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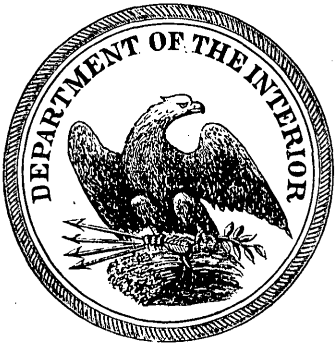

WASHINGTON
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1890

UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

REPORT OF WORK DONE

IN THE

DIVISION OF CHEMISTRY AND PHYSICS

MAINLY DURING THE

FISCAL YEAR 1887-'88

F. W. CLARKE, Chief Chemist

WASHINGTON
GOVERNMENT PRINTING OFFICE
1890

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PREFACE.

The present bulletin, like its predecessors numbered 9, 27, 42, and 55, contains the results of work completed in the Division of Chemistry and Physics during one fiscal year. Part of the investigations reported were begun in previous years; and other researches which are now under way are reserved for future publication. Still other work has appeared, or will appear, in separate bulletins; so that this issue represents only a part of the results obtained during the year which it covers.

F. W. Clarke,
Chief Chemist.

WORK DONE IN THE DIVISION OF CHEMISTRY AND PHYSICS IN 1887-'88.

THE CHEMICAL STRUCTURE OF THE NATURAL SILICATES.

BY F. W. CLARKE.

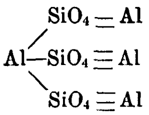
In any attempt to discuss the chemical structure of the inorganic silicates we are met at the outset by difficulties which are partly real and partly imaginary. On the one hand we have to deal entirely with non-volatile solids, of which, because of their fixedness, we can not certainly ascertain the true molecular weights. They are, furthermore, insoluble and, chemically speaking, non-plastic; that is, they yield but stubbornly to reagents, so that the changes of which they are structurally capable can rarely be studied in the laboratory. These difficulties are very real. On the other hand, most of the definite silicates are natural minerals, and as such are commonly supposed to have a bewildering complexity of constitution. This difficulty is only apparent, not real, and is due to several causes. First, few mineral species occur in a state of even approximate chemical purity; and secondly, many of them, being isomorphous, crystallize together to form seemingly homogeneous bodies to which rational formulæ can hardly be assigned. Impurities, indefinite crystalline mixtures, and defective analyses account for many apparent complications. Eliminate from any group of natural silicates these disturbing conditions, and we shall find in every case a simplicity of composition far removed from the complexity which is popularly assumed. Even on theoretical grounds we should expect simplicity of structure. The mineral silicates are, as a rule, exceedingly stable compounds, while complex molecules are relatively unstable. They are formed in nature under conditions of high temperature, or are deposited from solutions in which many reactions are simultaneously possible; circumstances that are strongly adverse to any great complications of structure. Finally, they are quite limited in number, only a few hundred at most being known; whereas, if complexity were the rule among them, slight variations in origin would produce great variations in character and millions of different minerals would be generated. That few substitutions occur is presumptive evidence that only few are possible, and hence simplicity of constitution is to be inferred. In fact, we find the same small range of mineral species occurring under the same associations in thousands of widely separated localities, a few typical forms containing a few of the commonest metals being almost universally distributed. The longer the evidence is considered the more overwhelming the argument for simple silicate structures becomes.

Suppose now that for any given silicate the empirical composition has been ascertained, how can its chemical structure be determined? We can not measure its vapor density and so deduce its molecular weight; but the problem is not therefore necessarily hopeless. Several lines of available evidence are open. In some cases the compound may be synthetically reproduced in the laboratory, a kind of mineralogical investigation in which rapid progress is now being made. Again, the constant association of the species with certain others sheds light upon its genesis, and still oftener its alterations in nature furnish important details. An alteration product, despised by the crystallographer, is really a record of chemical change, and such products may be of the highest scientific interest. In a few researches they have been produced artificially by reactions which were prolonged for months at a time, and so a mass of evidence is slowly accumulating, strictly analogous in kind to that which the organic chemist chiefly depends upon for ascertaining the structure of a hydrocarbon. All these lines of evidence are legitimate, and all converge towards truly scientific conclusions. We know that certain silicates originated together, and that each alters in certain definite ways; and from these facts we may draw perfectly fair inferences as to chemical structure and deduce rational formulæ which shall give fuller expression to our knowledge. The evidence for such formulæ is less perfect than that at the command of the carbon chemist, but it is none the less substantial so far as it goes. It is, furthermore, cumulative.

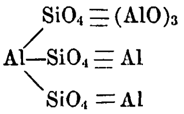
About three years ago, while I was working tentatively at the problem now under discussion, I received for examination certain specimens of topaz which were deeply altered upon their surfaces. Upon investigation the alteration product proved to be a variety of muscovite, and a study of the empirical formulæ of the two minerals revealed an unexpected relation between them. Further study brought out more extended relations connecting them with several other silicates, and by a natural series of steps I was led to adopt as a working hypothesis the supposition that double salts might be regarded as substitution derivatives of normal salts. This hypothesis, since then steadily applied to the discussion of the silicates, appears to be supported by a weighty mass of evidence, and it leads to the development of a series of structural formulæ which satisfy many conditions. They express and interpret known relations, lead to the detection of others, and point out suggestive and profitable lines of research. By these tests any hypothesis must stand or fall, and one which, meeting them successfully, has at the same time philosophical significance, may be fairly looked upon as valid.

That the great majority of the natural silicates are double salts need hardly be stated, and that a very great number of them contain aluminum is also a commonplace of chemistry. Of the latter some are orthosilicates, and some are meta-compounds; and the problem is to show how each series may be derived from its corresponding normal salt. As the orthosilicates are the most important, we may begin with their consideration. They represent the maximum of complication and offer the greatest difficulties.

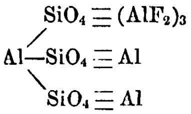
Fortunately, the orthosilicate of aluminum $Al_4(SiO_4)_3$, occurs in nature as the mineral xenolite. This species, which is now well established, was long thought to be an impure variety of fibrolite, Al_2SiO_5; and in their optical properties the two are apparently identical. Fibrolite bears the closest of relations to its isomer, andalusite; and to the latter, topaz, $Al_2SiO_4F_2$, is crystallographically akin. Topaz, as I have already stated, alters into muscovite, $Al_3KH_2(SiO_4)_3$; and so also does eucryptite, $AlLiSiO_4$. To these compounds we may add paragonite, which is merely a sodium mica, and we have at least six silicates, including the normal salt, which are all evidently related to each other. That their empirical formulæ show little or no connection is due to the fact that they do not represent true molecular weights, and on this point our fundamental hypothesis gives us a key to the problem. If we triple the formulæ given for fibrolite, topaz, and eucryptite, the substitution theory which I have suggested at once becomes applicable, and the derivation of all the others from xenolite is easy. The following structures will make this conception clear:



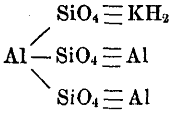
Xenolite.



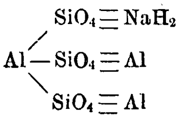
Fibrolite.



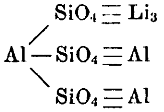
Topaz.



Muscovite.



Paragonite.

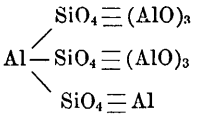


Eucryptite.

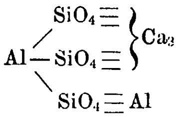
In the second of these formulæ the univalent group — $Al = O$ is assumed, and in the third we have the corresponding group — $Al = F_2$. I think no chemist will regard these assumptions as strained.

Now the foregoing symbols all represent a series of salts derived from the first one by various substitutions of a single aluminum atom.

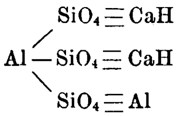
But further replacements are theoretically possible, and the following minerals seem to illustrate them:



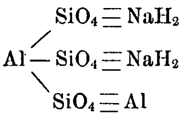
Dumortierite.



Grossularite.



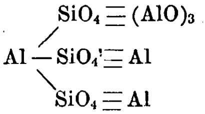
Prehnite.



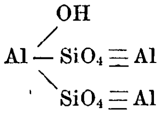
Natrolite.

Dumortierite, which has been little studied, appears to be related to fibrolite, and the formulæ exhibit a relation. Grossularite, the lime alumina garnet, is a common associate of muscovite, a fact which lends verisimilitude to the formulæ given above. The other two formulæ represent the known composition of prehnite and natrolite, but whether they indicate any deeper relations is not yet proven. They do, however, suggest lines of investigation, and so far fulfill a useful purpose. If they are true, prehnite should be derivable from garnet, and garnet and muscovite ought to be mutually derivable from each other. That garnets do alter into micas is already well known, although the exact character of the change is undetermined, and the micas involved in the reaction appear to be more complex than muscovite.

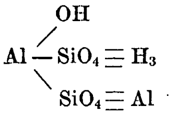
Returning now to fibrolite, we find that it is a mineral which is liable to alter through a process of hydration. Some of its alteration products have been described as species, notably under the names wörthite and westanite, the latter being apparently the final product. Certain other species of the same group frequently undergo a sort of degradation into clays, which, unfortunately, are often too impure to admit of precise formulation. Still, of the several clays which are certainly definite, two seem to fall into series with fibrolite and westanite, as the following structures show:



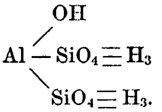
Fibrolite.



Westanite.

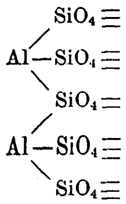


Kaolinite.

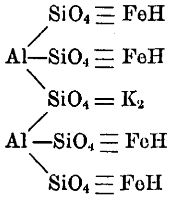


Montmorillonite.

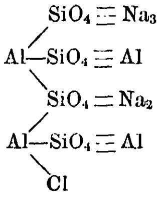
Now, suggestive as these formulæ are, they represent only a selection out of a much larger number, all of which seem to follow essentially the same structural rule. If the case rested here it would still be a strong one, but it becomes even stronger when we study some of the more complex orthosilicates, and some of the silicates containing other inorganic acids. In most of the foregoing instances we have one aluminum atom linked with three of the orthosilicic groups, making a sort of fundamental nucleus to which the other atoms of each molecule are attached. But in many cases we seem to have a semipolymerisation of that nucleus which results in the elimination of one of the silicas, leaving a new group of atoms which may be represented as follows:



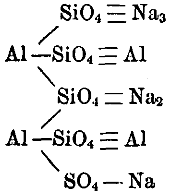
This group, saturated by various bases, seems to exist in many natural silicates, notably among the iron and magnesian micas; and from it certain mixed salts, like sodalite and nosean, may be represented as derived. Thus, to cite a few examples, we may write:



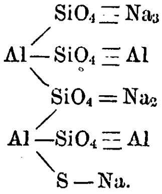
Annite.



Sodalite.



Nosean.



Ultramarine.

The last of these four formulæ is purely hypothetical and rests upon the recognized mineralogical analogies between lapis lazuli and nosean. It is, however, a formula which should be capable of synthetic verification, for ultramarine, itself a product of synthesis, yields many derivatives, the formation of which can be systematically studied. Possibly the lines of research followed by Lemberg, in his work on the alterations of elacolite, may be fitly applied to the investigation of lapis lazuli. As for annite, I have discussed its relations, together with those of the lithia micas, in a previous paper,[1] in which I have also given some

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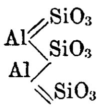
[1] Amer. Journ. Sci., Nov., 1886.

suggestions concerning the part played by fluorine in lepidolite, cryophyllite, and phlogopite. Sodalite and nosean were considered in a still earlier paper,[1] in connection with cancrinite, nephelite, and other species. It is hardly necessary to repeat either discussion here.

Passing now to the metasilicates, we find ourselves, as regards the aluminous salts, at some disadvantage. The normal compound, $Al_2(SiO_3)_3$, is not known to exist by itself in nature, although certain of its derivatives are common. Its formula, however, may be written in two ways, as follows, and to one of these types some of the double aluminous metasilicates should conform:

I.



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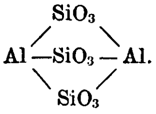
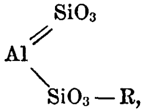
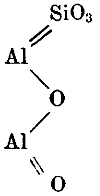


Which of the two is best sustained by evidence?

To answer this question we may appeal to several well-known minerals, such as spodumene $AlLi(SiO_3)_2$, jadeite, $AlNa(SiO_3)_2$, leucite, $AlK(SiO_3)_2$, and pyrophyllite, $AlH(SiO_3)_2$. All of these can be generalized under one formula, thus:



which is directly derivable from normal salt No. 1, and is not derivable from No. 2. Furthermore, kyanite, an isomer of fibrolite, Al_2SiO_5, is regarded by Groth and others as a basic metasilicate, for reasons which need not be reconsidered here. As such its formula is $Al_2(SiO_3)O_2$, which may be derived from either of the formulæ for the normal compound. But pyrophyllite often occurs as the gangue of kyanite, which suggests a genetic relation between the two, and so makes it highly probable that the latter mineral should be written



rather than as a derivative of the second formula for $Al_2(SiO_3)_3$. Formula No. 1, then, is the more probable formula for aluminum metasilicate. Two isomers may be possible, but the evidence so far favors only one compound.

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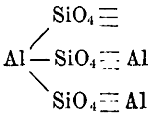
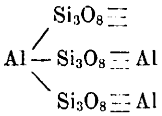
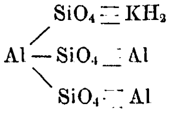
[1] Amer. Journ. Sci., April, 1886.

In addition to orthosilicic and metasilicic acids, at least two other silicic acids correspond to known salts. These are the compounds $H_2Si_2O_5$ and $H_4Si_3O_8$. Still more are possible, but it is not necessary to assume them in order to account for known minerals. Derived from $H_2Si_2O_5$ we have a few species, notably petalite, $AlLi(Si_2O_5)_2$, which is the equivalent of spodumene in structure. The other acid, $H_4Si_3O_8$, is represented only by the species albite and orthoclase, $AlNaSi_3O_8$ and $AlKSi_3O_8$ respectively. If we triple these formulæ we have structures quite analogous to the orthosilicates, in which the normal aluminum salt $Al_4(Si_3O_8)_3$ is the starting point for derivation. Now it is almost universally believed, in accordance with the views of Sterry Hunt and Tschermak, that the triclinic feldspars consist of various mixtures between albite and anorthite as two extremes. If our fundamental hypothesis is true, each of these minerals is derived by substitution from a normal salt, and the formulæ so deduced become strikingly suggestive:

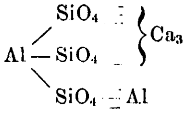




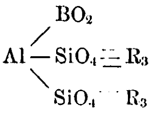
Anorthite is the lime salt corresponding to the first formula, and albite is the soda salt corresponding to the second. Another comparison is even more striking. The four silicates most frequently associated with each other in granite veins are muscovite, garnet, albite or orthoclase, and tourmaline. Tourmaline, according to the analyses made by Mr. Riggs in the laboratory of the United States Geological Survey, is always represented by the general formula $R'_9BO_2(SiO_4)_2$, in which at least the equivalent of R'_3 is present as aluminum. This gives us the following quartette of formulæ:



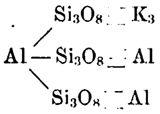
Muscovite.



Garnet.



Tourmaline.



Orthoclase.

The suggestiveness of these symbols can hardly be questioned. All four are covered by the one general hypothesis; and tourmaline, furthermore, is known to alter into muscovite.

Leaving the aluminous salts, the other silicates present few structural difficulties. Isomorphous mixtures become perhaps more common, but when they are resolved into their constituents relatively simple compounds are found. The commoner bivalent metals form both ortho- and metasilicates, and to them the substitution hypothesis, as a rule, easily applies. Only in the metasilicate series do we find notable difficulties, and they may be avoided by the assumption of polymeric molecules. Thus, instead of $R''SiO_3$ we should write $R''_2(SiO_3)_2$, in which one atom of R'' becomes replaceable. This conception is by no means new, and is indeed quite commonly in use; but I may be permitted to cite one item of evidence in its favor. When solutions of calcium chloride and sodium metasilicate are mixed, a white precipitate of calcium metasilicate is thrown down. This reaction I have studied under various conditions of temperature and concentration, and I find that when the precipitated salt is carefully dried over sulphuric acid it has the composition $2CaSiO_3.5H_2O$. That is, the double molecule $Ca_2Si_2O_6$ is required in order to avoid a formula containing a half molecule of water. By itself this fact is not of weighty importance, but it counts for something in confirmation of the prevalent views.

Concerning mixed silicate molecules, partly ortho- and partly meta-compounds, I have nothing at present to say. Such silicates undoubtedly exist, as well as aluminous silicates derived from normal salts of magnesia or lime. Nor do I venture to assert that all known silicates are as yet interpretable by simple structural means. There are many outstanding cases which still seem very obscure, but which I confidently expect will be cleared up in time. The micas, chlorites, and scapolites especially need a great deal of further study. Various theories have been proposed to account for the composition of these groups, but not one is absolutely conclusive and satisfactory. The new method of discussion which I have proposed is yet to be fully applied to these minerals but a wider knowledge of their variations is essential to its complete application. Whether the method shall be finally established as valid remains to be seen, but its results so far at least entitle it to respectful consideration. As a working hypothesis the substitution theory has value, even though it should be ultimately overthrown.

In conclusion, there is one question to be considered. With the silicates the supposition that double salts are substitution derivatives of normal salts appears to work exceedingly well. But how about double salts in general? With such compounds as the sulphates, chromates, tartrates, oxalates, etc., there seem to be few difficulties; but with the double haloids, acetates, formates, etc., the case is not so clear. Their explanation is troublesome, at least in accordance with current views concerning the valency of their acid radicles; but those views are not absolutely incapable of modification. There may be exceptions to the general hypothesis of derivation, but chemists are not likely to be satisfied with partial theories, and all double salts ought to come under one common law. Toward that ultimate purpose the present paper tends, even though the road which it opens may not reach the final goal.

SOME NICKEL ORES FROM OREGON.

By F. W. Clarke.

In or about the year 1881 extensive deposits of nickel silicates were discovered in Douglas County, Oregon. In appearance the ores are identical with the so-called "garnierite" and "noumeaite" of New Caledonia, and many specimens bearing these names have found their way into collections of minerals. At present the deposits at Riddle, Oregon, are being worked by the Oregon Nickel Company, and, through the kindness of Mr. Will Q. Brown, an admirable series of the ores was recently sent to the United States Geological Survey for investigation. According to Mr. Brown all the deposits lie at or near the surface, in beds from 4 to 30 feet thick. Mining is carried on through open cuts or quarries, and no second bed has ever been found underlying the first.

