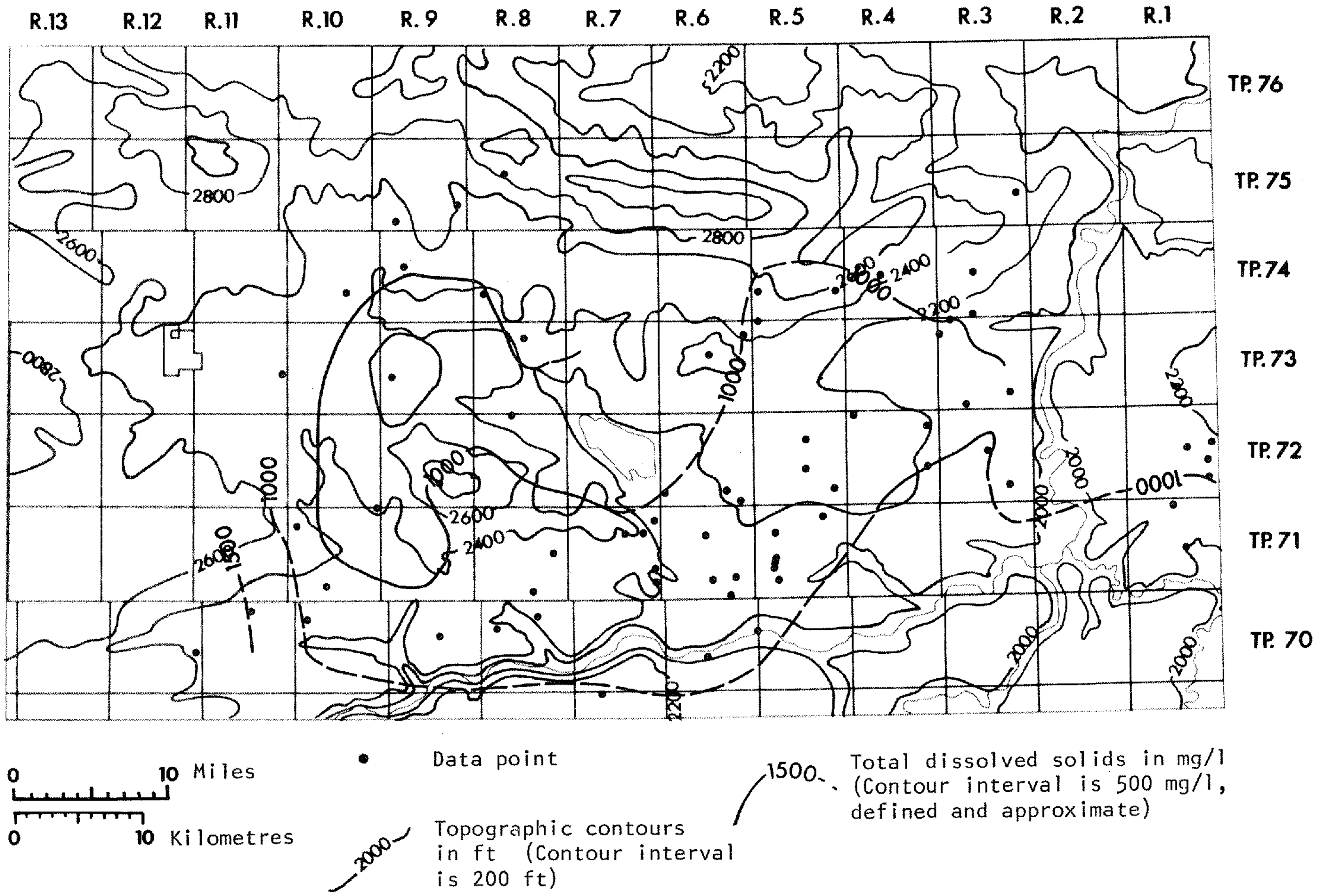

FIGURE 54. *Total dissolved solids; bedrock, 300 to 450 ft (91 to 137 m)*

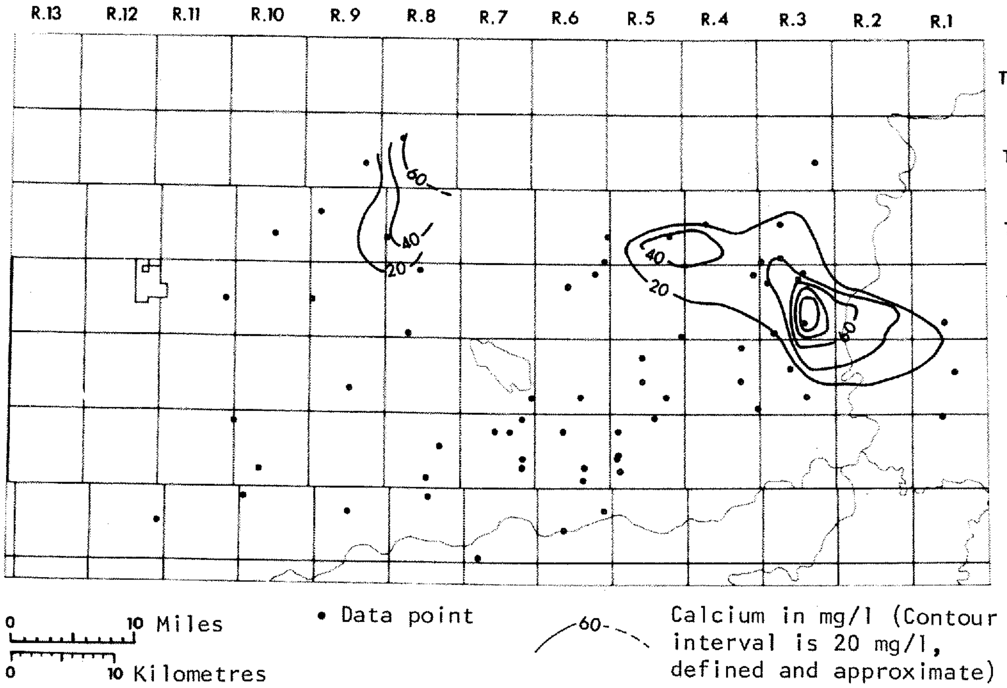

