POTASH INVESTIGATIONS IN 1924

By WALTER B. LANG

INTRODUCTION

It is now more than 12 years since Dr. J. A. Udden, of the Texas Bureau of Economic Geology and Technology, first definitely proved the existence of potash in the Permian salt beds of western Texas, although there had been good reason to suspect, on the basis of stratigraphic comparison with the salt deposits of the Stassfurt area in Germany, that similar economic minerals might be found in this region. The discovery of potash in the Texas Permian resulted from the drilling of a deep test hole for water south of Spur, in Dickens County. An analysis of brines from a depth of 2,200 feet in this hole yielded 5.4 per cent of potassium, calculated as chloride, and thereby gave impetus to an investigation that has persisted to the present day. Potash has also been found in the Markham salt dome, near Markham, Tex., and in a well drilled in Grant County, Utah.

This investigation has been hampered through being dependent in the main upon indirect methods of attack. The evidence so far obtained, except that from the Markham dome, has come from a study of cuttings and sludges from wells drilled solely for the purpose of discovering or producing petroleum. Only four tests have been begun with the primary intention of exploring for potash. All four have failed either to penetrate the salts or to encounter showings of potash.

AIMS AND RESULTS

Field investigations during the year 1924 were pursued with two aims in view—to determine more carefully the geographic distribution of potash salts and to acquire more specific data regarding the character of the salts at the several potash horizons and relationships existing between them. As the accomplishment of both aims has been dependent upon the cooperation of the wildcatter or the finding of oil, it is evident that the results obtained are the product of chance opportunity. Nevertheless, some notable contributions have been made which, added to those of the past, serve to strengthen the convic-

tion that the presence of commercial beds of potash in Texas and possibly in Utah will be proved when suitable means are utilized to demonstrate the facts definitely. The most significant results for the year were obtained from the Cowden well, in Crane County, the Mid-Kansas Harris Bros. well, in Crockett County; the Texon No. 1 (Group I) well, in Reagan County; and the Gray No. 1 well, in Matagorda County, all in Texas; and the Crescent Eagle well, in Grant County, Utah. These wells are described below under their respective counties. Figure 7 shows the general location of the potash-bearing localities mentioned with respect to other sources of potash, and Plate 2 shows the location of potash-bearing wells in the Permian of western Texas. The accompanying table summarizes the data regarding the most important finds of potash in these wells.

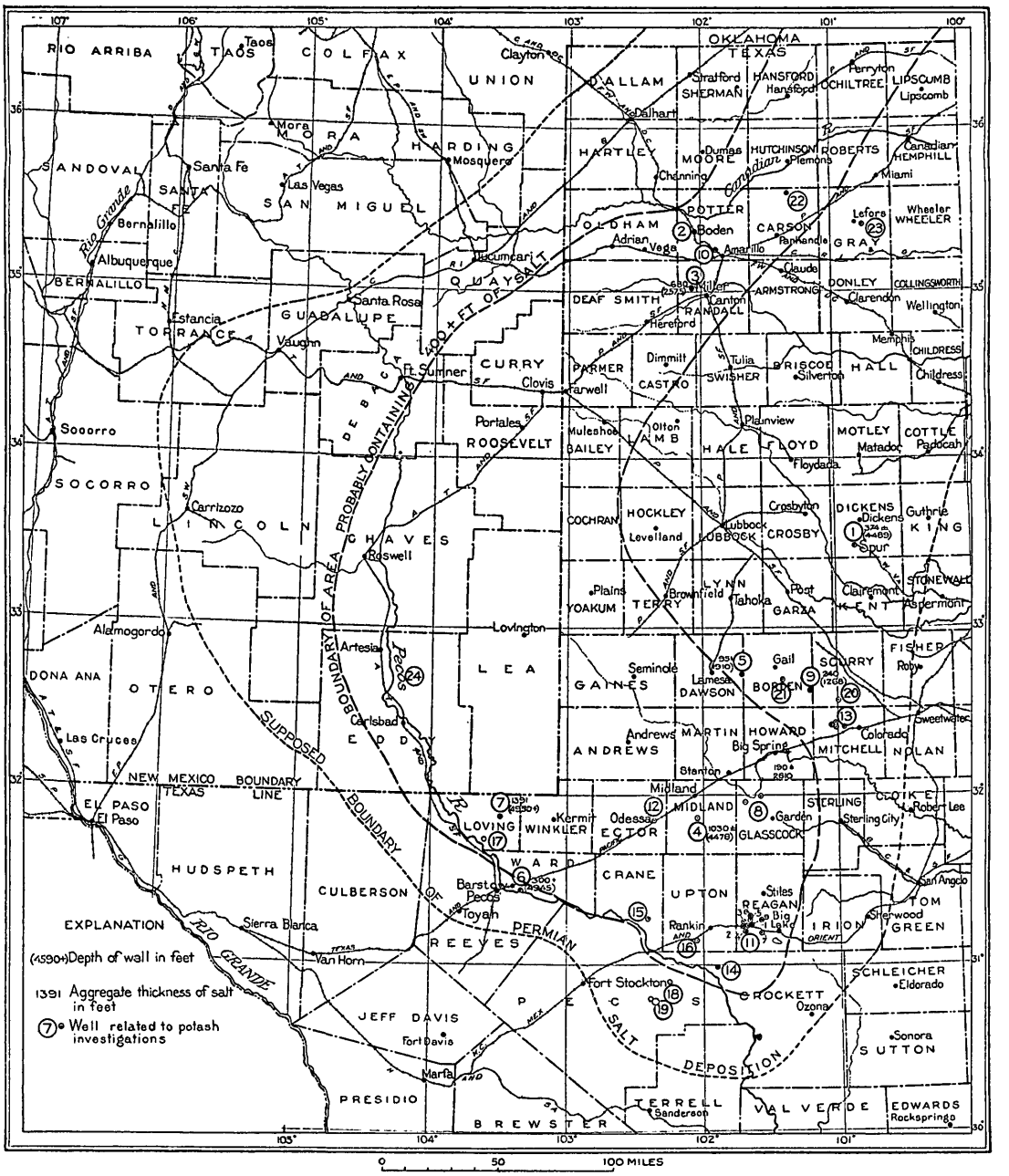
Counties in Texas in which potash has been found in the Permian beds and analyzed in the laboratory of the U. S. Geological Survey