The specimens at my disposal represent a wide range of appearances. They include samples of the country rock and of the associated chromite, and the nickel silicates themselves vary much in color and texture. The finest specimens are bright apple-green and quite compact, and from this they range through duller shades into masses of distinctly earthy texture. Most of them are intermixed with oxides of iron and with quartz; and even the purest mineral, like the garnierite of New Caledonia, is seamed with thin sheets of chalcedony. All of the nickel bearing samples are much decomposed; and one particularly beautiful specimen is distinctly a conglomerate or breccia, having nodules of the green ore imbedded in it side by side with pebbles and fragments of other material. Like all the nickel silicates which have been so far observed in nature, these ores are unmistakably products of alteration, and the problem of their genesis is somewhat interesting. For comparison with them I had a suite of the New Caledonia minerals, received from Professor Liversidge, and a large series of the genthites from Webster, N. C., collected by Mr. W. S. Yeates. All three localities have much in common, and the three sets of specimens point clearly to one conclusion, which will be stated farther on after the evidence for it has been presented.

In composition the nickel silicates from any locality vary widely; for the earthy nature of the material renders it impossible to secure anything like a homogeneous substance for analysis. The purest specimen of the Riddle ore was dark apple-green, compact, and amorphous; but so permeated with films of silica that a definite mineral could not be isolated. With the best material obtainable I secured the following results, which I give side by side with two published analyses by Hood,[1] in order to show the variations.

	Clarke.	Hood.	Hood.
Loss at 110° C	8.87	6.63	7.00
Loss on ignition	6.99		
$Al_2O_3 + Fe_2O_3$	1.18	1.38	1.33
SiO_2	44.73	48.21	40.55
MgO	10.56	19.90	21.70
NiO	27.57	23.88	29.66
	99.90	100.00	100.24

Neither lime, sulphates, chromium nor cobalt could be detected. Like the New Caledonia garnierite, the fragments of this silicate fell to pieces when immersed in water.

Of the New Caledonia silicates many analyses have been published, notably by Liversidge and Leibius, Typke, Damour, Garnier, and Ulrich, and they vary between widely separated extremes. Not only are there the variations due to mutual replacements of nickel and magnesia, with a range in the percentage of NiO from 0.24 to 45.15 per cent, but there are also great differences in silica and in hydration. It is therefore impossible to say whether we have to deal with one nickel salt, varying only in its impurities, or with several compounds, although the general similarity of the material from different localities renders the former supposition the more probable. According to Ulrich[2] the noumeaite and garnierite consist of a soapstone-like base, with a hydroxide or silicate of nickel distributed through it in veins and patches; while Des Cloizeaux[3] regards noumeaite as a magnesian hydrosilicate impregnated with nickel oxide. The latter view, however, is hardly probable, especially when we consider the origin of the minerals; and Typke[4] has cited evidence against it. The prevalent opinion, that we have to deal with one or more definite hydrosilicates of nickel, is best sustained by careful comparative study of the specimens, even though the salts may not be obtained pure or positively formulated. The reciprocal variation of nickel and magnesia in more than twenty published analyses excludes from further consideration the idea that the nickel is present to any great extent as hydroxide. For temporary convenience we may use the well-recognized name "genthite" generically, and apply it to all the nickel silicates from the above-named localities.

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[1] Mineral Resources of the United States, 1883.

[2] Amer. Journ. Sci., Third series, vol. 11, p. 235.

[3] Bull. Soc. Min., 1, 29.

[4] Chem. News, 34, 193.

Of the "country rock" surrounding the Oregon beds one large, clean, fresh specimen was received. This was subjected to analysis, and also, through the kindness of Mr. J. S. Diller, to careful microscopic study. The olivine separated from it by Mr. Diller was analyzed also, although the material was not absolutely free from enstatite and chromite, and both analyses are here presented together.

	Rock.	Olivine.
Ignition	4.41	.57
SiO_2	41.43	42.81
Al_2O_3	.04	....
Cr_2O_3	.76	.79
Fe_2O_3	2.52	2.61
FeO	6.25	7.20
NiO	.10	.26
MnO	none	none
CaO	.55	none
MgO	43.74	45.12
	99.80	99.36

It will at once be seen from these data that the rock contains nickel, and that the olivine separated from it contains even a larger proportion. This fact suggests a probable source of derivation for the nickel in the altered beds of ore, and this view is maintained by the microscopic investigation. Concerning the latter, Mr. Diller reports as follows, discussing both the rock and the genthite:

> The high specific gravity and dark yellowish green color of the country rock with which the genthite is associated at Riddle, Oregon, at once suggests that it belongs to the peridotites, and such it is proved to be by investigation. It is a holocrystalline granular rock, composed essentially of olivine and enstatite with a small percentage of accessory chromite and magnetite. The olivine predominates, so that the enstatite forms less than one-third of the mass. Both of these minerals are clear and colorless, but may be readily distinguished by their cleavage and optical properties. They are allotriomorphic, i. e. not bounded by crystallographic planes, and do not contain prominent inclusions, excepting a few grains of chromite and magnetite and fine ferritic dust. Notwithstanding the comparatively fresh condition of the rock, to which, according to Wadsworth, the name Saxonite may be applied, it is completely permeated by a multitude of cracks filled with serpentine resulting from alteration. Quartz also results from the metasomatic changes in the saxonite, and wherever the genthite occurs it is always associated with either quartz or serpentine.
>
> The genthite from Oregon varies in color from green to pale apple or yellowish green in reflected light, and is compact with a faint suggestion of fine granular structure. Generally it is dull, but where most compact and traversed by a series of minute fissures or seams of quartz it has a decidedly waxy luster. Under the microscope it usually appears to be an aggregation of irregular grains which have in transmitted light a pale yellowish green to coffee-brown color, and a peculiarly clouded waxy aspect. Where the grains are very thin the genthite may be said to be transparent and isotropic, but the majority of them are only translucent. In the narrow seam of genthite lying between seams of quartz the former is indistinctly fibrous and feebly double refracting; but its system of crystallization could not be definitely determined. In small veins it is free from grains of other minerals, but elsewhere it

is very intimately commingled with quartz. The relation of the two minerals is shown in the accompanying Fig. 1, in which the shaded portions (3) are genthite, and the clear ones (4) are quartz. The commingling of the two minerals is so intimate as to make it evident that both were deposited from solution in circulating waters. Veinlets of quartz are frequently found cutting across those of genthite, and in general it appears to be true that the latter mineral was laid down first, although it is probable that both were precipitated at about the same time. Although the purest genthite is to be found with quartz, the mineral is more commonly associated with serpentine; and this relation is a most important one in its genetic significance. The accompanying Fig. 2 represents the edge of one of the larger veins of genthite (3), with numerous veinlets or fissures extending out into the serpentine (2). The tributaries are abundant on both sides of the vein. Fig. 3 shows a vein of genthite (3) in the serpentine (2), which envelopes small masses of residuary oxide of iron (1), left by the decomposing olivine. The area represented is only 0.64 of a millimeter in

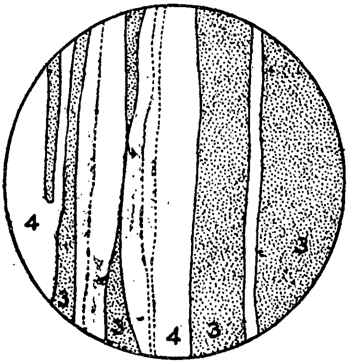

FIG. 1.—Genthite and quartz.

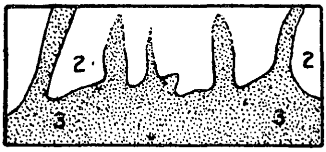

FIG. 2.—Genthite and serpentine.

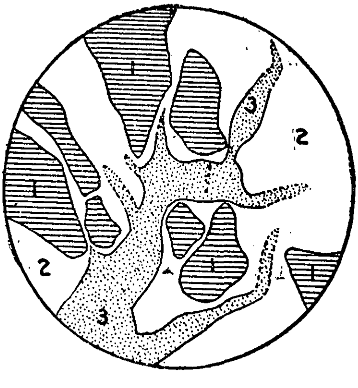

FIG. 3.—Genthite and serpentine with oxide of iron.

diameter and contains no olivine; but less than half a millimeter from the boundary of the vein much olivine still remains, although deeply coated with oxide of iron and serpentine. The branching starting from the vein of genthite, together with the manner in which the arms gradually fade away into the serpentine at once suggests the source from which the genthite has been drawn. The genthite and serpentine are thoroughly intermingled, but the former is generally present in such small quantities as to be overlooked unless it is the object of special research. It occurs in the serpentine directly connected with the grains of olivine from which the serpentine has been derived, and there is every reason to believe that the genthite came from the same source.

In order to secure completer confirmation of the idea that the nickel of the greater silicate deposits is derived from the alteration of nickeliferous olivine, Mr. Diller, at my request, also examined specimens from Webster, N. C., and from New Caledonia. Concerning the Webster genthite Mr. Diller reports that—

> It is almost identical with that from Oregon, excepting that it is not so thoroughly intermingled with quartz. The relation of the genthite to the serpentine and the olivine at the Webster locality is exactly the same as at Riddle. The rock at Webster differs slightly from that at Riddle in containing a smaller proportion of enstatite, and belongs to the peridotites to which the name "dunyte" has been applied.

He also finds the New Caledonia mineral to be identical with genthite in its physical properties, and says:

> Under the microscope it varies from pale yellowish green to light coffee-brown, and is either completely isotropic or exhibits only faint aggregate polarization. Like the genthite of Oregon it is deposited in layers and cavities thoroughly intermingled with quartz, and in the same thin section may be seen serpentine with traces of olivine and enstatite so disposed as to clearly indicate that the serpentine, noumeaite, and other secondary products have resulted from the alteration of peridotite.

This observation confirms the earlier one of Des Cloizeaux (loc. cit.) who stated that the noumeaite was imbedded in a serpentine rock which appeared to be derived from olivine, and which contained crystals of the latter mineral plentifully disseminated through it. A similar suggestion is made by Mr. H. J. Biddle,[1] who regards the nickel of the Webster deposits as an original constituent of the olivine rock, and cites an experiment of Mr. G. B. Hanna, who found 0.15 per cent. of nickel oxide in a chrysolite from Waynesville, N. C.

So far, the case appears to be clearly and conclusively settled as to the origin of the nickel silicates under discussion. Nickel is almost always present in small quantities in olivines, and T. Sterry Hunt, in reporting genthite from Michipicoten Island[2] calls attention to the fact that the metal is rarely absent from the serpentines, steatites, diallages, and actinolites of the Quebec group. Nevertheless, one other possible source of nickel must be noticed. Roth,[3] in speaking of the genthite from the chrome mines of Pennsylvania, attributes it to the alteration of nickeliferous chromite; and the almost universal association of the

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[1] Mineral Resources of the United States, 1886.

[2] Report Geol. Survey of Canada, 1863, p. 506.

[3] Allgem. und Chem. Geologie, vol. i, p. 225, 1879.

latter mineral with genthite, renders the view deserving of attention. But it must be remembered that chromite alters with great difficulty, while olivine decomposes with extreme ease; and moreover the genthite from Oregon contained no chromium, although that metal was diligently sought for. Furthermore, Mr. Diller examined some of the chromite from the Riddle mines, and found that although it was penetrated by crevices filled with secondary minerals containing genthite, the chromite itself showed no evidence of alteration.

Concerning the other silicates of nickel, described under the names of pimelite, alipite, conarite, röttisite, refdanskite, etc., little need here be said. Some of them are probably similar in origin to the better known genthite, although the conarite and röttisite, which contain small amounts of sulphur and arsenic, probably came from nickeliferous sulphides. For the other minerals above named there is too little evidence upon record to warrant any serious attempt at discussion.[1]

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[1] A full discussion of the nickel silicates from New Caledonia may be found in Professor Liversidge's work, entitled "The Minerals of New South Wales, etc.," published by Trübner &Co., in 1888.

NATURAL SODA; ITS OCCURRENCE AND UTILIZATION.

By Thomas Marean Chatard.

The enormous consumption of carbonate of sodium in consequence of the great variety of uses to which it is applied in manufactures and in daily life, has made its artificial production one of the most thoroughly studied branches of chemical technology. The valuable work of Lunge,[1] which is the standard authority on this subject, gives the history of this industry from its slender beginnings to its present vast expansion and shows what energy, ability and capital have been expended in the course of its development.

Of the many methods proposed for the manufacture of carbonate of sodium, but two, the Le Blanc and the ammonia processes, have fulfilled practical requirements and are, at present, contending together for the mastery of the field. So sharp is this competition that in many cases the Le Blanc process can live only through the demand for its by-products—the soda obtained yielding little or no profit—and if the problem of the utilization of the chlorine in the waste liquors of the ammonia process be ever economically solved, the former method must soon become a thing of the past.

Before the discovery of the Le Blanc process the only sources of carbonate of sodium were barilla, or the ashes of certain plants, and a small amount of "trona" or "natural soda" obtained from Hungary and a few African localities. The principal use of soda is in the manufacture of hard soaps, which, in default of this alkali, can be made by adding common salt to the "soft soap" produced by saponification of fats by means of the potash-lye obtained by the leaching of wood ashes. The addition of salt causes the soap to curdle, the sodium of the salt replacing the potassium of the "soft soap" while the residual liquid contains chloride of potassium. Such was the method of soap-making followed at that time, but the increasing cost of potash and of barilla gave a powerful impulse to the artificial soda manufacture which abroad has now become the most important branch of chemical industry.

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[1] Sulphuric Acid and Alkali, by George Lunge. Ph.D., three vols., London, 1880.

Nature has been bountiful in giving us, within our boundaries, sources of soda which await the union of capital and technical skill to become valuable producers of national wealth. These sources of natural soda are the alkaline lakes and "dry deposits" situated in that section of the country lying between the Rocky Mountains and the Sierra Nevada, known as the "Great Basin." Many are well known, having been described by the various Government expeditions and surveys; while some are too weak, too impure, or of too little extent to have a prospective value, others promise good results to well-directed practical development. To aid this, the present investigation has been undertaken by the United States Geological Survey.

This work naturally falls into two divisions—the collection and arrangement of previously existing knowledge and a study of the technical questions involved. As the literature of the subject consists of but few articles, most of which are to be found only in journals inaccessible to those more particularly interested, it has been deemed advisable to bring together, in a compact form, the information we possess concerning foreign localities, both as to their nature and the work done in connection with them. In regard to the study of the technology of the subject, it must be understood that this has its special difficulties, since laboratory experiments on a small scale, no matter how carefully conducted, can rarely reproduce the condition existing in large masses of such material, while the influence of the climate is also a very potent factor. For these reasons a portion of the work was done in the field, and more was contemplated, but unforeseen circumstances have prevented the complete prosecution of this plan, and the results so far obtained are published in order that others may be induced to take up the work and develop it on a practical scale.

COMPOSITION.

"Natural soda," so called to distinguish it from the soda produced by artificial processes, is the residue obtained by the evaporation of alkaline waters, without the aid of artificial heat. It is composed of sodium carbonate and bicarbonate, in varying proportions, mixed with impurities, mainly sodium chloride and sulphate. In comparing natural sodas from different localities we shall find that they vary widely in composition, so that a process of manufacture developed in one locality, and yielding there a very pure and cheap product, may fail completely when applied without proper modification to the material from another place.

The problem to be solved is the economical production of commercial sodium carbonate by the appropriate treatment of the natural soda, and the means to be employed are, in the main, solution, evaporation and fractional crystallization. By fractional crystallization we mean a methodical stoppage of the crystallizing process by removal of the remaining solution or "mother liquor" from the "crop" of crystals so far obtained. This "first crop" may be either the desired material in a purer condition than it was in the original solution or may consist mainly of impurities which we wish to remove.

As the first step in this study it is necessary for us to know the nature and properties of the salts composing natural soda, not only when they are pure, but also when in combination with each other, since the properties and reactions of each salt are modified by the presence of the others in its solution, and the extent of this influence is generally proportionate to the relative amounts of the salts present.

The substances to be considered are, therefore, sodium sulphate, chloride, carbonate and bicarbonate, and in describing them only those characteristics which seem to be of interest in this connection will be mentioned, since the text-books of chemistry, notably the work of Lunge already mentioned, give all needed general information with sufficient fullness.

SODIUM SULPHATE.

Sodium sulphate Na_2SO_4, or anhydrous sodium sulphate, is found in nature as the mineral Thenardite. Combined with ten molecules of water of crystallization or $Na_2SO_4 10H_2O$, it forms the mineral Mirabilite. Both of these minerals, as also the artificial sulphate, are soluble in water, and the solution on being evaporated yields, according to the temperature and other conditions, either anhydrous salt or salt with seven or ten molecules of water of crystallization.

The composition of these salts is as follows:

	Anhydrous.	With 7 H_2O.	With 10 H_2O
Na_2O	43.67	23.13	19.25
SO_3	56.33	29.85	24.84
H_2O	....	47.02	55.91
	100.00	100.00	100.00

Of the two hydrated salts, the one with 10 H_2O is generally known as crystallized Glauber's salt, and is formed when the solution is evaporated under ordinary conditions. It forms large transparent crystals which effloresce in the air, falling into a white powder and losing all of the water if the air is sufficiently dry. If, however, the solution is made strongly alkaline, by the addition of sodium carbonate, and evaporated at ordinary temperature, the crystals then obtained are anhydrous.[1] That the sulphate is under such circumstances anhydrous is also shown by the numerous analyses of mixed salts given in this paper, notably those on pages 63, 64, as the amount of water there found is insufficient for even the salt with one molecule of water of crystallization or Na_2SO_4, H_2O, said by Thomsen[2] to be formed under such conditions.

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[1] Schulz-Sellack: Journ. für prakt. Chem., series 2, vol. 2, p. 459.

[2] Thomsen: Ber. Deutsch. Chem. Ges., vol. 11, p. 2042.

The solubility of this salt in water increases with the temperature, 100 parts of water at 0°(32° F.) dissolving 5.02 parts Na_2SO_4, while at 33° C(91.4° F.), the point of greatest solubility, 50 parts Na_2SO_4 are dissolved. As different observers give different results it is well to state at this point that the solubility of a salt at any given temperature depends on whether we take the salt in its anhydrous condition or as combined with water of crystallization. The experiments of Loewel[1] show this very clearly for sodium sulphate, and it is also true for sodium carbonate. Of course the figures are only true for pure solutions; if other salts are present such as chlorides and carbonates the question becomes very complicated. The results obtained by the series of experiments on the evaporation of Owens Lake water, to be described later, may, however, aid us in forming correct conclusions, but so far we can only say that, from a practical point of view, the sodium sulphate which is always present to a greater or less extent in all alkaline waters and dry deposits is a most unwelcome guest, being of itself comparatively worthless, but by its presence greatly complicating any process devised for the extraction of the valuable carbonate. As will be seen later it is deposited to some extent with the "first crop" of crystals, even when this crop represents but a small portion of the total salts in solution, and, unlike sodium chloride, it has a distinctly deleterious effect upon the quality of the product. It must, therefore, be the aim of the manufacturer to prevent, or at least to control, its deposition as far as practicable, and to attain this result careful and judicious work will be necessary.