FIGURE 55. Calcium; bedrock, 300 to 450 ft (91 to 137 m)

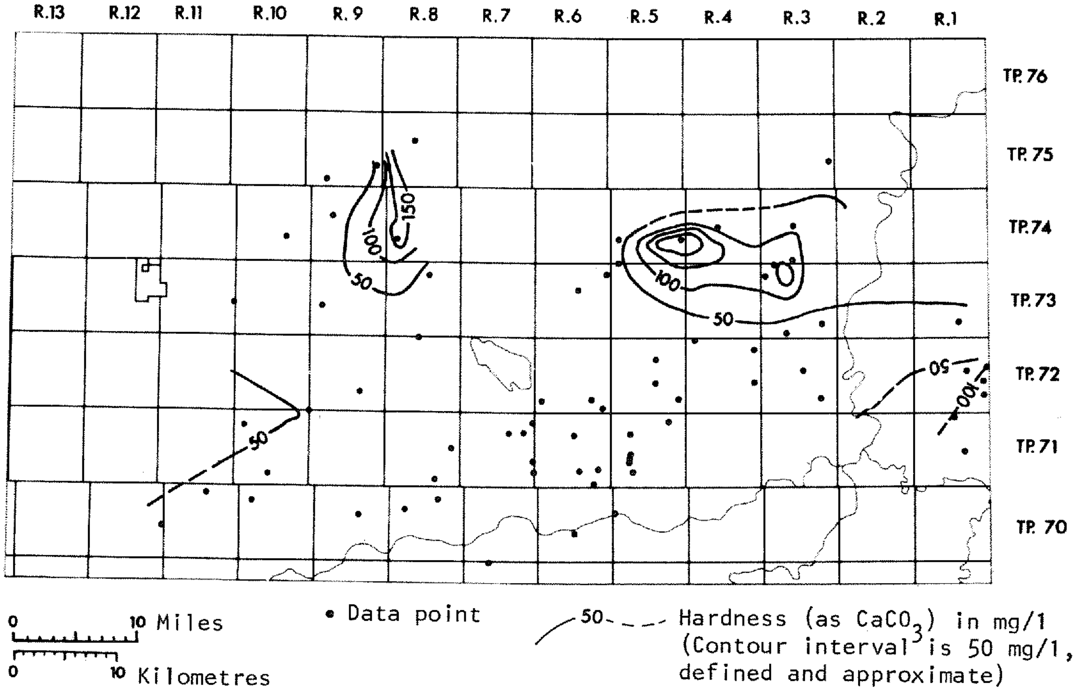

FIGURE 56. Hardness; bedrock, 300 to 450 ft (91 to 137 m)