County	Well [a]	Potash content	Year
Borden	G. A. Jones	22.9 per cent K in soluble salts	1922
Carson	S. B. Burnett No. 3, Texas Co.	Indications of less than 1½ per cent	1924
Crane	Cowden No. 1	7.4 per cent K_2O at 1,065–1,070 feet	1924
Crockett	Mid-Kansas Harris	8.92 per cent K_2O at 1,260–1,310 feet	1924
Dawson	Burns	15.2 per cent K_2O probably from 1,750 feet	1923
Dickens	Spur	5.4 per cent K calculated as chloride in brine at 2,200 feet.	1912
Glasscock	McDowell No. 4	7.5 per cent K_2O	1922
Gray	Saunders No. 1, Texas Co	Indications of low percentages	1924
Loving	Means	11.21 per cent K_2O at 995 feet	1922
Midland	Bryant	6 per cent K_2O at 2,410 feet	1921
Mitchell	Miller No. 2, California Co	4.24 per cent K_2O at 917–923 feet	1923
Potter	Boden	9.2 per cent in soluble salts at 875–925 feet	1915
Randall	Miller	10.5 per cent in soluble salts below 1,700 feet	1915
Reagan	Texon No. 3	9.75 per cent K_2O at 1,305–1,325 feet	1923
Scurry	Moore No. 1	0.71 per cent K_2O at 930–940 feet	1923
Ward	River	9.03 per cent K_2O at 1,600 feet	1921
Upton	Virginia-Texas	Estimated 10 per cent or more at 1,405 feet	1924
Reeves	Bell	Indications in brine analysis	1923
Pecos	Menzie-Transcontinental	7.83 per cent K_2O at 1,105–1,115 feet	1925

[a] In counties having more than one well with showings of potash the one with highest percentage has been selected for the table.

ACKNOWLEDGMENTS

Space will not permit acknowledgment in detail of the generous and courteous assistance extended to the writer in the field. Whatever may be the ultimate outcome of the Texas potash investigation, much credit is due to the drillers who have so heartily cooperated by furnishing information and samples within the time and means available to them. Specific credit should be given to Mr. L. W. Orynski, of the California Co.; Mr. Levi Smith, of the Big Lake Oil Co.; Mr. F. T. Pickrell and Mr. C. G. Cromwell, of the Texon Oil & Land Co.; Mr. S. F. Johnson, of the Texas Development Co.; Mr. R. F. Baker, of the Texas Co.; Mr. W. W. Lechner, of the Lou-Tex Corporation; and Mr. W. L. Karnes. Mr. Henry C. Allen, manager of the Crescent Eagle Oil Co., kindly granted permission to publish data relating to the company's well. The writer is also



MAP OF POTASH FIELD IN WESTERN TEXAS

No.	Well or field	County	No.	Well or field	County
	Texas			*Texas*—Continued	
1	Spur	Dickens.	15	Cowden	Crane.
2	Boden	Potter.	16	Virginia-Texas	Upton.
3	Miller	Randall.	17	Wheat	Loving.
4	Bryant	Midland.	18	Perry	Pecos.
5	Burns	Dawson.	19	Sherbino	Do.
6	River	Ward.	20	Moore and Wellborn	Scurry.
7	Means	Loving.	21	Parkhurst	Borden.
8	McDowell No. 4	Glasscock.	22	Burnett No. 3	Carson.
9	Jones	Borden.	23	Saunders No. 1	Gray.
10	Survey	Potter.		*New Mexico*	
11	Reagan County field [a]	Reagan.			
12	Newnham	Ector.	24	Artesia oil field	Eddy.
13	Mitchell County field	Mitchell.			
14	Harris	Crockett.			

[a] Small numbers indicate individual wells.

indebted to his colleagues of the Geological Survey, Mr. G. R. Mansfield, for cooperation and many helpful suggestions, and Mr. R. K. Bailey, for analyses of the samples.

