Data of Geochemistry

Sixth Edition

Chapter F. Chemical Composition of Subsurface Waters

GEOLOGICAL SURVEY PROFESSIONAL PAPER 440-F

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

White, Hem, and Waring—CHEMICAL COMPOSITION OF SUBSURFACE WATERS—Geological Survey Professional Paper 440-F

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MICHAEL FLEISCHER, *Technical Editor*

Chapter F. Chemical Composition of Subsurface Waters

By DONALD E. WHITE, JOHN D. HEM, *and* G. A. WARING

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Tabulation and discussion of chemical analyses. many previously unpublished, representing subsurface waters from many geologic environments, with descriptions of the sources of the waters

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DATA OF GEOCHEMISTRY, SIXTH EDITION

Michael Fleischer, *Technical Editor*

The first edition of the Data of Geochemistry, by F. W. Clarke, was published in 1908 as U.S. Geological Survey Bulletin 330. Later editions, also by Clarke, were published in 1911, 1916, 1920, and 1924 as Bulletins 491, 616, 695, and 770. This, the sixth edition, has been written by several scientists in the Geological Survey and in other institutions in the United States and abroad, each preparing a chapter on his special field. The current edition is being published in individual chapters, titles of which are listed below. Chapters already published are indicated by boldface.

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DATA OF GEOCHEMISTRY

CHEMICAL COMPOSITION OF SUBSURFACE WATERS

By Donald E. White, John D. Hem, and G. A. Waring

ABSTRACT

Chemical analyses, including many previously unpublished, of about 300 subsurface waters from many different geological environments throughout the world are tabulated, and descriptions of the sources of the waters are given. Analyses of the dilute ground waters are arranged according to the types of rocks in which they occur; the composition of the waters is affected by many other factors, geological, climatic, chemical, and biological. Analyses of other types of waters, such as various types of thermal waters and brines, are grouped in a genetic classification. The compositions of the waters are discussed, with special emphasis on median values of ratios of various constituents as a guide to the recognition of different genetic types of waters.

INTRODUCTION

This report is concerned with the chemical composition of waters of different origin that occur below the land surface in different geologic environments. Ground water, as usually defined, is the part of the subsurface water that is in the zone of saturation. Some water occurs also in the zone of aeration between the earth's surface and the zone of saturation and is, in part, in transit to the ground-water body. Other water, commonly not considered as ground water, occurs in disconnected fluid inclusions in rocks and within mineral grains, and is considered separately in another chapter. H_2O or OH ions occur also in the crystal lattices of hydrous minerals, and in solution in magma.

Most of the data of this report are concerned with the common types ordinarily considered as ground waters. A few special types of waters formed at the surface, at least in part from subsurface emanations in volcanic and hot spring environments, are appropriately considered here with waters entirely of subsurface origin.

OBJECTIVES

Clarke (1924b, p. 181–217) was concerned primarily with mineral waters; this is a loose but useful term for all waters that differ appreciably in composition or concentration from the common potable types. His classification was primarily by chemical type, and he grouped together waters of obviously very different origins.

This chapter deals with the characteristics of different types of subsurface water but does not attempt to consider all types of subsurface water. Many gradations exist from very dilute waters, differing little from atmospheric precipitation, to mineral waters of many chemical types. In the first part of this paper, the relatively dilute waters in contact with different kinds of rocks are considered in the hope that tentative criteria can be developed for identification of some meteoric ground waters of the most simple histories. In the second part, many groups of mineral waters of different geologic environment, chemical type, and probable origin are considered.

In table 29, median ratios of some important components are shown for 14 types of mineral waters, as well as the median content, in parts per million (ppm), of total reported constituents, SiO_2, and total combined nitrogen (calculated as NH_4). The choice of analyses was guided by principles other than those of rigid statistical treatment; many analyses differ greatly from the median values of the type. These differences may be caused by normal variations in a genetic type, by analytical errors, and by failure to recognize differences in genesis in waters included in a single table. The median values, however, are believed to constitute potential criteria for recognizing waters of different genetic types; they have been published previously with only slight differences by White (1960, p. 452). The specific numbers in table 29 are probably not significant, but the order of magnitude of each abundance ratio is believed to be significant for most waters of each type.

GENETIC CLASSIFICATION OF SUBSURFACE WATERS

Ground waters can be classified by genesis, by type of associated rock, by physical and chemical characteristics, or by use. A genetic classification is for many purposes the most desirable, but specific and applicable criteria are essential and can be developed only slowly and with thorough testing.

A tentative genetic classification is shown below, correlated with the tables that give probable examples. A genetic classification has many possibilities of error and incorrect interpretation, but each table contains analyses of waters from a specific geologic environment or of a chemical type that is significant even if the genetic correlation proves incorrect. Most of the suggested examples of nonmeteoric waters are probably slightly to greatly diluted with meteoric water.

A. Juvenile waters (not previously involved with atmospheric circulation; no good criteria are known for distinguishing them from B–5 waters).
  1. Magmatic water (some diluted waters given in tables 17 to 21).
  2. Other juvenile waters?

B. Recycled or resurgent waters (previously involved with atmospheric circulation).
  1. Meteoric waters.
    a. Precipitation and surface water. (See chapters E and G.)
    b. Soil water (few quantitative data; see text).
    c. Most near-surface ground water (tables 1 to 11, 26, and some analyses of table 27).
  2. Ocean water directly invading aquifers (no detailed analyses of proved examples).
  3. Connate or fossil waters.
    a. Waters of marine origin (most analyses of tables 12 to 16; analysis 7, and possibly analyses 8 and 11, of table 27).
    b. Nonmarine types (analyses 1 and 2 of table 27; possibly analysis 5 of table 15 and analysis 3 of table 16).
  4. Metamorphic waters.
    a. Water high in CO_2 and boron(?) (Some analyses of tables 22 and 23?).
    b. Other types that may exist.
  5. Magmatic waters (no good criteria are known for distinguishing them from A–1 waters; many diluted waters given in tables 17 to 21).

The arrangement of analyses in tables 1 to 11 does not imply that chemical composition of the rocks is the only decisive factor in determining composition of the meteoric ground waters. Climate obviously affects rate of chemical weathering and degree of dilution of the soluble products. Micro-organisms and plants influence the composition of ground water, as do man's activities. Most of the analyses given in the first 11 tables represent unpolluted water from temperate climates, ranging from humid to arid. Some of the more highly mineralized waters given in these tables probably contain small amounts of saline nonmeteoric waters.

OTHER ASPECTS

Many physical and chemical properties of water are reviewed by Hutchinson (1957, p. 195–220); isotopic data published through 1955 also are reviewed by Hutchinson, and recent isotopic data are planned for chapter DD of Data of Geochemistry.

A major part of the water of underground reservoirs passes through the soil on its way to the water table. On the other hand, much meteoric water penetrates the ground directly from surface streams, particularly in desert areas where recharge from streams is the principal means. Many of the processes involved in weathering of rocks and the formation of soil produce soluble mineral matter. The physical characteristics of soil water have been studied (Terzaghi and Baver, 1942, p. 331–384; Baver, 1956), but almost no quantitative data are available on compositions of moisture in the zone of weathering and soil formation. Plants synthesize organic compounds from water and CO_2 obtained largely from the atmosphere and give off CO_2 during respiration. Decomposition of organic matter, in major part by micro-organisms, also provides much CO_2 in the soil zone. Boynton and Reuther (1938, p. 37–42) found that the CO_2 content of soil gases increased downward in the soil zone; as much as 15 percent of CO_2 was found in the total gases. According to Thorne and Peterson (1954, p. 22), 2 to 10 liters of CO_2 per square meter of surface per day is produced in soil where plants are growing vigorously. These amounts of CO_2 if dissolved in water and available for reaction would account for 550 to 2,750 ppm of HCO_3 in water passing through the soil zone at a rate of 10 liters per square meter of surface per day and reacting with rocks to form soluble bicarbonates. In contrast, meteoric water in equilibrium with the CO_2 pressure of the atmosphere can contain only 60 to 100 ppm of HCO_3 (Hutchinson, 1957, p. 654–670). Many, if not most, ground waters contain more than 100 ppm of HCO_3; much CO_2 has apparently gone into solution in the soil zone, lowering the pH of soil solutions and increasing chemical activity.

Zonn (1945, p. 197–199) has studied the relation of ground water quality to soil type, and Maksimovich (1949, p. 26–32; 1950, p. 75–85) has attempted to relate composition of ground water to composition of soil moisture in soils of different types. Similar investigations seem not to have been made outside of the U.S.S.R.

The movement of water from the land surface to the main body of ground water is simple in concept but complicated in detail (see Meinzer, 1942, p. 397–412).

CHEMISTRY OF INDIVIDUAL CONSTITUENTS

The writers believe that a detailed discussion of the chemistry of individual constituents is not needed here. In any event, because research in the general field of water chemistry has been increasing in recent years, new knowledge of the field would soon make such a discussion obsolete. Some of the results of recent research relating to the chemistry of certain constituents are briefly outlined here. Additional information on these and other constituents can be found in discussions by Hutchinson (1957, p. 541–902) and Hem (1959a, p. 35–149).

SILICA

In former years the silicon dissolved in natural water was generally considered to be "colloidal silica" and the practice of reporting the element in terms of SiO_2 in water analyses has persisted. Recent research on the state of silicon in solution and its chemical behavior has given a basis of understanding not formerly available. Krauskopf (1956) suggested that silica in most natural water occurs as dispersed silicic-acid molecules and should be assigned the formula H_4SiO_4.

The solubility of amorphous silica was found by Alexander (1957) to increase as the particle size of the silica decreased. He reported a minimum solubility of 91 ppm for silica in massive form as SiO_2 at 25°C. The value given by Greenberg and Price (1957) for solubility of amorphous silica is 108 ppm at 25°C. A similar value is given by Okamoto, Okura, and Goto (1957); and White, Brannock, and Murata (1956) found an equilibrium value of about 110 ppm in high-silica hot-spring waters stored for sufficient time at 25°C. These investigators found that the solubility increased rapidly with increasing pH above about pH 9.0 because of the dissociation of the acid. The first dissociation constant for H_4SiO_4 was given by Greenberg and Price (1957) as $10^{-9.77}$. Silica also becomes more soluble at temperatures above 25°C.

Van Lier, de Bruyn, and Overbeek (1960) reported that as much as about 11 ppm quartz was soluble in water at 25°C and that saturation was attained slowly. The rate of silica solution also was studied by O'Connor and Greenberg (1958) and reported to be proportional to the surface area of solid exposed.

The silicic acid present in quantities above equilibrium values in highly siliceous waters, such as those represented in table 17, was found by White, Brannock, and Murata (1956) to polymerize slowly to yield colloidal suspensions of silica. The rate of polymerization is influenced by pH, temperature, degree of supersaturation, and presence of previously formed colloidal or crystalline silica.

IRON

The form and amount of iron in solution in ground water at chemical equilibrium is controlled by the nature of the iron minerals present, the pH and redox potential (Eh), and the activity of other ions in the solution. Graphical representation of these variables by means of Eh–pH, or stability-field, diagrams clearly shows the interrelationships. Such diagrams also are useful in studies of the chemistry of many other elements that may occur in solution. The stability-field diagram was extensively developed and utilized by Pourbaix (1949) in his studies of corrosion, and has been extensively applied in geochemistry by Garrels (1960).

Many of the water analyses in tables 1 to 27 report iron concentrations of 1 ppm or more. In almost all these waters the iron must be present in the ferrous form. For an amount this great to be retained in solution, however, a pH well below 7.0 or a low redox potential is required. The latter commonly occurs in ground-water bodies that are not in contact with air. When ground water containing ferrous iron is exposed to air, oxygen raises the Eh of the solution and the iron is oxidized to the ferric form and precipitated. The solubility of ferric iron exceeds 1.0 ppm only at a pH below 3.8 and at a high Eh. The solubilities and rates of oxidation of iron are affected by complexing with organic and inorganic ions and by other factors. Studies by Hem (1959b; 1960a; 1960b; 1961) discuss these factors in detail. The rate of oxidation of ferrous iron in aerated water has been studied by Stumm and Lee (1960; 1961).

CALCIUM, BICARBONATE, CARBONATE, AND pH

Chemical equilibria involving solid carbonate minerals, and dissolved calcium, hydrogen, and bicarbonate or carbonate ions are very important controls over the concentration of calcium in ground water. The system involving calcite may be simply represented

$$CaCO_3 + H^+ \rightleftharpoons HCO_3^{-1} + Ca^{+2}.$$

If a gas phase is present, the acitvities of H^{+1} and HCO_3^{-1} may also be controlled by the partial pressure of carbon dioxide. Some of the carbon dioxide combines with water to form carbonic acid, which is partly dissociated in solution. Hutchinson (1957, p. 653–690) has discussed carbon dioxide-bicarbonate equilibria in some detail.

In most ground waters no gas phase is present. However, some dissolved carbon dioxide and related species are present. The reactions among water, dissolved materials, and solid minerals control the hydrogen-ion activity. An important source of dissolved carbon dioxide is the air in soil pores, which is often strongly enriched in carbon dioxide. In some ground waters, however, a volcanic or metamorphic source of carbon dioxide may be important (White, 1957b, p. 1670–1671, 1678); Orfanidi (1957) also has noted the possibility for metamorphic CO_2 in certain waters of the Caucasus. Carbon dioxide may also be produced at depth by biochemical reduction of sulfate.

Hydrogen ions also are available in small quantities by dissociation of water itself. When pure water is equilibrated with calcite at 25°C, the pH of the solution is raised to a value between 9.9 and 10 (Garrels, 1960, p. 50), and the calcium content is about 5 ppm. If water is first allowed to dissolve carbon dioxide by contact with air and then is equilibrated with calcite in the absence of a gas phase, Garrels (1960, p. 57) has calculated that the final calcium content in solution will be only about 5.6 ppm. Rainwater moving directly to the ground-water reservoir with no opportunity for further enrichment in dissolved carbon dioxide is thus only a little more effective as a solvent for calcite than is pure water. A graphical representation of calcium, bicarbonate, and pH relationships in solutions at equilibrium with calcite has been published by Hem (1960c).

Weyl (1958) concluded that under normal conditions the solution of calcite occurs rapidly enough so that water in limestone below the water table is always saturated with calcite. The reverse reaction, precipitation of calcite, is considerably slower. A condition of equilibrium should, however, exist in most ground water. Field data that might be used to evaluate equilibria in ground water are difficult to obtain. Determinations of pH and perhaps of bicarbonate must be made in the field when samples are collected, if they are to represent accurately the conditions in the aquifer. Practically no data of this type are available. Analyses in table 6 represent the usual laboratory determinations made after the samples had been stored for several days or weeks.

The hydrogen-ion activity of ground water is involved in many other chemical equilibria besides those of carbon dioxide and carbonates. In extreme examples, as those in tables 19 and 20, the water may become strongly acid by solution of gases such as SO_3 or HCl.

MAGNESIUM

The reactions involved in solution of magnesium from carbonate minerals are similar to those for solution of calcite. However, as Garrels, Thompson, and Siever (1960) have noted, the precipitation of magnesium carbonate or dolomite from solution is extremely slow and equilibrium conditions with respect to magnesite or dolomite probably are not to be expected at low temperature and pressure. Some of the analyses in table 7 show the approximately equivalent amount of magnesium and calcium to be expected at saturation with dolomite. Some precipitation of calcium carbonate from such solutions, however, appears to occur and leads to a considerable excess of magnesium over calcium in solution.

VARIETIES OF IONIC SPECIES

The actual forms in which some ions occur in ground water are still incompletely known. The importance of ion-pairs or complexes undoubtedly increases as the total content of dissolved material increases. The degree of dissociation of dissolved carbon dioxide and the resulting ionic species is well recognized to be a function of pH, but the relationship of other anions to pH is not always recognized. Below a pH of 2, for example, sulfuric acid is only partly dissociated and HSO_4^{-1} needs to be considered.

The chemistry of major constituents of water is much better understood than is the chemistry of minor constituents. As a matter of fact, the literature contains almost no information on the minor-element content of the more dilute ground waters. Although the large number of water analyses in existence suggests that there is scientific and orderly precision in the study of chemistry of natural water, actually much research is needed before the field can be considered as well explored.

SOURCE AND SELECTION OF TABULATED DATA

The analyses in this chapter were obtained from published reports and from unpublished data in the files of the U.S. Geological Survey.

Effort has been made to achieve a wide geographic distribution of analyses, but because many more waters have been analyzed in some countries than in others, the distribution is necessarily uneven. Thousands of mineral waters and tens of thousands of "potable" ground waters have been analyzed; selection was made, in part, for geographic distribution, but in major part was based on geologic environment, the number of components that were determined, and the apparent accuracy of the entire analysis to the limited degree that quality can be judged. Components of special interest that commonly are not determined are K, Li, NH_4, F, Br, I, NO_3, and B (White, 1957b, p. 1661, 1666). Most of these components are not determined in dilute ground waters but are present in minor yet determinable quantities in many mineral waters. They are highly soluble in most chemical environments, and the quantity of each component that is present in a natural water is determined by the history of the water and the available supply of the component. Many mineral waters have been analyzed for one or two of these components, but few have been analyzed for most or all of them. Components such as the alkaline-earth elements and the heavy metals are of considerable interest, but the quantities present are much more likely to be determined by solubility in the particular water rather than by available supply. Water samples obtained from wells may contain small amounts of metals, such as zinc, copper, or iron, dissolved from pump parts of plumbing. Analyses suspected of being affected by this type of contamination were rejected, but the effect may not be entirely absent from the tabulated data.

A large proportion of analyses are not accompanied by satisfactory data on geologic environment of the waters. Many analyses of mineral waters are published in chemical or balneological journals without accompanying geological data, but effort was made to determine the geological environments of the samples whose analyses were selected.

In tables 1 to 11, analyses of waters from each rock type are given numerically in order of increasing dissolved matter, because, in general, the dilute waters are less likely to be affected by contamination with saline waters of nonmeteoric origin. In tables 12 to 27, analyses are arranged geographically.

UNITS AND TERMINOLOGY

Virtually all the analytical data are reported in the standard form of the U.S. Geological Survey. Concentrations of components in the waters have been reported in various publications in a wide variety of forms and chemical combinations; in this chapter all are expressed as parts per million, which for waters of or near unit density are also equivalent to milligrams per liter. Constituents that are present largely or entirely in dissociated form are reported also as equivalents per million (epm, or milligram equivalents per kilogram) computed from parts per million and combining weights of the ions.

Some elements, such as Si, B, As, P, and Al, have been reported in several different ionic and molecular species by different analysts. These are uniformly reported here as SiO_2, B, As, PO_4, and Al; equivalents per million are not calculated for these components or for Fe and some other metals, except in acid waters. Sulfide is reported as H_2S, except for a very few analyses where both H_2S and HS^{-1} were originally reported or where the water is very alkaline and sulfide ion is probably dominant. A minor element that has been determined in only a few analyses of a table is not shown in the tabulated data but is mentioned in the explanation of the table.

Specific conductance is expressed as micromhos at a standard temperature of 25° C. A mho is a unit of electrical conductance and is the reciprocal of ohm. "Specific" here implies the conductance of a 1-cm cube of the solution; the ability of a water to conduct electricity is increased as the concentration of dissociated ions increases, but there is no simple relationship between specific conductance and dissolved solids in parts per million. Uranium is reported in micrograms per liter (or parts per thousand million in waters of unit density) and radioactivity is reported in micromicrocuries per liter (curies $\times 10^{-12}$ per l).

In some published analyses, as many as six significant figures have been reported. These have been arbitrarily rounded in the following way: less than 1 ppm, 1 or 2 significant figures; 1 to 99 ppm, 2 significant figures; and over 100 ppm, 3 significant figures. All values for equivalents per million are reported to comparably significant figures but are not reported for more than two decimal places. Some published analyses show precise chemical balance of anions and cations; presumably one component (generally Na) has been calculated by difference. The equivalents per million reported here as significant figures generally do not balance exactly.

Rates of discharge of springs are stated in U.S. gallons per minute (gpm). One gpm equals 0.83311 Imp. gallons per minute, 3.7854 liters per minute, and 0.002228 cubic feet per second.

Stratigraphic nomenclature used is that of the published and unpublished sources and does not necessarily conform to that of the U.S. Geological Survey.

WATERS OF LOW MINERAL CONTENT ASSOCIATED WITH COMMON ROCK TYPES

The analyses of tables 1 to 11 were selected from about 1,200 analyses. Most of the water samples would be considered potable, with dissolved matter of less than 1,000 ppm. These dilute waters were selected largely from environments in which the waters were most likely to be atmospheric precipitation that was then influenced primarily by reactions with the rocks in which they are found (including associated soil zones).

Dilute waters are relatively scarce in some rocks, particularly in fine-grained sedimentary rocks such as siltstones and shales. (See table 5.) Most sedimentary rocks were deposited in a saline environment; extensive flushing or displacement is necessary to remove the highly soluble matter retained from such an environment. However, most of the rocks that are highly productive sources of ground water were deposited in nonmarine environments.

WATERS FROM IGNEOUS TERRANES

GRANITE, RHYOLITE, AND SIMILAR ROCK TYPES

Silicic igneous rocks generally yield only small supplies of water, except where extensively jointed or brecciated. Nevertheless, these rocks are utilized in many areas where better sources are lacking.

Ground waters from silicic igneous rocks (table 1) generally are relatively low in mineral content. The dominant ions are generally Na^+ and HCO_3^-; SiO_2 is generally very high for cold dilute waters and fluoride is relatively high. Calcium, magnesium, and pH are generally relatively low (table 1).

Such characteristics should be expected of meteoric waters in contact with silicic igneous rocks, which consist dominantly of chemically resistant quartz and sodium and potassium feldspars. The anomalously low indicated ratios of potassium to sodium relative to the ratios in other igneous rocks are surprising, because this group is normally high in potassium. The rocks of this group are also relatively high in lithium and boron, but these two elements have seldom been determined in dilute waters.

In table 1, the sulfate of analysis 14, the chloride of analyses 11, 13, and 15, and probably the fluoride of analyses 13 and 14 are all high and require special explanations that are not made here.

GABBRO, BASALT, AND ULTRAMAFIC ROCKS

Although most igneous rocks do not yield large quantities of ground water, some favorably situated permeable basalts yield enormous quantities.

The source rocks of the waters of analyses in table 2 consist dominantly of ferromagnesian minerals, with or without calcic plagioclase. All these minerals are less stable and more subject to chemical attack than the minerals of silicic rocks.

As expected, the waters of the group generally have high ratios of Ca/Na and Mg/Ca; the magnesium content of peridotite and serpentine is particularly high, and the magnesium content of waters from gabbro and basalt is nearly always higher than in waters from silicic igneous rocks. Although mafic rocks contain little or no quartz and are lower in total silica than felsic rocks, the chemical instability of the minerals accounts for relatively high content of SiO_2 in associated waters. Most of the waters are low in fluoride; although no data are available, further study may show that these waters are generally low in lithium and perhaps in boron relative to waters of silicic igneous rocks.

Table 2 shows that where pH and probably Eh (oxidation potential) are low, iron and manganese are relatively high (analyses 1 and 2). The high sulfate of analysis 2 suggests oxidation of sulfides or sulfate from some external source; much of the chloride of the waters of analyses 10, 15, and 16 may be from external sources.

ANDESITE, DIORITE, AND SYENITE

The waters given in table 3 are associated with rocks that are, in general, intermediate between granite and basalt in composition. Many of the ratios and contents, however, are not between the medians for granite and basalt, probably because of the small number of samples and lack of rigid statistical control and perhaps also because minor analytical errors can influence the ratios strongly when the waters are very dilute.

The high sulfate content of analysis 3 suggests sulfate from some external source.

WATERS FROM SEDIMENTARY TERRANES

SANDSTONE, ARKOSE, AND GRAYWACKE

Sandstone beds are widespread and are important aquifers throughout the world. Rocks of this group range in chemical composition from almost pure silica to rocks that are very similar chemically to granite, andesite, and basalt. The lithologic characters and chemical compositions of the rocks associated with waters given in table 4 have not been described sufficiently to warrant further subdivision.

The ratios of Ca/Na, K/Na, HCO_3/Cl, and SO_4/Cl are commonly a little higher than for most waters from igneous rocks, but the content of SiO_2 is generally less. Ground waters containing more than 1,000 ppm dissolved matter are relatively common in sandstone, especially at depths of more than several hundred feet. Many waters from sandstones contain dissolved matter clearly not derived from the clastic grains of the enclosing rocks, for example, the very high fluoride content (2 to 9 ppm) commonly reported in waters from the Dakota Sandstone (Cretaceous) of North Dakota and South Dakota.

A few waters from sandstone contain notable amounts of iron and are probably low in Eh; some of these waters also contain appreciable manganese.

SILTSTONE, CLAY, AND SHALE

Siltstone, clay, and shale are fine grained and, except for the more brittle jointed varieties, are very low in permeability. They are poor sources of water, but most are in areas where more productive sources are not available.

The bulk of the fine-grained sediments of the world were deposited in saline environments. Soluble components are likely to be retained as adsorbed ions on clay minerals or in interstitial saline water that was never completely removed by flushing because of low permeability of the rocks. One of the outstanding characteristics of this group (table 5) is the scarcity of waters with reported sums of less than 1,000 ppm.

The less mineralized waters in table 5 are generally relatively low in the ratios of Ca/Na, HCO_3/Cl, and F/Cl; the ratio of Mg/Ca is relatively high.

Many marine shales and muds are high in boron and iodine (White, 1957b, p. 1668, 1671; Degens and others, 1957); nonmarine shales appear to be low in boron and are probably also low in iodine; more attention should be given to these minor elements in waters of low mineral content, because these minor elements may reflect differences in the environments of deposition of the sedimentary rocks.

Many of the more saline waters given in table 5 are high in chloride, which is probably residual from the depositional environment. The low sulfate content of analyses 13 to 15 is probably related to organic content and reducing environment in the rocks. The relatively high bicarbonate content of these waters may be due to sulfate-reducing bacteria that have utilized the oxygen of sulfate to oxidize some of the organic carbon. Experimental studies by Foster (1950) suggest, however, that the presence of sulfate is not a necessary condition; she suggests that the high sodium content may be due to ion exchange of calcium with sodium from clay material and that carbonaceous material is the source of CO_2 for the waters of very high bicarbonate content. Other waters are relatively high in sulfate, some are acid and contain moderately high amounts of iron and aluminum (analyses 2 and 18); these characteristics are probably related to oxidation of pyrite in organic shales. Other waters are nearly neutral but contain notable quantities of iron and manganese (analyses 5, 11, and 16), probably because of moderately reducing environments.

Although commonly ascribed to pollution, the high nitrate content of some waters from shale (analyses 3, 8, 9, and, especially, 10) may also result from oxidation of NH_4 in organic matter and in exchange positions in clay minerals in sediments rich in organic matter.

LIMESTONE

Most limestones are dense, hard rocks that carry water only in fractures; some limestones, however, contain large solution channels and are highly productive. Perhaps the most productive limestones, however, are porous reef structures or other accumulations of shells where original porosity has commonly been increased by solution.

In addition to $CaCO_3$, many limestones also contain silica, clay minerals, dolomite, anhydrite, or gypsum. All the analyses of table 6 demonstrate the influence of some other minerals in addition to calcite. Dolomite, perhaps as a minor component, has undoubtedly influenced the composition of the water of analysis 9, and, to a lesser extent, many of the others. The water of analysis 14 seems to contain dissolved gypsum or anhydrite.

The quantity of alkaline-earth carbonate minerals that can be dissolved by ground water is controlled by the abundance of CO_2 and by carbonate equilibria. See reports by Hutchinson (1957, p. 653–690) and Garrels (1960, p. 43–60) for recent discussions that can be applied to many ground-water problems. The amounts of calcium and bicarbonate and the pH values suggest that all waters given in table 6 had sources of CO_2 capable of supplying larger amounts than the atmosphere. The partial pressure of CO_2 in the atmosphere is 0.00033 (Hutchinson, 1957, p. 654–655). Other sources of CO_2 for ground waters are organic activity in the soil zone and igneous or metamorphic processes at depth (White, 1957a; 1957b).

Many waters from limestone contain more nitrate than is characteristic of waters from igneous rocks. Although local pollution is a possible source of some of the nitrate, the oxidation of minerals or other substances containing ammonia should also be considered. Another possibility is that NH_4 may have been a component of some of the waters when collected, but became oxidized and was determined as nitrate.

DOLOMITE

Dolomite is generally similar to limestone in its water-bearing properties. Some types of dolomite are highly permeable and are economically important sources of water.

The weight ratio of magnesium to calcium in pure dolomite is 0.61 (ratio of equivalents, 1.0). Meteoric water that has been in contact only with pure dolomite should have these ratios if the dolomite dissolved nonselectively and if no calcite has been precipitated.

The ratio of Mg/Ca in 3 of the 6 analyses in table 7 is very close to 0.61; the ratio of analysis 2 is low, and the ratios of analyses 3 and 5 are high. Some other high-magnesium mineral may be present, or some $CaCO_3$ may have been precipitated from the two waters having high ratios.

The water from Fort Recovery, Ohio (analysis 6), contains very high sulfate and relatively high magnesium. The origin of the sulfate is not clear.

MISCELLANEOUS SEDIMENTARY ROCKS

Table 8 contains analyses of waters from some of the less common types of sedimentary rocks.

In general, the major chemical components of each rock type have low solubility values and have not markedly affected the chemical composition of the associated water. The outstanding exception is the high content of $CaSO_4$ in water from gypsum in analysis 5 (for analyses of other waters from associated Permian evaporites, see table 27). The very high sulfate content in the water of analysis 4 may be a result of oxidation of pyrite in the associated lignite.

The water of a well 200 feet deep, a short distance east of the city of Hot Springs, Ark. (analysis 2), is slightly thermal and has with little doubt been in contact with rocks other than chert. This water, as well as some others given in table 8, probably has a relatively low Eh, permitting significant iron and manganese to be in solution.

WATERS FROM METAMORPHIC TERRANES

QUARTZITE

Although the permeability and porosity of quartzite are generally very low, this type of rock may be a productive source of water if sufficiently brecciated. It is chemically similar to silica-rich sandstone (see tables 4 and 9).

Many waters from quartzite are low in SiO_2 and total dissolved matter and have a high ratio of K/Na; pH is commonly low, probably because of the scarcity of unstable minerals to react with dissolved CO_2.

MARBLE

Marble is the coarsely crystalline metamorphic equivalent of limestone. Two analyses of waters from marble (table 9) are very similar to those from limestone (table 6). Both waters are in equilibrium with CO_2 pressures that are considerably higher than the CO_2 pressure of the atmosphere (Hutchinson, 1957, p. 654–671). As in most limestone waters, excess CO_2 probably has been supplied from the soil.

SLATE, SCHIST, AND GNEISS

In general, metamorphic rocks yield only small supplies of water, because their permeability is low. Analyses of waters from several examples of metamorphosed shale and impure sandstone are included in table 10.

In many respects the waters from these metamorphosed rocks are similar to waters from shale and siltstone (table 5). Water from the metamorphic rocks, however, is commonly lower in mineral content and generally the ratio of Ca/Na is more than unity. The differences are best explained by extensive compaction and decrease of porosity of the rocks before and during metamorphism; interstitial saline water of the original environment has largely been forced out, and clay minerals of high ion-exchange capacity have been reconstituted to micas and anhydrous minerals of very low exchange capacity.

The very low content of dissolved matter of water from a metamorphosed iron-formation in Brazil (table 10, analysis 14) is noteworthy. The water is from a humid region, and the rocks are highly resistant to chemical attack. For comparison, see analysis 1 of table 8 from unmetamorphosed iron-formation of Minnesota.

Waters of analyses 12, 13, and 15 of table 10 are relatively high in chloride, and 13 and 15 are also high in sulfate; both components probably came from sources other than the enclosing rocks.

WATERS FROM UNCONSOLIDATED SAND AND GRAVEL

Unconsolidated sand and gravel are the most important sources of ground-water supply. They include alluvium of normal streams; glaciofluvial deposits, which, of course, can be considered a type of alluvium; and extensive marine and littoral strata of the coastal plains. The water most readily recoverable from unconsolidated deposits generally occurs in beds of gravel and sand accumulated and sorted through the action of streams.

The mineralogic composition of unconsolidated sand and gravel can be correlated in some places with the composition of the source rock. Especially in arid regions, the particles that make up these deposits are likely to be relatively unweathered fragments of the original rock.

The ratios and contents of the analyses given in table 11 are in general similar to those of other types as might be expected. The eight waters from alluvium of dominantly igneous origin (table 11, analyses 1, 2, 3, 6, 7, 10, and 18) are mostly similar to waters from igneous rocks, having relatively low total dissolved matter and relatively high silica content.

Most of the other analyses are of waters from alluvium derived from sedimentary rocks of many types. Total dissolved matter is commonly high, which is, in part, due to the large surface area per unit volume that is available for chemical reactions. This factor is particularly apparent in analyses 8, 12, and 16, which are of waters from relatively unweathered glacial sands and gravels in the north-central United States.

Ground waters from alluvium are hydrologically and chemically closely related to surface waters of the same drainage basin. A high content of dissolved matter can be present in such interrelated systems for any of the following reasons: (1) salts may be contributed from connate water or from salt beds in the basin (analyses 11, 19, and 20); (2) return flow from irrigation may introduce soluble matter leached from cultivated lands (analyses 11, 17, 19, and 20), possibly after several cycles of reuse; (3) in arid climates, evaporation and transpiration may concentrate soluble matter in the remaining water (analyses 14 and 15) and the ground water of alluviated valleys may have undergone several cycles of exposure to evaporation and of return as underflow into sediments (analysis 14); (4) activities of man provide salts in industrial wastes and in other forms. The high nitrate content in the waters of analyses 3, 5, 9, 13, 16, 18, 19, and 20 of table 11 may indicate pollution or direct aerobic decomposition of nitrogenous material, but other sources of these components, such as oxidation of NH_4 to nitrate, should be considered.

WATERS THAT MAY BE, IN PART, CONNATE

OIL-FIELD WATERS

The existence of connate or "fossil" water has been questioned by Chebotarev (1955) and others, but most geologists assume that many saline brines probably contain some water that is not greatly different in age from the enclosing rocks (White, 1957b, p. 1661–1678). Most connate waters probably consist of connate ocean water associated with marine sediments. Several waters that may be, in part, connate and are associated with marine and nonmarine evaporite deposits are included in table 27 (see in particular analyses 1, 2, and 7).

Near-surface marine sedimentary rocks in depositional basins and in coastal plains ordinarily have been flushed extensively by meteoric water. Most of the waters that have been collected from considerable depth in sedimentary basins, however, are saline and are probably connate. Nearly all these saline waters that have been analyzed for minor and major components were obtained from oil fields, but analyses 7 and 8 of table 13 are exceptions. These waters have a wide range in the proportions of individual components of dissolved matter. In most oil-field brines (see tables 12 and 13), the dominant anion is chloride (Chebotarev, 1955, p. 159) but in a few, bicarbonate or sulfate (table 14) exceeds chloride by weight.

In the chloride waters, sodium is, with rare exception, the dominant cation, but calcium very commonly is present in larger proportions than in sea water. Chloride waters are here divided into two major subtypes. In one, sodium is greatly dominant over calcium; in the other, calcium is relatively abundant. In tables 12 and 13, the dividing line is arbitrarily considered to be $Ca=0.1$ Na (by weight).

Some oil-field waters contain so little dissolved matter (Crawford, 1940; 1942; 1949, p. 210) that they are clearly almost entirely of meteoric origin. Other oil-field waters are very saline—commonly 5 to 10 times as saline as sea water—and their origin is a major problem that has long been debated (Mills and Wells, 1919; W. L. Russell, 1933; de Sitter, 1947; Chebotarev, 1955; White, 1957b). Most of these very saline waters are relatively high in calcium and several examples are included in table 13. A few high-calcium waters are lower in salinity than sea water (table 13, analyses 2 and 5) and probably result from dilution of high-density brines. In contrast, the brines that are low in calcium generally are similar in salinity to sea water or are lower in mineral content, but the waters of analyses 4, 5, 9, and 10 given in table 12 are exceptions.

Analyses 7 and 8 of table 13 are of Michigan brines exploited by the Dow Chemical Co. for dissolved salts. These brines are similar to waters associated with small oil pools in the same formations in other parts of the Michigan basin. They are not known to be associated with crystalline-salt deposits, and their high ratios of Br/Cl are indeed very good evidence against influence of precipitated NaCl; Br is accepted only to a minor extent in the crystal lattice of NaCl and is concentrated in residual brines. (See chapter Y.)

Most of the waters given in table 12 are from Tertiary rocks, but some are from rocks as old as Triassic; the water of analysis 10 may be from Permian rocks. In contrast, brines high in calcium are likely to be from Paleozoic and Mesozoic rocks, but the waters of analyses 1, 2, 3, and 12 of table 13 are from lower Tertiary rocks.

The oil-field brines high in sodium and chloride are commonly characterized by moderately high dissolved matter and NH_4, high ratio of I/Cl, and low ratios of K/Na, Li/Na, and SO_4/Cl (tables 12 and 29).

The chloride brines high in calcium are generally high in total dissolved matter and moderately high in NH_4 (tables 13 and 29). The ratio of Br/Cl in this group is perhaps the highest of all natural waters, although remarkably slight variations of Br/Cl are indicated for the different types included in table 29. Ratios of Li/Na, HCO_3/Cl, SO_4/Cl, and F/Cl are very low in the brines high in calcium, and K/Na, I/Cl, and B/Cl are moderately low. Barium is generally high where sulfate is low or absent; silica is near the minimum for all natural ground waters.

The characteristics and minor-element contents of sulfate and bicarbonate waters of table 14 are not sufficiently well known to distinguish them clearly from other waters that are high in sulfate and bicarbonate. Their origin, interrelationships, and minor constituents need further study. Chebotarev (1955, p. 159) has shown statistically that the average depth of bicarbonate waters in oil pools is about 2,300 feet and of sulfate waters, 1,700 feet. These waters doubtless grade upward into ground waters that are only moderately high in sulfate and bicarbonate.

SPRING WATERS SIMILAR IN COMPOSITION TO OIL-FIELD WATERS

A considerable number of cold to moderately thermal spring waters of relatively high salinity have compositions that are similar to oil-field brines high in sodium and chloride. The chemical characteristics of these spring waters, other than high salinity relative to that of other spring waters of similar temperature, include, in general, low sulfate and silica, moderately high combined nitrogen, low ratios of Li/Na and K/Na, and a high ratio of I/Cl (see tables 12, 15, and 29). The waters of table 15 generally are higher in bicarbonate, boron, and probably, sulfide than are those of table 12. Oil-field brines, however, seldom have been analyzed for sulfide and lithium and not ordinarily for boron and combined nitrogen.

Other spring waters are chemically very similar to oil-field brines high in calcium and chloride. (See tables 13, 16, and 29.) A major criterion for separating the waters of analyses given in tables 15 and 16 and in tables 12 and 13 is the weight ratio of Ca/Na; the separation is here made at 0.1. The high sulfate content in the waters of some analyses in table 16 suggests direct solution of $CaSO_4$ by water that may have been low in calcium. For several other waters given in table 16, waters high in sodium, chloride, and CO_2 may have come in contact with limestone, dissolving $CaCO_3$ and increasing the ratio of Ca/Na.

All the spring waters given in table 15 and many of those in table 16 are from rocks whose geologic environments seem from available data to be compatible with a connate origin for the water. The spring water from London, Oreg. (analysis 1), is, however, from nonmarine Eocene tuffs and basalts; that from Wiesbaden, Germany (analysis 6), is from pre-Tertiary mica gneiss; that from Thermopotamos, Greece (analysis 7), is from schist of Devonian age; that from Trompsberg, Union of South Africa (analysis 8), is from norite of Precambrian age; that from Tiberias, Israel (analysis 10), appears to be from Tertiary(?) basalt; that from Neshkin, U.S.S.R. (analysis 13), is from Silurian crystalline schist; and that from Arima, Japan (analysis 14), is from Tertiary rhyolite near granite. At least some of these waters are probably not connate, and others may have migrated from rocks of earlier association, as suggested by Kent (1951) for the Trompsberg water; extensive exchange of sodium for calcium from intermediate and basis igneous rocks is indicated. The waters of analyses 1 and 14 are moderately low in ratios of Br/Cl, and analyses 6, 7, 8, and 9 are notably low, suggesting that these waters may indeed not be connate. Further study is obviously needed.

Many spring waters are similar to the bicarbonate and sulfate waters of table 14 that are associated with petroleum. More study is needed on the origin of oil-field waters and more analytical work should be done on the minor components.

WATERS THAT MAY BE, IN PART, MAGMATIC

It is clear that magmatic waters cannot be sampled directly at their sources. Waters that are associated with especially high temperatures and heat flow and that are in areas of recent or active volcanism are of great interest, because they may contain at least some volcanic or magmatic water (White, 1957a). All students of the problem agree that most of the water discharged at the surface in thermal areas is probably meteoric in origin but that a part may be magmatic. Possible origins of the greatly different types of water that are found in volcanic environments have been discussed by Allen and Day (1935), Barth (1950), and others and have been reviewed recently by White (1957a) and Ivanov (1958a; 1958b). There is still much disagreement in regard to the origin of the different types.

Waters that are dominated by sodium, chloride, and bicarbonate are shown in tables 17 and 18. All theories of the origin of geysers require not only high temperatures at the surface but also high geothermal gradients from the surface to considerable depths: wherever wells have been drilled in geyser areas, temperatures considerably above the boiling points at the land surface have been found. The chloride in waters of geyser areas, therefore, is very likely to be of volcanic origin. However, any ground water that is heated sufficiently in a favorable environment may erupt as a geyser. The "Seawater Geyser" of Reykjanes, Iceland, for example (table 17, no. 8), has erupted as a true geyser (Barth, 1950, p. 23). Because this water is similar in composition to many of the waters given in tables 13 and 16, it is probably heated connate water rather than direct inflow of ocean water, as suggested by Barth, or volcanic water.

Most geyser waters (tables 17 and 29) are very high in silica and generally high in pH; the ratio of Li/Na is very high and B/Cl is moderately high. These waters are generally very low in combined nitrogen and, for mineral waters, are low also in total dissolved matter; the ratios of Ca/Na, Mg/Ca, and I/Cl are commonly near the minimum for natural waters, and Br/Cl may be significantly lower than in average crustal matter.

Some of the waters of table 18 may be, in part, connate; in areas of lower heat flow than in geyser areas, hot volcanic emanations are not so necessary to explain the anomaly and, therefore, the possibility of chloride from nonvolcanic sources may be a little greater. Water from Kuan-Tsu-Ling spring in northern Taiwan (table 18, no. 8), for example, has many of the chemical characteristics of water that may be connate or, possibly, metamorphic in origin (see tables 12, 13, 22, and 29); bicarbonate, boron, and the ratio of I/Cl are relatively high, and silica, sulfate, and the ratio of Li/Na are relatively low.

The median mineral matter and ratios of the analyses of table 18 (see table 29) are, in part, similar to those of geyser waters (tables 17 and 29) and, in part, to possible connate waters (tables 12, 15, and 29).

Many of the acid sulfate-chloride waters of table 19 are very closely associated with active or recent volcanism. All gradations exist between acid springs, large spring pools, and crater lakes; superheated fumaroles commonly are found in the vicinity. Possible origins of these unusual waters have been reviewed by White (1957a, p. 1647–1649). Their chemical characteristics (tables 19 and 29) are clearly derived, in part, from volcanic emanations and, at least in some places, by vigorous acid attack of associated rocks. The cation ratios are strongly influenced by associated rocks except, perhaps, the ratio of Li/Na, which may reflect a high content of lithium in certain volcanic emanations. Other outstanding characteristics of most waters of this group are very high contents of silica and of total dissolved matter and possibly low ratios of Br/Cl and I/Cl.

Acid sulfate waters (low in chloride) may also originate in several different ways (see Allen and Day, 1935, p. 65, 100–125, 393–448; Barth, 1950, p. 43; White, 1957a, p. 1651–1652). Most geologists agree, however, that one common origin involves partial condensation of vapors containing H_2S and the reaction of sulfide, water, and atmospheric oxygen to form sulfuric acid. The cation ratios of these acid waters are influenced greatly by the associated rocks (tables 20 and 29). Ammonium is very high in some waters, perhaps because of selective concentration of small amounts of NH_3 from the gases, due to low volatility in acid water. Sulfate is by far the dominant anion; and fluoride and boron, according to meager data, are somewhat high relative to chloride; silica and the ratios of Mg/Ca and K/Na are commonly high.

High-temperature waters high in bicarbonate and sulfate have been recognized in only a few volcanic areas, where they appear to be related to condensation of steam containing CO_2 and H_2S in ground water, commonly below the surface (White, 1957a, p. 1649). The ratios of HCO_3/Cl, SO_4/Cl, F/Cl, and B/Cl may be near the maximum for natural waters, but total dissolved matter and combined nitrogen may be relatively low.

WATERS THAT MAY BE, IN PART, METAMORPHIC

Metamorphic water has been defined (White, 1957b, p. 1662) as water that is or has been associated with rocks during their metamorphism and is probably derived largely from hydrous minerals during their reconstitution to anhydrous minerals.

Many thermal springs and mineral waters have characteristics that do not clearly indicate any of the groups previously considered. One type that may warrant special attention is characterized by high concentrations of sodium, bicarbonate, and boron and by relatively low chloride (see tables 22 and 29). Other similar waters associated with California quicksilver deposits are included in table 23 (analyses 1 to 3). White (1957b, p. 1678–1679) has suggested that these waters may be driven off from hydrous minerals of sedimentary rocks that are being progressively metamorphosed after interstitial connate water high in chloride has been largely driven off by compaction of the sediments. The group as a whole has, of course, high ratios of HCO_3/Cl and B/Cl, because these ratios were the criteria for selection. Other characteristics are relatively low temperatures; and, in most of the analyses, high ratios of I/Cl and low ratios of Li/Na and K/Na. These characteristics suggest a close relationship to possible connate waters (tables 12 and 15) and are not similar to those of waters most likely to contain a volcanic component (tables 17 and 19).

OTHER SPECIAL GROUPS

THERMAL WATERS ASSOCIATED WITH EPITHERMAL MINERAL DEPOSITS

Most mineral deposits were formed millions of years ago and probably were related to hydrothermal activity that has long since ceased. In contrast, some epithermal mineral deposits may have formed so recently that a study of associated waters may throw light on their origin and on the geochemistry of ore transport and deposition. The association of thermal springs with epithermal ore deposits has been reviewed recently by Schmitt (1950) and White (1955a). The evidence must always be examined with caution, because significant changes in nature of the discharging water may have occurred since the ore minerals were deposited; it is usually difficult to prove conclusively that the ore minerals are still being deposited from existing waters.