SODIUM CHLORIDE.

Sodium chloride (NaCl) or "common salt," contains 39.39 per cent. sodium and 60.61 per cent. chlorine. It crystallizes in cubes which, when the crystallization occurs on the surface of the solution, usually unite together to build up the well-known "hopper forms." The crystals formed on the bottom are generally incompletely developed, but sometimes, and this is particularly the case when certain other salts are present, the cubes are perfectly formed, transparent and very bright. Other crystal forms and modifications have also been observed.

One hundred parts pure water at 0° C (32° F.) dissolve 35.59 parts NaCl, and this solubility is but little increased by a rise in temperature as at 30°C (86° F.), only 36 parts are dissolved. Even at the boiling point of the saturated solution 109.7° C(129.5° F.) it contains but 40.35 parts. This peculiarity of solubility is of great importance in the practical treatment of the natural soda, since it renders the removal of the chloride a comparatively easy matter, the rate of deposition of the salt being but little influenced by changes of temperature of the solution.

If deposited with the crop it has no other effect than to reduce the percentage of alkali, and therefore the market value of the product,

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[1] Loewel: Ann. Chim. et Phys., series 3, vol. 49, p. 32.

while its presence in the solution up to a certain proportion appears to have a distinctly beneficial action as causing a more complete and satisfactory crystallization of the first crop.

The influence of chloride of sodium on the solubility of carbonate of sodium will be shown under the latter head by the tabulated results of experiments undertaken to determine it.

SODIUM CARBONATE.

Sodium carbonate or sodium monocarbonate Na_2CO_3 is composed of—

	Molecular weight.	Per cent.
Soda, Na_2O	62.0	58.53
Carbonic acid, CO_2	44.0	41.47
	106.0	100.00

It is an opaque white salt of a specific gravity of 2.5, and melts at a moderate red heat, losing a small portion of its carbonic acid, this loss occurring even when the salt is heated and cooled in a stream of dry carbonic acid. When fused in a crucible over an ordinary flame the loss of weight at a red heat is about six-tenths of 1 per cent.; as the heat increases so does the loss, so that at a yellow heat up to 1.75 per cent. is lost, but this is regained as the material cools, so that the final loss is that at a red heat. If the salt is fused in a current of air or of steam, the loss is continual and proportioned to the degree and duration of the heating, experiments giving a loss as high as 2.05 per cent.[1] A solution of sodium carbonate, if boiled, undergoes a small but continued loss of carbonic acid, and the same loss occurs if the solution is placed in a vacuum at ordinary temperatures. (Jacquelain.)

Sodium carbonate dissolves in water with evolution of heat. From its solution it crystallizes with 1, 2, 3, 5, 6, 7, 10 and 15 molecules of water; (1) according to the temperature of the solution, and (2) according to whether the solution, prepared at a boiling heat, in cooling down is freely exposed to the air or not.

Of these hydrates the monohydrate ($Na_2CO_3H_2O$), is found in nature as the mineral thermonatrite; "the trihydrated salt (Na_2CO_3, $3H_2O$), according to Schickendantz, is found as an afflorescence in dry places of the beds of rivers in the Cordilleras;"[2] while the decahydrate ($Na_2CO_310H_2O$), which is the ordinary "crystal soda" of commerce, has been found native by Olzewsky.[3] The anhydrous carbonate Na_2CO_3 also seems to occur, as Kayser[4] describes an incrustation which had evi-

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[1] Scheerer: Ann. d. Chemie u Pharm., 116, p. 129; Mallard: Ann. de Chimie, series 4, vol. 28, p. 89; Jacquelain: Ann. de Chimie, series 4, vol. 32, p. 193.

[2] Lunge: Sulphuric Acid and Alkali, vol. 2, p. 277.

[3] Olzewsky: Journal für prakt. Chemie, vol. 102, p. 375.

[4] Kayser, W.: Liebig's Jahresbericht der Chemie, 1850, pp. 759, 821.

dently been formed by the weathering of the clay slate upon which it was found. His analyses of both slate and incrustation are given and are interesting as bearing on the problems of rock decomposition and as showing one of the ways in which "natural alkali" is produced.

	Slate.
SiO_2	49.87
Al_2O_3	26.41
Fe_2O_3	6.95
Mn_2O_3	1.21
CaO	2.10
MgO	.87
K_2O	2.96
Na_2O	1.61
Sulphur	.39
Carbon	.65
H_2O	7.05
BaO	tr.
	100.27

	Incrustation.
$Fe.CO_3$	.19
$MgCO_3$	3.32
$CaCO_3$	1.81
Na_2CO_3	92.07
H_2O	1.85
	99.24

Sodium carbonate is most soluble, according to Mulder, in pure water at 32.5° C (90.5° F.), the solution then containing 59 parts Na_2CO_3 to 100 parts water, or 37.10 per cent. Hence a solution which has deposited crystals at the boiling point (105° C—221° F.) redissolves them while cooling till the temperature sinks below 32.5°C, when recrystallization begins. The solubility varies very greatly with the temperature; thus at 15.5°C (60°F.) the saturated solution contains 14.53 per cent. at 31.3°C, 30.04 per cent. and at 32°C, 31.78 per cent.

The presence of sodium sulphate or chloride decreases the amount of carbonate which a given amount of water can dissolve, and as the nature and extent of this influence is of importance in studying the conditions attending the separation of the carbonate from the natural deposits and solutions, all of which contain chlorides usually in larger proportions than carbonates, three series of experiments have been carried out and the results are given in the following table.

In series A the NaCl was dissolved in water and the solution was made up to 50cm³. The Na_2CO_3 was then added and the whole shaken vigorously, the shaking being repeated at intervals throughout the day. The graduated cylinders containing the solutions were allowed to stand till the next morning, when the mother liquors were filtered from the deposited salts, a perforated crucible with asbestos felt being used for this purpose.

The volume and temperature of the filtrate were noted, and 25 cm^3 were taken for the determination of the specific gravity. This portion was then diluted with water to 1000 cm^3, and of this dilute solution portions of 50cm^3 each were taken for the determinations. These portions as well as the 1000 cm^3 were in all cases weighed, and the results given have been calculated by the factors so found.

In series B the operations were the same, except that the Na_2CO_3 was dissolved first, the NaCl being added, in portions of 2.5 grams until a permanent deposit was formed, while for series C a saturated mother liquor of $Na_2CO_3, 10H_2O$ was employed, 50cm^3 being taken for each portion.

Series No.	In 50cm^3.		°C.	Sp. G.	Per cent. Na_2CO_3.	Average.	Per cent. NaCl.	Average.	Total per cent. of salts.
	Na Cl. grams.	Na_2CO_3 added.							
A1....	Saturated.	5.0	34.0	1.245	7.88	7.90	21.26	21.125	29.150
					7.92		21.24		
A2....	12.5	10.0	35.5	1.294	14.83	14.85	17.29	17.265	32.115
					14.87		17.24		
A3....	10.0	15.0	32.5	1.314	18.34	18.35	14.39	14.38	32.73
					18.36		14.37		
A4....	7.5	17.5	33.0	1.329	22.30	22.28	10.54	10.525	32.805
					22.26		10.51		
A5....	5.0	20.0	33.0	1.340	26.36	26.36	7.01	7.015	33.375
					26.36		7.02		
A6....	2.5	22.5	33.5	1.352	29.34	29.325	3.42	3.42	32.745
	Na_2CO_3 grams.	NaCl added.			29.31		3.42		
B1....	12.5	12.5	35.0	1.309	16.67	16.665	15.46	15.455	32.120
					16.66		15.45		
B2....	10.0	12.5	35.5	1.281	14.01	14.00	17.38	17.385	31.385
					13.99		17.39		
B3....	7.5	15.0	32.3	1.261	10.48	10.48	19.67	19.665	30.145
					10.48		19.65		
B4....	5.0	15.0	32.5	1.237	7.14	7.145	21.41	21.42	28.565
					7.15		21.43		
B5....	2.5	17.5	33.0	1.217	3.67	3.675	24.07	24.065	27.740
					3.68		24.06		
C1....	Saturated.	none....	31.3	1.3287	30.07	30.045	....	....	30.045
					30.02				
C2....	.. do	5.0	36.0	1.3435	26.59	26.595	7.26	7.265	33.860
					26.60		7.27		
C3....	...do	7.5	29.5	1.3114	19.415	19.416	13.08	13.08	32.496
					19.417		13.08		
C4....	...do	10.0	29.5	1.3139	18.59	18.595	14.62	14.62	33.215
					18.60		14.62		
C5....	...do	12.5	30.0	1.3146	18.81	18.825	14.48	14.47	33.395
					18.84		14.46		
C6....	...do	15.0	30.0	1.3204	19.29	19.295	14.17	14.16	33.455
					19.30		14.15		

In each of the experiments here tabulated, with the exception of C1 there was a considerable deposit of salts consisting of a mixture, in varying proportions, of the two salts employed, and the composition of the deposit can be calculated by the difference between the amounts originally taken in each case and those in solution.

It will be observed that in the A series the point of equilibrium in the percentages of the two salts in solution lies between A2 and A3, probably near to the point where equal weights of NaCl and Na_2CO_3 would be taken. This is substantially proved by B1 where 12.5 grams of each salt were used and the amount of Na_3CO_3 was 1.21 per cent. higher than that of the NaCl.

The salts, however, do not appear to dissolve in proportion to the amounts taken, the variations being greatest in the A series where the Na_2CO_3 was added to the solution of the NaCl; whereas in the B series, the Na_2CO_3 was first dissolved and the NaCl added the variations are much smaller. We may therefore conclude that if a mixture of these two salts is treated with an amount of water insufficient for complete solution, the amount of each dissolved will be approximately proportionate to the quantity present but that the approximation is not very close.

Series C shows the effect of the addition of increasing proportions of NaCl to a saturated solution of Na_2CO_3. $50cm^3$ of this solution at 31.3° C. weighs 66.3424 grams and contains 19.9224 grams Na_2CO_3, or, as given in the table, 30.045, per cent. The table shows that the addition of 7.5 grams NaCl gave the best result, but as some of it remained in the deposited Na_2CO_3, a less quantity might have been advantageously taken, say 6.64 grams or one-third of the weight of the Na_2CO_3 in solution. Had this been done we should probably have had little more Na_2CO_3 left in solution and that deposited would have been purer. If the amount of NaCl is increased, the excess as shown, remains undissolved and the character of the solution suffers but little change. The practical bearing of these results will be more apparent when we come to that portion of this paper treating of urao or the combination of sodium monocarbonate with sodium bicarbonate.

SODIUM BICARBONATE.

Sodium bicarbonate, $NaHCO_3$, contains—

	Per cent.
Soda, Na_2O	36.94
Carbonic acid, CO_2	52.36
Water, H_2O	10.70
	100.00

It is formed by the action of CO_2 on Na_2CO_3, hence is always produced when a solution of the latter salt is exposed to the air. At the ordinary pressure of the atmosphere the reaction is a slow one, but if pure CO_2 at a pressure of 30 pounds to the square inch is used the conversion is rapid.

The salt occurs in monoclinic tables usually combined into crusts. It has a somewhat alkaline taste; if entirely free from Na_2CO_3 it does not change turmeric, but reddens blue litmus. The best test for its purity, according to Hager, is calomel; 0.5 gram calomel mixed with 1 gram $NaHCO_3$ and 1.5 gram water and shaken up does not blacken in 24 hours in the absence of monocarbonate, but in its presence it turns more or less gray. In moist air or if moistened with water the salt loses CO_2, the more quickly the higher the temperature. Hence if a solution of bicarbonate is heated the bicarbonate is gradually destroyed and monocarbonate remains, which has an important bearing upon the problem of the economic treatment of natural soda.

$NaHCO_3$ is much less soluble in water than Na_2CO_3, 100 parts of water at 15.5°(60°F) dissolving only 8.9 parts or 8.17 per cent. The solubility is much diminished by the presence of sodium chloride or sulphate, or a mixture of both. A saturated solution of sodium chloride dissolves hardly any of the salt, a fact of great importance, since upon it is based the ammonia process for the manufacture of soda.

SODIUM SESQUICARBONATE.

Sodium sesquicarbonate, $Na_4H_2C_3O_9$, so called because the old dualistic formula was $(NaO)_2(CO_2)_3$ is described in all chemical works which treat the subject of the sodium carbonates at all fully. It is said to exist in nature as a mineral to which the name trona has been given and has been prepared artificially by R. Hermann[1] and Winkler.[2] Other chemists also claim to have obtained it. It represents a combination of one molecule of Na_2CO_3 with two molecules of $NaHCO_3$ or $Na_2CO_3, 2NaHCO_3$, which may also be written $Na_4H_2C_3O_9$. My own experiments, which will be given in detail further on, not only failed in reproducing this salt, but also throw considerable doubt upon its actual existence as a definite chemical substance, and not as a mixture of the two carbonates accidentally formed in these proportions.

There is, however, a very definite combination of the two carbonates, which occurs, as will be shown, widely distributed in nature and which bears the mineral name *urao*. This salt is composed of one molecule of sodium monocarbonate and one of sodium bicarbonate, plus two molecules of water of crystallization, or $Na_2CO_3, NaHCO_3+2H_2O$, or $Na_3HC_2O_6, 2H_2O$. It is very easily produced artificially, in a well crystallized condition, and is most important in this connection, since by its chemical behavior it gives the key to a rational economic process whereby the natural sodas can be made available for use in the arts.

For this reason it will be made the subject of a special section of this paper, but before taking it up we will briefly consider the principal localities of natural soda throughout the world and the character of the salts produced by them. In this manner a better idea of the extent

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[1] R. Hermann: Jour. für prakt. Chemie, vol. 26, p. 312.

[2] Winkler: Buchner's Repert. für Pharm., vol. 48, p. 215.

and difficulty of the problem can be obtained, while a mass of matter at present scattered through the various journals is brought together for comparison.

LOCALITIES AND MODE OF OCCURRENCE.

As a dry climate is the prime factor for the formation of deposits of natural soda, or of concentrated waters heavily charged with it, and as such climatic conditions exist in many parts of the world, there are numerous places where this material has been found or may reasonably be looked for. A complete list of these occurrences is not available, nor would it have any special value, and in speaking of the foreign localities only those will be described where the material is being utilized or where the local conditions are of interest for comparison with our home sources of supply.

HUNGARY.

In Hungary natural soda is found in many places, especially near the town of Szegedin.[1] It occurs as an efflorescence on the surface of moist places, the snow-white crust often extending for miles. The crude soda or "szekso" is collected by scraping the surface, the best time for this operation being the early morning before sunrise, particularly in the spring and when much dew has formed, as the material collected during the day is considered to be poorer in salts. As the crust is thin and much of the soil is gathered with it, the product is a grayish white earth; this is sold to the refiners, whose only test for its value was, at the date of the description, the sharpness of the taste. Moser[2] gives the following analysis of the szekso as gathered:

Soda, Na_2O	8.03
Potash, K_2O	3.12
Lime, CaO	2.72
Magnesia, MgO	Trace.
Alumina, Al_2O_3	2.33
Sulphuric acid, SO_3	3.48
Silica, SiO_2	1.04
Water, H_2O	15.50
Insoluble (sand, etc.)	54.99
Carbonic acid, CO_2	8.79
	100.00

In the refineries the earth is leached until the soda taste is no longer perceptible, giving a dark-brown solution containing sodium carbonate, sulphate, and chloride; this is evaporated to dryness and calcined, the mass being ultimately heated to complete fusion, and, when partly cooled, drawn from the furnace. The product when cold is broken up and sent to market.

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[1] Werner: A. Jour. f. prakt. Chemie, vol. 13, 1838, p. 127.

[2] Moser: Liebig's Jahresbericht, 1859, p. 812.

Schapringer[1] gives the following analyses of two samples of this soda. No. 1 is said to have been made by evaporating the leachings and drying the product in the air, while No. 2 is said to have been obtained by calcining No. 1:

	No. 1.	No. 2.
Sodium carbonate, Na_2CO_3....	28.87	40.25
Sodium chloride, $NaCl$........	31.00	53.93
Sodium sulphate, Na_2SO_4	.13	.45
Calcium carbonate $CaCO_3$.....	.39	1.54
Sand, clay, etc................	.41	1.45
Water	39.04	2.09
Loss	.16	.29
	100.00	100.00

It is difficult to understand these analyses, since No. 1, if air-dried, could not contain the amount of water here given, and if calcined could not yield a product of the composition of No. 2 which is, at best, very impure and of but little value. The analysis of the szekso shows no chlorides, which is also remarkable, when we consider the origin of this soda, which has been discussed by Szabo and Moser.[2] According to them the sandy soil contains a large proportion of soda minerals which decompose through the joint action of carbonate of lime, water, and air. The lime furnishes carbonic acid to the soda which is dissolved in the water with which the ground, in winter, is saturated. As the summer approaches and the ground becomes warmer, the decomposition increases, while the water rising to the surface and there evaporating leaves its salts behind.

Owing to the rude methods of refining, with consequent variations in composition, and the increasing cost of collection, the Hungarian soda has not been able to compete with the artificial product, and now supplies only a limited local consumption in the manufacture of the celebrated Szegedin soap. Its history, however, is interesting, since we have in the West many occurrences of soda similar to those of Hungary, and it would seem at first sight as though they could be utilized; but if in a country of such low wages as Hungary the cost of collection is too great we can hardly look for much success in attempting similar processes at home, unless we can find deposits comparatively pure and of considerable thickness. In default of such, we can expect satisfactory results only from the waters of the soda lakes, in which nature, having performed the leaching process, has collected and concentrated the salts.

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[1] Schapringer: Dingler, Polyt. Jour., vol. 189, p. 495.

[2] Szabo, J., and Moser, J.: Wagner's Jahresber., 1862, p. 223.

EGYPT.

The soda lakes of Egypt have been described by D'Arcet[1] and by Russegger.[2] They are nine in number, in the Desert of St. Macarius, sixty miles northwest of Cairo and about thirty[3] miles from the Nile, and are situated in a small valley running northeast and southwest. The largest, Nehelé, is five miles long by one-and-a-half wide, with a maximum depth of 20 feet. On the eastern side of the valley are a number of weak brine springs (some, indeed, being fresh) which feed these lakes in which, having no outlet, the concentration is continual, varied only by the annual rise and fall. Russegger observed that the lakes rise when the Nile is falling and fall during its rise, and ascribes this partly to the rains which occur during the decrease of the river and partly to the supposition that the rise of the river is sufficient to overflow the divides of the clay formation which underlies the desert sand, and the water then flows through the sand to the lowest points of the valley in which are the lakes. As, however, it takes much time for the water to travel that distance, the lakes are not reached, and therefore do not rise, until the end of the high-water season.

