1957

A Study of the Variation of the Fluoride Content of Certain Waters in the Vicinity of Albuquerque

E. Metz Beahm

BEAHM

FLUORIDE CONTENT OF CERTAIN WATERS

ACKNOWLEDGEMENT

The author wishes to thank Mayor Charles Lembke of the City of Albuquerque, and the City employees for their splendid cooperation in making this study possible.

CONTENTS

INTRODUCTION

In the first part of 1935, the City of Albuquerque was investigating the possibility of obtaining an additional water supply from the Jemez Mountains, which are about fifty miles to the north of the City. Black and Veatch, consulting engineers for the City, were asked to make a complete study of the problem. The question of fluorides in the water came up because it was known that the fluorides would cause mottled enamel in human teeth when the water was used during childhood, if the content was above 0.9 parts per million by accepted fluorine analysis methods. The question arose as to how the fluoride content of the Jemez stream would vary over a period of months, and how it would vary as the stream progresses along its course.

Through the recommendation of Black and Veatch, the City of Albuquerque decided to make a detailed study of the fluoride content of the Jemez waters over a sufficient period of time to determine a representative average.

This study was started in the first part of November, 1935, and continued until the next August. Monthly samples were obtained from numerous points along streams of the Jemez country, and, in addition to these, certain waters of

the Sandia Mountains, to the east of Albuquerque, and the present City wells, were included in the nine months period of study.

Prior to this study (September, 1935), Black and Veatch had had Dr. John D. Clark of the Chemistry Department of the University of New Mexico make a complete mineral analysis of certain Jemez waters, including the determination of fluorides. Owing to the limited time in which the analysis had to be done, the Fairchild method was used. Because this method gives results which indicate an abnormally high fluorine content, little evidence can be drawn from results obtained by the Fairchild method.

In the first part of October, 1935, the Van Atta Laboratory determined the fluoride content of two water samples from the Jemez by the Sanchis method. Still no definite conclusions could be drawn, because no one could say how the fluoride content would change over a period of months.

During the first part of this study, two methods of analysis were used, as a check on each other. The Foster method was soon dropped, and the Sanchis method used almost entirely. During the last three months of the study, the U. S. Public Health Service method was used as a check on the Sanchis method for the samples obtained from the Jemez country.

As an additional study, the author obtained samples from a few New Mexico towns and determined their fluoride content by the Sanchis method. These results are, also, included in this thesis.

MOTTLED ENAMEL

Mottled enamel is characterized by dull, chalky white patches distributed irregularly over the teeth, and in more severe cases by pitted and corroded teeth. There are at least three types of mottled enamel: (1) the mild chalky white type, (2) the more severe stained type, and (3) the pitted, corroded type. Mottled teeth are not only ugly to look at, but they are structurally weak and do not hold fillings well. Stains, varying in color from dark brown to yellow, so often associated with mottled enamel, are only secondary phenomena. The cause of the stain at the present time is still unknown, but it is possibly due to the lack of proper mineral elements.

The extent of the mottling resulting from continuous use of a water depends on the concentration of the fluorine in the water. Fluoride content below 0.9 P.P.M. will not cause mottled enamel, while the continuous use of water above 0.9 during the period in which the teeth are being formed will cause mottling.

Mottled enamel, which is endemic in the Texas panhandle, eastern New Mexico, southern Colorado, western Colorado, and Arizona, is found in many other sections of the

United States, some twenty-four States in all, in Mexico and in South America, as well as in parts of Europe and Asia.

Fluorine affects the teeth because it prevents calcification of the teeth. The teeth are formed by calcification within a cartilaginous membrane in which the lime salts are held in solution until they become tooth enamel. All enamel is laid down by the fifth year of life, except for the third molar, or wisdom tooth. Therefore, to prevent mottled enamel, steps must be taken from birth to the fifth year of life, during the forming of the tooth enamel. After the seventh year, it is too late, for there is no curative procedure which may restore the enamel.

Consequently, if a child uses fluorine-free water for the first seven years of his life, he will not be affected with mottled enamel, according to the accepted opinion of research workers.

"It has lately been observed that children who drink fluorine-free water for only one or two months a year show only mild mottling. Jack Wyatt in the Texas Dental Journal for November, 1935, therefore, suggests that children should be sent away from regions with fluorine-containing waters for one or two months a year, or, if that is impossible, should drink distilled water for the same length of time. In this manner, the child may escape mottling altogether, or get at least only a mild affection. To oppose the calcium-

decreasing influence of fluorine, milk and vegetables should be plentifully supplied." [1]

The above explanation might account for the fact that mottled enamel has not been noticed in the residents of the Jemez region even though at times some of the water contains more fluorine than required to cause mottled enamel, while at others, it contains only a very small amount, as during the spring run off, which will be noted best from the curves of the results.

There is no cure for mottled enamel. A dentist may remove the brown stain, but the mottled enamel is permanent and cannot be repaired. Fluorine causes its damage by its interfering with the calcification of the teeth during the period of their formation. Fluorine does not act directly in the mouth on the teeth that have already been formed, and so fluorine in drinking water will not affect the teeth of adults.

According to the Smiths [2] of Arizona, diet is not a factor in the production of mottled enamel, and mottled enamel cannot be prevented by dietary improvements. The use of fluoride-containing water for cooking purposes is not safe if the fluoride content is above 8.0 to 10.0 P.P.M.

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[1] Yearbook of Dentistry, 1936, p. 295.

[2] Smith, H. V., M. C. Smith and E. L. Foster, University of Arizona Tech. Bull. #61, p. 375.

At present the only solution to the problem of eradication lies in the prevention of its occurrence, and prevention is only possible by the use of drinking water containing less than 0.9 P.P.M.

The discovery of fluorine as being the causal factor of mottled enamel came from two sources independently in 1931, from the work of the Smiths in Arizona, and from the work of H. V. Churchill. The work of H. V. Churchill consisted of a spectrographic analysis of all waters that could be obtained from districts in which mottled enamel was known to occur and a comparison of these analyses with some made on water from non-endemic regions. Churchill discovered that the absorption lines of fluorine were present in waters from endemic regions. The work of the Smiths consisted of a detailed study of the people of St. David, Arizona, and the water which they drank. They did a great amount of experimental work on white rats, observing effects on the teeth.

A certain number of rats were given fluorine in the diet; others were given a residue of the St. David water in the diet. The effects upon the teeth of both groups of rats were found to be strikingly similar. From these experiments, and from the well-established fact that the children of St. David were widely afflicted with mottled enamel, fluorine in the drinking water was established as the causal factor.

Fluorine causes other physiological effects on the human body, as well as mottled enamel. The ingestion of fluorine compounds beyond certain limits is fatal to man and other animals. There is evidence that fluosilicates are more toxic than either sodium fluoride, or calcium fluoride, and that sodium fluoride is more toxic than calcium fluoride. Fluorine will affect the structure of the bones in the body in a manner generally similar to the effect upon the teeth. Furthermore, fluorine is believed to have some bearing on the clotting of blood. It has been observed that in cases of hemophilitic patients, the amount of fluorine in the blood is abnormally high. It has also been suggested in literature that fluorine might be the cause of endemic goiter. [3] This is a problem which, undoubtedly, should be investigated more thoroughly, because, if fluorine is the cause of goiter, and if the addition of iodine to the diet will prevent it, it might be established that iodine will also prevent some of the other physiological effects. Since the introduction of iodized salt is known to have made endemic goiter less prevalent than it used to be, and since it is also claimed by workers upon this problem that mottled enamel is also less prevalent, there would seem to be a possible connection between the wider use of iodized salt and the lower incidence of mottled enamel.

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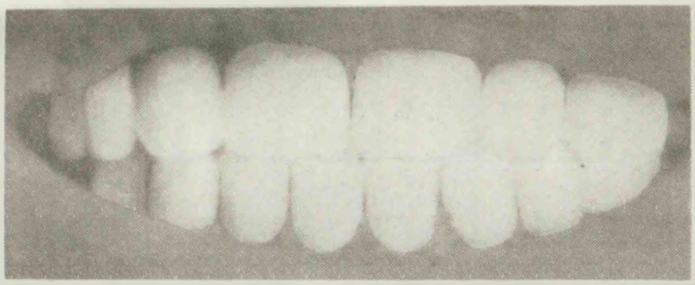
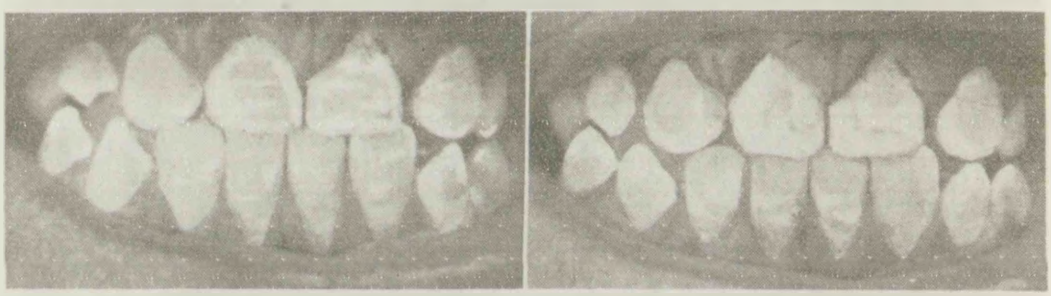
[3] McClure, F. J., Fluorine and its physiological effects - Physiological Reviews, Vol. 13, p. 297.

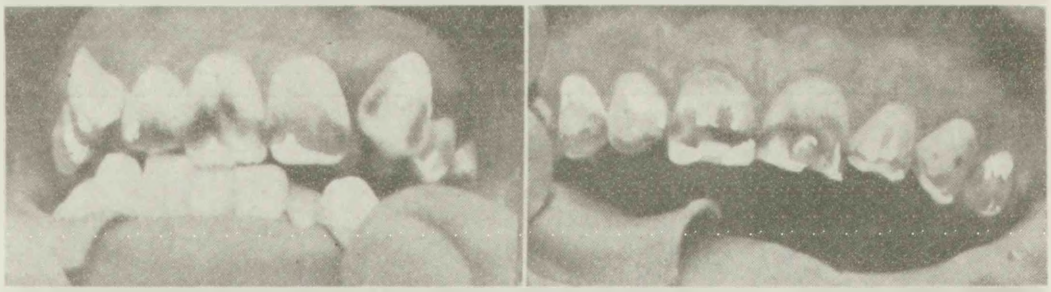
TYPES OF MOTTLED ENAMEL



NO MOTTLING



MILD MOTTLING



MODERATELY SEVERE MOTTLING

SEVERE MOTTLING

MOTTLED ENAMEL IN NEW MEXICO

The southwestern section of the United States has many localities in which mottled enamel is prevalent. There are about twenty-three States in which mottled enamel occurs. The largest endemic regions are possibly in the Texas panhandle, and in Arizona along the Gila and San Pedro rivers. Study of the prevalence of mottled enamel in New Mexico has been rather neglected. The only survey that has been made to determine the extent of its occurrence --and this survey was incomplete-- was made by the U. S. Public Health Service in 1933, by sending questionnaires to dentists and health officers of each county in New Mexico, and in other western States as well. The results of this survey, as it relates to New Mexico, are shown on the following map.

Through the courtesy of Miss Myrtle Greenfield of the State Public Health Laboratory, the author obtained water samples from some fifteen towns in the state. The results for fluorides by the Sanchis method are as follows:

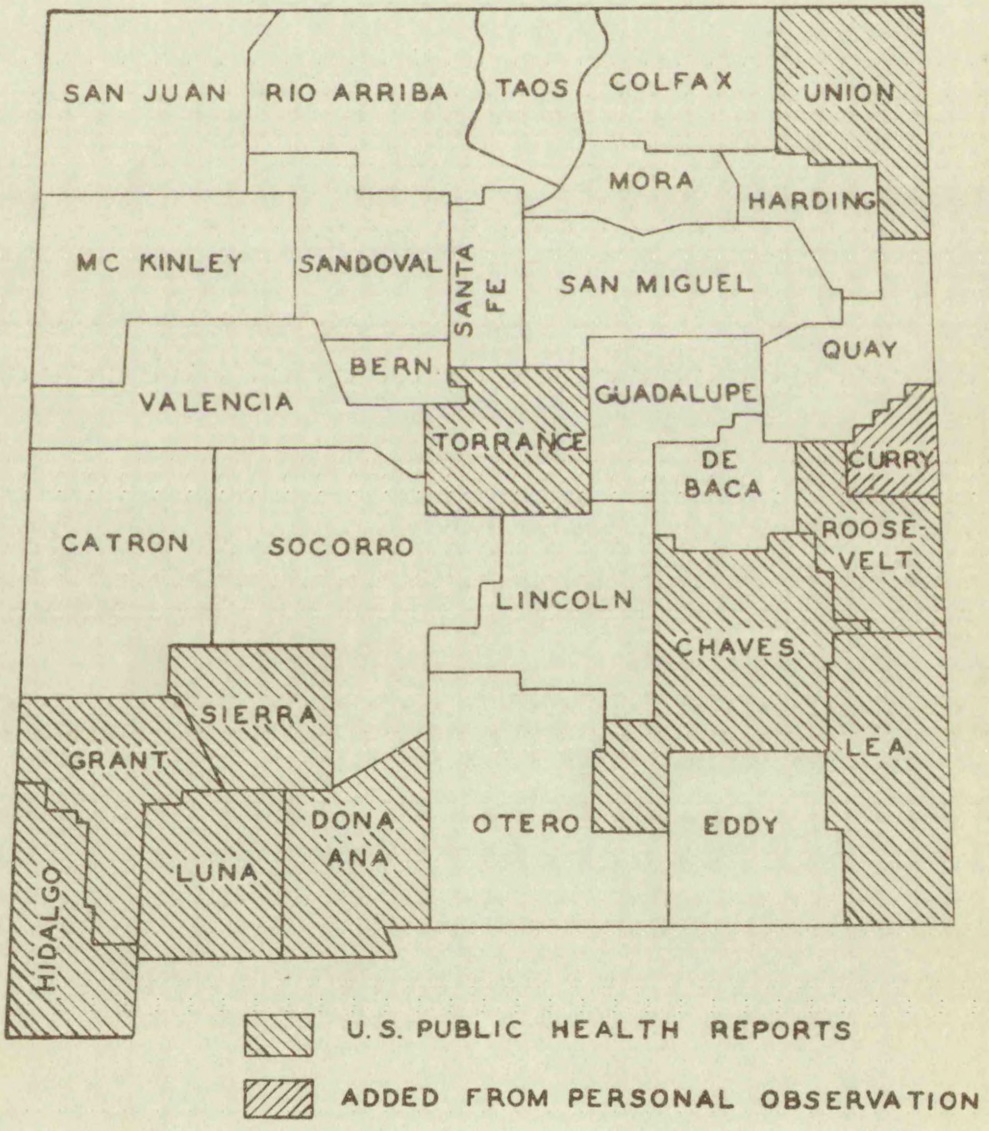
		P.P.M.	
Alamogordo- - - - - - - - -		0.15	
Albuquerque	#1 soft - - - - -	0.8	(9 mo. aver.)
	#2 " - - - - -	0.8	"
	#3 " - - - - -	0.75	"
	#4 - - - - -	0.6	"
	#3 hard - - - - -	0.4	"

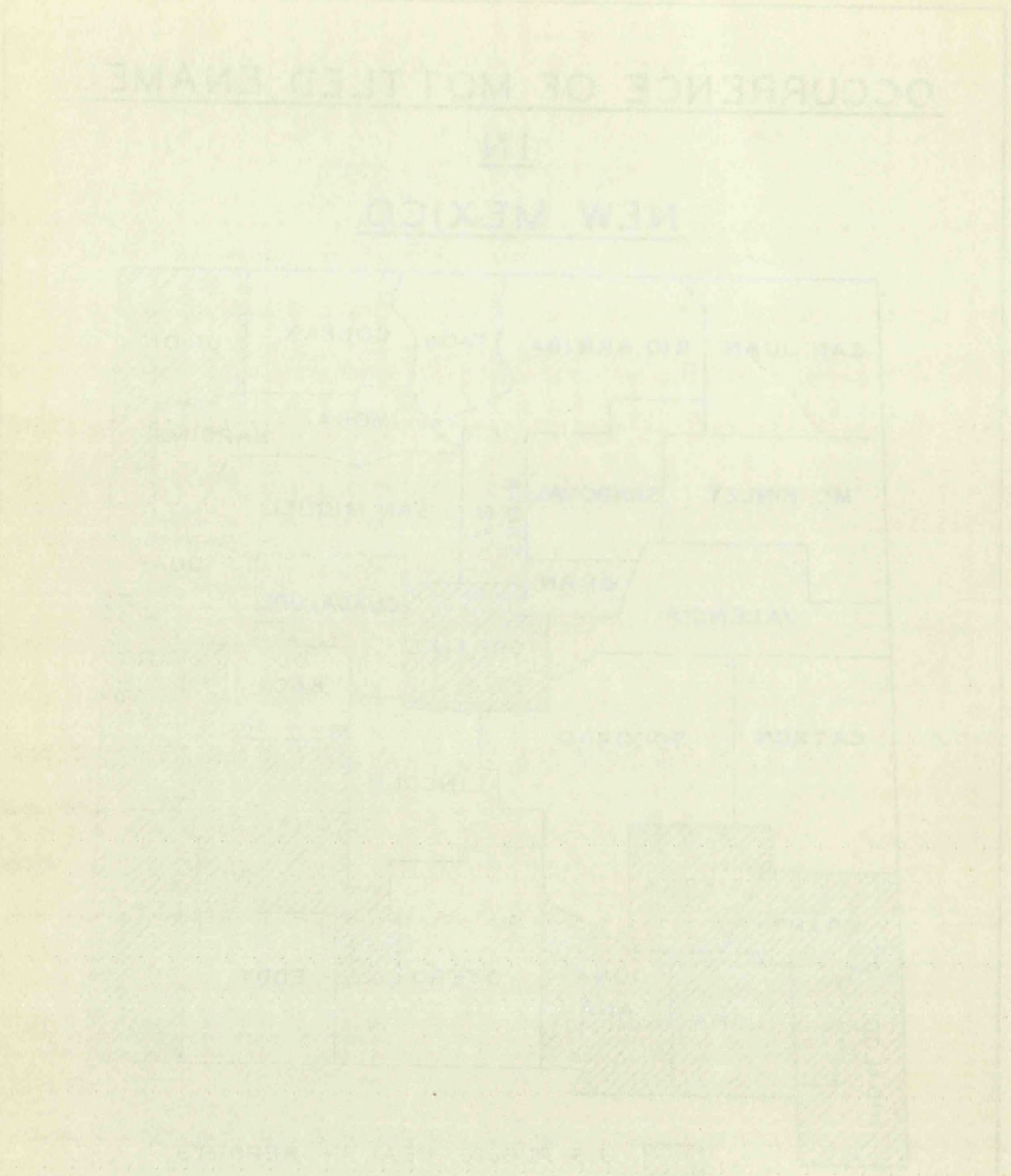
Albuquerque #4 hard - - - -	0.47	(9 mo. aver.)
Aztec- - - - - - - - - - -	0.5	
Carlsbad - - - - - - - - - -	0.6	
Clovis - - - - - - - - - -	1.7	
Dawson - - - - - - - - - -	0.3	
Deming - - - - - - - - - -	0.7	
Farmington - - - - - - - - -	0.8	
Fort Sumner- - - - - - - - -	1.6	(very small sample used)
Gallup - - - - - - - - - -	0.9	
Grants - - - - - - - - - -	0.5	
Las Vegas- - - - - - - - -	0.25	
Lordsburg City water- - - -	1.1	
Mountainair- - - - - - - - -	0.6	
Raton- - - - - - - - - -	0.15	
Road forks (near Lordsburg)	0.85	
Santa Fe- - - - - - - - - -	0.2	
Vaughn - - - - - - - - - -	0.6	

Most of these results are based on only one sample. Those that are near the toxic limit of 0.9 should be analyzed over a period of a year, and the average over this period be taken as the fluoride content of the water.