Table 23 includes six analyses of thermal waters occurring in or near quicksilver deposits. Other waters associated with notable quicksilver deposits are those from the thermal springs of the Elgin quicksilver mine, 3 miles northwest of Wilbur Springs, Calif. (table 15, analysis 2), which are very similar in composition to the waters given in table 23 (White, 1955a, p. 130–131); the brine from the Cymric oil-field, Calif. (table 12, no. 2; see also Stockman, 1947); water from Skaggs Springs, Sonoma County, Calif. (Everhart, 1950, p. 385–394; White, 1955a, p. 125; 1957b, p. 1676–1679); and water from Steamboat Springs, Nev. (table 17, no. 3). Waters associated with quicksilver deposits (tables 23 and 29) tend to be relatively high in total combined nitrogen and in the ratios of Mg/Ca, HCO_3/Cl, B/Cl, and I/Cl, but the ratios of Ca/Na, K/Na, and Li/Na are relatively low. The median pH of 7 should be noted because of the generally held belief that mercury is transported in alkaline waters. The waters appear to be closely related to those given in tables 12, 15, and 22. Of the analyses given in table 23, those of waters from the Abbott, Sulphur Bank, and Valley mines could have been included in table 22. The water of Steamboat Springs, Nev., is the only one associated with a notable quicksilver deposit that is also convincingly related to volcanism. It should be mentioned that the spring waters at Sulphur Bank, Calif., and Ngawha, New Zealand (table 23, nos. 1 and 6) are closely associated with Quaternary volcanic rocks, but these thermal waters are not clearly volcanic in origin.

Table 23 also includes an analysis (No. 15) of water from an epithermal silver-gold deposit; one analysis (No. 14) is of water from a spring depositing a notable amount of barite, six (Nos. 7 to 12) are from manganese-depositing springs, and two (Nos. 12 and 13) are from springs that have deposited fluorite-bearing travertine. These waters are not convincingly similar to any of the types included in tables 12 to 22.

The water of Steamboat Springs, Nev. (table 17), mentioned previously, is depositing considerable stibnite and arsenic and some gold and silver (Lindgren, 1906; Jones, 1912; Gianella, 1939; Brannock and others, 1948; p. 222–225; White, 1955a, p. 110–113). The water of Crabtree Springs, Calif. (table 22, analysis 3) contains appreciable amounts of arsenic and emerges from serpentine replaced by opal containing veinlets of realgar and marcasite. The iron phosphate deposits of Tjiater Springs, Java (table 19, analysis 11), contain about 2 percent arsenic.

In addition to the Peitou Spring, Taiwan, where deposition of lead sulfate has been reported (table 23, analysis 16), hokutolite, a lead-bearing barite, has also been identified at Shibukuro Springs, Honshu, Japan (Miura, 1938; 1939a; 1939b). A surprisingly high content of lead (8.3 ppm) has also been reported from Kuan-Tsu-Ling Spring in northern Taiwan (table 18, analysis 8). This spring, although associated with Pleistocene volcanic rocks, has many of the chemical characteristics of waters included in tables 12, 15, and 22.

NONTHERMAL SALINE AND ACID MINE WATERS

The composition of many nonthermal mine waters is of interest. Acid waters in pyritic deposits (table 24, analyses 4 to 8) are likely to be meteoric waters that have been acidified by oxidation of pyrite. Such acid waters commonly contain relatively large quantitites of heavy metals dissolved from adjacent rocks and ore deposits.

Other mineral waters from deep mines are not acid and are otherwise very different in composition from acid or normal meteoric waters. Some are very saline and their compositions may have resulted from contact with the wallrocks. Another distinct possibility is that the ore-bearing solutions or other postore waters of high mineral content were trapped and have not yet been flushed completely by meteoric water.

Analyses 2 and 3 of table 24 are similar in nearly all respects to those of the high-calcium brines of many oil fields (table 13). The analysis of water from the Calumet and Hecla copper mine (No. 2) is very similar to an earlier analysis from the nearby Quincy mine, reported to contain about 5 ppm of nickel and 14 ppm of copper (Lane, 1908, p. 110).

Saline water similarly dominated greatly by calcium chloride has been identified in the Sturgeon River gold mines of Canada (Bruce, 1941, p. 25–29; the salinity is 15.5 percent and the ratio of Ca/Na is 4.1). A very saline sodium chloride water was found in the Morro Velho mine of Minas Gerais, Brazil (written communication, D. W. J. Grey to Earl Ingerson). The water came from a vug lined with albite, calcite, ankerite, and quartz at a depth of 7,126 feet. A partial analysis showed Ca, 3,900 ppm; Mg, 1,200 ppm; Na, 46,400 ppm; Cl, 81,900 ppm; carbonates and sulfates, nil. Wallrocks are believed to be basic lava flows or spilites metamorphosed to carbonate schist.

Analysis 1 of table 24 is of a mine water of low mineral content that is similar in many aspects to meteoric water but that is unusually high in bicarbonate.

OTHER NONTHERMAL ACID MINERAL WATERS

Waters of analyses 9 and 10 included in table 24 are examples of nonthermal acid waters that are probably associated with oxidation of pyrite or native sulfur. They are similar to those of analyses 4 to 8 but are less closely associated with mines. Other similar nonthermal acid spring waters in Japan have been analyzed (Morimoto, 1954, p. 38, 93, 361, 367, 595–596, and 627–628).

SPRINGS WITH LARGE SPRING DEPOSITS

Most springs discharge at the surface without depositing significant amounts of mineral matter. However, some spring waters are unstable at atmospheric pressure and ordinary air temperatures and may deposit considerable amounts of solid material near their orifices.

Opaline sinter is the characteristic deposit of most of the geyser waters given in table 17. However, the quantity is relatively minor at Morgan Springs, Calif. (analysis 5). Sinter probably is not deposited ordinarily from waters that contain less than 200 ppm of silica (White, Brannock, and Murata, 1956).

Sinter was deposited rapidly from about 1920 to 1950 at Roosevelt Springs, Utah (table 18, analysis 3), but in recent years the flow of water from the principal spring has become very small and deposition of sinter is negligible. Travertine deposits ($CaCO_3$) of the Lýsuhóll Springs of Iceland (table 25, analysis 5) lie on earlier and more extensive deposits of sinter.

Calcite or aragonite travertine is considerably more common as a spring deposit than is sinter. The deposits of all the springs given in table 25, except at Lýsuhóll, Iceland (analysis 5), are very large as they are measurable in millions of tons. Urbain (1953) has estimated that 2 tons of travertine per day is deposited at Meskoutine Springs, Algeria (analysis 6).

Analyses of waters from other springs associated with notable travertine deposits are at Doughty, Colo. (table 23, analysis 14); Abraham, Utah (table 23, analysis 8); Poncha, Colo. (table 23, analysis 12); Ojo Caliente, N. Mex. (table 23, analysis 13); Tolenas, Calif. (table 15, analysis 3); Ain Djebel, Tunisia (table 16, analysis 9); and Saratoga, N.Y. (table 16, analysis 4).

A small part of the waters of some of the springs that deposit travertine may be of volcanic origin but diluted extensively with meteoric water (probably table 25, no. 3). The composition of such waters suggests contact with limestone and perhaps with gypsiferous sedimentary rocks, probably at relatively low temperatures (White, 1957a, p. 1652–1653). Other springs that deposit travertine may be unrelated to volcanism and have a source of CO_2 other than the atmosphere (see Introduction). All springs that deposit carbonate contain more CO_2 in solution at depth than can be retained at pressure and temperatures at the surface. As the pressure decreases, CO_2 is evolved and the pH increases, shifting the carbonate equilibria and causing precipitation of $CaCO_3$. The two analyses of waters from Keene Wonder Springs in Death Valley, Calif. (table 25, analyses 1 and 2), illustrate the chemical changes that occur when carbonated water with appreciable calcium is discharged at the surface.

Tjiater Springs in western Java (table 19, analysis 11) deposited hundreds of thousands of tons of jarosite ($KFe_3(SO_4)_2(OH)_6$) and iron phosphate high in arsenic. Many other spring waters deposit iron oxides at or near the surface. Ferrous iron is soluble in near-neutral waters with a moderately low oxidation potential but is oxidized near the surface to ferric iron, which precipitates because of the low solubility of ferric hydroxide (Hem, 1959b).

THERMAL METEORIC WATERS OF DEEP CIRCULATION

Some meteoric waters may circulate to depths of thousands of feet in areas where the permeability of the rocks is sufficiently high and differences in hydrodynamic pressure exist. The energy necessary for such deep circulation may be provided by artesian pressure and by differences in density caused by differences in temperature and salinity.

Most thermal spring waters have somewhat higher contents of dissolved matter than do associated meteoric waters. It is especially difficult to determine the origin of some of the small to moderate quantities of dissolved salts. They could be leached entirely from rocks, because of the long flow path and increased solvent action brought about through increase in temperature; or they could represent the admixture of small amounts of very saline water from connate or magmatic sources.

The waters of table 26 are of moderate to high temperatures, are of relatively low mineral content, and are especially low in chloride when compared with most hot-spring waters given in tables 15 to 25. They probably have circulated to great depths and their compositions probably have been determined almost entirely by the original composition of the meteoric water and by reaction with rocks.

According to Hutchinson (1957, p. 654–670), meteoric water in equilibrium with the CO_2 of the atmosphere could contain about 60 to perhaps 100 ppm of HCO_3. Most of the waters given in table 26 are within this range. Some additional CO_2 probably has been supplied by organisms in the soil; extensive reaction with silicate minerals and the resultant increase in pH in the waters of analyses 1, 4, and 6 given in table 26 have probably caused some subsurface precipitation of $CaCO_3$.

WATERS OF SALT DEPOSITS

Analyses of waters associated with evaporite deposits are shown in table 27. Analyses 1 to 5 are of waters from nonmarine saline deposits, and analyses 6 to 10 are of waters from marine saline deposits. Anhydrite and gypsum deposits are commonly included with the saline deposits. An analysis of water from gypsum is included in table 8 (analysis 5).

The relatively high concentration of minor elements in the brines of Searles Lake suggests that the brines are probably connate nonmarine waters that are similar in age to the enclosing salts; the highly soluble minor elements have been greatly concentrated by evaporation of water and by precipitation of the major dissolved components. The apparent absence of subsurface drainage from the basin makes unlikely the possibility of displacement by meteoric water and selective dissolving of minor components.

The water from the salt deposits of the Salado Formation (analysis 7) is particularly likely to be connate, although perhaps it is modified greatly in composition by diagenetic and metamorphic processes (see chapter Y). When the ratio of Br/Cl is notably greater than 0.003, the water is likely to be connate; in contrast, when the ratio of Br/Cl is notably less than 0.003 (as analyses 6 and 9), the water is likely to be meteoric in origin and salts are dissolved from crystalline deposits.

The sodium magnesium sulfate water, or "bitter" water, of Budapest, Hungary (table 27, analysis 12), is an example of other saline waters whose origin is highly uncertain. Vendl (1951, p. 188–196) suggests that pyrite has been oxidized extensively and carbonates have been dissolved, but other explanations appear equally or more attractive.

TABLE 1.—*Chemical analyses of ground waters from granite, rhyolite, and similar rock types*

Analysis	1		2		3		4		5		6		7		8	
Rock type and location	Silicic volcanics, Grandview, Idaho		Rhyolite, W. of Los Alamos, N. Mex.		Rhyolite tuff, S. of Mebane, N.C.		Rhyolite, Burns, Oreg.		Rhyolite, Beatty, Nev.		Granite, West Warwick, R.I.		Granite, McCormick Co., S.C.		Granodiorite, New Bedford, Mass.	
Date of collection	June 20, 1956		May 25, 1954		Mar. 23, 1955		Nov. 16, 1956		Feb. 22, 1956		May 26, 1955		Nov. 24, 1954		Oct. 31, 1955	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	37		55		39		62		52		20		35		17	
Al	.1		.1		2.7		.2		.0		.0		.1		.0	
Fe	.19		.08		1.1		.00		.22		.19		.18		.04	
Mn	.01		.0		.0		.0		.0		.0		.13		.00	
Cu	.00				.0		.0				.0		.0		.00	
Zn	.07										.07		.09		.03	
Ca	3.6	0.18	4.4	0.22	12	0.60	14	0.70	8.0	0.40	6.5	0.32	13	0.65	17	0.85
Mg	.8	.07	1.4	.12	2.2	.18	5.8	.48	1.0	.08	2.6	.21	4.3	.35	7.3	.60
Na	3.9	.17	11	.48	6.8	.30	20	.87	62	2.70	5.9	.26	8.4	.36	16	.70
K	2.3	.06	1.2	.03	.6	.02	5.2	.13	2.0	.05	.8	.02	3.5	.09	.9	.02
Total cations		0.48		0.85		1.10		2.18		3.23		0.81		1.45		2.17
HCO_3	21	0.34	42	0.69	80	1.31	112	1.84	131	2.15	38	0.62	72	1.18	51	0.84
CO_3	0		0		0		0		0		0		0		0	
SO_4	2.6	.05	1.9	.04	.1	.00	7.7	.16	22	.46	.9	.02	6.9	.14	22	.46
Cl	1.4	.04	2.0	.06	2.0	.06	4.0	.11	16	.45	5.0	.14	3.8	.11	15	.42
F	.1	.01	.6	.03	.1	.01	.3	.02	.5	.03	.5	.03	.2	.01	.0	.00
NO_3	1.9	.03	.3	.01	.8	.01	3.1	.05	6.7	.11	1.5	.02	.4	.01	27	.44
PO_4	.0				.1		.2		.2		.0		.1		.1	
Total anions		0.47		0.83		1.39		2.18		3.20		0.83		1.45		2.16
Total, as reported	75		120		148		234		302		82		148		173	
Specific conductance, micromhos at 25° C	47		80		130		217		319		76		150		236	
pH	6.6		7.2		6.9		7.6		7.9		7.6		7.0		6.3	
Temperature °C	9.4		12.8		15		14.4		15.6		11.1		18.1		10.0	
Beta-gamma activity μμc per l	<5		<10		5.4		<8		17		15		7.5		10	
Ra μμc per l	0.2		<0.1		<0.1		0.1		<0.1		0.4		0.2		0.3	
U μg per l	0.1		0.2		1.3		0.3		5.0		1.4		0.4		1.6	
Ratios by weight:																
Ca/Na	0.9		0.4		1.8		0.7		0.1		1.1		1.5		1.1	
Mg/Ca	.2		.3		.2		.4		.1		.4		.3		.4	
K/Na	.6		.1		.09		.3		.03		.1		.4		.06	
HCO_3/Cl	15		21		40		28		8.2		7.6		19		3.4	
SO_4/Cl	1.9		.9		.05		1.9		1.4		.2		1.8		1.5	
F/Cl	.07		.3		.05		.08		.03		.1		.05		0	

Analysis	9		10		11		12		13		14		15	
Rock type and location	Granite, Ellicott City, Md.		Quartz Monzonite, W. of Clayton, Idaho		Granite, Stellenbosch, Union of South Africa		Granite, Spokane, Wash.		Granite, Transvaal, Union of South Africa		Granite, Chester, Va.		Granite, NE. Transvaal, Union of South Africa	
Date of collection	Mar. 21, 1951		Sept. 8, 1954		Mar. 19, 1940		June 6, 1951		1944		Oct. 18, 1939		July 1941	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	39		27		10		25		45		17		76	
Al	.9		.1						.0					
Fe	1.6		.05				.22		.0		.03			
Mn	.0		.00				.0							
Cu			.00											
Zn														
Ca	27	1.35	34	1.70	6.0	0.30	87	4.34	27	1.35	67	3.34	96	4.79
Mg	6.2	.51	7.3	.60	11	.91	14	1.15	4.7	.39	5.0	.41	18	1.48
Na	9.5	.41	8.5	.37	} 85	3.70	{ 12	.52	152	6.59	197	8.57	} 258	11.23
K	1.4	.04	3.3	.08			{ 3.2	.08	5.7	.15	14	.36		
Total cations		2.31		2.75		4.91		6.09		8.48		12.68		17.50
HCO_3	93	1.52	136	2.23	43	0.70	268	4.39	214	3.50	126	2.07	710	11.64
CO_3	0		0		0		0		0		0			
SO_4	32	.67	20	.42	15	.31	33	.69	35	.73	468	9.74	20	.42
Cl	5.2	.15	1.2	.03	138	3.89	14	.39	138	3.89	24	.68	193	5.44
F	.0	.00	.2	.01	0	.00	.2	.01	6.6	.35	3.4	.18		
NO_3	7.5	.12	.2	.00			32	.52	.0	.00	.1	.00	0	.00
PO_4														
Total anions		2.46		2.69		4.90		6.00		8.47		12.67		17.50
Total, as reported	223		238		308		489		628		922		1,370	
Specific conductance micromhos at 25° C	258		255				569							
pH	6.6		7.5		6.8		7.3		7.1				7.7	
Temperature ° C	6		7.8				10.6		30.6					
Beta-gamma activity μμc per l			7											
Ra μμc per l			0.1											
U μg per l			4.6											
Ratios by weight:														
Ca/Na	2.8		4.0		0.07		7.2		0.2		0.3		0.4	
Mg/Ca	.2		.2		1.8		.2		.2		.07		.2	
K/Na	.1		.4				.3		.04		.07			
HCO_3/Cl	18		113		.3		19		1.6		5.2		3.7	
SO_4/Cl	6.2		17		.11		2.4		.3		20		.1	
F/Cl	0		.2		00		.01		.05		.1			

EXPLANATION FOR TABLE 1

1. Spring, southwest of Grandview, sec. 9, T. 10 S., R. 1 W., Owyhee County, Idaho. Water from pool below spring. Flows 25 gpm (estimated) from Tertiary silicic volcanic rocks. Unpublished data in U.S. Geol. Survey files; analyst, B. V. Salotto.
2. Spring, at head of East Fork of Jemez River, Sandoval County, west of Los Alamos, N. Mex. Flows 250 gpm (estimated) from rhyolite of Tertiary age. Unpublished data in U.S. Geol. Survey files; analysts, J. D. Honerkamp and J. D. Weeks.
3. Drilled well, 106 ft deep, 1 mile south of Mebane, Alamance County, N.C. In rhyolite tuff of Paleozoic(?) age. Unpublished data in U.S. Geol. Survey files; analysts, J. E. Whitney and J. A. Shaughnessy.
4. Well, 251 ft deep, sec. 12, T. 23 S., R. 30 E., Harney County, Oreg. In rhyolite of Danforth Formation of Tertiary (Pliocene) age. Unpublished data in U.S. Geol. Survey files; analyst, R. A. Wilson.
5. Spring, about 3 miles north of Beatty, Nye County, Nev. Flows 5 gpm from rhyolite of Tertiary age. Unpublished data in U.S. Geol. Survey files; analyst, R. A. Wilson.
6. Drilled well, 140 ft deep, West Warwick, Kent County, R.I. In Cowesett Granite of Mississippian(?) age. Unpublished data in U.S. Geol. Survey files; analysts, J. E. Whitney and J. A. Shaughnessy.
7. Drilled well, 252 ft deep, John de la Howe School, McCormick County, S.C. In granite of Carboniferous(?) age. Unpublished data in U.S. Geol. Survey files; analysts, J. E. Whitney and J. A. Shaughnessy.
8. Drilled well, 205 ft deep, New Bedford, Bristol County, Mass. In Dedham granodiorite of early Paleozoic age. Unpublished data in U.S. Geol. Survey files; analyst, D. E. Weaver.
9. Drilled well, 28 ft deep, Ellicott City, Howard County, Md. In Ellicott City Granite of late Paleozoic(?) age (Dingman and Meyer, 1954).
10. Snyders Spring, west of Clayton, near U.S. Highway 93, T. 11 N., R. 16 E., Custer County, Idaho. From quartz monzonite, probably late Mesozoic in age; contains 0.2 ppm boron (B). Unpublished data in U.S. Geol. Survey files; analysts, J. D. Honerkamp, J. D. Weeks, and J. O. Johnson.
11. Drilled well, at Edenville, 4.5 miles southwest of Stellenbosch, Cape Province, Union of South Africa (Bond, 1946). In Cape Granite of late Precambrian(?) age; water deposits iron oxide on standing; analyst, G. W. Bond.
12. Dug well, 45 ft deep, sec. 7, T. 26 N., R. 42 E., Spokane County, Wash. In granodiorite of pre-Tertiary age, surrounded by alluvium of Spokane River; much of detrital material is basaltic (Weigle and Mundorff, 1952).
13. Warm spring, lat 24°34′ S., long 27°36′ E., Buffelshoek, Transvaal, Union of South Africa. From Bushveld Granite of Precambrian age (Bond, 1946).
14. Drilled well, 386 ft deep, Chester, Chesterfield County, Va. (Cederstrom, 1945). In granite of Paleozoic age.
15. Drilled well, Malopena Camp, Kruger National Park, District of Letaba, northeastern Transvaal, Union of South Africa. In Archean granite (Bond, 1946).

TABLE 2.—*Chemical analyses of ground waters from gabbro, basalt, and ultramafic rock types*

Analysis	1		2		3		4		5		6		7		8	
Rock type and location	Gabbro, Waterloo, Md.		Gabbro, Laurel, Md.		Gabbro, Harrisburg, N.C.		Bushveld ultramafics, Pretoria district, Union of South Africa		Peridotite, Webster, N.C.		Serpentine, Lake Roland, Md.		Serpentine, Nottingham, Pa.		Basalt, Camas, Wash.	
Date of collection	Dec. 23, 1952		May 23, 1952		Feb. 22, 1955		Dec. 17, 1940				Mar. 19, 1954		Sept. 21, 1925		May 17, 1949	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	39		21		56		50		16		31		40		49	
Al	.0		.3								.2					
Fe	5.1		1.2		.06				.08		.06		.28		.04	
Mn	.19		.16		.00						.00					
Cu	[1].21										.00					
Zn	[1]2.7		.0								.05					
Ca	5.1	0.25	16	0.80	32	1.60	9.6	0.48	2.5	0.12	9.5	0.47	2.1	0.10	13	0.65
Mg	2.3	.19	10	.82	16	1.32	35	2.88	7.7	.63	51	4.19	76	6.25	9.0	.74
Na	6.2	.27	15	.65	25	1.09	5.8	.25	.2	.01	4.0	.17	4.2	.18	6.6	.29
K	3.2	.08	1.5	.04	1.1	.03			.0	.00	2.2	.06	1.0	.03	2.8	.07
Total cations		0.79		2.31		4.04		3.61		0.76		4.89		6.56		1.75
HCO_3	37	0.61	20	0.33	203	3.33	168	2.75	44	0.72	276	4.52	329	5.39	88	1.44
CO_3	0		0		0		0		.0		0		0		0	
SO_4	9.2	.19	59	1.23	10	.21	.5	.01	.0	.00	2.6	.05	8.5	.18	4.9	.10
Cl	1.0	.03	25	.70	13	.37	14	.40	.7	.02	12	.34	30	.85	6.9	.20
F	.0	.00	.1	.01	.2	.01			.3	.02	.0	.00			.1	.01
NO_3	.3	.01	2.2	.04	2.7	.04	28	.45			6.8	.11	2.7	.04	8.4	.14
PO_4	.0		.0								.0					
Total anions		0.84		2.31		3.96		3.61		0.76		5.02		6.46		1.89
Total, as reported	112		172		359		311		71		395		494		189	
Specific conductance micromhos at 25° C	77		259		388						427				181	
pH	6.7		5.6		6.8		7.6		8.5		8.3				7.7	
Temperature °C					16.7											
Beta-gamma activity μμc per l.																
Ra μμc per l.																
U μg per l.																
Ratios by weight:																
Ca/Na	0.8		1.1		1.3		1.7		12		2.4		0.5		2.0	
Mg/Ca	.4		.6		.5		3.6		3.1		13		18		.7	
K/Na	.5		.1		.4				.0		.6		.2		.4	
HCO_3/Cl	37		.8		16		12		63		23		11		13	
SO_4/Cl	9.2		2.4		.7		.04		.0		.2		.3		.7	
F/Cl	0		.004		.02				.4		0				.01	

Analysis	9		10		11		12		13		14		15		16	
Rock type and location	Columbia River Basalt, Farmington, Oreg.		Basalt, Oahu Island, Hawaii		Basalt, Moses Lake, Wash.		Basalt, Shoshone, Idaho		Olivine Basalt tuff-breccia, Buell Park, Ariz.		Deccan Basalt, Purna, Hyderabad, India		Snake River Basalt, Eden, Idaho		Stormberg Basalt, Barberton, Union of South Africa	
Date of collection	May 15, 1951		Mar. 6, 1928		May 1, 1950		Oct. 30, 1956		Sept. 29, 1948				Nov. 29, 1956		Sept. 20, 1941	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	50		63		55		33		31		30		44		43	
Al							.0						.05			
Fe	.43		.08		.03		.00						.03			
Mn							.00						.00			
Cu																
Zn																
Ca	24	1.20	17	0.85	29	1.45	48	2.40	20	1.00	62	3.09	54	2.69	68	3.39
Mg	15	1.23	12	.99	19	1.56	14	1.15	42	3.45	28	2.30	20	1.64	64	5.26
Na	12	.52	38	1.65	12	.52	16	.70	19	.83	24	1.04	51	2.22	95	4.14
K	5.3	.14	3.1	.08	3.5	.09	3.2	.08					7.2	.18		
Total cations		3.09		3.57		3.62		4.33		5.28		6.43		6.73		12.79
HCO_3	156	2.56	84	1.38	177	2.90	220	3.61	279	4.57	294	4.82	242	3.97	616	10.10
CO_3	0		0		0		0		0		0		0		0	
SO_4	1.6	.03	15	.31	15	.31	19	.40	22	.46	30	.62	61	1.27	15	.31
Cl	15	.42	63	1.78	6.9	.20	8.0	.23	7	.20	37	1.04	46	1.30	75	2.12
F	.2	.01			.4	.02	.3	.02	.2	.01			.4	.02	.0	.00
NO_3	.1	.00	.4	.01	9.7	.16	5.2	.08	2.5	.04			6.0	.10	16	.26
PO_4							.15						.00			
Total anions		3.02		3.48		3.59		4.34		5.28		6.48		6.66		12.79
Total, as reported	280		296		328		367		423		505		532		992	
Specific conductance micromhos at 25° C	427				340		404		458				641			
pH	7.7				7.9		8.0		8.2				7.7		7.1	
Temperature °C							13.1		12.2							
Beta-gamma activity μμc per l.							<11						<23			
Ra μμc per l.							<0.1						<0.1			
U μg per l.							2.7						2.7			
Ratios by weight:																
Ca/Na	2.0		0.4		2.4		3.0		1.1		2.6		1.1		0.7	
Mg/Ca	.6		.7		.7		.3		2.1		.5		.4		.9	
K/Na	.4		.08		.3		.2						.1			
HCO_3/Cl	10		1.3		26		28		40		7.9		5.3		8.2	
SO_4/Cl	.1		.2		2.2		2.4		3.1		.8		1.3		.2	
F/Cl	.01				.06		.04		.03				.009		0	

[1] Values considered dubious, possibly contaminated.

EXPLANATION FOR TABLE 2

1. Drilled well, 75 ft deep, Waterloo, Howard County, Md. In gabbro (Dingman and Meyer, 1954).
2. Drilled well, 35 ft deep, Laurel, Howard County, Md. In gabbro (Dingman and Meyer, 1954).
3. Drilled well, 79 ft deep, 1 mile south of Harrisburg, Cabarrus County, N.C. In gabbro. Unpublished data in U.S. Geol. Survey files; analyst, S. A. Phillips.
4. Drilled well, 120 ft deep, 5 miles west of Hartebeespoort Dam, on main road to Rustenburg, District of Pretoria, Transvaal, Union of South Africa. In norite, pyroxenite, and other ultramafic rocks of Bushveld complex of Precambrian age (Bond, 1946); analyst, G. W. Bond.
5. Drilled well, 250 ft deep, Webster, Jackson County, N.C. In periodotite (LeGrande, 1958).
6. Well Ed 22, 140 ft deep, Lake Roland, Baltimore County, Md. In serpentine (Dingman, Ferguson, and Martin, 1956).
7. Well 211, 100 ft deep, three-fourths of a mile southwest of Nottingham, Chester County, Pa. In serpentine (Hall, 1934).
8. Drilled well, 390 ft deep, near Camas, NW¼NE¼ sec. 8, T. 1 N., R. 3 E., Clark County, Wash. In basalt of Tertiary age (Griffin, Watkins, and Swenson, 1956).
9. Well at Farmington, NE¼NW¼ sec. 31, T. 1 S., R. 2 W., Washington County Oreg. In Columbia River Basalt of Tertiary age (Griffin, Watkins, and Swenson, 1956).
10. Well 153, Oahu Island, Hawaii. In late Tertiary basalt (Stearns and Vaksvik, 1935).
11. Drilled well, 210 ft deep, near Moses Lake, SW¼ sec. 28, T. 19 N., R. 24 E., Grant County, Wash. In Tertiary basalt (Mundorff, Reis, and Strand, 1952).
12. Well at Shoshone, sec. 2, T. 6 S., R. 17 E., Lincoln County, Idaho. In Tertiary basalt. Unpublished data in U.S. Geol. Survey files; analyst, R. A. Wilson.
13. Spring, 3½ miles east of Sawmill, Buell Park, Apache County, Ariz. (10 miles north of Fort Defiance). From olivine basalt tuff-breccia. Unpublished data in U.S. Geol. Survey files; analyst, L. S. Hughes.
14. Well at Purna Railway Station, State of Hyderabad, India. In Deccan Basalt of Cretaceous(?) age (Munn, 1934).
15. Well, 380 ft deep, Eden, NE¼ sec. 35, T. 9 S., R. 19 E., Jerome County, Idaho In Snake River Basalt of Tertiary age. Unpublished data in U.S. Geol. Survey files; analyst, M. Fishman.
16. Drilled well at Komatipoort, District of Barberton, Transvaal, Union of South Africa. In Stormberg lavas of Late Triassic age (Bond, 1946); analyst, G. W Bond.

EXPLANATION FOR TABLE 3

1. Spring, 16 miles northeast of Bear, sec. 3, T. 21 N., R. 2 W., Adams County, Idaho. Discharges 200 gpm from altered andesite flows and pyroclastics and younger intrusive dikes in Seven Devils Volcanics of Permian age. Unpublished data in U.S. Geol. Survey files; analysts, R. A. Wilson, J. D. Weeks, and J. O. Johnson.
2. Drilled well, 160 ft deep, 8 miles west of Asheboro, Randolph County, N.C. In Paleozoic andesite tuff. Unpublished data in U.S. Geol. Survey files; analyst, J. E. Whitney and J. A. Shaughnessy.
3. Drilled well, 683 ft deep, China Grove, Rowan County, N.C. In diorite. Unpublished data in U.S. Geol. Survey files.
4. Drilled well, 179 ft deep, at Hamilton County Jail, Lake Pleasant Village, Hamilton County, N.Y. In syenite of Precambrian age. Unpublished data in U.S. Geol. Survey files; analysts, J. A. Shaughnessy and J. E. Whitney.

TABLE 3.—*Chemical analyses of ground waters from andesite diorite, and syenite*

Analysis	1		2		3		4	
Rock type and location	Andesite, NE. of Bear, Idaho		Andesite tuff, W. of Asheboro, N.C.		Diorite, China Grove, N.C.		Syenite, Lake Pleasant, N.Y.	
Date of collection	Aug. 8, 1954		Mar. 22, 1955		---		Oct. 5, 1954	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	8.9	---	31	---	22	---	19	---
Al	.0	---	.2	---	---	---	.0	---
Fe	.00	---	.16	---	.04	---	.14	---
Mn	.00	---	.03	---	---	---	.00	---
Cu	---	---	.01	---	---	---	.00	---
Zn	---	---	---	---	---	---	.03	---
Ca	12	0.60	14	0.70	72	3.59	9.5	0.47
Mg	.5	.04	5.6	.46	4.1	.34	2.3	.19
Na	1.8	.08	9.6	.42	10	.44	2.8	.12
K	2.6	.07	.4	.01	2.8	.07	.6	.02
Total cations	---	0.79	---	1.59	---	4.44	---	0.80
HCO_3	38	0.62	74	1.21	114	1.87	38	0.62
CO_3	0	---	0	---	0	---	0	---
SO_4	6.3	.13	.1	.00	115	2.39	2.8	0.6
Cl	.0	.00	8.8	.25	6.5	.18	2.1	.06
F	.1	.01	.0	.00	.1	.01	.1	.01
NO_3	.2	.00	6.8	.11	.0	.00	2.5	.04
PO_4	.0	.00	.0	---	---	---	.1	---
Total anions	---	0.76	---	1.57	---	4.45	---	0.79
Total, as reported	70	---	151	---	347	---	80	---
Specific conductance micromhos at 25° C	78		163		---		80	
pH	7.7		7.2		7.7		7.6	
Temperature ° C	---		15.0		---		10.0	
Beta-gamma activity μμc per l	<5		<5		---		<5	
Ra μμc per l	<0.1		<0.1		---		0.1	
U μg per l	0.2		0.9		---		0.6	
Ratios by weight:								
Ca/Na	6.7		1.5		7.2		3.4	
Mg/Ca	.04		.4		.06		.2	
K/Na	1.4		.04		.3		.2	
HCO_3/Cl	---		8.4		18		18	
SO_4/Cl	---		.01		18		1.3	
F/Cl	---		.0		.02		.05	

TABLE 4.—*Chemical analyses of ground waters from sandstone, arkose, and graywacke*

Analysis	1		2		3		4		5		6		7		8	
Rock type and location	Catahoula Sandstone, Collins, Miss.		Dawson Arkose, E. of Monument, Colo.		Caseyville Sandstone, Dawson Springs, Ky.		Triassic Sandstone near Manchester, Conn.		St. Peter Sandstone Near Melbourne, Ark.		Homewood Sandstone Near Worthington, Pa.		Cretaceous sandstone, Monzi, Zululand, Union of South Africa		Arikaree Sandstone, SW. of Crawford, Nebr.	
Date of collection	Dec. 19, 1955		Sept. 2, 1955		Jan. 3, 1955		Nov. 4, 1954		Sept. 19, 1954		Mar. 3, 1955		Nov. 5, 1941		Sept. 19, 1954	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	25	----	35	----	9.4	----	14	----	12	----	8.0	----	20	----	61	----
Al	.2	----	.3	----	.1	----	.1	----	.2	----	.1	----	----	----	.1	----
Fe	.41	----	.20	----	4.2	----	.08	----	.06	----	.16	----	----	----	1.1	----
Mn	.00	----	.00	----	.21	----	.10	----	.00	----	.00	----	----	----	.15	----
Cu	----	----	----	----	.00	----	.00	----	----	----	.00	----	----	----	----	----
Zn	----	----	----	----	.00	----	.00	----	----	----	.00	----	----	----	----	----
Ca	2.4	0.12	9.6	0.48	16	0.80	27	1.35	50	2.50	44	2.20	14	0.70	35	1.75
Mg	.5	.04	1.9	.16	6.4	.53	10	.82	6.0	.49	7.6	.62	21	1.73	9.1	.75
Sr	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Na	2.6	.11	5.1	.22	13	.56	2.3	.10	2.4	.10	12	.52	36	1.57	7.8	.34
K	2.0	.05			2.2	.06	.8	.02	3.0	.08	3.9	.10			6.0	.15
Total cations	----	0.32	----	0.86	----	1.95	----	2.29	----	3.17	----	3.44	----	4.00	----	2.99
HCO_3	18	0.30	38	0.62	98	1.61	80	1.31	184	3.02	163	2.67	122	2.00	161	2.64
CO_3	0	----	0	----	0	----	0	----	0	----	0	----	0	----	0	----
SO_4	1.4	.03	7.4	.15	14	.29	31	.64	2.1	.04	28	.58	12	.25	5.5	.12
Cl	2.5	.07	1.8	.05	3.0	.08	5.6	.16	1.8	.05	6.4	.18	61	1.72	4.0	.11
F	.1	.01	.1	.01	.1	.01	.1	.01	0	.00	.1	.01	----	----	.3	.02
NO_3	.0	.00	1.5	.02	1.0	.02	18	.29	6.5	.10	1.2	.02	.2	.00	3.2	.05
PO_4	----	----	0	----	0	----	.1	----	0	----	0	----	----	----	----	----
Total anions	----	0.41	----	0.85	----	2.01	----	2.41	----	3.21	----	3.46	----	3.97	----	2.94
Total, as reported	55	----	101	----	168	----	189	----	268	----	274	----	286	----	294	----
Specific conductance micromhos at 25° C	38		91		194		233		299		327		----		283	
pH	6.2		6.7		7.2		7.8		7.4		8.0		5.6		7.8	
Temperature ° C	18.9		8.9		----		12.8		16.7		----		----		12.2	
Beta-gamma activity μμc per l	<5		<5		10		<10		<7		<10		----		<14	
Ra μμc per l	0.2		0.4		1.3		0.1		0.1		<0.1		----		<0.1	
U μg per l	0.1		0.1		2.1		0.6		0.3		0.2		----		3.8	
Ratios by weight:																
Ca/Na	0.9		1.9		1.2		12		21		3.7		0.4		4.5	
Mg/Ca	.2		.2		.4		.4		.1		.2		1.5		.3	
K/Na	.8		----		.2		.3		1.3		.3		----		.8	
HCO_3/Cl	7.2		21		33		14		102		26		2.0		40	
SO_4/Cl	.6		4.1		4.7		5.5		1.2		4.4		.2		1.4	
F/Cl	.04		.06		.03		.02		0		.02		----		.08	

Analysis	9		10		11		12		13		14		15		16		17	
Rock type and location	Navajo Sandstone, E. of Mexican Water, Ariz.		Pocono Sandstone near Jamestown, Pa.		Rensselaer Graywacke near Sand Lake, N.Y.		St. Peter and other Sandstone, Waukesha, Wis.		Franconia Sandstone, Mound, Minn.		Cambrian sandstone, Kaukauna Wis.		Sylvania Sandstone near Carleton, Mich.		Bushveld Sandstone, Pretoria, Transvaal, Union of South Africa		Oakville Sandstone, Kennedy, Tex.	
Date of collection	Mar. 11, 1955		May 26, 1954		Sept. 20, 1954		May 2, 1952		May 29, 1939		Oct. 27, 1955		Oct. 23, 1956		July 3, 1940		Dec. 9, 1955	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	11	----	14	----	12	----	8.7	----	20	----	6.9	----	14	----	56	----	58	----
Al	.2	----	.0	----	.0	----	----	----	----	----	.0	----	.2	----	----	----	.1	----
Fe	.50	----	1.3	----	.62	----	.37	----	.58	----	.72	----	.71	----	----	----	.05	----
Mn	.00	----	.00	----	.02	----	.05	----	.34	----	.07	----	.00	----	----	----	.00	----
Cu	.00	----	.00	----	.00	----	----	----	----	----	.00	----	.00	----	----	----	----	----
Zn	----	----	.00	----	----	----	----	----	----	----	----	----	.00	----	----	----	----	----
Ca	.8	0.04	44	2.20	74	3.69	60	2.99	78	3.89	157	7.83	153	7.63	74	3.69	65	3.24
Mg	.9	.07	11	.90	20	1.64	31	2.55	51	4.19	21	1.73	63	5.18	87	7.15	6.8	.56
Sr	----	----	----	----	----	----	52	1.19	----	----	20	.46	----	----	----	----	----	----
Na	144	6.26	60	2.61	34	1.48	12	.52	26	1.13	14	.61	24	1.04	81	3.52	374	16.27
K	.8	.02	4.1	.10	1.2	.03	4.0	.10	3.4	.09	4.6	.12	3.8	.10			20	.51
Total cations	----	6.39	----	5.81	----	6.84	----	7.35	----	9.30	----	10.75	----	13.95	----	14.36	----	20.58
HCO_3	217	3.56	327	5.36	381	6.24	285	4.67	490	8.03	241	3.95	330	5.41	774	12.68	378	6.20
CO_3	33	1.10	0	----	0	----	0	----	0	----	0	----	0	----	----	----	0	----
SO_4	64	1.33	22	.46	26	.54	111	2.31	60	1.25	330	6.87	362	7.54	12	.25	85	1.77
Cl	16	.45	4.4	.12	2.7	.08	12	.34	1.5	.04	8.0	.23	30	.85	32	.90	442	12.46
F	.3	.02	.2	.01	.2	.01	.5	.03	.2	.01	1.9	.10	1.1	.06	.2	.01	.8	.04
NO_3	.5	.01	2.0	.03	1.0	.02	.8	.01	2.4	.04	.3	.00	.1	.00	32	.52	5.2	.08
PO_4	----	----	0	----	0	----	----	----	----	----	.0	----	----	----	----	----	.1	----
Total anions	----	6.47	----	5.98	----	6.89	----	7.36	----	9.37	----	11.15	----	13.86	----	14.36	----	20.55
Total, as reported	489	----	490	----	553	----	577	----	733	----	806	----	982	----	1,150	----	1,440	----
Specific conductance micromhos at 25° C	630		533		609		658		802		963		1,190		----		2,130	
pH	9.2		7.4		8.2		7.6		8.0		7.3		7.6		----		7.6	
Temperature ° C	14.4		10.6		10.0		----		11.1		11.1		11.1		7.6		26.4	
Beta-gamma activity μμc per l	72		<20		<25		----		----		<25		<50		----		<68	
Ra μμc per l	<0.1		0.6		0.1		----		----		2.7		1.2		----		0.2	
U μg per l	6.9		0.7		5.0		----		----		0.5		2.1		----		15	
Ratios by weight:																		
Ca/Na	0.006		0.7		2.2		5.0		3.0		11		6.4		0.9		0.2	
Mg/Ca	1.1		.2		.3		.5		.7		.1		.4		1.2		.1	
K/Na	.006		.07		.04		.3		.1		.3		.2		----		.05	
HCO_3/Cl	14		74		141		24		327		30		11		141		.9	
SO_4/Cl	4.0		5.0		9.6		9.3		40		41		12		.4		.2	
F/Cl	.02		.05		.07		.04		.1		.2		.04		.006		.002	

EXPLANATION FOR TABLE 4

1. Drilled well, 240 ft deep, Collins, Covington County, Miss. In Catahoula Sandstone of Miocene(?) age. Unpublished data in U.S. Geol. Survey files; analyst, E. Zitnik.
2. Drilled well, 180 ft deep, 3 miles east of Monument, SW¼ sec. 9, T. 11 S., R. 66 W., El Paso County, Colo. In Dawson Arkose of Tertiary age. Unpublished data in U.S. Geol. Survey files; analyst, E. Zitnik.
3. Drilled well, 188 ft deep, Dawson Springs, Hopkins County, Ky. In Caseyville Sandstone of Pennsylvanian age. Unpublished data in U.S. Geol. Survey files; analysts, J. A. Shaughnessy and J. E. Whitney.
4. Drilled well, 602 ft deep, 1 mile east of Manchester, Hartford County, Conn. In sandstone of Triassic age. Unpublished data in U.S. Geol. Survey files; analysts, J. A. Shaughnessy and J. E. Whitney.
5. Spring, 1 mile east of Melbourne, SE¼ sec. 1, T. 16 N., R. 9 W., Izard County, Ark. From St. Peter Sandstone of Ordovician age. Unpublished data in U.S. Geol. Survey files; analysts, R. A. Wilson, J. D. Weeks, and J. O. Johnson.
6. Drilled well, 300 ft deep, near Worthington, Armstrong County, Pa. In Homewood Sandstone of Pennsylvanian age. Unpublished data in U.S. Geol. Survey files; analysts, J. E. Whitney and J. A. Shaughnessy.
7. Well at Monzi, Zululand, Union of South Africa. In Cretaceous sandstone (Bond, 1946); analyst, G. W. Bond.
8. Drilled well, 180 ft deep, 25 miles southwest of Crawford, NW¼ sec. 19, T. 29 N., R. 53 E., Sioux County, Nebr. In Arikaree Sandstone of Miocene age. Unpublished data in U.S. Geol. Survey files; analysts, J. D. Honerkamp, J. D. Weeks, and J. O. Johnson.
9. Drilled well, 592 ft deep, 6 miles east of Mexican Water, Apache County, Ariz. In Navajo Sandstone of Jurassic age. Unpublished data in U.S. Geol. Survey files; analysts, J. E. Whitney and J. A. Shaughnessy.
10. Drilled well, 122 ft deep, 0.3 mile northeast of Jamestown, Crawford County, Pa. In Pocono Sandstone of Mississippian age. Unpublished data in U.S. Geol. Survey files; analysts, J. A. Shaughnessy and W. F. White.
11. Drilled well, 166 ft deep, 1.2 miles northeast of Sand Lake, Rensselaer County, N.Y. In Rensselaer Graywacke of Cambrian age. Unpublished data in U.S. Geol. Survey files; analysts, J. A. Shaughnessy and J. E. Whitney.
12. North Street well, 1,907 ft deep, Waukesha, Waukesha County, Wis. In St. Peter, Mt. Simon, and associated sandstones of Cambrian to Ordovician age (Lohr and Love, 1954a).
13. Well, 509 ft deep, Mound, Hennepin County, Minn. In Franconia Sandstone of Cambrian age (Prior, Schneider, and Durum, 1953).
14. Drilled well, 557 ft deep, Kaukauna, NW¼ sec. 25, T. 21 N., R. 18 E., Outagamie County, Wis. In sandstone of Cambrian age. Unpublished data in U.S. Geol. Survey files; analysts, B. V. Salotto and D. E. Weaver.
15. Drilled well, 100 ft deep, south-southeast of Carleton, NW¼ sec. 21, T. 5 S., R. 9 E., Monroe County, Mich. In Sylvania Sandstone of Devonian age. Unpublished data in U.S. Geol. Survey files; analyst, D. E. Weaver. See table 13, analysis 8, for deep saline water of Sylvania sandstone.
16. Drilled well, 140 ft deep, on Kalkheuvel 389, District of Pretoria, Transvaal, Union of South Africa. In Bushveld Sandstone (arkosic) of Triassic age (Bond, 1946, p. 141–142); analyst, G. W. Bond.
17. Drilled well, 416 ft deep, Kennedy, Karnes County, Tex. In Oakville Sandstone of Miocene age. Unpublished data in U.S. Geol. Survey files; analyst, R. A. Wilson.