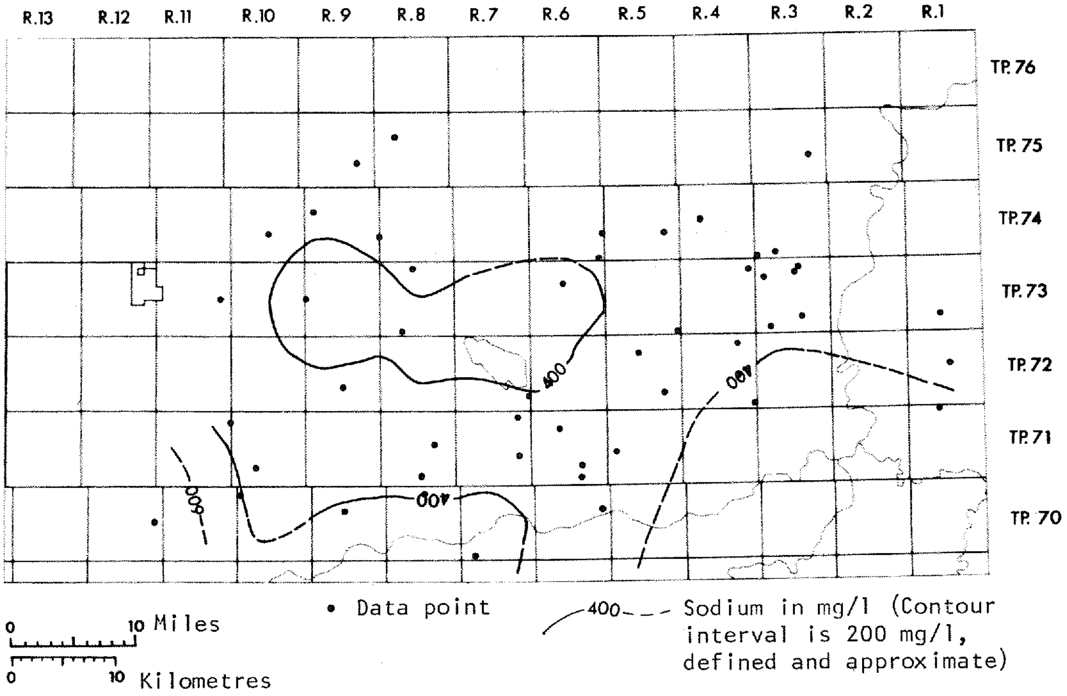

FIGURE 57. Sodium; bedrock, 300 to 450 ft (91 to 137 m)