There is much need for an extended and detailed study of the waters of the state. A water should not be discarded or called safe on the results of one analysis, but only on the basis of an extended study of possibly a year or more.

OCCURRENCE OF MOTTLED ENAMEL IN NEW MEXICO





HISTORY OF FLUORINE

It was known as early as 1670 that glass was attacked by the fumes produced when fluorspar was acted upon by nitric acid. It was not until the first part of the nineteenth century that this reaction was used, probably for the first time, to test for the presence of these same fumes in a substance of animal origin. As a result of these tests, the presence of fluorine in fossil teeth was reported. Later Gay-Lussac found fluorine in the enamel of normal teeth.

The toxicity of the compounds of fluorine to man became evident when the chemists Thenard and Davy, while experimenting in trying to produce pure fluorine, were made seriously ill by accidently breathing the vapor of hydrofluoric acid, and, also, when Louyet and Nickles lost their lives from the same cause.

Much work was done by A. Ampere and others to try to separate the element fluorine from its compounds by electrolysis, and other methods, but fluorine was so active chemically that they failed.

It was not until June 26th, 1886, that Henri Moissan first isolated the element fluorine by the electrolysis of a

solution of potassium fluoride in anhydrous hydrofluoric acid, in an apparatus made entirely of platinum.

OCCURRENCE OF FLUORINE

Fluorine is the most chemically active substance known. Fluorine can hardly be said to occur free in nature, although some chemists believe that free fluorine occurs as occluded gas in violet felspar and violet fluorspar. In its combined state fluorine is fairly widely distributed in rocks. F. W. Clarke places fluorine as the twentieth most abundant element on the earth. Very small quantities of fluorine are commonly present in igneous rock. The most characteristic minerals containing fluorine are calcium fluoride (fluorspar), and cryolite, which is a double fluoride of aluminum and sodium. Apatite is a phosphate containing fluorine. Fluorine is also contained in other phosphates, such as fluorapatite, phosphorite, sombrerite, coprolites, and staffelite.

The presence of fluorides was noticed in certain mineral waters as far back as the middle of the nineteenth century. It was not until 1931, however, that it was found that small quantities of fluorine were present in the drinking waters of certain localities, and that this was the cause of mottled enamel.

Fluorine has been reported present in foodstuffs, and

in malt liquors its presence is the rule rather than the exception. The presence of fluorides in fruits and vegetables may be due to the use of a fluoride insecticide spray, or to irrigation with water containing fluorides, or to both causes.

Fluorides occur in the teeth and bones of animals in small quantities and have been known to be present in them since the first part of the nineteenth century. Fluorine is also present in other animal organisms.

REMOVAL OF FLUORIDES FROM DRINKING WATERS

Considerable study has been done on the subject of the removal of fluorides from drinking waters, but so far all the methods that have been developed are not economically possible.

Four main methods have been developed to remove fluorine from the water: (1) treatment with alum to cause absorption of the fluorine and settling to the bottom; (2) use of carbon as an absorbent after the water has been made acid to P^{H3} or less; (3) electrolysis of water, using aluminum electrodes, thereby creating an alum precipitate and settling the fluorides; (4) filtration of water through a filter of powdered aluminum.

For the most part these methods are incapable of functioning properly and are not economically practical, although the Aluminum Company of America has placed on the market a product known as "Defluorite", which is a specially prepared activated alumina produced under a patent held by H. V. Churchill. The "Defluorite" may be regenerated by passing a five per cent solution of caustic soda through the filter and then neutralizing the excess alkali by very dilute hy-

drochloric acid. It is claimed by laboratory tests [3] that the method is practical because of the fact that the alumina may be regenerated, thereby making the method economically possible even for small communities. From the results obtained from these laboratory tests, it is shown that water having a high fluoride content may be reduced under the minimal threshold.

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[3] Removal of Fluorides from Natural Waters by Defluorite. H. G. Swope and H. H. Hess, Ind. and Eng. Chemistry, Vol. 29, PP 424-7, April 1937.

THE SANDIA MOUNTAINS

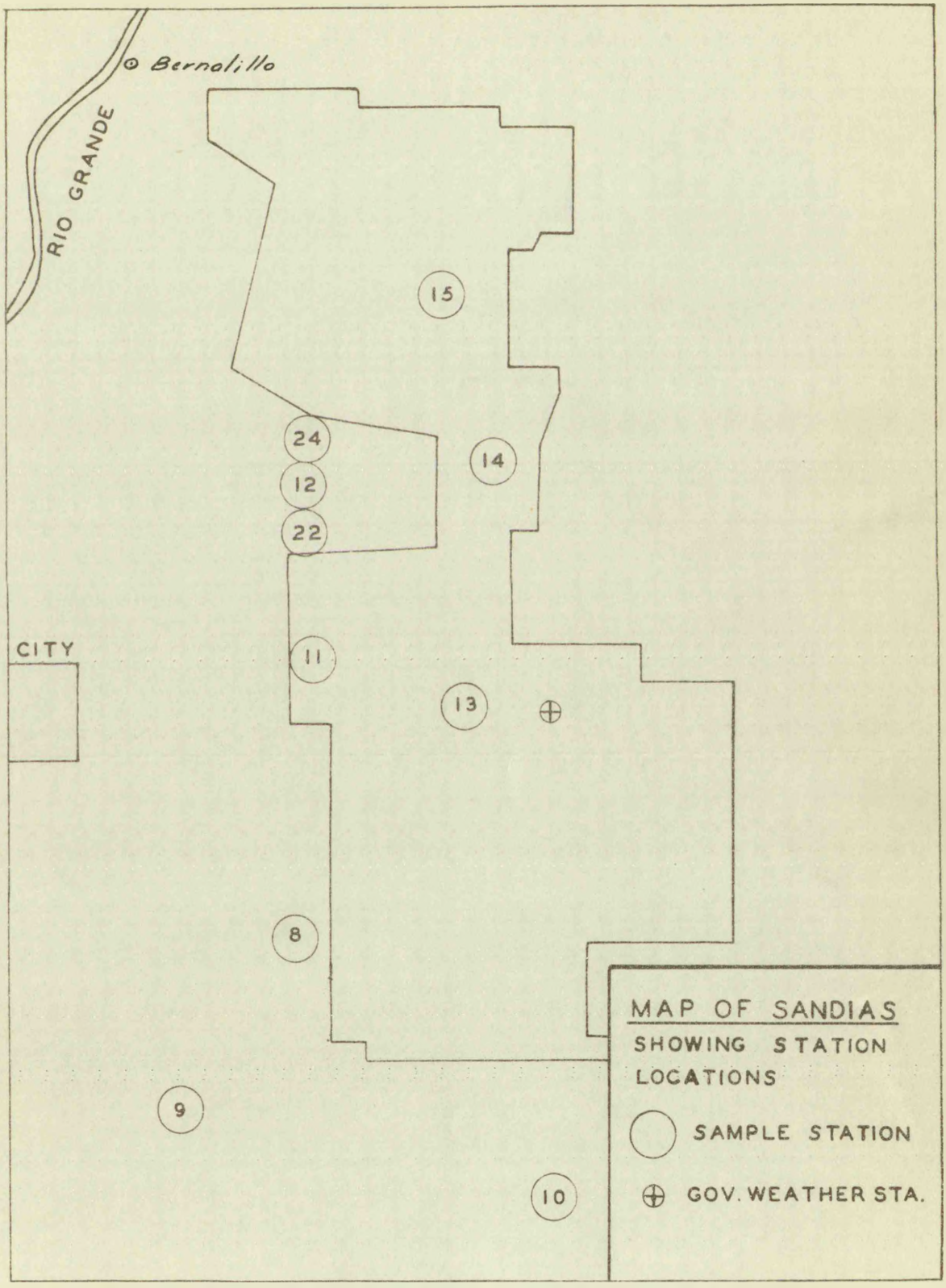
The Sandia Mountains are about ten miles to the east of Albuquerque. The western side of the mountains is very rough and contains many small canyons. The rim of the mountains is very distinct and the limestone cap on the eastern side has a very gentle slope. The western slope is steep and is composed mainly of granite. This slope was formed by a great fault zone which extends along the western front parallel with the crest of the mountains. The variation in altitude between the western base of the Sandias and the rim rock, or, in other words, the throw of this fault, is about forty-five hundred feet.

The coarse porphyritic granite which occurs all along the western front of the main ridge of the mountains is the core of the uplift. The general appearance of the granite is very rough, varying in color from a gray to a pinkish rock.

The eastern side of the mountains has a gentle slope of ten to fifteen degrees as compared with that of the western slope which is about forty-five degrees. This eastern slope is covered by a layer of limestone which has outcrops of sandstone in some places.

There are no hot springs in the Sandia Mountains.

The springs are all clear and cool. The only pronounced mineral springs in the region are the Coyote Springs, which are highly charged with carbon dioxide. The water from this spring has a fluoride content of above one part per million. This was, no doubt, picked up by the action of the carbonic acid in the water upon the igneous rock through which the spring must pass to reach the surface. The springs on the west slope of the mountains all have a fluoride content of above one part per million, with the exception of Hell Canyon, where the limestone cap extends over the western side of the mountains. The springs on the eastern slope that were tested were found to have a very low fluoride content. This goes to show that the water on the west side was picking up its fluoride content from the granite rock through which it had to pass to reach the surface. In the laboratory, a sample of this granite was crushed and treated with water charged with carbon dioxide and then the fluoride content of the water was determined by a modified distillation method, and was found to be 1.4 P.P.M., which was very close to the value for the fluoride content of the spring waters on that side of the mountain.


Bernalillo
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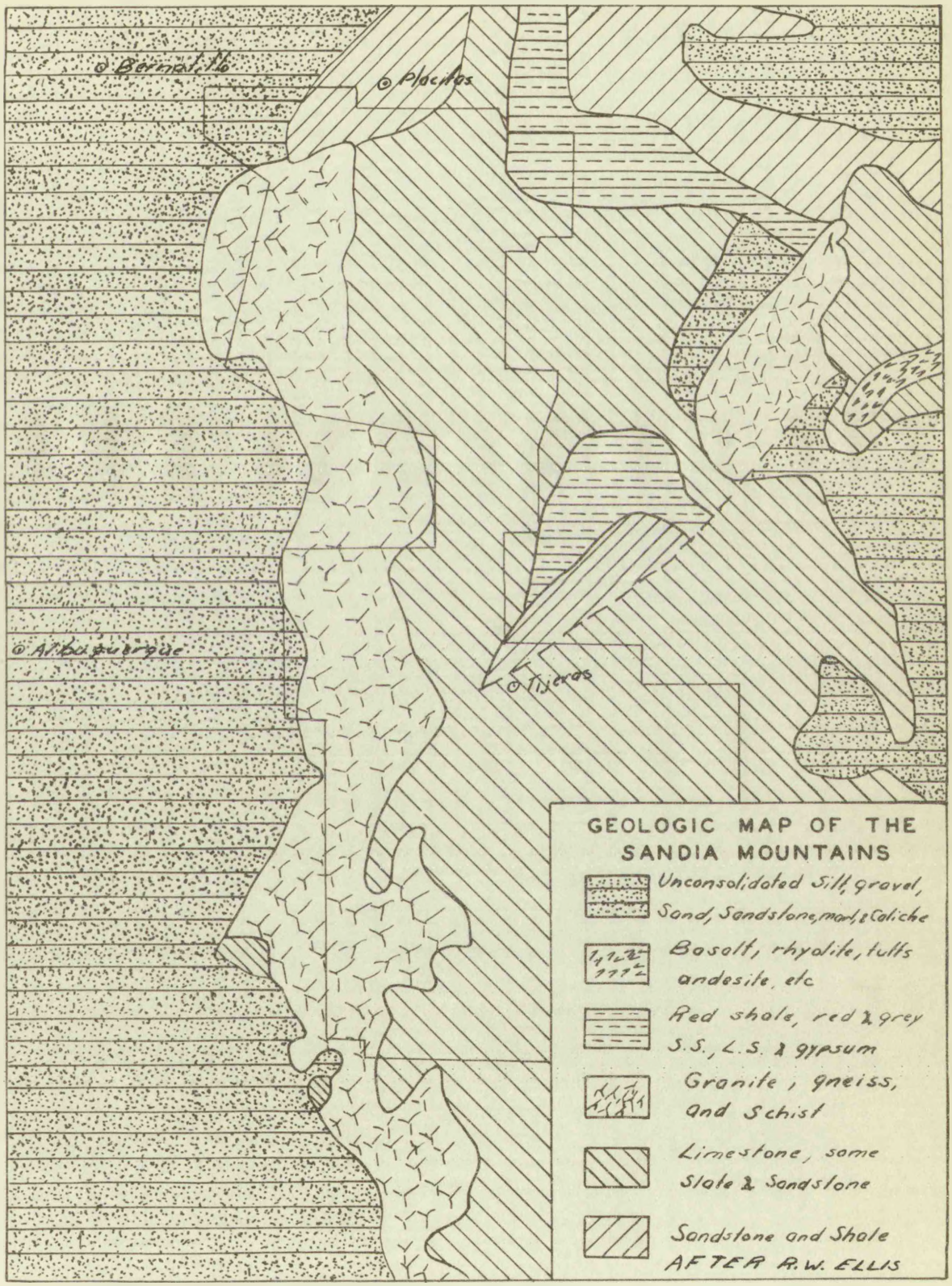
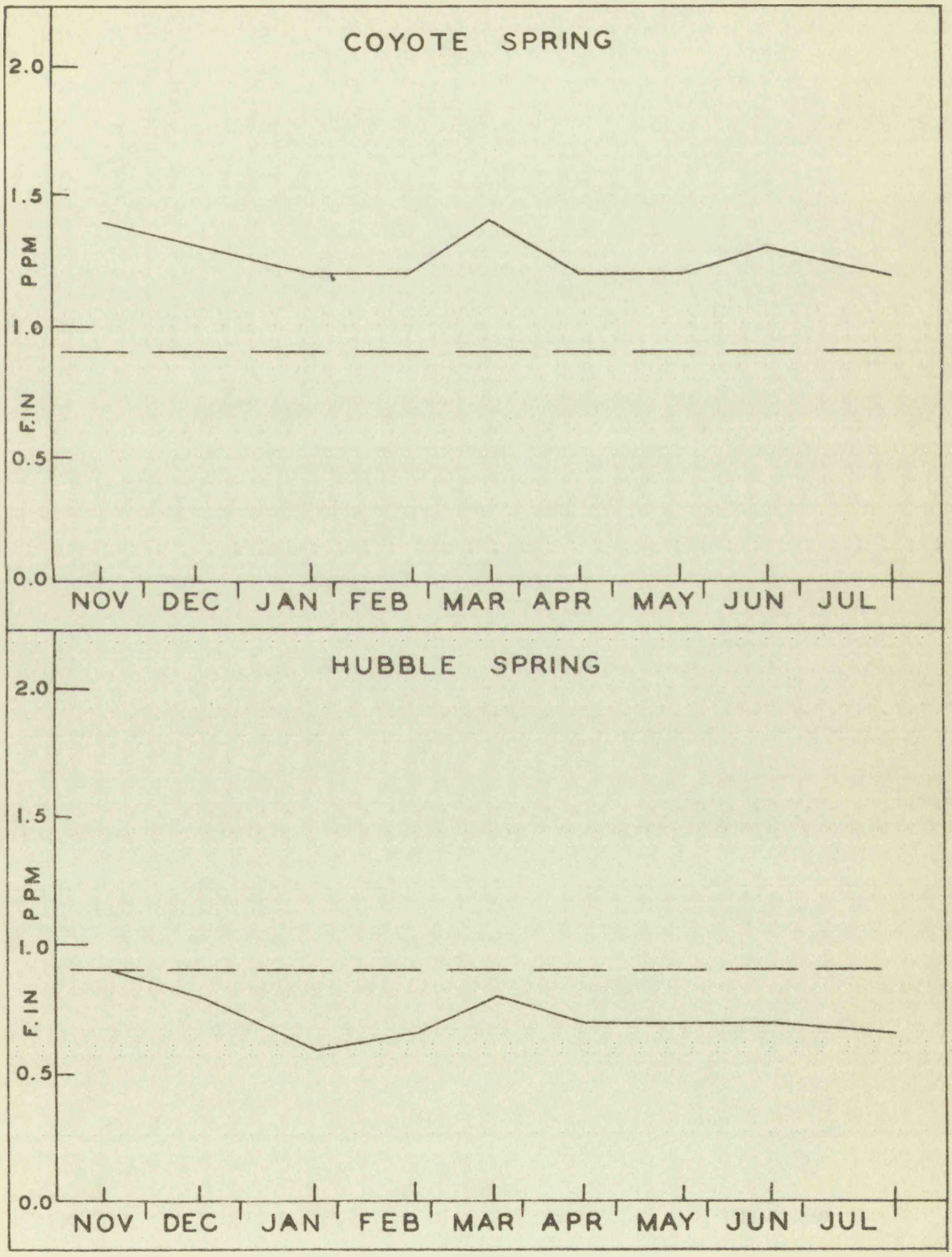
MAP OF SANDIAS
SHOWING STATION
LOCATIONS
SAMPLE STATION
GOV. WEATHER STA.