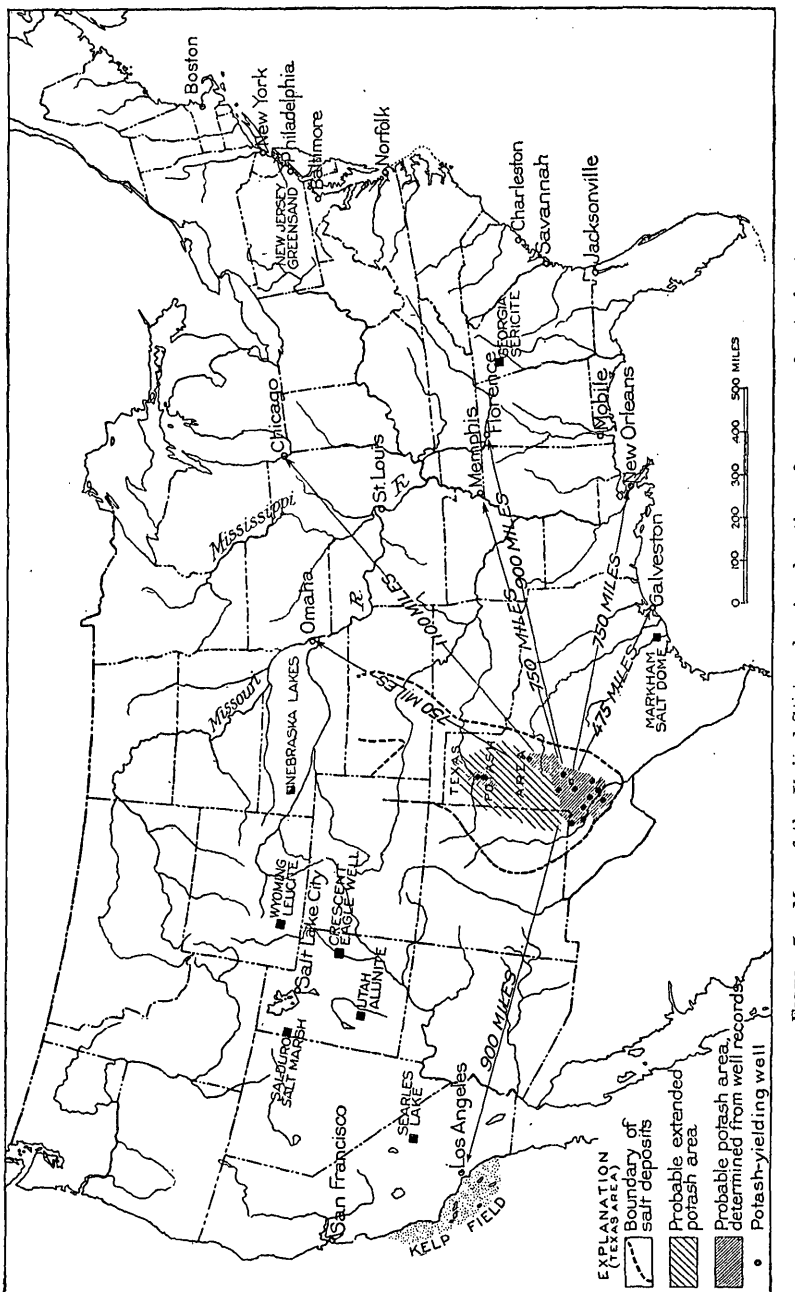


FIGURE 7.—Map of the United States showing location of sources of potash

TEXAS

Borden County.—A series of unwashed samples was obtained from the Reeves-Parkhurst well, in the SW. ¼ sec. 27, block 30, T. 4 N., Texas & Pacific survey, Borden County, Tex., from the surface down to 2,000 feet. Of these samples 43 from depths of 1,005 to 1,520 feet and two from depths of 1,695 to 1,705 feet and 1,775 to 1,790 feet have been analyzed, of which only three have shown more than 2 per cent of K_2O. These samples came from depths of 1,115 to 1,125, 1,140 to 1,150, and 1,310 to 1,320 feet. The richest sample, at 1,140 to 1,150 feet, carried 2.46 per cent of K_2O. The unwashed samples taken at 1,695 to 1,705 and 1,775 to 1,790 feet, after being treated to remove the red clay, showed good specimens of polyhalite and on analysis were found to contain 6.55 and 2.03 per cent of K_2O, indicating the presence of thin bands of this mineral at those depths intercalated between the beds of salt and red shale. It is possible that these showings may represent beds closely associated with those that yielded good samples from the G. A. Jones well, in Borden County, and the Burns well, in Dawson County.

Carson County.—A series of samples received from the Texas Co., from its S. B. Burnett No. 3 well, showed on a preliminary qualitative test no favorable indications of potash.

Crane County.—The most notable contribution during the year to our knowledge of the Texas potash beds has come from the Cowden No. 1 well, in southern Crane County, 22 miles by road from Girvin, on the Kansas City, Mexico & Orient Railroad, and 60 miles from Midland, on the Texas & Pacific Railroad. This well, though the second in the county to be drilled in the salt measures, is the first to afford any specific data on potash. In the spring of 1922 a well was drilled on the McKnight property, 4 miles south of Metz, to a depth of 1,003 feet and was reported to have entered the salts at 850 to 900 feet. No log was ever available, as strict secrecy was maintained during the progress of the work.

The Cowden No. 1 well has been sampled carefully from the top to a depth of 2,650 feet, and where the salt series was penetrated bailing was done every 5 feet, regardless of the favorable character of the formations for rapid drilling. The absence of water in or above the salts also made it possible to take a series of samples of bailing waters to support the analyses of the cuttings. The results of the investigation were announced in Press Notice 18209, which was accompanied by a diagram presenting a comparison of cuttings and water analyses. The conditions at the Cowden well were ideal for accurate sampling within the limits applied. A closer approach to the limits of accuracy for churn drilling might have been made by bailing the hole thoroughly every 2 feet.