TABLE 5.—*Chemical analyses of ground waters from siltstone, clay, and shale*

Analysis	1		2		3		4		5		6		7		8		9	
Rock type and location	Hattiesburg Clay, Prentiss, Miss.		Ohio Shale, Park Lake, Ky.		Brunswick Shale, Wyckoff, N.J.		Tuffaceous clay, near Sheaville, Oreg.		Chicopee Shale, Chicopee, Mass.		Shale, Transvaal, Union of South Africa		Clay, Georgetown, S.C.		Brule Siltstone, Harrisburg, Nebr.		Ecca Shale, Cape Province, Union of South Africa	
Date of collection	Dec. 19, 1955		Jan. 5, 1955		Feb. 27, 1957		June 28, 1956		Dec. 8, 1954		May 8, 1941		Jan. 10, 1947		Nov. 9, 1955		Nov. 7, 1941	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	12	------	22	------	16	------	43	------	15	------	40	------	12	------	64	------	32	------
Al	.2	------	1.5	------	.0	------	.0	------	.0	------	------	------	------	------	.4	------	------	------
Fe	.00	------	.39	------	.02	------	.00	------	1.0	------	------	------	.92	------	.00	------	------	------
Mn	.00	------	.22	------	.00	------	.00	------	.08	------	------	------	------	------	.00	------	------	------
Cu	------	------	.05	------	.00	------	------	------	.00	------	------	------	------	------	------	------	------	------
Zn	------	------	.36	------	.00	------	------	------	.03	------	------	------	------	------	------	------	------	------
Ca	1.2	0.06	15	0.75	29	1.45	29	1.45	96	4.79	32	1.60	1.6	0.08	44	2.20	62	3.09
Mg	.5	.04	7.5	.62	16	1.32	11	.90	19	1.56	46	3.78	.7	.06	9.2	.76	64	5.26
Na	2.1	.09	36	1.56	12	.52	31	1.35	18	.78	34	1.48	210	9.13	129	5.61	92	4.05
K	.8	.02	3.5	.09	1.1	.03	8.0	.20	1.5	.04					10	.26		
Total cations	------	0.21	------	3.02	------	3.32	------	3.90	------	7.17	------	6.86	------	9.27	------	8.83	------	12.40
HCO_3	8.0	0.13	3.2	0.05	126	2.06	173	2.84	133	2.18	366	6.00	447	7.33	346	5.67	362	5.93
CO_3	0	------	0	------	0	------	7	.23	0	------	0	------	32	1.07	0	------	0	------
SO_4	.5	.01	128	2.66	22	.46	33	.69	208	4.33	4	.08	1.5	.03	76	1.58	106	2.21
Cl	2.0	.06	21	.59	12	.34	6.0	.17	25	.70	28	.79	28	.79	42	1.18	140	3.95
F	.0	.00	.2	.01	.2	.01	.7	.04	.4	.02	0	------	.9	.05	.1	.01	.6	.03
NO_3	2.2	.04	.5	.01	26	.42	.0	------	.4	.01	0	------	.0	.00	16	.26	16	.26
PO_4	.0	------	.0	------	.0	------	.0	------	.0	------	------	------	------	------	.2	------	------	------
Total anions	------	0.24	------	3.32	------	3.29	------	3.97	------	7.24	------	6.87	------	9.27	------	8.70	------	12.38
Total, as reported	30	------	239	------	260	------	342	------	517	------	550	------	735	------	737	------	875	------
Specific conductance micromhos at 25°C	26		373		340		365		690		------		------		839		------	
pH	6.1		4.9		7.9		8.5		7.8		7.8		8.6		7.7		7.6	
Temperature °C	19.4		10.0		10.6		16.7		12.5		------		20		11.1		------	
Beta-gamma activity μμc per l	<5		16		<10		16		<25		------		------		<23		------	
Ra μμc per l	0.1		2.1		<0.1		<0.1		0.7		------		------		0.1		------	
U μg per l	<0.1		18		1.4		0.1		1.5		------		------		16		------	
Ratios by weight:																		
Ca/Na	0.6		0.4		2.4		0.9		5.3		0.9		0.008		0.3		0.7	
Mg/Ca	.4		.5		.6		.4		.2		1.4		.4		.2		1.0	
K/Na	.4		.1		.09		.3		.08		------		------		.08		------	
HCO_3/Cl	4.0		.2		10		29		5.3		13		16		8.2		2.6	
SO_4/Cl	.2		6.1		1.8		5.5		8.3		.1		.05		1.8		.8	
F/Cl	.0		.01		.02		.1		.02		.0		.03		.002		.004	

Analysis	10		11		12		13		14		15		16		17		18	
Rock type and location	Willard Shale, Lyon County, Kans.		Camillus and Vernon Shales, Syracuse, N.Y.		Shale, Cuyahoga County, Ohio		Benton Shale, La Prele, Wyo.		Shale, Pekin, N.C.		Eutaw Clay, Linden, Ala.		Pierre Shale, Langdon, N. Dak.		Precambrian shale, Cape Province, Union of South Africa		Jackson Shale, Monticello, Ark.	
Date of collection	Sept. 11, 1951		May 3, 1956		Jan. 15, 1952		Aug. 16, 1950		Feb. 28, 1955		Mar. 17, 1952		Oct. 27, 1954		Mar. 19, 1940		Dec. 13, 1955	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	11	------	5.5	------	19	------	13	------	17	------	13	------	26	------	50	------	98	------
Al	------	------	.0	------	------	------	------	------	.1	------	3.6	------	2.2	------	------	------	28	2.33
Fe	.21	------	3.5	------	1.3	------	4.1	------	8.2	------	.16	------	3.5	------	------	------	.88	------
Mn	------	------	.13	------	.00	------	------	------	.07	------	------	------	21	------	------	------	9.6	.34
Cu	------	------	.02	------	------	------	------	------	.12	------	------	------	------	------	------	------	------	------
Zn	------	------	.00	------	------	------	------	------	.05	------	------	------	------	------	------	------	------	------
Ca	95	4.74	227	11.33	123	6.13	8.5	0.42	48	2.40	6.1	0.30	416	20.76	331	16.52	424	21.16
Mg	43	3.54	29	2.38	70	5.76	.4	.03	29	2.38	2.1	.17	143	11.76	237	19.49	194	15.95
Na	109	4.74	12	.52	61	2.65	310	13.48	447	19.44	624	27.13	362	15.74	698	30.36	416	18.10
K			2.7	.07	2.2	.06	5.0	.13	8.4	.21	5.7	.15	14	.36			11	.28
Total cations	------	13.02	------	14.30	------	14.60	------	14.06	------	24.43	------	27.75	------	48.62	------	66.37	------	58.16
HCO_3	344	5.64	288	4.72	539	8.83	580	9.51	579	9.49	642	10.52	104	1.70	914	14.98	0	------
CO_3	0	------	0	------	0	------	12	.40	0	------	0	------	0	------	0	------	0	------
SO_4	120	2.50	439	9.14	283	5.89	2.0	.04	1.5	.03	1.6	.03	2,170	45.18	152	3.16	2,420	50.38
Cl	36	1.02	24	.68	3.5	.10	142	4.00	536	15.12	592	16.70	38	1.07	1,710	48.22	380	10.72
F	.2	.01	.0	.00	.4	.02	1.0	.05	1.2	.06	2.8	.15	.2	.01	0	------	1.8	.09
NO_3	239	3.86	.9	.01	.1	.00	2.6	.04	.2	.00	1.5	.02	.1	.00	0	------	3.1	.05
PO_4	------	------	.0	------	------	------	------	------	------	------	------	------	------	------	------	------	.0	------
Total anions	------	13.03	------	14.55	------	14.84	------	14.04	------	24.70	------	27.42	------	47.96	------	66.36	------	61.24
Total, as reported	997	------	1,030	------	1,100	------	1,080	------	1,680	------	1,890	------	3,300	------	4,090	------	3,990	------
Specific conductance micromhos at 25° C	------		1,210		1,180		1,340		2,410		2,710		3,560		------		4,570	
pH	------		7.6		7.3		8.2		8.1		7.7		6.3		7.5		4.0	
Temperature °C	------		11.1		11.1		10.6		17.8		26.7		6.1		------		------	
Beta-gamma activity μμc per l	------		<50		------		------		<100		------		<110		------		<140	
Ra μμc per l	------		<0.1		------		------		0.6		------		<0.1		------		1.7	
U μg per l	------		2.1		------		------		24		------		0.3		------		17	
Ratios by weight:																		
Ca/Na	0.9		19		2.0		0.03		0.1		0.01		1.1		0.5		1.0	
Mg/Ca	.5		.1		.6		.05		.6		.3		.3		.7		.5	
K/Na	------		.2		.6		.02		.02		.3		.04		------		.03	
HCO_3/Cl	9.6		12		154		4.1		1.1		1.1		2.7		.5		0	
SO_4/Cl	3.3		18		81		.01		.003		.003		57		.09		6.4	
F/Cl	.006		.0		.1		.007		.002		.005		.005		.0		.005	

EXPLANATION FOR TABLE 5

1. Drilled well, 148 ft deep, Prentiss, Jefferson Davis County, Miss. In clay of Hattiesburg Formation of Miocene age. Unpublished data in U.S. Geol. Survey files; analyst, E. Zitnik.
2. Spring, Park Lake, Fleming County, Ky. From Ohio Shale of Devonian age. Unpublished data in U.S. Geol. Survey files; analysts, J. A. Shaughnessy and J. E. Whitney.
3. Drilled well, 300 ft deep, Wyckoff, Bergen County, N.J. In Brunswick Shale of Triassic age. Unpublished data in U.S. Geol. Survey files; analyst, D. E. Weaver.
4. Spring, one-quarter mile southeast of Sheaville, sec. 24, T. 28 S., R. 46 E., Malheur County, Oreg. From tuffaceous clay of Miocene age. Unpublished data in U.S. Geol. Survey files; analyst, R. A. Wilson.
5. Well, 110 ft deep, Chicopee, Hampden County, Mass. In Chicopee Shale of Late Triassic age. Unpublished data in U.S. Geol. Survey files; analysts, J. E. Whitney and J. A. Shaughnessy.
6. Borehole Donkerhoek 178, Transvaal, Union of South Africa. In slightly metamorphosed shale of Transvaal System of Precambrian age (Bond, 1946); analyst, G. W. Bond.
7. Drilled well, 720 ft deep, Georgetown, Georgetown County, S.C. In clay of Black Creek Formation of Cretaceous age. Unpublished data in U.S. Geol. Survey files; analyst, F. H. Pauszek.
8. Drilled well, 80 ft deep, Harrisburg, SE¼ sec. 2, T. 18 N., R. 56 W., Banner County, Nebr. In Brule Siltstone of Oligocene age. Unpublished data in U.S. Geol. Survey files; analyst, E. Zitnik.
9. Drilled well at Brittstown, Cape Province, Union of South Africa. In shale of Ecca Series of Permian age (Bond, 1946); analyst, G. W. Bond.
10. Dug well, 38 ft deep, SE¼SE¼ sec. 28, T. 21 S., R. 11 E., Lyon County, Kans. In Willard and Dry Shales of Pennsylvanian age (O'Connor, 1953).
11. Drilled well, 300 ft deep, Syracuse, Onondaga County, N.Y. In Camillus and Vernon Shales of Silurian age. Unpublished data in U.S. Geol. Survey files; analyst, B. V. Salotto.
12. Drilled well, 72 ft deep, Strongsville Township, Cuyahoga County, Ohio. In shale of Mississippian age. Unpublished data in U.S. Geol. Survey files.
13. Drilled well 32-73-8 DAB, 725 ft deep, La Prele area, Converse County, Wyo. In Benton Shale of Cretaceous age (Rapp, 1953). Also reported; B, 1.6 ppm.
14. Drilled well, 130 ft deep, one-half mile east of Pekin, Montgomery County, NC. In shale of Triassic age. Unpublished data in U.S. Geol. Survey files; analysts. J. E. Whitney and J. A. Shaughnessy.
15. Drilled well, 1107 ft deep, Linden, NE¼NW¼ sec. 6, T. 15 N., R. 2 E., Marengo County, Ala. In clay of Eutaw Formation of Cretaceous age. Unpublished data in U.S. Geol. Survey files; analyst, J. H. Hubble.
16. Dug well, 35 ft deep, Langdon, SE¼ sec. 14, T. 161 N., R. 60 W., Cavalier County, N. Dak. In Pierre Shale of Cretaceous age. Unpublished data in U.S. Geol. Survey files; analysts, J. D. Honerkamp, J. D. Weeks, and J. O. Johnson.
17. Drilled well, 80 ft deep, Ridgemore Farm, near Faure, Cape Province, Union of South Africa. In shale of Malmesbury Series of Precambrian age (Bond, 1946); analyst, G. W. Bond.
18. Well, 22 ft deep, 7 miles northeast of Monticello, NE¼ sec. 30, T. 11 S., R. 6 W., Drew County, Ark. In Jackson Clay of Eocene age. Unpublished data in U.S. Geol. Survey files; analyst, E. Zitnik.

TABLE 6.—*Chemical analyses of ground waters from limestone*

Analysis	1		2		3		4		5		6		7	
Source (formation or age) and location	Miocene limestone, Gainesville, Fla.		Warsaw Limestone, Tuscumbia, Ala.		Miocene limestone, Brooksville, Fla.		Bangor Limestone, Irondale, Ala.		Ocala Limestone, Lake City, Fla.		Meagher Limestone, Ennis, Mont.		Castle Hayne Limestone, New Bern, N.C.	
Date of collection	Apr. 16, 1946		Apr. 10, 1956		July 5, 1946		Sept. 3, 1952		Mar. 16, 1957		Sept. 10, 1956		Feb. 21, 1956	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	10	-------	7.7	-------	8.9	-------	10	-------	25	-------	11	-------	21	-------
Al	-------	-------	.0	-------	-------	-------	-------	-------	.1	-------	.2	-------	.0	-------
Fe	.04	-------	.23	-------	.05	-------	.14	-------	.17	-------	.00	-------	3.5	-------
Mn	-------	-------	.08	-------	-------	-------	-------	-------	.00	-------	.00	-------	.02	-------
Cu	-------	-------	.00	-------	-------	-------	-------	-------	.00	-------	-------	-------	-------	-------
Zn	-------	-------	.00	-------	-------	-------	-------	-------	.02	-------	-------	-------	-------	-------
Ca	15	0.75	43	2.15	48	2.40	58	2.89	39	1.95	53	2.64	76	3.79
Mg	6.7	.55	1.2	.10	5.8	.48	3.2	.26	15	1.23	19	1.56	1.3	.11
Na	3.2	.14	1.5	.06	4.0	.17	3.4	.15	7.5	.33	2.8	.12	5.0	.22
K	.6	.02	.7	.02	.7	.02	.6	.02	1.3	.03	1.6	.04	.7	.02
Total cations	-------	1.46	-------	2.33	-------	3.07	-------	3.32	-------	3.54	-------	4.36	-------	4.14
HCO_3	74	1.21	133	2.18	168	2.75	164	2.69	196	3.21	187	3.06	240	3.93
CO_3	0	-------	0	-------	0	-------	0	-------	0	-------	0	-------	0	-------
SO_4	2.6	.05	3.2	.07	6.4	.13	7.0	.15	1.8	.04	61	1.27	.2	.00
Cl	3.4	.10	2.2	.06	4.8	.14	7.5	.21	9.8	.28	2.2	.06	8.0	.23
F	.4	.02	.1	.01	.1	.01	.1	.01	.5	.03	.3	.02	.2	.01
NO_3	1.8	.03	5.9	.10	.0	.00	8.9	.14	.8	.01	1.4	.02	.2	.00
PO_4	-------	-------	.0	-------	-------	-------	-------	-------	.1	-------	.05	-------	.0	-------
Total anions	-------	1.41	-------	2.42	-------	3.03	-------	3.20	-------	3.57	-------	4.43	-------	4.17
Total, as reported	118	-------	199	-------	247	-------	263	-------	297	-------	340	-------	356	-------
Specific conductance micromhos at 25° C	143		224		287		301		327		409		393	
pH	7.0		7.3		7.7		7.5		8.0		7.8		7.1	
Temperature °C	22.2		16.1		23.9		17.8		22.2		12.2		16.7	
Beta-gamma activity $\mu\mu$c per l	-------		<10		-------		-------		14		-------		-------	
Ra $\mu\mu$c per l	-------		0.2		-------		-------		0.6		-------		-------	
U μg per l	-------		0.3		-------		-------		0.2		-------		-------	
Ratios by weight:														
Ca/Na	4.7		29		12		17		5.2		19		15	
Mg/Ca	.4		.03		.1		.06		.4		.4		.02	
K/Na	.2		.5		.2		.2		.2		.6		.1	
HCO_3/Cl	22		60		35		22		20		85		30	
SO_4/Cl	.8		1.5		1.3		.9		.2		28		.03	
F/Cl	.1		.05		.02		.01		.05		.1		.03	

Analysis	8		9		10		11		12		13		14	
Source (formation or age) and location	Edwards Limestone, Uvalde, Tex.		Laurel Limestone, Bardstown, Ky.		Bayport dolomitic Limestone, Grand Rapids, Mich.		Pahasapa Limestone, Rapid City, S. Dak.		Lebanon Limestone, Mt. Juliet, Tenn.		Conasauga Limestone, Birmingham, Ala.		San Andres Limestone, Roswell, N. Mex.	
Date of collection	Nov. 2, 1945		Jan. 4, 1955		Jan. 21, 1953		Aug. 20, 1954		Nov. 17, 1954		Oct. 3, 1952		May 14, 1954	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	11	-------	11	-------	8.4	-------	23	-------	9.2	-------	11	-------	12	-------
Al	-------	-------	.1	-------	-------	-------	.1	-------	.0	-------	-------	-------	.2	-------
Fe	.08	-------	.02	-------	.07	-------	.00	-------	.22	-------	1.4	-------	.01	-------
Mn	-------	-------	.00	-------	-------	-------	.00	-------	.33	-------	-------	-------	.01	-------
Cu	-------	-------	.00	-------	-------	-------	-------	-------	.00	-------	-------	-------	-------	-------
Zn	-------	-------	.00	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Ca	74	3.69	61	3.04	79	3.94	92	4.59	124	6.19	96	4.79	140	6.99
Mg	9.5	.78	34	2.80	28	2.30	37	3.04	28	2.30	37	3.04	41	3.37
Na	24	1.04	9.0	.39	8.1	.35	5.9	.26	14	.61	61	2.65	31	1.35
K	7.0	.18	1.1	.03	5.7	.15	4.9	.13	3.0	.08	1.2	.03	1.3	.03
Total cations	-------	5.69	-------	6.26	-------	6.74	-------	8.02	-------	9.18	-------	10.51	-------	11.74
HCO_3	277	4.54	291	4.77	267	4.38	207	3.39	460	7.54	291	4.77	236	3.87
CO_3	0	-------	0	-------	0	-------	0	-------	0	-------	0	-------	0	-------
SO_4	19	.40	20	.42	51	1.06	214	4.46	57	1.19	91	1.89	315	6.56
Cl	24	.68	11	.31	29	.82	1.8	.05	18	.51	112	3.16	42	1.18
F	.4	.02	.1	.01	.0	.00	.5	.03	.1	.01	.1	.01	.9	.05
NO_3	4.1	.07	44	.71	28	.45	.3	.00	5.0	.08	20	.32	3.8	.06
PO_4	-------	-------	0	-------	-------	-------	.0	-------	.0	-------	-------	-------	-------	-------
Total anions	-------	5.71	-------	6.22	-------	6.71	-------	7.93	-------	9.33	-------	10.15	-------	11.72
Total, as reported	450	-------	482	-------	504	-------	587	-------	720	-------	722	-------	823	-------
Specific conductance micromhos at 25° C	570		587		649		705		808		963		1,040	
pH	7.0		8.2		7.3		7.4		7.8		7.3		7.6	
Temperature °C	-------		14.4		-------		48.9		13.9		16.7		20.6	
Beta-gamma activity $\mu\mu$c per l	-------		<25		-------		17		<25		-------		<10	
Ra $\mu\mu$c per l	-------		0.1		-------		2.0		0.1		-------		0.1	
U μg per l	-------		0.7		-------		6.4		1.2		-------		1.0	
Ratios by weight:														
Ca/Na	3.1		6.8		9.8		16		8.9		1.6		4.5	
Mg/Ca	.1		.6		.4		.4		.2		.4		.3	
K/Na	.3		.1		.7		.8		.2		.02		.04	
HCO_3/Cl	12		26		9.2		115		26		2.6		5.6	
SO_4/Cl	.8		1.8		1.8		119		3.2		.8		7.5	
F/Cl	.02		.009		.0		.3		.006		.001		.02	

EXPLANATION FOR TABLE 6

1. Glen Springs, 2 miles northwest of Gainesville, Alachua County, Fla. Flows 150 gpm from limestone of Miocene age (Ferguson, Lingham, Love, and Vernon, 1947).
2. Artesian spring, Tuscumbia, NW¼ sec. 9, T. 4 S., R. 11 W., Colbert County, Ala. From Warsaw Limestone of Mississippian age. Unpublished data in U.S. Geol. Survey files; analyst, D. E. Weaver.
3. Weekiwachee spring, 12 miles southwest of Brooksville, Hernando County, Fla. Flows 71,000 gpm from limestone of Miocene age (Ferguson, Lingham, Love, and Vernon, 1947).
4. Drilled well, 210 ft deep, Irondale, Jefferson County, Ala. In Bangor Limestone of Mississippian age (Robinson, Ivey, and Billingsley, 1953).
5. Drilled well, 275 ft deep, 1792 Putnam St., Lake City, Columbia County, Fla. In Ocala Limestone of Eocene age. Unpublished data in U.S. Geol. Survey files; analyst, D. E. Weaver.
6. Spring, 9 miles south of Ennis, SW¼ sec. 13, T. 7 S., R. 2 W., Madison County, Mont. Flows 15,000 gpm from Meagher Limestone of Cambrian age. Unpublished data in U.S. Geol. Survey files; analyst, R. A. Wilson.
7. Drilled well, 126 ft deep. New Bern, Craven County, N.C. In Castle Hayne Limestone of Eocene age. Unpublished data in U.S. Geol. Survey files; analyst, S. H. Phillips.
8. Well, 350 ft deep, Uvalde, Uvalde County, Tex. In Edwards Limestone of Cretaceous age (Petit and George, 1956).
9. Spring, southwest border of Bardstown, Nelson County, Ky. Flows 15 gpm from Laurel Limestone of Silurian age (dolomitic in some areas). Unpublished data in U.S. Geol. Survey files; analysts, J. A. Shaughnessy and J. E. Whitney.
10. Drilled well, 57 ft deep, northeast of Grand Rapids, SE¼SE¼ sec. 1, T. 8 N., R. 12 W., Kent County, Mich. In Bayport Dolomitic Limestone of Mississippian age; water may be from sandstone lenses in this formation (Stramel, Wisler, and Laird, 1954).
11. Well, 4,645 ft deep, Rapid City, NW ¼ sec. 18, T. 2 N., R. 9 E., Pennington County, S. Dak. In Pahasapa Limestone of Mississippian age. Unpublished data in U.S. Geol. Survey files; analysts, J. D. Honerkamp, J. D. Weeks, and J. O. Johnson; also reported: B, 0.41 ppm.
12. Drilled well, 69 ft deep, Mount Juliet, Wilson County, Tenn. In Lebanon Limestone of Ordovician age. Unpublished data in U.S. Geol. Survey files; analysts, J. E. Whitney and J. A. Shaughnessy.
13. Drilled well, 310 ft deep, Birmingham, Jefferson County, Ala. In Conasauga Limestone of Cambrian age (Robinson, Ivey, and Billingsley, 1953).
14. Flowing well, 843 ft deep, 10 miles southeast of Roswell, SW¼ sec. 15, T. 11S., R. 25 E., Chaves County, N. Mex. Flows 2,000 gpm from San Andres Limestone of Permian age. Unpublished data in U.S. Geol. Survey files; analysts, R. A. Wilson, J. D. Weeks, and J. O. Johnson.

TABLE 7.—*Chemical analyses of ground waters from dolomite*

Analysis	1		2		3		4		5		6	
Formation location	Gasconade Dolomite, Alley, Mo.		Copper Ridge Dolomite, Center Point, Ala.		Niagara Dolomite, West Allis, Wis.		Precambrian dolomite near Irene, Pretoria, Transvaal, Union of South Africa		Peebles Dolomite, Bainbridge, Ohio		Guelph Dolomite, Fort Recovery, Ohio	
Date of collection	June 19, 1925		Oct. 1, 1952		Oct. 29, 1954		Oct. 2, 1939		May 13, 1955		Mar. 20, 1955	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	5.4		9.2		18		24		11		14	
Al					.2				.0		.2	
Fe	.17		.34		.39				.48		4.2	
Mn					.03				.13		.05	
Cu					.00				.00		.00	
Zn					.00						.00	
Ca	30	1.50	34	1.70	35	1.75	67	3.34	28	1.40	178	8.88
Mg	18	1.48	14	1.15	33	2.71	39	3.21	72	5.92	86	7.07
Na	4.6	.20	2.0	.09	28	1.22	8.0	.35	3.5	.15	76	3.30
K			.6	.02	1.3	.03			1.7	.04	3.5	.09
Total cations		3.18		2.96		5.71		6.90		7.51		19.34
HCO_3	160	2.62	160	2.62	241	3.95	390	6.39	398	6.52	285	4.67
CO_3	4	.13	0		0		0		0		0	
SO_4	1.4	.03	3.7	.08	88	1.83	1.0	.02	28	.58	707	14.72
Cl	5.0	.14	2.5	.07	1.0	.03	17	.48	5.0	.14	11	.31
F			.1	.01	.9	.05	.0	.00	.1	.01	1.7	.09
NO_3	.9	.02	3.2	.05	1.2	.02	.4	.01	31	.50	1.1	.02
PO_4					0				.0			
Total anions		2.94		2.83		5.88		6.90		7.75		19.81
Total, as reported	229		230		448		546		579		1,370	
Specific conductance ..micromhos at 25 °C			259		511				663		1,510	
pH			7.5		8.2		7.9		7.6		7.4	
Temperature °C			16.7		10.3				13.3		15.0	
Beta-gamma activity ..μμc per l					<25				<25		<50	
Ra ..μμc per l					0.1				0.2		0.6	
U ..μg per l					<0.1				0.8		2.0	
Ratios by weight:												
Ca/Na	6.5		17		1.2		8.4		8.0		2.3	
Mg/Ca	.6		.4		.9		.6		2.6		.5	
K/Na			.3		.04				.5		.05	
HCO_3/Cl	32		64		241		23		80		26	
SO_4/Cl	.3		1.5		88		.06		5.6		64	
F/Cl			.04		.9		.0		.02		.15	

EXPLANATION FOR TABLE 7

1. Alley Spring, Alley Spring State Park, sec. 25, T. 29, N., R. 5 W., Shannon County, Mo. Flows 16,600 gpm from Gasconade Dolomite of Ordovician age (Beckman and Hinchey, 1944).
2. Harvey Spring, 1½ miles southeast of Center Point, Jefferson County, Ala. From Cooper Ridge Dolomite of Cambrian age (Robinson, Ivey, and Billingsley, 1953).
3. Drilled well, 500 ft deep, 2 miles west of West Allis, sec. 6, T. 6 N., R. 21 E., Milwaukee County, Wis. In Niagara Dolomite of Silurian age. Unpublished data in U.S. Geol. Survey files; analysts, J. E. Whitney and J. A. Shaughnessy.
4. Drilled well, 100 ft deep, 1 mile south of Irene, on main road to Johannesburg, District of Pretoria, Transvaal, Union of South Africa. In dolomite of Precambrain age (Bond, 1946); analyst, G. W. Bond.
5. Drilled well, 95 ft deep, 3.3 miles west of Bainbridge, Ross County, Ohio (on U.S. Highway 50). In Peebles Dolomite of Silurian age. Unpublished data in U.S. Geol. Survey files; analysts, J. E. Whitney and J. A. Shaughnessy.
6. Drilled well, 208 ft deep, Fort Recovery, Mercer County, Ohio. In Guelph Dolomite of Silurian age. Unpublished data in U.S. Geol. Survey files; analysts J. E. Whitney and J. A. Shaughnessy.

TABLE 8.—*Chemical analyses of ground waters from miscellaneous sedimentary rocks*

Analysis	1		2		3		4		5	
Rock type and location	Biwabik Iron Formation, Grand Rapids, Minn.		Big Fork Chert, Hot Springs, Ark.		Phosphoria Phosphate, Garrison, Mont.		Lignite, Fort Union Formation Belfield, N. Dak.		Gypsum, Castile Formation, W. of Red Bluff, N. Mex.	
Date of collection	Sept. 22, 1954		May 28, 1956		Apr. 2, 1957		Mar. 9, 1957		Nov. 25, 1949	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	14	--------	26	--------	8.6	--------	11	--------	29	--------
Al	.0	--------	.9	--------	.1	--------	.1	--------	--------	--------
Fe	.65	--------	.95	--------	1.3	--------	.90	--------	--------	--------
Mn	.00	--------	.18	--------	.00	--------	.09	--------	--------	--------
Ca	54	2.70	26	1.30	36	1.80	74	3.69	636	31.74
Mg	19	1.56	1.9	.16	14	1.15	53	4.36	43	3.54
Na	7.5	.33	7.4	32	2.3	.10	624	27.14	17	.74
K	5.8	.15	2.8	.07	1.8	.05	5.4	.14		
Total cations	--------	4.74	--------	1.85	--------	3.10	--------	35.33	--------	36.02
HCO_3	271	4.44	68	1.11	131	2.15	702	11.51	143	2.34
CO_3	0	--------	0	--------	0	--------	0	--------	0	--------
SO_4	6.1	.13	34	.71	40	.83	1,080	22.49	1,570	32.69
Cl	.5	.01	2.2	.06	2.0	.06	25	.70	24	.68
F	.1	.01	.1	.01	.9	.05	.3	.02	--------	--------
NO_3	1.2	.02	.1	.00	.8	.01	.0	--------	18	.29
PO_4	.0	--------	.0	--------	.45	--------	.15	--------	--------	--------
Total anions	--------	4.61	--------	1.89	--------	3.10	--------	34.72	--------	36.00
Total, as reported	380	--------	171	--------	239	--------	2,580	--------	2,480	--------

Analysis	1	2	3	4	5
Specific conductance...micromhos at 25° C	413	199	294	3,060	2,510
pH	7.8	6.5	7.4	7.1	--------
Temperature °C	7.8	28.9	12.8	5.0	--------
Beta-gamma activity μμc per l	<14	<7	<8	<85	--------
Ra μμc per l	2.6	0.8	2.1	0.2	--------
U μg per l	0.2	--------	2.7	1.0	--------
Ratios by weight:					
Ca/Na	7.2	3.5	16	0.1	37
Mg/Ca	3.5	.07	.4	.7	.07
K/Na	.8	.4	.8	.009	--------
HCO_3/Cl	500	31	66	28	6.0
SO_4/Cl	12	15	20	43	65
F/Cl	.2	.05	.4	.01	--------

EXPLANATION FOR TABLE 8

1. Drilled well, 573 ft deep, Grand Rapids, Itasca County, Minn. In Biwabik Iron Formation of Precambrian age, consisting of ferruginous sediments, largely unmetamorphosed in this area. Unpublished data in U.S. Geol. Survey files; analysts, R. A. Wilson, J. D. Weeks, and J. O. Johnson.
2. Drilled well, 200 ft deep, east of city of Hot Springs, SW¼ sec. 33, T. 2 S., R. 19 W., Garland County, Ark. In Big Fork Chert of Ordovician age. Unpublished data in U.S. Geol. Survey files; analyst, B. P. Robinson.
3. Drainage water from 1,000-ft level, Anderson phosphate mine, Garrison, sec. 10, T. 10 N. R. 10 W., Powell County, Mont. From Phosphoria Formation of Permian age. Unpublished data in U.S. Geol. Survey files; analyst, J. O. Johnson.
4. Drilled well, 85 ft deep, Belfield, sec. 4, T. 139 N., R. 99 W., Stark County, N. Dak. In lignitic coal of Fort Union Formation of Teriary age. Unpublished data in U.S. Geol. Survey files; analyst, Darwin Golden.
5. Jumping Springs, sec. 17, T. 26 S., R. 26 E., 15 miles west of Red Bluff, Eddy County, N. Mex. Flows 5 gpm from gypsum of Castile Formation of Permian age (Hendrickson and Jones, 1952). See table 27 for analyses of saline waters from associated evaporite deposits.

TABLE 9.—*Chemical analyses of ground waters from quartzite and marble*

Analysis	1		2		3		4		5		6		7	
Rock type and location	Mutual Quartzite, Kamas, Utah		Pretoria Quartzite, Transvaal, Union of South Africa		Quartzite, Bucks County, Pa.		Quartzite, Cliffs Shaft Mine, Mich.		Sioux Quartzite, Sioux Falls, S. Dak.		Sylacauga Marble, Sylacauga, Ala.		Cockeysville Marble, Baltimore County, Md.	
Date of collection	Oct. 20, 1954		Nov. 27, 1940		Sept. 7, 1953		Jan. 28, 1952		Aug. 28, 1954		Apr. 27, 1955		May 5, 1953	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	3.6	-------	8.0	-------	17	-------	7.6	-------	15	-------	9.9	-------	17	-------
Al	.0	-------	-------	-------	-------	-------	.0	-------	.2	-------	.0	-------	.3	-------
Fe	.00	-------	-------	-------	1.6	-------	.21	-------	.91	-------	.03	-------	.16	-------
Mn	.00	-------	-------	-------	-------	-------	.20	-------	1.6	-------	.04	-------	.01	-------
Cu	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	.00	-------	.05	-------
Ca	2.6	0.13	1.6	0.08	25	1.25	32	1.60	102	5.09	39	1.95	64	3.19
Mg	.4	.03	5.8	.48	5.1	.42	16	1.32	35	2.88	10	.82	9.4	.77
Sr	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Na	1.0	.04	2.8	.12	4.5	.20	8.5	.37	12	.52	2.7	.12	3.4	.15
K	1.8	.05			3.8	.10	3.1	.08	4.6	.12	.3	.01	2.0	.05
Total cations	-------	0.25	-------	0.68	-------	1.97	-------	3.37	-------	8.61	-------	2.90	-------	4.16
HCO_3	8	0.13	18	0.30	80	1.31	144	2.36	346	5.67	162	2.66	223	3.66
CO_3	0	-------	0	-------	0	-------	0	-------	0	-------	0	-------	0	-------
SO_4	3.4	.07	2.0	.04	13	.27	39	.81	130	2.71	2.4	.05	19	.40
Cl	.8	.02	9.9	.28	8.0	.23	8.0	.23	3.0	.08	3.8	.11	5.6	.16
F	.1	.01	.0	-------	.4	.02	.2	.01	.5	.03	.0	.00	.1	.01
NO_3	1.2	.02	4.0	.06	.3	.01	2.7	.04	.4	.01	5.8	.09	.6	.01
PO_4	.1	-------	-------	-------	-------	-------	.0	-------	.0	-------	.0	-------	.0	-------
B	-------	-------	-------	-------	-------	-------	.2	-------	.4	-------	-------	-------	-------	-------
Total anions	-------	0.25	-------	0.68	-------	1.84	-------	3.45	-------	8.50	-------	2.91	-------	4.24
Total, as reported	23	-------	52	-------	159	-------	262	-------	652	-------	236	-------	345	-------

	1	2	3	4	5	6	7
Specific conductance micromhos at 25° C	36	-------	206	323	742	260	394
pH	6.5	6.5	7.1	7.9	7.4	7.9	7.6
Temperature °C	7.2	-------	11.7	7.2	11.7	19.4	-------
Beta-gamma activity μμc per l	<5	-------	-------	-------	<17	<10	-------
Ra μμc per l	0.1	-------	-------	-------	2.2	<0.1	-------
U μg per l	<0.1	-------	-------	-------	8.1	<0.1	-------
Ratios by weight:							
Ca/Na	2.6	0.6	5.6	3.8	8.5	14	19
Mg/Ca	.2	3.6	.2	.5	.3	.3	.1
K/Na	1.8	-------	.8	.4	.4	.1	.6
HCO_3/Cl	10	1.8	10	18	115	43	40
SO_4/Cl	4.3	.2	1.6	4.9	43	.7	3.4
F/Cl	.1	.0	.05	.02	.2	.0	.02

EXPLANATION FOR TABLE 9

1. Spring, Mirror Lake, SW¼ sec. 26, T. 1 S., R. 9 E., Duchesne County, near Kamas, Utah. Flows 20 gpm from Mutual Quartzite of Precambrian age. Unpublished data in U.S. Geol. Survey files; analysts, R. A. Wilson and J. D. Weeks.
2. Drilled well, 50 ft deep, on Onbekend 226, northeast of Benoni, Transvaal, Union of South Africa. In quartzite in Pretoria Series of Precambrian age (Bond, 1946); analyst, G. W. Bond.
3. Drilled well, 504 ft deep, Bucks County, Pa. In quartzite of Cambrian age (Greenman, 1955.)
4. Drip from roof of 6th-level raise, Cliffs Shaft iron mine, Marquette mining district, Mich. In quartzite of Precambrian age (Stuart, Brown, and Rhodehamel, 1954). See table 24, analyses 2 and 3 for analyses of saline waters found at depth in Michigan copper and iron mines.
5. Well, 172 ft deep, Sioux Falls, SW¼ sec. 13, T. 101 N., R. 50 W., Minnehaha County, S. Dak. In Sioux Quartzite of Precambrian age. Unpublished data in U.S. Geol. Survey files; analysts, J. D. Honerkamp, J. D. Weeks, and J. O. Johnson.
6. Drilled well, 179 ft deep, Sylacauga, NE¼ sec. 32, T. 21 S., R. 4 E., Talledega County, Ala. In Sylacauga Marble of Paleozoic or Precambrian age. Unpublished data in U.S. Geol. Survey files; analysts, J. E. Whitney and J. A. Shaughnessy.
7. Drilled well, 95 ft deep, Baltimore County, Md. In Cockeysville Marble of Precambrian age (Dingman, Ferguson, and Martin, 1956).

TABLE 10.—*Chemical analyses of ground waters from slate, schist, gneiss, and miscellaneous metamorphic rocks*

Analysis	1		2		3		4		5		6		7		8	
Rock type and location	Siamo Slate, Morris Mine, Mich.		Wissahickon Schist, Arcadia, Md.		Mica Schist, Wilkesboro, N.C.		Wissahickon Schist, Bucks County, Pa.		Brevard Schist, Suwanee, Ga.		Quartzitic Schist, Vassalboro, Maine		Schist and Slate, Tonasket, Wash.		Baltimore Gneiss, Bucks County, Pa.	
Date of collection	Mar. 25, 1952		May 12, 1954		Mar. 17, 1955		Apr. 28, 1953		Jan. 8, 1957		Mar. 27, 1957		Oct. 25, 1954		Apr. 30, 1953	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	8.2	--------	14	--------	26	--------	12	--------	21	--------	13	--------	18	--------	17	--------
Al	.0	--------	.0	--------	--------	--------	--------	--------	.0	--------	.0	--------	.1	--------	--------	--------
Fe	.12	--------	.16	--------	2.6	--------	.04	--------	.11	--------	.09	--------	.00	--------	.10	--------
Mn	.50	--------	.02	--------	.00	--------	--------	--------	.02	--------	.00	--------	.00	--------	--------	--------
Cu	--------	--------	.00	--------	--------	--------	--------	--------	.00	--------	.00	--------	--------	--------	--------	--------
Zn	--------	--------	[1] .18	--------	--------	--------	--------	--------	.02	--------	--------	--------	--------	--------	--------	--------
Ca	101	5.04	3.1	0.16	10	0.50	22	1.10	27	1.35	29	1.45	82	4.09	7.4	0.37
Mg	5.6	.46	1.2	.10	1.6	.13	9.1	.75	5.7	.47	9.7	.80	9.0	.74	5.0	.41
Na	13	.57	3.3	.14	5.5	.24	21	.91	16	.70	35	1.52	9.1	.40	4.7	.20
K	10	.26	.8	.02	1.0	.03	4.4	.11	.7	.02	3.6	.09	2.8	.07	2.0	.05
Total cations	--------	--------	--------	0.42	--------	0.90	--------	2.87	--------	2.54	--------	3.86	--------	5.30	--------	1.03
HCO_3	212	3.47	21	0.34	45	0.74	26	0.42	138	2.26	183	3.00	234	3.83	23	0.38
CO_3	0	--------	0	--------	0	--------	0	--------	0	--------	0	--------	0	--------	0	--------
SO_4	128	2.66	1.2	.02	3.0	.06	48	1.00	9.6	.20	28	.58	63	1.31	11	.23
Cl	5.2	.15	2.4	.07	2.5	.07	34	.96	2.5	.07	7.9	.22	1.5	.04	11	.31
F	.5	.03	.0	.00	.1	.01	.1	.01	.5	.03	1.1	.06	.1	.01	.1	.01
NO_3	.0	--------	.4	.01	1.4	.02	30	.48	.0	.00	.0	--------	1.2	.02	7.4	.12
PO_4	.0	--------	.1	--------	--------	--------	--------	--------	.0	--------	.0	--------	--------	--------	--------	--------
Total anions	--------	6.31	--------	0.44	--------	0.90	--------	2.87	--------	2.56	--------	3.86	--------	5.21	--------	1.05
Total, as reported	[2] 489	--------	48	--------	99	--------	207	--------	221	--------	310	--------	421	--------	89	--------
Specific conductance micromhos at 25°C	574		41		92		384		237		344		481		120	
pH	7.4		6.3		6.9		5.2		8.0		8.0		7.7		7.2	
Temperature °C	7.2		--------		--------		12.2		18.3		10.6		11.7		12.2	
Beta-gamma activity μμc per l	--------		--------		--------		--------		<10		<5		<14		--------	
Ra μμc per l	--------		--------		--------		--------		0.2		0.1		0.1		--------	
U μg per l	--------		--------		--------		--------		0.3		<0.1		1.4		--------	
Ratios by weight:																
Ca/Na	7.8		0.9		1.8		1.0		1.7		0.8		9.0		1.6	
Mg/Ca	.06		.4		.3		.4		.4		.3		.1		1.1	
K/Na	.8		.2		.2		.2		.04		.1		.3		--------	
HCO_3/Cl	41		8.8		18		.8		55		23		156		2.1	
SO_4/Cl	25		.5		1.2		1.4		3.8		3.5		42		1	
F/Cl	.1		.0		.04		.002		.2		.1		.07		.009	

Analysis	9		10		11		12		13		14		15	
Rock type and location	Willimantic Gneiss, Willimantic, Conn.		Grenville Gneiss, Bloomingdale, N.Y.		Port Deposit Gneiss, Baltimore County, Md.		Hornblende gneiss, Paddysland, Transvaal, Union of South Africa		Gneiss complex, SE. of Nipton, Calif.		Quartz-hematite, Itabira District, Minas Gerais, Brazil		Greenstone, Yanceyville, N.C.	
Date of collection	Oct. 25, 1954		June 7, 1954		Mar. 25, 1953		1941		Dec. 22, 1955		--------		--------	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	13	--------	23	--------	31	--------	86	--------	30	--------	2.8	--------	31	--------
Al	.1	--------	--------	--------	.2	--------	.0	--------	.4	--------	.2	--------	--------	--------
Fe	.09	--------	.40	--------	2.7	--------	--------	--------	.00	--------	.4	--------	1.3	--------
Mn	.00	--------	--------	--------	.22	--------	--------	--------	.00	--------	.0	--------	--------	--------
Cu	.00	--------	--------	--------	.01	--------	--------	--------	--------	--------	--------	--------	--------	--------
Zn	.06	--------	--------	--------	.00	--------	--------	--------	--------	--------	--------	--------	--------	--------
Ca	19	0.95	33	1.65	28	1.40	59	2.93	90	4.49	.7	0.03	95	4.74
Mg	5.1	.42	7.2	.59	1.9	.16	57	4.66	69	5.67	.7	.06	40	3.29
Na	4.4	.19	1.1	.05	6.8	.30	99	4.29	72	3.13	1.3	.06	21	.91
K	3.2	.08			4.2	.11	5.8	.15	2.0	.05	.4	.01		
Total cations	--------	1.64	--------	2.29	--------	1.97	--------	12.03	--------	13.34	--------	.16	--------	8.94
HCO_3	39	0.64	108	1.77	121	1.98	506	8.30	516	8.46	7.4	0.12	304	4.98
CO_3	0	--------	0	--------	0	--------	0	--------	0	--------	0	--------	0	--------
SO_4	30	.62	15	.31	1.4	.03	17	.35	132	2.75	0	--------	76	1.58
Cl	5.8	.16	7.0	.20	1.0	.03	106	2.99	76	2.14	.4	.01	85	2.40
F	.7	.04	.2	.01	.1	.01	4.0	.21	.6	.03	--------	--------	.0	.00
NO_3	15	.24	--------	--------	.2	.00	--------	--------	.6	.01	.6	.01	.3	.00
PO_4	.0	--------	.0	--------	.0	--------	--------	--------	.0	--------	.0	--------	--------	--------
Total anions	--------	1.70	--------	2.29	--------	2.05	--------	11.85	--------	13.39	--------	0.14	--------	8.96
Total, as reported	135	--------	195	--------	199	--------	940	--------	989	--------	15	--------	654	--------
Specific conductance micromhos at 25° C	178		261		192		--------		1180		11		--------	
pH	6.9		7.4		6.9		7.4		8.1		5.8		--------	
Temperature °C	13.3		9.4		--------		--------		10.5		--------		--------	
Beta-gamma activity μμc per l	<10		<10		--------		--------		<34		--------		--------	
Ra μμc per l	<0.1		<0.1		--------		--------		<0.1		--------		--------	
U μg per l	0.5		1.0		--------		--------		37		--------		--------	
Ratios by weight:														
Ca/Na	4.3		30		4.1		0.6		1.2		0.5		4.5	
Mg/Ca	1.2		6.5		.3		.6		.8		1		.4	
K/Na	.7		--------		.6		.06		.03		.3		--------	
HCO_3/Cl	6.7		15		121		4.8		6.8		18		3.6	
SO_4/Cl	5.2		2.1		1.4		.2		1.7		0		.9	
F/Cl	.1		.03		.1		.04		.008		--------		.0	

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[1] Value considered dubious, possible contamination.

[2] Includes components mentioned in explanation.