The surface of the country is the desert sand, under which is a layer of blackish-gray clay, 20 feet thick, resting upon a tertiary sandstone. This clay is strongly impregnated with chloride of sodium and carries much gypsum, the quantity of both salts being much greater in the lower than in the upper part; it also contains much carbonate of lime. The gypsum is either scattered in single crystals through the whole mass of the clay, or, especially in the lower part, interstratified with it in thin layers intermixed with desert sand and common salt, forming a kind of gypsum sandstone.

The lakes, formed by the leaching out of the soil, are therefore strong solutions of chloride of sodium containing in addition varying proportions of carbonate and sulphate of sodium. During the dry season, the smaller lakes dry up entirely, leaving on the bottom a salt crust of the composition of the entire lake; the larger lakes, on the other hand, do not dry up, but, as they become more concentrated, deposit salt crusts the composition of which depends upon the percentage of carbonate of sodium in the water.

In some of the lakes, bottom deposits are said to have gradually formed whose upper portion, 16 feet thick, consists essentially of sodium chloride, whilst the lower one, 17 feet thick, contains sodium carbonate. The above mentioned crusts, which are 15 to 18 inches thick, are pushed off by means of poles and spades, spread out to dry on the banks, and carried in baskets to the Nile, whence the salt is shipped to

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[1] D'Arcet: Comptes rendus, September, 1845, vol. 10. Dingler Polyt. Jour., vol. 98, p. 159.

[2] Russegger: Karsten's Archio, vol. 16, 1842, p. 380.

[3] Lunge: Sulphuric Acid and Alkali, vol. 2, 1880, p. 285—gives "five miles" as the distance from the Nile. He also quotes "Landerer, Wagner's Jahresb. 1858, p. 68," in this connection, but the volume for that year does not seem on examination to have anything by this author or on the subject.

other parts. It is called "latroni" in the Levant and in Greece; the Egyptians use it to soften their very hard drinking water by precipitating its lime and magnesia salts, the water being afterwards filtered. Its principal use is in Crete for soap making. From Alexandria yearly about 2,500 tons are exported.[1]

This soda has been analyzed by Remy,[2] who describes the sample as bright gray, crystalline, effloresced on surface, slowly soluble in cold water, more rapidly in hot, leaving a little residue partly soluble in hydrochloric acid. The analytical results are as follows:

Sodium chloride, $NaCl$	8.160
Sodium sulphate, Na_2SO_4	2.147
Sodium silicate, Na_2SiO_3	.288
Sodium sesquicarbonate, $Na_4H_2C_3O_9$	47.292
Sodium carbonate Na_2CO_3	18.430
Calcium carbonate $CaCO_3$	.200
Water	19.669
Insoluble	4.106
	100.292

ARMENIA.

As described by Abich,[3] the lakes of the Araxes plain in Armenia lie in the volcanic region of Ararat and show a great variety of composition. The lake of Tasch-Burun is situated on "the most distant of the lava masses which have broken out at the northwestern base of the Great Ararat," and its water carries 6.66 per cent. of salts, mainly sodium chloride as shown by analysis No. 1. Analysis No. 2 gives the composition of the crusts which are deposited on the shore in hot weather; these attain a thickness of a half-inch and are of a reddish color.

Other lakes are found southeast of Little Ararat among the volcanic lavas of this mountain. One of these lakes, remarkable for the reddish color of its water, lies on the left side of the valley close under the steep declivities of the greatest heights of the Gundusdag range which is formed of sandstone, dolomite, slates, and limestone and is broken through and shattered by a red quartz-porphyry. The surface of the country is a whitish clay, supporting a strong growth of soda plants.

The shore of this lake, which is about a mile in circumference, is very soft, so that walking is difficult, and is covered with crusts of a hard reddish salt having a laminated fracture. The crusts extend out upon the surface of the lake and portions are floating upon it, so that the whole looks as though it were about to freeze. Soundings showed that crusts had also formed on the bottom, apparently covering the whole of it. The water contains 30.63 per cent. of salts, the composition of which is shown by analysis No. 3, while No. 4 is the composition of the bottom crusts, and No. 5 of the floating portions.

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[1] Lunge: Sulphuric Acid and Alkali, vol. 2, p. 286.

[2] Remy: Journal für prakt. Chemie, vol. 57, p. 321.

[3] Abich: Jour. für prakt Chemie, vol. 38, p. 4.

The heavy bottom crusts are described as being composed of successive layers, each of which is a very solid radiated aggregate of crystals; the red coloring matter is deposited between the layers, which adhere closely together. The floating crusts have nearly the same composition and structure, but the layers are much thinner and the salt is almost white. The analyses are remarkable as showing that not only the sulphate but also the carbonate has crystallized almost free from water. Abich concludes that this is due to the formation of a "double salt" of sodium sulphate and carbonate, for which he proposes the mineral name "makite." In the vicinity of this "red lake," are a number of small pools of a wine-yellow color, but without salt crusts. The water of one of these contained 34.74 per cent. of salts of the composition of analysis No. 5. Other lakes are mentioned in the original paper, but the waters were poorer in sodium carbonate and sulphate and richer in sodium chloride.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
	Tasch-Burun.		Red Lake.			Yellow pool.
	Water.	Crusts.	Water.	Crusts.		Water.
				Bottom.	Floating.	
Sodium carbonate, Na_2CO_3	14.71	22.91	12.08	18.42	16.09	68.90
Sodium sulphate, Na_2SO_4	10.36	16.05	18.18	77.44	80.56	15.55
Sodium chloride, NaCl	74.61	51.49	69.73	1.92	1.62	15.50
Water, H_2O	....	9.88	....	1.18	.55	....
	99.68	100.33	99.99	99.96	98.82	99.95

The views of Abich as to the mode of formation of these salts will be given in the section treating of the origin of natural soda.

OCCURRENCE OF URAO IN VENEZUELA, SOUTH AMERICA.

This locality is described by Palacio Faxar[1] as being in a valley named La Lagunilla in the province of Maracaibo, 48 miles from the city of Merida. In the center of this valley, the soil of which is said to consist of limestone, lies a little lake which in the rainy season has a length of 210 meters and a breadth of 106. Although its greatest depth is not over 3 meters, it never dries up entirely even in the driest seasons. The water is yellowish-green, has a soapy feel, an alkaline taste, and a peculiar smell. During the hot season a salt crystallizes on the bottom. This salt, called urao, is collected every two years by the Indians of the neighborhood, who obtain from 100,000 to 160,000 pounds, according to the demand, which is for the manufacture of *mo*, a dried extract of tobacco used by the natives as a stimulant.

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[1] Faxar: Ann. de Chimie, ser. 2, vol. 2, p. 432. Also, Pogg. Ann., vol. 7, p. 101.

The Indians obtain the salt by diving for it, and the peculiar manner in which this is done is thus described by Boussingault:[1]

> To collect the urao, the Indians make an excavation on the bottom of the lake, several meters in extent, and plant therein a stake 14 to 16 feet long, the upper end of which reaches above the surface of the water. When this is accomplished an Indian resting upon this stake places the end of a second one upon the deposit and holds it at a certain inclination. As soon as this is done, a second Indian glides down the inclined stake, plunges beneath the surface of the water and after the lapse of a few minutes returns with a portion of the salt. According to the information we have received, the deposit of urao, which is not very thick, is covered by a layer of material containing crystals of calcite. Above this is a bed of ooze, one meter in thickness.

The excavation spoken of in the beginning of this extract is apparently made for the purpose of removing these upper layers; the crystals of so-called calcite were later shown to be gay-lussite $Na_2CO_3,CaCO_3+5H_2O$; and the inclined pole is used to enable the diver in such a dense solution to reach the bottom. Concerning this water, Boussingault very curiously says: "The water of the lake is only slightly saline; animals drink it with pleasure."

As the water is necessarily a strong alkaline mother liquor, often completely saturated, it is evident that this statement is incorrect. Faxar (loc. cit.), more accurately says of the divers: "Their death is inevitable if they swallow a certain quantity of the water."

He also says that the action of the water reddens the hair of the divers.

The Urao is described by Boussingault as "crystallized in prismatic needles arranged in radiating masses; a little softer than calcite. Taste alkaline; does not effloresce." His analysis is as follows:

Carbonic acid, CO_2	39.00
Soda, Na_2O	41.22
Water, H_2O	18.80
Impurities	98
	100.00

NORTH AMERICAN LOCALITIES.

The various exploring and surveying expeditions sent by the Government into the region of the Great Basin have to some extent examined and reported upon the alkaline deposits and lakes lying within the range of their labors. Private prospectors, also, recognizing the future value of these salts, have not overlooked them, especially when the rapid development of the borax industry caused every accessible salt-flat or marsh to be scrutinized and tested for that substance. In this way natural soda has been found in many places, but the absence of the necessary transportation facilities has, until lately, rendered any plan for the utilization of the soda a matter of the future.

Within the past few years the railroad facilities through this region have greatly increased and are continually extending, so that some of

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[1] Boussingault: Ann. de Chimie, ser. 2, vol. 29, p. 110.

the more promising localities are within easy reach. The consumption of soda in this country is already great and steadily growing larger, and it remains for technical skill, supported by capital, to develop these resources and to convert a hitherto valueless, even obnoxious, material into a source of wealth. That this can be done there is no reasonable doubt; that it will be done should not be doubtful to any one who knows the activity and enterprise of our people. The advantages flowing from a successful prosecution of such an undertaking are reaped not only by the operators, but also by the entire section of country in which the work is carried on, and as, except in some favored localities, nature has not been bountiful to this region, well-directed art must extend its aid.

The expense of the necessary preliminary investigations is considerable, but without these capital can hardly be expected to take any decided steps. A great deal of information, in the aggregate, has been gathered by various observers, but scattered as it is through various publications it is not readily available. It has therefore been deemed advisable to bring this knowledge together so that we may have a proper starting point for future work.

In proceeding to describe the localities within the boundaries of the United States only those concerning which we have reliable information will be considered, and it will be found that their number and variety are great enough to furnish types for any others which future investigators may bring to notice.

Wyoming.—Along the line of the Union Pacific Railway in the Territory of Wyoming are several places where natural soda is found. The best description of these is the following, from a paper on "Glass Materials," by Jos. D. Weeks, published by the Geological Survey in the "Mineral Resources of the United States, calendar year 1885":

> The soda property generally known as the "Union Pacific Lakes" lies about 13 miles nearly due south of Laramie and is reached by a branch of the Union Pacific Railway. The property embraces some 2,000 acres, including five "lakes," in all but one of which the soda is solid. The lakes are connected, and seem to drain one into another. All of the soil near Laramie is more or less impregnated with the sulphate of soda, and the common sources, it is believed, are springs, water from which bears large percentages of soda salts.
>
> The physical condition of the soda in the lakes varies much with the season. In wet years the soda is almost fluid, while in dry years, in all but one of the lakes, it is solid and in this one it occurs as a saturated solution. In the solid lakes the soda contains many thin layers of mixed clay and soda. Analysis of a sample of this mixture shows:

Analysis of deposits of soda salts at Laramie, Wyo.

	Per cent.
Iron, lime magnesia	22.33
Alumina, soda, hydrochloric and sulphuric acids	40.82
Silica	36.85
Organic matter	traces.
	100.00

The soda when taken pure contains large quantities of water, which fact interferes seriously with its employment in the manufacture of sodium hydrate.

Its composition only varies slightly, and the following may be taken as typical analyses:

Average analysis of soda deposits near Laramie, Wyo.

	No. 1.	No. 2.	No. 3.
	Per ct.	*Per ct.*	*Per ct.*
Sulphate of soda	44.55	41.41	39.78
Water	54.98	54.79	59.66
Insoluble matter	.47	3.80	.56
	100.00	100.00	100.00

These lakes are the only ones from which soda is being taken for use.

The soda works near Laramie were built by the Union Pacific Railway and leased to Mr. Howard Hinckley. The process used is the old "black ash," with stationary furnace. The capacity of the works is about 2 tons of sodium hydrate per day. The capacity of the furnace is 3½ tons of sodium sulphate per day. Rescreened coal from the Rock Spring Mine is used and the limestone necessary is obtained near Laramie. The "black balls," formed of the fused soda, coal and lime, are broken up and washed in four lixiviating pans, and the liquor is then taken to two settling vats. Thence it is drawn to the "causticizer," which is a large circular tank in which are two perforated vessels containing caustic lime, around which the solution of sodium carbonate is agitated. After the causticising the liquor is passed through three long circular iron settlers. The clear liquor is then drawn to the "V-pan," where waste heat is used to aid the evaporation of the solution. The slightly concentrated liquor is then drawn to the "boat pan," which is set upon the reverberatory furnace. The evaporation is then continued as long as possible, and the now concentrated solution is then drawn to another room into the "finishing pot." This is a large cast-iron pot set directly over a furnace. Here all remaining traces of water are driven off at a low red heat. The hydrate at this stage is generally black and small quantities of niter are added to the fused mass to whiten it. The hydrate is then ladled into sheet-iron vessels and shipped. Some of the Laramie caustic soda has been used by the Denver Soap Company, which reports favorable results from its use. The works at Laramie are not well adapted to the most economical handling of the soda. Improvements are now being made by which the number of men employed will be greatly reduced and the composition of the "black balls" be made more uniform.

When the soda works were first begun it was supposed that the natural occurrence of the material as a sulphate, rendering unnecessary the reduction of the chloride to the form of a sulphate, would greatly decrease the ultimate cost of the caustic soda; but it was found that the very large quantity of water present in the soda as it comes from the lakes, more than offset, by the trouble and delay it cost in the furnaces, the gain in the natural form of the soda.

The Laramie works produced from July to January, 1885, about 30 tons of caustic soda. Defects in the plant have caused great delay and loss of some of the caustic soda, and it has been decided to close the works until alterations now being made can be completed. The lessee of the works states that good reports of the caustic soda have been made by users of it.

The "Donney" soda lakes are situated about 18 miles southwest of Laramie and are three in number covering, with the land included, approximately 520 acres. In one lake the deposit is 11 feet thick; in the others it is 5 to 6 feet. The soda from these lakes is similar to that from the Union Pacific lakes and there seems to be an underground connection between the two groups. In boring an artesian well near these lakes to prospect the underlying strata, a brine was obtained which upon analysis showed—

Analysis of brine from near the Donney Lakes.

	Grains per gallon.	Per cent.
Sodium chloride	2002.0	2.86
Sodium sulphate	777.2	1.10

The large percentage of salt is very curious, as only traces of it are found in these lakes.

The soda deposits in Carbon County are situated in the Sweet Water valley, near Independence Rock, and are nearly 50 miles due north of Rawlins. These deposits contain both carbonate and sulphate of soda, and are generally known as the "Dupont Lakes." The lakes are four in number, and vary from 6 to 2,000 acres in area, and are held by United States patents in the name of L. Dupont. There are five claims known as the "New York Soda Mine," 160 acres; the "Philadelphia," 80; the "Omaha," 20; the "Wilmington," 160, and the "Wilkesbarre," 20. The Omaha soda mine includes 20 acres, of which 5 are covered with carbonate and sulphate of soda, mixed with a little chloride of sodium and sand blown in from the surrounding soil. Several bore-holes were put down and show an average thickness of about 6 feet.

Amount of Na_2Co_3 contained in the samples.

No. 1, 3½ feet from surface	per cent	24.62
No. 2, surface	per cent	41.55
No. 3, surface near shore	per cent	32.42
No. 3, water	pounds per gallon	1.33

A fused sample showed 52.23 per cent. of carbonate of soda. A fuller analysis of a sample taken from the surface showed:

Analysis of surface soda from Carbon County, Wyo.

Moisture	9.01
Insoluble	2.61
Sulphate of soda	25.75
Chloride of sodium	2.13
Carbonate of soda	30.62
Bicarbonate of soda	30.09
	100.21

Another sample from near the surface contained 56.3 per cent of water:

Analysis of dry salt.

	Per cent.
Chloride of sodium	0.65
Sulphate of soda	59.29
Carbonate of soda	27.60
Insoluble matter	1.20

The variations and the proportions of carbonate and sulphate of soda are shown by the following table, the samples having been dried:

Samples.	NaCl.	Na_2SO_4.	Na_2CO_3.
	Per cent.	*Per cent.*	*Per cent.*
Five feet below surface	0.979	64.05	15.60
Do	0.32	65.08	16.70
Surface	0.81	17.02	80.60

The Wilkesbarre claim is about one mile west of the Omaha, and the soda is in solution. Samples of this solution showed by analysis:

	Per cent.
No. 1, Na_2CO_3 grains per gallon— 3,728	=6.39
No. 2, Na_2CO_3 grains per gallon— 4,905	=8.40

The Wilmington claim is located one-quarter of a mile west of the Wilkesbarre, and covers 160 acres. The soda here is also in solution. Its depth has never been determined. It has been sounded with a 40-foot rope without finding bottom in the center. A sample of this solution contained 2,343 grains per gallon (4.01 per cent.) A sample which had crystallized out by cold, when dried showed:

Chloride of sodium	1.83
Sulphate of soda	39.04
Carbonate of soda	59.00
Insoluble matter	9.23

The New York and Philadelphia are both upon one lake, which is solid, and is 4 miles west of the Wilmington. Two bore-holes have been put down in this lake. One, at a distance of 50 feet from the shore, showed 4 feet of soda; the other, at a distance of 230 feet from the shore, passed through 14 feet of solid soda without touching bottom. Three samples taken from this lake showed as follows:

	No. 1.	No. 2.	No. 3.
Chloride of sodium	1.83	2.04	2.52
Sulphate of soda	71.37	44.77	72.40
Carbonate of soda	3.10	5.00	5.10
Insoluble matter	22.82	47.50	19.03
	99.12	99.31	99.05

Fifteen miles from these soda deposits good limestone, containing 2 per cent of magnesia, occurs in the Seminoe mountains. Near the limestone is a good 8-foot vein of coal. A comparison of the analyses from the Donney and Union Pacific lakes and those of the Dupont lakes show how much greater the percentage of carbonate of soda in the latter is. The Sweet Water country is still out of the reach of transportation, and until a railway is built in this direction these soda deposits must remain undeveloped.

The Wyoming occurrences are typical sulphate deposits, and in many respects resemble those of Armenia, already described. Although they all contain more or less carbonate, yet, so far as we now know, it is not possible to extract the carbonate economically by natural crystallization processes. Under the most favorable circumstances the use of artificial heat is necessary, and, as stated above, the native sulphate, owing to the large proportion of water, has no advantage in point of cost and ease of working over the artificial. Careful and systematic study and experiment will doubtless, however, develop a good commercial method for the treatment of this material, since fuel can be easily obtained at a steadily decreasing cost, and transportation facilities are becoming greater.

Proceeding westwardly from the Wyoming deposits one finds numerous occurrences of salts more or less alkaline in character. Descriptions and analyses of many of these are given by King[1] and Russell;[2] but

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[1] King: Geol. Expl. 40th parallel, vols. 1 and 2.