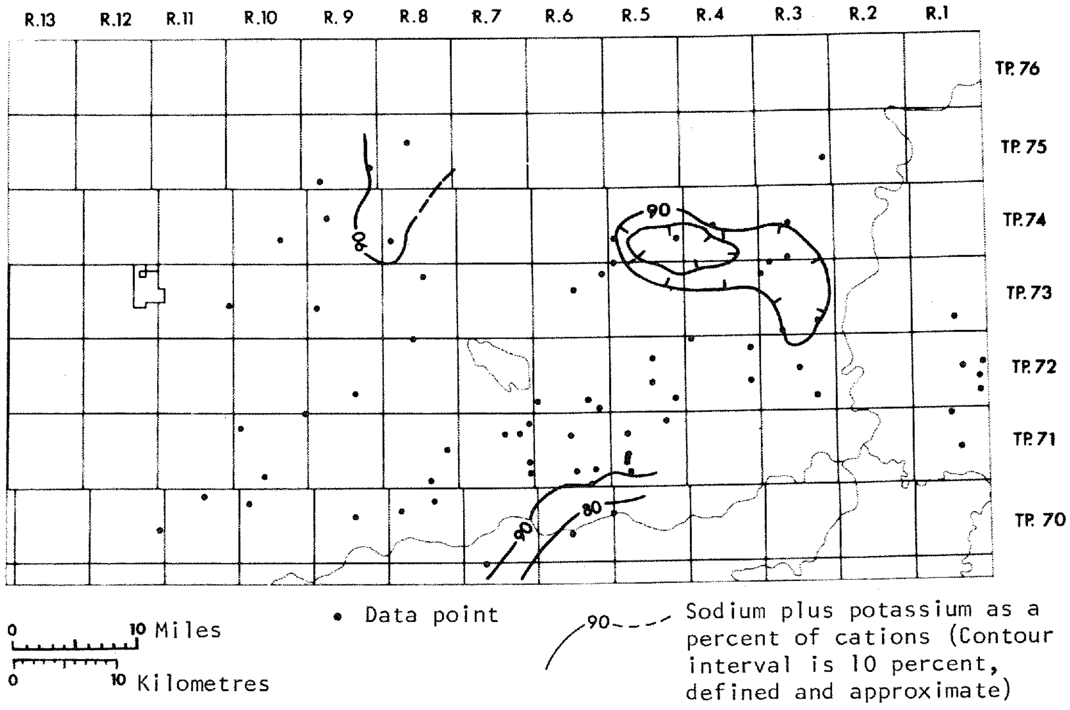

FIGURE 58. Epm percent sodium plus potassium; bedrock, 300 to 450 ft (91 to 137 m)

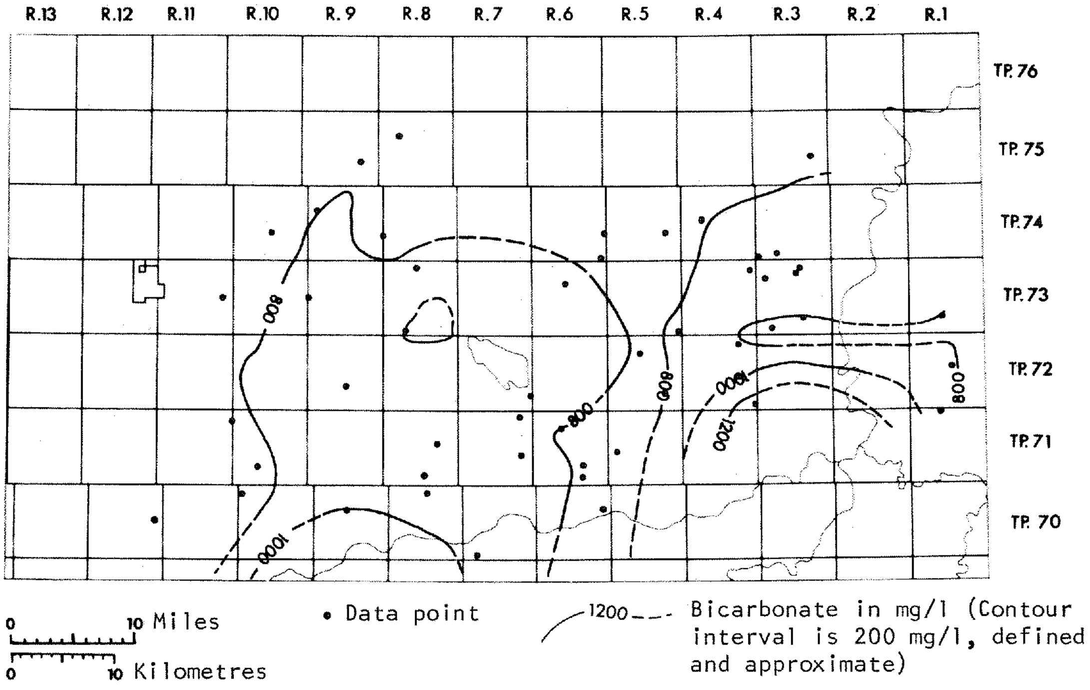

FIGURE 59. Bicarbonate; bedrock, 300 to 450 ft (91 to 137 m)