EXPLANATION FOR TABLE 10

1. Drip from roof of drift on 8th level, Morris Mine, Marquette iron mining district, Mich. In Siamo slate of Precambrian age. Contains 2 ppm and 0.05 epm Sr and 2.9 ppm B, which are included in totals (Stuart, Brown, and Rhodehamel, 1954).
2. Drilled well, 223 ft deep, Arcadia, Baltimore County, Md. In Wissahickon Schist (albite facies) of Precambrian age (Dingman, Ferguson, and Martin, 1956).
3. Drilled well, 700 ft deep, Wilkesboro, Wilkes County, N.C. In mica schist. Unpublished data in U.S. Geol. Survey files; analyst, S. A. Phillips.
4. Well, 450 ft deep, Bucks County, Pa. In Wissahickon Schist of Precambrian age (Greenman, 1955).
5. Drilled well, 600 ft deep, Suwanee, Gwinnett County, Ga. In Brevard Schist of Cambrian age. Unpublished data in U.S. Geol. Survey files; analyst, D. E. Weaver.
6. Drilled well, 250 ft deep, Vassalboro, Kennebec County, Maine. In fine-grained quartzitic schist of Precambrian(?) age. Unpublished data in U.S. Geol. Survey files; analyst, D. E. Weaver.
7. Spring, Tonasket, NW¼ sec. 20, T. 38 N., R. 26 E., Okanogan County, Wash. Flows 4.5 gpm from schist and slate of Paleozoic age. Unpublished data in U.S. Geol. Survey files; analyst, J. D. Honerkamp.
8. Drilled well, 80 ft deep, Bucks County, Pa. In Baltimore Gneiss of Precambrian age (Greenman, 1955).
9. Drilled well, 180 ft deep, Willimantic, Windham County, Conn. In Willimantic Gneiss of Gregory, probably of Carboniferous age or younger. Unpublished data in U.S. Geol. Survey files; analysts, J. E. Whitney and J. A. Shaughnessy.
10. Drilled well, 304 ft deep, Bloomingdale, Essex County, N.Y. In Grenville Gneiss of Precambrian age. Unpublished data in U.S. Geol. Survey files; analysts, J. A. Shaughnessy and W. F. White.
11. Drilled well, 167 ft deep, Baltimore County, Md. In Port Deposit granitic gneiss of Precambrian age (Dingman, Ferguson, and Martin, 1956).
12. Warm spring, Paddysland, Transvaal, Union of South Africa. From hornblende gneiss of Precambrian age (Kent, 1949).
13. Wheaton Springs, 12 miles southeast of Nipton, San Bernardino County, Calif. Flows 5 gpm from sillimanite-biotite-garnet gneiss complex (Olson and others, 1954). Unpublished data in U.S. Geol. Survey files; analyst, E. Zitnik.
14. Spring, in Sant' Anna area, Itabira district, Minas Gerais, Brazil. From itabirite, a quartz hematite-mica rock, of Precambrian age; analyst, V. M. Campos Paiva of Brazil Dept. Nacl. Produção Mineral. (written communication, J. V. N. Dorr, 2d, and A. L. Miranda Barbosa).
15. Drilled well, 485 ft deep, Yanceyville, Caswell County, N.C. In greenstone of Paleozoic age (LeGrand, 1958).

TABLE 11.—*Chemical analyses of waters from unconsolidated sand and gravel*

Analysis	1		2		3		4		5		6		7	
Source and location	Alluvium, Plymouth, N.H.		Alluvium, Cave Junction, Oreg.		Alluvium, Vancouver, Wash.		Alluvium, Clear Spring, Md.		Alluvium, Clinton, Iowa		Alluvium, Pigeon Spring, W. of Lida, Nev.		Alluvium, lake beds, Bruneau, Idaho	
Date of collection	Oct. 19, 1955		Dec. 19, 1956		May 17, 1949		Feb. 21, 1957		June 8, 1954		Feb. 23, 1956		Nov. 23, 1953	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	23	--------	25	--------	50	--------	5.2	--------	18	--------	25	--------	77	--------
Al	.0	--------	.0	--------	--------	--------	.0	--------	.1	--------	.0	--------	--------	--------
Fe	.01	--------	.03	--------	.02	--------	.10	--------	.04	--------	.05	--------	.0	--------
Mn	.03	--------	.00	--------	--------	--------	.00	--------	.00	--------	.00	--------	--------	--------
Ca	6.8	0.40	6.4	0.32	15	0.75	36	1.80	44	2.20	45	2.25	3.6	0.18
Mg	1.2	.10	7.8	.64	5.2	.43	2.4	.20	18	1.48	20	1.65	.5	.04
Na	2.6	.11	5.8	.25	4.2	.18	1.7	.07	6.0	.26	16	.70	100	4.35
K	.9	.02	.2	.01	5.6	.14	1.1	.03	2.5	.06	2.6	.07	3.1	.08
Total cations	--------	0.63	--------	1.22	--------	1.50	--------	2.10	--------	4.00	--------	4.67	--------	4.65
HCO_3	17	0.28	64	1.05	64	1.05	120	1.97	144	2.36	207	3.39	141	2.31
CO_3	0	--------	0	--------	0	--------	0	--------	0	--------	0	--------	0	--------
SO_4	9.0	.19	.8	.02	11	.23	1.0	.02	53	1.10	35	.73	38	.79
Cl	5.0	.14	5.5	.16	2.9	.08	1.3	.04	5.0	.14	17	.48	12	.34
F	.1	.01	.0	.00	.2	.01	.1	.01	.1	.01	.1	.01	24	1.26
NO_3	1.2	.02	.7	.01	7.2	.12	.8	.01	28	.45	3.6	.06	2.9	.05
PO_4	.0	--------	.0	--------	--------	--------	.0	--------	--------	--------	.0	--------	--------	--------
B	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	.3	--------
Total anions	--------	0.64	--------	1.24	--------	1.49	--------	2.05	--------	4.06	--------	4.67	--------	4.75
Total, as reported	67	--------	116	--------	165	--------	170	--------	319	--------	371	--------	402	--------
Specific conductance micromhos at 25° C	72		113		140		208		397		446		455	
pH	6.1		6.5		7.6		7.8		8.0		7.8		7.9	
Temperature °C	9.4		--------		10.0		10.0		12.2		13.9		33.9	
Beta-gamma activity μμc per l	<5		<7		--------		<5		6		--------		--------	
Ra μμc per l	<0.1		<0.1		--------		0.1		<0.1		--------		--------	
U μg per l	0.1		<0.1		--------		<0.1		0.3		--------		--------	
Ratios by weight:														
Ca/Na	2.6		1.1		3.6		21		7.3		2.8		0.04	
Mg/Ca	.2		1.2		.3		.06		.4		.4		.1	
K/Na	.3		.03		1.3		.6		.4		.2		.03	
HCO_3/Cl	3.4		12		22		92		29		12		12	
SO_4/Cl	1.8		.1		3.8		.8		11		2.1		3.2	
F/Cl	.02		.0		.07		.08		.02		.006		2.0	

Analysis	8		9		10		11		12		13		14	
Source and location	Glacial outwash, Eden Valley, Minn.		Alluvium, Enid, Okla.		Alluvium, Te Aroha, New Zealand		Alluvium, Mesa, Ariz.		Glacial outwash, Columbus, Ohio		Alluvium, Gaylord, Kans.		Alluvium, Douglas, Ariz.	
Date of collection	Nov. 2, 1955		May 28, 1952		--------		Sept. 19, 1951		May 28, 1952		May 3, 1950		Dec. 13, 1955	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	24	--------	21	--------	63	--------	26	--------	20	--------	28	--------	27	--------
Al	.1	--------	--------	--------	1.6	--------	--------	--------	--------	--------	--------	--------	.0	--------
Fe	.00	--------	.00	--------	1.0	--------	.08	--------	2.3	--------	.42	--------	.02	--------
Mn	.08	--------	--------	--------	--------	--------	--------	--------	.00	--------	--------	--------	.00	--------
Ca	86	4.29	49	2.45	96	4.79	58	2.89	126	6.29	132	6.59	3.2	0.16
Mg	27	2.22	13	1.07	37	3.04	22	1.81	43	3.54	16	1.32	1.0	.08
Na	5.1	.22	105	4.57	20	.87	146	6.35	13	.56	53	2.31	262	11.40
K	3.0	.08	3.0	.08			4.0	.10	2.1	.05	7.6	.19	2.4	.06
Total cations	--------	6.81	--------	8.17	--------	8.70	--------	11.15	--------	10.44	--------	10.41	--------	11.70
HCO_3	337	5.52	384	6.29	477	7.82	184	3.02	440	7.21	302	4.95	149	2.44
CO_3	0	--------	0	--------	0	--------	0	--------	0	--------	18	.60	16	.53
SO_4	60	1.25	27	.56	5.0	.10	39	.81	139	2.89	187	3.89	125	2.60
Cl	6.0	.17	34	.96	20	.56	255	7.19	8.0	.23	32	.90	210	5.92
F	.0	.00	.3	.02	--------	--------	.0	.00	.7	.04	.3	.02	2.0	.10
NO_3	.0	.00	7.8	.13	--------	--------	2.9	.05	.2	.00	18	.29	2.5	.04
PO_4	.2	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	.05	--------
B	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	.2	--------	--------	--------
Total anions	--------	6.94	--------	7.96	--------	8.48	--------	11.07	--------	10.37	--------	10.65	--------	11.63
Total, as reported	548	--------	644	--------	721	--------	737	--------	794	--------	795	--------	800	--------
Specific conductance micromhos at 25° C	623		739		--------		1180		885		943		1260	
pH	7.5		7.4		--------		7.7		7.6		8.4		9.0	
Temperature °C	7.8		--------		--------		18.3		13.3		13.3		20.0	
Beta-gamma activity μμc per l	<17		--------		--------		--------		--------		--------		<34	
Ra μμc per l	0.3		--------		--------		--------		--------		--------		<0.1	
U μg per l	0.7		--------		--------		--------		--------		--------		3.8	
Ratios by weight:														
Ca/Na	17		0.5		4.8		0.4		9.7		2.5		0.01	
Mg/Ca	.3		.3		.4		.4		.3		.1		.3	
K/Na	.6		.03		--------		.03		.2		.1		.009	
HCO_3/Cl	56		11		24		.7		55		9.4		.7	
SO_4/Cl	10		.8		.2		.2		17		5.8		.6	
F/Cl	.0		.009		--------		.0		.09		.009		.01	

TABLE 11.—*Chemical analyses of waters from unconsolidated sand and gravel*—Continued

Analysis	15		16		17		18		19		20	
Source and location	Alluvium, Fresno County, Calif.		Glacial deposits, N. of Malcolm, Iowa		Alluvium, Fort Morgan, Colo.		Alluvium, St. Croix Island, Virgin Islands		Alluvium, Gila Bend, Ariz.		Alluvium, NW. of Pecos, Tex.	
Date of collection	Sept. 18, 1951		Nov. 17, 1955		July 28, 1948		April 15, 1940		Mar. 1948		Mar. 28, 1950	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	30		14		26		35		37		43	
Al			.8									
Fe			.26				.93					
Mn			.05									
Ca	63	3.14	120	5.99	210	10.48	30	1.50	307	15.32	856	42.71
Mg	54	4.44	49	4.03	74	6.09	24	1.97	82	6.74	190	15.63
Na	160	6.96	122	5.31	163	7.09	814	35.41	} 1100	47.85	738	32.10
K	2.6	.07	6.2	.16	12	.31	10	.26				
Total cations		14.61		15.49		23.97		39.14		69.91		90.44
HCO_3	160	2.62	339	5.56	348	5.70	828	13.57	327	5.36	152	2.49
CO_3			0				0				0	
SO_4	505	10.51	439	9.14	784	16.32	351	7.31	575	11.97	1910	39.77
Cl	57	1.61	6.0	.17	62	1.75	625	17.63	1820	51.32	1510	42.58
F			.1	.01	.7	.04	1.6	.08	2.5	.13		
NO_3	1.3	.02	26	.42	2.1	.03	17	.27	82	1.32	468	7.55
PO_4	1.1		.0									
B					.4				3.2		1.6	
Total anions		14.76		15.30		23.84		38.86		70.10		92.39
Total, as reported	1030		1120		1680		2740		4340		5870	
Specific conductance..micromhos at 25° C	1340		1330		1980				6860		7560	
pH	8.5		7.4		7.8						7.1	
Temperature °C	27.8		11.9		12.8				25.6		20.8	
Beta-gamma activity μμc per l			<45									
Ra μμc per l			0.2									
U μg per l			0.1									
Ratios by weight:												
Ca/Na	0.4		1.0		1.3		0.04		0.3		1.2	
Mg/Ca	.9		.4		.4		.8		.3		.2	
K/Na	.02		.05		.07		.01				.1	
HCO_3/Cl	2.8		57		5.6		1.3		.2		.1	
SO_4/Cl	8.9		73		13		.6		.3		1.3	
F/Cl			.02		.01		.003		.001			

EXPLANATION FOR TABLE 11

1. Well, 48 ft deep, Plymouth, Grafton County, N.H. In Quaternary alluvium derived from igneous and metamorphic rocks. Unpublished data in U.S. Geol. Survey files; analyst, B. V. Salotto. Also reported are Cu, 0.00 ppm; Zn, 0.00 ppm.
2. Drilled well, 40 ft deep, southeast of Cave Junction, SE¼ sec. 28, T. 39 S., R. 8 W. Josephine County, Oreg. In Quaternary alluvium derived from igneous and metamorphic rocks. Unpublished data in U.S. Geol. Survey files; analyst, R. A. Wilson.
3. Spring, near Vancouver, NW¼SW¼ sec. 33, T. 2 N., R. 2 E., Clark County, Wash. From Quaternary allvium derived from igenous rocks (Griffin, Watkins, and Swenson, 1956).
4. Spring, Clear Spring, Washington County, Md. Flows 100 gpm from Quaternary alluvium derived from sedimentary rocks. Unpublished data in U.S. Geol. Survey files; analyst, D. E. Weaver. Also reported are Cu, 0.00 ppm; Zn, 0.00 ppm.
5. Drilled well, 160 ft deep, Clinton, SE¼ sec. 22, T. 81 N., R. 6 E., Clinton County, Iowa. In Quaternary alluvium of the Mississippi River. Unpublished data in U.S. Geol. Survey files; analysts, R. A. Wilson, J. D. Weeks, and J. O. Johnson.
6. Pigeon Spring, about 15 miles west of Lida, T. 6 S., R. 39 E., Esmeralda County, Nev. Flows 5 gpm from Quaternary alluvium derived from igneous and metamorphic rocks. Unpublished data in U.S. Geol. Survey files; analyst, R. A. Wilson.
7. Flowing well, 976 ft deep, in SE¼SE¼ sec. 24, T. 6 S., R. 5 E., near Bruneau Village, Owyhee County, Idaho. In tuffaceous sand of Idaho Formation of probable Pliocene age, consisting of lake beds and terrestrial deposits underlying basaltic volcanic rocks. Flows 25 gpm. Unpublished data in U.S. Geol. Survey files; analyst, J. F. Santos.
8. Well, 80 ft deep, Eden Valley, NE¼SE¼SE¼ sec. 1, T. 121 N., R. 31 W., Meeker County, Minn. In Pleistocene glacial outwash. Unpublished data in U.S. Geol. Survey files; analyst, E. Zitnik.
9. Well 71 ft deep, Enid, NW¼ sec. 7, T. 23 N., R. 7 W., Garfield County, Okla In Quaternary alluvium from sedimentary rocks. Unpublished data in U.S. Geol. Survey files; analyst, J. M. Myers.
10. Cold Spring C, Te Aroha, Aroha subdivision, Hauraki, North Island, New Zealand. From Quaternary alluvium derived from late Tertiary lavas and tuffs (Henderson and Bartrum, 1913). See table 22, analysis 10, for Te Aroha thermal water high in Na, HCO_3, and B.
11. Drilled well, 500 ft deep, Mesa, Maricopa County, Ariz. In alluvial valley fill of Quaternary age (Lohr and Love, 1954b).
12. Well, 117 ft deep, Nelson Road Waterworks, Columbus, Franklin County, Ohio. In Pleistocene glacial outwash gravel. Unpublished data in U.S. Geol. Survey files; analyst, R. W. Leonard.
13. Well, 50 ft deep, Gaylord, sec. 11, T. 5 S., R. 14 W., Smith County, Kans. In Quaternary alluvium derived from sedimentary rocks (Leonard, 1952).
14. Drilled well, 340 ft deep, Douglas, NW¼NW¼SE¼ sec. 10, T. 24 S., R. 27 E., Cochise County, Ariz. In Quaternary alluvial valley fill. Unpublished data in U.S. Geol. Survey files; analyst, R. A. Wilson.
15. Drilled well, 1,529 ft deep, sec. 36, T. 19 S., R. 17 E., Fresno County, Calif. In Quaternary alluvium (Krieger, Hatchett, and Poole, 1957).
16. Drilled well, 407 ft deep, 10 miles north of Malcom, NW¼NE¼ sec. 11, T. 81 N. R. 15 W., Poweshiek County, Iowa. In Pleistocene subglacial sand and gravel. Unpublished data in U.S. Geol. Survey files; analyst, R. A. Wilson.
17. Well, 90 ft deep, Fort Morgan, sec. 26, T. 4 N., R. 56 W., Morgan County, Colo. In Quaternary alluvium (Krieger, Hatchett, and Poole, 1957).
18. Dug well, 11 ft deep, Annas Hope, St. Croix Island, Virgin Islands. In alluvium derived from the Mt. Eagle Volcanics and perhaps, in part, from the Kingshill Marl (Cederstrom, 1950).
19. Well, 135 ft deep, near Gila Bend, sec. 8, T. 5 S., R. 4 W., Maricopa County, Ariz. In Quaternary alluvium (Krieger, Hatchett, and Poole, 1957).
20. Well 225 ft deep, 2 miles northwest of Pecos, Reeves County, Tex. In Quaternary alluvium (Winslow and Kister, 1956).

TABLE 12.—*Chemical analyses of oil-field and gas-field waters dominated by sodium chloride*

Analysis	1		2		3		4		5		6	
Name of field and location	Seaboard, Fresno County, Calif.		Cymric, Kern County, Calif.		Maine Prairie, Solano County, Calif.		Timbalier Bay, Lafourche Parish, La.		Katarzyna near Pomiarkach, Poland		Przedgorza Karpat, Galicia, Poland	
Date of collection	April 20, 1954		June 14, 1955		May 11, 1955		1958					
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	31		47		32		25		2		14	
Al			.4				5.0					
Fe			1.2				8.6		8		14	
Mn			.08				[1] 1.1					
As			0				.00					
Ca	543	27.1	373	18.6	211	10.53	2,600	129.7	908	45.3	1,080	54.0
Mg	126	10.4	115	9.45	66	5.4	1,060	87.2	935	76.9	441	36.3
Na	6,750	293.5	5,820	253.2	5,880	255.7	51,400	2,236	89,900	3,911	[1] 11,800	512
K	99	2.53	132	3.38	168	4.30	193	4.94	3,090	78.9		
Li			4.3	.62	2.0	0.29	5.5	.79				
NH_4	52	2.9	51	2.8	24	1.4	147	8.15				
Total cations		[1] 337		288		278		2,470		4,110		602
HCO_3	191	3.13	535	8.77	565	9.26	147	2.41	258	4.24	115	1.89
CO_3	0		0	.00	0		0	.00				
SO_4	0		1.6	.03	12	0.25	2.6	.05	9,230	192.2	104	2.17
Cl	11,600	327	9,840	277.5	9,230	260.3	89,700	2,530	139,000	3,920	21,000	596
F	0.4	0.02	3.4	.18	1.2	0.06	1.1	.06				
Br	58	.73	30	.38	32	.40	86	1.08	105	1.32	91	1.14
I	23	.18	23	.18	23	.18	19	.15	[1] 199	1.57	122	.96
NO_2	0		0				.00					
NO_3	70	1.13	3	.05	0.7	0.01	7.9	.13				
PO_4							.00					
B	57		140		25		20					
Total anions		332		287		270		2,530		4,120		602
Total, as reported	[1] 19,600		17,100		16,300		145,000		244,000		34,800	
Specific conductance micromhos at 25° C	31,500		25,800		25,500		138,000					
pH	6.9		7.5		7.1		6.6				6.8	
Temperature °C			49½				70					
Density at 20° C	1.0133		1.009		1.0106		1.104		1.185		1.025	
Ratios by weight:												
Ca/Na	0.080		0.064		0.036		0.051		0.010		0.090	
Mg/Ca	.23		.31		.31		.41		1.03		.41	
K/Na	.015		.023		.029		.0038		.034			
Li/Na			.00074		.0003		.00011					
HCO_3/Cl [2]	.016		.054		.061		.0016		.0019		.0055	
SO_4/Cl	.0000		.0002		.0013		.000029		.066		.0050	
F/Cl	.00003		.0003		.0001		.000012					
Br/Cl	.0050		.0030		.0035		.00096		.0008		.0043	
I/Cl	.0020		.0023		.0025		.00021		.0014		.0058	
B/Cl	.0049		.014		.0027		.00012					

Analysis	7		8		9		10		11	
Name of field and location	Hajduszoboszlo, SW. of Debrecen, Hungary		Tiszakürt, SE. of Budapest, Hungary		Moinesti near Moinesti, Rumania		North Makat, Kazakh district, USSR		South Kwanto, Chiba Prefecture, Japan	
Date of collection			1943(?)							
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	23		95		5.2					
Al	[1] 4.2		Tr							
Fe	0.5		29		24				[1] 5.4	
Mn	[1] Tr		Tr							
As			[1] 5.8							
Ca	14	0.70	174	8.68	1,990	99.3	3,210	160.2	170	8.48
Mg	2.1	.17	22	1.8	836	68.8	1,690	139	325	26.7
Na	1,760	76.4	4,930	214.5	47,200	2,053	70,900	3,083	[1] 10,000	435
K	24	.62	89	2.28	169	4.32	279	7.14		
Li	[1] 0.4	.06	[1] 84	12.1						
NH_4			40	2.2	[1] 23	1.3	22	1.22	47	2.60
Total cations		78.0		242		2,230		3,390		473
HCO_3	[1] 1,360	22.3	1,120	18.4	42	0.69	75	1.23	832	13.63
CO_3			Tr							
SO_4	1.6	.03	24	.50	24	.50			<2	
Cl	1,950	55.1	7,490	211.2	78,800	2,222	120,000	3,380	16,200	457
F			9.4	.50						
Br	24	.29	22	.28	127	1.59	127	1.58	81	1.02
I	8.4	.07	2.1	.02	[1] 11	.09	1.4	.01	132	1.04
NO_2										
NO_3										
PO_4			Tr							
B	5.4		89				35		14	
Total anions		77.8		231		2,220		3,380		473
Total, as reported	5,180		14,200		129,000		196,000		27,800	
Specific conductance micromhos at 25° C										
pH									7.8	
Temperature °C	73								20	
Density at 20° C							1.160		[1] 1.02	
Ratios by weight:										
Ca/Na	0.0080		0.035		0.042		0.045		0.017	
Mg/Ca	.15		.13		.42		.53		1.9	
K/Na	.014		.018		.0036		.0039			
Li/Na	.0002		.017							
HCO_3/Cl [2]	.70		.15		.00053		.00062		.051	
SO_4/Cl	.0008		.0032		.00030				.000	
F/Cl			.0012							
Br/Cl	.012		.0029		.0016		.0010		.0050	
I/Cl	.0043		.00028		.00014		.00001		.0081	
B/Cl	.0028		.012				.00029		.00087	

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[1] Components mentioned in explanation of table.

[2] Includes CO_3 as HCO_3.

EXPLANATION FOR TABLE 12

1. Seaboard Oil Co. well S.T.U. 35-13, 6,300 ft deep, sec. 13, T. 15 S., R. 17 E., Fresno County, Calif. Producing from Eocene sandstone. Collected by R. E. Thronson and W. B. Mitchell, Jr., California Division of Water Resources; analyzed by D. D. Watson, U.S. Geol. Survey. Included in totals is Ba, 12 ppm (0.17 epm). Analysis not previously published.
2. Honolulu Oil Co. well 22-166, 4,952 ft deep, Cymric oil field, NW¼SE¼ sec. 22, T. 29 S., R. 21 E., Kern County, Calif. Some mercury has been recovered from this well (Stockman, 1947). Producing from Oceanic Sandstone of Oligocene age; bottom-hole temperature 81°C, discharge temperature 49½°C. Analyzed by C. E. Roberson, U.S. Geol. Survey; H_2S not found; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in original water: evaporated residue at 180°C, 18,000; Al, 0.2; Fe, 0.2; Mn, 0.2; Cu, 0.04; Li, 2.6; Rb, 0.2; Sr 80; Ba, 7.1. Analysis not previously published. See table 28, analysis 1, for gas analysis by U.S. Bureau of Mines.
3. Amerada Petroleum Corp. Peters gas well 1, Maine Prairie gas field, sec. 10, T. 5 N., R. 2 E., Solano County, Calif. Producing from depths of 5,590 to 5,630 ft in the Meganos Formation of Eocene age (C. R. McClure, written communication). Collected by C. R. McClure, California Division of Water Resources; analyzed by R. O. Hansen, U.S. Geol. Survey. Analysis not previously published.
4. Gulf Oil Corp. well PP 19, 7,790 ft deep, Timbalier Bay oil field, T. 23 S., R. 21 E., Lafourche Parish, La. Producing from depths of 5,904 to 5,910 ft where temperature was 70° C in Pliocene shallow-shelf and shoreline sands with shale streaks on north flank of Timbalier Bay salt dome, with salt at depth of 7,782 ft. Collected with cooperation of Dr. Marcus Hanna, who believes that brine is not directly influenced by contact with the salt of the dome (written communication). Analysis by H. C. Whitehead of U.S. Geological Survey; also determined Cu, 0.02 ppm; Zn and Pb, 0.00 ppm; spectrographic analysis of evaporated residue by Nola B. Sheffey, converted to ppm in original water: evaporated residue at 180° C, 152,900; Al, 1.5; Fe, 0.8; Mn, 1.1; Cu, 0.3; Ni, 1.5; Cr, 0.6; Li, 2.3; Sr, 11; Ba, 150. Analysis not previously published.
5. Katarzyna oil field near Pomiarkach, Poland, from a depth of 300 ft in the Argiles Saliferes Formation of Miocene age (Katz, 1928, p. 13-15, 49-52). Analysis converted from mg per l; this water has the highest iodine content reported by Schoeller (1956, p. 100-113) in oil-field brines.
6. Well 29, 1,550 ft deep, Przedgorza, Galicia, Poland, probably in lower Tertiary rocks (Chajec, 1949, p. 367; Emmons, 1931, p. 631). Analysis converted from mg per l. Alkalies determined by difference of anions and cations.
7. Artesian test well for gas, 3,600 ft deep, Hajduszoboslo gas field 6 miles southwest of Debrecen, Hungary. Discharges 450 gpm water (Emszt, 1928, p. 146) probably from Cretaceous limestone (Szalai, 1951, p. 181). HCO_3 converted from reported equivalent CO_3; Al, Mn, and Li from analysis of very similar water from well 2, 6,665 ft deep, probably from Triassic strata (Papp, 1951, p. 155; Szalai, 1951, p. 181). Abundant gas (table 28, analysis 2) accompanies water.
8. Tiszakürt, about 60 miles southeast of Budapest, Hungary. Production from about 7,500 ft from Triassic limestone (Telegdi-Roth, 1950, p. 81; Vajk, 1953, p. 40-42). Li and As are surprisingly high and should be checked; trace of Cu and Sr reported. Analyzed by J. Bodnar, Dec. 1943.
9. Well 24, 2,050 ft deep, of Soc. Steaua Romana in the Moinesti field of northeast Rumania. Produces from Oligocene rocks. Naphthenic acids and trace of Sr reported present (Petrescu, 1938, p. 26-28). In 15 other analyses, I is as much as 167 ppm and NH_4 as much as 372 ppm.
10. Well 43, 1,750 ft deep, North Makat, Kazakh district, U.S.S.R., near northeast shore of Caspian Sea. In Permo-Triassic rocks (Sulin, 1948, p. 410-411). Analysis expressed in mg per liter and equivalents per liter converted to ppm.
11. Well A-226, 1,800 ft deep, South Kwanto gas fields, Bōsō Peninsula, Chiba Prefecture, Japan, 2.5 km northeast of Otaki. Brine produced for iodine and dissolved gases (30.7 cc per l; see table 28, analysis 3) from sandstone and shale of Upper Pliocene Otadai and Kiwada Formations. Temperature 20° C; analyses reported in g per l, converted to ppm by assuming a density of 1.02; 4.3 ppm of total Fe reported as ferrous iron; Na and K not reported, here calculated by difference.

TABLE 13.—*Chemical analyses of oil-field waters and other deep-well brines high in sodium and calcium chlorides*

Analysis	1		2		3		4		5		6		7	
Name of field and location	Raisin City, Fresno County, Calif.		South Mountain, Ventura County, Calif.		West Bay, Plaquemines Parish, La.		Barnhill, Wayne County, Ill.		Paintsville, Johnson County, Ky.		Lee, Calhoun County, W. Va.		Michigan Basin (Dundee Limestone) Mich.	
Date of collection	Apr. 20, 1954				June 17, 1958						1937			
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	36				16		16		5.9				<50	
Al					3.1		7		8.6					
Fe					110		[1]0		4.4		7		18	
Mn					[1]30		0						6.0	
Ca	2,190	109.3	5,890	293.9	9,210	459.6	7,130	355.8	1,340	66.9	8,450	421.7	32,800	1,637
Mg	832	68.4	69	5.7	1,070	88.0	2,400	197	368	30.3	2,040	168	6,440	530
Sr					[1]180				41	.94	[1]2,610	59.6	940	21.45
Ba	42	0.61			[1]17				66	.96	1,550	20.6	12	.17
Na	14,800	643	4,140	180.1	63,900	2,780	[1]49,000	2,133	8,010	348.4	28,900	1,257	51,500	2,240
K	251	6.42	117	2.99	869	22.23			96	2.46	298	7.62	2,460	62.9
Li					19	2.7							23	3.3
NH_4	31	1.7			188	10.4	167	9.26					202	11.2
Total cations		829		483		3,360		2,700		450		1,930		4,510
HCO_3	193	3.16	17	0.28	115	1.88	136	2.23	120	1.97	51	0.84		
CO_3	0		0	.00										
SO_4	0.0		18	.37	153	3.18	82	1.71	0		0	.00	140	2.91
Cl	29,000	818	17,000	479	124,000	3,500	[1]95,400	2,690	15,500	437	68,400	1,929	160,000	4,510
F	0.6	0.03			1.4	.07							<4	
Br	108	1.35	91	1.14	393	4.91			92	1.15	373	4.67	1,310	16.4
I	21	.17	21	.17	18	.14			0.4	.00	4	.03	8	.06
NO_2	0				.00									
NO_3	44	.71			0		64	1.03						
PO_4					0				0					
B	8.3		Tr		9.4				0				60	
H_2S													nil	
Total anions		823		481		3,510		2,690		440		1,930		4,530
Total, as reported	47,600		27,400		[1]200,000		154,000		25,700		113,000		256,000	

Analysis	1	2	3	4	5	6	7
Specific conductance micromhos at 25°C	68,600		158,000				
pH	6.4		6.3	7.2	7.3		
Temperature, °C			[1]87½				
Density at 20°C	1.034	[2]1.015	1.151		1.0156	1.072	1.214
Ratios by weight:							
Ca/Na	0.15	1.4	0.14	0.14	0.17	0.29	0.64
Mg/Ca	.38	.012	.12	.34	.27	.24	.20
K/Na	.017	.028	.014		.012	.010	.048
Li/Na			.00030				.00045
HCO_3/Cl [3]	.0066	.0010	.00090	.0014	.0077	.00075	
SO_4/Cl	.00000	.0011	.0012	.00085	.00000	.00000	.00087
F/Cl	.00002		.00001				<.00003
Br/Cl	.0037	.0053	.0032		.0059	.0055	.0081
I/Cl	.00072	.0012	.00015		.00003	.00006	.00005
B/Cl	.00028		.000076				.00038

Analysis	8		9		10		11		12		13	
Name of field and location	Michigan Basin (Sylvania Sandstone) Mich.		Playa Huincul, Neuquen Territory, Argentina		Höllviken, Scania district, Sweden		Gevelsberg, Ruhr district, West Germany		Boryslaw area, Poland		Polasna-Krasnokamsk, NW. of Molotov City, USSR	
Date of collection					Apr. 18, 1944				1926			
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	<20		13		8				7			
Al	<5		16									
Fe	22		35		43		78		106			
Mn	2.0				15		20					
Ca	74,800	3,724	9,990	498.5	12,700	634	6,890	343.8	17,300	863.3	16,000	798
Mg	9,960	819	918	75.5	1,100	90.5	571	47.0	1,880	155	3,750	308
Sr	2,650	60.5	84	1.92	9	.21	235	5.36				
Ba	nil		282	4.11	1	.01	13	.19				
Na	22,500	979	21,700	944	28,100	1,222	20,500	982	75,000	3,260	61,000	2,654
K	[1]9,120	233.3	32	.82	919	23.5	[1]3,950	101.0	310	7.93	1,080	27.6
Li	70	10.1	3.9	.56	5.5	.79	0.2	.03				
NH_4	506	28.1			28	1.55	716	39.7			156	8.65
Total cations		5,850		1,530		1,970		1,430		4,290		3,800
HCO_3							876	14.36	187	3.06	51	0.84
CO_3												
SO_4	40	.83			10	.21	0		340	7.08	474	9.87
Cl	208,000	5,870	54,100	1,526	69,400	1,957	48,900	1,379	152,000	4,290	134,000	3,780
F	<4				4	.21						
Br	2,910	36.4	30	.38	358	4.48	2.8	.04	297	3.72	614	7.68
I	40	.32	2	.02	3	.02	0.3	.00	15	[1].12	17	.13
NO_2					16	.27						
NO_3												
PO_4					<1		0.1					
B	380				<1		0.8					
H_2S	>0.1				0						[1]140	
Total anions		5,910		1,530		1,960		1,390		4,300		3,800
Total, as reported	331,000		87,200		113,000		82,800		247,000		217,000	

See footnotes at end of table.

TABLE 13.—*Chemical analyses of oil-field waters and other deep-well brines high in sodium and calcium chlorides*—Continued

Analysis	8	9	10	11	12	13
Name of field and location	Michigan Basin (Sylvania Sandstone) Mich.	Playa Huincul, Neuquen Territory, Argentina	Höllviken, Scania district, Sweden	Gevelsberg, Ruhr district, West Germany	Boryslaw area, Poland	Polasna-Krasnokamsk, NW. of Molotov City, USSR
Date of collection			Apr. 18, 1944		1926	
Specific conductance...micromhos at 25°C						
pH						6.4
Temperature, °C		35		27		
Density at 20°C	1.292		1.088		1.193	1.172
Ratios by weight:						
Ca/Na	3.3	0.46	0.45	0.34	0.23	0.26
Mg/Ca	.13	.091	.086	.082	.11	.23
K/Na	.41	.0015	.033	.19	.0041	.018
Li/Na	.003	.00018	.0002	.00001		
HCO_3/Cl [3]				.018	.0012	.00038
SO_4/Cl	.0019		.00014	.00000	.0022	.0035
F/Cl	<.00002		.00006			
Br/Cl	.014	.00055	.0052	.000057	.0020	.0046
I/Cl	.00019	.00004	.00004	.00006	.000099	.00013
B/Cl	.0018			.00002		

[1] Components mentioned in explanation of table. [2] Estimated. [3] Includes CO_3 as HCO_3.

EXPLANATION FOR TABLE 13

1. Seaboard Oil Co. well S.T.U. 305-13, Raisin City, sec. 13, T. 15 S., R. 17 E., Fresno County, Calif. Water from depth of 4,700 ft; well produces from Miocene Tar Formation (same analysis as in White, 1957b, p. 1664, but locality incorrectly called Seaboard Field). Collected by R. E. Thronson and W. B. Mitchell, Jr., of California Division of Water Resources· analyzed by D. D. Watson, U.S. Geol. Survey; gas analysis of table 28, analysis 4 (Anderson and Hinson, 1951, p. 50–51) from nearby well from depth of 4,975 ft.
2. Well H. No. 6, South Mountain, Ventura County, Calif.; water from depth of 3,285 ft in sandstone of the Sespe Formation of upper Eocene or Oligocene age (Hudson and Taliaferro, 1925, p. 1076). Recalculated from analysis showing hypothetical combinations, in grains per gallon.
3. Gulf Oil Corp. well 28–E, 9,500 ft deep, West Bay oil field, Buras Levee district, sec. 35, T. 22 S., R. 30 E., Plaquemines Parish, La. Producing from 8,366 to 8,374 ft; bottom-hole temperature 87½° C, temperature of sample when collected 42° C. Producing from silty Miocene sandstone, probably of deep-water deposition, about 200 ft from salt near crest of West Bay salt dome, believed by Dr. Marcus Hanna to be a deep-seated dome generally lacking in an anhydrite cap and little affected by solution of salt (written communication). Hanna believes that the water sample has not been in contact with the salt dome. Collected June 17, 1958, with cooperation of Hanna; analyzed by H. C. Whitehead of U.S. Geol. Survey. Also reported, in ppm: Cu, 0.00; Pb, 0.60, Zn, 5, As, 0.00. Spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in original water: evaporated residue at 180° C, 214,200, Al, 4.3; Fe, 51; Mn, 30; Cu, 0.4; Ni, 2.1; Li, 9.8; Sr, 180; Ba, 17. Analysis not previously published.
4. Well about 2 miles north of Barnhill, sec. 31, T. 2 S., R. 8 E., Wayne County, Ill. Water from depth of 3,374 to 3,385 ft in Ste. Genevieve Limestone of Mississippian age (Meents, Bell, Rees, and Tilbury, 1952, p. 33). Highest Cl content reported in about 500 analyses; Na+K determined by difference; total Fe, unfiltered, 0.6 ppm.
5. Brine from Pennsylvanian sandstone, Paintsville, Johnson County, Ky.; depth not stated. Apparently from an artesian well, producing 2 gpm of brine (Hauser, 1953, p. 67).
6. Tom Campbell farm well 2, 1¼ miles south of Creston, Calhoun County, W. Va.; water from depth of 1,402 ft near top of Salt Sand of Pottsville Series of Early Pennsylvanian age (Price, Hare, McCue, and Hoskins, 1937, p. 36, 67, 98). Highest Sr content of about 180 analyses). Analyzed by J. B. McCue, West Virginia Geol. Survey.
7. Location not specified· analysis reported by Dow Chemical Co. to be typical of commercial-brine analyses from vuggy Dundee Limestone of Middle Devonian age, Michigan basin, Michigan, from depths of 1,500 to 4,200 ft. Most components are recalculated from hypothetical chemical combinations but some were given as ions.
8. Location not specified; sample reported by Dow Chemical Co. to be a typical brine from Sylvania Sandstone of Early Devonian age, Michigan basin, Michigan, from depths of 2,000 to 5,500 ft. Most components are recalculated from hypothetical chemical combinations but some are given as ions; also reported are Cu, <1 ppm; Pb, <5 ppm; and Ni, <5 ppm. K content is notably high. See table 4, analysis 15 for shallow water of low salinity from Sylvania.
9. Test well 23, on border of Playa Huincul oil field, Neuquen Territory, Argentina; producing thermal water from depth of 2,640 to 2,850 ft from Upper Jurassic sandstone associated with shale (Sussini and others, 1938, p. 157; Emmons, 1931, p. 611). Analysis reported with metals given as oxides, converted to ions.
10. Höllviken 1 brine well, Scania district, southernmost Sweden, producing from depth of 4,050 to 4,140 ft from sandstone of Early Cretaceous (Cenomanian) age (Brotzen and Assarsson, 1951, p. 222–223; Schoeller, 1956, p. 182–183). Brines at deeper levels in Cenomanian and underlying Triassic rocks are similar in composition but generally increase in salinity downward. Analysis converted from mg per l; Cs, 5 ppm.
11. Brine well, near Gevelsberg in Ruhr area, West Germany, producing from depth of 3,275 ft (Komlev, 1933, p. 208). Rocks at surface are probably of Cretaceous age; brine probably is from Triassic rocks. K content is surprisingly high; Ra, 1.80 μμc per l; As, 0.06 ppm.
12. Ullman well, in the Boryslaw area, Poland, producing from a depth of 3,100 ft from rocks of Couches de Polanica of upper Oligocene age (Katz, 1928, p. 18, 20). Analysis recalculated from mg per l; I content is intermediate in range reported by Katz.
13. Krasnokamsk well 62, in the Kama River region, about 25 miles northwest of Molotov City, U.S.S.R., producing from depth of 3,240 to 3,250 ft from Carboniferous limestone containing some $CaSO_4$ and NaCl; overlain by nearly 400 ft of impermeable anhydrite (Kuznetsov and Novikov, 1943, p. 62; Kuznetsov, 1943, p. 151–154; see also Schoeller, 1956, p. 186). All waters of field are high in H_2S and contain as much as 900 ppm.

TABLE 14.—*Chemical analyses of waters high in sulfate and bicarbonate associated with oil fields*

Analysis	1		2		3		4		5	
Name of field and location	Midway Sunset, Kern County, Calif.		Coalinga, Fresno County, Calif.		Pilot Butte, Fremont County, Wyo.		South Casper Creek, Natrona County, Wyo.		Coalinga, Fresno County, Calif.	
Date of collection	June 22, 1954		Oct. 25, 1955		June 18, 1959		Sept. 15, 1958		Jan. 8, 1952	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	59		22		36		16		61	
Al					1.4		.64			
Fe					.75		.24			
Mn					.00		.00			
As					.00		.00			
Ca	501	25.0	407	20.3	216	10.78	266	13.27	40	2.0
Mg	103	8.47	491	40.4	99	8.14	82	6.74	35	2.9
Sr					[1]9.6		[1]5.7			
Ba					[1].3		[1].12			
Na	1,020	44.4	1,800	78.3	3,250	141.38	378	16.44	1,570	68.3
K	9.8	0.25	10	.26	78	2.00	21	.54	33	.84
Li					2.3	.33	.4	.06		
NH_4					11	.61	.0			
Total cations		78.1		139		163.24		37.05		74.0
HCO_3	112	1.84	336	5.51	201	3.29	156	2.56	2,900	47.5
CO_3	0	.00	0	.00	10	.33	0		0	.00
SO_4	1,590	33.1	5,760	119.9	6,650	138.45	1,170	24.36	415	8.64
Cl	1,300	36.7	500	14.1	596	16.81	370	10.43	612	17.26
F	0.3	.02	1.0	.05	6.0	.32	3.5	.18	0.6	.03
Br	7.7	.10			.7	.01	1.5			
I	2.3	.02			1.3	.01	.0			
NO_2					.00		.00			
NO_3	343	5.53	11	.18	2.2	.04	.0		1.4	.02
PO_4					.03		.03			
B	3.9		9.6		26		.44		13	
CO_2										
H_2S					62		24			
Total anions		77.3		140		159.26		37.53		73.5
Total, as reported	5,050		9,350		11,200		2,490		5,680	
Specific conductance micromhos at 25° C	7,040				13,300		3,220			
pH	7.5				8.3		7.6			
Temperature °C	25									
Ratios by weight:										
Ca/Na	0.49		0.23		0.066		0.70		0.025	
Mg/Ca	.21		1.2		.46		.31		.88	
K/Na	.0096		.0056		.024		.056		.021	
Li/Na					.00071		.001			
HCO_3/Cl[1]	.086		.67		.37		.42		4.7	
SO_4/Cl	1.2		12		11		3.2		.68	
F/Cl	.00023		.002		.010		.0095		.0001	
Br/Cl	.0059				.0012		.0041			
I/Cl	.0018				.0022		.000			
B/Cl	.0030		.019		.044		.0012		.021	

Analysis	6		7		8		9	
Name of field and location	East of Salt Creek, Natrona County, Wyo.		Ellis Pool, Alberta, Canada		Bukkszek, Hungary		Mezokovesd, Hungary	
Date of collection	June 16, 1958		Jan. 8, 1958					
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	32		13		55		39	
Al	1.4		.85		0.3		0	
Fe	.84		.04		3.3		Tr	
Mn	.00		.00				0	
As	.01		.23					
Ca	3.2	0.16	9.6	0.48	154	7.68	193	9.63
Mg	1.5	.12	15	1.23	162	13.3	65	5.3
Sr	[1].7		[1].9		.3	.01	3.1	.07
Ba	[1]1.3		[1]2.2		.9	.01	0.04	.00
Na	1,550	67.42	1,740	75.69	9,090	395.4	324	14.09
K	4.3	.11	20	.51	151	3.86	62	1.58
Li	.2	.03	1.2	.17	Tr	.00	1.2	.17
NH_4	.0		2.6	.14	3.9	.22	0.7	.04
Total cations		67.84		78.22		420		[1]30.9
HCO_3	2,710	44.42	2,650	43.43	15,200	249	1,250	20.5
CO_3	0		84	2.80				
SO_4	22	.46	223	4.64	893	18.59	26	0.54
Cl	710	20.02	830	23.41	5,370	151.4	343	9.67
F	14	.74	5.8	.31				
Br	7.3	.09	3.5		29	.36	Tr	.00
I	4.1	.03	.6		15	.12	.05	.00
NO_2	.00		.00					
NO_3	.0		.0					
PO_4	.12		.12		Tr		.3	.00
B	7.4		1.4				2.9	
CO_2					3,100		1,030	
H_2S	.6							
Total anions		65.76		74.59		419		30.7
Total, as reported	5,070		5,600		[1]34,200		[1]3,360	
Specific conductance micromhos at 25° C	5,800		6,670					
pH	8.0		8.6					
Temperature °C			37		19.5			
Ratios by weight:								
Ca/Na	0.0021		0.0055		0.017		0.60	
Mg/Ca	.47		1.6		1.05		.34	
K/Na	.0028		.011		.017		.19	
Li/Na	.00013		.00069				.0037	
HCO_3/Cl[1]	3.8		3.4		2.8		3.6	
SO_4/Cl	.031		.27		.16		.076	
F/Cl	.020		.0070					
Br/Cl	.010		.0042		.0054			
I/Cl	.0058		.00072		.0027		.0001	
B/Cl	.10		.0017				.0085	

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[1] Includes CO_3 as equivalent HCO_3.