Analyses of 233 cuttings made in the chemical laboratory of the Geological Survey represent samples from depths of 560 to 2,075 feet. The top of the salt appeared at 590 feet, and the first indication of an appreciable showing of potash (1.62 per cent K_2O) was found at 700 to 705 feet. Of the five major potash-bearing zones three are between depths of 890 and 1,075 feet, and the other two, which are much alike in mineralogic characteristics, lie between 1,405 and 1,465 feet. These lower strata show a higher percentage of associated anhydrite and may be inferred to be interbanded layers of halite, anhydrite, and polyhalite, the polyhalite probably becoming more persistent or thicker as the amount of potash shown by the analysis increases. A study of the samples and of the analyses demonstrates very definitely the gradually increasing concentration of potash salts in the ancient embayments and their sudden dilution by a refreshening of the evaporating waters. This sudden change is well illustrated by the samples obtained at depths of 1,400 and 1,405 feet. At 1,405 feet only 56.8 per cent of the salts were soluble, and the potash content of the sample was 5.39 per cent, whereas at 1,400 feet the solubility rose to 99.7 per cent and the potash content of the sample was reduced to 0.33 per cent. The 1,400-foot cutting is composed of almost pure halite (common salt). The three upper potash-rich zones appear to be more intimately associated with halite and to have been deposited as saline flats that at times approached a condition of complete absence of surface water.

Crockett County.—Western Crockett County has hitherto been unexplored by deep drilling, but the analyses of samples from two wells are now available from the laboratory of the Geological Survey, and the results indicate that the northwestern part of the county is likely to yield excellent showings of potash on further exploration. From the Mid-Kansas Harris Bros. No. 1 well 13 samples were obtained, and the analyses are given below.

Analyses of samples from Mid-Kansas Harris Bros. No. 1 well, Crockett County

Depth (feet)	Per cent of soluble salts in sample	Per cent of K_2O		Depth (feet)	Per cent of soluble salts in sample	Per cent of K_2O	
		In sample	In soluble salts			In sample	In soluble salts
1,000–1,050	3.30	0.12	3.65	1,350–1,390	56.80	8.35	14.70
1,050–1,100	12.50	.18	1.44	1,390	56.90	1.30	2.29
1,205–1,213	93.70	1.76	1.87	1,410–1,420	91.30	4.42	4.84
1,213–1,233	87.40	3.84	4.40	1,550	94.60	2.72	2.87
1,240–1,255	86.50	4.07	4.70	1,690–1,785	78.80	2.15	2.73
1,255–1,260	29.10	.70	2.40	1,785–1,830	64.80	2.20	3.40
1,260–1,310	65.20	8.92	13.70				

The samples from depths of 1,260 to 1,310 feet and 1,350 to 1,390 feet gave 8.92 and 8.35 per cent of K_2O, respectively. Not only

are the analyses high in potash, but the samples on examination suggest the presence of well-bedded deposits of polyhalite. This location appears promising and should receive careful attention by anyone seriously interested in commercial potash development. As will be noted the series is not continuous, and each sample represents a long interval, making it impossible to assign proper value to the results. On questioning the driller it was learned that the samples do not represent any particular bailing, but each is a random sample supposed to represent many bailings over the interval recorded. For example, all bailings between 1,260 and 1,310 feet were considered by the driller to be the equivalent in type to the one which he saved. Although such a conclusion is quite untenable and contrary to what has been found in the past, where bailing samples at closer intervals have been available for examination, the analyses are nevertheless of value as important indicators.

The conditions above outlined afford an excellent example of the necessity for core drilling, or at least in standardized wells for careful drilling and close sampling at the rig.

Twenty-two salt samples from depths of 1,159 to 1,625 feet in the Levi Smith et al. well gave on analysis in the laboratory of the Geological Survey fair indications of potash throughout the series. The samples between 1,230 and 1,250 feet and between 1,290 and 1,320 feet showed more than the average content. The richest sample came from a depth of 1,250 feet and contained 3.81 per cent of K_2O. The sample taken at 1,310 feet contained 2.88 per cent of K_2O.

Gray County.—Of 137 samples analyzed qualitatively from the Saunders No. 1 well of the Texas Co., in the southeast corner of sec. 3, block B–1, Gray County, representing a range in depth from 600 to 1,435 feet, only 17 gave indications of as much as 1 per cent of potash, and none showed unmistakable evidence of the presence of polyhalite crystals.

Matagorda County.—A sample of salt taken in coring the Gray No. 1 well of the Rycade Oil Corporation on the Markham salt dome, near Markham, showed on analysis in the laboratory of the Geological Survey 15 per cent of K_2O. The sample was obtained at a depth of 4,800 feet on the flank of the dome. The salts are a mixture of coarse crystals of white and salmon-pink color, high in chlorides and low in sulphates, with a total solubility of 97.7 per cent. The specimen is a mixture of sylvite and halite crystals.

This discovery is the first indication of potash in the salt domes of the Gulf coast and should serve to stimulate further investigation of the salts. The presence of fossil algae is evidence of the sedimentary origin of the salts, and it is hoped that potash may be en-

countered at shallower depths on the domes. A depth of 4,800 feet is likely to be unfavorable, if not prohibitive, for economic mining, though the fact that these salts are chlorides suggests the method of of solution and the application of the air lift for extraction.

Mitchell County.—There are now in Mitchell County more than 40 producing oil wells, besides many new additions on the north side of the present field. Although samples have been obtained from many of the wells, some of which have been continuous sets through the salts, only scanty indications of potash have resulted from the analyses. The best sample so far analyzed in the laboratory of the Geological Survey came from the Miller No. 2 well of the California Co., at a depth of 917 to 923 feet, and showed 4.24 per cent of K_2O. It is not to be inferred from the results so far obtained that all Mitchell County is to be classed as unfavorable territory. They suggest, however, that the oil field of this county is on the eastern border of the potash-rich salts.