[2] Russell: Geol. Hist. of Lake Lahontan U. S. Geol. Survey, Mon. No. 11.

most of them are only thin efflorescences or incrustrations, and, so far as we know, none have any commercial value until we reach

The soda lakes at Ragtown, Nevada.–These remarkable alkaline lakes or ponds are described at length by King in the work just cited,[1] also by Russell, Monograph, 11, pp. 73–80. From the latter report the following extracts are taken:

> On the Carson desert, about 2 miles northeast of Ragtown, are two circular depressions that are partially filled with strongly alkaline waters and known as the Soda Lakes or Ragtown Ponds. * * * The larger lake is 268.5 acres in area. * * * The rim in its highest part rises 80 feet above the surrounding desert, and is 165 feet higher than the surface of the lake which it incloses. The outer slope of the cone is gentle, and merges almost imperceptibly with the desert surface; but the inner slope is abrupt, and at times approaches the perpendicular. A series of careful soundings gives 147 feet as the greatest depth of the lake. The total depth of the depression is therefore 312 feet, and its bottom is 232 feet lower than the general surface of the desert near at hand.
>
> The walls encircling the lake exhibit well exposed sections of stratified lapilli mingled with an abundance of angular grains, kernels and masses of basalt, some of which are 2 and 3 feet in diameter, and scoriaceous, especially in the interior. * * * The form of the cones and the nature of the materials of which they are composed leave no doubt this is a crater ring, viz, a low cone of eruption containing a large crater. That the cones were not formed during a single eruption, but have a long and complicated history, and are perhaps sublacustrine in their origin, is shown by the alternation of ejected and sedimentary materials in the crater walls.

"The smaller lake," according to Hague, "in most of its features, bears a close resemblance to the one just described and from which it is separated by a narrow ridge only an eighth of a mile wide. It has the same crater-like basin, but the banks are not more than 60 or 70 feet in height and the lake, even in spring, is scarcely more than one-fifth of a mile in diameter. There is no supply of fresh water from the surface, and at the time of our visit, in August, the water was much more dense than in the larger lake. Over a great part of the surface was found a thick incrustation of trona strong enough to bear up a man, under which is a greenish slime and occasional pools of water. One characteristic feature of the shore is the green and purplish tints of the moist sands, which, upon being dried, present the usual earthy colors."

The trona from the small soda lake, upon being subjected to analysis yielded the following:[2]

Sulphate of soda	0.99
Chloride of sodium	1.10
Carbonate of soda	66.27
Water and free carbonic acid	28.83
Insoluble residue	2.81
	100.00

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[1] Vol. 1, p. 510—513; vol. 2, p. 746—750.

[2] Hague: King's Rep. 40th Parallel, vol. 2, 1877, p. 749. Russell (op. cit., p. 73., note) says: "The smaller lake (in 1882) had been so changed by excavation and the construction of evaporating vats that its original form had been destroyed. Its surface is 20 feet higher than the larger lake and 65 feet below the general desert surface. The highest point on the crater rim is 80 feet above the bottom of the depression."

Hague also says of these lakes (op. cit., p. 746): "they lie below the level of the plain, in which are probably ancient craters, and are not observed until just before reaching the brink." King (op. cit., vol. 1, p. 512) considers "that during the period of the occupancy of this region by Lake Lahontan * * * these crater-like lakes were points of extremely powerful springs deriving their great activity from volcanic sources," and gives his observations at Mono Lake, to which we shall refer later.

Russell, on the other hand, says (p. 74):

> The hypothesis that the craters were formed by the action of extremely powerful sublacustrine springs, as advanced by King, would not account for the nature of the material forming the crater walls, nor the presence of the numerous volcanic bombs that depress the strata on which they rest. If the cavities owed their origin to springs of very great magnitude rising in the bottom of Lake Lahontan, it is evident that the outflowing waters would have cut channels of overflow when the lake evaporated to a horizon below the rim of unconsolidated material that surrounded them; but the crater walls are now continuous and unbroken by stream channels. On the other hand, had the springs become extinct before the evaporation of the lake, the cavities they formerly occupied would be buried beneath lake beds. This, as our observations show, is not the case, but both the inner and outer surfaces of the cones are free from lake sediments. The latest additions to the cones must have been of post-Lahontan date. * * * There are no streams either tributary to or draining these lakes; their total water-supply, excepting the small amount derived from direct precipitation, is derived from subterranean sources. Around the immediate shores of the larger lake there are a number of fresh-water springs; the largest of these is situated on the northern border of the basin and issues from a small fault at an elevation of about 15 feet above the water surface. As the lake is 50 feet below the level of the Carson River at its nearest point, we may safely look to this stream as the probable source of the water-supply, which reaches the craters by percolation through the intervening marls and lapilli deposits. The bottom of the lake is a continuation of the slope of the inner walls of the crater, * * * is a fine black tenacious mud, having a strong odor of sulphuretted hydrogen. When exposed to the air for some time this material loses its inky color, and shows itself to be of the same nature as the fine dust-like lapilli that form a large part of the crater walls. The organic matter impregnating these sediments is evidently derived from the millions of brine shrimps (*Artemia gracilis*) and the larvæ of black flies that swarm in the dense alkaline waters.

My own observations in the summer of 1887 were confined to the technical aspects of the manufacture of sodium carbonate as carried on there, and the short time at my disposal did not allow me to take more than a cursory view of the formation, but I have little doubt that Mr. Russell's conclusions are correct, since they are supported by what may be seen at both Mono and Owen's Lakes.

The details of the manufacture of soda at these lakes are of great interest, since, as they differ so greatly in composition, an entirely different method must be employed for each.

The water of the larger lake collected in 1867 was analyzed by O. D. Allen (King's Rep., vol. 2, p. 747), and two samples, collected in 1882 by Mr. Russell in the central portion of the lake at the respective depths of 1 foot and 100 feet, were examined by me. My results, given below, agree very well, but differ from those of Allen mainly in that he reports the existence of sulphides, while I was unable to find any. If, as is very probable, Allen's sample was shipped to him in a keg, the presence of sulphides is easily accounted for by the reduction of sulphates by the action of the wooden vessel, since every sample of alkali water sent to this office in kegs has shown decomposition with resulting sulphuretted hydrogen, while the same material shipped in glass, as were Mr. Russell's waters, was free from it.

The variations in composition between the water at 1 foot and that at 100 feet may in part be due to the fact that the mother liquors of the soda works are run back into the lake. These mother liquors are poorer in carbonate and richer in chloride than the original water, and may in the course of years have changed the composition of the upper part of the lake.

The results are stated in grams per liter,[1] and the hypothetical combinations between the constituents are such as they may reasonably be expected to form. The columns of percentages show the relation of the constituents to each other, and will be found of practical value.

	No. 1 (1 foot).		No. 2 (100 feet).	
Specific gravity at 19.8° C.	1.0995.		1.0983.	
	Weight.	Per cent.	Weight.	Per cent.
Silica, SiO_2	.304	.24	.310	.25
Magnesium, Mg	.270	.21	.270	.21
Potassium, K	2.520	1.95	2.670	2.13
Sodium, Na	45.840	35.53	44.270	35.23
Boric acid, B_4O_7	.314	.24	.3.7	.26
Chlorine, Cl	45.690	35.41	44.270	35.23
Sulphuric acid, SO_3	10.8.0	8.37	10.593	8.43
Oxygen, O	2.160	1.68	2.117	1.69
Carbonic acid, CO_2	15.351	11.89	15.128	12.04
Oxygen, O	5.583	4.34	5.501	4.38
Hydrogen (in bicarbonates) H	.179	.14	.188	.15
	129.011	100.00	125.644	100.00

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[1] The statement of results of analyses of such waters as so many grammes to the liter is preferable to the usual method of stating them as so many parts per thousand or per million. Any one handling such material necessarily measures his solutions by volume and his products by weight. The metrical system is used throughout as in every respect more practical for the manufacturer, being not only a decimal system, but also giving an instantaneous conversion from measure to weight, and vice versa, without the labor of calculation. As small variations are sometimes met with in the tables found in ordinary books, we give the following as the best for comparison:

A liter of pure water at 4°C = 1000 grammes = 1 kilo = 2.2046 lbs. = .264131 U. S. gallons, 1000 kilos = 1.1023 ton (2000 lbs.). 1 U. S. gallon = 3.786 liters.

1 meter = 39.3708 inches. 1000 liters = 1 cubic meter.

The specific gravity of a liquid is the weight of a liter in grams. Thus a liter of Ragtown water, specific gravity 1.0995, weighs 1099.5 grams and a cubic meter 1099.5 kilos.

Hypothetical combination.	No. 1.		No. 2.	
	Weight.	Per cent.	Weight.	Per cent.
Silica, SiO_2	.304	.24	.310	.25
Magnesium carbonate, $MgCO_3$	.945	.73	.945	.75
Potassium chloride, KCl	4.808	3.73	5.094	4.06
Sodium chloride, NaCl	71.521	55.44	68.957	54.88
Sodium sulphate, Na_2SO_4	19.170	14.86	18.800	14.96
Sodium, bi-borate (borax) $Na_2B_4O_7$	.406	.31	.423	.34
Sodium carbonate, Na_2CO_3	16.868	13.08	15.484	12.32
Sodium bicarbonate, $NaHCO_3$	14.989	11.61	15.631	12.44
	129.011	100.00	125.644	100.00

The Ragtown Soda Works.—Mr. Russell's monograph contains an excellent map of the two lakes, drawn on so large a scale that the evaporating vats and their arrangements are clearly shown. He also gives many details of the manufacturing processes employed.

Two sets of works were in operation at the "Big Lake" in 1887, one belonging to Griswold & Epperson, the other to Smith & Allen. Both works use the same process and the evaporating vats are alike. Owing to the narrowness of the beach it was necessary to build the vats in the water, which was done by running out levees at right angles to the shore and connecting the ends of these by a main dike, thus forming rectangular compartments, which by use gradually became practically water-tight. Along the shore back of the vats runs a ditch, which is kept filled with lake water, and from this the vats are filled as needed.

Certain of the vats are used as "crystallizers," the rest as "evaporators." At the beginning of the season all are filled with lake water, and as this concentrates it is drawn from the evaporators into the crystallizers, so as to keep the latter at the proper depth—about 12 to 15 inches. As fast as this is done the evaporators are filled up with lake water from the ditch. In concentrating the brine gradually becomes a deep red (see page 95) and when it reaches 30° Baumé crystallization usually begins. From this time on, the crystallizers must be carefully watched lest the soda as it forms should be too much contaminated with sulphate or chloride. There is no simple means of detecting the formation of sulphate, but when common salt forms it crystallizes in minute glistening cubes upon the surface of the brine. A sudden lowering of the temperature generally has this effect, which must be remedied by drawing off a part of the mother liquor and supplying its place with concentrated brine from the evaporaters or even with lake water. This drawing off is, of course, only necessary if the vat is already full, otherwise the concentrated brine or lake water is added directly to the vat in sufficient quantity to re-dissolve the NaCl.

The crystallization process is allowed to go on in this manner until the sheet of crystals at the bottom of the vat has grown thick enough to be easily gathered or "lifted," say one-half inch to 1½ inches. The mother liquor is then drawn off into the lake, and the crop lifted and stacked up to drain. As this soda is made during the summer it is known as "summer soda," and is the product of the Big Lake. This is the material called in King's report "trona," but is in reality "urao," as will be shown by the analysis on page 52. In the process of gathering the crystal sheet is broken up into cakes, which are a hard and compact aggregate of crystals sometimes well-formed.

When the crop is drained it is heated in a furnace to remove the water of crystallization and the excess of carbonic acid, and is then sacked and shipped as "soda ash."

The furnace is a single hearth reverberatory, the hearth bed being made of iron plate. The fire gases pass over the charge to the end of the hearth, then through two side flues, one on each side, under the iron plate, back to the bridge wall, thence return through a center flue to the end of the hearth, where the stack is placed. The soda is dumped through an opening in the top of the arch onto the hearth, and is spread out evenly and heated for three hours, and then stirred from time to time until it is entirely dry. The furnacing as there practiced is a very simple operation, as the material parts with its water readily, and does not fuse, or even sinter, unless the heat is too high, and this is easily prevented by a little care in the stirring. In regular operation nine charges are worked off in a week; the fuel is sage-brush, gathered in the vicinity. Annual production about 450 tons, but this could easily be made much larger.

The operations at the Little Lake are conducted on an entirely different principle. The lake, as described in King's report, no longer exists, but the present appearance of the place is well shown in Russell's map. In the center of the depression there were at the time of my visit (1887) four large but shallow pits, besides a shallow pool somewhat larger, and filled with fresh water from the small springs which issue from the sides of the crater. Two of the pits are used as crystallizers and are supplied from the others, which contain a lye of about 12° to 13° Baumé. The lye is formed by the gradual solution of the "ledge" or deposit of crystallized sodium carbonate which exists in the bottom. No analysis of this ledge has so far as is known ever been made, and in consequence of the work which has been done it is difficult to obtain specimens. That material which was dug out for me had a close resemblance to dirty ice, although at one time it could be obtained in masses of considerable size and quite clean. Its appearance and the nature of its solution leave no doubt that it is a natural "crystal soda" or Na_2CO_3 $10H_2O$ in a comparatively pure condition.

The solution of this deposit, owing to the small amount of bicarbonate present, yields but little "summer soda." The concentration therefore continues, more lye being added from time to time until cold weather sets in. Usually by January the lye is sufficiently concentrated and chilled, resulting in a copious crystallization of "winter soda" or Na_2CO_3, $10H_2O$, which is deposited on the thin layer of summer soda on the bottom of the vat.

When no more crystals appear to form, by which time the deposit is 10 or 12 inches thick, the crop is lifted and carefully stacked preparatory to the drying process, the most delicate part of the work. The $10H_2O$ salt contains 63 per cent. of water, and parts with most of it with great ease and rapidity, so that if heated to 33°C. (90°F.) it melts in its own water of crystallization and becomes a liquid. In drying the crop great care must therefore be exercised lest the material should become liquid and much of it be lost.

The crop is therefore kept in the stacks until the approach of warm weather, when it is broken up and spread in a layer two or three inches deep on the drying floors, which are covered with light sheds open at the sides. The material is turned over from time to time and the lumps broken up. When the drying is completed the product is a thoroughly effloresced white powder, in which the summer soda appears as small pieces of thin cakes. The annual product amounts to about 300 tons.

Before giving the analyses of the products of the two lakes, a few words of comparison between these two processes will aid much in giving a clear understanding of the meaning conveyed by the analytical figures.

The analysis of the water of the Big Lake has already been given. Though no analysis of the deposit of the Little Lake can be furnished, it is evident that it must give a solution much poorer in chloride and sulphate than the first locality. Let us see why this must be so.

When Hague visited these lakes in 1868 they had never been worked, and were therefore in their original condition. From the Little Lake he collected the material of which the analysis is given on page 46. On the shore of the Big Lake there were "large fields of dazzling white carbonate of soda," a sample of which was examined by O. D. Allen with the following results:

Water, H_2O	19.90
Insoluble residue	.80
Sulphuric acid, SO_3	.73
Chlorine, Cl	.98
Carbonic Acid, CO_2	36.86
Soda, Na_2O	40.55
	99.82
Deduct oxygen = Cl	.22
	99.60

The deduction of oxygen=Cl is made because the whole of the Na is calculated as oxide Na_2O, whereas that part combined with Cl is present as Na.

To compare these two analyses, let us calculate the hypothetical combination of this last analysis and place it side by side with the first one, in which the 28.83 per cent. of CO_2 and H_2O have been divided into the constituents, so that the full theoretical amount of Na_2CO_3 is supposed to be present. If the theoretical amount of $NaHCO_3$ be taken, the results will be found to vary very slightly.

	Big Lake.	Little Lake.
Insoluble matter	.80	2.81
Sodium sulphate, Na_2SO_4	1.29	.99
Sodium chloride, NaCl	1.61	1.10
Sodium carbonate, Na_2CO_3	45.05	44.25
Sodium bicarbonate, $NaHCO_3$	34.66	34.90
Water, H_2O	16.19	15.95
	99.60	100.00

If we were to deduct the insoluble matter from each of these analyses and recalculate them we should find but little difference between the two samples, which will be referred to later in the section treating of urao. They evidently represent the first and purest crystallization of the "summer soda" from the two lakes.

At the Big Lake, however, the process must stop at the point where this crystallization is obtained, while at the Little Lake the process is allowed to go on and the "winter soda" is collected with the summer product. Russell procured samples of the "market soda" from each of these lakes, but neither of them seems to have been correctly taken, as the Little Lake soda contains too large a proportion of summer soda and the Big Lake material is the result of attempts, which naturally failed, to make winter soda at that place.

	Big Lake.	Little Lake.
	F. W. Taylor.	Chatard.
Silica, SiO_2	.449	.27
Iron and alumina, Fe_2O_3, Al_2O_3	.011	....
Calcium sulphate, $CaSO_4$	.038	....
Magnesium sulphate, $CaSO_4$	.040	....
Sodium chloride, NaCl	2.193	3.31
Sodium sulphate, Na_2SO_4	49.437	5.10
Sodium carbonate, Na_2CO_3	40.714	52.20
Sodium bicarbonate, $NaHCO_3$	....	25.05
Water, H_2O	7.118	14.16
	100.000	100.09

These two analyses are valuable for comparison in this connection, although in the first one the acid CO_2 of the $NaHCO_3$ was not determined, being included in the H_2O which was evidently determined by difference. The chilling of the solutions would not materially increase the deposition of NaCl, but would greatly increase that of Na_2SO_4, hence the solution of the Little Lake must contain much less of the latter salt than the other water, the analysis of which has been given.

The combined product of the two lakes, as has been stated, is about 750 tons per annum. The Little Lake has nearly reached the limit of its annual capacity, but the Big Lake might without great expense yield far more. With proper working the two lakes should yield 1,500 tons per annum.

Mono Lake, Mono County, Cal.—A very extensive description of this locality is given by Mr. I. C. Russell in his article "Quaternary History of Mono Valley," in the Eighth Annual Report of the U. S. Geological Survey, and I can only repeat what I have elsewhere said "that this large body of water, of a composition so favorable to utilization, is, for practical purposes, inaccessible and that the high altitude and consequent shortness of the evaporating season would, under any circumstances, render the success of any industry established there very doubtful.[1] The composition of the water is, as shown by the annexed analysis, very similar to that of Owen's Lake, which will be considered directly, and the same methods of economic treatment would apply to both, but owing to the reasons given above, there is little prospect that any extended use of the water of Mono Lake can ever be made.

The sample analyzed was collected by Mr. Russell in 1882 and was taken at the depth of one foot, on east side of lake.

Specific gravity, 1.045 at 15.5°.