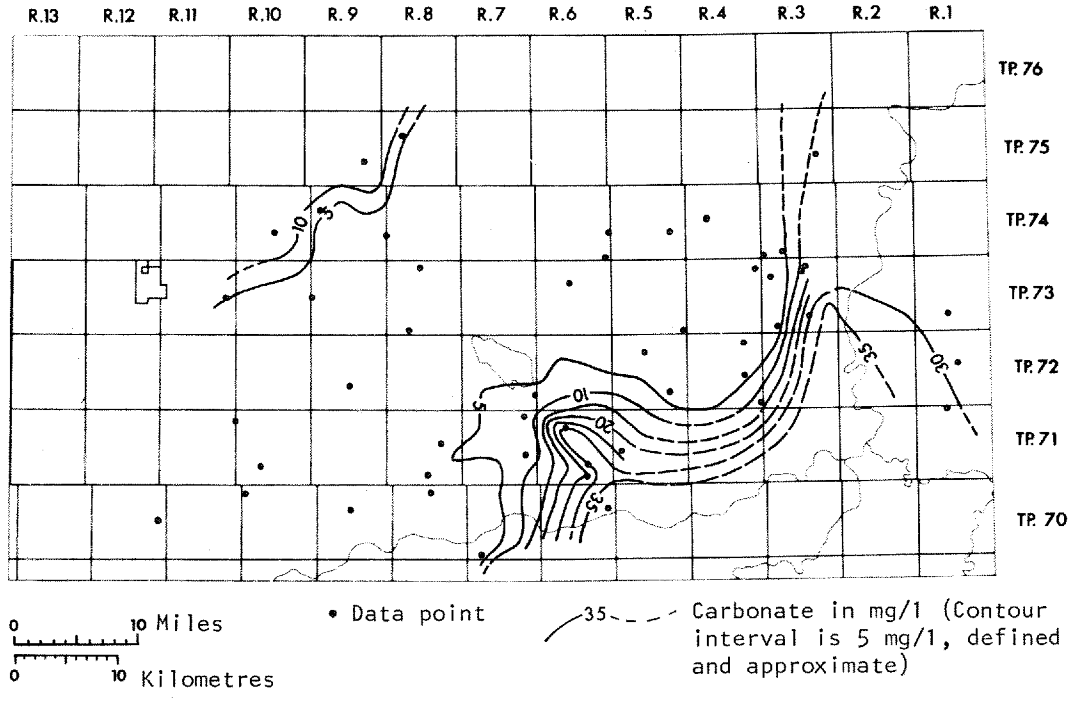

FIGURE 60. Carbonate; bedrock, 300 to 450 ft (91 to 137 m)

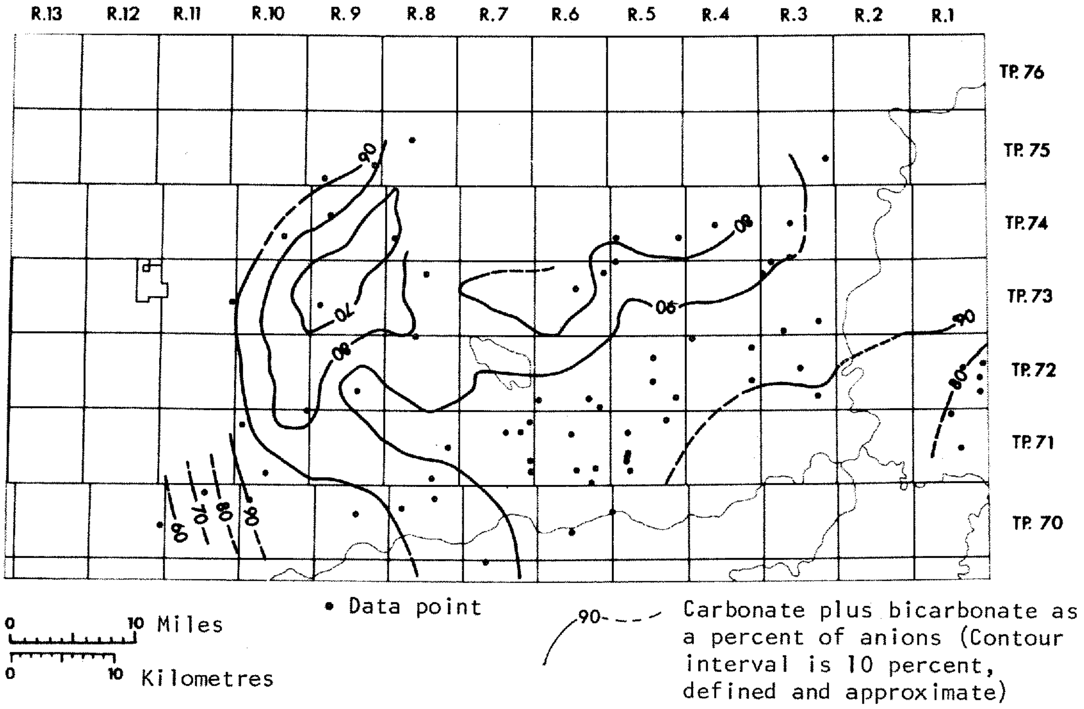

FIGURE 61. Epm percent carbonate plus bicarbonate bedrock, 300 to 450 ft (91 to 137 m)