EXPLANATION FOR TABLE 14

1. Irrigation well, 250 ft deep, on border of Midway-Sunset oil field, sec. 34, T. 31 S., R. 24 E., Kern County, Calif. Sulfate water used for irrigation. Collected by J. M. Morris, Jr., California Division of Water Resources; analyzed by D. D. Watson, U.S. Geol. Survey; analysis not previously published.
2. Sulfate well water, 70 ft deep, west border of Coalinga oil field, NE¼ sec. 10, T. 20 S., R. 14 E., 6 miles northwest of Coalinga, Fresno County, Calif. In probable marine sandstone of Etchegoin or the Jacalitos Formation, Pliocene age. Sample collected by California Division of Water Resources, analyzed by U.S. Geol. Survey; analysis not previously published.
3. British American Oil Producing Co. well 1-E. T., Pilot Butte oil field north west of Riverton, NW¼ sec. 22, T. 3 N., R. 1 W., Fremont County, Wyo. Drilled in 1942 to 6,395 feet; producing from depths of 5,804 to 5,839 ft and 6,036 to 6,258 ft from Embar Formation of Permian and Triassic age. Collected by K. P. Moore, analyzed by H. C. Whitehead of the U.S. Geol. Survey, who also reported 0.00 ppm Cu, Pb, and Zn; density is 1.007. Quantitative spectrographic analysis by Nola B. Sheffey, converted to ppm in original water: Cu, 0.08; Ag, 0.003; Fe, 0.2; Cr, 0.01; Al, 0.2; Ti, 0.03; Sr, 9.6; Ba, 0.3; Li, 3.7; Rb, 0.1. Mo, W, Ge, Sn, Pb, Zn, Cd, Sb, Mn, Co, Ni, V, Ga, La, Zr, Be, and Cs are below detection limits in solids. Analysis not previously published.
4. Pure Oil Co. well No. F-11, South Casper Creek, west of Casper, Natrona County, Wyo., producing from Tensleep Sandstone of Pennsylvanian age from depths of 2,585 to 2,630 ft. Collected by K. P. Moore; analyzed by H. C. Whitehead of the U.S. Geol. Survey, who reported Pb, 0.01 ppm; Cu, 0.00 ppm. Quantitative spectrographic analysis, by Nola B. Sheffey, converted to ppm in original water: Cu, 0.005; Mn, 0.01; Ni, 0.04; Fe, 0.03; Cr, 0.005; Al, 0.03; Ti, 0.008; Sr, 5.7; Ba, 0.12. Ag, Mo, W, Ge, Sn, Pb, Zn, Cd, Sb, Co, V, Ga, La, Zr, Be are below detection limits in solids. Analysis not previously published.
5. Carbonate waste water, from East Side area of Coalinga oil field, SW¼ sec. 35, T. 19 S., R. 15 E., Freson County, Calif. Most oil production of this area is from Temblor Formation of Miocene age, from stratigraphic traps on east flank of Coalinga anticline. Collected by California Division of Water Resources; analyzed by U.S. Geol. Survey; analysis not previously published.
6. Sinclair Oil and Gas Co. Well 2, 6,014 ft deep, northeast of Edgerton, in SW¼ sec. 10, T. 40 N., R. 78 W., Natrona County, Wyo. Producing at depths of 4,566 to 4,604 ft from Frontier Formation of Upper Cretaceous age. Collected by K. P. Moore; analyzed by H. C. Whitehead of the U.S. Geol. Survey, who reported 0.00 ppm.Pb and Cu. Quantitative spectrographic analysis by Nola B. Sheffey, converted to ppm in original water: Cu, 0.06; Ni, 0.04; Fe, 0.1; Cr, 0.003; Al, 0.1; Sr, 0.7; Ba, 1.3; Li, 0.3. Ag, Mo, W, Ge, Sn, Pb, Zn, Cd, Sb, Mn, Co, V, Ga, La, Ti, Zr, Be, Rb, Cs are below detection limits in solids. Analysis not previously published.
7. Conrad Province Well 57-33b, sec. 33, T. 5, R. 15, west 4th meridian, Alberta, Canada. Drilled in 1946 to 3,026 ft; producing from a depth of 3,016 to 3,026 ft from Ellis Sandstone of Jurassic age. Collected by Brian Hitchon of the Research Council of Alberta; analyzed by H. C. Whitehead of the U.S. Geol. Survey, who also reported 0.00 ppm Cu, and Pb; 0.03 ppm Zn. Quantitative spectrographic analysis, by Nola B. Sheffey, converted to ppm in original water: Cu, 0.03; Ag, 0.04; Sn, 0.2; Ni, 0.04; Fe, 0.04; Al, 0.09; Zr, 0.01; Sr, 0.9; Ba, 2.2; Li, 1.1. Mo, W, Ge, Pb, Zn, Cd, Sb, Mn, Co, Cr, V, Ga, La, Ti, Be, Rb, and Cs are below detection limits in solids. Analysis not previously published.
8. Bicarbonate water, from well located at Bukkszek, about 60 miles northeast of Budapest, Hungary; water from depth of 450 ft from beds of probable Cretaceous age (Telegdi-Roth, 1950, p. 80, 83). Analyzed by K. Ernst, May 1937.
9. Bicarbonate water, from well located at Mezokovesd, about 70 miles east-northeast of Budapest, Hungary. Water from a depth of 2,870 ft, probably from Cretaceous or Triassic limestone (Telegdi-Roth, 1950, p. 80, 83). Analyzed by J. Karpat, May 1939. Also reported are 0 ppm, Ti, Cu, As, and H_2S; COS, 20 ppm.

TABLE 15.—*Chemical analyses of spring waters similar in composition to oil-field brines of the sodium chloride type*

Analysis	1		2		3		4		5		6	
Name of springs and location	Tuscan, Tehama County, Calif.		Wilbur, Colusa County, Calif.		Tolenas, Solano County, Calif.		Mercey, Fresno County, Calif.		Stinking, Springs Box Elder County, Utah		Bad Hamm, West Westphalia, Germany	
Date of collection	Dec. 14, 1955		Aug. 3, 1949		Oct. 3, 1956		June 13, 1955		April 5, 1958			
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	15		190		75		75		48		10	
Al	0.9		[1] 0.3		[1] 0.2				1.05		Tr	
Fe	.2		[1] .1		[1] .1				.03		20	
Mn	.3		[1] .3						.00		.2	
Ca	19	0.95	1.4	0.07	454	22.65	43	2.15	946	47.20	1,730	86.3
Mg	17	1.4	58	4.7	239	19.7	nil		297	24.4	262	21.5
Sr	[1] 13	.30	[1] .8	.18	12	.27	9	.21	[1] 31		65	1.47
Ba	72	1.05	[1] 1	.01	[1] 1.3				[1] 4.1		Tr	
Na	7,900	344.1	9,140	397.4	6,100	265.4	830	36.1	12,600	548	29,400	1,279
K	59	1.51	460	11.76	181	4.63	7.1	.18	571	14.60	360	9.21
Li	[1] 2.0	.29	14	2.0	9.0	1.30	0.1	.01	6.9	.99	11	1.6
NH_4	[1] 59	3.3	303	16.8	0.2	.01	5	.28	40	2.2	33	1.8
Total cations		353		433		314		38.9		637		1,400
HCO_3	1,060	17.4	7,390	121.2	6,340	103.9	13	0.21	324	5.31	1,530	25.1
CO_3	154	5.13	0	.00	0		31	1.03	0			
SO_4	0	.00	23	.48	.3	.01	5	.10	111	2.31	1,430	29.8
HS												
Cl	11,800	333	11,000	310	7,510	211.8	1,300	36.7	21,600	609	47,700	1,345
F	5	.26	1.1	.06	2	.11	.4	.02	1.9	.10		
Br	[1] 5.3	.07	[1] 15	.19	20	.25	None (?)		15	.19	17	0.21
I	[1] 1.3	.01	[1] 16	.13	3	.10	20	.16	1.3	.01	.2	.00
NO_2					0				.00			
NO_3					165	2.66	.5	.01	.0			
PO_4	0.5	0.02							.00		.2	.00
B	[1] 201		292		360		10		3.6		770	
CO_2												
H_2S	172		178		0				60		Tr	
Total anions		356		432		319		38.2		617		1,400
Total, as reported	21,600		29,100		21,500		2,350		36,600		83,300	
Specific conductance micromhos at 25° C	32,500		33,600		24,600		2,160		53,900			
pH	8.4		7.2		6.7		8.6		6.7			
Temperature °C	28½		57		20.0		46		48		33	
Density at 20° C	1.009		1.016		1.012				1.025			
Ratios by weight:												
Ca/Na	0.0024		0.00015		0.074		0.051		0.075		0.058	
Mg/Ca	.89		41		.53		<.02		.31		.15	
K/Na	.0074		.050		.029		.0086		.045		.012	
Li/Na	.00025		.0015		.0015		.0001		.00055		.00037	
HCO_3/Cl [2]	.12		.66		.85		.058		.015		.032	
SO_4/Cl	.0000		.0021		.00004		.004		.0051		.030	
F/Cl	.00036		.00009		.0003		.0003		.000088			
Br/Cl	.00045		.0014		.0026		<.001(?)		.00069		.00036	
I/Cl	.00011		.0015		.0017		.015		.000060		.000004	
B/Cl	.017		.036		.048		.0076		.00017			

Analysis	7		8		9		10		11		12	
Name of springs and location	Bad Hall, SW. of Linz, Austria		Smrdaky, ESE. of Breclav, Czechoslovakia		Chokrak, Crimea, USSR		Toyotomi, Hokkaido Prefecture, Japan		Isobe, Gumma Prefecture, Japan		Hanmer, South Island, New Zealand	
Date of collection					Oct. 1, 1937							
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	8.9		29		20		20		45			
Al	Tr						<0.1		0.3		1.0	
Fe	6.1		3.0				0.5		6			
Mn	Tr											
Ca	244	12.18	81	4.04	495	24.7	76	3.79	220	10.98	10	0.50
Mg	156	12.8	53	4.4	441	36.3	32	2.6	47	3.9	.3	.02
Sr	13	.30										
Ba												
Na	6,460	281.0	925	40.24	[1] 9,640	419.3	4,200	182.7	10,400	452	379	16.48
K	10	.26	38	.97	441	11.28	320	8.19	290	7.4	4.0	.10
Li	2.3	.33										
NH_4	52	2.9	4.2	0.23	150	8.32			[1] 20	1.11	3.0	.17
Total cations		310		49.9		500		197		475		17.3
HCO_3	425	6.97	410	6.72	1,010	16.5	1,690	27.7	7,510	123.1	196	3.21
CO_3												
SO_4	0	.00	11	.23	1.1	.02	<0.5	.00	21	.44	19	.39
HS			78	2.36	139	4.20					4.7	.14
Cl	10,700	302	1,390	39.2	16,900	477	6,230	175.7	12,700	358	483	13.61
F												
Br	78	.98	Present		133	1.66	17	.21	20	.25		
I	39	.31	2.2	0.02	45	0.36	24	.19	47	.37		
NO_2	.03	.00										
NO_3			0									
PO_4			Present						[1] 9			
B	42		Present		18		148		128		49	
CO_2	26		11		394				1,160			
H_2S			577		279							
Total anions		310		48.5		500		204		482		17.4
Total, as reported	18,300		3,610		30,100		12,800		32,600		1,150	

See footnotes at end of table.

TABLE 15.—*Chemical analyses of spring waters similar in composition to oil-field brines of the sodium chloride type*—Continued

Analysis	7	8	9	10	11	12
Name of springs and location	Bad Hall, SW. of Linz, Austria	Smrdaky, ESE. of Breclav, Czechoslovakia	Chokrak, Crimea, USSR	Toyotomi, Hokkaido Prefecture, Japan	Isobe, Gumma Prefecture, Japan	Hanmer, South Island, New Zealand
Date of collection			Oct. 1, 1937			
Specific conductance micromhos at 25 °C						
pH			7.2	7.9	8.2	8.0
Temperature °C	Cold(?)	12	Cold	42	16.2	49
Density at 20° C			1.02			
Ratios by weight:						
Ca/Na	0.038	0.084	0.051	0.018	0.021	0.026
Mg/Ca	.63	.65	.89	.42	.21	.03
K/Na	.0015	.041	.046	.076	.028	.011
Li/Na	.00035					
HCO_3/Cl[2]	.040	.29	.060	.27	.59	.41
SO_4/Cl	.0000	.0079	.000065	.0000	.0017	.039
F/Cl						
Br/Cl	.0073		.0078	.0027	.0016	
I/Cl	.0036	.0016	.0027	.0038	.0037	
B/Cl	.0039		.0011	.024	.010	.10

[1] Components mentioned in explanation of table.

[2] Includes CO_3 as HCO_3.

EXPLANATION FOR TABLE 15

1. Spring, rising in large concrete-lined pool in southern part of Tuscan area, NE¼ sec. 32, T. 28 N., R. 2 W., Tehama County, Calif. Probably from rocks of Cretaceous Chico Formation overlain unconformably by volcanic agglomerate of Pliocene Tuscan Formation. Flows about 10 gpm; total flow of springs from area about 30 or 40 gpm; no spring deposits, but travertine veins are in bedrock. Analyzed spring has little associated gas but combustible gas is present in nearby "Natural Gas" Spring (Waring, 1915, p. 290). Collected by R. C. Scott, U.S. Geol. Survey; analyzed by B. V. Salotto, who also found 5.2 μμc per l Ra and 6 μg per l U. He also reported Cu, 0.00 ppm; Zn, 0.00 ppm. Li, NH_4, Sr, Br, I, and B determined by H. Kramer, C. E. Roberson, and P. W. Scott of U.S. Geol. Survey in sample collected June 9, 1954, having same Cl content. Analysis not previously published.
2. Main spring, spring 22, Wilbur, NW¼ sec. 28, T. 14 N., R. 5 W., Colusa County, Calif. Discharge of spring is 15 gpm and discharge of group is about 40 gpm (White, 1957b, p. 1674–1677; Waring, 1915, p. 99–103). From rocks of Knoxville Formation of Late Jurassic age, near serpentine intrusions (W. B. Meyers, U.S. Geol. Survey, written communication). No spring deposits, but water is associated with quicksilver and gold deposits. Analyzed by W. W. Brannock of U.S. Geol. Survey, who also reported 0.0 ppm Sb and 0.0 ppm As. Components determined on later samples of similar chloride content: Determinations of Br and I by Brannock; 0.2 ppm Hg by J. D. Pera of Buckman Laboratories Inc.; Fe; Al; Mn; Cu, 0.00 ppm; Zn, 0.00 ppm; 3 μμc per l Ra and 0.8 μg per l U reported by B. V. Salotto; Sr and Ba determined by spectrographic analysis; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in the original water: evaporated residue at 180° C, 23,500; Fe, 0.1; Cu, 0.05; Ag, 0.02; Pb, 1.4; Cr, 0.07; W, 9.4; Li, 12; Rb, 1.2; Cs, 0.7; Sr, 1.4; Ba, 1.9. See table 23, analysis 2, for water analysis from Abbott quicksilver mine, 2 miles to southwest.
3. Spring, near crest of ridge at Tolenas, 4 miles north of Fairfield, sec. 1, T. 5 N., R. 2 W, Solano County, Calif. About ¼ gpm of water and at least as much gas discharging near crest of travertine ridge, about 200 ft long, on interbedded shale and sandstone of Cretaceous Chico Formation (Waring, 1915, p. 162–163; Weaver, 1949, p. 106–107). Gas is not combustible and probably is largely CO_2; total discharge of water from area is only a few gpm. Analyzed by C. E. Roberson, U.S. Geol. Survey; As, 0.00 ppm also reported; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in original water: evaporated residue at 180° C, 17,700; Al, 0.2; Fe, 0.1; Cu, 0.02; Sr, 0.7; Ba, 1.3. Analysis not previously published.
4. Main spring, Mercey, SE¼ sec. 15, T. 14 S., R. 10 E. Fresno County, Calif. Flows 7 to 10 gpm from gravels overlying fractured greenstone associated with Franciscan Sandstone of Late Jurassic or Early Cretaceous age. The water may rise along a fault zone close to the contact of Franciscan and Cretaceous Chico Formations (Anderson and Pack, 1915, p. 212–213). Spring is 3 miles southeast of Mercey quicksilver mine (Yates and Hilpert, 1945). Analyzed by H. Almond and S. Berman, U.S. Geol. Survey. Analysis not previously published.
5. Stinking Springs, also known as Lampo or Connors Springs, NW¼ sec. 30, T. 10 N., R. 3 W., 6.8 miles northwest of Corinne and immediately north of Great Salt Lake, Box Elder County, Utah. Sampled spring discharges about 30 gpm and is easternmost and largest spring of a group that has total discharge of about 75 gpm from near contact of Quaternary sediments and Lower Carboniferous limestone (Emmons, 1893, p. 386). Collected by J. H. Feth, analyzed by J. P. Schuch of U.S. Geol. Survey; also determined are SO_3, 0 ppm; As, 0.00 ppm. Spectrographic analysis of evaporated residue by Nola B. Sheffey, converted to ppm in original water: evaporated residue at 180°C, 37,300; Al, 0.8; Fe, 0.2; Mn, 0.1; Cu, 0.04; Sr, 31; Ba, 4.1. Analysis not previously published.
6. Well, 2,130 ft deep, near Bad Hamm, Ruhr district, West Germany, in Kreide Formation of Late Cretaceous age (Himstedt, 1907, p. 163). Analyzed by C. R. Fresenius, 1882; methane present.
7. Upper Gunther well, Bad Hall, north-central Austria, 25 miles southwest of Linz (Schmölzer, 1955, p. 197); drilled in area of springs known and used since eighth century. Well is 820 ft deep in Molasse of Tertiary age, overlying Oligocene and Miocene sedimentary rocks. Also reported is a trace of Cu. Analysis of gas from one well is given in table 28, analysis 5 (Grill, 1952, p. 89).
8. Well 6, in spring area at Smrdaky, about 20 miles east-southeast of Breclav, in southwest Czechoslovakia; producing from depth of 990 ft from Burdigalian-Helvetian rocks of early and middle Miocene age (Janáček and Janák, 1956, p. 72–74, 96). Water also contains naphtha, and associated gases include H_2S and CH_4.
9. Resort with drilled wells, about 160 ft deep, in former cold-spring area on east border of Chokrak marsh, 1 mile from south shore of Sea of Azov and about 12 miles north of Kerch, Crimea, U.S.S.R. Water is from shale, limestone, and dolomite of Karagan and Chokrak Formations of Tertiary age (Fomichév, 1948, p. 221–232). Analyzed by I. S. Krasnikova and M. S. Svemina. Na reported as 642 ppm, but reported equivalents and strong unbalance of cations and anions clearly indicate that this figure is a misprint for 9,462 ppm. Analysis is Fomichév's type 2; for his type 1. see table 22, analysis 6.
10. Toyotomi, near northwestern tip of Hokkaido, Japan. Spring discharges from Pliocene sandstone and mudstone, probably marine (Muto, 1954, p. 408–409). Nearest Quaternary volcanic rocks are those of Pleistocene Rishiri volcano, an island 25 miles to the west.
11. Isobe, Gumma Prefecture, in central part of Honshu, Japan. Spring discharges 2 gpm from middle or late Miocene sandstone, shale, and conglomerate (Muto, 1954, p. 408–409). Nearest Quaternary volcano is Haruna, 10 miles to the north-northeast (H. Kuno, written communication). Analyzed by Muto (1954, p. 409) except for NH_4 and PO_4, which are analyzed by Tokyo Hygienic Laboratory, 1930 (Morimoto, 1954, p. 246–247).
12. Springs and well, 300-ft deep, at Hanmer, near south base of Seaward Kaikoura Range, South Island, New Zealand. Discharge is from thick alluvial gravel overlying graywacke of Mesozoic age (J. Healy, written communication). For gas analysis (Farr and Rogers, 1929, p. 300–308) see table 28, analysis 6.

TABLE 16.—*Chemical analyses of spring waters similar to oil-field brines of the sodium calcium chloride type*

Analysis	1		2		3		4		5		6		7		8	
Name and location	London, Lane County, Oreg.		Willow Creek, Shasta County, Calif.		Utah, Weber County, Utah		Saratoga, Saratoga County, N.Y.		Tolsona, Copper River Basin, Alaska		Wiesbaden, N. of Mainz, Germany		Thermopotamos, Euboea Island, Greece		Trompsberg, Orange Free State, Union of South Africa	
Date of collection	Sept. 3, 1957		Nov. 30, 1956		Apr. 5, 1958		Aug. 7, 1938		Sept. 21, 1956							
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	19		22		38		13		16		64		58		26	
Al	0.12		0.04		0.46		3.4		0.2				0.2		[1]1	
Fe	.00		[1].05		.42		1.8		.3		3.0		1.1			
Mn	.00		.00		1.9		[1]0.003				0.7		.02		[1]Tr	
Cu	.00		[1].05		.00						0.001					
Pb	.00		.00		.01											
Zn	.00		.00		.00				.01							
As	.13		.00		.00						.08					
Ca	480	23.95	1,120	55.9	1,140	56.9	623	31.09	787	39.27	344	17.17	1,780	88.8	473	23.6
Mg	29	2.4	2.4	.20	70	5.8	197	16.2	111	9.13	48	4.0	329	27.1	20	1.6
Sr	[1]7.9		[1]6.6		[1]28				[1]51	1.16	12	.27			7.2	0.16
Ba	[1]5.7		[1].2		[1]1.1		13	.18	14	.20	0.7	.01			[1]1	.01
Na	810	35.24	2,670	116.1	7,030	305.8	2,030	88.3	4,660	202.7	2,660	115.7	10,000	435	2,670	116.1
K	8.2	.21	7.5	.19	901	23.05	380	9.72	60	1.53	95	2.43	441	11.28	16	.41
Li	.0		2.2	.32	9.9	1.43	7.6	1.09	[1]0.5	.07	3.5	.50	.5	.07	[1]6	.8
NH_4	.0		21	1.16	5.4	.30	11	.61	5.6	.31	7.0	.39	1.1	.06	nil	.00
Total cations		61.8		174		393		147		254		140		562		143
HCO_3	76	1.25	0	0.00	192	3.15	3,870	63.4	143	2.34	595	9.75	590	9.67	None(?)	0.00
CO_3	0.8		20	.67	0				0						60	2.00
SO_4	1.2	.02	38	.79	189	3.93			0.0	.00	63	1.31	1,120	23.3	946	19.70
Cl	2,100	59.2	6,080	171.5	13,300	375	2,970	83.8	8,870	250.1	4,590	129.6	18,500	522	4,250	119.9
F	.0		.0		3.2	.17			0.3	0.02					3.6	.19
Br	3.7	.05			8.2	.10	9.4	.12	17	0.21	2.5	.03	62	.78	Nil	.00
I	.2	.00			.2	.00	1.0	.01	3.7	.03	.02	.00	.08	.00		
NO_2	.02	.00	.00		.00				.00	.00	[1].4	.01			Nil	.00
NO_3	9.3	.15	6.6	.11	.0				.07	.01	[1].6	.01			Nil	.00
PO_4	.34				.00						.03		.04			
B	3.0		1.8		5.1				35		1.0		6.6		[1]4	
CO_2											234		338			
H_2S			.1		.0											
Total anions		60.7		173		382		147		253		141		556		142
Total, as reported	3,550		10,000		22,900		10,100		14,800		[1]8,730		33,200		8,480	
Specific conductance micromhos at 25° C	6,270		14,300		34,300				23,600							
pH	7.6		9.0		7.3		6.2		7.1		6.81		6.65		8.95	
Temperature ° C	Slightly warm		17		57		Cold		Cold		65.3		78.2		37	
Density at 20°			1.004		1.013				1.008				1.025			
Ratios by weight:																
Ca/Na	0.59		0.42		0.16		0.31		0.17		0.13		0.18		0.17	
Mg/Ca	.060		.0022		.061		.32		.14		.14		.19		.042	
K/Na	.010		.0028		.13		.19		.013		.036		.044		.0059	
Li/Na	.0000		.00083		.0014		.0037		.0001		.0013		.00005		.0022	
HCO_3/Cl[2]	.036		.0066		.014		1.3		.016		.13		.032		.029	
SO_4/Cl	.00057		.0063		.014		.000		.00000		.014		.061		.22	
F/Cl	.0000		.00000		.00024				.00003						.00084	
Br/Cl	.0018				.00062		.0032		.0019		.00054		.0034		.0000	
I/Cl	.0001				.00002		.00034		.00042		.00000		.00000			
B/Cl	.0014		.00030		.00038				.0039		.00021				.001	

Analysis	9		10		11		12		13		14		15	
Name and location	Ain Djebel, SSW. of Tunis, Tunisia		Tiberias, Near Sea of Tiberias, Israel		Geyser Suyu, Anatolia, Turkey		Staraia Matsesta, Abkhaz, USSR		Neshkin, Siberia, USSR		Arima, Hyōgo Prefecture, Japan		Naganuma, Yamagata Prefecture, Japan	
Date of collection														
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	20		23		22		[1]17		95		146		72	
Al	13				3.2				9.3		71		.9	
Fe	5		7.8		.06				.1		157		4.3	
Mn											42			
Cu											.1			
Pb											.4			
Zn											.2			
As											0			
Ca	1,000	49.9	3,930	196.1	3,190	159.2	538	26.85	3,490	174.2	3,880	193.6	2,310	115.2
Mg	275	22.6	825	67.9	65	5.3	180	14.8	25	2.1	38	3.13	162	13.3
Sr							29	.66			2.0	.05		
Ba											59	.86		
Na	5,240	227.9	6,910	300.6	18,600	809.1	3,560	154.7	6,190	269.3	19,600	853	7,080	308.0
K	283	7.24	77	1.97	1,990	51.0	138	3.53	840	21.5	4,440	113.6	554	14.16
Li	1	.1					1.2	.17			53	7.6	1.7	.24
NH_4					4.3	.24	8.3	.46			44	2.44	.7	.04
Total cations		308		567		18,025		201		467		[1]1,174		451
HCO_3	204	3.34	366	5.98	64	1.05	384	6.29	27	0.44	567	9.29	69	1.13
CO_3	400	13.33			0	.00								
SO_4	3,000	62.5	891	18.53	149	3.10	1.9	.04	1.2	.02	0.0	.00	4.9	.10
Cl	8,290	233.8	19,200	541	36,100	1,018	6,060	170.9	16,500	465	41,700	1,176	15,900	449
F											.7	.04		
Br	68	.85	1.4	.02			26	.33			52	.65	34	.43
I	Tr	.00					3.7	.03			.9	.01	17	.13
NO_2	0.2	.00									0	.00		
NO_3	1.2	.02			68	1.10					0	.00		
PO_4	Tr				2.2						1.4			
B							13				535		3.6	
CO_2					96		[1]119				370		31	
H_2S	0.3		28				[1]248		Present		.9		4	
Total anions		314		566		1,023		178		465		1,186		451
Total, as reported	18,800		32,300		60,400		11,300		27,200		[1]71,800		26,200	

See footnotes at end of table.

TABLE 16.—*Chemical analyses of spring waters similar to oil-field brines of the sodium calcium chloride type*—Continued

Analysis	9	10	11	12	13	14	15
Name and location	Ain Djebel, SSW. of Tunis, Tunisia	Tiberias, Near Sea of Tiberias, Israel	Geyser Suyu, Anatolia, Turkey	Staraia Matsesta, Abkhaz, USSR	Neshkin, Siberia, USSR	Arima, Hyōgo Prefecture, Japan	Naganuma, Yamagata Prefecture, Japan
Date of collection							
Specific conductance micromhos at 25° C							
pH			6.2			5.8	7.7
Temperature ° C	54.5	61.9	100	24±	55	94.0	61
Density at 20°			1.047		(1)	(1)	1.017
Ratios by weight:							
Ca/Na	0.19	0.57	0.17	0.16	0.56	0.20	0.33
Mg/Ca	.28	.21	.020	.30	.0071	.0097	.070
K/Na	.054	.011	.063	.39	.14	.23	.078
Li/Na	.0002			.00034		.0027	.00024
HCO_3/Cl[2]	.12	.019	.0017	.063	.0016	.014	.0043
SO_4/Cl	.36	.044	.0041	.00031	.00007	.00000	.00031
F/Cl						.00002	
Br/Cl	.008	.00007		.0043		.0012	.0021
I/Cl	.0000			.00061		.00002	.0011
B/Cl				.0022			.00023

[1] Components mentioned in description.

[2] Includes CO_3 as HCO_3.

EXPLANATION FOR TABLE 16

1. Main spring, London, NW¼ sec. 40, T. 22 S., R. 3 W., Lane County, Oreg., discharges about 10 gpm from nonmarine tuffs and basalt flows of Calapooga Formation of Eocene age. Collected by Linn Hoover; analyzed by J. P. Schuch of U.S. Geol. Survey; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in the original water: evaporated residue at 180°C, 4,360; Al, 0.2; Fe, 0.4; Ti, 0.03; Cu, 0.004; Sr, 7.9; Ba, 5.7. Analysis not previously published.
2. Main spring of small group on Willow Creek, half a mile above junction with Crystal Creek, lat 40°40′ N., long 122°38′ W., Shasta County, Calif. Discharge of spring estimated at 1 gpm, and total discharge of group is 5 gpm; from fractured quartz prophyry dike cutting pillow lavas of Copely Greenstone of Paleozoic age. Collected by J. Albers, analyzed by H. C. Whitehead of U.S. Geol. Survey; also reported and included in totals, OH, 3.6 ppm (0.21 epm); spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in the original water: evaporated residue at 180°C, 10,700; Al, 0.3; Fe, 0.05; Cu, 0.05; Ag, 0.01; Sr, 6.6; Ba, 0.2. For analysis of gases, see table 28, analysis 7; collected by U.S. Bureau of Reclamation June 8, 1956. Analysis not previously published.
3. Spring, Weber County, Utah: northernmost of four springs near boundary between Weber and Box Elder Counties and 8 miles north of Ogden. Discharges about 25 gpm from alluvium overlying Pleistocene Lake Bonneville sediments near frontal fault of Wasatch Range. Collected by J. H. Feth; analyzed by J. P. Schuch, U.S. Geol. Survey; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in the original water: evaporated residue at 180° C, 23,200; Al, 0.7; Fe, 0.1; Ti, 0.1; Cu, 0.1; Sr, 28; Ba, 1.1. Analysis not previously published.
4. Coesa spring, Saratoga, Saratoga County, N.Y.; one spring of group emerging along fault in Canajoharie Shale of Middle Ordovician age overlying Little Falls Dolomite (Strock, 1941, p. 857); water also tapped by drilling to dolomite. Spring deposits consist of travertine. Analyzed by S. Drexler. Mn determined by L. W. Strock (average of Hayes and Orenda springs, very similar in Cl content to Coesa spring); also determined spectrographically, in ppm: Zr, 0.4; Sn, 0.03; Ti and V, each <0.0016; Co, <0.0005; Ni, 0.0003; Be, 0.001 (Strock, 1941, p. 860).
5. Southwestern spring, on crest of mud cone 1.5 miles west of V.A.B.M. Shepard and 0.3 mile north of Glenn Highway, Gulkana A–4 quadrangle, Copper River Basin, Alaska. Discharges 1 to 2 gpm of muddy water accompanied by little gas, including H_2S. Area is underlain by glacial deposits which 2 miles to the south are at least 500 ft thick. Possibly a few hundred feet of Eocene sand and gravel and probably a few thousand feet of marine siltstone and shale of Matanuska Formation of Late Cretaceous age beneath the till (A. Grantz, written communication). Sample collected by F. Robinson and F. Rucker; analyzed by G. Gaston; Sr and Li analyzed by C. E. Roberson, U. S. Geol. Survey. For gas analysis see table 28, analysis 8; collected by A. Grantz, Sept. 7, 1957, analyzed by U.S. Bureau of Mines. Analysis not previously published.
6. Kochbrunnen spring, eastern most of the four principal springs at Wiesbaden, north of Mainz, west-central Germany. Discharges 350 gpm from fault in mica gneiss (Michels, 1954, p. 113–117). Analysis by Fresenius and Fresenius (1936, p. 28–35), with NO_2 and NO_3 from a later very similar analysis (Michels 1954, p. 115). Also reported and included in totals: Rb, 0.4 ppm (0.00 epm); Cs, 0.3 ppm (0.00 epm). For gas analysis see table 28, analysis 9 (Fresenius and Fresenius, 1936, p. 32).
7. Thermopotamos spring, near northwest end of Euboea Island, Greece. Spring apparently discharges from fault in Devonian schist overlain by Carboniferous limestone east of major anticline (Pertessis, 1937, p. 93–94; Deprat, 1903). This is one of the new and hotter springs formed at time of major earthquake under Gulf of Euboea, April 27, 1894 (Dambergris, 1896, p. 385–393). Analysis reported as hypothetical chemical combinations (Pertessis, 1937, p. 93–94), converted to ppm.
8. T. G. 1 well, 4,700 ft. deep, near Trompsberg, south of Odendaalsrus, Orange Free State, Union of South Africa; lat 30°03′ S., long 25°44′ E. Artesian discharge of 500 gpm (Kent, 1949, table 3, p. 243, 248, 253) from norite, probably of Bushveld Complex of Precambrian age, overlain by Dwyka Series; water is highest in salinity of South African thermal waters. Kent suggests NaCl may be derived from leaching of Dwyka tillite, ground waters of which are shown by Bond (1946, p. 106–122) to be relatively high in NaCl. Analyzed by W. Sunkel and P. Kok, 1948. Mn, Al, Ba, Li, and B aré spectrographic determinations by B. Wasserstein.
9. Spring, Ain Djebel, located 20 miles south-southwest of Tunis, Tunisia; discharges 2½ gpm from large travertine deposit on Lower Cretaceous and Upper Jurassic sedimentary rocks near crest of faulted anticline (Berthon, 1927, p. 23, 94–110). Analysis in mg per l; sp gr not stated; reported quantities probably should be decreased by about 1 percent.
10. "Open" spring of Old Bath, west side of Sea of Tiberias, Israel, discharging from basalt of probable Tertiary age (A. Friedmann, 1913, p. 1493–1494; Luke and Keith-Roach, 1934, p. 401–402).
11. Geyser Suyu, in Kizilca Tuzlasi group of saline springs 3 miles southwest of Ayvacik, near Tuzla, in northwest Anatolia, Turkey (Caglar, 1948, p. 250, 253; Prof. E. Goksu, written communication). Geyser Suyu is not a true geyser but surges regularly to height of a few feet. Springs emerge along a fault at the base of a mountain chain of Tertiary andesite with marine Mio-Pliocene sedimentary rocks to the east; no Quaternary volcanic rocks nearby.
12. Staraia Matsesta well 8, in spring area 2 miles northwest of shore of Black Sea and 6 miles from Sochi, Abkhaz area, U.S.S.R. (Vinogradov, 1948, p. 26–27; Tsebricoff, 1928). Spring emerges from caves near a major fault on a large anticline in Upper Cretaceous marl overlain by Tertiary shale. Discharge of springs in area at least 140 gpm (Martel, 1904, p. 999–1001; Renngarten, 1927). Analysis is of well water and includes SiO_2, S_2O_3 (1 ppm), CO_2, and H_2S (including 100 ppm reported as HS) from a very similar analysis reported by Ovchinnikov (1947, p. 138) from Matsesta well 4.
13. Neshkin spring, about 20 miles south of Neshkin village on Chukchee Peninsula, Siberia, U.S.S.R. Discharge of two vents is about 80 gpm (Rabkin, 1937, p. 93-101) from crystalline schist of Silurian age; slight odor of H_2S. Analysis given in g per l; sp gr not given, but analysis converted to ppm by assuming sp gr of 1.02.
14. Tenmangu-no-yu spring of Arima group, 9 miles northeast of Kōbe, Honshu, Japan (Ikeda, 1949, 1955a, 1955b; Kimura, 1953); spring discharges from lower or middle Miocene rhyolite near a fault separating rhyolite from granite to the south (H. Kuno, written communication). Nearest Quaternary volcano is a small cone of olivine basalt at Yakuno, 41 miles to the northeast. Water analyzed by Ikeda (1955a, 1955b). Stated in g per l; sp gr not given but assumed to be 1.05; additional components, in ppm: Rb, 3.3 (0.04 epm); Cs, 2.4 (0.02 epm); V, 5.7; Cr, 0.09; Mo, 0.06; Ti, 2.5; Sb, 0; Be, 0.01; Ge, 0; Ga, 0; Ag, 0; Ni, 0.001; Co, 0.001; Bi, 0; Cd, 0; In, 0; Sn, 0.0005; Ra, 212×10^{-12}; Th, 250×10^{-17}; Rn, 510×10^{-12} in curies per l.
15. Naganuma, Yamagata Prefecture, northern Honshu, Japan. Springs discharge 35 gpm from alluvium overlying Miocene or Pliocene sediments. Nearest Quaternary volcanoes are Chōkai, 20 miles to north-northeast, and Gassan, 20 miles to south-southeast (H. Kuno, written communication). Analyzed by Yamagata Hygienic Laboratory, 1949 (Morimoto, 1954, p. 150–151).

TABLE 17.—*Chemical analyses of thermal waters from geyser areas in volcanic environments*

Analysis	1		2		3		4		5		6		7	
Name and location	Upper Basin, Yellowstone Park, Wyo.		Norris Basin, Yellowstone Park, Wyo.		Steamboat Springs, Washoe County, Nev.		Beowawe Geysers, Eureka County, Nev.		Morgan, Tehama County, Calif.		Geyser Bight, Umnak Island, Alaska		Haukadalur, ENE. of Reykjavik, Iceland	
Date of collection	Oct. 16, 1957		Aug. 3, 1951		Aug. 9, 1949		Sept. 1, 1957		July 29, 1949		Aug. 17, 1946		Aug. 31, 1958	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	363	--------	[1] 529	--------	293	--------	373	--------	233	--------	150	--------	359	--------
Al	.2	--------	--------	--------	[1] .5	--------	.0	--------	--------	--------	--------	--------	.89	--------
Fe	.06	--------	--------	--------	[1] 0.05	--------	.04	--------	[1] .2	--------	[1] .1	--------	.02	--------
Mn	.0	--------	--------	--------	[1] .05	--------	.0	--------	--------	--------	[1] .01	--------	.00	--------
As	1.5	--------	3.1	--------	2.7	--------	.02	--------	2.2	--------	3.8	--------	.06	--------
Sb	--------	--------	0.1	--------	0.4	--------	--------	--------	.0	--------	None	--------	--------	--------
Ca	.8	0.04	5.8	0.29	5.0	0.25	.8	0.04	79	3.94	40	2.00	.4	0.02
Mg	.0	--------	.2	.02	.8	.06	.0	--------	.8	.06	.2	.02	.5	.04
Sr	0.	--------	[1] .4	.00	[1] .5	.01	0.	--------	[1] 14	.32	[1] .3	--------	[1] .02	--------
Na	352	15.3	439	19.1	653	28.4	230	10.00	1,400	60.9	350	15.22	233	10.14
K	24	.61	74	1.89	71	1.82	16	.41	196	5.01	18	.46	11	.28
Li	5.2	.75	8.4	1.21	7.6	1.10	1.3	.19	9.2	1.32	2	.29	.2	.03
NH_4	.0	--------	.1	.00	<1	--------	.5	.03	<1	--------	<0.1	--------	.1	.01
Total cations	--------	16.7	--------	22.5	--------	31.6	--------	10.67	--------	71.6	--------	18.0	--------	10.50
HCO_3	0	--------	27	0.44	305	5.00	116	1.90	52	0.85	29	0.48	0	--------
CO_3	70	2.33	0	--------	0	--------	149	4.97	0	--------	10	.33	128	4.27
SO_4	23	.48	38	.79	100	2.08	89	1.85	79	1.64	130	2.71	102	2.12
Cl	405	11.42	744	20.98	865	24.39	30	.85	2,430	68.5	482	13.59	126	3.55
F	25	1.32	4.9	.26	1.8	.09	15	.79	1.5	.08	1.2	.06	12	.63
Br	1.5	.02	.1	.00	0.2	.00	.4	.00	[1] 0.8	.01	--------	--------	.2	--------
I	.3	.00	.0	--------	0.1	.00	.0	--------	[1] 0.0	--------	--------	--------	.0	--------
NO_3	1.8	.03	--------	--------	--------	--------	.4	.01	--------	--------	None	--------	.0	--------
PO_4	1.3	--------	--------	--------	--------	--------	.07	--------	--------	--------	--------	--------	.09	--------
B	4.4	--------	12	--------	49	--------	2.0	--------	88	--------	49	--------	1.1	--------
H_2S	2.6	--------	.0	--------	4.7	--------	5.5	--------	0.7	--------	--------	--------	2.7	--------
Total anions	--------	[1] 17.1	--------	22.5	--------	31.6	--------	10.37	--------	71.1	--------	17.2	--------	[1] 10.75
Total, as reported	[1] 1,310	--------	1,890	--------	2,360	--------	1,030	--------	4,590	--------	1,270	--------	[1] 980	--------
Specific conductance micromhos at 25°C	1,790		2,490		3,210		1,050		6,920		--------		1,150	
pH	9.6		7.5		7.9		9.5		7.8		[1] 6.9		9.7	
Temperature °C	94		84.5		89.2		96		95.4		101.5		100	
Ratios by weight:														
Ca/Na	0.002		0.013		0.0077		0.003		0.056		0.11		0.002	
Mg/Ca	.0		.03		.2		.0		.01		.005		1.3	
K/Na	.068		.17		.11		.070		.14		.051		.047	
Li/Na	.015		.019		.012		.0057		.0066		.006		.0004	
HCO_3/Cl [2]	.35		.036		.35		14		.021		.10		2.1	
SO_4/Cl	.057		.051		.12		3.0		.033		.26		.81	
F/Cl	.062		.0066		.0021		.50		.00061		.0024		.10	
Br/Cl	.0037		.0001		.0002		.013		.0003		--------		.0016	
I/Cl	.0007		.0000		.0001		.00		.0000		--------		.000	
B/Cl	.011		.015		.057		.067		.036		.10		.0096	

Analysis	8		9		10		11		12		13		14	
Name and location	Reykjanes, SW. of Reykjavik, Iceland		Hveravellir, West-central, Iceland		Shumhaya, Kamchatka, USSR		Geizernye, Kamchatka, USSR		Pauzhetsk, Kamchatka, USSR		Tokaanu, North Island, New Zealand		Wairakei, North Island, New Zealand	
Date of collection	Sept. 4, 1958		Aug. 31, 1958		--------		Sept. 27, 1951		Oct. 18, 1950		--------		--------	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	[1] 97	--------	609	--------	294	--------	256	--------	[1] 190	--------	302	--------	386	--------
Al	.66	--------	.55	--------	.8	--------	.0	--------	.0	--------	5.7	--------	--------	--------
Fe	.28	--------	.21	--------	5.0	--------	.0	--------	.0	--------	None	--------	--------	--------
Mn	.05	--------	.00	--------	[1] .02	--------	.0	--------	--------	--------	--------	--------	--------	--------
As	.12	--------	.05	--------	--------	--------	.1	--------	1.1	--------	--------	--------	--------	--------
Sb	--------	--------	--------	--------	[1] .1	--------	--------	--------	--------	--------	--------	--------	--------	--------
Ca	2,200	109.78	2.0	0.10	15	0.75	27	1.35	64	3.20	44	2.20	26	1.29
Mg	45	3.70	.5	.04	15	1.23	3.7	.30	10	.41	.4	.03	<0.1	--------
Sr	[1] 15	--------	.003	--------	[1] .01	--------	--------	--------	--------	--------	--------	--------	--------	--------
Na	13,800	600.3	156	6.79	456	19.84	597	25.96	1,010	44.4	2,180	94.8	1,130	49.2
K	1,920	49.11	15	.38	93	2.38	60	1.53	88	2.25	216	5.52	146	3.73
Li	7.4	1.07	.2	.03	--------	--------	--------	--------	--------	--------	--------	--------	12.	1.73
NH_4	1.4	.08	.1	.01	.8	.04	.0	--------	--------	--------	1.8	.10	.9	.05
Total cations	--------	764.04	--------	7.35	--------	24.2	--------	[1] 29.1	--------	50.2	--------	102.7	--------	56.0
HCO_3	5	0.08	112	1.84	89.	1.46	81	1.33	37	0.60	70	1.15	35	0.57
CO_3	0	--------	17	.57	0(?)	--------	38	1.27	9.0	.30	0	--------	0(?)	--------
SO_4	128	2.66	178	3.71	150	3.12	114	2.37	83	1.73	74	1.54	35	.73
Cl	27,400	772.68	63	1.78	700	19.74	859	24.22	1,680	47.5	3,410	96.2	1,930	54.4
F	.7	.04	3.3	.17	1.2	.06	--------	--------	.8	.04	--------	--------	6.2	.33
Br	98	1.23	.0	--------	8.0	.10	1.3	.01	3.2	.03	--------	--------	--------	--------
I	.5	--------	.0	--------	--------	--------	.0	--------	.0	--------	--------	--------	--------	--------
NO_3	.9	.01	.3	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
PO_4	.16	--------	.14	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
B	13	--------	.68	--------	8.4	--------	21	--------	[1] 31	--------	99	--------	26	--------
H_2S	0.2	--------	2.5	--------	--------	--------	--------	--------	--------	--------	--------	--------	1.1	--------
Total anions	--------	776.70	--------	8.07	--------	24.5	--------	[1] 29.2	--------	50.2	--------	98.9	--------	56.6
Total, as reported	45,700	--------	1,160	--------	[1] 1,840	--------	2,060	--------	3,210	--------	6,400	--------	[1] 3,750	--------

See footnotes at end of table.

TABLE 17.—*Chemical analyses of thermal waters from geyser areas in volcanic enviroments*—Continued

Analysis	8	9	10	11	12	13	14
Name and location	Reykjanes, SW. of Reykjavik, Iceland	Hveravellir, West-central, Iceland	Shumhaya, Kamchatka, USSR	Geizernye, Kamchatka, USSR	Pauzhetsk, Kamchatka, USSR	Tokaanu, North Island, New Zealand	Wairakei, North Island, New Zealand
Date of collection	Sept. 4, 1958	Aug. 31, 1958	---	Sept. 27, 1951	Oct. 18, 1950	---	---
Specific conductance micromhos at 25°C	63,800	842	---	---	---	---	---
pH	6.7	8.7	8.4	8.7	8.4	7.4	8.6
Temperature °C	100	90.5	98	98.9	100.6	Boiling	Boiling
Ratios by weight:							
Ca/Na	0.16	0.013	0.033	0.045	0.063	0.020	0.023
Mg/Ca	.020	.3	1.0	.14	.16	.009	.00
K/Na	.14	.096	.20	.10	.087	.099	.13
Li/Na	.0001	.0006	---	.0	---	---	.011
HCO_3/Cl [2]	.0002	2.4	.13	.18	.033	.021	.018
SO_4/Cl	.0047	2.8	.21	.13	.049	.022	.018
F/Cl	.00003	.052	.0017	---	.0005	---	.0032
Br/Cl	.0036	.000	.011	.0015	.0019	---	---
I/Cl	.00002	.000	---	.0000	.0000	---	---
B/Cl	.00047	.011	.012	.024	.018	.029	.013

[1] Components mentioned in explanation of table.