Reagan County.—Reagan County continues to serve as the chief source of potash information, as a result of the development of a producing oil field in an area underlain by good showings of potash. A relatively sharp fold in the "sands" producing oil at 3,000 feet is also suggested by the potash-bearing salt beds. Between the discovery well (Santa Rita No. 1) and the No. 9 Santa Rita well there is a rise in these beds of 160 feet to the mile, as shown by the position of the top of the salts. This is the first known apparent flexure in the salt beds.

Analyses now available from new wells give further assurance of the lateral persistence of the potash beds and have also exposed a new and deeper horizon of promising character. A sample from the No. 7 Santa Rita well at 1,725 to 1,735 feet gave an analysis 8.05 per cent of K_2O. A sample at 1,650 to 1,660 feet in the Texon No. 1 (Group I) well, 2 miles east of the No. 7, showed 7.8 per cent of K_2O. From a comparison of the character of the samples and of the altitude of the wells it is believed that these two samples represent contemporaneous deposition. If the conditions of drilling and sampling at the wells in this field could be made the same, reliable deductions as to the richness and continuity of the beds might be possible. For the present such determinations in detail are hazardous.

Four samples from a series of 30, taken at depths ranging from 1,225 to 1,676 feet in the Santa Rita No. 9 well and analyzed in the laboratory of the Geological Survey, contained more than 5 per cent of K_2O, the highest, in the sample from 1,276 to 1,295 feet, being 5.85 per cent. This well is also of interest as having made an initial production of 58 barrels of oil an hour, which, combined with 125

barrels an hour from the Santa Rita No. 11, stimulated an intensive campaign of drilling that is still in progress. Santa Rita No. 10 well was drilled with rotary equipment, and 11 widely spaced samples from this well, at depths of 1,447 to 2,060 feet, have been analyzed. The sample taken at 1,467 to 1,487 feet was the richest, containing 2.54 per cent of K_2O. Out of a series of 31 samples from the Santa Rita No. 11 well, from 1,080 to 1,490 feet, only two showed on analysis a potash content above 1.5 per cent. The sample from 1,210 to 1,220 feet showed 2.10 per cent, and the sample from 1,470 to 1,490 feet gave the high content of 8.82 per cent. Qualitative tests of unwashed samples from the Brandon-McCamey well, in sec. 27, block 2, 4 miles north of the Santa Rita No. 1 well, gave no indications of potash amounting to more than 1.5 per cent, but samples from depths of less than 1,300 feet were not obtainable.

The analyses of samples from the Mid-Kansas McIntosh well No. 1, in sec. 1228, serve as an indication of the run of potash to the north.

Analyses of samples from Mid-Kansas McIntosh well No. 1, Reagan County

Depth (feet)	Per cent of soluble salts in sample	Per cent of K_2O		Depth (feet)	Per cent of soluble salts in sample	Per cent of K_2O	
		In sample	In soluble salts			In sample	In soluble salts
1,189–1,195	18.40	3.09	16.80	1,290–1,360	55.60	1.26	2.26
1,195–1,200	32.20	1.16	3.60	1,360–1,400	81.40	2.62	3.22
1,210–1,215	87.80	.48	.55	1,400–1,520	96.60	2.51	2.60
1,215–1,225	90.30	.97	1.07	1,520–1,590	96.30	1.55	1.61
1,250–1,290	75.70	2.60	3.43	1,590–1,725	91.30	2.41	2.64

Although the series is continuous, some samples represent intervals as great as 70 to 120 feet, and the results are therefore of questionable value.

The Texon No. 1 (Group II) well, in sec. 22, block 9, is of interest as being the deepest hole in Texas, having been drilled to a depth of 6,005 feet without encountering showings of oil. Of the 17 samples from depths of 1,220 to 1,640 feet, analyzed in the laboratory of the Geological Survey, only two, taken at 1,230 and 1,430 feet, ran as high as 2 per cent of K_2O. Each sample represented a 10-foot interval. Analyses of a series of bailing-water samples substantiate the corresponding analyses from cuttings in the well.

The best series of analyses obtained during the year came from the Texon No. 1 (Group I) well, in sec. 1, block 8, and is presented in the table below.

Analyses of samples from Texon No. 1 (Group I) well, Reagan County

Depth (feet)	Per cent of soluble salts in sample	Per cent of K_2O		Depth (feet)	Per cent of soluble salts in sample	Per cent of K_2O	
		In sample	In soluble salts			In sample	In soluble salts
1,220–1,230	94.00	1.58	1.68	1,455–1,465	76.20	0.22	0.29
1,230–1,240	94.00	1.35	1.43	1,465–1,475	93.30	.27	.29
1,240–1,250	95.60	.71	.74	1,475–1,485	89.60	1.23	1.37
1,250–1,260	82.70	.92	1.11	1,485–1,500	90.70	2.24	2.47
1,260–1,270	66.90	.49	.73	1,500–1,520	91.30	.69	.75
1,270–1,280	78.70	.34	.43	1,520–1,530	82.00	2.65	3.23
1,280–1,290	90.10	1.13	1.25	1,530–1,550	50.50	2.61	5.17
1,290–1,300	89.70	.54	.60	1,550–1,570	77.80	.85	1.09
1,300–1,310	82.00	.41	.50	1,570–1,580	72.50	3.32	4.58
1,310–1,320	93.30	.78	.83	1,580–1,600	82.80	4.46	5.38
1,320–1,330	93.60	.87	.93	1,600–1,615	92.70	.24	.26
1,330–1,340	90.80	.98	1.08	1,615–1,625	17.00	.13	.76
1,340–1,350	82.20	6.41	7.80	1,625–1,630	16.90	.08	.47
1,350–1,360	85.60	.95	1.11	1,630–1,640	16.30	.46	2.82
1,360–1,370	97.10	.66	.68	1,640–1,650	84.00	.28	.33
1,370–1,380	93.50	4.40	4.72	1,650–1,660	84.70	7.80	9.21
1,380–1,390	96.50	.65	.67	1,660–1,670	96.90	2.10	2.17
1,390–1,405	94.50	1.28	1.35	1,670–1,680	80.70	.96	1.19
1,405–1,415	59.70	9.56	16.03	1,680–1,690	95.20	2.20	2.31
1,415–1,425	81.80	2.65	3.24	1,720–1,730	71.50	2.60	3.64
1,425–1,435	92.10	.41	.44	1,730–1,740	78.00	2.30	2.95
1,435–1,445	90.10	.30	.33	1,740–1,750	67.80	.77	1.13
1,445–1,455	94.80	.92	.97				