Bernal. Hts
Placitas
Albuquerque
Tijeras
GEOLOGIC MAP OF THE SANDIA MOUNTAINS
Unconsolidated Silt, gravel, Sand, Sandstone, marl, & Caliche
Basalt, rhyolite, tuffs andesite, etc
Red shale, red & grey S.S., L.S. & gypsum
Granite, gneiss, and Schist
Limestone, some Slate & Sandstone
Sandstone and Shale
AFTER R.W. ELLIS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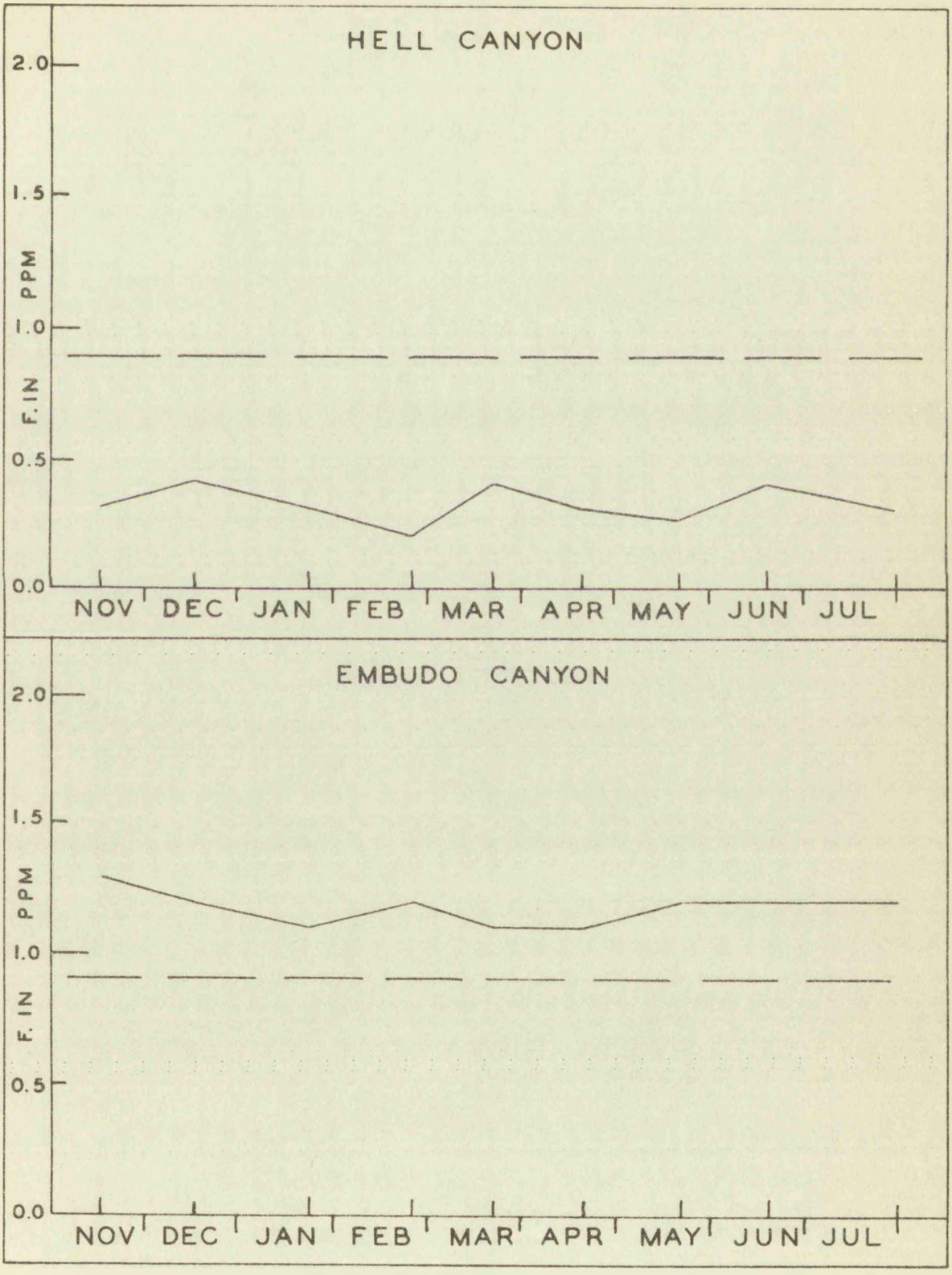
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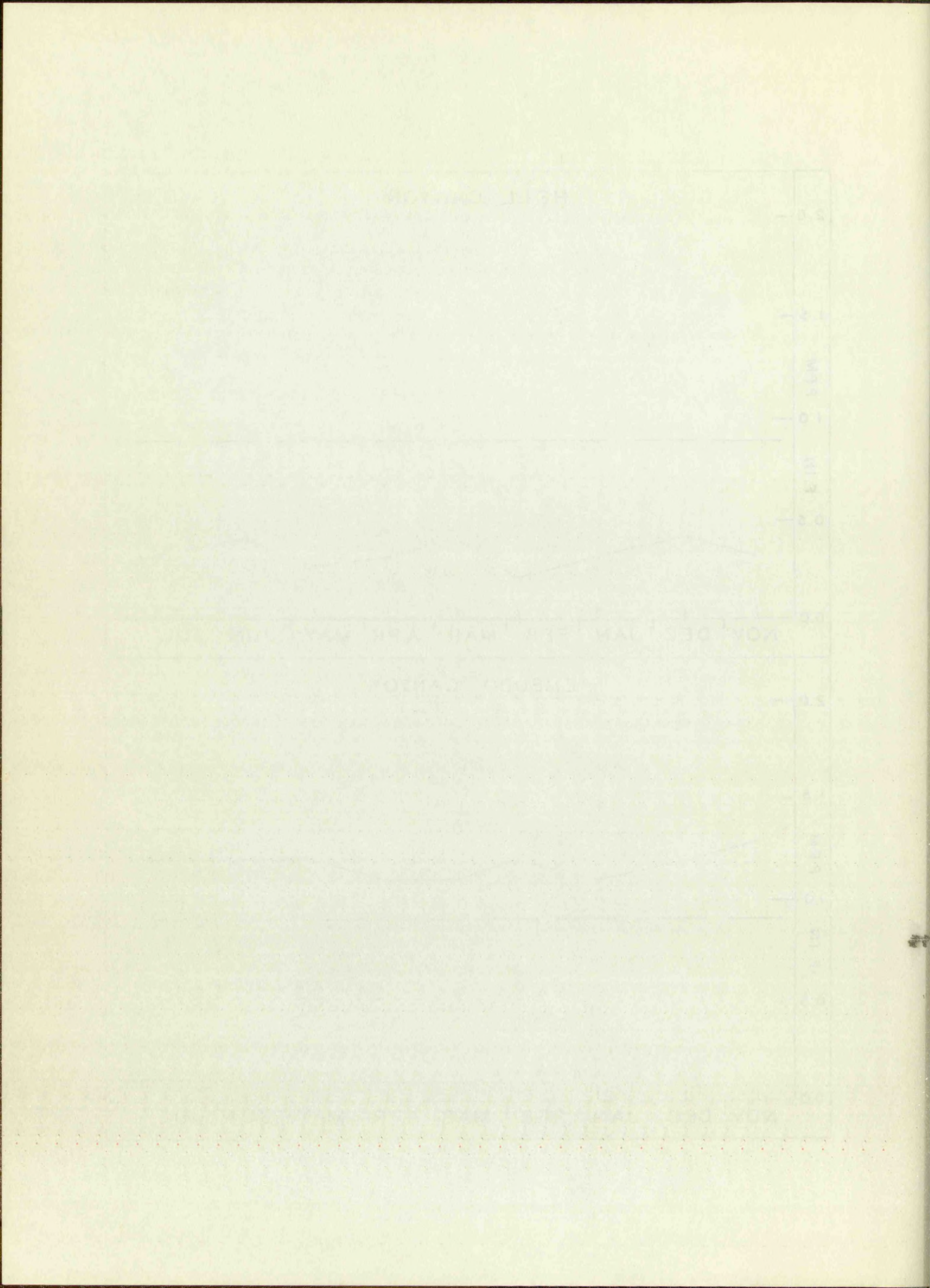

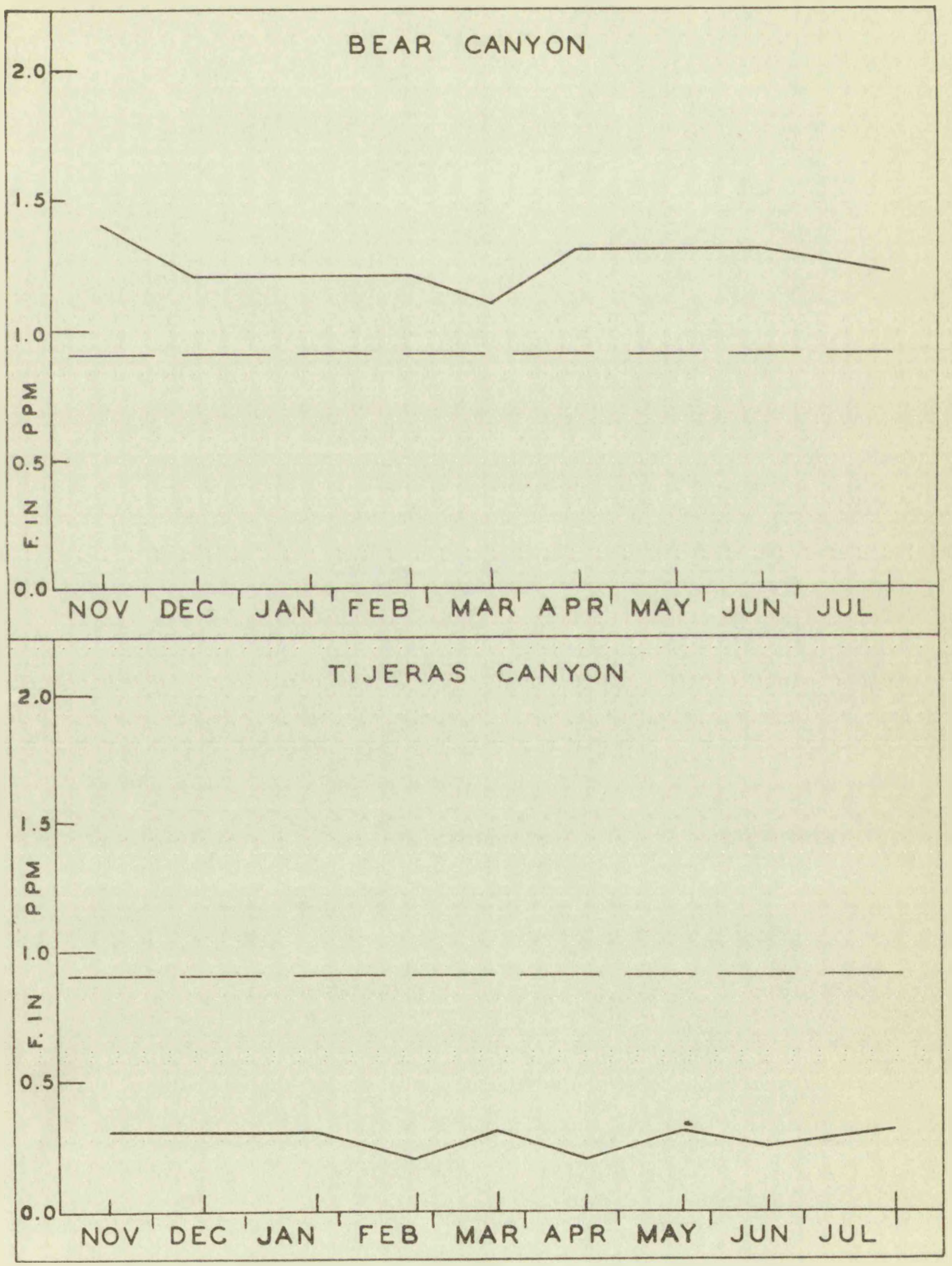
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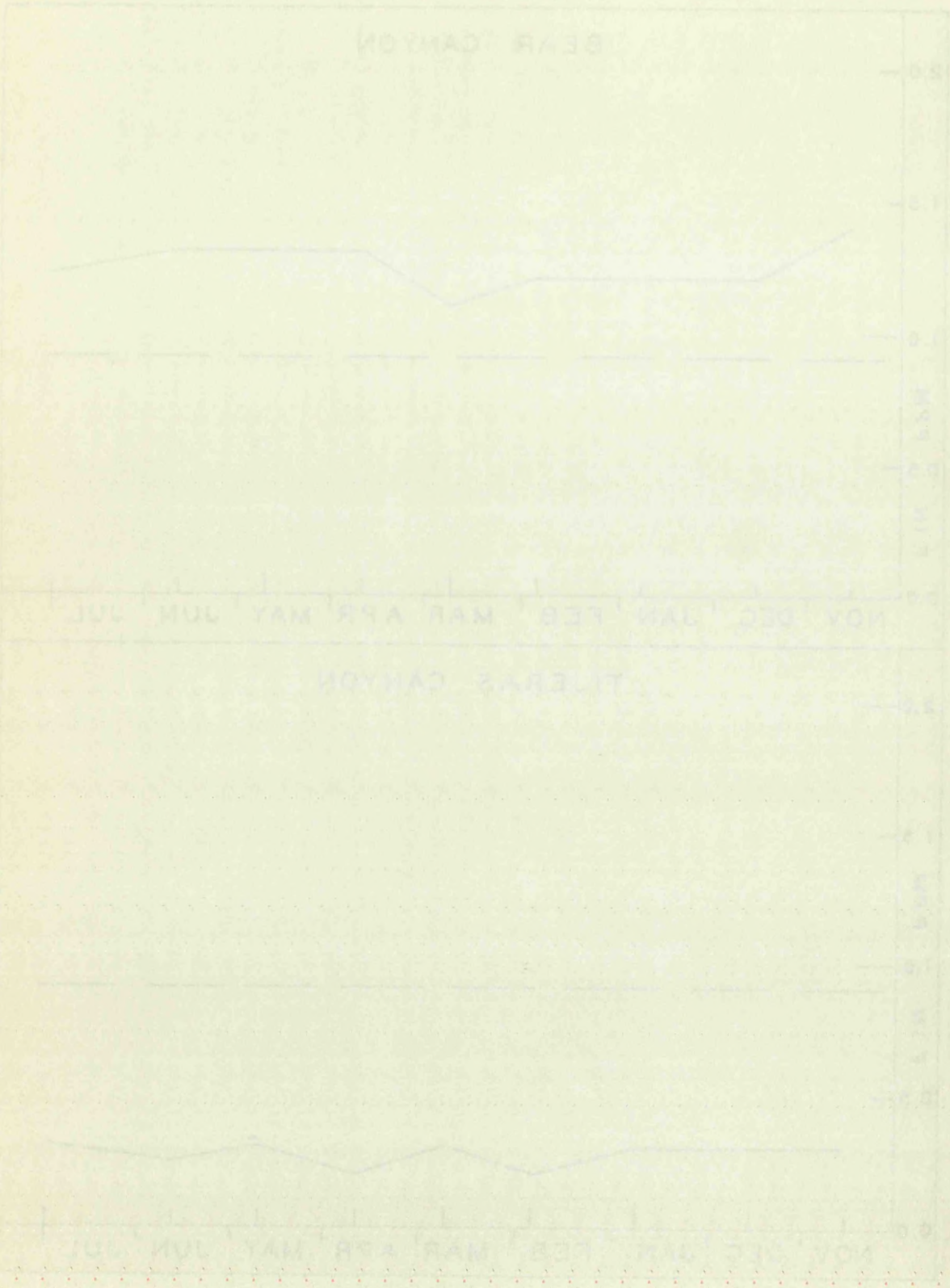