[2] Includes CO_3 as HCO_3.

EXPLANATION FOR TABLE 17

1. Spring, 50 feet south of Upper Basin drill hole described by Fenner (1936, p. 228–281; White, 1955a, p. 103–105); located northwest of Old Faithful Inn and 650 feet south of Three Sisters springs in Upper Basin of Yellowstone National Park, Wyo. Discharges 10 to 15 gpm from hydrothermally altered dacite obsidian of probable late Pliocene age overlain by 213 ft of Pleistocene sediments and 7 ft of siliceous sinter. A maximum temperature of 180° C was measured at a depth of 406 ft, the bottom of the hole. Analyst, H. C. Whitehead, U.S. Geol. Survey; also determined are Zn, Pb, NO_2, Ti, and Cu, each 0.00 ppm; OH, 26 ppm (1.53 epm, included in total); spectrographic analysis on evaporated residue, by Nola B. Sheffey, converted to ppm in original water: evaporated residue at 180° C, 1,320, Al, 0.9; Fe, 0.04; Ga, 0.03; Ti, 0.004; Cu, 0.003; Mo, 0.06; W, 0.1; Cr, 0.001; Ge, 0.05; Li, 11; Rb, 0.2; Cs, 0.3; Sr, 0.004; Ba, 0.1. For analysis of gas from drill hole see table 28, analysis 10 (Allen and Day, 1935, p. 86). Analysis not previously published.
2. Unnamed spring with small periodic discharge, Norris Basin, Yellowstone National Park, Wyo. Spring is depositing much silica 200 ft southwest of Pearl geyser (White, 1957a, p. 1640–1641; Allen and Day, 1935, p. 482–483) and about 700 ft northwest of spring given in table 19, analysis 1. Bedrock is welded rhyolite tuff overlain by alluvium and sinter. In drill hole, 3,000 ft to north temperature of 205° C was measured at a depth of 246 ft (Fenner, 1936, p. 289–292; White, 1955a, p. 103–110). Analysts, P. Scott, W. W. Brannock; Sr determined by C. E. Roberson, U.S. Geol. Survey. Also reported is Hg, 0.0 ppm. For gas analysis see table 28, analysis 11; sample from similar slightly alkaline spring in northeastern part of Norris Basin (Allen and Day, 1935, p. 86, 468–469).
3. Spring 8, near east edge of Main Terrace, Steamboat Springs, 10 miles south-southeast of Reno, NE¼ sec. 33, T. 18 N., R. 20 E., Washoe County, Nev. Discharge is 0.25 gpm; total for whole spring system is about 700 gpm. GS–5 drillhole, 250 ft to northwest of the spring, penetrated 84 ft of sinter, 71 ft of altered alluvium and, finally, altered granodiorite. Maximum temperature of 172° C was found at a depth of 379 ft (White, 1955a, p. 103–104, 110–113; 1957a, p. 1639–1647). Analyst, W. W. Brannock, U.S. Geol. Survey. Fe, Al, Mn, Sr, and Ba (0.05 ppm) by spectrographic analysis. For gas analysis see table 28, analysis 12; sample from spring of lower temperature (73° C) 130 ft to northwest.
4. Large spring at base of terrace, Beowawe Geysers, Eureka County, Nev., described by Nolan and Anderson (1934, p. 224–226); periodic discharge ranges from 0 to 75 gpm. Bedrock of terrace is basaltic andesite, overlain by opaline sinter (Nolan and Anderson, 1934, p. 216–218). Analyst, H. C. Whitehead, U.S. Geol. Survey, who also determined Cu, Pb, Zn, Ti, NO_2, each 0.00 ppm. Analysis not previously published.
5. Growler spring, Morgan, NE¼ sec. 11, T. 29 N., R. 4 E., Tehama County, Calif., on east fork of Mill Creek, about 5 miles south of active Mount Lassen volcano (White, 1957a, p. 1640). Discharges 7 to 10 gpm from Brokeoff Andesite (Williams, 1932, map), overlain by alluvium and a little sinter. Analyst, W. W. Brannock, U.S. Geol. Survey; also determined on other samples from same spring are Hg (0.0 ppm), Br, and I by Brannock; Sr by H. Almond; U (0.5 ppb), Cr (0.01 ppm) (spectrographic), and Fe (0.2 ppm) by others of U.S. Geological Survey.
6. Geyser H-1, 4½ miles southeast of Geyser Bight, Umnak Island, Alaska (Byers and Brannock, 1949, p. 720, 726–730). Discharges 175 gpm from monzonite and Plio-Pleistocene basalt flows of Mount Recheschnoi, overlain by alluvium. Area is 20 miles southwest of active basalt volcano, Okmok. Analyst, W. W. Brannock. Also reported is Mo, 0.005 ppm; Fe, Mn, and Sr determined spectrographically.
7. Sisjodandi spring, which occasionally erupts as a small geyser, about 1,500 ft south of Geysir, near the south end of the thermal area east-northeast of Reykjavik, Iceland (Barth, 1950, p. 95–100). Discharges from siliceous sinter and alluvium, probably underlain by late Cenozoic sodic rhyolite and surrounded by basaltic lava flows and breccias. Collected by Gunnar Bodvarsson, State Electricity Authority; analyzed by C. E. Roberson of U.S. Geological Survey, who also reported Cu, Pb, Zn, NO_3, each 0.00 ppm; OH, 30 ppm and 0.18 epm (included in totals). Quantitative spectrographic analysis, by Nola B. Sheffey, converted to ppm in original water: Cu, 0.003; Ag, 0.0008; Ge, 0.03; Pb, 0.02; Ni, 0.006; Fe, 0.12; Cr, 0.002; V, 0.003; Al, 0.64; Ga, 0.004; Ti, 0.02; Sr, 0.02; Ba, 0.02; Li, 0.1; Rb, 0.06. Mo, W, Sn, Zn, Cd, Sb, Mn, Co, La, Zr, Be, Cs below detection limits in solids. Analysis not previously published. For analysis of gas see table 28, analysis 13; sample from small boiling spring, 150 ft northwest of Geysir (Thorkelsson, 1940, p. 13, 23).
8. An erupting well about 100 ft north of Gunna and 1,000 ft northeast of "Sea water geyser," Reykjanes, southwest of Reykjavik, Iceland (Barth, 1950, p. 115, and G. Bodvarsson, written communication, 1958). The well is 532 ft deep and is in an area of Recent basalt flows, overlying Pleistocene basalt tuff and breccia of the Moberg Formation. Sample collected by Gunnar Bodvarsson, State Electricity Authority; analyzed by C. E. Roberson of the U.S. Geol. Survey, who also reported Cu, Pb, Zn, each 0.00 ppm; NO_2, 0.06 ppm; additional SiO_2 that may have precipitated after collection, but not included in totals, 446 ppm; density, 1.031. Quantitative spectrographic analysis, by Nola B. Sheffey, converted to ppm in original water: Cu, 0.05; Mn, 2.5; Al, 0.5; Sr, 15; Ba, 11; Li, 6.6; Rb, 3.8. Ag, Mo, W, Ge, Sn, Pb, Zn, Cd, Sb, Co, Ni, Fe, Cr, V, Ga, La, Ti, Zr, Be, and Cs are below detection limits in solids. Analysis not previously published. For gas analyses see table 28, analysis 14 (Thorkelsson, 1928).
9. Blahver (Blue Spring) in the southern part of the thermal area, Hveravellir, west-central Iceland (No. 493 of Barth, 1950, p. 145–146). The area contains siliceous sinter and many geysers and is underlain by postglacial basalt flows. Collected by G. Bodvarsson State Electricity Authority; analyzed by C. E. Roberson of the U.S. Geol. Survey, who also reported Cu, Pb, Zn, each 0.00 ppm; NO_2, 0.03 ppm. Quantitative spectrographic analysis, by Nola B. Sheffey, converted to ppm in original water: Cu, 0.007; Ag, 0.0006; Mo, 0.03; Ge, 0.05; Ni, 0.006; Fe, 0.1; Cr, 0.001; V, 0.008; Al, 0.1; Ga, 0.02; La, 0.05; Sr, 0.003; Ba, 0.01; Li, 0.3; Rb, 0.02. W, Sn, Pb, Zn, Cd, Sb, Mn, Co, Ti, Zr, Be, and Cs are below detection limits in solids. For gas analysis from same area see table 28, analysis 15; analyzed by B. Lindal of State Electricity Authority.
10. Sugar-bowl Geyser (Ustinova, 1949, p. 152, 155), Shumhaya, Kamchatka, U.S.S.R., discharging from late Tertiary(?) lava near semiactive Semiachinskie Volcano (Piip, 1937, p. 154–156). Mn, Sr, and Sb determined by spectrographic analysis, which also included Ga, 0.1 ppm; Ti, 0.001 ppm; Be, 0.05 ppm.
11. Velikan (Giant) Geyser, Kamchatka, U.S.S.R.; one of a vigorous group of geysers; average discharge of geyser about 25 gpm: total discharge of group more than 400 gpm. In alluvium on Quaternary volcanic rocks of southeast Kamchatka (Ivanov, 1958a, p. 202–207; 1958b, p. 482). Believed by Ivanov to be underlain by Tertiary marine strata. Is near active volcanoes Kikhpin'ch, Uzon, and B. Semyachik. Analyst, S. S. Krapivina, who also reported Ti, looked for but not found.
12. Paryashchii 1, Pauzhetsk, Kamchatka, U.S.S.R.; a spring discharging 17 gpm in a group of springs and geysers discharging more than 400 gpm from alluvium in Quaternary volcanic rocks of southeast Kamchatka (Ivanov, 1958a, p. 202–207). Near active volcanoes Kosheleva and Kambal'no. Analyst, E. F. Prokof'eva, except SiO_2 and B determined by E. P. Ryabichkina from 1955 sample. For gas analysis, by I. S. Krasnikova, of nearby Pauzhetsk (New Geyser) see table 28, analysis 16.
13. Taumatapuhipuhi Geyser, Tokaanu, North Island, New Zealand (Grange, 1937, p. 100–101, 105). Springs emerge near south shore of Lake Taupo from Kakaramea Andesite of Plio-Pleistocene age, overlain by alluvium and siliceous sinter (Grange, 1937, map of Puketi and Omoho districts; Healy, 1942).
14. Drillhole 4, 1,245 ft deep, about 3,000 ft southeast of Geyser Valley (Grange, 1955, map), Wairakei, North Island, New Zealand. In highly altered sediments of Pliocene(?) Huka formation, overlain by Pleistocene(?) Wairakei pumiceous breccia and alluvium (Steiner, 1953, 1955). Maximum temperature of 228° C was measured at a depth of 970 ft (Banwell, 1955, p. 55; Banwell and others, 1957, table 2). Analyst, S. H. Wilson (1955, p. 37); also reported and included in totals is free CO_2, 11 ppm. For gas analysis from well 4/1, about 100 ft southeast of well 4, see table 28 analysis 17 (Wilson, 1955, p. 29).

TABLE 18.—*Chemical analyses of thermal sodium chloride bicarbonate waters from nongeyser areas associated with volcanism*

Analysis	1		2		3		4		5		6		7		8	
Name and location	Hot Creek, Mono County, Calif.		Niland, Imperial County, Calif.		Roosevelt, Beaver County, Utah		Jemez, Sandoval County, New Mexico		Cerro Prieto, Baja California, Mexico		Agnano, WSW. of Naples, Italy		Nalachevskie, Kamchatka, USSR		Kuan-Tsu-Ling N. of Taipei, Taiwan	
Date of collection	May 17, 1957		Feb. 3, 1954		Sept. 11, 1957		Aug. 31, 1949		Feb. 4, 1954		---		---		About 1933	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	131	---	75	---	313	---	93	---	[1]106	---	152	---	125	---	69	---
Al	.0	---	---	---	<.04	---	---	---	---	---	---	---	Tr	---	---	---
Fe	.04	---	---	---	<.04	---	.03	---	---	---	4.2	---	[1]1.4	---	1.1	---
Mn	.0	---	---	---	.0	---	---	---	---	---	4.5	---	[1].3	---	.02	---
Pb	.00	---	---	---	.00	---	---	---	---	---	.09	---	---	---	8.3 (?)	---
As	1.0	---	---	---	2.0	---	---	---	---	---	.01	---	5.9	---	---	---
Ca	4.4	.22	385	9.2	22	1.10	138	6.88	370	18.46	383	19.11	249	12.43	8.4	.42
Mg	.2	.02	580	47.7	.0	.00	6.6	.54	23	1.9	122	10.0	32	2.6	7.8	.64
Sr	0	---	---	---	0	---	---	---	---	---	Tr	---	.06	---	---	---
Na	350	15.2	7,280	316.7	2,500	108.8	572	24.88	4,580	199.2	3,050	132.7	1,060	46.1	3,730	162.3
K	20	.51	537	13.74	488	12.48	70	1.79	679	17.37	717	18.34	144	3.68	132	3.38
Li	1.7	.24	18	2.6	27	3.9	---	---	10	1.4	1.5	.22	0	---	7.7	1.11
NH_4	.1	.00	---	---	.0	---	---	---	---	---	25	---	.6	.03	---	---
Total cations	---	16.19	---	400	---	126.3	---	34.1	---	238	---	181.8	---	64.8	---	167.9
HCO_3	497	8.15	1,600	26.2	156	2.56	735	12.05	66	1.08	1,570	25.7	519	8.51	5,420	88.7
CO_3	7.9	.26	0	---	0	---	0	---	0	---	---	---	0	---	---	---
SO_4	90	1.87	384	7.99	73	1.52	49	1.02	250	5.2	451	9.39	445	9.27	74	1.54
Cl	200	5.64	12,900	364	4,240	119.6	795	22.41	8,170	230.4	5,220	147.2	1,590	44.8	2,770	77.8
F	10	.53	0.4	.02	7.5	.39	5.2	.27	0.8	.04	---	---	[1].8	.04	---	---
Br	.7	.01	---	---	3.3	.04	---	---	---	---	5.1	.06	6.0	.08	14	.17
I	.4	.00	---	---	.3	.00	---	---	---	---	0.2	---	[1]1.0	.01	13	.10
NO_2	.00	---	---	---	.01	.00	---	---	---	---	---	---	Tr	---	---	---
NO_3	0	---	4.9	.08	11	.18	.8	.01	5.0	.08	---	---	Tr	---	---	---
PO_4	.8	---	---	---	2.2	---	---	---	---	---	1.4	---	---	---	---	---
B	10	---	53	---	38	---	11	---	12	---	0.2	---	72	---	200	---
H_2S	.2	---	---	---	---	---	---	---	---	---	---	---	0	---	---	---
Total anions	---	16.46	---	398	---	124.3	---	35.8	---	237	---	182.4	---	62.7	---	168.3
Total, as reported	1,330	---	23,800	---	7,880	---	2,480	---	14,300	---	[1]11,800	---	4,250	---	12,500	---
Specific conductance micromhos at 25° C	1,620		17,860		12,700		3,560		12,570		---		---		---	
pH	8.3		6.4		7.9		7.2		5.9		---		[1]6.45		8.3	
Temperature 20° C	93		40		55		65.5		82		70.5		73		77	
Density at 20° C	---		1.013		1.001		---		1.005		---		---		---	
Ratios by weight:																
Ca/Na	0.013		0.052		0.0088		0.24		0.081		0.13		0.23		0.0023	
Mg/Ca	.05		1.5		.00		.048		.062		.32		.13		.93	
K/Na	.057		.073		.20		.12		.15		.24		.14		.035	
Li/Na	.005		.0025		.011		---		.0022		.00049		.000		.0021	
HCO_3/Cl [2]	2.6		.12		.037		.92		.0081		.30		.33		2.0	
SO_4/Cl	.45		.030		.017		.062		.031		.086		.28		.027	
F/Cl	.050		.00003		.0018		.0065		.0001		---		[1].0005		---	
Br/Cl	.0035		---		.00078		---		---		.001		.0038		.0051	
I/Cl	.002		---		.00007		---		---		.00004		[1].0006		.0047	
B/Cl	.050		.0041		.0090		.013		.0015		.00004		.043		.072	

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[1] Components mentioned in explanation of table.

[2] Includes CO_3 as HCO_3.

EXPLANATION FOR TABLE 18

1. "Geyser" spring, NE¼ sec. 25, T. 3 S., R. 28 E., Mono County, Calif.; on east bank of Hot Creek, 3 miles northeast of U.S. Highway 395 and 15 miles southeast of Mono Craters, which consist of late Pleistocene and Recent obsidian and pumiceous rhyolite (Putnam, 1949); surrounded by Pleistocene rhyolite, in part, hydrothermally altered. The spring boils vigorously, discharging 5 to 10 gpm and depositing some travertine near center of active zone, 1,500 feet long, on Hot Creek. Analyzed by H. C. Whitehead, U.S. Geol. Survey, who also reported, Cu 0.00 ppm, Zn 0.01 ppm, Ti 0.00 ppm. Analysis not previously published.
2. Well, at abandoned dry-ice plant 4 miles west-southwest of Niland, Imperial County, Calif., and 1½ miles east of the Salton Sea and Mullet Island, which is one of a group of late Quaternary pumiceous rhyolite domes (Kelley and Soske, 1936; Waring, 1915, p. 41; White, 1955b, p. 1121–1123). Artesian discharge of 20 to 30 gpm from well reported 511 ft deep and entirely in Cenozoic alluvium of basin of Salton Sea. Analyzed by H. Kramer, U.S. Geol. Survey. Water qualitatively similar to that of thermal well on Mullet rhyolite dome drilled through rhyolite and more than 1,000 ft into underlying sediments, where steam was found (Kelley and Soske, 1936, p. 502; White, 1955b, p. 1123). For analysis of gas see table 28, analysis 18; sample from well 400 ft deep, in alluvium 4 miles north of Mullet Island (Anderson and Hinson, 1951, p. 50–51). Analysis not previously published.
3. Springs, 15 miles northeast of Milford, Beaver County, Utah, in fault zone in granitic rocks overlain to east by Quaternary(?) obsidian (Lee, 1908, p. 20–21). About 1908 the largest spring was discharging 10 gpm at a temperature of 88°C and was "boiling," with steam escaping from crevices; abundant silica was being deposited in gelatinous and spongy masses (Lee, 1908, p. 20). When visited by H. E. Thomas in 1950 (oral communication), temperature of main spring was 85°C; discharge was a few gpm; and hard porous opal, as much as 4 in. thick, had precipitated on walls of wooden trough. In September 1957 temperature was only 55°C, discharge was less than 0.05 gpm, and discharge of all springs and seeps was not more than 2 gpm. Analyzed by H. C. Whitehead, U.S. Geol. Survey; also reported are Cu, Zn, and Ti, each 0.00 ppm; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in the original water; evaporated residue at 180°C, 7,860; Al, 0.02; Fe, 0.06; Cu, 0.02; Ge, 0.08; Li, 20; Rb, 9.4; Cs, 0.7; Sr, 1.8; Ba, 0.01. Analysis not previously published.
4. Spring, in pool behind bathhouse, 12 miles north of Jemez, sec. 22(?), T. 18 N., R. 2 E., Sandoval County, N. Mex. Discharges about 10 gpm (total discharge of group of springs about 200 gpm) from fault in red beds of Permian age (Stearns and others, 1937, p. 167), overlain by late Cenozoic rhyolite, tuff, and basalt (Kelly and Anspach, 1913). Collected by J. D. Hem, analyzed by J. L. Hatchett of U.S. Geol. Survey. Analysis not previously published.
5. Springs, Cerro Prieto, Baja California, Mexico, 25 miles south of Mexicali; a spring in a small sulfur-covered pool discharges about 1 gpm from northwest edge of saline flat, which also contains other small springs, mud volcanoes, and sulfur deposits. Springs discharge from fine clastic Quaternary sediments near southeast base of Cerro Prieto, a Pleistocene volcano of hypersthene andesite flows and flow breccias (White, 1955b, p. 1123). Analysed by H. Kramer, U.S. Geol. Survey. Analysis not previously published.
6. Sprudel spring, Agnano, in central part of Phlegraean Plain about 10 miles west-southwest of Naples and 20 miles west of Mount Vesuvius, Italy (Zambonini and others, 1925, p. 434–474; Ventriglia, 1951, p. 282–295). Spring flows from trachytic tuffs near Quaternary cinder cones that probably are underlain by thick trachytic tuffs and lavas (Falini, 1951, p. 211). Wells, as much as 300 ft deep, in Agnano area have water of lower temperature than that of spring (Penta, 1949, p. 346). Also reported are Ti, 0.001 ppm; Ba, 0.6 ppm; dissolved CO_2, 103 ppm, which are included in totals. Gases, 72.9 cc per l of water, included in table 28, analysis 19.
7. Spring 1, or "Kettle" spring, of Nalachevskie group, near head of Nalacheva River in southeast Kamchatka, U.S.S.R., about 30 miles from east coast, in area of active Quaternary andesite and basalt volcanoes (Piip, 1937, p. 130, 247–250; Ivanov, 1958a, p. 199–201). Analyzed by B. E. Kuteinikov, 1933; reported Mn may include Zn; Rb and Cs, each reported as 0 ppm; Sb, 0.6 ppm; S_2O_3, 0 ppm. F, free CO_2, and pH from very similar analysis (Ivanov, 1958a, p. 199–201) except that I was looked for but not found. For gas analysis see table 28, analysis 20; analyzed by I. S. Krasnikova from sample collected by Ivanov in 1951.
8. Spring in Kuan-Tsu-Ling, north of Taipei, northern part of Taiwan. Discharges from andesite flows and agglomerates of Pleistocene Tatun Formation, overlying Mio-Pliocene marine strata (Juan, 1956, pl. 2). Spring water is milky from suspended matter that consists largely of SiO_2, Al_2O_3, $CaCO_3$, FeO, and TiO_2. Analysis reported in millimoles per l, converted to ppm, with no correction for specific gravity (Pan, 1952). Also reported are Ti, 0.2 ppm; Zn, 0.2 ppm; Zr, trace, and Cu, 0.6 ppm.

TABLE 19.—*Chemical analyses of acid sulfate-chloride springs in volcanic environments and crater lakes*

Analysis	1		2		3		4		5		6		9	
Name and location	Norris Basin, Yellowstone Park, Wyo.		Copahue Volcano, Neuquen Territory, Argentina		Ebeco Volcano, Paramushir Island, USSR		Lower Mendeleev Kunashir Island, USSR		Kusatsu Shirane, Gumma Prefecture, Honshu, Japan		Yakeyama, Niigata Prefecture, Honshu, Japan		Noboribetsu, Iburi Prefecture, Hokkaido, Japan	
Date of collection	Aug. 27, 1954		----		Aug. 30, 1955		Oct. 30, 1954		----		----		Feb. 1, 1938	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	369	----	160	----	59	----	270	----	444	----	640	----	480	----
Al	1.5	0.17	162	18.0	62	6.9	93	10.4	13	1.5	340	37.8	13	1.45
Fe^{+2}	.8	.04	217	7.77	202	7.23	219	7.82	7.2	.39	970	52.1	35	1.25
Fe^{+3}			----	----	37	1.99	31	1.66					----	----
Mn	----	----	----	----	3.2	.12	.4	----	----	----	----	----	1.0	.07
Ca	6.5	.33	180	8.98	92	4.59	150	7.45	32	1.60	2,010	100.3	109	5.46
Mg	.0	----	30	2.5	32	2.6	68	5.6	1.3	.11	520	42.8	17	1.4
Na	243	10.57	169	7.35	108	4.70	121	5.27	1,380	60.0	1,540	67.0	592	25.8
K	61	1.56	Tr	----	92	2.35	105	2.68	231	5.91	380	9.72	54	1.38
Li	3.2	.46	----	----	2.4	.35	----	----	[1] .2	.03	----	----	----	----
NH_4	3.4	.19	8.5	.47	5.0	.28	6.9	.38	----	----	----	----	5.5	.31
H	[1] 7.8	7.7	[1] 301	299	[1] 1,790	1,776	20	20	[1] 78	78	[1] 431	428	----	----
Total cations	----	21.0	----	344.1	----	1,807	----	61.3		147.5	----	738	----	37.1
HCO_3	0	----	----	----	----	----	----	----	----	----	----	----	86(?)	1.41
HSO_4	----	----	----	----	----	----	911	9.39	----	----	----	----	----	----
SO_4	454	9.45	12,700	264	996	20.74	1,150	24.0	4,490	93.5	8,380	173.9	274	5.70
Cl	408	11.51	2,640	74.5	63,200	1,782	983	27.78	1,910	53.9	20,000	564	1,060	30.0
F	----	----	----	----	71	3.74	1.2	.06	----	----	----	----	----	----
Br	----	----	----	----	44	.55	.3	.00	----	----	----	----	----	----
I	----	----	----	----	.4	.00	.0	----	----	----	----	----	----	----
PO_4	----	----	----	----	----	----	----	----	----	----	----	----	.6	----
B	6.9	----	----	----	Very much	----	32	----	----	----	115	----	39	----
H_2S	----	----	----	----	----	----	----	----	----	----	----	----	[1] 6.9	----
Total anions	----	21.0	----	[1] 344	----	1,807	----	61.2	----	147.4	----	738	----	37.1
Total, as reported	1,570	----	[1] 16,900	----	66,800	----	4,160	----	8,590	----	35,300	----	[1] 2,810	----
pH	2.47		----		[1] Strongly acid		1.7		----		0.4		3.2	
Temperature ° C	87		20		100		----		91		88		91	
Density at 20° C	----		----		----		----		----		----		1.003	
Ratios by weight:														
Ca/Na	0.027		1.1		0.85		1.2		0.023		1.3		0.18	
Mg/Ca	.00		.17		.35		.45		.041		.26		.16	
K/Na	.25		.00		.85		.87		.17		.25		.091	
Li/Na	.013		----		.022		----		.0001		----		----	
HCO_3Cl	.000		----		----		----		----		----		.081(?)	
SO_4/Cl[2]	1.1		4.8		.016		2.1		2.4		.42		.26	
F/Cl	----		----		.0011		.0012		----		----		----	
Br/Cl	----		----		.00070		.0003		----		----		----	
I/Cl	----		----		.000006		.0000		----		----		----	
B/Cl	.017		----		----		.033		----		.0057		.037	

Analysis	8		9		10		11		12		13	
Name and location	Yang Ming Shan, North of Taipai, Taiwan		Taal Volcano, Luzon, Philippine Islands		Kawah Idjen Volcano, Java, Indonesia		Tjiater, Java, Indonesia		Frying Pan Lake, Tarawera region, New Zealand		White Island, Bay of Plenty, New Zealand	
Date of collection	----		March 1907		1941(?)		----		June 24, 1932		----	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	322	----	(1)	----	184	----	157	----	412	----	164	----
Al	600	66.7	7,600	845	4,130	490	66	7.34	4	0.44	1,880	208.0
Fe^{+2}	95	3.40	5,100	182.6	----	----	[1] 18	.97	2	.11	10,500	376.3
Fe^{+3}	----	----	9	.48	1,600	86.0					130	6.9
Mn	----	----	(1)	----	----	----	2.4	.09	----	----	24(?)	1.3
Ca	263	13.12	2,810	140.2	783	39.07	111	5.54	14	.70	2,370	118.3
Mg	73	6.0	318	26.2	848	69.7	24	2.0	4	.3	6,770	556.5
Na	75	3.26	7,420	322.2	988	42.98	68	2.96	609	26.47	7,100	308.8
K	11	.28	125	3.20	791	20.23	30	.77	51	1.30	926	23.7
Li	----	----	----	----	----	----	----	----	----	----	----	----
NH_4	----	----	----	----	----	----	[1] 12	.67	2	.11	17	.9
H	27	27	[1] 464	460	[1] 740	734	----	----	[1] .8	.8	287	285
Total cations	----	119.8	----	1,980	----	1,482	----	16.3	----	30.2	----	[1] 1,886
HCO_3	----	----	----	----	----	----	----	----	0	----	----	----
HSO_4	----	----	----	----	----	----	----	----	----	----	7,600	78.4
SO_4	3,730	77.7	30,800	641	46,100	960.0	407	8.47	262	5.46	2,170	45.2
Cl	1,490	42.0	47,500	1,339	18,500	522.0	567	15.99	878	24.74	57,300	1,615
F	----	----	----	----	----	----	13	.68	----	----	806	42.4
Br	----	----	----	----	----	----	----	----	----	----	37	.5
I	----	----	----	----	----	----	0	----	----	----	5.6	----
PO_4	2.9	----	(1)	----	----	----	0.3	----	----	----	----	----
B	----	----	----	----	----	----	----	----	4.4	----	5.9	----
H_2S	216	----	----	----	----	----	----	----	None	----	28	----
Total anions	----	119.7	----	1,980	----	1,482	----	25.1	----	30.2	----	[1] 1,783
Total, as reported	6,900	----	102,000	----	74,900	----	1,480	----	2,240	----	[1] 98,300	----
pH	1.6		Strongly acid		Strongly acid		2.25		3.1		Strongly acid	
Temperature ° C	81		100		----		44		55		[1] Hot.	
Density at 20° C	1.006		1.072		[1] 1.05		----		----		[1] 1.08	
Ratios by weight:												
Ca/Na	3.5		0.38		0.79		1.6		0.021		0.33	
Mg/Ca	.28		.11		1.1		.22		.29		2.9	
K/Na	.14		.017		.80		.44		.084		.13	
Li/Na	----		----		----		----		----		----	
HCO_3Cl	----		----		----		----		.000		----	
SO_4Cl[2]	2.5		.65		2.5		.72		.30		.17	
F/Cl	----		----		----		.023		----		.014	
Br/Cl	----		----		----		----		----		.00064	
I/Cl	----		----		----		.000		----		.0001	
B/Cl	----		----		----		----		.0050		.0001	

[1] Components mentioned in explanation of table.
Includes HSO_4.

EXPLANATION FOR TABLE 19

1. Green Dragon spring, southern part of Norris Basin, Yellowstone National Park, Wyo.; discharges about 40 gpm (White, 1955a, p. 107; 1957a, p. 1640, 1648) from hydrothermally altered alluvium overlying late Cenozoic welded rhyolite tuff. About 700 ft southeast of spring given in table 17, analysis 2. Analyzed by H. Kramer, U.S. Geol. Survey; H calculated by difference.
2. Crater lake of Copahue, a Quaternary trachyte volcano, Neuquen Territory, Argentina. Lake is a third of a mile in diameter and heated by volcanic gases (Corti and Camps, 1930, p. 380; Sussini and others, 1938). Area also has sulfur deposits. Analyzed by H. Corti, reported as hypothetical chemical combinations, converted to ionic form; H calculated by difference; also reported is S_2O_3, 326 ppm (5.82 epm), included in totals.
3. Lake, in central funnel of upper (southern) crater of Ebeco volcano, near north end of Paramushir Island, Kurile Islands, U.S.S.R. (Ivanov, 1957, p. 70). Rocks consist largely of andesite flows and tuffs. Sample analyzed by S. S. Krapivina, who also reported, in ppm, Co, 0.3; Ni, 0.1; Cu, 0.03; Ti, 0.2; Sr, 0.8; As, 0.6. H and most of Cl reported as free HCl; pH reported −1.7, requiring 50 molar HCl solution; pH of about −0.25 seems more probable. For gas analysis see table 28, analysis 21.
4. Main spring, Lower Mendeleev group, Kunashir Island in northern Kurile Islands, U.S.S.R.; discharge is 115 gpm (Ivanov, 1958b, p. 480). Collected by Ivánov; analyzed by S. S. Krapivina, who also determined Ti, 0.2 ppm; Cu, 0.09 ppm; As, 0.9 ppm.
5. Main spring of a group near active Kusatsu Shirane volcano, Gumma Prefecture, Honshu, Japan (Yamagata, 1951, p. 159). Springs discharge from pyroxene andesite flows and pyroclastic rocks of volcano; many active solfataras (H. Kuno, written communication). H calculated by difference; Li, Rb (0.3 ppm), and Cs (0.1 ppm) determined spectrographically. A less complete analysis of water from the strongly acid crater lake of this volcano was published by Minami and others (1952, p. 4).
6. At southern base of active Yakeyama volcano, Niigata Prefecture, Honshu, Japan (Muto, 1954, p. 408–409). Spring discharges from hornblende,pyroxene andesite lavas and pyroclastic deposits of the volcano overlying Miocene or Pliocene sedimentary rocks. H calculated by difference.
7. Main spring of group, Noboribetsu, Iburi Prefecture, southwestern Hokkaido, Japan. Total discharge of springs is about 1,000 gpm from Miocene sedimentary rocks at west base of Pleistocene volcano Kuttara. This volcano consists of pyroxene andesite and has a summit caldera lake (Okuno and others, 1938, p. 853, 857–858; Ishizu, 1915; H. Kuno, written communication). H_2S, including 3.9 ppm reported as HS, from sample of Sept. 26, 1937; determined by dithizone and included in totals: Cu, 0.16 ppm; Zn, 0.36 ppm; and Pb 0.34 ppm; free CO_2, 41 ppm. Traces of Cd, Ti, Ni, and Ba determined spectrographically. Other springs in the area are acid sulfate type given in table 20 (Okuno, 1939, p. 689). Partial analyses by Usumasa and Morozumi (1955) are reported to be of water from main spring but are neutral and very different in composition.
8. Yang Ming Shan spring, near extreme north end of Taiwan, discharges from hydrothermally altered Pleistocene basalt overlying Mio-Pliocene marine sediments (Pan, Lin, Hseu, Sun, and Chan, 1955, p. 27–30; Yen, 1955; Juan, 1956).
9. Crater lake of active andesitic Taal volcano, Luzon, Philippine Islands. Sample collected by Bacon (1907, p. 118), March 1907 (prior to 1911 eruption); H calculated by difference. Other pre-eruption analyses reported as much as 332 ppm PO_4, 401 ppm SiO_2, and 303 ppm Mn (Neumann van Padang, 1953, p. 36).
10. Crater lake of active Kawah Idjen, a basaltic andesite volcano on shoulder of Merapi, Besuki Residency, eastern Java, Indonesia (Neumann van Padang, 1951, p. 157–158; Bemmelen, 1949b, p. 105–106). Volcano had violent eruption in crater lake in 1817 and minor eruptions in 1796, 1917, and 1936. Crater lake contains $1\frac{1}{4} \times 10^9$ cubic ft of strongly acid water with more than 100,000 tons dissolved aluminum sulfate. Analyzed 1941, cations reported as grams of oxide per liter, converted to ppm by assuming density of 1.05; $H+$ calculated by difference.
11. Tjipanas spring 1, in Krawang Residency, western Java, Indonesia. Discharges 1,300 gpm from hot spring deposits of jarosite $(KFe_3(SO_4)_2(OH)_6$ and iron phosphate high in As (Bemmelen, 1949a, v. 1A, p. 215; v. 2, p. 232–239). These deposits contain hundreds of thousands of tons and lie on andesite and basalt flows of Tangkuban, an active volcano about 3 miles southwest. The iron phosphate deposits contain about 2 percent of arsenic. Analyzed by Laboratory for Mineral Research, Mining Department, Java; inorganic Fe, 18 ppm; total Fe, 20 ppm; reported NH_3 converted to NH_4.
12. Frying Pan Lake, Tarawera region, New Zealand, at site of volcanic eruptions in 1886 and 1917 (Grange, 1937, p. 93, 103, 105; White, 1957a, p. 1640, 1642, 1648). Discharge is more than 1,000 gpm. Bedrock is rhyolitic tuff and breccia of the Waitahanui Series of Plio-Pleistocene age, overlying Pliocene rhyolite and overlain by more than 10 feet of basaltic ash from the 1886 Tarawera eruption (Grange, 1937, map of Tarawera district). H calculated by difference; analysis of gases from small hot spring on edge of lake given in table 28, analysis 22 (Grange, 1937, p. 110–111).
13. Hot spring pool in crater of White Island, an active andesitic volcano in Bay of Plenty off northeast coast of North Island, New Zealand. Some fumaroles have temperatures as much as 500°C. Sample collected and analyzed by S. H. Wilson, New Zealand Department of Scientific and Industrial Research (1959, p. 37). Reported in g per l, converted to ppm assuming density of 1.08. Also reported and included in totals: $S_4O_6^{-2}$ (tetrathionate), 157 ppm (1.4 epm); $S_5O_6^{-2}$ (pentathionate), 9.3 ppm (0.1 epm); As, 5.7 ppm; Sr, 9.3 ppm (0.2 epm). For analysis of gas, same locality but different pool, see table 28, analysis 23.

TABLE 20.—*Chemical analyses of acid sulfate spring waters associated with volcanism*

Analysis	1		2		3		4		5		6	
Name and location	"The Geysers", Sonoma County, Calif.		Bumpass Hell, Shasta County, Calif.		Norris Basin, Yellowstone Park, Wyo.		Mud Volcano Group, Yellowstone Park, Wyo.		Sulphur Springs, Sandoval County, N. Mex.		Uzon Volcano, Kamchatka, USSR	
Date of collection	-----		1953		Aug. 25, 1954		-----		Aug. 31, 1949		Aug. 26, 1950	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	225	-----	240	-----	109	-----	540	-----	216	-----	292	-----
Al	14	1.67	31	3.4	2.4	0.27	146	16.2	56	6.2	444	49.39
Fe^{+2}	63	2.26	18	.65	-----	-----	0	-----	-----	-----	412	14.76
Fe^{+3}	0	-----	5.5	.30	.8	.04	17	.91	33	1.77	-----	-----
Mn	1.4	.05	-----	-----	-----	-----	-----	-----	3.3	.12	-----	-----
Ca	47	2.35	6.5	.32	2.2	.11	14	.70	185	9.23	83	4.15
Mg	281	23.1	5.3	.44	0	-----	11	.91	52	4.2	35	2.87
Na	12	.52	32	1.39	2.0	.09	16	.70	6.7	.29	[1] 11	[1] .48
K	5	.13	13	.33	3.0	.08	17	.44	24	.61	14	.61
NH_4	1,400	77.6	14	.78	30	1.66	26	1.44	-----	-----	[1] 547	30.4
H	9.5	9.4	6.2	6.2	[1] 14	14.0	43	42.7	[1] 13	12.6	14	14
Total cations	-----	[1] 117.3	-----	13.8	-----	16.3	-----	64.0	-----	35.1	-----	116.7
HCO_3	0	-----	-----	-----	0	-----	-----	-----	0	-----	0	-----
S_4O_6	[1] 0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
HSO_4	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
SO_4	5,710	118.9	718	14.95	758	15.78	3,150	65.6	1,570	32.7	5,550	115.6
Cl	[1] .5	.02	1.1	.03	15	.42	Tr	-----	3.5	.10	12	.37
F	-----	-----	-----	-----	-----	-----	1	.05	1.1	.06	.4	.02
Br	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	-----
I	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	-----
NO_3	-----	-----	-----	-----	-----	-----	-----	-----	0	-----	Tr	-----
B	3.1	-----	.2	-----	6.9	-----	-----	-----	-----	-----	0	-----
H_2S	-----	-----	20	-----	-----	-----	0	-----	-----	-----	2	-----
Total anions	-----	118.9	-----	15.0	-----	16.2	-----	65.1	-----	32.9	-----	116.0
Total, as reported	7,770	-----	1,110	-----	943.	-----	3,980	-----	2,160	-----	7,420	-----
Specific conductance (micromhos at 25 °C)	-----		-----		-----		-----		4,570		-----	
pH	[1] 1.8±		-----		1.97		-----		1.9		1.86	
Temperature °C	Boiling?		79.0		90		65		65±		60	
Ratios by weight:												
Ca/Na	3.9		0.20		1.1		0.88		28		[1] 8	
Mg/Ca	6.0		.81		0		.78		.28		4.2	
K/Na	.42		.41		1.5		1.1		3.6		[1] 1	
Li/Na	-----		-----		.0		-----		-----		-----	
HCO_3/Cl	.0		-----		0		-----		.0		.0	
SO_4/Cl_2	11,000		650		51		>1,000		450		460	
F/Cl	-----		-----		-----		>1		.31		.03	
Br/Cl	-----		-----		-----		-----		-----		.00	
I/Cl	-----		-----		-----		-----		-----		.00	
B/Cl	6.2		.11		.46		-----		-----		.00	

Analysis	7		8		9		10		11	
Name and location	Koshelevsk, Kamchatka, USSR		North Mendeleev, Kunashir Island, USSR		Yunohanazawa, Kanagawa Prefecture, Honshu, Japan		Nasu, Tochigi Prefecture, Japan		Ketetahi, Tongariro Volcano, New Zealand	
Date of collection	Aug. 15, 1951		Oct. 1, 1954		-----		-----		-----	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	120	-----	274	-----	283	-----	147	-----	162	-----
Al	-----	-----	78	8.7	120	13.3	85	8.59	8.9	1.00
Fe^{+2}	19	0.67	112	6.07	} 3.9	1.40	{ 28	1.02	-----	-----
Fe^{+3}	-----	-----	34	1.22	}		.0	-----	.7	.04
Mn	1.2	.05	.6	.02	-----	-----	.3	.01	-----	-----
Ca	40	2.00	79	3.95	103	5.14	64	3.19	76	3.80
Mg	13	1.06	8.7	.71	13	1.1	31	2.55	28	2.3
Na	60	2.62	455	19.79	33	1.44	22	.96	63	2.76
K	18	.45	9.6	.23	2.9	.07	7.1	.18	3.5	.09
NH_4	101	5.60	8.0	.44	-----	-----	3.1	.17	374	20.7
H	.05	.05	20	20	-----	-----	15	14.9	1.6	1.6
Total cations	-----	12.50	-----	61.1	-----	22.5	-----	31.57	-----	32.3
HCO_3	0	-----	-----	-----	-----	-----	-----	-----	-----	-----
S_4O_6	-----	-----	-----	-----	-----	-----	2	0.01	[1] 103	0.92
HSO_4	-----	-----	1,590	16.4	-----	-----	1,440	14.83	149	1.54
SO_4	594	12.36	2,020	42.1	1,040	21.6	602	12.53	1,220	25.3
Cl	4.8	.13	93	2.63	2.6	.07	169	4.77	18	.50
F	.0	-----	.9	.04	-----	-----	.4	.02	-----	-----
Br	.3	.00	.4	.00	-----	-----	.00	-----	-----	-----
I	.0	-----	.0	-----	-----	-----	.000	-----	-----	-----
NO_3	-----	-----	-----	-----	-----	-----	.000	-----	-----	-----
B	26	-----	12	-----	-----	-----	57	-----	93	-----
H_2S	-----	-----	44	-----	Tr	-----	35	-----	-----	-----
Total anions	-----	12.49	-----	61.2	-----	21.7	-----	32.16	-----	28.3
Total, as reported	997	-----	[1] 4,840	-----	1,600	-----	[1] 2,780	-----	2,300	-----
Specific conductance (micromhos at 25 °C)	-----		-----		-----		-----		-----	
pH	4.3		1.70		2.3		1.5		2.8	
Temperature °C	92.5		69.0		78		69.9		[1] 70	
Ratios by weight:										
Ca/Na	0.67		0.17		3.1		2.9		1.2	
Mg/Ca	.33		.11		.13		.48		.37	
K/Na	.30		.021		.088		.32		.060	
Li/Na	-----		-----		-----		.0005		-----	
HCO_3/Cl	.000		.00		-----		.000		-----	
SO_4/Cl [2]	120		39		400		12		68	
F/Cl	-----		.01		-----		.002		-----	
Br/Cl	.06		.004		-----		.0000		-----	
I/Cl	.00		.000		-----		.0000		-----	
B/Cl	-----		.13		-----		.33		5.2	

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[1] Components mentioned in explanation of table.

[2] Includes HSO_4.