Fifty-three samples were received and analyzed. The last eight are omitted from the table because they contain less than 0.5 per cent K_2O. Of the 53 samples analyzed 15 ran over 1.5 per cent of K_2O, 6 over 3 per cent, and 3 over 5 per cent. The highest analysis, 9.56 per cent of K_2O in the sample, equivalent to 16.03 per cent of K_2O in the soluble salts, represented a sample taken between depths of 1,405 and 1,415 feet.

Scurry County.—An excellent series of 75 samples from depths of 600 to 1,495 feet in the Humphreys Wellborn No. 1 well, in sec. 102, block 97, Houston & Texas Central Railroad survey, Scurry County, was furnished to the Geological Survey by Mr. W. W. Lechner, in charge of drilling operations. All the samples on analysis in the laboratory showed negligible percentages of potash, as did also samples from the Moore No. 1 well, over a mile to the northeast. The best sample from the Wellborn No. 1 well came from a depth of 1,040 to 1,045 feet, and contained 0.52 per cent of K_2O, equivalent to 0.73 per cent of K_2O in the soluble salts. Samples taken at 820, 1,280, and 1,290 feet gave slightly more than 1 per cent of K_2O in the soluble salts, owing to the low solubility of the material. Higher percentages of potash may be found in samples from wells drilled farther west in this county, but it is unlikely that deposits of comparable thickness or quality are to be found to the east or northeast.

Influences affecting further investigation.—The discovery of potash in the Cowden well, in Crane County, has served to strengthen a former conviction that to the east, in a belt roughly parallel to

Pecos River, thick deposits of salt would be found with good showings of potash. This well serves to add another link to a chain of evidence that the region extending in a southeasterly direction from Lea County, N. Mex., to western Crockett County, Tex., is likely to prove the most favorable area for potash exploration. The character of the cuttings and the analyses of the salts in the Means well, in Loving County, the River well, in Ward County, the Cowden well, in Crane County, the recent Virginia-Texas well, in Upton County, and the Mid-Kansas Harris Bros. well, in Crockett County, all show that this extensive area is underlain by many potash-rich beds. It is hoped that in the near future more wells will be drilled in this general region and that the operating companies will find it to their interest to sample carefully when drilling through the salts.

From information now available from wells in the Reagan County field it appears that the best showings of potash will be found in the immediate vicinity of Texon and to the west and southwest. In case core drilling is contemplated a location should be selected near wells which under close sampling showed high percentages at different horizons. Analyses of samples now available from territory north of the Reagan County field suggest a thinning of the deposits of potash in that general direction.

KANSAS

A sample submitted for analysis from the Wood Oil Co.'s Ransom No. 1 well, in sec. 5, T. 26 S., R. 41 W., Hamilton County, Kans., showed less than 0.5 per cent of K_2O.

UTAH

The Crescent Eagle well, which is being drilled for oil 7 miles west of Thompsons, Grant County, Utah, on the Denver & Rio Grande Western Railroad, is reported to have encountered at a depth of 3,150 feet a white, fine, even-grained salt very similar to sugar in appearance. A sample of this salt, when analyzed in the laboratory of the Geological Survey, proved to be a hydrous chloride of magnesium and potassium. From a comparison of the chemical and optical characteristics of the salt it is believed to be carnallite.

Analysis of salt from Crescent Eagle well and the theoretical composition of carnallite

	Salt	Carnallite
Mg	8.8	8.7
K	13.9	14.1
H_2O	39.6	39.0
Cl [a]	37.7	38.2
	100.0	100.0

[a] Cl determined by difference, including traces of sodium, calcium, and sulphate.

The following optical data were obtained:

Optical features of salt from Crescent Eagle well and carnallite

	Salt	Carnallite
Optical activity	+	+
α index	1.46	1.466
γ index	1.48	1.494
β index	Not determined	1.475
Axial angle	Between 70° and 80°	70°

This salt is tentatively believed to be in the McElmo formation. A second deposit of salts was found at 3,910 to 3,917 feet, apparently identical in physical characteristics with the first. A sample of this salt was dried on the steam bath in the chemical laboratory of the Geological Survey and probably lost some of its water of hydration. Upon analysis, however, it was found to contain 49.05 per cent of K_2O in the sample and 49.90 per cent K_2O in the soluble salts, the percentage of soluble salts in the sample was 98.30. This high percentage of K_2O appears to indicate a mixture of carnallite and sylvite (KCl). No sulphate is present. Although the well was not cased below the upper salt, the difference in composition above noted indicates that the sample from the 3,910-foot level represents in fact a separate bed and not cavings from the upper bed, though some material from above may have mingled with the sample from the lower bed.