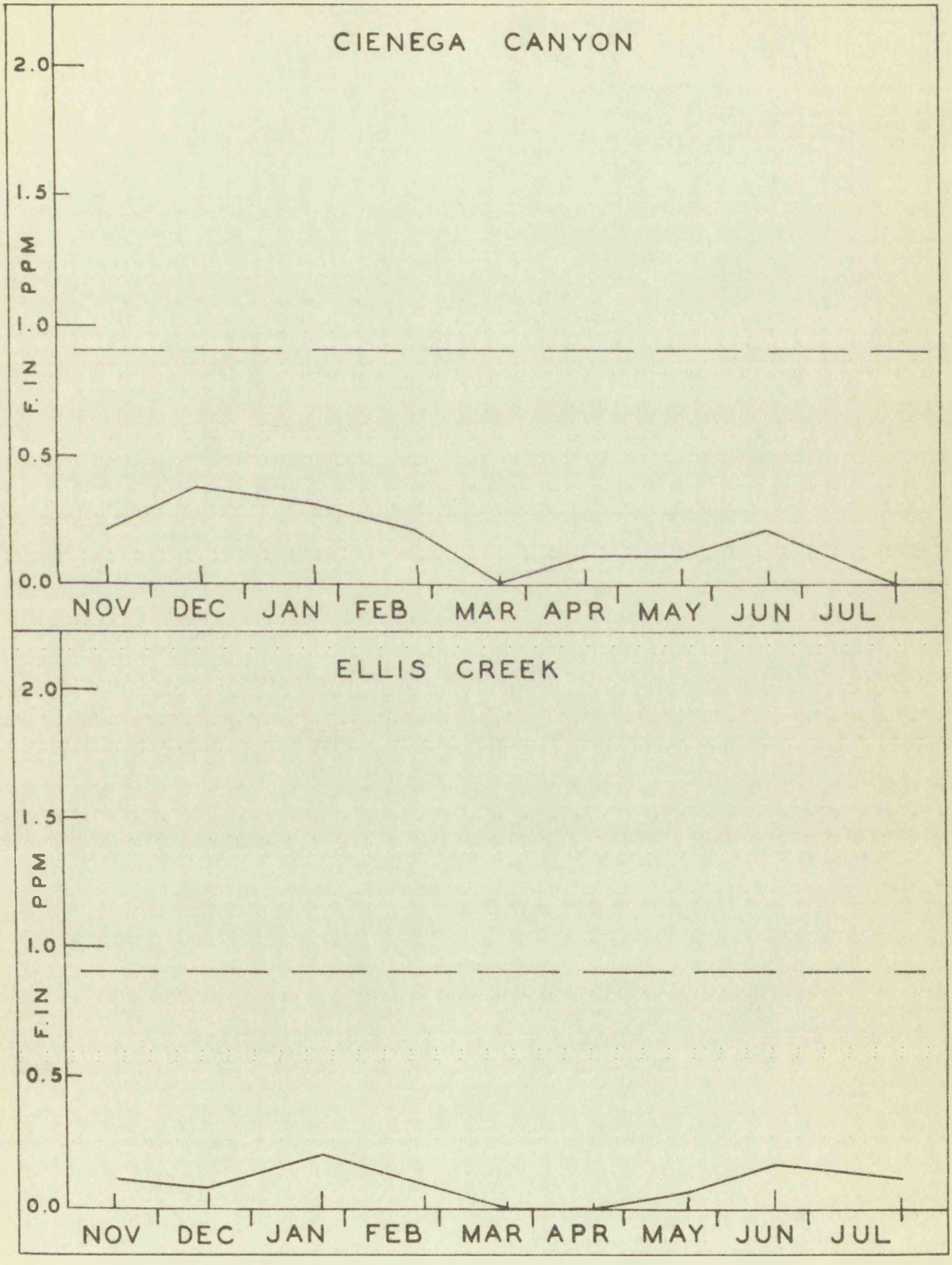
CIENEGA CANYON
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JEMEZ COUNTRY

Throughout the Jemez Region there are numerous hot springs. The most famous of these are the Jemez Hot Springs and the Sulfur Springs. These springs are more than likely of volcanic origin. Most of these springs have a high mineral content, and hence a high fluoride content. Those hot springs which do not have a high mineral content are probably heated by coming in contact with hot rock, and are heated indirectly. Such springs as these, I think, might be represented by the Spenser Hot Spring just above "Battleship-rock" on the San Antonio, and by the San Antonio Hot Spring, which is about five miles up the San Antonio from La Cueva. The mineral analyses of these springs appear in the data at the end of this thesis.

It is entirely possible that those hot springs which are highly mineralized add to the fluoride content of the streams of this locality, since the fluoride content of the Jemez River increases when it passes Soda Dam. However, I do not think that is the entire cause, since the volume of the Jemez Hot Springs and the springs at Soda Dam is relatively small in comparison to volume of the stream. At Soda Dam, there is a granite wall across the canyon, and the water

from the springs at Soda Dam comes to the surface after encountering this granite wall in its southern course, which causes the springs to extend in a line across the canyon. It is entirely possible that this granite increases the fluoride content of the stream, and thus furnishes a case very similar to the cause in the Sandia Mountains.

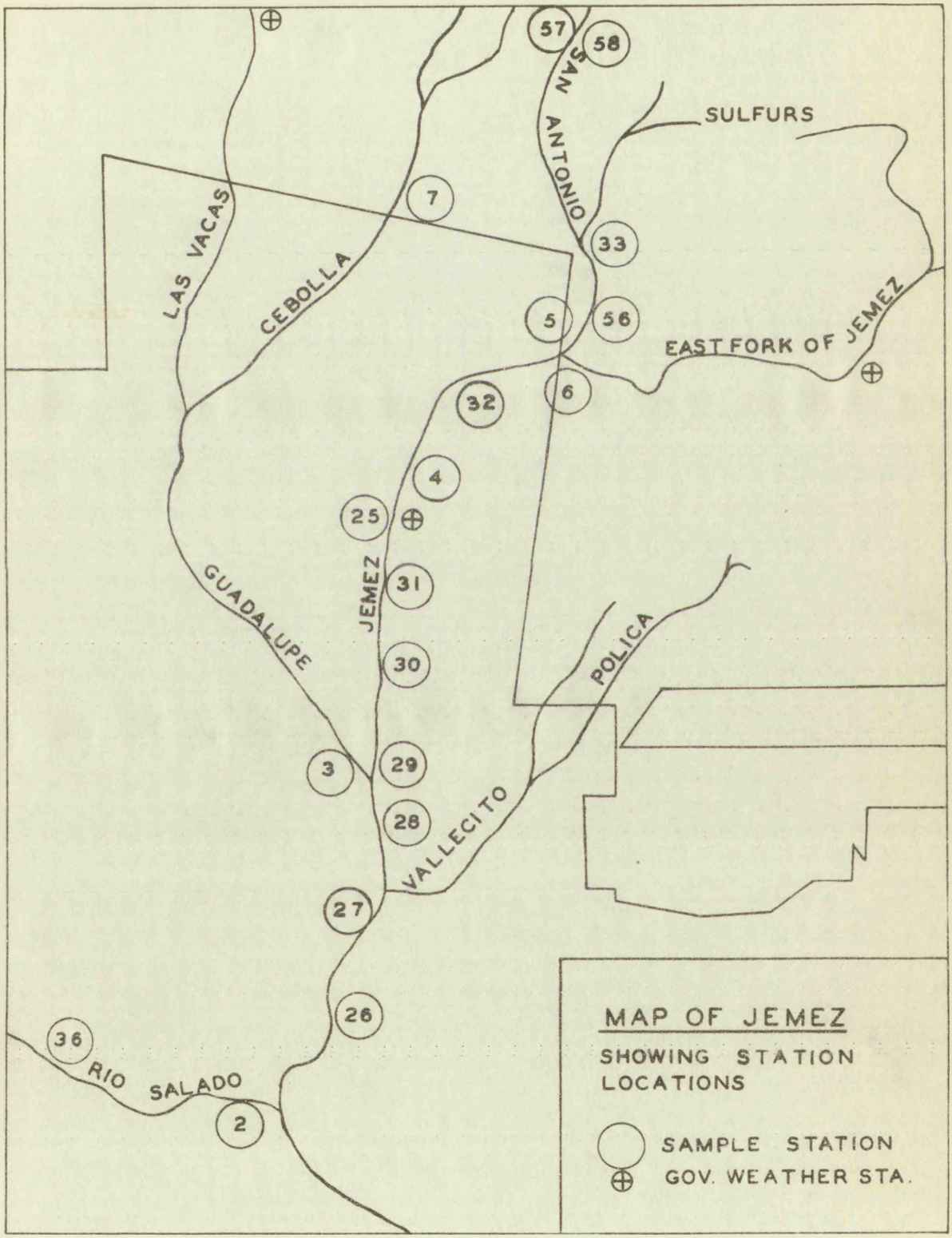
It will be noticed from the curves that the monthly variation of the fluoride content covers quite a wide range. The highest point on the curves occurs during the dead of winter, when everything is frozen up and the flow in the streams is low. The lowest point on all the curves is during the spring when the volume of the streams is the greatest. This was the expected result. During the winter, the flow of the water is slower, and it has more time in which to pick up fluorine from the fluorine-bearing rocks. Also, in the winter the flow is small and any source of fluorine, such as water from a hot spring, would make up a larger percentage of the total water in the stream. Both of these factors probably influence the increase of the fluoride content in the winter. During the spring, the stream is in flood stage; consequently, the water has less time in which to pick up the fluorides, and the volume of any hot springs which may supply fluorides is relatively much smaller than during the winter months.

Upon examination of the weather reports from weather stations in the Jemez region, it is found that the precipita-

tion during the period of study was considerably below normal, the normal being considered the average over a ten-year period, or longer.

If the precipitation during the period of this study had been greater, the result would probably have been that the fluoride content of the stream would have been lower, especially during the spring, when it would have caused much greater run-off.