	In 1 liter.	Per cent.	Hypothetical composition.		Per cent.
SiO_2	.0700	.12	SiO_2	.0700	.13
K	.9614	1.79	$(Al_2Fe_2)O_3$	.0030	.005
Na	19.6853	36.81	$CaCO_3$	.0500	.09
Ca	.0200	.037	$MgCO_3$	.1928	.36
Mg	.0551	.10	$Na_4B_4O_7$	.2071	.39
$(Al_2Fe_2)O_3$	.0030	.005	KCl	1.8365	3.44
SO_4	6.6720	12.480	NaCl	18.5033	34.60
CO_3	13.6903	25.61	Na_2SO_4	9.8690	18.45
B_4O_7	.1600	.30	Na_2CO_3	18.3556	34.33
Cl	12.1036	22.64	$NaHCO_3$	4.3856	8.20
H	.0522	.10			
	53.4729	100.00		53.4729	100.00

Abert Lake, Oregon.—This lake, situated in southeastern Oregon, may in time become of considerable importance, for though at present far distant from railroads and hence unavailable, yet with proper transpor-

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[1] Chatard, Am. Jour. Sci., ser. 3, vol. 36, p. 148.

tation facilities the water could be utilized. The subjoined analysis of the water shows it to be the best suited for solar evaporation of all the lakes of the Great Basin, since, though not as concentrated as some others, the relation of the constituent salts is such that simple evaporation should give a very pure product. Summer Lake, not far distant, is supposed to have a similar composition.

Both lakes have been described by I. C. Russell[1] and by H. T. Biddle.[2] Mr. Russell's paper contains the following analysis of the waters of Abert Lake, which shows a very large percentage of potash (loc. cit. p. 454).

Sp. G., 1.02317.	Grams in liter.	Sp. G., 1.02317.	Grams in liter.
Silica in solution..	0.065	K_2CO_3	10.961
NaCl...............	7.219	$MgCO_3$	.006
KCl................	8.455		27.357
K_2SO_4	9.921		

From what is known of geological chemistry and the phenomena of rock decomposition, it is safe to say that no lake of this composition, or containing such a large proportion of potash, could be formed, but if such an occurrence should ever be discovered, the rock decompositions yielding such a solution must necessarily be entirely different from all those so far observed. It is due to my friend Dr. Taylor, who made the analysis in 1882, to state that when, some years later, his attention was called to this matter he at once recognized the unlikelihood of such a composition, but as the balance of his sample had not been preserved and he was unable to find the figures of his analyses, he could not rectify the error, which is probably only a simple arithmetical error of calculation in the estimation of the alkalies.

Mr. Biddle collected and examined a sample of the water of Abert Lake, and being unable to verify Dr. Taylor's results sent me the residue of his sample, which was examined with great care to settle the doubt. The sample was "collected by H. T. Biddle at middle of west side of lake, one foot below surface, 30–40 feet from shore, September, 1887." The total quantity at my disposal was about 200cm.^{3}, an amount too small for any extended research, but sufficient for all practical purposes. For each determination, 25cm.^{3} = 25.7792 grams were taken.

Specific gravity, 1.03117 at 19.8°.

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[1] Russell: Geological Reconnaissance in Southern Oregon, Fourth Annual Report U. S. Geological Survey, p. 435 et seq.

[2] Biddle, H. T.: Am. Jour. Sci., 3d ser. vol. 35, p. 475.

	Contents in 25 cm³.			In 1 liter.	Per cent.		Hypothetical composition.	Per cent.
	A.	B.	Average.					
SiO_2	.0063	.0053	.00580	.232	.59	SiO_2	.232	.59
K	.0133	.0136	.01345	.538	1.37	KCl	1.027	2.62
Na	.3674	.3671	.36725	14.690	37.51	NaCl	21.380	54.58
SO_3	.0148	.0146	.01470	.588	1.50	Na_2SO_4	1.050	2.68
O	.0030	.0029	.00295	.118	.30	Na_2CO_3	10.611	27.09
CO_2	.1755	.1757	.17560	7.024	17.93	$NaHCO_3$	4.872	12.44
O	.0615	.0616	.06155	2.462	6.28			
Cl	.3365	.3366	.33655	13.462	34.67			
H in bicarbonates				.058	.15			
				39.172	100.00		39.172	100.00

This analysis shows, as would be expected, that the water of Abert Lake does not differ materially from that of any other alkali lake so far discovered. Its low percentage of sulphate is its greatest merit, since, as will be shown under the section treating of Owen's Lake, it is of all the impurities the most difficult to remove and the most deleterious when present.

Dry deposits in the United States.—With the exception of Owen's Lake, the foregoing are the only lakes which have a prospective value for the alkali industry, although there are many others which are alkaline, but are too dilute for profitable working. There is, however, another class of alkali occurrences which may in time become available, though at present of minor importance. These are the so-called dry deposits left by the desiccation of shallow lakes formed in the wet season by the drainage of the surrounding country, but drying up more or less completely during the summer, leaving an incrustation of salts often of considerable extent, though usually of no great thickness.

In the region of the Black Rock Desert and adjacent parts lying between Abert Lake and the line of the Central Pacific Railway there are many places which furnish such salts. The following analyses will give an idea of their composition:

No. 1. Soluble portion of incrustation from near Black Rock Point, Black Rock Desert. Chatard. I. Russell, Monograph XI, U. S. Geological Survey, p. 231.
No. 2. Quinn's River salts. O. D. Allen. King, 40th Parallel Survey, vol. 2, p. 791.
No. 3. Hardin City salts, O. D. Allen. King, ibid., p. 792.

	No. 1.	No. 2.	No. 3.
SiO_2	2.18	*1.82	
KCl	1.39	†8.57	
NaCl	59.32	85.27	18.47
$Na_2B_4O_7$ (borax)	1.00		
Na_2SO_4	27.05	1.75	27.55
Na_2CO_3	9.06	2.59	52.10
	100.00	100.00	98.12

*Residue. †Water.

The next five are also from King's 40th Parallel Exploration, and show the general character of the alkaline incrustations of eastern and central Nevada. In each case the amount of H_2O necessary to form $NaHCO_3$ has been added and the analysis calculated to 100 per cent. for comparison.

No. 4. Ruby Valley, Nevada (Woodward), vol. 1, p. 503.
No. 5. Valley of Deep Creek, Utah (Woodward), vol. 2, p. 474.
No. 6. Antelope Valley, Nevada (Woodward), vol. 2, p. 541.
No. 7. Humboldt Valley, Nevada (Woodward), vol. 2, p. 594.
No. 8. Brown Station, Humboldt Lake (Woodward), vol. 2, p. 744.

	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
K_2SO_4	2.79	4.68	1.88	....	....
Na_2SO_4	28.32	17.43	33.31	4.42	49.67
NaCl	2.11	38.01	24.51	7.24	20.88
Na_2CO_3	58.69	25.12	25.95	48.99	7.02
$NaHCO_3$	8.09	14.76	14.35	36.01	11.13
$Na_2B_4O_7$	....	....	....	3.34	11.30
	100.00	100.00	100.00	100.00	100.00

At many localities in western Nevada and in that portion of California east of the Sierra, incrustations of like character occur. Of these perhaps the most important are the soda lakes in Long Valley, California, lying southeastwardly of Mono Lake. The country is highly volcanic and the rocks are in many places much decomposed, having upon them efflorescences and incrustations. There are many warm springs, the waters of which flow into the lakes. These are several in number, connected together, with a drainage during the wet season into the headwaters of Owen's River. The shore shows in most places a salt crust around the margin, but in the hurried visit I paid this locality in the summer of 1886, I had no time to make a more particular examination, especially as the lakes are the deepest portions of extensive morasses, which in the winter are completely flooded. In the vicinity are large stretches of playa covered with thin sheets of alkaline salts, which are said to grow to the thickness of two or three inches on the approach of cold weather, when the material is gathered for the use of the mills at Bodie. A little to the north of the lakes is a so-called "hopper," a depression in the plain resembling on a small scale the Little Lake at Ragtown. The deepest part is filled with a small pool on which is a salt crust which covers the remainder of the bottom. The alkali from this place is also collected. Were there any facilities for transportation Long Valley might be made to yield a considerable amount of soda annually.

There are many other localities in this region, but further enumeration would be useless as the entire country is volcanic in its character, and so far as there is any drainage the water flows into Owen's Lake.

Owen's Lake.—By far the most important natural source of soda is Owen's Lake, Inyo County, California, both on account of its magnitude and of the facilities for carrying on extensive operations.

It was visited by a party of the Wheeler Survey in 1875, and is described in the reports of Lieutenant Birnie and Dr. Oscar Loew, published in "Report of U. S. Geographical Surveys west of the 100th Meridian, 1876," pp. 130–135 and 189–190. Both in the summer of 1886 and of 1887 I spent some time at the lake, and as the Inyo Development Company has begun the manufacture of soda at Keeler, a small village on the shore of the lake at the terminus of the Carson and Colorado Railroad, every needed facility for observation and experiment was most courteously extended.

Loew (loc. cit.) states that the greatest length of the lake is 17 miles, its greatest width 9 miles, and greatest depth 51 feet. The total surface is given by him as nearly 110 square miles, and from his analysis of the water he calculates the total contents of the lake in sodium carbonate as 22,000,000 tons, and suggests the utilization of this great chemical treasure.

The lake lies between the Sierra Nevada on the west and the Inyo range on the east and has no outlet, the lowest point of the rim of the valley to the southward being, as I am informed, about 50 feet higher than the present level of the lake. On the western side several small streams from the Sierra make their way to the lake, but the greater portion of the water supply is furnished by the Owen's River which empties into the lake at its northern end. This, according to Loew, is a stream about 30 feet wide, 2 feet deep, with a velocity of about 5 miles an hour. It was my intention to collect accurate data concerning this river, as well as to get samples of the water taken at different points so as to determine the origin of the carbonate in the lake, but circumstances have prevented the prosecution of this part of the investigation.

As would be naturally expected the lake is somewhat higher in the spring than in the autumn, but its average depth suffers but little change, hence the evaporation from its surface seems to be at present about equal to the amount of water received from all sources. As the valley lies between two high ranges of mountains, and is open to the north and south, there is usually a good breeze through the greater part of the twenty-four hours, thus much increasing the evaporation which may safely be taken as about 5 feet in the year, though experiments give a larger result.

On the eastern side, the valley slopes gradually from the foot-hills to the lake. The shore is covered in most places with a strong growth of salt grass, though there are extensive sandy flats which are bare.

In the lake itself are large quantities of a sort of "algous or fungoid plant, floating in small globular masses of a whitish or yellowish green" (Loew). This collects in patches upon the water and becomes black with the clouds of "alkali flies" or ephydra which settle on it. In addition to the larva of these flies the water swarms with the artemia.

A carefully selected sample of the water of this lake taken September 17, 1886, gave me the following results. All the determinations were made in duplicate, the duplicates agreeing very closely. Specific gravity, 1.062 at 25°.

	In 1 liter.	Per cent.		Hypothetical composition.	Per cent.
SiO_2	.220	.28	SiO_2	.220	.28
K	1.644	2.13	$(Al_2Fe_2)O_3$	.038	.13
Na	28.500	36.96	$(CaMg)Co_3$	.055	
Ca	.014	.02	$Na_4B_4O_7$	.475	.63
Mg	.005	......	KCl	3.137	4.07
Fe_2O_3	.014	.02	NaCl	29.415	38.16
Al_2O_3	.024	.03	Na_2SO_4	11.080	14.38
SO_4	7.505	9.73	Na_2CO_3	26.963	34.95
B_4O_7	.367	.49	$NaHCO_3$	5.715	7.40
CO_3	19.398	25.16			
Cl	19.344	25.09			
H	.063	.10			
	77.098	100.00		77.098	100.00

Owen's Lake Soda Works.—The works of the Inyo Development Company begun in the winter of 1885-'86, had so far progressed by the summer that a small amount of crude soda was produced. Lack of experience on the part of those in charge caused, however, many delays and disappointments, and it was not until the summer of 1887 that, under the management of Mr. Frank Gray, formerly of Ragtown, a fair start was made.

There are now nearly 15 acres of vats, mostly well made. The slope of the ground is such that the vats can be, in general, arranged in two lines so that the upper ones can be used as evaporators, the lower as crystallizers. By the method introduced by Mr. Gray the lye is allowed to concentrate in the crystallizers, more concentrated solution from the evaporators being added from time to time, till a sufficient quantity of the first crop is formed. This first crop is, however, comparatively soft and mushy owing to the small size of the crystals, so the mother liquor is drawn off; clear, well-settled lake water is added in sufficient quantity to redissolve the crystals and when this is done as completely as practicable, the vat is then filled up from the evaporators. By this means a new solution is obtained, containing a much smaller proportion of chlorides and sulphates than the original lake water, and the crystals obtained from it are much larger and purer. The crystallization is allowed to go on, with additions from the evaporators until the cooler weather begins, when the soda is lifted.

The cake is then two or more inches in thickness, and if proper care be taken during its formation it should be quite clean and contain but little sulphate or chloride. An analysis of a sample of the crop of 1887, a good specimen but not better than could be made on a large scale with experience and judicious management, is given on page 76; "best specimen," while the "crude" is the undissolved first crop.

The process of furnacing this material so as to convert it into soda ash is very simple and easy, since the water and acid CO_2 is driven out at a temperature but little above 150° C. (300° F.), and no fusion takes place. If the material represented by the "best specimen" be thus heated it would give an ash containing 97.77 per cent. Na_2CO_3, while the "crude" treated in the same manner would yield a 94 per cent. ash. When we consider that these favorable results have been obtained in the infancy of a process, without special skill or experience, it is not unreasonable to expect that, under proper technical management and with suitable arrangements and appliances, a product averaging 98 per cent. Na_2CO_3 can be made regularly and in large quantities, at this locality.

The calculation of Loew shows that this lake contains 22,000,000 tons of Na_2CO_3, and if we make the moderate estimate that one-half of this amount can be extracted from it, and consider the natural advantages of climate and of the character of the shore which in many places is well adapted for the location of extensive works, there seems to be no reason why, in time, a large and flourishing industry should not develop there.

The small amount of the annual rain-fall and the very great annual evaporation resulting from a long season of very warm and dry weather, are extremely favorable. No experiments determining the annual excess of evaporation over precipitation, have been made in this region, but we have reason to think that it is not less than 7 feet per annum. The experiments now to be detailed show a much greater rate, but as they were carried on in small vessels fully exposed to the rays of the sun, the daily loss is, of course, far larger than would occur when an earth vat of large size is used for the purpose.

EXPERIMENTS ON THE EVAPORATION AND FRACTIONAL CRYSTALLIZATION OF THE WATER OF OWEN'S LAKE.

These investigations were made during the summer of 1886, for the purpose of obtaining information needed for the devising of manufacturing methods suitable for such waters.

Evaporation.—On September 6, noon, a granite-ware pot 7½ inches interior diameter, 6 inches deep, with straight sides, was filled 5¾ inches deep with lake water, specific gravity 1.057 at 18.3° (65° F.) The pot then contained 8½ pints, the measurement of depth being made by sliding a rule along the side of the vessel until the lower end of the rule just touched the water. By having a thin strip of metal bent over the edge of the vessel the measurements can be made very closely. By using short hydrometers the specific gravity of the solution could be readily taken without disturbing the liquid.

Date.	Hour.	Depth to surface.	Loss.	Specific gravity.	Temperature.	Remarks.
		Inches.	*Inches.*			
Sept. 6	12 m	¼	....	1.057	65° F. 18.3° C.	Filled pot; water filtered and clear.
Sept. 7	7.30 a. m.	⅞	⅝	1.07	60° 15.5°	
Sept. 7	5.30 p. m.	1¼	⅜	....		
Sept. 8	8.40 a. m.	1⅝	⅜	1.077	71° 21.7°	
Sept. 8	4.35 p. m.	2	⅜	1.082	82° 27.8°	
Sept. 9	7.45 a. m.	2¼	¼	1.090	75.5° 24°	
Sept. 9	4.15 p. m.	2½	¼	1.093	85° 29.4°	
Sept. 10	8.25 a. m	2¾	¼	1.103	71° 21.7°	Slightly whitish deposit at edge of liquid. Liquid slightly turbid.
Sept. 10	5.15 p. m.	3	¼	1.110	85° 29.4°	
Sept. 11	7.50 a. m.	$3\frac{3}{16}$	$\frac{3}{16}$	1.120	67.5° 15.8°	A minute surface crystallization observed, probably $CaCO_3$. Liquid more turbid.
Sept. 11	5.15 p. m.	3½	$\frac{5}{16}$	1.127	84° 28.9°	Hot wind from south.
Sept. 12	8.30 a. m.	3⅝	⅛	1.138	74° 23.3°	Liquid quite turbid. A thin granular precipitate on bottom and sides of vessel.

The concentrated solution was at this time transferred to a smaller granite-ware pot 6½ inches wide, 5½ inches deep. The surface of the solution was 2¼ inches below edge of pot, and, as the capacity of the vessel had been carefully measured for successive depths, the volume of the solution was 3½ pints. The granular precipitate which adhered to the large pot consisted of $CaCO_3$ with a little Fe_2O_3.

As the original solution measured 8½ pints there was a loss of 5 pints, or 58.82 per cent., in bringing it to 1.138 (18° B.) at 23.3° (74° F.). When the liquid reaches 1.096 (13° B.) it begins to deposit its $CaCO_3$, the maximum of deposit being at about 1.130–1.138 (17°–18° B.). No increase of deposit was observed after the latter point was reached.

Date.	Hour.	Depth.	Loss.	Specific gravity.	Temperature.	Remarks.
		Inches.	*Inches.*			
Sept. 12	4.45 p. m.	$2\frac{9}{16}$	$\frac{5}{16}$	1.150	$\frac{89^\circ}{31.67^\circ}$	
Sept. 13	7.35 a. m.	$2\frac{3}{4}$	$\frac{3}{16}$	1.165	$\frac{64^\circ}{17.78^\circ}$	
Sept. 13	4.45 p. m.	3	$\frac{4}{16}$	1.175	$\frac{84.5^\circ}{29.1^\circ}$	
Sept. 14	8.20 a. m.	$3\frac{1}{4}$	$\frac{4}{16}$	1.190	$\frac{72^\circ}{22.2^\circ}$	
Sept. 14	5.00 p. m.	$3\frac{1}{2}$	$\frac{4}{16}$	1.215	$\frac{85^\circ}{29.44^\circ}$	
Sept. 15	9.00 a. m.	$3\frac{10}{16}$	$\frac{2}{16}$	1.232	$\frac{75^\circ}{24^\circ}$	
Sept. 15	4.30 p. m.	$3\frac{3}{4}$	$\frac{2}{16}$	1.250	$\frac{87.5^\circ}{23.9^\circ}$	
Sept. 16	8.45 a. m.	$3\frac{7}{8}$	$\frac{2}{16}$	1.260	$\frac{77^\circ}{25^\circ}$	Incipient crystallization.
Sept. 16	4.35 p. m.	4	$\frac{2}{16}$	1.273	$\frac{100^\circ}{37.78^\circ}$	Crust formed.