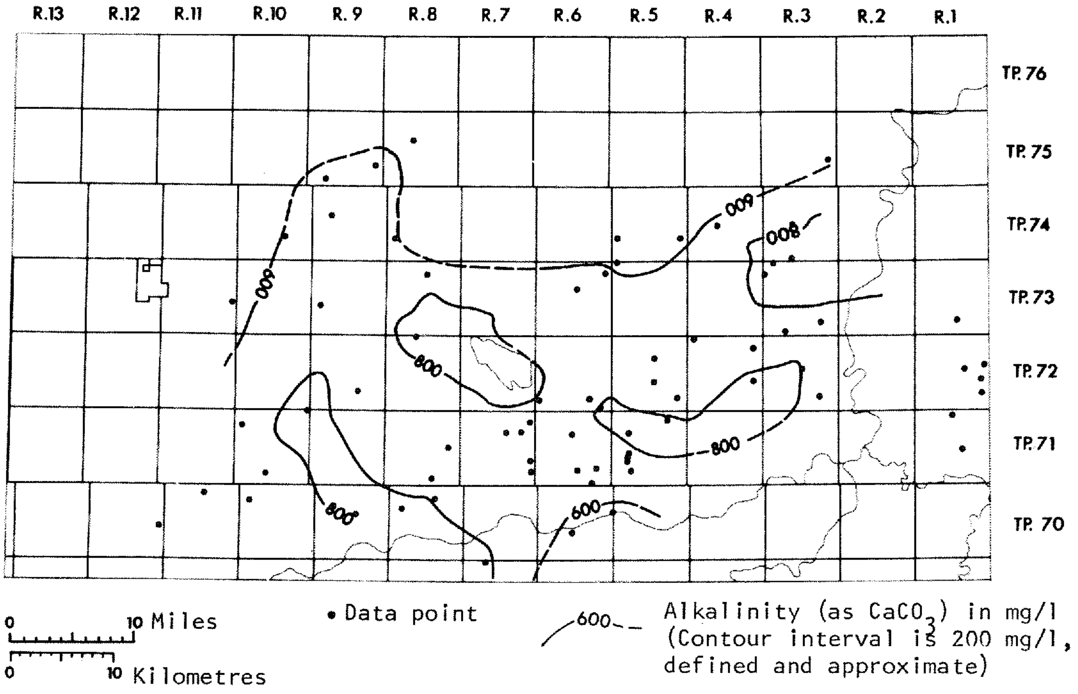

FIGURE 62. Alkalinity; bedrock, 300 to 450 ft (91 to 137 m)