No study was made of the composition of the rocks of the proposed Jemez reservoir bed. However, Miss Gladys Swope, of the Kansas State Board of Health, examined samples of rock from the Jemez Country, and reported that the rocks produced a fluoride content as high as 2.4 parts per million in the water after leaching. The author does not know the location from which the rock samples were obtained, or the method that was used in the analysis. Because Miss Swope's study was limited, her results are of no particular import, except to show that the water might pick up a fluoride content from the rocks. A detailed study should be made of the possibility of the waters picking up a fluoride content while in storage, and to what possible extent. The author obtained two samples of soil from around La Cueva, and leached them in water and determined the fluoride content of the water, which he found to be lower than 0.9 P.P.M., which is much lower than the results obtained by Miss Swope.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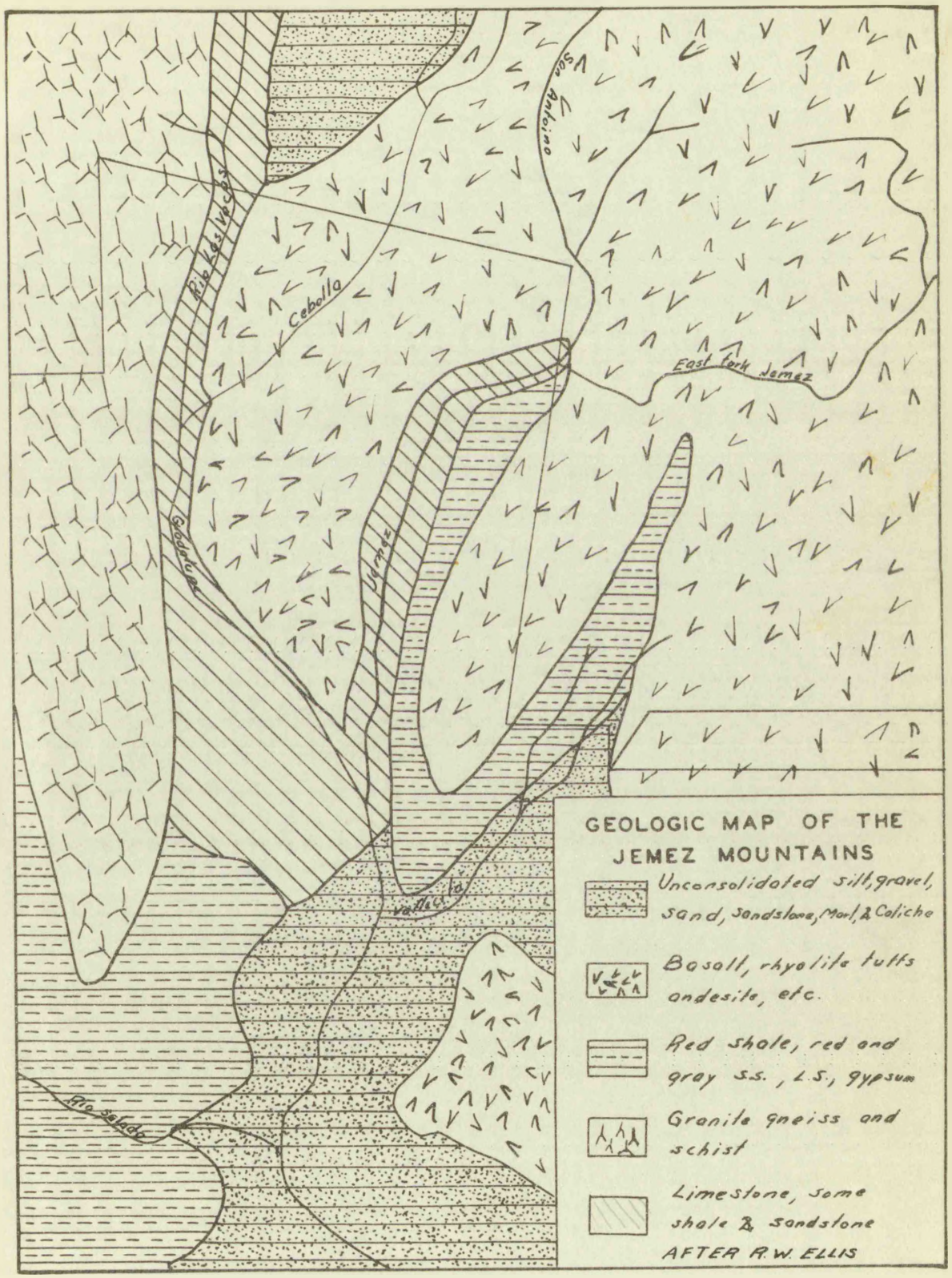
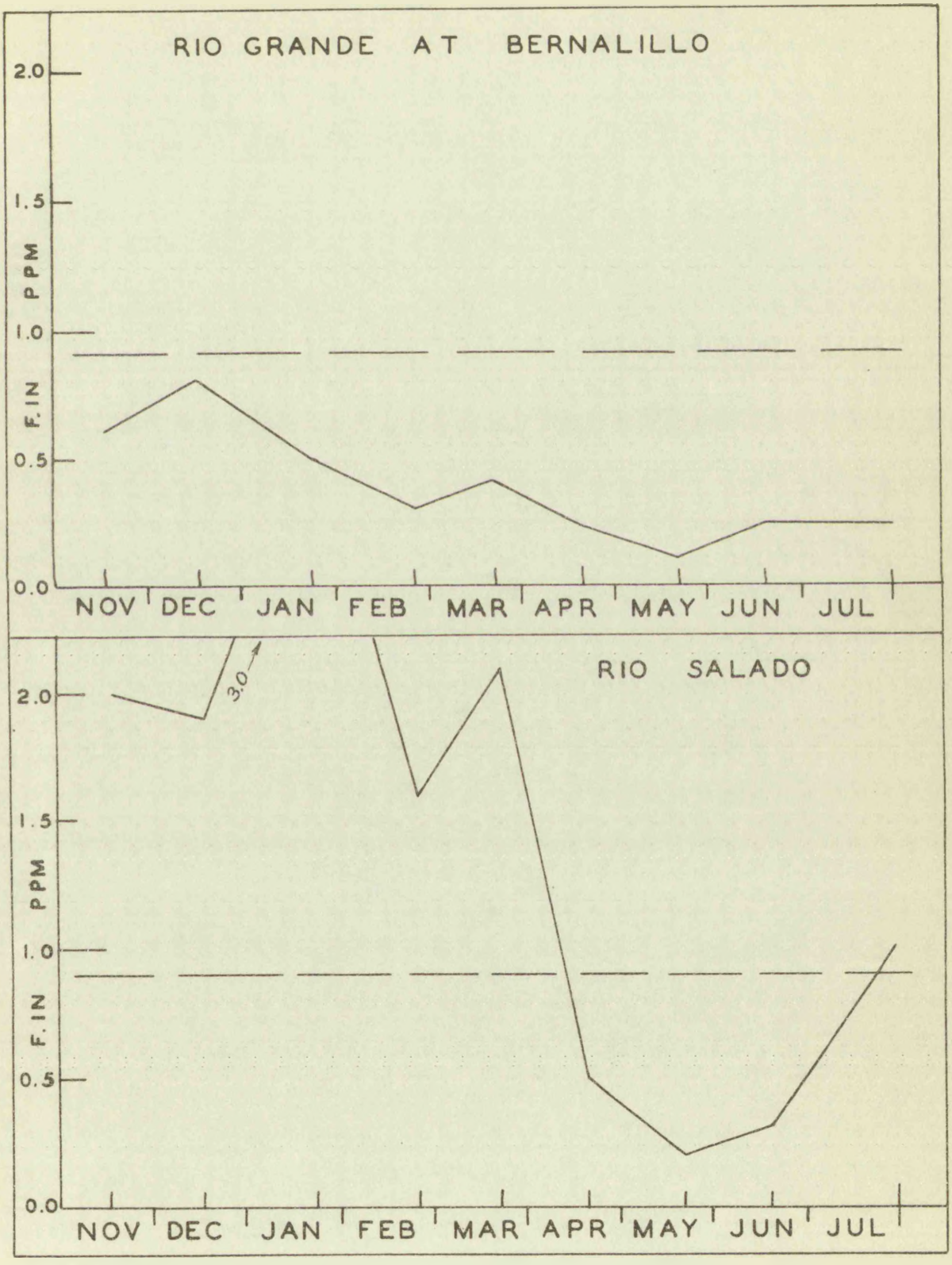
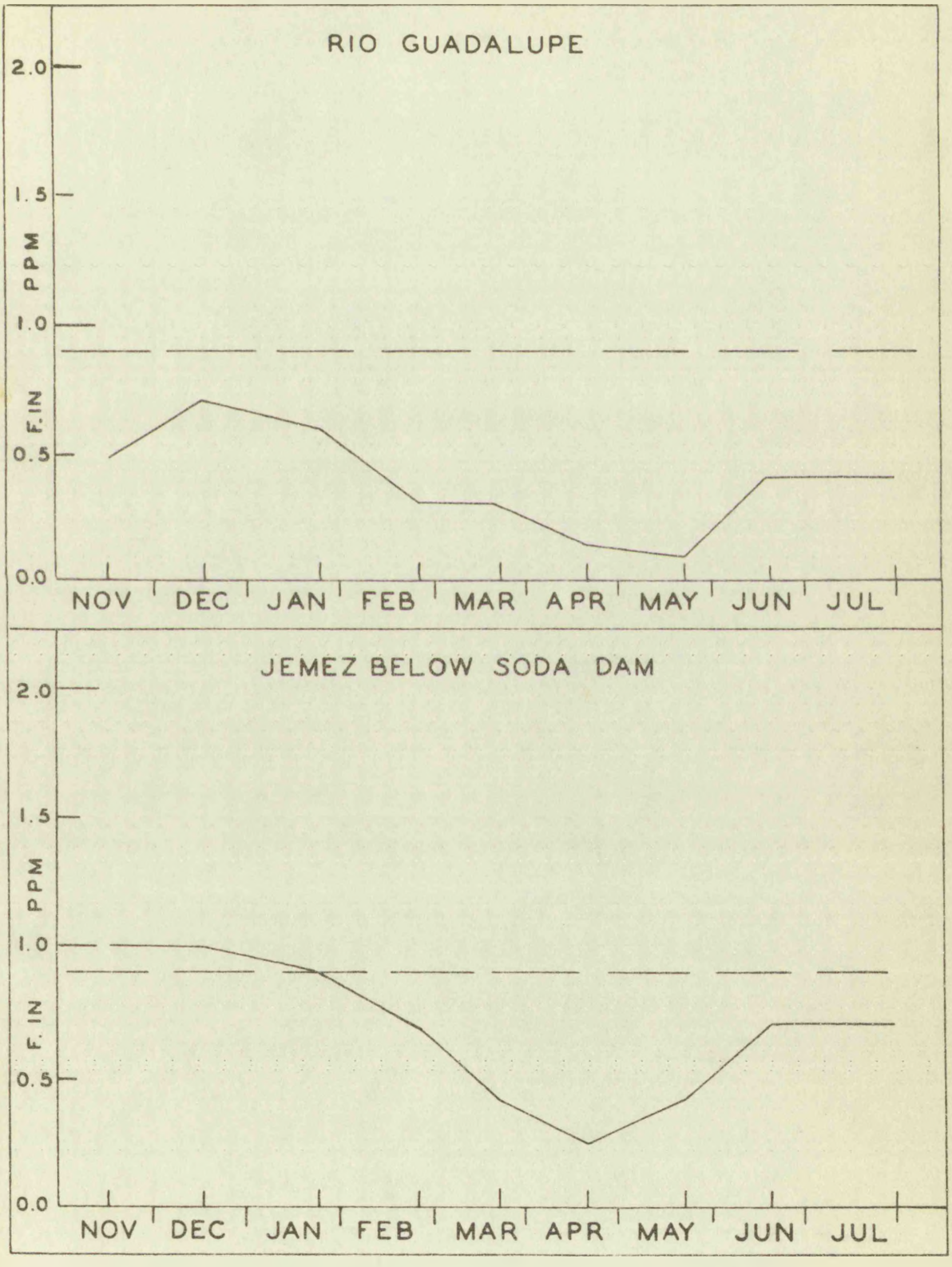
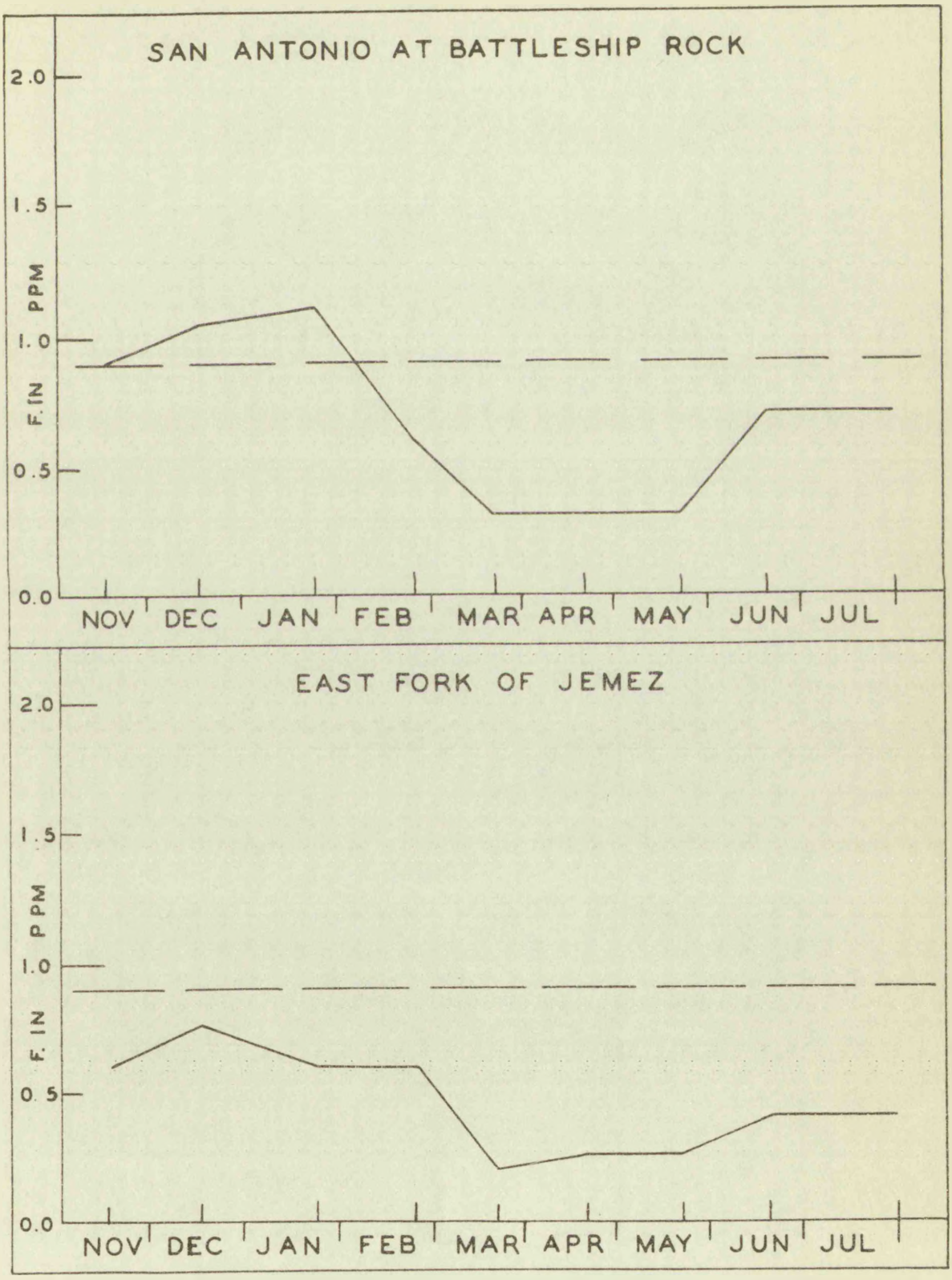
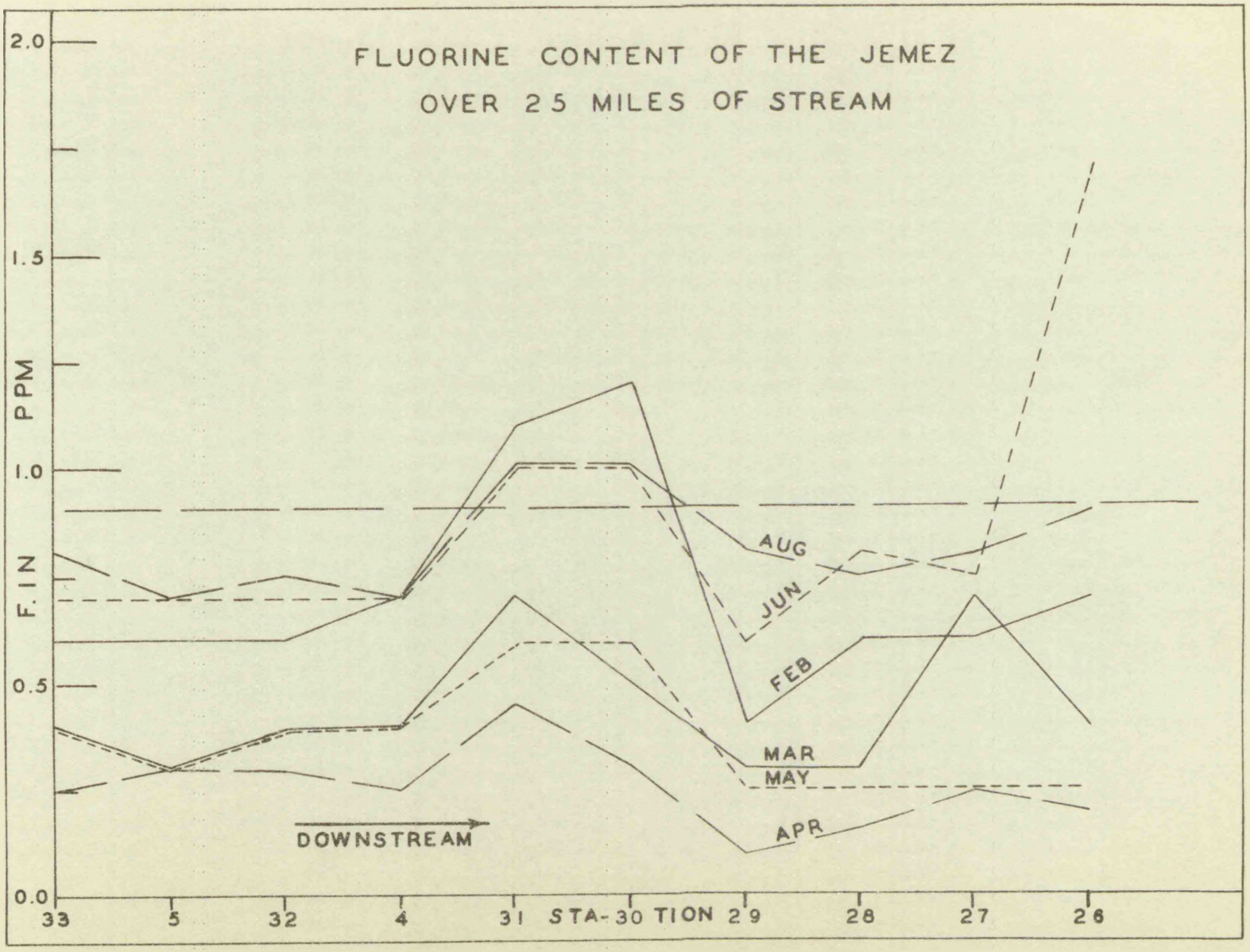
58
SAN ANTONIO
SULFURS
7
LAS VACAS
CEBOLLA
33
5
56
EAST FORK OF JEMEZ
6
32
4
25
JEMEZ
31
GUADALUPE
POLICA
30
3
29
28
VALLECITO
27
26
36
RIO SALADO
2
MAP OF JEMEZ
SHOWING STATION LOCATIONS
SAMPLE STATION
GOV. WEATHER STA.


Rio Guadalupe
Cebolla
Rio Jemez
Soda Dam
East Fork Jemez
Valles Caldera
Rio Salado
GEOLOGIC MAP OF THE JEMEZ MOUNTAINS
Unconsolidated silt, gravel, sand, sandstone, Marl, & Caliche
Basalt, rhyolite tuffs andesite, etc.
Red shale, red and gray s.s., L.S., gypsum
Granite gneiss and schist
Limestone, some shale & sandstone
AFTER R.W. ELLIS


RIO GRANDE AT BERNALILLO
2.0
1.5
1.0
0.5
0.0
F. IN PPM
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
RIO SALADO
3.0
2.0
1.5
1.0
0.5
0.0
F. IN PPM
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL


RIO GUADALUPE
2.0
1.5
PPM
1.0
F. IN
0.5
0.0
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
JEMEZ BELOW SODA DAM
2.0
1.5
PPM
1.0
F. IN
0.5
0.0
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL


SAN ANTONIO AT BATTLESHIP ROCK
2.0
1.5
1.0
0.5
0.0
F. IN PPM
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
EAST FORK OF JEMEZ
2.0
1.5
1.0
0.5
0.0
F. IN PPM
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL


FLUORINE CONTENT OF THE JEMEZ
OVER 25 MILES OF STREAM
2.0
1.5
1.0
0.5
0.0
F. IN PPM
AUG
JUN
FEB
MAR
MAY
APR
DOWNSTREAM
33
5
32
4
31
STA-30 TION 29
28
27
26

ALBUQUERQUE CITY WELLS

The City of Albuquerque is supplied with water from a system of wells located at various points in the City. In the well system there are four deep wells, which range in depth from 450 to 700 feet, and numerous shallow wells, which range in depth from 55 feet to 90 feet. The shallow wells are much harder than the deep wells and are, consequently, used only in the summer time, when the demand for water is highest. It will be noticed from the results of this study that these harder wells contain less fluoride than the soft wells do. Over the nine-month period of study, the two hard wells tested had a fluoride content of a little over 0.4 parts per million, while the four soft wells, over the same period, averaged over 0.75 parts per million.

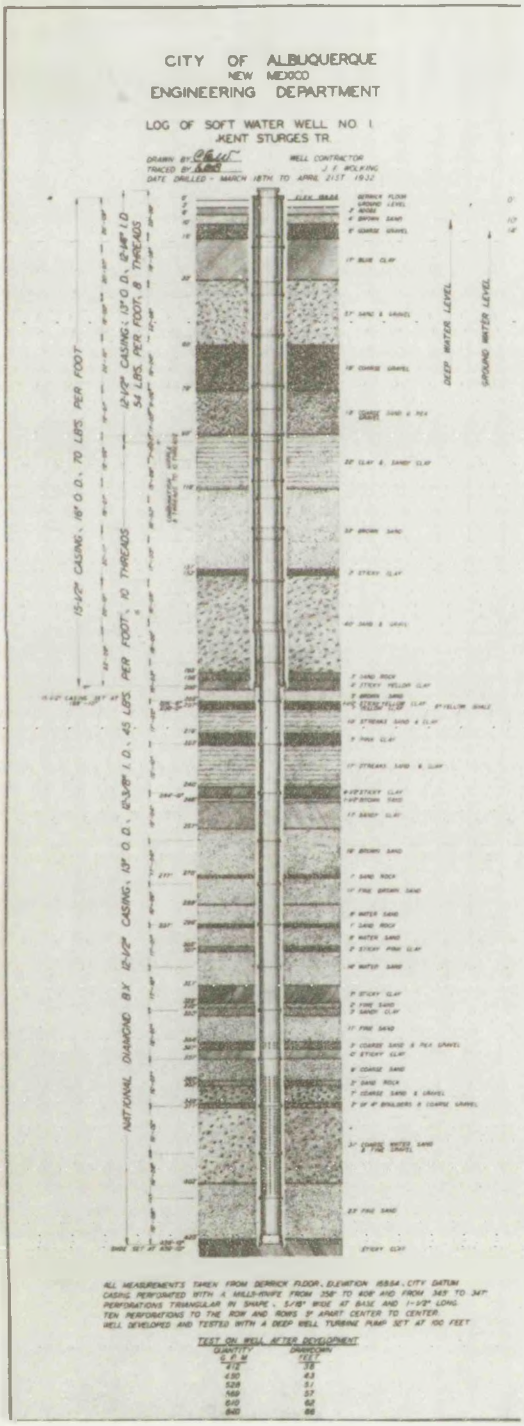
The geology of the region of the City underlying the Rio Grande deposits is probably very similar to that of the Sandia Mountains to the east of Albuquerque, which are formed by an uplift. It will be remembered that the Sandias are composed of a granite core with a limestone cap over the east side. It will also be remembered that the water that came in the form of springs from the granite had a fluoride content of more than one part per million. It is probable that the higher

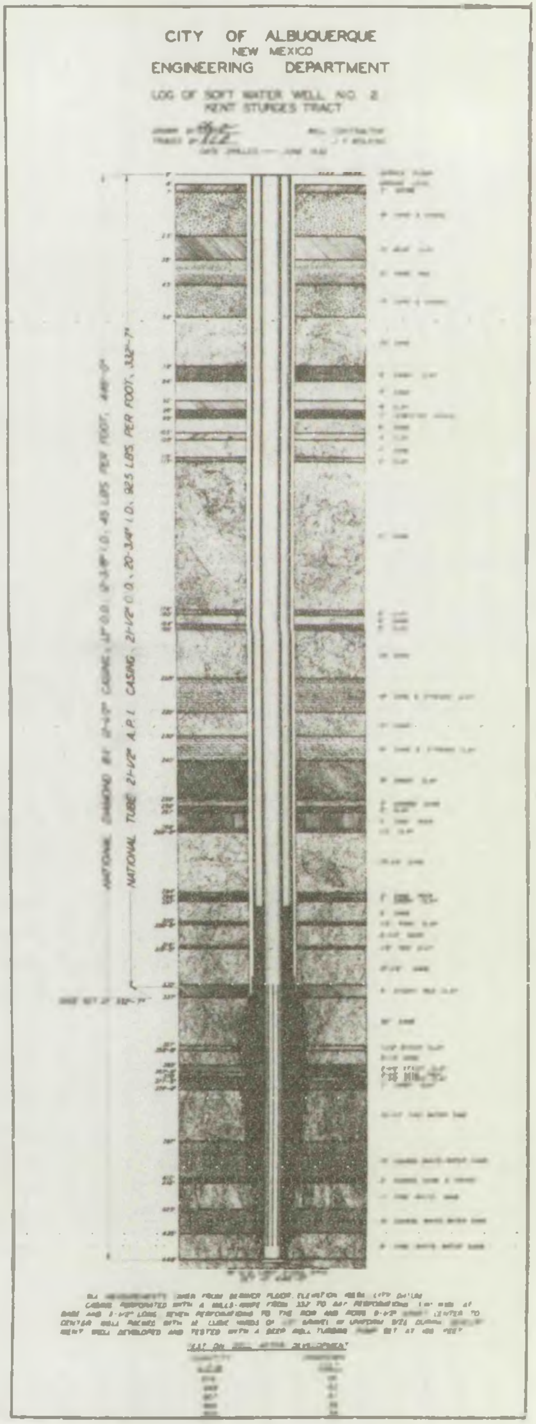
fluoride content of the deep wells over the hard wells is due to the same cause; that is, the deep wells are nearer the granite core of the Albuquerque-Sandia region.