At 8.45 a. m., the solution measured $1\frac{2}{3}$ pints. Hence during the concentration to the crystallizing point the liquid lost $6\frac{5}{6}$ pints, or 80.4 per cent. of its bulk, or 5 volumes of Owen's Lake water at the specific gravity and temperature above given are reduced to one volume when crystallization begins. From these figures the proper relation between the evaporating and the crystallization surface is at once obtained. As should be expected the daily loss diminishes as the solution concentrates; the total time of evaporation was nearly ten days, the average loss one-half inch per diem, maximum loss one inch, minimum one-fourth inch. Observations on earth vats, although roughly made, indicate an average evaporation of one-fourth inch in twenty-four hours under the same circumstances.

The rapid heating of the solution as soon as a crystal crust had formed on the surface is also worthy of notice.

Fractional crystallization.—The following experiments were made in order to determine the character and composition of the successive crops of crystals obtained by the continued evaporation of a portion of Owen's Lake water, until the point is reached when the sun's heat is no longer sufficient to drive off the water except with great slowness; or, in other words, to observe the gradations and extent of a practical soda evaporation.

September 3, 11.30 a. m.—Five quarts of filtered, partly concentrated lake water were put into each of two granite-ware pans, which were then placed in the sun. The water had a specific gravity of 1.135 at $\frac{80^\circ}{26.67^\circ}$, the 10 quarts, so taken, being equivalent to 25 quarts of original water.

September 5, 8.30 a. m.—The solution in each pan had deposited a small quantity of a fine granular precipitate, while a few stout acicular crystals were floating on the surface. Solution pan No. 1, 1.282; No. 2, 1.270, both at $\frac{65^\circ}{13.3^\circ}$. Filled up pans with filtered water from vat, specific gravity 1.19 at $\frac{76^\circ}{24.4^\circ}$, adding to each 3 quarts, equivalent to 7½ quarts original water. The total amount in the two pans was therefore equivalent to 40 quarts of lake water.

September 6, 7.30 a. m.—Both pans showed a large crop of crystals on bottom, while the liquid was turbid, with small crystals floating in it. Specific gravity of both solutions, 1.250 at $\frac{60^\circ}{15.5^\circ}$.

September 7.—Both pans had a stout crust with large deposit.

3.45 p. m.—Poured off mother liquor from both pans and drained crystals. The crop A1 weighed 1½ pounds when dry. The combined mother liquors measured 5½ quarts and had a specific gravity of 1.312 at $\frac{80.5^\circ}{27.9^\circ}$. This was put in one of the pans and allowed to evaporate.

September 8.—The solution was covered by a thin crust, with a considerable deposit of minute crystals on bottom.

September 9.—Poured off mother liquor from second crop, A2, which weighed 1 pound, and drained the crystals thoroughly. Mother liquor 1.312 at $\frac{77^\circ}{25^\circ}$.

September 10, 8.30 a. m.—Pan showed a considerable deposit of fine granular salts with thin crust on surface.

September 11, 8.30 a. m.—Drew off mother liquor and secured third crop, A3., which was highly saline to taste, and weighed three-fourths of a pound. The mother liquor had a specific gravity of 1.315 at $\frac{79.25^\circ}{26.25^\circ}$.

September 12, 5 p. m.—The solution was covered with thin, floating crusts, and its temperature was $\frac{103^\circ}{39.44^\circ}$, while the same thermometer exposed for five minutes to the direct rays of the sun showed barely $\frac{90^\circ}{32.2^\circ}$; another solution; B, of about 1.29 showed $\frac{91^\circ}{32.78^\circ}$.

The evaporation of this concentrated solution was very slow, so it was undisturbed until the 18th, when, as no further reduction in volume could be observed, the mother liquor was poured off, leaving the fourth crop A4. It had a specific gravity of 1.327 at $\frac{96.6}{35.75}$.

To observe the effect of cold at this stage, the vessel containing the solution was surrounded with ice. After four hours, at a temperature of $\frac{45^\circ}{7.22^\circ}$ a large deposit of a slushy material, looking like wet snow, was obtained. This crop, A5, was collected and placed in a pan to dry, but speedily melted in its water of crystallization, afterwards becoming a dry cake on the bottom of the pan. The mother liquor had a specific gravity of 1.300 at $\frac{57^\circ}{13.89^\circ}$, and was preserved for analysis.

The salts so obtained were analyzed with the following results, to which is prefixed an analysis of a sample of the crude soda made at the works in that year:

	Crop 1886.	A1.	A2.	A3.	A4.	A5.
Sp. gr. mother liquor	1.280 (80° F.)	1.312 (80.5°)	1.312 (77°)	1.315 (79.25°)	1.327 (96.6°)	1.300 (57°)
Water at 120° C., H_2O	23.82	17.10	5.04	3.57	2.37	10.53
Water at red heat, H_2O	.33	.54	.41	.29	.24	.92
Insoluble matter	1.55	.078	....	....	....	....
Organic matter	.18	.032	....	....	....	*1.14
Silica, SiO_2	.14	.055	.055	.27	.05	.16
Alumina, Al_2O_3	.01	.01	.015	.03	.01	.02
Lime, CaO	.01	.07	.02	....	....	....
Magnesia, MgO	.01	.01	.009	.009	....	....
Sulphuric acid, SO_3	1.07	1.795	14.33	15.05	10.70	3.22
Chlorine, Cl	2.36	4.84	21.81	28.81	37.59	13.01
Carbonic acid, CO_2	33.04	33.98	15.00	9.67	7.25	24.93
Soda, Na_2O	37.91	41.87	46.93	48.47	48.69	47.29
Potash, K_2O	.32	.68	.71	.72	.76	1.85
	100.75	101.15	104.33	106.64	108.66	103.07
Deduct O=Cl	.53	.78	4.91	6.49	8.75	2.93
	100.22	100.37	99.42	100.15	99.91	100.14

* Boric acid, B_2O_3.

Hypothetical combination.

	Crop 1886.	A1.	A2.	A3.	A4.	A5.
H_2O	20.87	14.51	4.33	3.43	2.24	11.03
Insoluble	1.55	.078	....	....	....	....
Organic	.18	.032	.09	.06		
SiO_2	.14	.055			.05	.16
Al_2O_3	.01	.01			.01	.02
$(CaMg)CO_3$	.04	.14				
KCl	.51	1.07	1.12	1.14	1.21	2.93
NaCl	3.51	7.44	35.06	45.59	60.99	19.16
Na_2SO_4	1.89	3.18	25.44	26.70	19.01	5.70
Na_2CO_3	40.87	43.75	22.84	18.19	12.51	55.04
$NaHCO_3$	30.65	30.12	10.53	4.06	3.88	4.09
$Na_2B_2O_4$ (sodium borate)	....	....	....	....	....	2.01
	100.22	100.37	99.41	100.17	99.91	100.14

Another series of crystallizations was made at the same time (series B). In this, the first crop, B1 was collected when the mother liquor stood at a specific gravity of 1.285 at $\frac{80^\circ}{26.67^\circ}$; second crop, B2 with mother liquor of 1.325 at $\frac{81^\circ}{27.22^\circ}$; third crop, B3, mother liquor of 1.323 at $\frac{75^\circ}{23.89}$, and B4 under the same circumstances as A5.

	B1.	B2.	B3.	B4.
H_2O at 120° C	18.68	7.35	2.37	9.30
H_2O at red heat	.43	.41	.38	1.30
Insoluble	.17			
SiO_2	.27	.04	.04	.21
Al_2O_3	Trace.	.02		
CaO	.05			
MgO	.02			
SO_3	1.49	12.44	13.55	3.59
Cl	3.70	22.03	35.50	14.74
CO_2	34.72	15.31	6.10	23.25
Na_2O	40.87	46.39	49.61	47.62
K_2O	.65	.63	.73	2.21
B_2O_3				*1.10
	101.05	104.62	108.28	103.32
	.83	4.96	8.00	3.32
	100.22	99.66	100.28	100.00

Specific gravity of mother liquor.

B1	1.285 (80°)
B2	1.325 (81°)
B3	1.323 (75°)
B4	1.300 (57°)

* By difference.

Hypothetical combination.

	B1.	B2.	B3.	B4.
H_2O	15.97	6.89	2.69	10.51
Insoluble	.17			
SiO_2	.27	.04	.04	.21
Al_2O_3	Trace.	.02		
(CaMg) CO_3	.07			
KCl	1.02	1.00	1.15	3.51
NaCl	5.30	35.51	57.60	21.60
Na_2SO_4	2.62	22.08	24.24	6.31
Na_2CO_3	42.33	25.00	14.02	54.91
$NaHCO_3$	32.47	9.12	.54	.87
$Na_2B_2O_4$				2.08
	100.22	99.66	100.28	100.00

In B4 the boric acid, which was proved to exist in some quantity, was estimated by difference, as the process for its determination is tedious, and exact figures for this substance in cases like the present are of little consequence. In the hypothetical combination the neutral borate $Na_2B_2O_4$ is given instead of borax or the acid borate $Na_2B_4O_7$. The latter can hardly be supposed to exist in such strongly alkaline solutions as those which produced A5 and B4. In the original water the acid borate is set down as probably existing, since a considerable excess of CO_2 is there present, which decomposes the neutral borate, forming $Na_2B_4O_7+Na_2CO_3$.[1]

DISCUSSION OF RESULTS.

In comparing these analyses let us first consider "crop 1886," A1 and B1. These are the first crops of a solar evaporation, and are the only ones of any technical importance, unless suitable processes can be devised for utilizing the mother liquors, which by simple evaporation yield products of too low grade for the market, where the value is fixed by the percentage of Na_2CO_3 in the ash and the proportion of other salts must not exceed certain limits.

Compared in this way, crop 1886 mother liquor 1.280 is the purest, B1, mother liquor 1.285, comes next, and A1, mother liquor 1.312, is the worst. It is evident, therefore, that if the first crop is to be used directly for making soda ash the concentration should not be allowed to run as far as 1.280, but, as, in such a case, the crop would be a comparatively small one, the advantages of a recrystallization are plainly indicated by comparison of the crop of 1886 with the "best" and "crude" of the crop of 1887. (See page 76.)

The rapid increase of SO_3 and Cl is shown by the two series. SO_3 reaches its maximum in A3 and B3 and then rapidly declines, while Cl is greatest in A4 and B3. $NaHCO_3$ is deposited in great part in the early stages of the crystallization; so that, when afterwards, most of the sulphates and chlorides are got rid of, the remaining solution contains a very large proportion of Na_2CO_3, which separates when the solution is chilled.

The solar evaporation thus divides itself into three stages; first, the deposition of a comparatively pure compound of Na_2CO_3 and $NaHCO_3$; second, the formation of a product consisting in great part of sulphates and chlorides; and third, the production of a mother liquor requiring an artificial heat for its further evaporation, but rich in Na_2CO_3, and containing the major portion of the potash and boric acid.

Fractional crystallization of water of Mono Lake.—In this connection it will be interesting to compare the results of a similar series of crystallizations of some water from Mono Lake. This water had been concentrated by heating, and consequently most of the bicarbonate was reduced to normal carbonate; besides, the total quantity at disposal was so small that the results are not very reliable, but will show the general rule.

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[1] Gmelin-Kraut; Anorg. Chem, II, 1, p. 157.

The concentrated water was about one-sixth of the original in volume, and had a specific gravity of 1.210. On being exposed to a dry atmophere for quite a long period it began to deposit cubes of NaCl, and then a quantity of indefinite crystals (C1). These were collected, the mother liquor showing a specific gravity of 1.348. In time this solution gave a second crop C2, but did not vary in specific gravity. When, however, the third crop C3, had been obtained, the mother liquor showed a reduced specific gravity of 1.335. Continued evaporation yielded C4 mother liquor 1.361, and C5, mother liquor 1.381. The final evaporation to dryness gave C6. C5, when examined, was a mixture of cubes of NaCl resting on a layer of salts which, however, was too small in quantity to give accurate determinations, since, though carefully ground and mixed, concordant results could not be obtained. In such cases, where different salts crystallize together, concordant results can be looked for only when the sample, carefully weighed, is dissolved in water and portions of the solution weighed out for analysis. The figures obtained show that the composition of C5 lies between C4 and C6.

	C1.	C2.	C3.	C4.	C6.
Sp. gr. mother liquor	1.348	1.348	1.335	1.361	Dry.
H_2O	15.21	12.15	.80	4.59	11.37
SiO_2	.07	.17	.16	trace.	.13
CaO	.03	.08	.03	.04	.01
MgO	.23	.22	.01	trace.	trace.
SO_3	1.54	7.99	27.68	9.14	3.75
Cl	11.97	13.29	18.40	37.20	26.87
CO_2	29.91	24.24	8.15	7.97	14.24
Na_2O	43.02	44.45	48.39	49.02	39.93
K_2O	.43	.43	.30	.45	9.60
	102.41	103.02	103.92	108.41	105.90
O=Cl	2.69	3.00	4.14	8.38	6.05
	99.72	100.02	99.78	100.03	99.85

Hypothetical combination.

	C1.	C2.	C3.	C4.	C6.
H_2O	12.28	10.98	.69	4.18	11.31
SiO_2	.07	.17	.16	....	.13
$CaCO_3$	.05	.14	.05	.07	.02
$MgCO_3$	.48	.46	.02	....	....
KCl	.69	.69	.47	.71	15.20
NaCl	19.18	21.34	29.96	60.75	32.36
Na_2SO_4	2.73	14.18	49.13	16.22	6.65
Na_2CO_3	36.87	41.07	18.27	14.22	33.69
$NaHCO_3$	27.37	10.99	1.03	3.88	.49
	99.72	100.02	99.78	100.03	99.85

The comparison of series C with A and B illustrates still further the rule of deposition for each of the constituent salts. In addition we see that while the percentage of chlorides in C1 is much greater than in the others, the amount of sulphates varies very slightly, though this variation may give us important hints, as it may have an especial bearing upon the separation of the carbonates.

The relation of Na_2CO_3 and $NaHCO_3$ is brought out by comparing the percentages of the two salts with their molecular weights, $Na_2CO_3=106$, $NaHCO_3=84$, which gives us the following results:

	Per cent. Cl.	Per cent. SO_3.	Per cent. $NaHCO_3$; per cent. Na_2CO_3.
Crop 1886	2.36	1.07	30.65 : 40.87 :: 84 : 112
A1	4.84	1.79	30.12 : 43.75 :: 84 : 122
B1	3.70	1.49	32.47 : 42.33 :: 84 : 109.5
C1	11.97	1.54	27.37 : 36.87 :: 84 : 113.1

The true molecular proportion would be 84 : 106, so that in each case we have an excess of Na_2CO_3, the excess being greatest in A1 where the percentage of SO_3, 1.79, is the largest. Strictly speaking, only A1 and B1 are really comparable, having been obtained under like condition, while crop 1886 was the product of a large mass of liquid, and the solution C from another locality had been boiled.

A1, as shown by the specific gravity of the mother liquor, is the product of a greater degree of concentration than B1, and is less pure, which, as already stated, seems to fix the limit of production of a first crop, for Owen's Lake water, at the point where the mother liquor has reached a specific gravity of 1.280, or even something less, since above this point the amount of sulphates and chlorides rapidly increase without compensation by increase of carbonates.

We are now prepared to study the nature of this combination of Na_2CO_3 and $NaHCO_3$ on which such stress is laid, for reasons that will appear in the following discussion:

URAO.

Native urao from Venezuela.—The occurrence in Venezuela of this form of native alkali has already been described on page 40, and on page 35, it was stated that this material is found in many places, is of the greatest importance in the technology of natural soda, and would be treated in a separate section. Referring to page 41 for Boussingault's description of this salt, and repeating the results there given, we have:

Found.		Hypoth. comp.	
Na_2O	41.22	Na_2CO_3	46.98
CO_2	39.00	$NaHCO_3$	37.24
H_2O	18.80	H_2O	14.80
Impurities	.98	Impurities	.98
	100.00		100.00

The impurities are insoluble matter with chlorides and sulphates, all of which can be deducted when we desire to calculate the formula of the compound as these salts are under the circumstances anhydrous (see page 29), hence merely diminish the percentage of urao in the original material.

The formula already given for urao is

$$Na_2CO_3, NaHCO_3+2H_2O,^1$$

and if we deduct the impurities from Boussingault's analysis and recalculate the residue to 100 per cent. and likewise calculate the theoretical percentages for the above formula, we shall have

	Impurities deducted.	Theoretical. Na_2CO_3 NaH $CO_3+2\,H_2O$.	Difference.
Na_2O	41.63	41.15	+.48
CO_2	39.38	38.94	+.44
H_2O	18.99	19.91	—.92
	100.00	100.00	

Theoretical composition.

Na_2CO_3	47.44	46.90	+.54
$NaHCO_3$	37.61	37.17	+.44
$2\,H_2O$	14.95	15.93	—.98
	100.00	100.00	

Again, if we take the proportion between the Na_2CO_3 and the $NaHCO_3$ we have

$$Na_2CO_3 : NaHCO_3 :: 106 : 84 :: 47.44 : 37.50,$$

while the amount of $NaHCO_3$ found is 37.61, a difference of only 0.11 per cent. Hence Boussingault's urao is an almost theoretically pure salt, showing only a small loss of water and a trifling increase of $NaHCO_3$.

Native urao from Egypt.—The analysis of Egyptian soda by Remy, given on page 89, if calculated in the same manner, shows a remarkable agreement with the foregoing. In his original paper, Remy gives as found SiO_2, 0.144; CaO, 0.078; CO_2, 32.160; SO_3, 1.210, and Cl, 4.95 per cent., hence by reducing his analysis, as given, to its constituents we have

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[1] Laurent; Ann. de Chimie, series 3, vol. 36, p. 348.

	Recalculated.		Hypothetical composition.	
Insoluble	4.106	Insoluble	4.106	=14.758
SiO_2	.144	SiO_2	.144	
SO_3	1.210	$CaCO_3$	.20	
Cl	4.950	NaCl	8.160	
CO_2	32.160	Na_2SO_4	2.148	
CaO	.078	Na_2CO_3	38.45	
Na_2O	39.080	$NaHCO_3$	30.70	
H_2O	19.669	H_2O	16.38	
	101.397			
O=Cl	1.110			
	100.287		100.288	

If now we deduct from the last column the 14.758 of impurities we shall get column *a*; if we recalculate to 100.00, column *b*; while if we figure the theoretical proportions of $NaHCO_3$ and H_2O required for the 44.95 per cent. of Na_2CO_3 in *b*, we obtain column *c*, and consequently the differences.

	a	*b*	*c*	Difference.
Na_2CO_3	38.45	44.95	44.95	0.00
$NaHCO_3$	30.70	35.90	35.62	+ .28
H_2O	16.38	19.15	15.27	+3.88
	85.53	100.00		

True character of trona, or the native sesquicarbonate.—From this it appears that Remy's trona, after deducting the impurities, is urao with a very slight excess of $NaHCO_3$, but 3.88 per cent. excess of H_2O. Whether or not the presence of this excess of water is to be ascribed to the Na_2SO_4 will become clearer as we go on.