EXPLANATION FOR TABLE 20

1. Devils Kitchen spring, "The Geysers," (Allen and Day, 1927, p. 33), 11 miles east of Cloverdale, Sonoma County, Calif. Seeping discharge from pool on landslide material underlain by Franciscan graywacke, greenstone, and serpentine of Mesozoic age (Bailey, 1946, p. 211–215, pl. 29); no true geysers. Area is 3 miles west of Cobb Mountain, a Pleistocene(?) rhyolite volcano (Brice, 1953, p. 35, 37). Gas analysis from well 1, 460 feet north-northeast of spring (Allen and Day, 1927, p. 60, 76; White, 1957a, p. 1648), given in table 28, analysis 24. Analyzed by E.T. Allen, who also reported and included in totals: S_2O_3, 0 ppm; Ni, trace; Cr, 2 ppm (0.23 epm). Cl and pH determined by H. Kramer, U.S. Geol. Survey, on sample collected March 24, 1954, which also contained 5,070 pp, of SO_4 and 2.7 ppm of B.
2. Spring in thermal area, Bumpass Hell, Shasta County, Calif., 2 miles south of Lassen Peak, a dacite volcano last active from 1912 to 1919. Spring, 250 ft north-northeast of junction of principal streams draining thermal area, is in hydrothermally altered Brokeoff Andesite of upper Pliocene or Pleistocene age (Williams, 1932, p. 374–375, map). Sample collected and analyzed by P. S. Bennett of U.S. National Park Service. Analysis not previously published. For gas analysis, apparently from same spring, see table 28 analysis 25 (Day and Allen, 1925, p. 95, 133).
3. Locomotive Spring, Norris Basin, Yellowstone National Park, Wyo., 80 ft southeast of Congress Pool and 200 ft west-southwest of Norris Basin drillhole (Fenner, 1936, p. 282–310; White, 1955a, p. 103-107). Seeping discharge; bedrock is acid-leached welded rhyolite tuff of Pliocene(?) age. Analyzed by H. Kramer, U.S. Geol. Survey; also reported is Li, 0.0 ppm. H calculated by difference. Analysis not previously published. For gas analysis from Locomotive Spring or a nearby spring, see table 28, analysis 26 (Allen and Day, 1935, p. 86).
4. Big Sulphur Pool, 0.2 mile north of Mud Volcano, Yellowstone National Park, Wyo. (Allen and Day, 1935, p. 422, 427); little or no discharge. Pool is in glacial material overlying rhyolite of Pliocene(?) age (Hague and others, 1899, Canyon sheet of geologic folio). For gas analysis see table 28, analysis 27 (Allen and Day, 1935, p. 86, 418).
5. One of about eight springs in sec. 3, T. 19 N., R. 3 E., Sulphur Springs, Sandoval County, N. Mex., Small discharge, but total for the group (same type?) is about 500 gpm (Stearns and others, 1937, p. 167) in area of late Pliocene or Pleistocene rhyolite overlying Paleozoic sediments. Gas analysis of Alum Spring given in table 28, analysis 28 (Renick, 1931, p. 89). Analyzed by U.S. Geol. Survey; H+ computed from pH. Analysis not previously published.
6. Boiling mud pot in west field of crater of Uzon, a semiactive basaltic andesite volcano in southeastern Kamchatka, U.S.S.R. Crater contains many mud pots and mud volcanoes (Ivanov, 1958a, p. 195–196; Piip, 1937, p. 171, 172, 248, 267). Sample collected by B. I. Piip; analyzed by M. S. Suetina. Ti, 5.4 ppm is included in total; As, HCO_3, Br, I, and B were not detected. Na not determined by Suetina; reported value is from 1933 analysis (Piip, 1937, p. 171–172), probably less than amount actually present. For gas analysis from nearby vent see table 28, analysis 29.
7. Mud pot on upper slopes or in crater of semiactive Koshelevsk volcano of southeastern Kamchatka, U.S.S.R. (Ivanov, 1958a, p.195–196). Collected by G. A. Gonsovsk; analyzed by E. F. Prokof'eva; As, not found. For gas anlysis of nearby boiling lake see table 28, analysis 30; poor summation suggests misprint.
8. Lower spring, Northern Mendeleev group, Kunashir Island, Kurile Islands, U.S.S.R. Discharge is about 30 gpm (Ivanov, 1958b, p. 479). Collected by V. V. Ivanov; analyzed by S. S. Krapivina, who also reported and included in totals: Sr, trace; Ba, 0.0 ppm, As, 0.7 ppm; Cu 0.03 ppm; Ti, 0.4 ppm.
9. Yoemon-Yu spring of Yunohanazawa group in Hakone caldera, Kanagawa Prefecture, Honshu, Japan (Kuroda, 1941b, p. 69–74). Springs discharge from pyroxene andesite on east flank of postcaldera late Pleistocene Kami-yama volcano (H. Kuno, written communication). Analyzed by K. Kuroda, who also reported Cu, 0.045 ppm.
10. Yumato spring, Nasu, Tochigi Prefecture, Japan; "gushing out" of southeast slope of Nasudake, an active andesite volcano (Kimura, Yokoyama, and Ikeda, 1955, p. 201). Also reported, in ppm, and included in totals: Li, 0.01; Rb, 0.01; Cs, 0.01; As, 1.9; Sr, 0.00X; Ba, 0.00X; V, 0.5; Cr, 0.004; Mo, 0.0009; Ti, 0.2; Ge, 0.0000X; Be, 0.0000X; Ga, 0.0000X; Cu, 0.03; Pb, 0.07; Zn, 0.14; Bi, 0.0001; Sb, 0.0001; Sn, 0.0002; Co, 0.000X; Ni, 0.000X; Cd, 0.0001; Ag, 0.001; In, 0.0001; Au, 0.00000; Zr, 0.000X; NO_2, 0.000; HPO_4, 6.1; CO_2, 66; HSO_3, 0.6; S_2O_3, 0.3; S_3O_6, 0; S_5O_6, 0.
11. Ketetahi, one of group of springs and fumaroles in hydrothermally altered area on north flank of Tongariro, a large active andesitic volcano south of Lake Taupo, North Island, New Zealand (Wilson, 1953, p. 453, 456; J. Healy, written communication). Analyzed by S. H. Wilson; converted from milliequivalents and millimoles per liter; S_5O_6 included by Wilson with S_4O_6.

TABLE 21.—*Chemical analyses of thermal bicarbonate sulfate waters in volcanic environments*

Analysis	1		2		3		4		5	
Name and location	"The Geysers," Sonoma County, Calif.		Steamboat well GS-7, Washoe County, Nev.		Sulphur Springs, St. Lucia Island, British West Indies		Yonono, Kagoshima Prefecture, Kyushu, Japan		Wairakei well 5, North Island, New Zealand	
Date of collection			May 22, 1952		July 1951		1953			
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	66		14						191	
Ca	58	2.89	6.0	0.30	62	3.09	41	2.05	12	0.60
Mg	108	8.88	0		11	.90	17	1.4	1.7	.14
Na	18	.78	9.3	.40	64	2.70	25	1.09	230	10.00
K	6	.15	4.5	.12			12	.31	17	.43
Li			0						1.2	.17
NH_4	111	6.15					.1	.01	.2	.01
Total cations		18.85		0.82		6.69		4.86		11.35
HCO_3	176	2.88	21	0.34	272	4.46	254	4.17	670	10.98
CO_3	0		None		0					
S_2O_3	2.7	.02								
SO_4	763	15.89	24	.50	80	1.67	22	.46	11	.23
Cl	1.5	.04	.5	.01	23	.65	5.1	.14	2.7	.08
F			0		0				3.7	.19
NO_3			Tr		0					
B	15		1.3		[1] 1		2.2		.5	
CO_2							Tr		0	
H_2S	0		2.4						0	
Total anions		18.83		0.85		6.78		4.77		11.48
Total, as reported	1,330		83.0		513		378		1,140	
Specific conductance....micromhos at 25° C				85		715				
pH				6.5		7.9		7.5		6.7
Temperature °C		100		[1] 161		Boiling		69		Boiling
Ratios by weight:										
Ca/Na		3.2		0.64		0.95		1.6		0.052
Mg/Ca		1.9		.0		.17		.41		.14
K/Na		.33		.48				.48		.074
Li/Na				.00						.0052
HCO_3/Cl		120		40		12		51		250
SO_4/Cl		510		50		3.5		4.4		4.1
F/Cl				.0		.0				1.4
B/Cl		10		3		.05		.44		.02

[1] Components mentioned in explanation of table.

EXPLANATION FOR TABLE 21

1. "The Geysers," Sonoma County, 11 miles east of Cloverdale, Calif.; Witches Cauldron spring on bank of Geyser Creek about 125 ft southwest of steam wells 1 and 2 and 400 ft north of Devils Kitchen spring (table 20, analysis 1; Allen and Day, 1927, p. 33, fig. 1) and in same geologic setting; no true geysers in the area. Analyzed by E. T. Allen, who also reported and included in totals: Al, Ni, and Cr, each 0 ppm; Mn, 0.6 ppm; Fe, trace. See gas analysis 24, table 28, for well 1.
2. Drill hole GS-7, in Silica Pit, western part of Steamboat Springs thermal area, Washoe County, Nev. (White, 1955a, p. 103, 111; 1957a, p. 1649–1650). Drill hole penetrated acid-leached granodiorite for 112 feet, where acid water was found. Relations indicate high-temperature steam, CO_2, and other gases rising near bottom of hole, at depth of 402 ft, and condensing in a perched water table that is dominantly of meteoric water. Sample collected near bottom of steam-filled hole under pressure; analysis by H. Kramer, U.S. Geol. Survey. Analysis not previously published. For gas analysis see table 28, analysis 31.
3. Sulphur Springs, St. Lucia Island, British West Indies; boiling spring in southeastern part of thermal area, 1½ miles southeast of Soufrière at altitude of 800 to 900 ft; little or no discharge (G. Bodvarsson, written communication). In Tertiary sandstone and conglomerate overlain by basaltic lava near contact with siliceous porphyritic plug situated a few miles from Qualibu, an active volcano that erupted in 1766 (Perret, 1939, fig. 1). Sample collected by G. Bodvarsson; analyzed by U.S. Geol. Survey; boron reported "slightly greater than 1 ppm." Analysis not previously published.
4. Yonono hot spring, in Kirishima volcano group, Kagoshima Prefecture, Kyushu, Japan; hot spring is in area 150 by 500 ft with many fumaroles of high temperature. In pyroxene andesite lava on southern flank of one of Recent cones of the volcano group. Test boring to 280 ft depth found water at a temperature of more than 125° C. Analyzed 1953 (Subterranean Heat Research Group, 1955, p. 585; H. Kuno, written communication). Also reported is Fe, trace.
5. Drillhole 5, western part of thermal area, Wairakei, North Island, New Zealand (Wilson, 1955, p. 37). Nearly 2½ miles northwest of well 4 (see table 17, analysis 14), in similar bedrock (Steiner, 1955, fig. 5, fig. 10) but hydrothermal alteration characterized by albite rather than by potassium-bearing minerals. Sample analyzed by S. H. Wilson. Gas analysis, table 28, analysis 32, is from well 6, which has water similar to that of well 5 but is 1,000 ft to the east (Wilson, 1955, p. 29).

TABLE 22.—*Chemical analyses of spring waters high in sodium bicarbonate and boron*

Analysis	1		2		3		4		5	
Name and location	E. of Altoona mine, Trinity County, Calif.		Mud Springs, Mendocino County, Calif.		Crabtree, Lake County, Calif.		Gilroy, Santa Clara County, Calif.		Arkos area, Haromszek County, Rumania	
Date of collection	Oct. 16, 1956		Oct. 7, 1956		Oct. 6, 1956		June 16, 1955		Mar. 3, 1943	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	82	---	38	---	200	---	100	---	16	---
Al	---	---	---	---	.4	---	---	---	Tr	---
Fe	---	---	---	---	.0	---	---	---	2.6	---
Mn	---	---	---	---	.1	---	---	---	.1	---
As	---	---	.13	---	1.0	---	---	---	Tr	---
Ca	409	20.41	48	2.40	62	3.09	21	1.05	541	27.0
Mg	7.2	.59	169	13.9	208	17.1	120	9.87	314	25.8
Sr	3.7	.08	3.7	.08	0	---	4.6	.10	Tr	---
Na	3,520	153.1	5,400	234.9	1,710	74.4	270	11.75	1,650	71.8
K	306	7.83	170	4.35	34	.87	5.1	.13	33	.84
Li	10	1.4	2.7	.39	4.1	.59	.2	.02	[1] 8.7	1.25
NH_4	---	---	.0	---	[1] 0	---	2.4	.13	---	---
Total cations	---	183.4	---	256	---	[1] 96.1	---	23.1	---	126.7
HCO_3	8,370	137.2	14,500	238	3,890	63.8	1,200	19.7	6,770	111.0
CO_3	0	---	0	---	0	---	0	---	---	---
SO_4	483	10.06	26	.54	16	.33	5	.10	3.2	.07
Cl	1,350	38.1	610	17.20	1,200	33.8	130	3.67	554	15.62
F	---	---	.4	.02	.6	.03	.4	.02	.6	.03
Br	---	---	2.	.03	4	.05	.0	---	2.7	.03
I	---	---	1.5	.01	1.6	.01	.3	---	2.5	.02
NO_2	---	---	.0	---	[1] 94	2.04	---	---	---	---
NO_3	---	---	0	---	0	---	0	---	---	---
B	120	---	530	---	290	---	13	---	47	---
CO_2	---	---	---	---	---	---	---	---	2,380	---
H_2S	<1	---	---	---	0	---	.2	---	---	---
Total anions	---	185.4	---	256	---	[1] 100.1	---	23.5	---	126.7
Total, as reported	14,700	---	21,500	---	7,720	---	1,870	---	12,300	---
Specific conductance micromhos at 25°C	13,600		16,700		7,850		1,340		---	
pH	6.8		7.3		6.7		6.8		(1)	
Temperature °C	13.5		18		41.5		42		5.5	
Density at 20°C	1.007		1.013		---		---		1.008	
Ratios by weight:										
Ca/Na	0.12		0.0089		0.036		0.078		0.33	
Mg/Ca	.018		3.5		3.3		5.7		.58	
K/Na	.087		.031		.020		.019		.020	
Li/Na	.0028		.0005		.0024		.0007		.0053	
HCO_3/Cl[2]	6.2		24		3.2		9.2		12	
SO_4/Cl	.36		.043		.013		.04		.0057	
F/Cl	---		.0007		.0005		.003		.001	
Br/Cl	---		.003		.003		.000		.0049	
I/Cl	---		.0025		.0013		.002		.0045	
B/Cl	.089		.87		.24		.10		.084	

Analysis	6		7		8		9		10	
Name and location	Chokrak, Kerch, Crimea, USSR		Essentuki, Caucasus, USSR		Malkinsk, Kamchatka, USSR		Futamata, Hokkaido, Japan		Te Aroha, North Island, New Zealand	
Date of collection	---		---		Sept. 28, 1950		1936		---	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	14	---	---	---	[1] 204	---	51	---	115	---
Al	---	---	7	---	.0	---	.7	---	.8	---
Fe	---	---	---	---	[1] 20	---	3.5	---	Tr	---
Mn	---	---	---	---	.0	---	---	---	---	---
As	---	---	---	---	[1] .4	---	---	---	.4	---
Ca	74	3.69	157	7.83	301	15.03	554	27.64	8	0.40
Mg	82	6.7	84	6.9	61	5.0	356	29.3	4	.3
Sr	---	---	---	---	---	---	---	---	---	---
Na	1,770	77.0	3,440	149.6	728	31.66	2,390	103.9	3,160	137.5
K	81	2.07	10	.26	25	.63	614	15.70	40	1.02
Li	---	---	1	.1	---	---	---	---	[1] 5	.72
NH_4	23	1.27	---	---	0	---	5.4	.30	4	.22
Total cations	---	90.7	---	164.7	---	52.3	---	176.8	---	140.2
HCO_3	1,990	32.6	5,990	98.2	2,040	33.48	6,440	105.6	6,660	109.2
CO_3	---	---	---	---	---	---	---	---	199	6.63
SO_4	227	4.73	---	---	Tr	---	125	2.60	388	8.08
Cl	1,620	45.7	2,350	66.3	691	19.46	2,440	68.8	581	16.38
F	---	---	---	---	.6	.03	---	---	---	---
Br	16	.20	5	.06	.1	.00	Tr	---	Tr	---
I	12	.09	1.1	.01	.0	---	Tr	---	.3	---
NO_2	---	---	---	---	---	---	---	---	---	---
NO_3	---	---	---	---	---	---	---	---	---	---
B	44	---	[1] 12	---	7.9	---	59	---	132	---
CO_2	171	---	---	---	---	---	685	---	---	---
H_2S	[1] 360	---	---	---	---	---	---	---	0	---
Total anions	---	[1] 83.3	---	164.6	---	53.0	---	177.0	---	140.3
Total, as reported	6,480	---	12,100	---	4,080	---	13,700	---	11,300	---

See footnotes at end of table.

TABLE 22.—*Chemical analyses of spring waters high in sodium bicarbonate and boron*—Continued

Analysis	6	7	8	9	10
Name and location	Chokrak, Kerch, Crimea, USSR	Essentuki, Caucasus, USSR	Markinsk, Kamchatka, USSR	Futamata, Hokkaido, Japan	Te Aroha, North Island, New Zealand
Date of collection	--------	--------	Sept. 28, 1950	1936	--------
Specific conductance.....micromhos at 25°C	--------	--------	--------	--------	--------
pH	7.3	--------	6.2	6.6	8.3
Temperature °C	Cold	14.0	5.6	42	85½
Density at 20°C	1.00	--------	--------	1.008	--------
Ratios by weight:					
Ca/Na	0.042	0.046	0.41	0.23	0.0025
Mg/Ca	1.1	.54	.20	.64	.5
K/Na	.046	.0029	.034	.26	.013
Li/Na	--------	.0003	--------	--------	.002
HCO_3/Cl[2]	1.2	2.5	3.0	2.6	12
SO_4/Cl	.14	--------	.00	.051	.67
F/Cl	--------	--------	.0009	--------	--------
Br/Cl	.0099	.0021	.0001	--------	.000
I/Cl	.0074	.00046	.0000	--------	.0005
B/Cl	.027	.0051	.011	.024	.23

[1] Components mentioned in explanation of table.
[2] Includes CO_3 as HCO_3.

EXPLANATION FOR TABLE 22

1. Springs, in NW¼ sec. 19, T. 38 N., R. 5 W., Trinity County, Calif., about 6 miles east of Altoona quicksilver mine. Discharge about 2 gpm from landslide material on fine-grained diorite of pre-Tertiary age. Collected by E. H. Bailey; analyzed by C. E. Roberson, U.S. Geol. Survey. Springs evolved some gas and deposited a little travertine. Analysis not previously published.
2. Mud Springs, Mendocino County, Calif.; northeasternmost of a group of springs and small mud volcanoes near crest of ridge, 6 miles west of Laytonville (Waring, 1915, p. 176–177; Bailey and White, 1957, p. 1818). Spring is 6 ft in diameter; discharge is about 0.05 gpm muddy water, from graywacke and shale similar to Mesozoic Yager Formation and is accompained by abundant gas that is probably largely CO_2. Analyzed by C. E. Roberson, U.S. Geol. Survey; analysis not previously published.
3. Southeasternmost spring of two warm springs in Crabtree area, northeast bank of Rice Fork of Eel River, in NE¼ sec. 36, T. 17 N., R. 9 W., Lake County, Calif. Discharges about 20 gpm from serpentine adjacent to shale of Mesozoic Franciscan Group. Serpentine at creek level is altered to opal and carbonate and contains veinlets of marcasite and realgar. Analyzed by C. E. Roberson, U.S. Geol. Survey; when combined nitrogen was determined nearly 4 months after analysis was begun, all of it was nitrite but it probably was NH_4 when sample was collected; pH and HCO_3 were determined immediately after bottle was opened and are considered reliable. Spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in the original water: evaporated residue at 180° C, 6,140; Al, 0.1; Fe, 0.1; Mn, 0.04; Cu, 0.01; Ge, 0.3; Sr, 0.4; Ba, 1.5. Analysis not previously published.
4. Main spring, E½ sec. 36, T. 9 S., R. 4 E., 200 feet above Coyote Creek, 13 miles northeast of Gilroy, Santa Clara County, Calif. Discharges about 10 gpm from Franciscan graywacke near serpentine. Analyzed by H. Almond and S. Berman, U.S. Geol. Survey; analysis not previously published.
5. Benko cold spring, Arkos area, in southeastern Carpathian Mountains, Haromszek County, central Rumania (Straub, 1950, p. 46, 104–105). Discharges from Quaternary alluvium in basin nearly surrounded by Cretaceous limestone and shale that overlie schist. Highest in Li of 51 springs reported by Straub, who also reported traces of Cu, Ba, and Ag; pH reported as 8.99, which is too high for reported HCO_3 and CO_2, with CO_3 absent.
6. Resort with drilled wells in cold-spring area, east border of Chokrak Marsh 1 mile from Sea of Azov and 12 miles north of Kerch, Crimea, U.S.S.R. Water from Karagan and Chokrak Formations of Tertiary age, consisting of shale, limestone, and dolomite (Fomichév, 1948, p. 227). This is type 1 of Fomichév; for type 2, see table 15, analysis 9. Analyzed by I. S. Krasnikova and M. S. Suemina, 1937, who also reported HS, 247 ppm (7.48 epm); HS here included in H_2S.
7. Well 17 at Essentuki resort, Caucasus, U.S.S.R. Water, called "hydrocarbon water", from marl and clay of early Tertiary age (Ovchinnikov, 1947, p. 116–117). Boron determination from Shinkarenko (1948), as well as Zn, 0.08 ppm; Cu, 0.3 ppm; Ba, 2.8 ppm. For gas analysis see table 28, analysis 33.
8. Lower cold CO_2 spring with small discharge from southern part of Middle Range of Kamchatka, U.S.S.R., in Malkinsk area of strongly metamorphosed pre-Tertiary sedimentary, volcanic, and granitic rocks (Ivanov, 1958a, p. 199–201). Collected by V. V. Ivanov; analyzed by E. F. Prokof'eva; Ti and NH_4 were looked for but not found; also reported are silicic acid, 2,651 ppm, and arsenic acid 63.6 ppm, which values are considered to be misprints of decimal points, recalculated to SiO_2 and As. Gas analysis given in table 28, analysis 34.
9. Futamata or Ninomata springs, Tojima area, southwest Hokkaido, Japan (Morimoto, 1954, p. 33). Discharge 240 gpm from middle Miocene andesite and altered rhyolite tuff interbedded with sandstone and mudstone (H. Kuno, written communication). Nearest volcanoes are Recent Yōkei, 25 miles to northeast, and active Usu, 25 miles to southeast. Analysis by Tokyo Hygienic Laboratory.
10. Periodically erupting well, 229 ft deep, in hot-spring area, Te Aroha, North Island, New Zealand (Henderson, 1938, p. 727, 728). Springs emerge at western base of Te Aroha Mountain, a salient on fault scrap of east margin of Hauraki graben. Well penetrated Quaternary alluvium on andesite of Tertiary(?) age cut by veins of quartz, calcite, and pyrite (J. Healy, written communication). Abundant gas evolved; analysis given in table 28, analysis 35. See table 11, analysis 10, for analysis of a cold spring at Te Aroha.

TABLE 23.—*Chemical analyses of thermal waters closely associated with epithermal mineral deposits*

Analysis	1		2		3		4		5		6		7		8	
Name and location	Sulphur Bank mine, Lake County, Calif.		Abbott Mine, Colusa County, Calif.		Valley Mine, Napa County, Calif.		Amedee Springs, Lassen County, Calif.		Boiling Springs, Valley County, Idaho		Ngawha Springs, North Island, New Zealand		Rose Creek Spring, Pershing County, Nev.		Abraham Springs, Juab County, Utah	
Associated metal or mineral	Hg, Sb		Hg		Hg		Hg		Hg		Hg, Sb		Mn, W		Mn	
Date of collection	Mar. 26, 1957		Mar. 27, 1957		Oct. 18, 1957		Oct 22, 1957		Aug. 5, 1953		------		May 22, 1957		Sept. 12, 1957	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	42	------	16	------	95	------	96	------	81	------	119	------	70	------	75	------
Al	.6	------	1.6	------	.1	------	.23	------	[1]0.1	------	0	------	.0	------	.0	------
Fe +2	.0	------	.0	------	.6	------	.01	------	[1]0.4	------	0	------	[1].5	------	.0	------
Fe +3											------	------				
Mn	.1	------	.0	------	.1	------	[1].00	------	[1]0.004	------	------	------	.2	------	.8	0.03
As	.00	------	.00	------	.00	------	.16	------	<0.1	------	.2	------	.00	------	.06	------
Ca	20	1.00	64	3.19	19	0.95	16	0.80	2.2	0.11	18	0.90	62	3.09	352	17.56
Mg	55	4.5	443	36.4	90	7.40	.0	------	0	------	1	.08	27	2.2	49	4.03
Sr	[1].6	------	[1].5	------	0	------	.0	------	[1]0.2	------	------	------	0	------	0	------
Ba	[1].3	------	[1].2	------	0	------	[1].05	------	------	------	------	------	0	------	0	------
Na	1,190	51.8	1,500	65.3	476	20.71	227	9.87	74	3.22	689	29.97	570	24.80	770	33.50
Ki	23	.59	39	1.00	8.2	.21	6.8	.17	1.9	.05	57	1.46	19	.49	54	1.38
Li	4.4	.63	1.8	.26	.0	------	.0	------	[1].02	.00	[1]5	.72	1.6	.23	.0	------
NH_4	464	25.7	22	1.22	2.5	.14	.5	.03	------	------	129	7.15	.7	.04	.1	.01
Total cations	------	84.2	------	107.4	------	29.4	------	10.87	------	3.38	------	40.3	------	30.9	------	56.5
HCO_3	3,290	53.9	2,710	44.4	1,490	24.4	27	.44	79	1.29	470	7.70	1,280	21.0	142	2.33
CO_3	0	------	0	------	0	------	10	.33	27	.90	------	------	0	------	0	------
SO_4	598	12.45	467	9.72	16	.33	288	6.00	12	.25	332	6.91	102	2.12	704	14.66
Cl	644	18.16	1,900	53.6	229	6.46	160	4.51	14	.40	929	26.20	235	6.63	1,480	41.7
F	1.0	.05	1.0	.05	1.3	.07	4.5	.24	11	.58	------	------	5.5	.29	4.5	.24
Br	1.6	.02	3.8	.05	1.0	.01	.2	.00	------	------	Tr	------	.2	.00	1.8	.02
I	3.2	.03	6.3	.05	.8	.01	.1	.00	------	------	0	------	.0	------	.1	.00
NO_2	.0	------	14	.30	.0	------	.00	------	------	------	------	------	.00	------	.1	.00
NO_3	0	------	4	.06	0	------	.0	------	.5	.01	------	------	.8	.01	2.5	.04
PO_4	------	------	------	------	.3	------	.40	------	------	------	------	------	.8	------	[1].06	------
B	620	------	56	------	67	------	4.1	------	.1	------	677	------	9.6	------	.9	------
H_2S	12	------	<1	------	<1	------	[1].2	------	<1	------	9	------	------	------	0	------
Total anions	------	84.6	------	108.2	------	31.3	------	11.52	------	3.43	------	40.8	------	30.1	------	59.0
Total, as reported	6,970	------	7,250	------	2,500	------	841	------	[1]304	------	3,440	------	2,380	------	3,640	------
Specific conductance micromhos at 25° C	7,430		8,960		2,740		1,270		321		------		2,690		5,640	
pH	6.8		7.1		6.5		8.5		9.1		6.2		6.4		6.6	
Temperature °C	69.5		[1]26		32		92		88		83		22		82	
Density at 20° C	------		------		------		------		------		------		------		------	
Ratios by weight:																
Ca/Na	0.017		0.043		0.040		0.071		0.029		0.027		0.11		0.46	
Mg/Ca	2.7		6.9		4.7		.00		0.0		.056		.44		.14	
K/Na	.012		.026		.017		.030		.026		.082		.033		.070	
Li/Na	.0037		.0012		.000		.000		.0003		.007		.0028		.0000	
HCO^3/Cl[3]	5.1		1.4		6.5		.29		9.6		.51		5.5		.096	
SO_4/Cl	.92		.25		.07		1.8		.85		.36		.43		.48	
F/Cl	.0015		.0005		.0057		.028		.78		------		.023		.0030	
Br/Cl	.0024		.0020		.0044		001		------		.000		.0009		.0012	
I/Cl	.0047		.0033		.0035		.0006		------		.000		.000		.0001	
B/Cl	.96		.030		.29		.026		.006		.72		.041		.0006	

Analysis	9		10		11		12		13		14		15		16	
Name and location	Ouray Springs, Ouray County, Colo.		Warmwaterberg Springs, Cape Province, Union of South Africa		Akan Mine, Hokkaido, Japan		Poncha Springs, Chaffee County, Colo.		Ojo Caliente Springs, Taos County, N. Mex.		Doughty Springs, Delta County, Colo.		Mizpah mine, Tonopah, Nye County, Nev.		Peitou Springs, North of Taipei, Taiwan	
Associated metal or mineral	Mn, W		Mn		Mn		Fluorite (Mn, W)		Fluorite		Barite		Ag, Au		Pb	
Date of collection	Sept. 3, 1958		------		------		Aug. 29, 1958		------		------		------		------	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO^2	49	------	15	------	46	------	84	------	60	------	21	------	65	------	167	------
Al	.14	------	------	------	------	------	.53	------	.3	------	0.5	------	0.7	------	104	11.6
Fe +2	.42	------	[1].6	------	------	------	.46	------	1.2	------	0.7	0.03	.7	------	------	------
Fe +3					6.7	0.24						0.06	------	------	151	8.11
Mn	.92	0.03	.9	0.03	1.8	.07	.10	------	------	------	1.6	------	------	------	------	------
As	.00	------	------	------	------	------	.00	------	Tr	------	------	------	------	------	------	------
Ca	376	18.76	18	.90	104	5.20	17	0.85	23	1.15	106	5.29	69	3.44	141	7.04
Mg	6.1	.50	6.0	.49	74	6.10	.2	.02	9.5	.78	39	3.21	6.3	.52	41	3.4
Sr	[1]1.7	------	[1]8	------	------	------	[1].4	------	1.4	.03	6.6	.15	------	------	------	------
Ba	[1].05	------	[1]7	------	------	------	[1].1	------	Tr	------	13	.19	------	------	.4	.01
Na	111	4.83	22	.78	(2)	------	190	8.26	996	43.33	1,060	46.11	149	6.48	1,010	43.9
Ki	8.0	.20	8.9	.23			6.6	.17	31	.79	62	1.59	3.4	.09	374	9.57
Li	1.0	.14	[1].2	------	------	------	.0	------	3.4	.49	3.1	.45	------	------	------	------
NH_4	.3	.02	0	------	------	------	.0	------	Tr	------	1.2	.07	------	------	205	11.36
Total cations	------	24.5	------	2.43	------	11.6	------	9.30	------	46.6	------	57.2	------	10.53	------	[1]149.0
HCO_3	128	2.10	85	1.39	(3)	------	210	3.44	[1]2,230	36.5	[1]1,490	[1]24.4	157	2.57	0	------
CO_3	0	------	0	------	------	------	0	------	(1)	------	------	------	11	.37	------	------
SO_4	1,030	21.4	11	.23	572	11.92	200	4.16	151	3.14	625	13.01	327	6.81	2,730	56.8
Cl	45	1.27	37	1.04	307	8.65	54	1.52	231	6.51	701	19.77	36	1.02	3,250	91.7
F	3.0	.16	.2	.01	------	------	11	0.58	[1]16	.84	------	------	------	------	------	------
Br	.0	------	------	------	------	------	.0	------	------	------	5.2	.07	0	------	------	------
I	.2(?)	.00	------	------	------	------	.0	------	Tr(?)	------	Tr	------	0	------	------	------
NO_2	.00	------	------	------	------	------	.00	------	------	------	------	------	------	------	------	------
NO_3	.9	.01	0	------	------	------	.0	------	[1].9	.01	------	------	Tr	------	------	------
PO_4	.06	------	------	------	------	------	.02	------	.2	------	[1]0	------	------	------	1.0	------
B	.23	------	------	------	------	------	.09	------	1.2	------	1.9	------	------	------	18	------
H_2S	.0	------	0	------	------	------	0	------	------	------	47	------	------	------	------	------
Total anions	------	24.9	------	2.67	------	------	------	9.70	------	47.0	------	[1]57.2	------	10.77	------	148.5
Total, as reported	1,760	------	205	------	------	------	774	------	3,760	------	6,190	------	825	------	[1]8,250	------

See footnotes at end of table.

TABLE 23.—*Chemical analyses of thermal waters closely associated with epithermal mineral deposits*—Continued

Analysis	9	10	11	12	13	14	15	16
Name and location	Ouray Springs, Ouray County, Colo.	Warmwaterberg Springs, Cape Province, Union of South Africa	Akan Mine, Hokkaido, Japan	Poncha Springs, Chaffee County, Colo.	Ojo Caliente Springs, Taos County, N. Mex.	Doughty Springs, Delta County, Colo.	Mizpah mine, Tonopah, Nye County, Nev.	Peitou Springs, North of Taipei, Taiwan
Associated metal or mineral	Mn, W	Mn	Mn	Fluorite (Mn, W)	Fluorite	Barite	Ag, Au	Pb
Date of collection	Sept. 3, 1958			Aug. 29, 1958				
Specific conductance micromhos at 25° C	2,020			994				
pH	6.8	7.5	8.0	7.6	[1] 7.2			Acid
Temperature ° C	[1] 62	45.6	52.4	70	[1] 46	17	41	90
Density at 20° C					1.003	1.004		
Ratios by weight:								
Ca/Na	3.4	0.82		0.089	0.023	0.1	0.46	0.14
Mg/Ca	.016	.33	0.71	.01	.41	.37	.091	.29
K/Na	.072	.40		.035	.031	.058	.023	.37
Li/Na	.009			.000	.0034	.0029		
HCO_3/Cl [3]	2.8	2.3		3.9	9.7	2.1	5.0	.000
SO_4/Cl	23	.30	1.9	3.7	.65	.89	9.1	.83
F/Cl	.067	.005		.20	.069			
Br/Cl	.000			.000		.0074	.00	
I/Cl	.004			.000	.00		.00	
B/Cl	.001			.002	.0052	.0027		.0053

[1] Components mentioned in explanation of table.

[2] Not reported.

[3] Includes CO_3 as HCO_3.

EXPLANATION FOR TABLE 23

1. Spring in Sulphur Bank mine, one of the most productive quicksilver mines in the United States (Becker, 1888, p. 251–269; Everhart, 1946, p. 125–153; White, 1955a, p. 117–120), in SW¼ sec. 5, T. 13 N., R. 7 W., on shore of Clear Lake, Lake County, Calif. Variable discharge, ranging from about 1 to 15 gpm from north wall of Herman Pit, about 120 ft below original surface, from hydrothermally altered graywacke and shale of Mesozoic Franciscan Formation, overlain by Pleistocene lake beds and pyroxene andesite flow. Analyzed by C. E. Roberson, U.S. Geol. Survey; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in the original water: evaporated residue at 180°C, 5,220; Al, 0.2; Fe, 0.1; Mn, 0.2; Cu, 0.01; Ge, 0.2; Li, 3.6; Sr, 0.6; Ba, 0.3. Analysis not previously published. Tritium content of sample was $1.1 \pm 0.2 \times 10^{-18}$, determined by F. Begemann, University of Chicago. For gas analysis of sample from Herman Shaft, see table 28, analysis 36 (Becker, 1888, p. 258).
2. Thermal water from Abbott mine, located in NE¼ sec. 31, T. 14 N., R. 5 W., Colusa County, Calif. near crest of ridge 2 miles southwest of Wilbur Springs (see table 15, analysis 2). Drainage from Reardon Tunnel, 200-foot level, pumped from bottom of main shaft at 300-ft level. Average discharge is about 25 gpm; temperature of 26°C measured at portal of tunnel; temperature at source probably about 33°C (White, 1955a, p. 131). Ore and thermal water, accompanied by some combustible gas, are controlled by fractures and breccia zones in serpentine and Upper Jurassic Knoxville sandstone and shale. Water sample analyzed by C. E. Roberson, U.S. Geol. Survey; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in the original water: evaporated residue at 180°C, 5,930; Al, 0.06; Fe, 0.04; Cu, 0.006; Li, 2.1; Rb, 0.06; Sr, 0.5; Ba, 0.2. Analysis not previously published.
3. Water from Valley quicksilver mine, Aetna Springs Resort, Napa County, Calif., SW¼ sec. 1, T. 9 N., R. 6 W. (White, 1955a, p. 130; Yates and Hilpert, 1946, p. 260; Waring, 1915, p. 156–159). Water pumped from shaft of old mine in opalized silica-carbonate rock (altered serpentine) near contact with Knoxville shale and sandstone. Analyzed by H. C. Whitehead, U.S. Geol. Survey; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in the original water; evaporated residue at 180°C, 1,870; Al, 0.08; Fe, 2.1; Mn, 0.06; Cu, 0.2; Ni, 0.02; Ge, 0.07; Li, 0.08; Rb, 0.02; Sr, 0.3; Ba, 0.3.. Analysis not previously published.
4. F. W. Dickson spring A–1, 1,000 ft south-southwest of old Amedee railroad station, east side of Honey Lake, Lassen County, Calif. (Dickson and others, 1957). Cinnabar, metacinnabar, and minor travertine deposited in vent. Total discharge of group is about 1,000 gpm from thick alluvium of Honey Lake basin. Collected by J. Feth and S. M. Rogers; analyzed by J. P. Schuch, U.S. Geol. Survey, who also determined Ti, 0.02 ppm; Cu, Pb, Zn each 0.00 ppm; H_2S 0.2 ppm (sample of May 22, 1957). Spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in the original water: evaporated residue at 180°C, 850; Al, 0.04; Fe, 0.02; Mn, 0.003; Ti, 0.005; Cu, 0.01; Pb, 0.009; Mo, 0.06; W, 0.2; Cr, 0.002; Ge, 0.02; Ni, 0.02; Sr, 0.06; Ba, 0.05. Analysis not previously published.
5. Largest spring, near north end of spring terrace, Boiling Springs, NW¼ sec. 22, T. 12 N., R. 5 E., on west bank of Middle Fork of Payette River in Valley County, Idaho. Discharges about 30 gpm; total discharge of group is about 125 gpm. Springs emerge from shear zone in granodiorite of Idaho batholith, associated with carbonate-cemented terrace gravel, and have deposited small, amount of calcite, cinnabar, metacinnabar, and manganese oxide (White 1955a, p. 124–125). Analyzed by H. Kramer, U.S. Geol. Survey, who also reported Sb 0.1 ppm; Hg, 0.0 ppm; spectrographic analysis, in ppm, indicate Fe, 0.4; Al, 0.1; Mn, 0.004; Cu, 0.01, Ag, 0.005; Sr, 0.2; Cr, 0.003; Li, 0.02; and B, 0.3. Analysis not previously published.
6. Ngawha Springs, North Island, New Zealand; "Jubilee" Bath of area G of Fleming (1945, p. 255–276) near Tuwhakino Lake. Discharge is apparently slight; temperature at surface is 43°C; at sandy bottom, 83°C. Springs are in late Quaternary lake sediments overlying claystone of Kaeo Series of Late Cretaceous to early Tertiary age. Miocene and late Quaternary basalts are within a few miles of the area. Springs have deposited cinnabar and a little stibnite (Henderson, 1944, p. 60; White, 1955a, p. 123–124). Water analyzed by L. R. L. Dunn, I. C. McDowall, S. H. Wilson, and M. Fieldes of the New Zealand Dominion Laboratory. Li determined by spectrographic analysis; also reported are Rb, 0.5 ppm, and Ca, 0.1 ppm. For analysis of gas from Velvet Bath, about 50 feet to south, see table 28, analysis 37.
7. Travertine-spring terrace near north end of East Range, about 2 miles southwest of Rose Creek and 12 miles southwest of Winnemucca, sec. 28, T. 35 N., R. 36 E. Pershing County, Nev. (White, 1955a, p. 134). Discharges about 1 gpm from travertine and Quaternary sand and gravel containing as much as 9 percent Mn and 0.3 percent WO_3. Water sample analyzed by J. P. Schuch, U.S. Geol. Survey, who also reported 0.03 ppm Ti; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in original water: evaporated residue at 180°C, 1,700; Al 0.02; Fe, 0.02; Mn, 0.09; Be, 0.002; Cu, 0.002; Sr, 0.2; Ba, 0.2. Analysis not previously published.
8. Abraham Springs, Juab County, Utah; orifice in east fork of north ditch, about 200 ft north of crest of travertine cone; same as spring 2 of Callaghan and Thomas (1939, p. 908–912; White, 1955a, p. 133-134), 19 miles north-northwest of Delta. Discharge of spring about 25 gpm; total discharge of springs in area about 1,200 gpm. Springs discharge through Pleistocene Lake Bonneville sediments overlain by travertine-spring deposits containing manganiferous zone about 1 ft below surface. Pleistocene basalt flow issued about 4 miles northwest of spring, with flow front only 1,500 ft to west. Water sample analyzed by J. P. Schuch, U.S. Geol. Survey; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in original water: evaporated residue at 180°C, 3,740; Fe, 0.02; Mn, 0.3; Cu, 0.004; Li, 1.1; Rb, 0.2; Sr, 8.2; Ba, 0.2. Analysis not previously published.
9. Spring at southwest edge of Ouray, Ouray County, Colo., and about 40 ft above valley floor, issuing from terrace of travertine; Mn and Fe oxides lie on Pleistocene gravels and Mississippian Leadville Limestone. Discharges about 15 gpm; temperature is 59°C at surface of wood-framed vent; 62°C at 6-ft depth; no gas. Flocculent deposit from present spring water contains 15 percent Mn, 7 percent Fe, and 0.2 percent W; a high-grade Mn oxide veinlet from the western part of the terrace contains, in percent: Mn, 50; Fe, 0.1; W, >1; Pb, 1; Cu, 0.05; Zn, 0.3; V, 0.015; Mo, 0.003; Be, 0.03; Ba, 0.7; Sr, 0.5; Sb, 0.5; and La, 0.01. Water sample analyzed by H. C. Whitehead, U.S. Geol. Survey; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in original water: evaporated residue at 180°C, 1,760; Al, 0.05; Fe, 0.03; Mn, 0.9; Ti, 0.02; Cu, 0.02; Ag, 0.002; Mo, 0.02; Sr, 1.7; Ba, 0.05. Analysis not previously published.
10. Warmwaterberg Springs, Cape Province, Union of South Africa. Springs discharge from Table Mountain Series of Devonian age. Deposits estimated to contain 600,000 tons, containing (in weight percent): Fe_2O_3, 57½; MnO, 0.55; MnO_2, 8.55; BaO, 1.45; and P_2O_5, 1.18 (Kent, 1949, p. 240, 243, 245, 247). Age of deposit estimated to be 850,000 years, if all Fe and Mn in present water are deposited at constant rate. Analyzed by W. Sunkel and P. Kok, 1947; Mo, 1 ppm; Ba, 7 ppm; Sr, 8 ppm; Li, 0.2 ppm, determined by spectrograph.
11. Akan mine, Hokkaido, Japan; hot-spring deposit is mined for manganese on south slope of Mea-kan-dake, a pyroxene andesite volcano. Spring is hottest of 4 manganese-bearing springs; the deposit is more than 6 ft thick, the ore averages about 25 percent manganese, and one sample analyzed for Co contained 0.2 percent. Analysis from Kimura and Shima, 1954.
12. Largest of several hot springs about a quarter of a mile southeast of Poncha Springs fluorite deposit and 5 miles southwest of Salida, Chaffee County, Colo. (R. T. Russell, 1947; 1948). Total discharge of hot springs reported to be 500 gpm and maximum temperature 75½°C (Stearns and others, 1937, p. 133), but present discharge of this spring is estimated as 30 gpm and total of the group is perhaps 50 gpm. Springs emerge from fault in Precambrian gneiss overlain by travertine deposit of calcite, minor opal, chalcedony, tungsten-bearing manganese oxide, and fluorite; Poncha Springs fluorite deposit controlled by same fault; late Tertiary rhyolite and andesite are within a few miles of springs. Water sample analyzed by H. C. Whitehead, U.S. Geol. Survey, who also reported Cu and Pb, each 0.00 ppm, and Zn, 0.07 ppm; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in original water: evaporated residue at 180°C, 1,250; Al, 0.2; Fe, 0.04; Mn, 0.02; Ti, 0.01; Cu, 0.08; Mo, 0.08; Cr, 0.003; Ge, 0.01; Sr, 0.4; Ba, 0.1. Analysis not previously published.
13. Soda Spring, 12 miles northwest of Barranca, Taos County, N. Mex.; total discharge of Ojo Caliente springs is about 350 gpm (Stearns and others, 1937, p. 167). Springs issue from travertine near fluroite-barite vein containing minor amounts of gold and silver; an inactive travertine terrace lies about 500 ft above present springs (Lindgren, 1910); bedrock is fine-grained gneiss overlain by andesite tuffs. Analyzed by W. F. Hillebrand, 1893 (Clarke, 1924a, p. 192–193), with HCO_3 calculated from reported carbonate. Temperature, F, NO_3, and pH from similar sample of same spring collected October 6, 1949, and analyzed by L. S. Hughes, U. S. Geol. Survey.
14. Drinking Spring, 3 miles southwest of Hotchkiss, Doughty Springs, on North Fork of the Gunnison River, Delta County, Colo. Discharges 5 to 6 gpm

EXPLANATION FOR TABLE 23—Continued

(Headden, 1905, p. 1–8, 15–16; George and others, 1920, p. 213, 313). Springs emerge near base of cliff of Dakota(?) Sandstone of Late Cretaceous(?) age and have formed a travertine-barite deposit 400 ft long, 115 ft wide, and about 20 ft thick. Deposit near Drinking Spring and several other springs is nearly pure $BaSO_4$. Sample collected and analyzed by W. P. Headden (1905, p. 15–16); total CO_2, 3,080 ppm, of which 1,070 ppm is here assigned by difference of anions and cations to HCO_3 and 2,010 ppm considered as free CO_2. Phosphate analysis by George; trace of Zn reported by Headden.

15. Water from drill hole, 2,316-ft deep, which was started at 1,500-ft level of shaft of Mizpah mine, Tonopah district, Nye County, Nev., and penetrates to a point 816 feet below that level (Bastin and Laney, 1918, p. 26–30). Silver-gold ores largely in hydrothermally altered intermediate volcanic rocks of Tertiary age (Nolan, 1935, p. 1–49; White, 1955a, p. 138–139). Trace of Zn also reported.
16. One of springs of Peitou group, north of Taipei and near north end of Taiwan; group formerly known as Hokuto Springs; one of the springs deposited hokutolite, a lead-bearing variety of barite (Okamoto, 1911, p. 21). May be Peitou Valley hot spring 1 of Yen (1955, p. 136, 139), which has present temperature of 68°C and discharge of 260 gpm. Water issues from or from very near Pleistocene basalt flows that overlie marine sedimentary rocks of Mio-Pliocene age. Analysis converted from hypothetical compounds, H^+ 54 ppm (54 epm) probably calculated by difference and is included in totals; trace of Pb reported.

TABLE 24.—*Chemical analyses of nonthermal, saline and acid waters from mines and from acid-forming areas*

Analysis	1		2		3		4		5	
Name and location	Homestake mine, Lawrence County, S. Dak.		Centennial mine, Houghton County, Mich.		Greenwood mine, Marquette County, Mich.		Comstock Lode, Storey County, Nev.		Tonopah district, Nye County, Nev.	
Date of collection	Dec. 20, 1957		Aug. 22, 1956		Mar. 25, 1952					
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	19.		<10		6.8		576		15	
Al	.35		5.4		.0		9,000	1,000	3	0.33
Fe^{+2}	.06		1.0		1.2				7	.25
Fe^{+3}							469	25.20		
Mn	.00		2.5		1.9		841	30.61	75	2.73
Ni										
Cu			(1)				148	4.66		
Zn										
Ca	5.2	0.26	62,900	3,140	452	22.56	1,160	57.9	249	12.43
Mg	2.4	.20	179	14.7	155	12.7	6,240	513	10	.82
Na	373	16.22	11,900	518	1,080	47.0	498	21.7	135	5.87
K	10	.26	38	.97	54	1.38			12	.30
Li	.3	.04	7.0	1.01						
NH_4	.4	.02	<10							
H										
Total cations		17.00		3,670		[1]83.8		1,650		22.7
HCO_3	884	14.49	24	0.39	28	0.46	0		0	
HSO_4										
SO_4	6.7	.14	88	1.83	2.1	.04	78,600	1,636	1,020	21.2
SO_3	2.8	.07								
Cl	38	1.07	128,000	3,610	3,030	85.5	120	3.38	65	1.83
F	5.5	.29			.4	.02				
Br	.26	.00	997	12.47					0?	
I	.06	.00	3.2	.03					0?	
NO_2	.00		<1							
NO_3	3.5	.06	<25	0	.0				0	
PO_4	.04				.0					
B	.6		2.5		11					
Total anions		16.12		3,620		86.0		1,640		23.0
Total, as reported	1,350		204,000		[1]4,830		97,700		1,590	

Analysis	1	2	3	4	5
Specific conductance....micromhos at 25° C	1,420		8,380		
pH	7.6	6.5	5.4	Acid	Acid
Temperature ° C	39	Cold	13	Cold	?
Density at 20°		1.174		[1]1.07	
Ratios by weight:					
Ca/Na	0.014	4.3	0.42	2.3	1.8
Mg/Ca	.46	.0028	.34	6.7	.04
K/Na	.027	.0032	.050		.087
Li/Na	.0008	.0006			
HCO_3/Cl	23	.00018	.0092	.00	.00
SO_4/Cl [2]	.18	.00069	.00069	660	16
F/Cl	.14		.0001		
Br/Cl	.007	.0078			.00
I/Cl	.002	.00003			.00
B/Cl	.02	.00002	.0036		

See footnotes at end of table.