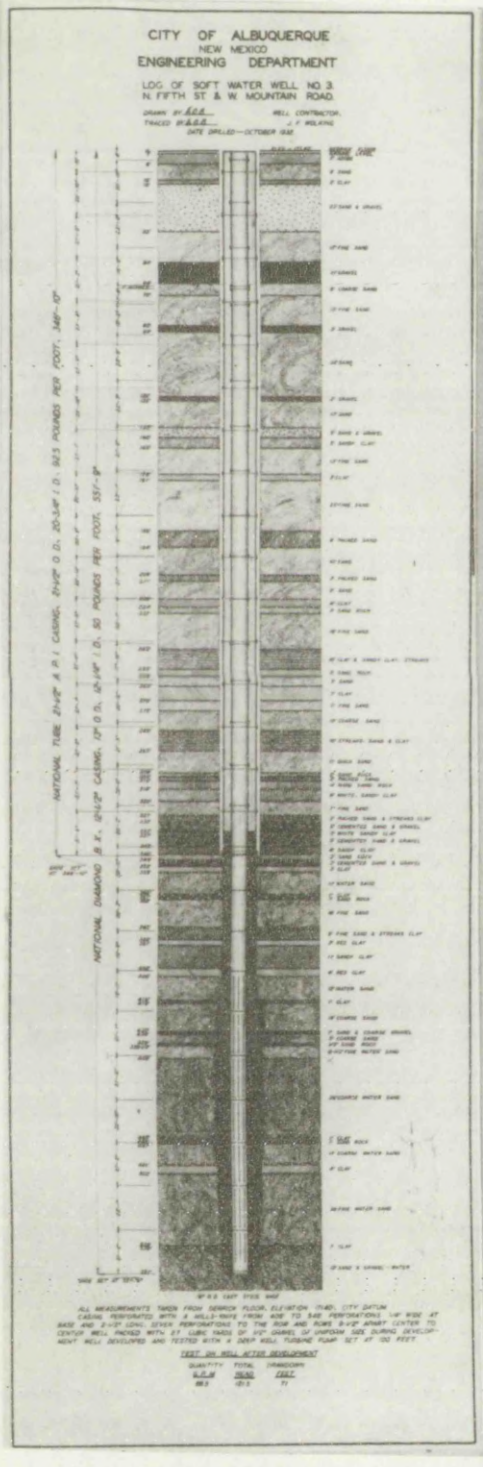
It will be noticed that No. 4 soft well, which is the deepest of the wells, contains less fluorine than do the other soft wells. It appears at first that this would disprove the theory, but this well has its casing pierced to a higher level than the other wells and this accounts for the fact that the fluoride content of this well is lower than the other soft wells.

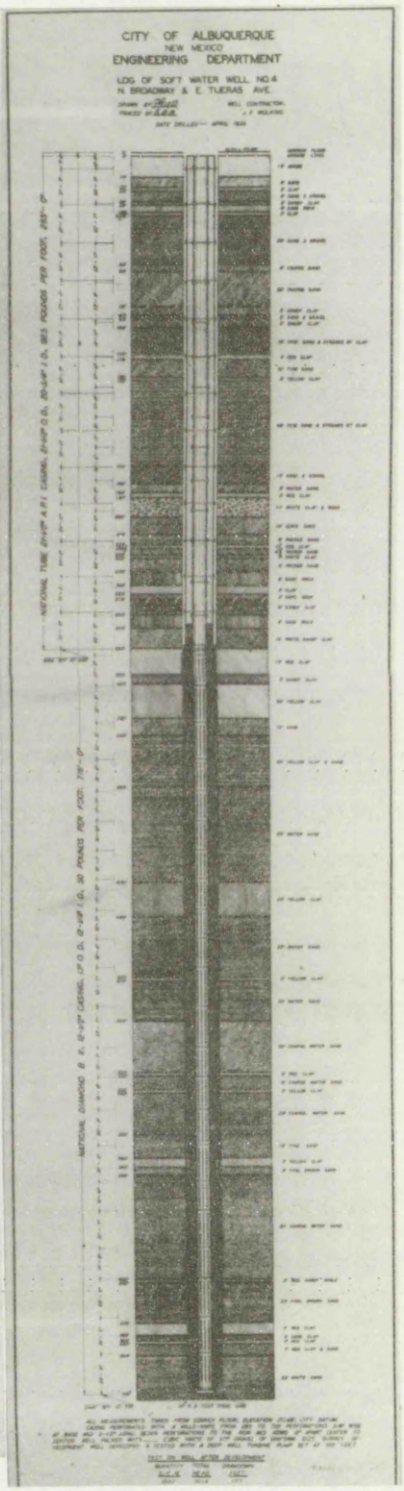
Over the nine-months period of study, the fluoride content of the soft wells remained fairly constant, apparently varying only one or two tenths of a part per million. The hard wells, however, varied over a considerably wider range. In February, the fluoride content was lowest, while in April it was the highest, a condition exactly the reverse of that found on the Jemez streams. This may be explained as follows. In February, the ground water is low and there is relatively little water to hinder its flow. Hence, it percolates through the ground faster, and, therefore, picks up less fluorine. In April, during the flood stages, there is so much water that the percolation through the soil is retarded, and hence it picks up more fluorine, because it is in contact with the fluorine-bearing rocks a greater time. The soft wells are deeper and the percolation of water at

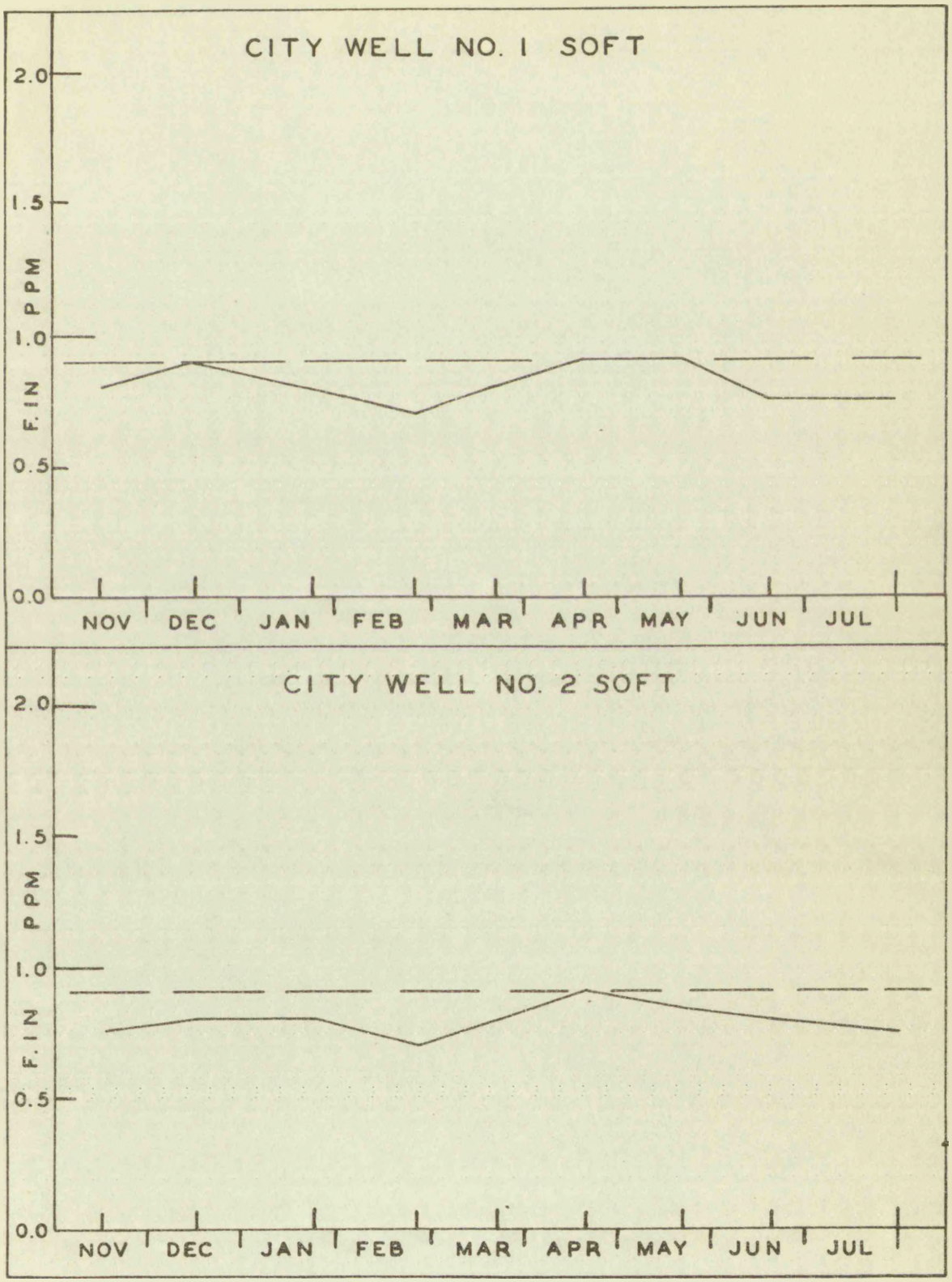
these levels is less subject to retardation by conditions existing during flood stages. However, it will be noticed that they are affected similarly, but to a much less pronounced extent.

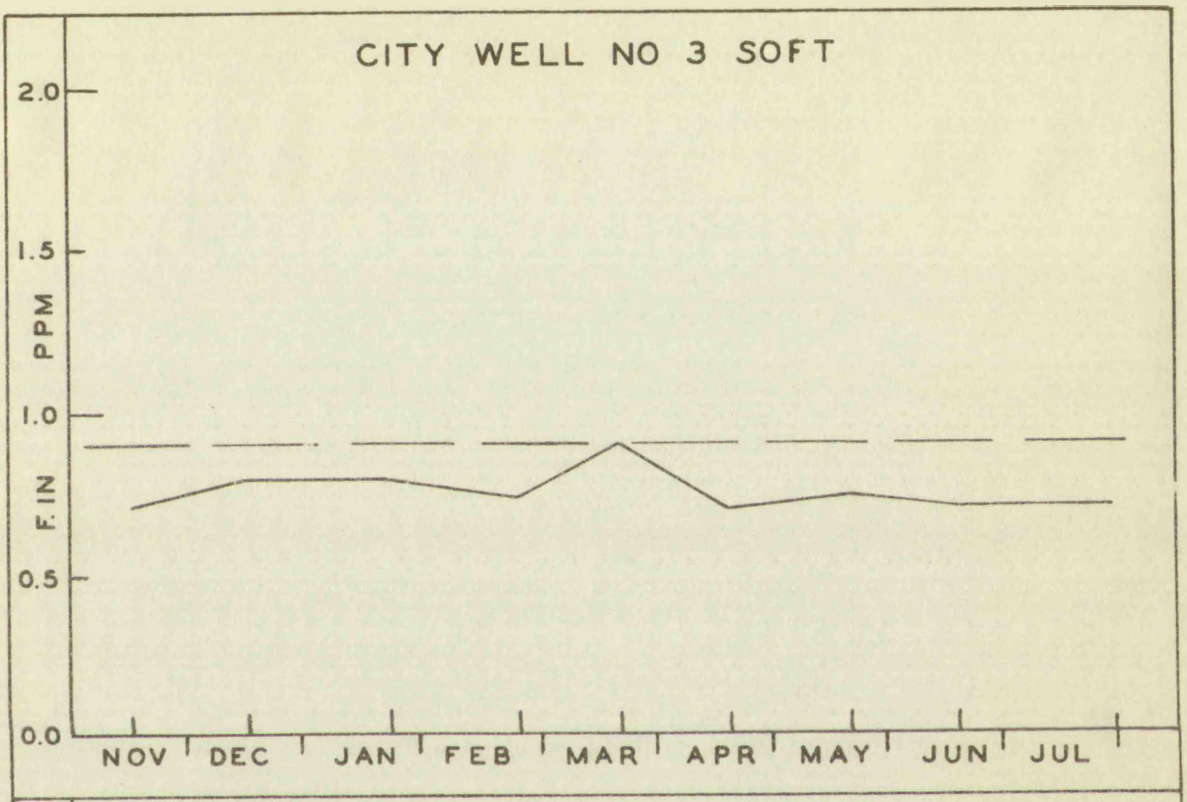

CITY OF ALBUQUERQUE
NEW MEXICO
ENGINEERING DEPARTMENT
LOG OF SOFT WATER WELL NO. 1
KENT STURGES TR.
DRAWN BY
TRACED BY
WELL CONTRACTOR
J. F. WOLKING
DATE DRILLED - MARCH 18TH TO APRIL 21ST 1932
DERRICK FLOOR
GROUND LEVEL
BROWN SAND
COARSE GRAVEL
BLUE CLAY
DEEP WATER LEVEL
GROUND WATER LEVEL
15-1/2" CASING, 18" O.D., 70 LBS. PER FOOT
12-1/2" CASING, 13" O.D., 12-1/4" I.D., 54 LBS. PER FOOT, 8 THREADS
NATIONAL DIAMOND BX 12-1/2" CASING, 13" O.D., 12-3/8" I.D., 45 LBS. PER FOOT, 10 THREADS
FINE SAND
STICKY CLAY
ALL MEASUREMENTS TAKEN FROM DERRICK FLOOR, ELEVATION 4958.64, CITY DATUM
CASING PERFORATED WITH A MILLS-KNIFE FROM 258' TO 408' AND FROM 345' TO 347'
PERFORATIONS TRIANGULAR IN SHAPE, 5/16" WIDE AT BASE AND 1-1/2" LONG
TEN PERFORATIONS TO THE ROW AND ROWS 5" APART CENTER TO CENTER
WELL DEVELOPED AND TESTED WITH A DEEP WELL TURBINE PUMP SET AT 100 FEET
TEST ON WELL AFTER DEVELOPMENT
QUANTITY G.P.M.
DRAWDOWN FEET
412 38
450 43
528 51
569 57
610 62
640 66