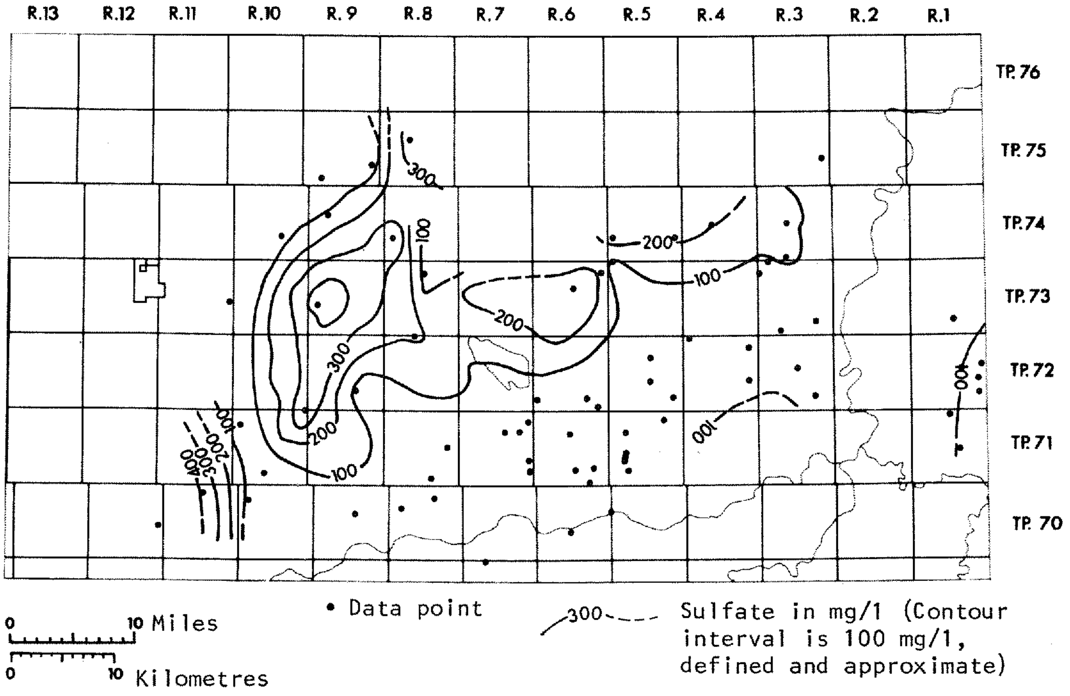

FIGURE 63. *Sulfate; bedrock, 300 to 450 ft (91 to 137 m)*

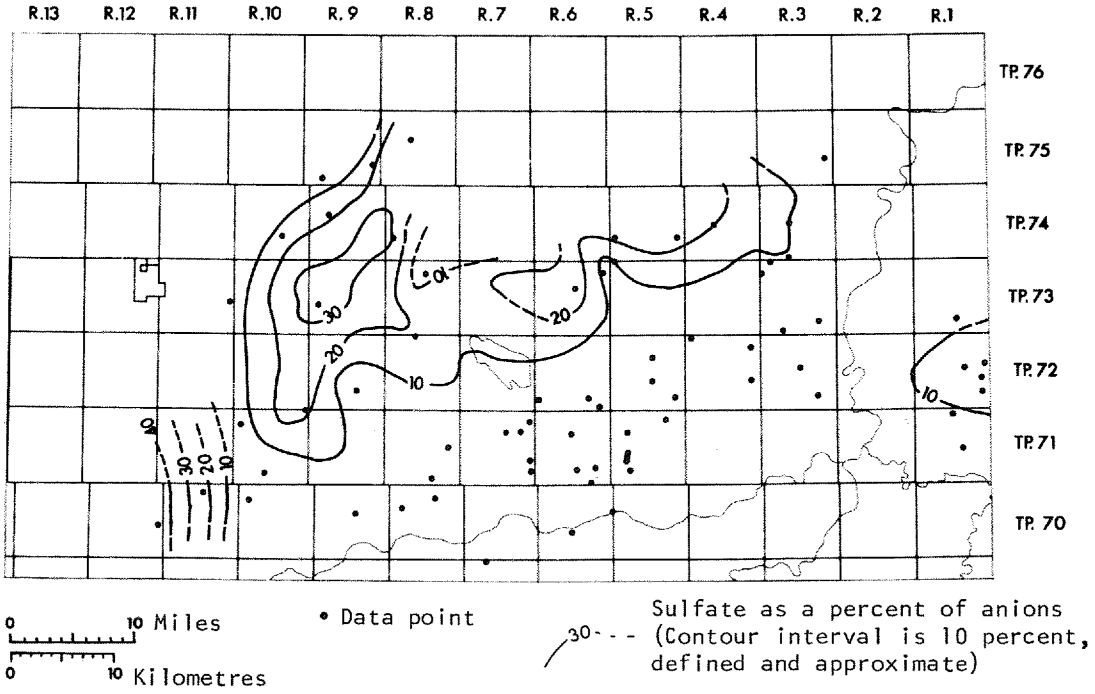

FIGURE 64. *Epm percent sulfate; bedrock, 300 to 450 ft (91 to 137 m)*