TABLE 24.—*Chemical analyses of nonthermal, saline and acid waters from mines and from acid-forming areas—Continued*

Analysis	6		7		8		9		10	
Name and location	Butte district, Silver Bow County, Mont.		Red Mountain district, San Juan County, Colo.		Cananea mine, Sonora, Mexico		"Poison" spring, Washoe County, Nev.		Kinkei spring, Tochigi Prefecture, Japan	
Date of collection			Dec. 1933							
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	48		66		56		98		107	
Al	84	9.33	29	3.2	22	2.5			107	11.9
Fe^{+2}					524	18.76	[1]400	[1]42.0	284	10.17
Fe^{+3}	160	8.59	37	1.98					235	12.6
Mn	12	.44	.07	.00	153	5.57	[1]10	.36	.3	.01
Ni	[1].5	.00					[1].6	.02	.06	.00
Cu	59	1.85	2.0	.06	60	1.89	[1]2	.06	1.0	.03
Zn	852	26.06			252	7.70			.1	.00
Ca	133	6.63	16	.79	753	37.57	283	14.12	15	.75
Mg	62	5.09	4.3	.35	86	7.07	39	3.2	3.2	.26
Na	40	1.74	4.2	.18	198	8.61	65	2.83	1	.04
K	13	.33	1.1	.03			.9	.02	0	
Li									(1)	
NH_4										
H			3.3	3.3					3.8	3.8
Total cations		[1]61.4		9.89		89.7		62.6		39.6
HCO_3	0		0		0		0			
HSO_4									387	3.99
SO_4	2,670	55.6	466	9.70	4,460	92.9	3,100	64.5	1,690	35.2
SO_3										
Cl	13	.37			22	.62	6.0	.17	18	.51
F							1.0	.05		
Br										
I										
NO_2										
NO_3							0			
PO_4										
B							.2		(1)	
Total anions		56.0		9.70		93.5		64.7		39.7
Total, as reported	[1]4,200		629		6,590		4,010		2,850	

Analysis	6	7	8	9	10
Specific conductance....micromhos at 25° C					
pH	[1]Acid	Acid	Acid	2.45	2.4
Temperature ° C				Cold	9
Density at 20°		1.0011			1.003
Ratios by weight:					
Ca/Na	3.3	3.8	3.8	4.4	15
Mg/Ca	.47	.26	.11	.14	.21
K/Na	.33	.26		.01	.0
Li/Na					
HCO_3/Cl	.0		.00	.00	.00
SO_4/Cl[2]	210		200	520	120
F/Cl				.2	
Br/Cl					
I/Cl					
B/Cl				.03	

[1] Components mentioned in explanation of table.
[2] Includes HSO_4.

EXPLANATION FOR TABLE 24

1. Water from cavity penetrated by drill hole started at 5,600-ft level, at the then-existing bottom of Homestake gold mine, Lawrence County, S. Dak. (see Noble, 1950, p. 234, 235). Collected by A. Slaughter of Homestake Mining Co. and analyzed by H. C. Whitehead and J. P. Schuch, U.S. Geol. Survey, who also determined Cu, Pb, As, Tl, each 0.00 ppm; Zn, 0.04 ppm. Spectrographic analysis of evaporated residue by Nola B. Sheffey, converted to ppm in the original water: evaporated residue at 180°C, 911, Al 0.03; Fe, 0.01; Cu, 0.0009; Cr, 0.003; Sr, 0.2; Ba, 0.06. Analysis not previously published. Similar to analysis of Noble (1950, p. 234, 235) except that all forms of sulfur are lower.
2. Water from 7,075 ft south on 48 level of Centennial No. 2 shaft of Calumet and Hecla copper mine, Houghton County, Mich., and about 3,000 ft vertically below surface. Rate of flow about 1 drop per second from back of drift in Kearsarge amygdaloid; water was clear when collected by A. Schillinger, of Calumet and Hecla, Inc. Analyzed by C. E. Roberson, U.S. Geol. Survey. Spectrographic analysis of evaporated residue by Nola B. Sheffey, converted to ppm in the original water; evaporated residue at 180° C, 225,000; Al, 4.5; Fe, 3.2; Mn, 0.7; Cu, 0.7; Li, 1.1; Cs, 9.1; Sr, 320; Ba, 4.1. Analysis not previously published.
3. Water flowing from drill hole 162 on 5th level of Greenwood iron mine, Marquette County, Mich., 183 feet below sea level (Stuart and others, 1954, p. 10–11, 86–87); highest in salinity of analyses reported by Stuart. In bedrock of this area, mineral content of water increases with depth, with Cl, in general, increasing very rapidly; at first, Na increases in proportion to Cl, but at greater depths Ca increases more rapidly than Na (Stuart and others, 1954, p. 86). Water from Goodrich Quartzite of Upper Huronian age, immediately above the iron-formation. Sample analyzed by U.S. Geol. Survey; also reported and included in totals are Sr, 6 ppm (0.14 epm); Ba, <0.5 ppm. See table 9, analysis 4, for a water of low salinity in the Cliffs Shaft iron mine of Michigan.
4. Water from Central tunnel of Comstock Lode, Storey County, Nev.; an acid mine water (Reid, 1905, p. 192) from hydrothermally altered andesite and other rocks containing pyrite (Coats, 1940; Thompson, 1956; White, 1955a, p. 139–140). Analysis reported as hypothetical oxides in mg per l, converted to ppm by assuming a density of 1.07. Also reported are Ag, 0.2 ppm; and Au, 0.004 ppm.
5. Water from West End mine, 500 ft level, Tonopah district, Nye County, Nev. (Bastin and Laney, 1918, p. 29); water is acid owing to oxidation of sulfides, and apparently cold, in contrast to deep thermal Tonopah waters (see table 23, analyis 15). An epithermal silver-gold deposit in hydrothermally altered Tertiary volcanic rocks (Nolan, 1935; White, 1955a, p. 138–139). Also reported is a trace of As.
6. Water from crosscut on 1,200-ft level, St. Lawrence mine, Butte district, Silver Bow County, Mont. (Lindgren, 1933, p. 62), in oxidizing sulfides of copper-bearing hydrothermally altered quartz monzonite of Boulder batholith. Also reported and included in totals: Sn, 17 ppm (0.57 epm) Cd, 41 ppm (0.73 epm). Co included with Ni; and Sn may have been introduced from sample container.
7. Water from Genessee-Vanderbilt mine near West Magnolia ore body north of Silverton, Red Mountain district, San Juan County, Colo., from altered andesite with disseminated pyrite (Burbank, 1950, p. 293, and unpublished analysis). Sample collected by W. S. Burbank, analyzed by E. T. Erickson, U.S. Geol. Survey; analysis not previously published.
8. Water from Cananea mine, 900-ft level, Sonora, Mexico; in copper-bearing granitic rocks and porphyry intrusive into Paleozoic limestone (Lindgren, 1933, p. 63, 722–723); affected by oxidation of disseminated sulfides.
9. "Poison" spring on west slope of Virginia Range, NE¼sec. 35, T. 18 N., R. 20 E., 3 miles east of Steamboat Springs, Washoe County, Nev. Water issues from short prospect adit in pyritized andesite of Kate Peak Formation of Miocene or Pliocene age (Thompson, 1956, p. 62–63, pl. 3) that is bleached near surface by acid from oxidation of pyrite. Discharges about 2 gpm; sample analyzed by H. Kramer, U.S. Geol. Survey. R_2O_3, 715 ppm, determined by spectrographic analysis to be about 10 percent Fe and 90 percent Al, approximately equal to 400 ppm of metallic ions and 42 epm; Mn, Ni, Cu, and Ag (0.3 ppm) also determined spectrographically. Analysis not previously published.
10. Kinkei Spring, Tochigi Prefecture, Japan; a cold spring at top of Keichyo Mountain, a Quaternary andesite(?) volcano. Analyst, K. Kuroda (1941a, p. 234–237); also determined, in ppm: Ti, 0.1; As, 1 (0.04 epm); Cr, 0.07; V, 0.05; Mo, 0.002; Ga, 0.001; Bi present and possibly traces of Li, Hg, and B.

TABLE 25.—*Chemical analyses of spring waters depositing travertine*

Analysis	1		2		3		4		5		6	
Name and location	Keene Wonder, Inyo County, Calif.		Keene Wonder, Inyo County, Calif.		Mammoth, Yellowstone Park, Wyo.		Big Horn, Hot Springs County, Wyo.		Lýsuhóll, Snaefellsnes Peninsula, Iceland		Meskoutine, Constantine Province, Algeria	
Date of collection	Nov. 7, 1954		Nov. 7, 1954		Sept. 5, 1957		Sept. 1957		Sept. 30, 1958			
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	60		[1] 57		60		36		171		66	
Al					.2		.4		0.00			
Fe					.06		.04		2.6			
Mn					.00		.05		.00			
As					.5		.2		.03		.5	
Ca	89	4.44	[1] 23	1.15	272	13.57	374	18.66	136	6.79	202	10.08
Mg	43	3.5	[1] 38	3.1	68	5.59	74	6.1	32	2.63	37	3.0
Sr	3.5	.08	[1] 1.7	.04	[1] .4		[1] .7					
Na	932	40.54	1,040	45.2	129	5.61	271	11.79	406	17.66	205	8.92
K	42	1.07	45	1.15	69	1.76	44	1.13	29	.74	47	1.20
Li	.8	.12	.9	.13	2.3	.33	.9	.13	.5	.07		
NH_4					1.0	.06	.0		.0	.00		
Total cations		49.8		50.8		26.9		37.8		27.89		23.2
HCO_3	1,210	19.8	1,070	17.5	667	10.93	756	12.39	1,520	24.91	[1] 372	6.10
CO_3	0		29	.97	0		0		0		(1)	
SO_4	719	14.97	796	16.57	501	10.43	726	15.12	38	.79	381	7.93
Cl	514	14.49	567	15.99	170	4.79	320	9.02	84	2.37	327	9.2[illegible]
F	7.0	.37	6.0	.32	2.4	.13	3.5	.18	2.2	.12		
NO_3	.9	.01	1.0	.02	0		.0		.0			
B	8.6		9.6		4.3		7.8		.57			
H_2S					2.6		5.5		.2		6.8	
Total anions		49.6		51.4		26.3		36.7		28.19		23.2
Total, as reported	3,630		3,680		[1] 1,950		2,620		2,420		1,640	
Specific conductance..micromhos at 25° C	4,640		4,790		2,220		3,030		2,370			
pH	7.4		8.4		6.6		6.2		6.4			
Temperature ° C	33		23±		72		57		41.6		95	
Ratios by weight:												
Ca/Na	0.095		0.022		2.1		1.4		0.34		0.99	
Mg/Ca	.48		1.7		.25		.20		.24		.18	
K/Na	.045		.043		.53		.16		.071		.23	
Li/Na	.0009		.0009		.018		.003		.001			
HCO_3/Cl [2]	2.3		2.0		3.9		2.4		18		1.1	
SO_4/Cl	1.4		1.4		2.9		2.3		.45		1.2	
F/Cl	.014		.011		.014		.011		.026			
Br/Cl					[1] .0041				[1] .002			
I/Cl					[1] .0006				[1] .000			
B/Cl	.017		.017		.025		.024		.007			

[1] Components mentioned in explanation of table.

[2] Includes CO_3 as HCO_3.

EXPLANATION FOR TABLE 25

1. Keene Wonder Spring, west front of Funeral Range, Death Valley, S½ sec. 1, T. 15 S., R. 46 E., Inyo County, Calif. Sampled spring discharges about 30 gpm, which is the largest discharge of group, near northwest end of a ½-mile-long travertine terrace. Vent temperature, 34° C; water sample was collected 150 feet downstream from vent, where first significant amount of carbonate was deposited. Springs discharge through travertine, alluvium, and probably Tertiary and Paleozoic rocks, including carbonate rocks. Collected by F. M. Byers, analyzed by H. Kramer, U.S. Geol. Survey; analysis not previously published.
2. Same spring and date of collection as that for analysis 1, but about 1,000 ft. downstream from vent, where approximately 11 percent of water has been lost by evaporation, judging from contents of Na, Cl, and B. Most of the Ca, some Sr and Mg, and minor amounts silica have been precipitated. Analysis not previously published.
3. Mammoth Spring, at north end of travertine ridge, west edge of Main Terrace, Yellowstone National Park, Wyo. Discharges about 4 gpm; average total discharge of group about 750 gpm (Allen and Day, 1935, p. 59–60). Springs emerge through very extensive deposits of travertine overlying pre-Tertiary sedimentary rocks, including abundant limestone and dolomite; also associated with late Tertiary rhyolite tuffs and basalt (Hague and others, 1899, sheets 10 and 19). Analysis by J. P. Schuch, U.S. Geol. Survey, who also reported, in ppm and included in totals: Ba, 0; Ti, 0.03; Br, 0.7; I, 0.1; NO_2, 0; PO_4 0.8. Spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in original water: evaporated residue at 180°C, 1,610; Al, 0.03; Fe, 0.04; Mn, 0.03; Ti, 0.02; Cu, 0.003; Li, 1.1; Rb, 0.2; Cs, 0.2; Sr, 0.4; Ba, 0.1. Analysis not previously published. Gas analysis from Main Terrace given in table 28, analysis 38 (Allen and Day, 1935, p. 86, 377).
4. Big Horn Spring, Hot Springs County, Wyo.; main spring discharges about 12,600 gpm and is one of largest hot springs in world. Extensive travertine deposit overlies Triassic red beds of Chugwater Formation near axis of anticline (Darton, 1906, p. 194–200; Burk, 1952, p. 93–95); the thermal water may rise from Tensleep Sandstone of Pennsylvanian age. Analysis by H. C. Whitehead, U.S. Geol. Survey; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in original water: evaporated residue at 180°C, 2,320; Fe, 0.01; Mn, 0.04; Cu, 0.002; Sr, 0.7; Ba, 0.09: Also reported: NO_2, 0.0 ppm; analysis not previously published.
5. Drilled well in Lýsuhóll warm spring area, Snaefellsnes Peninsula, Iceland, 16 miles east of Snaefellsjokull, a late Quaternary glacier-bearing volcano of rhyloite and basalt (Barth, 1950, p. 122). Discharges about 40 gpm in area of recent travertine in larger area of siliceous sinter deposited by former springs on hydrothermally altered granophyre. Springs evolve much gas (table 28, analysis 39), and deposit Fe_2O_3 as well as $CaCO_3$. Collected by G. Bodvarsson, State Electricity Authority. Analysis, not previously published, by C. E. Roberson, U.S. Geol. Survey, who also reported, in ppm: Cu, Pb, Zn, NO_2 each, 0.00; Br, 0.2; I, 0.0; PO_4, 0.06.
6. Springs at Meskoutine, 6 miles west of Guelma, Constantine Province, northeastern Algeria. Estimates of total discharge are 1,500 gpm by Braun (1872), 4,000 gpm by Urbain (1953), and 8,000 gpm by Pouget and Chouchak (1925)l Regardless of exact amount, the Meskoutine group is remarkable for magnitude of discharge and high temperature. The springs issue from very extensive travertine deposits, about 4 square kilometers in area, with a thickness of perhaps 120 feet, and precipitate about 2 tons per day of $CaCO_3$ from a total of about 9 tons of $CaCO_3$ in solution (Urbain, 1953). The springs rise along faults in upper Miocene conglomerate, shale, and sandstone, underlain by Lower Cretaceous limestone (Joleaud, 1914). The sample, probably from the main spring (Grande Cascade), was collected and analyzed by Guigue and Betier (1951); 183 ppm CO_3 was reported but is here converted to equivalent HCO_3.

TABLE 26.—*Chemical analyses of thermal waters that are probably entirely meteoric in origin*

Analysis	1		2		3		4		5		6	
Name and location	Bowers, Washoe County, Nev.		Hot Springs, Garland County, Ark.		Warm Springs, Meriwether County, Ga.		Kristenes, Akureyri area, Iceland		Plombiers, France		Yuzawa Fukushima Prefecture, Honshu, Japan	
Date of collection	March 8, 1954				June 13, 1935		Aug., 1949		Aug. 25, 1952		1951	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	44		46		23		109		90		24	
Al			.2								.2	
Fe					.01		1.2				.6	
Ca	2.8	0.14	47	2.35	21	1.05	6.0	0.30	4.9	0.24	2.4	0.12
Mg	1.0	.08	5.1	.42	12	1.0	1.8	.15	.3	.02	.4	.03
Na	49	2.13	4.8	.21	1.6	.07	55	2.39	81	3.52	11	.48
K	.4	.01	1.6	.04	3.6	.09			5.3	.14	1.7	.04
Li	[1] .08	.01	Tr									
Total cations		2.37		3.02		2.21		2.84		3.92		0.67
HCO_3	34	0.56	168	2.75	118	1.93	46	0.75	85	1.39	17	0.28
CO_3	26	.86					24	.80	0		1.1	.04
SO_4	35	.73	7.8	.16	7.3	.15	49	1.02	76	1.58	9.4	.20
Cl	5.4	.15	2.5	.07	1.8	.05	13	.37	6.8	.19	5.6	.16
F			0		.1	.01	.7	.04				
NO_3			.4	.01	.1	.00						
PO_4			.08	.00	[1] .1	.00						
B	.2		.3									
Total anions		2.30		2.99		2.14		2.98		3.16		[1] 0.73
Total, as reported	198		284		189		306		[1] 359		[1] 74.3	
Specific conductance..micromhos, at 25° C	242						267					
pH	9.3				[1] 7.5		9.3		7.6		9.4	
Temperature °C	47		64		31		75		65		28	
Ratios by weight:												
Ca/Na	0.057		9.8		13		0.11		0.06		0.22	
Mg/Ca	.36		.11		.57		.33		.06		.16	
K/Na	.008		.33		2.3				.065			
Li/Na	.002		.0									
HCO_3/Cl[2]	16		67		66		7.3		13		3.4	
SO_4/Cl	6.5		3.1		4.1		3.8		11		1.7	
F/Cl			.0		.06		.054					
Br/Cl			.0									
I/Cl			.0									
B/Cl	.04		.12									

[1] Components mentioned in explanation of table.
[2] Includes CO_3 as HCO_3.

EXPLANATION FOR TABLE 26

1. Main Spring, Bowers NW¼ sec. 3, T. 16 N., R. 19 E., 10 miles south-southwest of Steamboat Springs Washoe County, Nev. (table 17, analysis 3). Discharges 40 to 50 gpm from fractures in granodiorite in footwall of basin-range fault, west side of Washoe Valley. Accompanying gas is minor in amount and spring deposits are absent. Analyzed by W. W. Brannock, U.S. Geol. Survey ; Li determination by H. Kramer, sample of March 8, 1954; analysis not previously published.
2. Big Iron Spring, Garland County, Ark., largest and hottest of the group of hot springs (Haywood and Weed, 1902). Discharges 15 gpm from Mississippian Hot Springs Sandstone, which overlies Devonian Arkansas Novaculite and older Paleozic shale and cherts (Bryan, 1922, p. 426-436). Travertine deposit is as much as 8 feet thick, in places, and contains some manganese oxides (D. F. Hewett, oral communication 1957). Tritium (H^3) content of the water in March 1953 (prior to explosion of first thermonuclear bomb) was 2.5±1.4 $T/H \times 10^{18}$ (Von Buttlar and Libby, 1955, p. 83), which is almost that of surface water. This proves that the water is largely, if not entirely, meteoric in origin and had a short subsurface travel time. Analysis of associated gases, evolved in proportion of 19.5 cm^3 per l of water, is given in table 28, analysis 40 (Haywood and Weed, 1902). Also reported, in ppm; Mn, 0.3; NH_4, 0.04; NO_2, 0.002; traces of Sr, Ba, Br, and I, and absence of As.
3. Warm Springs, Meriwether County, Ga., east source; discharges about 620 gpm (Hewett and Crickmay, 1937, p. 7, 17, 21). Water issues from Hollis Quartzite, overlain by Manchester Schist and underlain by Woodland Gneiss, all Precambrian in age. No spring deposits. Sample analyzed by W. L. Lamar, U.S. Geol. Survey. U (0.5 ppb) and pH determined by U.S. Geol. Survey from sample collected in 1950. Minor amount of gas accompanies water (see table 28, analysis 41).
4. Flowing well at Reykhusalaug, about 6 miles south of Akureyri in northern Iceland; discharges about 25 gpm. Temperatures of small springs are about 45°C (Barth, 1950, p. 127), but higher temperatures are obtained from wells with greater discharge. Hot water rises along contacts of basic dikes cutting nearly horizontal early Tertiary(?) plateau basalts (G. Bodvarsson, written communication). Analyzed by S. Hermannson, Iceland State Electricity Authority. Gas analysis given in table 28, analysis 42, is from same type of water from Sydri-Reykir, north of Hvita River in southern Iceland with temperature of 100°C; analyzed by B. Lindal, State Electricity Authority.
5. Romain Spring, Plombiers, Vosges Mountains, France. Apophyllite, chabazite, opal, chalcedony, tridymite, fluorite, and calcite are reported from pore spaces of brick and cement of Roman baths built 2,000 years ago; crusts formed in places on masonry surfaces. Glaciated granite bedrock is unaltered (Daubrée, 1879; Lovering, 1950, p. 243). Collected by T. S. Lovering, analyzed by W. W. Brannock, L. Shapiro, and P. W. Scott, U.S. Geol. Survey, who also reported and included in total 10 ppm of free CO_2. For analysis of gas of Capucbin Spring, Plombiers, see table 28, analysis 43 (Moureu, 1906). Nearly 0.3 percent of total gases is He (Moureu and Biquard, 1908).
6. Yuzawa, Fukushima Prefecture, Honshu, Japan; discharges 60 gpm from Cretaceous(?) granodiroite (Morimoto, 1954, p. 193; H. Kuno, written communication). Analyzed by Fukushima Hygienic Laboratory, 1951, which also reported and included in totals: specific gravity, 1.0001; OH, 0.9 ppm (0.05 epm).

TABLE 27.—*Chemical analyses of waters associated with salt deposits and miscellaneous waters of high salinity*

Analysis	1		2		3		4		5		6	
Name and location	Searles Lake brine, Inyo County, Calif.		Searles Lake brine, Inyo County, Calif.		Bristol Dry Lake, San Bernardino County, Calif.		Great Salt Lake Desert, Tooele County, Utah		Trona deposit, Sweetwater County, Wyo.		Glenwood Springs, Garfield County, Colo.	
Date of collection									Feb. 1958		Sept. 9, 1957	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2									47		35	
Al	11								.00		.24	
Fe									.00		.00	
Mn									.00		.08	
As	198		243								.00	
Ca	16	0.80			43,300	2,160	1,360	67.9	3.7	0.18	526	26.25
Mg					1,070	88.0	1,720	141.5	4.6	.38	77	6.3
Sr					962	21.95	<10	.0	[1] .6		[1] 13	
Na	110,000	4,790	119,000	5,220.00	57,400	2,500	51,600	2,245	84,700	3,684	6,630	288.4
K	26,000	665	15,600	409	3,300	84.4	2,650	67.8	158	4.04	158	4.04
Li	81	11.7	30	4.3			1.8	.26	.5	.07	.9	.13
NH_4	19	1.05							1.3	.07	1.2	.07
Total cations		5,470		5,630		4,860		2,520		3,690		325
HCO_3									13,800	227	752	12.33
CO_3	[1] 27,100	900	[1] 38,400	1,280			<10	0.0	88,500	2,950	0	
OH												
S^{-2}	386	24.1	1,810	112.9								
SO_4	46,000	958	49,400	1,029	210	4.37	3,680	76.6	167	3.48	1,160	24.2
Cl	121,000	3,416	105,000	2,960	173,000	4,880	86,600	2,442	21,300	601	10,300	290
F	15	.79	15	.79					18	.95	1.6	.08
Br	860	10.76	580	7.26			<10	.0	22	.28	2.4	.03
I	29	.22	25	.20			<10	.0	8.6	.07	.3	.00
NO_3									0		1.2	.02
PO_4	922	19.44	535	11.28					110		.0	
B	3,380		4,090				<3		133		.9	
H_2S									0.0			
Total anions		5,300		[1] 5,400		4,880		2,520		3,780		327
Total, as reported	[1] 336,000		[1] 335,000		279,000		148,000		209,000		[1] 19,600	

Analysis	1	2	3	4	5	6
Specific conductance..micromhos at 25° C					103,000	27,800
pH					10.0	6.6
Temperature ° C			Cold		23	52
Density at 20° C				1.11	1.204	1.011
Ratios by weight:						
Ca/Na	0.00015		0.75	0.026	0.000044	.079
Mg/Ca			.025	1.3	1.2	.15
K/Na	.24	0.13	.057	.051	.0019	.024
Li/Na	.00074	.00025		.00003	.00001	.00014
HCO_3/Cl [2]	.45	.73		.000	9.6	.073
SO_4/Cl	.38	.47	.0012	.042	.0078	.11
F/Cl	.00012	.00014			.00084	.00016
Br/Cl	.0071	.0055		.000	.0010	.00023
I/Cl	.00024	.00024		.000	.00040	.00003
B/Cl	.028	.039		.0000	.0062	.00009

Analysis	7		8		9		10		11		12	
Name and location	Salado brine, Lea County, N. Mex.		Salado brine, Eddy County, N. Mex.		Seep from Salado, Eddy County, N. Mex.		Lyons well, Wayne County, N.Y.		Aqua de Ney Spring, Siskiyou County, Calif.		Budapest well, Hungary	
Date of collection	Sept. 1957		Feb. 7, 1939		July 17, 1958		May 3, 1956		Oct. 25, 1957		1932	
	ppm	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*	*ppm*	*epm*
SiO_2	7.9				9.1		15		[1] 3,400		11	
Al	57				2.4		.0		.9		4.8	
Fe	[1] 350				1.0		[1] 4.4		.00		.04	
Mn	[1] 26				[1] .8		[1] .2		[1] .00		.02	
As	.00				.00				[1] .00			
Ca	9	0.45	97	4.80	430	21.46	2,040	101.8	2.5	0.12	414	20.66
Mg	56,700	4,660	38,300	3,150	2,090	172	487	40.1	.9	.07	3,430	282
Sr					[1] 40		13	.30	[1] .2		.08	.00
Na	14,300	622	[1] 43,900	1,910	95,500	4,154	11,600	505	8,710	378.9	4,070	177.1
K	23,800	609	2,090	53.5	3,180	81	107	2.74	116	2.97	89	2.28
Li	16	2.3			2.8	.40	34(?)	4.9	1.5	.22	.04	.01
NH_4	68	3.77			1.1	.06			122	6.76		
Total cations		5,990		5,120		4,430		655		389		482
HCO_3	534	8.75	1,380	22.6	117	1.92	91	1.49	0		1,080	17.7
CO_3	0		0		0		0		4,790	159.7		
OH									948	55.7		
S^{-2}												
SO_4	6,970	145.1	222,000	4,620	10,600	221	2,650	55.2	172	3.58	21,300	443
Cl	200,000	5,630	16,800	474	157,000	4,430	21,200	598	5,950	167.9	627	17.68
F	5.5	.29			3.1	.16	1.2	.06	2.0	.10		
Br	1,340	16.8			35	.44			9.2	.12	.1	.00
I	12	.09			0.5	.60			5.4	.04		
NO_3	5.5	.09			0		25	.40	10	.20	4.2	.07
PO_4					.00		.0		.00		.6	.01
B	590				20				200			
H_2S					0.0				400			
Total anions		5,800		5,120		4,650		655		[1] 398		478
Total, as reported	304,000		325,000		269,000		38,300		[1] 25,300		31,000	

See footnotes at end of table.

TABLE 27.—*Chemical analyses of waters associated with salt deposits and miscellaneous waters of high salinity*—Continued

Analysis	7	8	9	10	11	12
Name and location	Salado brine, Lea County, N. Mex.	Salado brine, Eddy County, N. Mex.	Seep from Salado, Eddy County, N. Mex.	Lyons well, Wayne County, N.Y.	Aqua de Ney Spring, Siskiyou County, Calif.	Budapest well, Hungary
Date of collection	Sept. 1957	Feb. 7, 1939	July 17, 1958	May 3, 1956	Oct. 25, 1957	1932
Specific conductance..micromhos at 25° C	83,600	------	178,000	54,000	29,700	------
pH	5.2	------	6.9	6.7	[1] 10.9	------
Temperature ° C	------	Cold	37	10.5	Cold	Cold
Density at 20° C	1.263	1.345	1.209	1.027	1.018	------
Ratios by weight:						
Ca/Na	0.0006	0.0022	0.0045	0.18	0.00029	0.10
Mg/Ca	6,000	400	4.9	.24	.36	8.3
K/Na	1.7	.048	.033	.0092	.013	.022
Li/Na	.0011	------	.000029	.0029(?)	.00017	.00001
HCO_3/Cl [2]	.0027	.082	.00074	.0043	1.6	1.7
SO_4/Cl	.035	13	.068	.13	.029	34
F/Cl	.000028	------	.000020	.00006	.00034	------
Br/Cl	.0067	------	.00022	------	.0015	.0002
I/Cl	.000060	------	.000003	------	.00091	------
B/Cl	.0030	------	.00013	------	.034	------

[1] Components mentioned in explanation of table.
[2] Includes CO_3 as HCO_3.

EXPLANATION FOR TABLE 27

1. Composite brine from interstices of "Upper salt" body, 90 feet thick, at Searles Lake, Inyo County, Calif. Probably representative only of brine from lower half of stratified salt layer (G. I. Smith, written communication, 1957) Exact location of sampled wells not known. Analysis by American Potash and Chemical Corp., with major constituents reported as hypothetical combinations; also reported, in ppm, and included in totals: W 54; Sb 5; Rb, 1; Mo 0.7; Ge 0.3. All carbonate reported as CO_3, although some may be HCO_3. Analysis, not previously published.
2. Composite brine from "Lower salt" body, 40 ft thick, at Searles Lake, Inyo County, Calif. Exact location of sampled wells not known. Analysis by American Potash and Chemical Corp., with major constituents reported as hypothetical combinations; all carbonate reported as CO_3. Also reported is W, 31 ppm. Analysis not previously published.
3. West-central part of Bristol Dry Lake, 6 miles south of Amboy and 1 mile north of celesite saline deposits, San Bernardino County, Calif. Sample from drainage canal in salt body of National Chloride Co. (Durrell, 1953, p. 13). Analyst, W. W. Brannock, U.S. Geol. Survey.
4. Composite of 126 brine samples from auger holes few feet deep in Great Salt Lake Desert, Tooele County, Utah. Most of the brines were interstitial in salt deposits and were analyzed principally for K and Mg (Nolan, 1927, p. 39).
5. Seep from shale immediately above main 10-ft trona bed of Intermountain Chemical Co. in Bridger subbasin of Green River Basin, Sweetwater County, Wyo., 10 miles west and 7 miles north of Green River. Collecting point is about 1,500 feet below the surface; the trona bed is interbedded with shale, oil shale, sandstone, limestone, and evaporites of the 900-ft thick Laney Shale Member of the Green River Formation and is about 100 ft above the base of the member (Bender Hash, Intermountain Chemical Co., written communication); discharge at the site was nil at first but then increased, leading Hash to believe this water is not connate water from the trona deposits but is meteoric water from the Tower Sandstone Member of the upper part of the Green River Formation. Collected by Bender Hash and analyzed by H. C. Whitehead, U.S. Geol. Survey; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in original water: evaporated residue at 180°C, 205,700; Fe, 1.4; Ti, 0.4; Li, 1.1; Sr, 0.6; Ba, 3.1. Analysis not previously published.
6. Main spring of Glenwood Hot Spring Lodge, Garfield County, Colo. Discharges approximately 1,500 gpm from alluvium overlying Cretaceous sedimentary rocks. The Paradox Formation of Lower Pennsylvanian age, consisting of salt deposits, gypsum, and other interbedded sediments, is believed to occur at depth. Analyzed by H. C. Whitehead and C. E. Roberson, U.S. Geol. Survey, who also reported Cu and Pb, each 0.00 ppm; Zn, 0.08 ppm; NO_2, 0.13 ppm. Spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in original water; evaporated residue at 180° C, 19,500; Al, 1.2; Fe, 0.1; Cu, 0.02; Li, 1.8; Rb, 0.8; Sr, 13; Ba, 0.4. Analysis not previously published.
7. National Potash Co. mine, sec. 18, T. 20 S., R. 32 E., in Carlsbad area, Lea County, N. Mex. Brine seeping at 1,700-ft depth into new workings from clay on bottom and lower sides of postore epigenetic halite that has replaced part of the rock salt in middle "barren" part of Tenth Ore Zone, 650 ft below top of Salado Formation and 920 feet below top of Upper Permian evaporates (C. L. Jones, U.S. Geol. Survey, written communication). Discharge of about 1/40 gpm eventually ceased. Collected by C. L. Jones; analyzed by C. E. Roberson, U.S. Geol. Survey; spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in original water; evaporated residue at 180°C, 422,000; Al, 35; Fe, 350; Mn, 26; Ga, 0.005; Ti, 1.9; Zr, 0.06; Be, 0.002; Cu, 0.5; Pb, 0.04; Co, 0.007; Ni, 0.04; Cr, 0.1; V, 0.08; Li, 3.3; Rb, 33; Cs, 13; Sr, 0.004(?); Ba, 3.4. Analysis not previously published. The brine was accompanied by a small amount of odorless gas, probably similar to gas given in table 28, analysis 44, and collected elsewhere in the Salado Formation by Jones.
8. Test well Yates 1, 195 ft deep, SE¼SW¼ sec. 24, T. 25 S., R. 26 E., Eddy County, N. Mex. Sulfate water found at 142 and 145 ft; after standing, water flowed over casing from 142-ft zone. Water from evaporite deposits of Permian age, perhaps gypsum and anhydrite of Castile Formation ("lower Salt Series"). Sample collected by W. B. Lang, analyzed by W. W. Brannock, U.S. Geol. Survey; Na determined by difference. Analysis not previously published.
9. Brine seep in sandbar, half a foot above level of Pecos River, near Malaga, NE¼ sec. 20, T. 24 S., R. 29 E., Eddy County, N. Mex. Discharges about 0.1 gpm; Probably meteoric water that has come in contact with saline deposits of Salado Formation of Permian age (C. L. Jones, written communication). Collected by C. L. Jones; analyzed by H. C. Whitehead, of U.S. Geol. Survey, who also determined Cu, Pb, and NO_2, each 0.00 ppm. Spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in original water: evaporated residue at 180° C, 276,500; Fe, 1.4; Mn, 0.8; Cu, 0.6; Li, 1.4; Sr, 40; Ba, 2.5. Analysis not previously published.
10. Well, 393 ft deep, town of Lyons, Wayne County, N.Y.; penetrated the Salina Formation of Silurian age from depths of 130 to 371 ft; Salina generally consists of shale, marly sandstone, and impure limestone, all impregnated in places with salts. Collected by R. Heath; analysis by G. F. Scarbro of U.S. Geol. Survey, who reported total Fe and Mn, Zn, each 0.2 ppm; Cu, 0.00 ppm; Ra, 11 μμc per l; U, 5.9 ppb. Analysis not previously published.
11. Aqua de Ney Spring, Siskiyou County, Calif.; main spring is 5 miles southwest of Mount Shasta, on the north bank of Ney Springs Creek of the Weed quadrangle. Discharges from serpentine in schistose rock (Waring, 1915, p. 264–265). Collected by J. Feth and S. Rogers; analyzed by J. P. Schuch, U.S. Geol. Survey (Feth, Rogers, and Roberson, 1961). Water is remarkable for its very high pH and SiO_2 ,which may be highest on record); analysis verified 5 times at 2 laboratories. In other respects, the water strongly resembles probable connate waters given in table 15. Also determined and included in totals: SO_3 439 ppm (10.89 epm); NO_2, 0.00 ppm; Cu, 0.30 ppm; Pb, 0.00 ppm; Zn, 0.20 ppm; reported Mn and As from 1958 sample. John D. Hem determined Eh, −0.11; total CO_2, 2,500 ppm; and SiO_2, 3,400 ppm. Spectrographic analysis of evaporated residue, by Nola B. Sheffey, converted to ppm in the original water: evaporated residue at 180° C, 30,400; Al, 3.3; Zr, 0.3; Cu, 0.03; Mo, 0.09; Li, 4; Sr, 0.2; Ba, 1.1.
12. Ferencz Joseph "bitter" mineral water from shallow well in southern or southwestern suburb of Budapest, Hungary. According to Vendl (1951, p. 188–196), the water comes from middle Oligocene Kiscell Clay. Analyzed by J. Jendrassik, who also reported Ti, 0.01 ppm; free CO_2 15 ppm.

TABLE 28.—*Chemical analyses of gases accompanying or related to waters of tables 12 to 27, in volume or mole percent*

No. and locality of sample	Related water analysis		Temperature (°C)	CO_2	CO	CH_4	C_2H_6 and related gases	H_2	H_2S	SO_2	NH_3	O_2	N_2	A	He	H_3BO_3	Total	H_2O (mole percent of total gas)
	Table	Analysis																
1. Cymric field, Kern Co., Calif.	12	2	50±	2.10		79.63	18.27										100.00	
2. Hajduszoboszlo, Hungary		7	73±	5.0		85.6	1.0					0.7	[1]7.7				100.00	
3. South Kwanto fields, Chiba Prefecture, Japan		11	20	.2		93.9						.7	[1]5.2				100.00	
4. Raisin City field, Fresno County, Calif.	13	1		1.9		95.2	1.5					1.4	.0		0.0		100.00	
5. Bad Hall, Austria	15	7	Cold	0.2	0.0	99.8	.0	0.0				.0	.0				100.0	
6. Hanmer, S. Island, New Zealand	15	12	50±	.5		96.5							[1]2.9		.12		100.02	
7. Willow Creek, Shasta County, Calif.	16	2	17	.0	.0	81.6	1.1	.0				1.6	[1]15.7				100.0	
8. Tolsona Spring, Copper River Basin, Alaska		5	Cold	.2		66.9	.0		0.0			Tr.	32.6	0.1	.1		99.9	
9. Wiesbaden, Germany		6	65±	84.24		.49						.52	14.74	.005	.0009		99.9959	
10. Upper Basin, Yellowstone National Park, Wyo.	17	1	95±	95.10		.10		.10	.55			.00	[1]4.15				100.00	
11. Norris Basin, Yellowstone National Park, Wyo.		2	90±	89.20	.00	.55		2.30	.00			1.40	[1]6.55				100.00	
12. Steamboat Springs, Washoe County, Nev.		3	80±	97.7		<.03		.03	.5			.2	1.6	.04	<.05		100.15	
13. Haukadalur, Iceland		7	95±	80.1		.4		.2	2.0			.3	[1]17.0				100.0	
14. Reykjanes, Iceland		8	95±	93.8		.14		.06	1.6			.3	[1]4.1				100.0	
15. Hveravellir, Iceland		9	95±	81.7		.6		.1	5.3				[1]12.3				100.0	99.95
16. Pauzhetsk, Kamchatka, USSR		12	98.6	3.50		2.07			.00				[1]94.43				100.00	
17. Well 4/1, Wairakei, New Zealand		14	97±	82.73		.11	.39	2.37	8.36		5.36		[1].65			0.03	100.00	99.96
18. Niland, Imperial County, Calif.	18	2	40±	97.0		2.6	.0						[1].4		.0		100.0	
19. Agnano, Italy		6	70±	80.3								3.4	[1]16.3				100.0	
20. Nalachevskie, Kamchatka, USSR		7	74.8	93.43		.74			.00				[1]5.83				100.00	
21. Ebeco Volcano, Kurile Islands, USSR	19	3	100	91.31	1.00	.00	.00	.25	Tr. (?)	5.34		.00	[1]2.10				100.00	
22. Frying Pan Lake, New Zealand		12	55±	94.0		.6		.4	?			.5	[1]4.5				100.0	
23. White Island, New Zealand		13	95±	86.3		.0		9.8	2.0				[1]1.9				100.0	
24. "The Geysers", Sonoma County, Calif.	20	1	150±	63.50		15.29		14.67	1.69		1.28		[1]3.53			(.14±)	100.10	98.06
25. Bumpass Hell, Tehama County, Calif.		2	79±	93.05	.00	.20		.45	.55			.25	5.38	0.7			99.95	
26. Norris Basin, Yellowstone National Park, Wyo.		3	90±	97.40		.20		.00	.75			.05(?)	[1]1.60				100.00	
27. Mud Volcano group, Yellowstone National Park, Wyo.		4	65±	98.90		.10		.00	.10			.00	[1]1.00				100.1	
28. Sulphur Springs, Sandoval County, N. Mex.		5	65±	77.9		.0		.0	20.1			1.1	[1].9		.0		100.0	
29. Uzonskie, Kamchatka, USSR		6	96.0	85.8		7.6	.00		.4				[1]6.2	.024	<.001		100.25	
30. Koshelevsk, Kamchatka, USSR		7	97.8	[2]66.02		24.33	.46		(2)				[2]0.19				91.00(?)	
31. Steamboat Springs, Washoe County, Nev.	21	2	161	98.3				.1	Present [1]			.1	[1]1.5				100.0	
32. Well 6, Wairakei, New Zealand		5	175±	98.06		.12	.05	.18	.63		.06		[1].89			.007	99.997	99.49
33. Essentuki, Caucasus, USSR	22	7	14±	89.1		7.0			.3			.2	3.0	[1].04	[1].06		99.7	
34. Malkinsk, Kamchatka, USSR		8	5.6	98.6		.0			.0				[1]1.40				100.0	
35. Te Aroha, New Zealand		10	85±	98.80			.02		.0			.30	[1].90				100.02	
36. Sulphur Bank, Lake County, Calif.	23	1	75±	89.34		7.94			.23		Present		[1]2.49				100.00	
37. Ngawha, New Zealand		6	83±	90.6		6.6		1.0	.02				[1]1.8				100.02	
38. Mammoth, Yellowstone National Park, Wyo.	25	3	70±	97.90		.00		.00	.00			.45	[1]1.65				100.00	
39. Lýsuhóll, Snaefellsnes, Iceland		5	41±	93.0				1.0					[1]6.0				100.0	
40. Hot Springs, Garland County, Ark.	26	2	64±	35.4					.0			19.5	[1]45.1				100.0	
41. Warm Springs, Meriwether County, Ga.		3	31±	.59		0.						13.91	[1]85.50				100.00	
42. Sydri-Reykir, Iceland		4	100	6.7		0.0		.0	<.1				[1]93.3				100.1	99.85
43. Plombiers, France		5	65±	1.0								8.90	88.65	1.45	.3		100.0	
44. Salado Fm., Lea County, N. Mex.	27	7		.3		1.4	.2	.0	.0			.8	97.1	.2	.0		100.0	

[1] Includes inert gases not reported.

[2] Includes H_2S as well as CO_2.

TABLE 29.—*Approximate median ratios and contents, by weight, of analyses in tables 12 to 26, compared to ocean water*

	Table	Number of analyses	Ca/Na	Mg/Ca	K/Na	Li/Na	[1]HCO$_3$/Cl	SO$_4$/Cl	F/Cl	Br/Cl	I/Cl	B/Cl	Total reported ppm	SiO$_2$ (ppm)	Total reported N as NH$_4$	pH
Ocean water	------	------	0.038	3.2	0.036	0.00001	0.0074	0.14	0.00007	0.0034	0.000003	0.00024	34,500	7	0.05	8.0
Oil-field brines:																
NaCl type	12	11	.04	.4	.015	.0003	.02	.0005	.0002	.003	.002	.003	30,000	30	40	7.0
Na-Ca-Cl type	13	13	.3	.15	.02	.0002	.001	.0008	.00002	.005	.00008	.0002	120,000	10	200	6.7
Springs that may contain connate water:																
NaCl type	15	12	.05	.5	.03	.0003	.2	.002	.0003	.0015	.002	.015	20,000	30	40	7.8
Na-Ca-Cl type	16	15	.2	.1	.05	.0005	.03	.005	.00005	.002	.0001	.0005	20,000	25	7	7.1
Springs that may contain volcanic water:																
Geyser waters	17	14	.03	.06	.10	.006	.1	.1	.002	.0015	.0000	.02	2,000	300	1±	8.4
Non-geyser NaCl type	18	8	.06	.1	.13	.002	.3	.06	.001	.003	.0006	.01	10,000	110	1±	7.2
Acid SO$_4$-Cl type	19	13	.8	.3	.2	.01	.00	.7	.01	.0006	.0000	.01	9,000	300	6	2.2
Acid SO$_4$ type	20	11	1.5	.4	.4	.00	.00	400.	.03	.004	.000	.3	2,000	200	30	1.9
Acid HCO$_3$-SO$_4$ type	21	5	1.	.2	.4	.005	50.	10.	.0	------	------	.4	500	70	1±	7.0
Springs that may contain metamorphic water, NaHCO-boron type	22	10	.05	.6	.02	.002	5.	.05	.001	.002	.002	.1	12,000	80	5	6.8
Miscellaneous waters:																
Springs associated with mercury deposits	23	6	.04	.5	.03	.001	2.	.4	.006	.002	.003	.1	3,000	90	20	7.0
Springs associated with manganese and tungsten deposits	23	6	.5	.3	.07	.001	.3	.5	.02	.001	.000	.002	2,000	60	1±	6.8
Springs depositing travertine	25	6	1.	.3	.15	.001	.2	1.4	.01	.003	.000	.02	2,000	60	1	6.5
Heated meteoric waters	26	6	.2	.2	.1	------	15.	4.	.06	------	------	.1	200	50	------	9.2

[1] Includes CO$_3$ as equivalent HCO$_3$.

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