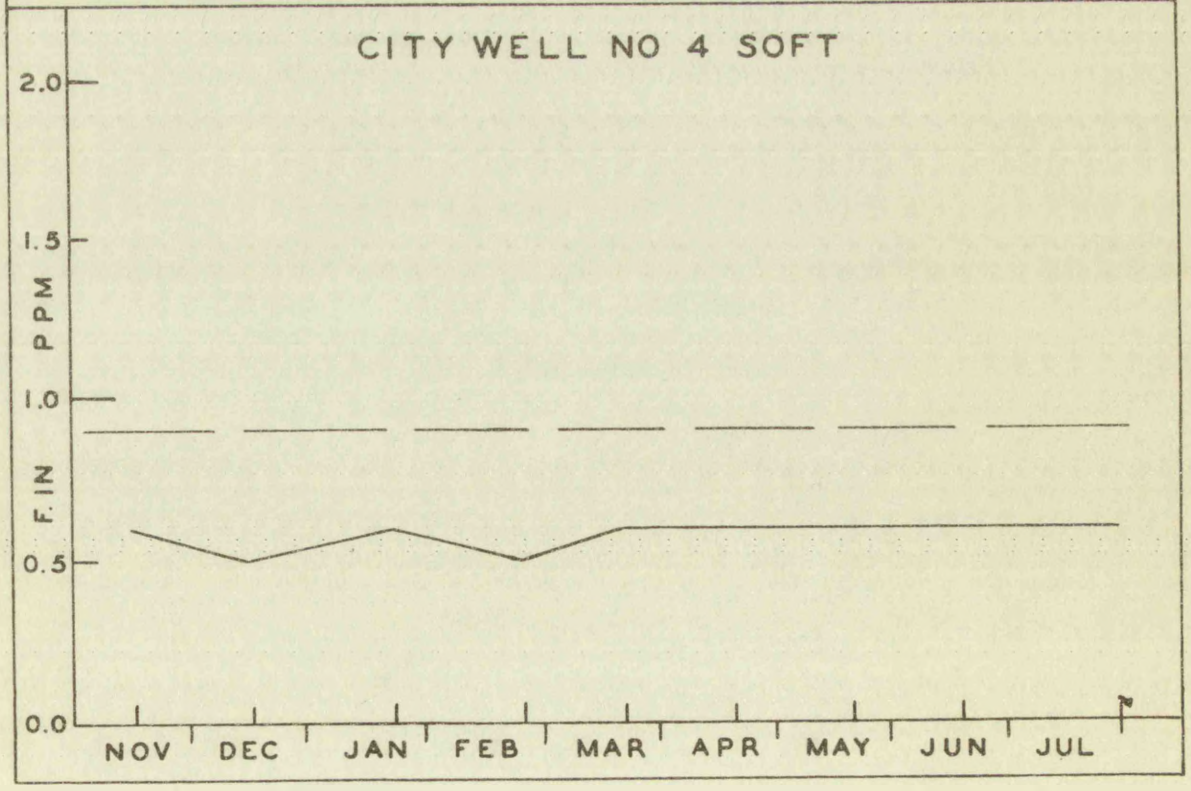

CITY OF ALBUQUERQUE
NEW MEXICO
ENGINEERING DEPARTMENT
LOG OF SOFT WATER WELL NO. 2
KENT STURGES TRACT

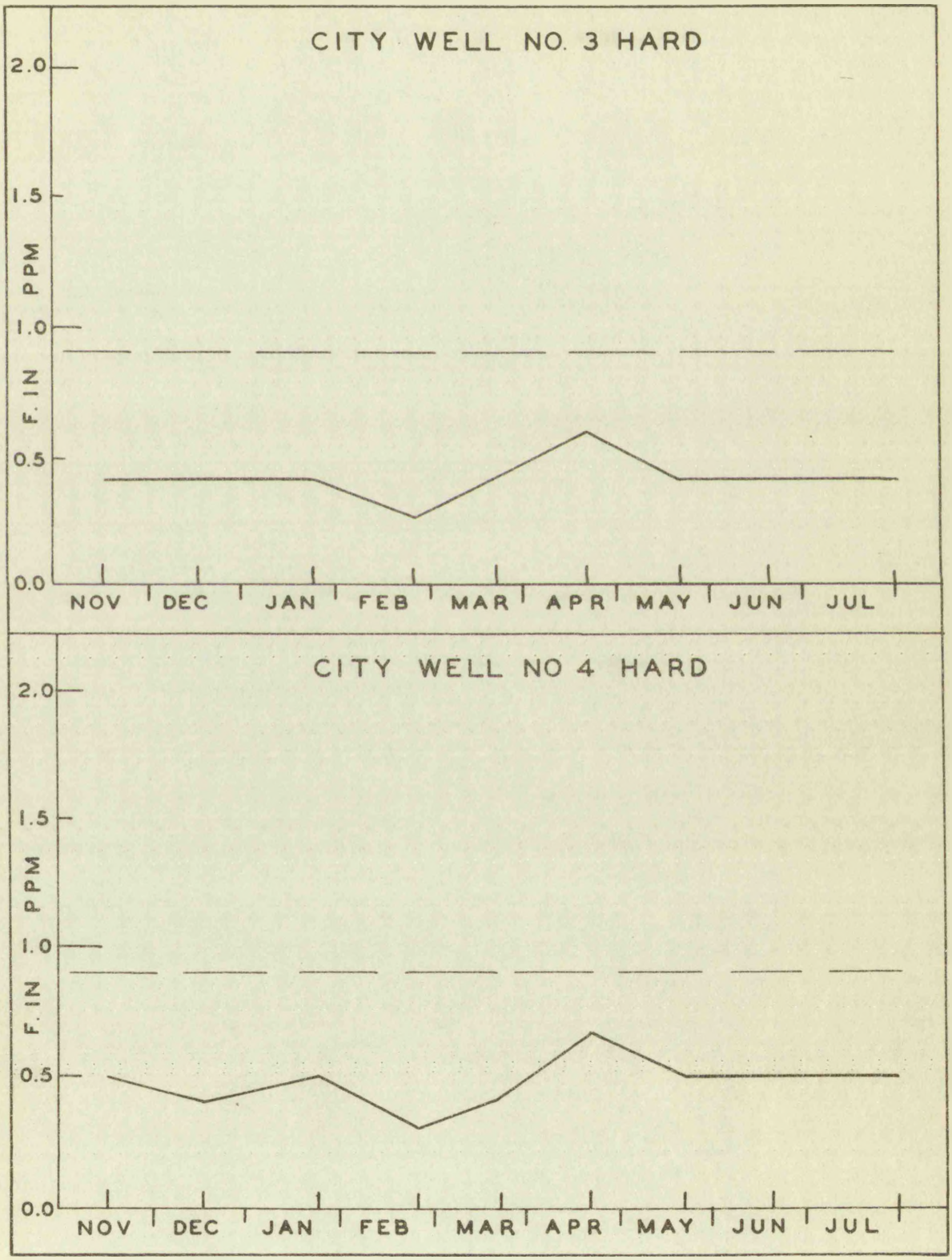

CITY OF ALBUQUERQUE
NEW MEXICO
ENGINEERING DEPARTMENT
LOG OF SOFT WATER WELL NO. 3
N. FIFTH ST. & W. MOUNTAIN ROAD.
DRAWN BY
TRACED BY
WELL CONTRACTOR
DATE DRILLED—OCTOBER 1938
NATIONAL TUBE 21-1/2" A.P.I. CASING, 21-1/2" O.D., 20-3/4" I.D., 94.5 POUNDS PER FOOT, 346'-0"
NATIONAL DIAMOND (8 X), 6-1/2" CASING, 12" O.D., 6-1/4" I.D., 50 POUNDS PER FOOT, 551'-0"
TEST ON WELL AFTER DEVELOPMENT

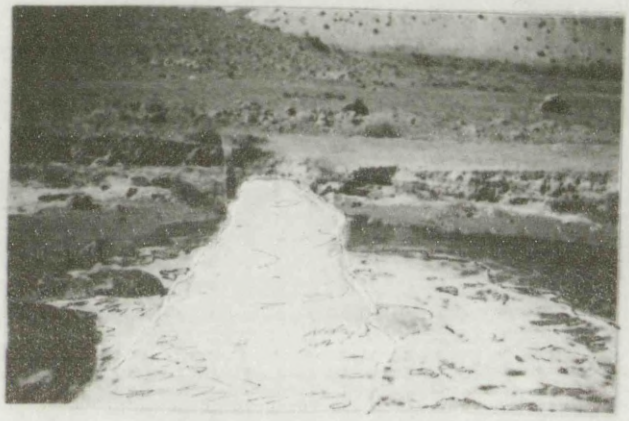

CITY OF ALBUQUERQUE
NEW MEXICO
ENGINEERING DEPARTMENT
LOG OF SOFT WATER WELL NO. 4
N. BROADWAY & E. TUERAS AVE.
DRAWN BY
TRACED BY
WELL CONTRACTOR
DATE DRILLED—APRIL 1939
NATIONAL TUBE 21-1/2" A.P.I. CASING, 21-1/2" O.D., 20-3/4" I.D., 94.5 POUNDS PER FOOT, 283'-0"
NATIONAL DIAMOND (8 X), 6-1/2" CASING, 12" O.D., 6-1/4" I.D., 50 POUNDS PER FOOT, 715'-0"
TEST ON WELL AFTER DEVELOPMENT


CITY WELL NO. 1 SOFT
2.0
1.5
1.0
0.5
0.0
F. IN PPM
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
CITY WELL NO. 2 SOFT
2.0
1.5
1.0
0.5
0.0
F. IN PPM
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL


CITY WELL NO 3 SOFT
2.0
1.5
1.0
0.5
0.0
F. IN PPM
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL


CITY WELL NO 4 SOFT
2.0
1.5
1.0
0.5
0.0
F. IN PPM
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL


CITY WELL NO. 3 HARD
2.0
1.5
1.0
0.5
0.0
F. IN PPM
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
CITY WELL NO 4 HARD
2.0
1.5
1.0
0.5
0.0
F. IN PPM
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL



ARTESIAN WELL ON
RIO SALADO

SODA DAM

ORIGINAL JEMEZ
HOT SPRINGS

BEAR FALLS

CIENEGA CANYON
IN WINTER

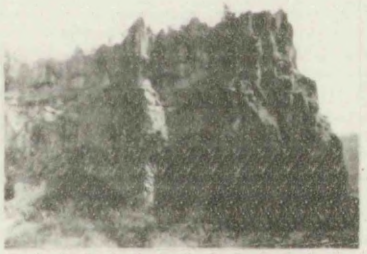
UPPER RIO SAN
ANTONIO

RIO SAN ANTONIO
IN WINTER

EAST FORK JEMEZ
IN WINTER

TENT ROCKS ON
RIO SAN ANTONIO

ELLIS CREEK



BATTLESHIP ROCK

HUBBLE SPRING

RIO CEBOLLA COUNTRY

METHODS OF

DETERMINATION OF FLUORIDES IN NATURAL WATERS

SANCHIS METHOD[4]

REAGENTS

Standard Sodium Fluoride Solution: Prepare a stock solution containing 2.21 grams of C. P. dry sodium fluoride per liter. Dilute 10 ml. of stock solution to 1 liter (1 ml. equals 0.01 mg. of fluorine).

Indicator: Prepare a stock solution as follows (a) Dissolve 0.17 gram of alizarin sodium sulfonate in 100 ml. of distilled water.

Add (a) to (b) slowly with constant stirring. Shake at intervals and allow to stand overnight. Dilute 20 ml. of stock solution to 100 ml. to serve as indicator. When not in use, these solutions are best kept in a cool dark closet.

Hydrochloric acid, 3N.

Sulfuric acid, 3N.

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[4] J. M. Sanchis - Determination of Fluorides in Natural Waters, J. Ind. Eng. Chem. Anal, Ed. 6 - 134-5, March 15, 1934.

PREPARATION OF STANDARDS

To each of a series of nine 250-ml. Erlenmeyer flasks, add 0, 2.5, 5.0, 7.5, 10, 15, 20, 25, and 30 ml. of standard fluoride solution (1 ml. equals 0.01 mg. of fluorine) made up to 100 cc. with distilled water.

The suggested standards cover from 0 to 3 p.p.m. of fluorine, which is a suitable range for potable water. The fluoride content of the unknowns can be estimated to the nearest 0.1 p.p.m. by interpolation. These standards are treated in a manner identical to that prescribed for the unknowns below.

PROCEDURE

A 100-ml. aliquot of the sample to be analyzed, freed from turbidity and suspended solids by filtration if necessary, is placed in a 250-ml. Erlemeyer flask. To each 100-ml. aliquot thus measured, and to the prepared standards add exactly 2.0 ml. of 3N hydrochloric acid, 2.0 ml. of 3N sulfuric acid, and 2.0 ml. of indicator solution.[1]

Place flasks on a hot plate. Bring the contents rapidly to the boiling point and remove soon after boiling begins. Do not allow to boil vigorously nor to simmer for

a long time.

Four hours after cooling, or the following day, transfer the standards to properly labeled 100 ml. matched Nessler tubes and make up to the mark with distilled water. Transfer each of the unknowns, in turn, to a 100 ml. Nessler tube and compare it's color with that of the standards.

If a reddish percipitate appears in any of the aliquots after cooling, disperse it by rapid whirling of the contents of the flask prior to their transfer to the Nessler tube and proceed with the determination as usual.

DISCUSSION OF METHOD

Thompson and Taylor, in their method for determining fluorides in sea water, recommend the preparation of fluorine standards with a solution of salts having a sulfate-to-chloride ratio analogous to that of sea water. The direct application of this procedure to fresh waters did not seem practical because of the wide fluctuation of their chloride to sulfate ratio, almost necessitates the preparation of a set of standards for each sample to be analyzed. This procedure, however, has been recently suggested, with some modifications, by Elvove.

The substitution of standards made up with distilled water for those prepared with a solution of the salts present in the unknowns did not prove successful when hydro-

chloric acid only was used for the acidification of samples and standards. Tests made on a series of synthetic waters, indicated that the presence of sulfates interfered seriously with the quantitative determination of fluorides.

Attempts to remove the sulfates by precipitation with barium chloride, followed by filtration through asbestos, were not altogether satisfactory. However, substitution of half the amount of hydrochloric acid, to be added to both the unknowns and standards, by an equivalent amount of sulfuric acid, effectively eliminated the interference of sulfates in the amounts normally found in fresh waters. Under these conditions, it was necessary to increase the concentration of the indicator in order to obtain a color range, varying from pink to yellow-green, which would permit an easy matching of the standards with the unknowns.

The results of several hundred determinations, made with synthetic waters by the method here proposed, indicate that chlorides, sulfates, bicarbonates, sodium, calcium, and magnesium up to 500 P.P.M.; manganese up to 200 P.P.M.; silicates up to 50 P.P.M.; phosphates, boron, copper, and iron up to 5 P.P.M.; and sulfides up to 2 P.P.M. do not interfere with the quantitative determination of fluorine.

The permanency of the color allows the estimation to be made whenever convenient, within a day or so, after four hours following the heat treatment, provided that the samples

and standards are treated at the same time, and in an indentical manner.

Organic matter and phosphates, if present in the samples in appreciable amounts, tend to throw some of the indicator out of solution. If the reddish precipitate formed is slight, it is possible to disperse it by rapid whirling of the contents of the flask and to compare the color as usual without difficulty or material sacrifice of accuracy. In extreme cases when the amount of precipitate is such that the matching of color cannot be made satisfactorilly, the method proposed by Willard and Winter, or it's modification as suggested by Boruff and Abbott may be used to advantage.

SUMMARY

The zirconium-alizarin method for the colorimetric determination of fluoride has been modified for the quantitative estimation of the ion in potable waters. The suggested procedure makes possible the use of distilled water in the preparation of the standards instead of synthetic water of similar mineral content, as that of the water analyzed. This permits the use of one set of standards for the determination of fluorides in any number of fresh water samples regardless of the composition of their mineral content. The method has been found to be reliable, convenient, and

specially suited to routine determinations when a large number of samples are to be analyzed at one time.

Note [1] The intensity and shade of the color produced depend on the concentration of indicator, and of each of the acids in the aliquots. It is, therefore, necessary to add identical amounts of these reagents to both standards and unknowns in order to obtain the maximum possible accuracy in the determination. The use of narrow-bore 2 ml. pipets has been found satisfactory for the addition of acids and indicator.

ELVOVE METHOD[5]

The fluoride estimation by the following procedure is made after determinations of Calcium, Magnesium, Sodium, Chlorides and Sulfate have been concluded, so as to enable the preparation of the synthetic water for the standards. In many cases, however, fairly close results are obtained, which may be useful for most practical purposes, by taking into consideration, in the preparation of the standards, the sulfate content only. In general, the latter simplification may be considered applicable to potable waters showing total solids of not more than about 500 parts per million, which are free from appreciable quantities of phosphate, and where there is no reason for suspecting the presence of ordinary constituents in unusual concentration. A sulfate solution of convenient concentration for use in the preparation of the standards is listed among the reagents. Similar stock solutions of known concentration of $CaCl_2$, Na_2SiO_3, $MgCl_2$, NaCl, $FeCl_3$, $AlCl_3$, etc., may be kept on hand for convenience in the preparation of standards with water containing, also, other constituents of the sample in addi-

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[5] U. S. Public Health Service, Reprint 1596, Revised September 19, 1935.

tion to sulfate. When a large number of samples of water of essentially similar characteristics are being examined for fluoride, the method of Sanchis may be found useful.

1. REAGENTS

(a) Zirconium oxychloride solution. Dissolve 0.5 g. zirconium Oxychloride ($ZrOCl_2 8H_2O$) in distilled water and make up to 100 ml.

(b) Alizarin sodium monosulfonate solution. Dissolve 0.1 g. alizarin sodium monosulfonate in distilled water and make up to 100 ml.

(c) Zirconium-alizarin reagent. To a chosen volume (50 ml.) of (a) add slowly, drop by drop, with stirring, an equal volume (50 ml.) of (b). If a turbidity remains after the final mixing, allow to stand for a few hours, or over night, until it clears. Finally, dilute the mixed solutions with double volume (200 ml.) of distilled water.

Keep solutions (b) and (c) in cool dark closet.

This reagent, applied in accordance with the following prodedure, is most sensitive to fluoride when freshly prepared. Hence, when dealing with waters containing only about 1 part per million of fluoride (F), it should be used before it is more than a few days old.

(d) Standard sodium fluoride solution. Dissolve 0.2210 g. sodium fluoride (NaF) in distilled water and make

up to 100 ml. From this stock solution, prepare the standard solution by diluting 5 ml. to 100 ml. with distilled water: 1 ml. is equivalent to 0.05 mg. of fluorine.

(e) 5 N. Hydrochloric acid.

(f) Sodium sulfate solution. Dissolve 14.8 g. fluoride-free anhydrous sodium sulfate (Na_2SO_4) in distilled water and make up to 1 liter; 1 ml. is equivalent to 10 mg. sulfate (SO_4).

2. PROCEDURE

To 100 ml. of the sample of water, or a smaller quantity diluted to 50 ml. with distilled water, and to each of 100 ml. of standards containing known amounts of fluoride in water of similar composition as the sample used (prepare on the basis of the analysis), add 10 ml. of 5 N HCl and 1 ml. of the zirconium-alizarin reagent, mixing well after each addition. Allow to stand, at room temperature, over night (about 18 hours) and then compare the color of the sample, in standard Nessler tubes, with the colors of the fluoride standards.

The fluoride standards are prepared so that neighboring tubes in the series vary from each other by 0.01 mg. of fluorine. Depending on the concentration of fluoride in the sample under examination, and on the sensitivity of the available zirconium-alizarin reagent, the fluorine quantities of

suitable series may be 0, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, and 0.07 mg., respectively, or 0, 0.06, 0.07, 0.08, 0.09, 0.10, 0.11, and 0.12 mg., respectively. These are obtained by measuring out, from a finely graduated 1 ml. pipette, the corresponding volumes of the standard sodium fluoride solution and diluting with synthetic water of similar composition as the sample to 50 ml., or diluting with a volume of the synthetic water equal to that of the sample used and distilled water to 50 ml.

Erlenmeyer flasks of about 125 ml. are convenient for the preliminary mizing. The mixed solutions should, however, be transferred to the Nessler tubes as soon as practicable. The solutions should, also, be well mixed immediately before the colorimetric comparisons, since there appears a tendence for the coloring matter to precipitate on standing.

The calculation to parts per million is made as usual and the results are expressed in terms of fluorine (F).

FOSTER METHOD[6]

The Foster method is, also, a colorimetric method. It is based on the fact that the intensity of the color produced with thiocynate by a given amount of iron in the presence of fluoride is less than that produced in the absence of fluoride by an amount depending on the quantity of fluoride present, if there is an excess of iron. By determining the excess of iron reacting with ammonium thiocynate, the quantity withdrawn by the fluoride from a given amount of iron may be found, and from this the amount of fluoride in the sample of water.

A colorimeter should be used in this method so good results will be obtained in a volume of about 75 c.c. 0.375 mg. of iron produces about as deep a color as can be read in a colorimeter on this amount of iron 0.25 mg. of fluoride produces a marked fading, and even as little as 0.025 mg. produces a fading that can be detected in a colorimeter.

The details of the procedure follow.

Neutralize the alkalinity of 50 c.c. of the sample of water contained in a comparison tube with 0.05 N nitric acid.

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[6]M. D. Foster. Colorimetric Determination of Fluorine in Waters. J. Ind. & Eng.Chem.Anal. Ed. 5:234-6 (1933)

Do not add an indicator but calculate from the alkalinity determination the amount of acid necessary to neutralize the volume of water used. If the alkalinity is high, use a stronger solution of nitric acid (0.02 N) in order to keep the volume of the neutralized sample within 60 c.c. Add 5 c.c. of ferric chloride solution (1 c.c. = 0.075 mg. of iron, with 30 c.c. of N. hydrochloric acid to a liter) plus the amount necessary to counteract the effect of the sulfate and chloride present and 10 c.c. of ammonium thiocynate (24 gms. in a liter). Make up the volume to about 75 c.c and mix well.