At the lower bed brine flowing 4 gallons a minute was encountered. Upon analysis this brine was found to contain 43.72 grams of soluble salts to 100 cubic centimeters. The potash content of the brine was 3.16 grams of K_2O to 100 cubic centimeters, or 7.22 per cent in the soluble salts. The brine is high in calcium and magnesium and is essentially a calcium-magnesium chloride brine.

White and brown salty materials reported to come from an intermediate depth, 3,625 feet, were also analyzed in the laboratory of the Geological Survey, but these proved to contain less than 1 per cent of K_2O in the soluble salts.

If the carnallite salts are bedded deposits of sedimentary origin, it is hoped that other wells now being drilled in the immediate vicinity may record their presence. This region is known to be faulted, and it is possible that the carnallite may be a secondary deposit formed by concentration along the faults. It is essential, therefore, that more definite geologic information be obtained before any economic significance may be attributed to the discovery.

The well is 19 miles from the nearest water, and a lift of more than 500 feet will be necessary for pumping.

SUGGESTIONS FOR DRILLING AND MINING

Drilling.—The conditions cited for the Mid-Kansas well on page 34 illustrate how a method that is advantageous in drilling for oil may not be applicable to potash. It is customary in contract drilling to take advantage of the facility with which the salts are penetrated by slipping the cable often many times the length of a screw before bailing out the hole. The analyses of samples taken under such circumstances, though of value in a general way, do not afford the more specific and accurate data that are essential to the solution of the problem whether or not the potash beds are commercial.

It is essential for accurate correlation of data that the conditions of drilling be maintained as nearly constant as possible. Changes in the rate of drilling, the penetration of water sands, introducing small but often unknown flows of water, the ineffectual shutting off of water by improper setting of the casing, and many other conditions encountered in the customary wildcat drilling practice make it difficult to obtain reliable material for analysis and comparison.

Salt samples taken from the bailer should never be washed longer than is absolutely necessary to remove the excess of fine sludge, and the cuttings should then be immediately spread out upon a board to dry. Under no circumstances should hot water be used to wash the bailings.

Where a core-drill test for potash is desired on a new location, greater speed and economy would result by churn drilling with a portable rig the formations overlying the salt beds. After reaching the top salts, which may lie anywhere from 600 to 1,200 feet below the surface, depending upon the location, the diamond-drilling machinery may be moved into position to core the salt beds, a saturated brine solution being used for drilling water to prevent loss of core.

The Germans have used in the exploration of their potash deposits a 30 per cent solution of magnesium chloride. In view of the fact that no potash-bearing mineral other than polyhalite has been found in the Texas Permian and that this mineral is relatively low in solubility, it is not believed that the use of a magnesium-chloride drilling solution in this region would prove of sufficient advantage over a saturated solution of sodium chloride to warrant the additional expense. Where the potash-bearing salts are highly soluble chlorides the magnesium-chloride drilling solution is desirable.

As previous analyses have shown that the top salts are low in potash, drilling by churn drill may be continued until the first indication of salt is encountered. The unconsolidated Permian and Triassic "red beds" overlying the salts offer greater difficulties to diamond drilling than to churn drilling. It is believed that this method would effect a sufficient saving in time and expense to more

than compensate for the necessity for a dual equipment, especially where more than one core test is to be made.

The Geological Survey has repeatedly emphasized in press bulletins and other publications the necessity for core drilling to determine the exact relationships and thicknesses existing in the potash-bearing members. Up to the present time three attempts have been started with core drills and one investigation was made with the churn drill by the Geological Survey. All these tests have so far failed to yield results, either because of financial difficulties that prevented the test being carried to and through the salts, or because sites were chosen that failed to give potash showings.

These failures to locate potash salts, one in New Mexico east of Carlsbad, the other by the Geological Survey at Cliffside in Potter County, Tex., were made in 1917, when knowledge of the distribution of potash in this region was very meager. Since then four oil fields have been developed within the limits of the salt area, and, besides their own contributions, they have stimulated wildcatting over much territory that has furnished and will continue to furnish interesting data on the distribution and percentage of potash in well cuttings. As a result of what is now known of the potash field, sites may be chosen which, if tested by core drilling, should yield positive results. It is advisable to choose initial locations for diamond or core drilling as near as possible to wells that have already shown favorable indications of potash. In the Reagan County oil field, where an opportunity was afforded to obtain samples from many wells ranging from 800 to 2,000 feet or more apart, it is evident that although the potash beds extend laterally their richness and apparent thickness can not be depended upon to remain constant.

Excellent opportunities await the investigator who is interested in the development of potash in western Texas to test old wells at a nominal cost and with a reasonable assurance of success. A few wells that have yielded good showings of potash still remain open—that is, they have not been plugged and abandoned. In case it is intended later to carry the well deeper to test for oil, the hole may be bridged 50 feet above the top of the deepest bed showing a high percentage of potash. A section of diamond-drill casing is welded into an old bailer of the size of the hole at the point to be tested, with one end set flush on the outer rim at the base and the other end secured at the top, slightly offsetting the center on the opposite side, so that a small angle is made between the drill casing and the axis of the hole. The bailer, connected to a string of drill casing, is lowered into the well and cemented in place to prevent loss of drilling water and rotation or change of position after drilling has commenced. A diamond core bit, lowered on the rods, will be deflected at a low angle of di-

vergence from the vertical into fresh ground. As the salt beds are easy to cut, the diamond drill may be relied upon to maintain a true course. (See fig. 8.) Where many favorable showings are present at different horizons successive coring may be done by beginning at the lower showing and working back up the hole, bridging or plugging back as the situation may require. Not only uncompleted wells that have been standing idle but also those which have failed to produce oil but have shown good analyses of potash may be critically examined before they are abandoned. By this method valuable preliminary information, possibly sufficient to solve, at least in part, the problem now at hand, would be obtained at a very small cost.