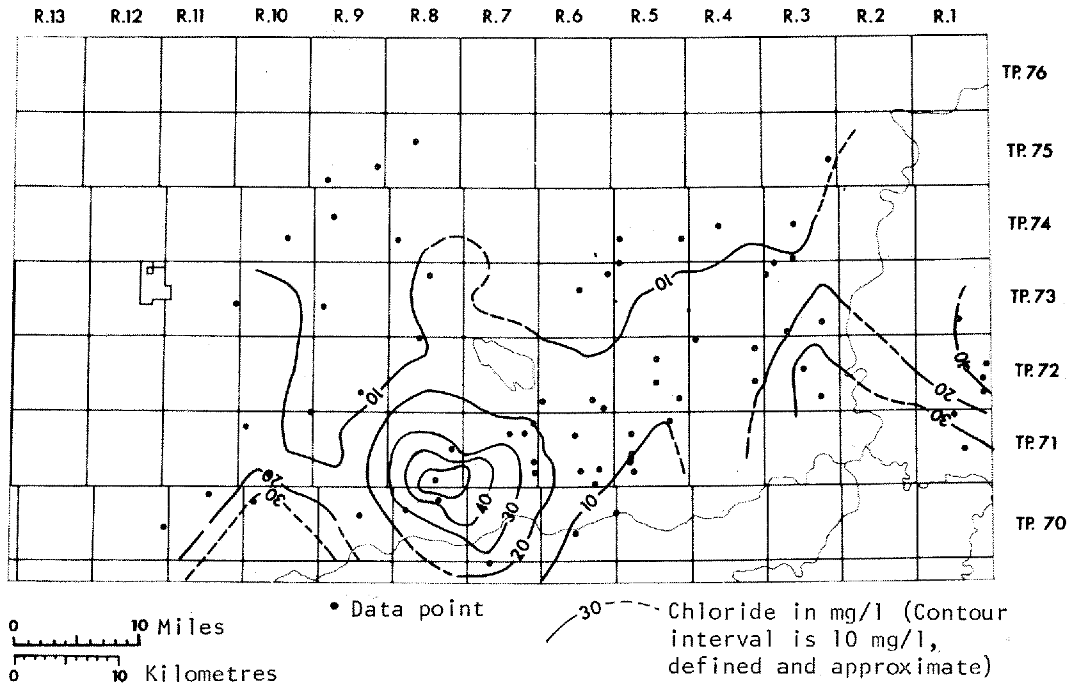

FIGURE 65. Chloride; bedrock, 300 to 450 ft (91 to 137 m)

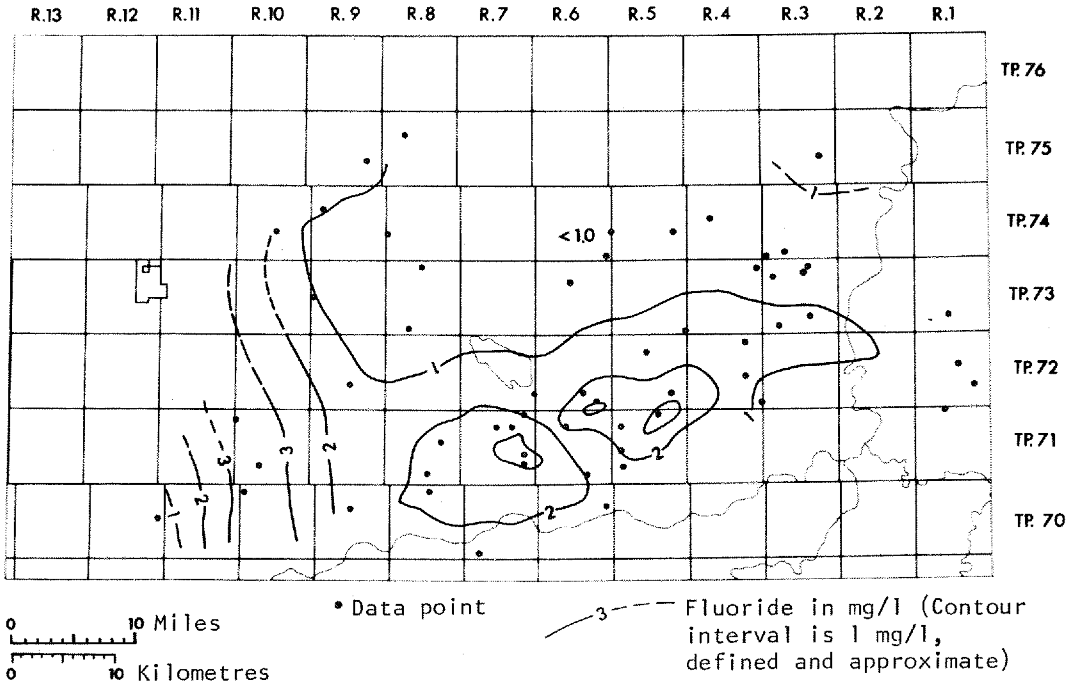

FIGURE 66. Fluoride; bedrock, 300 to 450 ft (91 to 137 m)