Compare in a colorimeter with a standard containing a known amount of iron (2 to 5 c.c. of ferric chloride solution the amount depending on the depth of color of the sample) and 10 c.c. of ammonium thiocynate solution in the same volume. Subtract the amount of iron found from 0.375 to get the amount withdrawn. It's equivalent in fluoride may be determined. The ammonium thiocynate should be added to the sample and the standard at the same time, and the comparison made immediately. The color of the standard should not be over 50 per cent greater or less than the color of the sample. If the color of the sample is too weak to be compared with a 2 c.c. sample - - that is, if the sample contains more than 0.40 mg. of fluoride - - a smaller sample should be taken.

The sample used for the determination should not contain more than 50 mg. of sulfate or 100 mg. of chloride. If it contains less than 2.5 mg. of sulfate and/or 5.0 mg. of chloride iron in excess of 0.375 mg. need not be added.

It is advisable that each analyst work out his own curves for fluoride, sulfate, and chloride. Sulfate produces a similar but very much smaller effect upon the red color than the fluoride does, but it is, also, quantative and a curve showing the effect of definite amounts of sulfate in terms of iron or fluorine may be made. Then for each sample, the effect of the sulfate present may be subtracted to obtain the true fluoride content. Chloride produces a slight fading, but for quantities below 500 parts per million, it is so small that it may be ignored. The effect of the sulfate and chloride is the same whether they are present as calcium, magnesium, or sodium salts.

WILLARD AND WINTER METHOD[7]

The Willard and Winter method of determining fluorides in water consists of titrating soluble fluoride and silico fluoride solutions with standard thorium nitrate, using a zirconium-alizarin mixture as indicator.

(1) Determination with no interfering elements present.

Any ion which forms a precipitate or a non-dissociated salt with fluorine, or with thorium, interferes with the titration. Such elements are Ca, Ba, Fe (ic), Al, and PO4.

The reagents used for determining fluorine in solution, when no interfering elements are present, are as follows: (1) zirconium nitrate, 1 gram of $Zr(NO3)_4SH_2O$ in 250 c.c. of water. (2) Alizarin red, 1 gram of sodium alizarin sulfonate in 100 c.c. of ethyl alcohol. Filter off the undissolved residue and add 150 c.c. of ethyl alcohol to the flitrate. The two solutions are kept in stock and mixed, three parts of (1) and two parts of (2) as needed. The color should be violet-red when mixed. (3) Thorium nitrate solution, standardized against a known fluoride solution.

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[7] H. H. Willard & B. O. Winter - Volumatric Determination for Fluorine. J. Ind. & Eng. Chem. Anal. Ed. 5:7-10, January 15, 1933.

(4) Standard fluoride solution, lithium fluoride, 0.02 N. solution or specially purified sodium fluoride of the desired concentration. (5) Hydrochloric acid, approximately 1 to 50.

Dissolve a weighed quantity of the fluoride in water and make up to a given volume. Transfer an aliquot of the solution to be analyzed to a small taltform beaker, add water to make a volume of approximately 20 c.c. and 3 drops of the zirconium-alizarin mixture. If necessary, add just enough dilute hydrochloric acid to destroy the color. Add an equal volume of neutral ethyl alcohol, and titrate over a white surface in good light with the standard thorium nitrate to a faint permanent reappearance of color. When titrating with 0.01 N. thorium nitrate, make a correction for the fluorine which combines with the indicator. Determine this by titrating the number of drops of indicator used in the titration with 0.01 N. fluoride solution to the disappearance of the color.

(11) Determination with interfering elements present.

When interfering elements are present in the soluble fluoride solutions, the fluorine must be separated from the other elements before the titrations can be made. This may be done by volatilizing it as hydrofluosilicic acid by simply adding perchloric or sulfuric acid (perchloric acid is preferable since nearly all of the perchlorates are very

soluble), water, and several pieces of glass to the sample in a distillation flask, and distilling. When only a small quantity of fluoride (10 mg. or less) is present in the sample, and the temperture is not allowed to rise above approximately 125° C., the pieces of glass appear to supply the silica necessary to combine with the fluorine to form hydrofluosilicic acid and there is no noticeable etching of the flask. If there is more fluorine present, or the temperature is allowed to rise higher, silica is taken from the flask, and etching is noticeable. In either case, however, the fluorine is recovered quantitatively.

Place the sample in a small distillation flask, and add a few glass beads or pieces of porous plate, 5 c.c. of 60 per cent perchloric acid and sufficient water to cause the solution to boil at 110° C or less. Place the flask on an asbestos mat with an opening large enough so that about one-third of the flask will be exposed to the flame. Close with a two-hole rubber stopper through which passes a thermometer and a capillary tube, both of which extend down into the liquid. Connect a dropping funnel with the capillary tube so that water may be added during the process of distillation and fill this with water. Connect the flask with a water condenser. The distillate may be collected in an open container. Distill until the boiling point of the solution reaches 135° C and hold at approximately that tempera-

ture by allowing water to run into the flask from the dropping funnel, until all of the fluorine is volatilized. This is usually accomplished by distilling over 50 to 75 c.c. Add 6 drops of the zirconium-alizarin mixture and dilute sodium hydroxide drop by drop until the color of the indicator appears. Add an equal volume of ethyl alcohol and then dilute acid until the color of the indicator just appears (at this point it is advisable to cause the color to appear and disappear two or three times to be sure to have the solution very slightly acid). Titrate with thorium nitrate as previously directed under the determination for soluble fluorides when no interfering elements are present.

FAIRCHILD METHOD[8]

The procedure of the method is as follows:

Pipet 100 c.c. of water into a 250 c.c. glass-stoppered Erlenmeyer flask, add 1 drop of methyl red, and 1.0 N. hydrochlorid acid dropwise until acid. Add 10 c.c. of 20 per cent sodium chloride solution. Filter, wash, and discard any precipitate. Add an excess of 0.08 M. ferric chloride over that required for completion of the reaction.

$$FeCl_3 + 3NaF = FeF_3 + 3NaCl$$

5 c.c. is the proper amount for fluorine content from 0.001 to 0.0100 gram. Add 2 c.c. of 1.0 N. hydrochloric acid and 10 c.c. of 5 per cent potassium iodide solution, and stopper the flask. Immerse it in a water bath at a temperature of $38 \pm 1^{\circ}$ C. and allow it to remain in the bath 30 minutes. Iodine is liberated by the ferric chloride in excess of that required to act with the fluorine present. Quickly cool the flask, and titrate the iodine with standard thiosulfate solution, using starch an an indicator. Simultaneously carry through a control sample with 100 c.c. of distilled water

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[8]Occurrence of Fluorides in Some Waters of United States, H. V. Churchill, J. Ind. & Eng. Chem. 23: 996-8, September, 1911.

and the qualities of reagents used in the analysis. The difference in thiosulfate consumption between the control and the sample represents the ferric chloride consumed in the reaction with fluoride. If the thiosulfate solution contains 4.354 grams of crystillized salt per liter, it will be equivalent to 0.001 gram fluorine per cubic centimeter.

If the fluoride content shown is very low, repeat the analysis using a larger sample. Evaporate this to 100 c.c. in platinum. Do not allow the solution to become strongly concentrated during evaporation, lest hydrofluoric acid be lost.

SUMMARY OF METHODS

The Fairchild Method gives results which average two to three times higher than the results by the other methods. By this method, the minimum concentration of fluroine in water which will cause mottled enamel is between 2.0 and 2.7 P.P.M. By the other methods (Sanchis, Foster, Willard, Winter, and Elvove) the minimum concentration is between 0.9 and 1.0 P.P.M.

The results obtained by the last named methods are in close agreement, and the Fairchild Method has fallen into disuse.

The Elvove Method has been accepted by the A.P.H.A. for their standard method, because of its flexibility in dealing with all types of water regardless of the sulfate or chloride content of the water being analyzed.

D A T A

FLUORIDE ANALYSIS

SANCHIS METHOD

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Rio Grande at Bernalillo	0.6	0.8	0.5	0.3	0.4	0.25	0.1	0.25	0.25
Rio Salado	2.0	1.9	3.0	1.6	2.1	0.5	0.2	0.3	1.0
Rio Guadalupe	0.5	0.7	0.6	0.3	0.3	0.15	0.1	0.4	0.4
Jemez below Soda Dam	1.0	1.0	0.9	0.7	0.4	0.25	0.4	0.7	0.7
San Antoine at Battleship Rock	0.9	1.05	1.1	0.6	0.3	0.3	0.3	0.7	0.7
East Fork Jemez at Battleship Rock	0.6	0.75	0.6	0.6	0.2	0.25	0.25	0.4	0.4
Rio Cebolla	0.5	0.55	-	-	-	-	0.2	0.35	-
Coyote Springs	1.4	1.3	1.2	1.2	1.4	1.2	1.2	1.3	1.2
Hubble Springs	0.9	0.8	0.6	0.65	0.8	0.7	0.7	0.7	0.65
Hell Canyon	0.3	0.4	0.3	0.2	0.4	0.3	0.25	0.4	0.3
Embudo Canyon	1.3	1.2	1.1	1.2	1.1	1.1	1.2	1.2	1.2
Bear Canyon	1.4	1.2	1.2	1.2	1.1	1.3	1.3	1.3	1.2
Tijeras Canyon above 7 springs	0.3	0.3	0.3	0.2	0.3	0.2	0.3	0.25	0.3
Cienega Canyon	0.2	0.35	0.3	0.2	0.0	0.1	0.1	0.2	0.0
Ellis Creek	0.1	0.05	0.2	-	0.0	0.0	0.05	0.15	0.1
City Well #1 soft	0.8	0.9	0.8	0.7	0.8	0.9	0.9	0.75	0.75
City Well #2 soft	0.75	0.8	0.8	0.7	0.8	0.9	0.85	0.8	0.75
City Well #3 soft	0.7	0.8	0.8	0.75	0.9	0.7	0.75	0.7	0.7
City Well #4 soft	0.6	0.5	0.6	0.5	0.6	0.6	0.6	0.6	0.6
City Well #3 hard	0.4	0.4	0.4	0.25	0.4	0.6	0.4	0.4	0.4
City Well #4 hard	0.5	0.4	0.5	0.3	0.4	0.65	0.5	0.5	0.5
Embudito Canyon	-	1.25	-	-	-	-	-	-	-
Pino Canyon	-	-	2.0	-	-	-	-	-	-
Jemez at San Ysidro	-	-	-	0.7	0.4	0.2	0.25	1.7	0.9
Jemez at pueblo	-	-	-	0.6	0.7	0.25	0.25	0.75	0.8
Jemez at Canon	-	-	-	0.6	0.3	0.15	0.25	0.8	0.75

SANCHIS METHOD - CONTINUED

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Jemez at Rio Guadalupe	-	-	-	0.4	0.3	0.1	0.25	0.6	0.8
Jemez 3 mi north of Rio Guadalupe	-	-	-	1.2	0.5	0.3	0.6	1.0	1.0
Jemez 3 mi below Jemez Springs	-	-	-	1.1	0.7	0.45	0.6	1.0	1.0
Jemez 2.4 mi above Soda Dam	-	-	-	0.6	0.4	0.3	0.4	0.7	0.75
San Antoino at La Cueva	-	-	-	0.6	0.4	0.25	0.4	0.7	0.8
San Antoino 6 mi above La Cueva	-	-	-	-	-	-	-	1.0	-
San Antoino hot spring	-	-	-	-	-	-	-	0.6	-
Spencer Spring on Rio Antoino	-	-	-	-	-	-	-	0.5	-

U. S. PUBLIC HEALTH SERVICE METHOD

Rio Guadalupe	-	-	-	-	-	-	0.1	0.4	0.5
Jemez below Soda Dam	-	-	-	-	-	-	0.4	0.7	0.8
San Antoino at Battleship Rock	-	-	-	-	-	-	0.3	0.8	0.8
East Fork Jemez at Battleship Rock	-	-	-	-	-	-	0.5	0.6	0.5
Rio Cebolla	-	-	-	-	-	-	-	0.35	-
Jemez at San Ysidro	-	-	-	-	-	-	0.35	1.9	1.0
Jemez at Pueblo	-	-	-	-	-	-	0.35	0.85	0.7
Jemez at Canon	-	-	-	-	-	-	0.4	0.9	0.8
Jemez at Guadalupe	-	-	-	-	-	-	0.2	0.5	0.8
Jemez 3 mi north of Rio Guadalupe	-	-	-	-	-	-	0.6	1.0	1.0
Jemez 3 mi below Jemez Springs	-	-	-	-	-	-	0.5	1.1	0.9
Jemez 2.4 mi above Soda Dam	-	-	-	-	-	-	0.45	0.8	0.75
San Antoino at La Cueva	-	-	-	-	-	-	0.4	0.7	0.9

MINERAL WATER ANALYSIS

A mineral water analysis was made on the samples that were collected in May. The analyses were made on the samples this month because the streams this month furnished a more representative sample than earlier, because of the high waters, or later in the summer when the streams were low.

The analyses were made in accordance with the standard methods of the American Public Health Association.

MINERAL WATER ANALYSIS

The analyses were made on the samples collected May 1936, except for samples 2a and 7a, which were run on samples collected in November, and were run by J. V. Stewart and Coy Ham, respectively, who are students at the University. The samples are listed as follows:

1. Rio Grande at Bernalillo
2. Rio Salado at San Ysidro
2a. Rio Salado at San Ysidro (Nov.)
3. Rio Guadalupe
4. Rio Jemez below Soda Dam
5. San Antoino at Battleship Rock
6. East Fork Jemez at Battleship Rock
7a. Rio Cebolla (Nov.)
8. Coyote Springs
9. Hubble Springs
10. Hell Canyon
11. Embudo Canyon
12. Bear Canyon
13. Tijeras Canyon above seven springs
14. Cienega Canyon
15. Ellis Creek
16. City Well #1 soft
17. City Well #2 soft
18. City Well #3 soft
19. City Well #4 soft
20. City Well #3 hard
21. City Well #4 hard
25. Jemez hot springs
26. Jemez at San Ysidro
27. Jemez at pueblo
28. Jemez at Canon
29. Jemez at Rio Guadalupe
30. Jemez 3 miles north of Rio Guadalupe
31. Jemez 3 miles below Jemez Springs
32. Jemez 2.4 miles above Soda Dam
33. San Antoino at La Cueva
36. Hot springs supplying Rio Salado

MINERAL

No.	T.S.	SiO_2	Fe_2O_3 Al_2O_3	Ca
1	179	28.9	3.0	20.1
2	250	20.0	0.9	31.0
2a	12,562	90.8	-	505.6
3	118	21.0	2.8	25.2
4	246	26.6	1.0	21.6
5	145	14.2	1.2	19.2
6	110	47.9	3.2	6.1
7a	96	-	1.0	15.7
8	1610	16.2	2.8	255.2
9	594	26.8	2.1	88.5
10	394	23.0	1.6	46.6
11	380	17.0	1.5	40.3
12	267	20.8	1.0	41.3
13	297	13.0	1.7	53.6
14	222	25.0	1.4	62.7
15	204	53.6	1.5	42.1
16	317	65.6	1.3	28.1
17	300	61.4	1.0	30.0
18	311	44.8	1.3	36.4
19	331	60.3	1.4	42.2
20	430	33.2	0.8	88.2
21	909	37.1	1.6	171.0
25	1,947	74.4	2.6	39.6
26	187	8.8	1.6	23.8
27	186	9.4	2.4	40.5
28	164	7.4	1.0	41.8
29	165	10.6	2.2	24.7
30	262	27.8	2.8	39.5
31	290	30.2	3.0	37.3
32	142	24.8	1.8	15.8
33	127	22.2	1.4	21.7
36	10,983	29.0	6.8	204.5

* Sodium and Potassium calculated as

WATER ANALYSIS

Mg	SO_4	Cl	CO_3	HCO_3	Na*
4.1	45.2	9.5	8.0	74.3	33.8
0.3	41.6	23.4	8.6	110.4	50.9
97.3	5280.0	3232.0	10.2	111.7	3905.0
3.1	22.9	4.5	2.0	109.3	23.7
4.6	42.6	46.4	0.0	123.4	69.1
4.4	33.7	2.5	0.0	69.0	14.5
0.5	11.8	2.8	0.0	55.2	21.0
1.0	9.8	7.6	0.0	49.7	8.7
54.0	114.8	388.1	0.0	1095.0	355.6
30.1	221.2	35.6	0.0	232.0	66.6
17.5	51.7	22.1	13.8	299.0	82.3
18.7	52.3	11.1	0.0	318.0	76.5
13.1	36.5	8.5	4.0	261.0	56.7
16.7	96.2	15.6	0.0	189.0	37.2
4.7	18.1	3.3	0.0	212.0	10.4
3.0	21.7	3.3	0.0	193.2	33.8
8.0	58.4	12.6	0.0	176.0	59.6
7.7	56.9	12.0	0.0	166.8	52.7
7.2	70.1	12.0	0.0	177.0	57.1
8.6	59.6	16.5	0.0	167.2	40.6
10.4	137.5	25.3	0.0	169.0	132.2
25.8	374.0	82.4	0.0	314.0	114.3
6.0	128.3	865.0	0.0	471.0	811.8
4.9	16.1	27.0	0.0	141.0	45.5
4.2	13.5	18.2	0.0	126.3	12.4
4.7	11.0	17.2	0.0	123.3	6.5
4.2	10.5	10.0	0.0	115.5	20.5
2.4	16.6	61.4	0.0	152.0	59.9
4.3	26.5	63.1	0.0	152.8	70.0
2.2	23.2	2.5	0.0	71.5	18.9
3.0	17.8	2.7	0.0	64.0	4.0
64.9	3878.0	3173.0	0.0	959.0	4268.0

Sodium

A COMPLETE BIBLIOGRAPHY OF MOTTLED ENAMEL

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AND

REMOVAL OF FLUORIDES FROM WATER

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