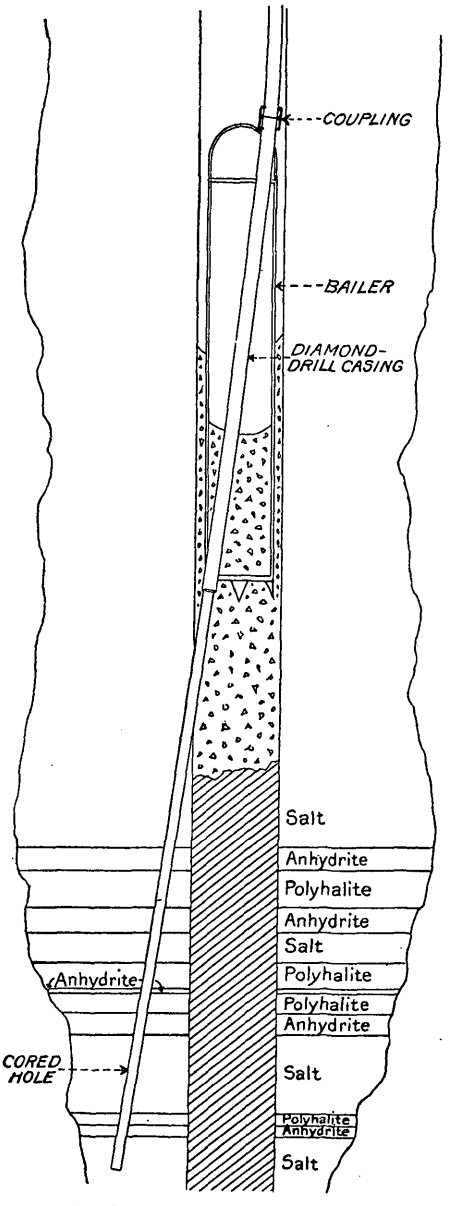


FIGURE 8.—Sketch showing method of coring a well for selected beds

Mining.—There is little reason to believe that the geologic conditions in the potash area of western Texas offer difficult problems to the mining of the potash salts. So far as known at present mining will be necessary to extract the potash, as the mineral polyhalite, which carries the potash, is relatively insoluble in comparison with the associated halite. To apply a method such as the Frasch process, now employed to produce sulphur on the Gulf coast of Texas, would result in leaving behind in the ground the polyhalite plus the anhydrite. Unless the injected water were permitted to remain in contact with the salts for a considerable period of time the brine pumped out would contain a concentrated solution of sodium chloride and calcium sulphate with a much lower percentage of mag-

nesium and potassium sulphate. Owing to the relatively low percentage of potash recovered by this method the cost of concentration would probably be prohibitive.

The areas of thick deposits of salt with which the best potash beds are associated may be assumed to be free from water. At first there was reason to suspect that a flow of water might be encountered on the top of the salts, as had been reported by some well drillers. These reports were later determined to be in error, the water being due to failure to effect a proper shut-off at a higher level. In areas where a considerable amount of drilling for oil has been done pulling of the outer strings of casing after production is established may result in an introduction of water to the salt beds. It is essential in localities such as the Reagan County field, where a heavy drilling program has followed commercial production of oil at 3,000 feet below the surface and good showings of potash have been penetrated in a variable range between 1,150 and 1,750 feet, to use every precaution to keep water from contact with the salt measures. Although the presence of water in the salts will not necessarily prohibit the mining of the potash, it may introduce difficulties and increased costs of mining that would eliminate that particular area on a competitive basis.

Temperatures taken in deep wells in the potash area indicate that a normal gradient may be expected. At 1,500 feet below the surface the temperature is 81° F., which is within the limits of congenial conditions for mining. Mining at great depth usually involves high temperatures, which in conjunction with a high humidity produce an environment very deleterious to the miner. In both of the foreign fields from which we import our potash mining methods are applied to obtain the salts. In Germany it is necessary to mine at depths between 3,500 and 5,000 feet; in the Oligocene deposits of Alsace the sylvite and halite salts are found on the average at 1,700 to 2,200 feet. In both fields deeper mining is necessary than would be required in western Texas, where showings that may reasonably be expected to prove commercial have now been located at as shallow a depth as 900 feet, and the maximum depth for showings likely to prove of value appears to be 1,800 feet.

If, as noted on page 33, the upper polyhalite beds of the Cowden well, in Crane County, Tex., are intimately associated with halite, concentration of the polyhalite after mining may be readily effected by dissolving out the halite, which is highly soluble in comparison to the polyhalite. If the beds of polyhalite at 1,400 feet and lower are too finely banded with anhydrite, which make selection in the mine difficult or impossible, the upper zones may prove the more valuable. Their favorable composition, combined with their relatively shallow depth, places them in favorable comparison from the miner's standpoint with the deposits of Stassfurt and Alsace.