Klaproth[1] in 1802 published the following analysis of a natural soda from near Fezzan in the Desert of Sahara:

	As published.	Impurities deducted.		Hypothetical composition.
Na_2O	37.00	37.95	Na_2CO_3	35.88
CO_2	38.00	38.97	$NaHCO_3$	45.96
H_2O	22.50	23.08	H_2O	18.16
Na_2SO_4	2.50	....		
	100.00	100.00		100.00

To this mineral the name trona has been given and it is considered as a native sesquicarbonate of sodium. As previously stated (page 35)

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[1] Klaproth: Beiträge zur Chem. Kenntniss d. Mineralkörper, III, 1802, p. 83. Also see Dana's Mineralogy, article Trona.

"sesquicarbonate" is the name given to a supposed compound of Na_2CO_3 and $NaHCO_3$ in the proportion of one molecule of Na_2CO_3 to two of $NaHCO_3$, with the addition of water. As by the dualistic formula formerly in use sodium monocarbonate was written NaO, CO_2, and the bicarbonate NaO, HO, $2CO_2$, the formula of the compound was written 2 NaO, 3 CO_2 whence its name, the HO being omitted, not being considered an essential constituent. The formula of the theoretical sesquicarbonate is Na_2CO_3, 2 $NaHCO_3+3$ H_2O, which gives us the following percentages with which Klaproth's results are compared:

	Theoretical.	Klaproth.	Difference.
Na_2CO_3	32.32	35.88	+3.56
$2NaHCO_3$	51.22	45.96	−5.26
$3H_2O$	16.46	18.16	+1.70
	100.00	100.00	....

These differences are too great to be considered as slight variations from a theoretical formula, such as are shown by Boussingault's mineral. If Klaproth's trona be compared with a theoretical urao the differences are still larger being −11.02 Na_2CO_3, +8.79 $NaHCO_3$ and +2.23 H_2O, hence we see that we have here a mixture to which neither formula can be assigned.

Joffre[1] analyzed a trona stated to have come from the same locality and supposed to be the same as Klaproth's. He describes the mineral thus:

> Incrustations of about 2 to 3 centimeters in thickness. It is in masses which are crystalline and perfectly white, except the lower part which is colored by a trace of oxide of iron.

After giving the figures of the analysis below, he says:

> The first three numbers correspond to sesquicarbonate of soda, contaminated with a little carbonate of soda * * * should be included in the mineral species named urao. The presence of carbonate of lime and of chloride of sodium may give confirmation to the views of M. Berthollet concerning the origin of natural soda, which he ascribes to the reaction of these two substances upon each other.

	Joffre.	Impurities deducted.		Hypothetical composition.	Theoretical sesquicarbonate.	Difference.
Na_2O	39.41	40.01	Na_2CO_3	40.08	32.32	+7.76
CO_2	39.58	40.18	$NaHCO_3$	44.93	51.22	−6.29
H_2O	19.52	19.81	H_2O	14.99	16.46	−1.47
Sand	.53					
Fe_2O_3	.01					
$CaCO_3$	.05					
NaCl	.46					
Na_2SO_4	.44					
	100.00	100.00		100.00	100.00	....

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[1] Joffre: Bull. Societé Chimique, vol 12, p. 102.

The differences are, therefore, still greater than in Klaproth's trona, and in fact, as far as is known, the only analyses of natural soda which give a composition at all near to true sesquicarbonate are those of Popp.[1]

Popp's specimens came from Egypt, and are described as "distinctly crystalline salt crusts almost an inch thick," No. 1 was "an aggregate of small, transparent prismatic crystals, the prisms being clearly distinguishable."

	No. 1.	No. 2.	No. 3.
Insoluble	1.65	1.35	.40
CaO	.55	trace.	....
SO_3	1.65	13.53	37.56
Cl	5.11	20.25	1.58
CO_2	33.15	16.55	13.50
Na_2O	36.34	43.68	43.10
H_2O	22.50	8.87	4.05
	100.95	104.23	100.19
Deduct O=Cl	1.15	4.56	.35
	99.80	99.67	99.84

Hypothetical composition.

	No. 1.	No. 2.	No. 3.
Insoluble	1.65	1.35	.40
Na_2SO_4	2.93	24.01	66.67
NaCl	8.42	33.38	2.61
$CaCO_3$	.99	....	....
Na_2CO_3	25.81	13.40	10.60
$NaHCO_3$	42.00	20.93	17.37
H_2O	18.00	6.60	2.19
	99.80	99.67	99.84

Deducting impurities as before and recalculating, we have,

	No. 1.	No. 2.	No. 3.
Na_2CO_3	30.08	32.74	35.15
$NaHCO_3$	48.94	51.13	57.59
H_2O	20.98	16.13	7.26
	100.00	100.00	100.00

From the composition of No. 1, Popp deduced the formula Na_2CO_3, 2 $NaHCO_3+4\ H_2O$; No. 2 is close to Na_2CO_3, $2NaHCO_3+3\ H_2O$, while No. 3 approximates Na_2CO_3, $2\ NaHCO_3+H_2O$. The theoretical percentages

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[1] Popp: Ann der Chemie u. Pharm., vol. 155, p. 348.

of these degrees of hydration and the differences from the respective analyses are as follows:

	4 H_2O.	Difference No. 1.	3 H_2O.	Difference No. 2.	1 H_2O.	Difference No. 3.
Na_2CO_3	30.64	—.56	32.32	+.42	36.30	—1.15
$NaHCO_3$	48.55	+.39	51.22	—.09	57.54	+ .05
H_2O	20.81	+.17	16.46	—.33	6.16	+1.10
	100.00	....	100.00	....	100.00	....

These results are very remarkable and would appear to settle affirmatively the existence of true sesquicarbonate in nature, but we shall have occasion to refer to them later and give reasons for further doubt. The analysis of the incrustation from Brown's Station, Nev., given on page 56, may be disregarded in this connection, as the existence of the sesquicarbonate appears to have been assumed and one of the determinations obtained "by difference."

Artificial production of sesquicarbonate.—The artificial production of sesquicarbonate has been claimed by both Winkler and Hermann.

Winkler,[1] by dissolving 100 parts Na_2CO_3 and 152 parts $NaHCO_3$ in 1,920 parts of water and carefully adding 1,920 parts of 80 per cent. alcohol, so that the two liquids did not mix, obtained, after the lapse of several days, fine, transparent, non-efflorescent, acicular crystals. These adhered to the sides of the vessel and with them were crystals of hydrated monocarbonate and bicarbonate, the latter principally on the bottom. His analysis of the acicular crystals is given below.

Hermann[2] mixed thoroughly Na_2CO_3, $10\ H_2O$ and $NaHCO_3$ in the proportion of 1 : 2, melted the mixture in the water of crystallization, and allowed the cold mass to remain in damp air for some weeks. At the end of that time the mass had become crystalline and its cavities were lined with crystals of sesquicarbonate, which he analyzed.

Both Winkler and Hermann give as the formula of the salt, $2\ Na_2O$, $3\ CO_2 + 3\ H_2O$ or Na_2CO_3, $2\ NaHCO_3 + 2\ H_2O$, as is shown by the analyses.

	Molecular weight.	Theoretical per cent.	Winkler.	Hermann.
$2\ Na_2O$......	124	40.00	41.13	40.00
$3\ CO_2$.......	132	42.58	43.30	43.06
$3\ HO_2$.......	54	17.42	15.57	16.94
	310	100.00	100.00	100.00

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[1] Buchner's Repert. f. Pharm., vol. 48, p. 215.

[2] Journ. f. prakt. Chem., vol. 26, p. 312.

Hypothetical composition.

	Molecular weight.	Theoretical.	Winkler.	Difference.	Hermann.	Difference.
Na_2CO_3	106	34.20	36.33	+2.13	33.02	−1.18
2 $NaHCO_3$	168	54.19	53.87	— .32	56.04	+1.85
2 H_2O	36	11.61	9.80	−1.81	10.94	— .67
	310	100.00	100.00	....	100.00	......

By following the directions given by Winkler small needles, such as he describes, were obtained; from these the material for analyses was selected with great care and appeared to be free from the other salts which had crystallized simultaneously. As the latter are sodium bicarbonate, and hydrated monocarbonate, the separation must be carefully made, else results may be obtained showing great variety in the proportions of the two. The amount of salt thus secured was small, but sufficient for the following duplicate analyses:

	a	b		a	b	Average.
H_2O	19.19	19.31	H_2O	14.64	14.75	14.69
CO_2	40.01	40.01	Na_2CO_3	42.72	42.67	42.70
Na_2O	40.69	40.67	$NaHCO_3$	42.53	42.57	42.55
	99.89	99.99		99.89	99.99	99.94

These results do not agree with those of Winkler nor with any of the salts described by Popp. Morever, no simple theoretical formula can be assigned to the combination, and we have either a sesquicarbonate plus an excess of Na_2CO_3, or what is more probable, urao plus an excess of $NaHCO_3$.

The following table is a comparison of the foregoing analyses. As the proportion of water present varies for each sample, the percentage of Na_2CO_3, 2 $NaHCO_3$, or as it may be called "anhydrous sesquicarbonate," is calculated for each, and the excess, whether of monocarbonate or bicarbonate, thus shown.

	Na_2CO_3, 2 $NaHCO_3$.	Excess.	
	Per cent.	*Per cent.*	
Remy	62.42	18.43	Na_2CO_3
Joffre	73.28	11.73	Na_2CO_3
Klaproth	74.96	6.88	Na_2CO_3
Popp, No. 1	77.75	1.27	$NaHCO_3$
Popp, No. 2	83.39	.48	Na_2CO_3
Popp, No. 3	90.86	1.88	$NaHCO_3$
Hermann	85.35	3.72	$NaHCO_3$
Winkler	87.86	2.34	Na_2CO_3
Chatard	69.40	15.85	Na_2CO_3

The other analyses of natural soda which are known show still larger excesses of Na_2CO_3 than these. So far, therefore, the evidence in favor of the existence of sesquicarbonate is very unsatisfactory and must remain so until some one has succeeded in producing it by crystallization from aqueous solution by simple evaporation. My own experiments on the artificial formation of urao[1] appear to demonstrate the non-existence of the salt.

In addition to the analyses already given, we have Laugier's[2] examination of a Barbary soda, Pfeiffer's[3] analysis of an East Indian soda, and Wallace's[4] of several samples of soda from the Loonar Lake.

Wallace calls especial attention to the proportion of CO_2 to Na_2O as shown by his work, and remarks that although the text-books generally state that the trona from Egypt and other localities consisted of sodium sesquicarbonate, yet the analyses show that the sesquicarbonate and the neutral carbonate are associated in nearly equal proportions, and it appears likewise that under the circumstances in which the deposits were made, a compound of soda was formed that contains nearly four equivalents of soda to five of carbonic acid. In no case had he found the Na_2O and the CO_2 to be present in the proportions necessary to form either the neutral carbonate or the sesquicarbonate, and it is his opinion that lack of uniformity in stating the results of analysis was the cause of the error.

Tabulating the results of these analyses we have,

	Urao.	Excess Na_2CO_3.	Urao.	Excess.
Allen, Big Lake, Ragtown (p. 52)	78.39	1.32	100	1.68
Allen, Little Lake, Ragtown (p. 52)	78.98	.17	100	.21
Chatard, Little Lake, Ragtown (p. 52)	56.66	20.59	100	30.34
Woodward, Ruby Valley (p. 56)	18.30	48.48	100	264.92
Woodward, Deep Creek (p. 56)	33.38	6.50	100	19.47
Woodward, Antelope Valley (p. 56)	32.46	7.84	100	24.12
Woodward, Humboldt Valley (p. 56)	81.45	4.55	100	5.58
Pfeiffer	6.33	30.25	100	478.00
Laugier	52.48	25.48	100	48.55
Wallace, Dulla Khar	75.52	12.13	100	16.06
Wallace, Nummuck Dulla	5.54	2.34	100	42.24
Wallace, Papree	38.49	8.53	100	22.16
Wallace, Bhooskee	23.11	8.38	100	36.26

It is evident from the above that while, in each case, there is an excess of the neutral carbonate, the amount of this excess bears no general relation to the amount of urao or of sesquicarbonate present, and we must consider natural soda either as an indefinite mixture of

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[1] Pp. 78 et seq.

[2] Laugier: Dingler's Polyt. Jour., vol. 18, p. 482.

[3] Pfeiffer: Journ. f. prakt. Chemie, vol. 61, p. 439.

[4] Wallace: Chem. News, vol. XXVII, p. 203.

the neutral carbonate and the bicarbonate or as a certain definite compound of these two salts, having the composition either of urao ($Na_2Co_3,NaHCO_3$) or of sesquicarbonate ($Na_2CO_32NaHCO_3$) generally intermixed with an excess of one or the other of the two constituents.

No other combinations of these two substances have, up to the present time, been claimed to exist; the evidence for the sesquicarbonate has been given, and it remains to consider the proof of the existence of urao, not only as an occasionally occurring mineral, but also *the sole natural combination of the two carbonates.*

Urao from Owen's Lake.—We have already discussed Boussingault's analysis of the original urao, and showed that this gave percentages remarkably close to the theoretical for the formula

$$Na_2CO_3,NaHCO_3+2H_2O,$$

and on page 59 reference was made to certain salts from Owen's Lake which are now to be considered.

The "best specimen," as there stated, is the result of the spontaneous evaporation of the water of the lake, for although the crystallization occurred in an artificial ground vat and the first crop was redissolved in lake water, yet nothing was added to the water, and solar heat only was the evaporating agent. Hence such a product is purely natural in its character, and must be considered as a "mineral," and not as an artificial substance.

The piece examined was one of several broken from a large fragment of the crystal sheet covering the bottom of the vat. It was a mass about two inches thick, the upper portion of which was well crystallized and translucent; the intermediate part, an interlamination of thin translucent crystallized sheets and of fine granular crystalline white material; the bottom of the specimen is a layer similar to the upper part, but thinner, the crystals being much smaller.

The analysis marked "best specimen" was made from the upper portion, which presented a columnar radiated structure, the crystals being so grown together that the terminations alone were visible and these so combined together that each combination had a curved ridge-like termination or cockscomb form. The specific gravity of the material was 2.1473 taken in benzol at 21.7° C. The "crude" is the fine granular material from the central part of the specimen, and is the undissolved residue of the first crop.

The "twig" urao was formed on a branching grass root which happened to be suspended in the water of a small natural lagune on the east side of the lake. It has the form of a stout twig or of a branching coral, each of the branches forming a cylinder, a section of which shows the radiated structure, while the surface of the cylinder is rough, the curved edges of the crystal aggregates giving a lenticular appearance. The color is brownish, and one side of the specimen shows crystals of NaCl and much sand, as the evaporation of the water finally left it lying on the mud of the bottom.

The "lagune" specimen is from another small lagune near by, and consists of a thin sheet, the surfaces of which are rough like the preceding specimen. Color pink, due to organic matter. (See p. 95).

"Beach vat." This was formed in a vat dug in the beach and allowed to fill by seepage from the surrounding soil. Analyses of this seepage water will be found on page 94.

	Best specimen.			Average.
Insoluble (inorganic)				.02
Cl	.195	.191		.193
SO_3	.707	.697		.702
CO_2	38.18	38.11	38.10	38.13
Na_2O	40.98	41.01		40.995
H_2O	20.12	20.09	20.00	20.07
				100.110
Deduct O=Cl				.04
				100.07

	Crude.	Twig.	Lagune.	Beach vat.
Insoluble (inorganic)	.22	2.92	.40	4.10
Insoluble (organic)		.14	.12	.27
SiO_2	.10	.05	.09	.04
Cl	1.57	2.73	.21	1.83
SO_3	.79	.76	.63	.84
CO_2	37.00	35.24	37.50	35.10
Na_2O	41.26	40.22	40.08	39.36
CaO			.06	
K_2O			trace	
MgO			.02	
H_2O	19.62	18.31	19.94	18.58
	100.56	100.37	99.05	100.12
O=Cl	.35	.61	.05	.41
	100.21	99.76	99.00	99.71

Hypothetical composition.

	Best specimen.	Crude.	Twig.	Lagune.	Beach vat.
Insoluble	.02	.22	3.06	.52	4.37
SiO_2		.10	.05	.09	.04
$CaCO_3$				.10	
$MgCO_3$				.04	
NaCl	.32	2.58	4.50	.34	3.01
Na_2SO_4	1.25	1.39	1.35	1.12	1.49
Na_2CO_3	45.86	45.28	42.46	48.73	42.36
$NaHCO_3$	36.46	34.74	33.63	31.49	33.44
H_2O	16.16	15.90	14.71	16.57	15.00
	100.07	100.21	99.76	99.00	99.71

Deducting NaCl and other impurities, as before, and recalculating to 100 per cent., we have—

	Best.	Crude.	Twig.	Lagune.	Beach vat.
Na_2CO_3	46. 57	47. 20	46. 76	50. 35	46. 65
$NaHCO_3$	37. 03	36. 22	37. 04	32. 53	36. 83
H_2O	16. 40	16. 58	16. 20	17. 12	16. 52
	100. 00	100. 00	100. 00	100. 00	100. 00

Finally, if we compare these new percentages with the theoretical figures for urao, already given, we shall find the following differences:

	Theoretical.	Best.	Crude.	Twig.	Lagune.	Beach vat.
Na_2CO_3	46. 90	—. 33	+. 30	—. 14	+3. 45	—. 25
$NaHCO_3$	37. 17	—. 14	—. 95	—. 13	—4. 64	—. 34
H_2O	15. 93	+. 47	+. 65	+. 27	+1. 19	+. 59

These small differences show that each of the samples is urao. In each case there is a varying amount of NaCl, Na_2SO_4 and other impurities to be deducted, but when this is done, the residue in four out of the five samples has a very close agreement with the formula of the mineral. In the case of the "lagune" the differences are quite large, but as the local circumstances attending the production of each specimen are well known, the explanation is simple.

The "best specimen," although obtained like the others by the spontaneous evaporation of the natural water, is, in effect, a recrystallization occuring in a shallow basin of no great extent. The process was slow, the insoluble impurities had time to settle, and the product was gathered as soon as a tendency to deposit NaCl was observed. That this was successfully done is shown by the analysis, but the percentage of Na_2SO_4 is not materially different from that of the other specimens made under less favorable circumstances. That this is to be expected follows from what we know of the relative solubility of the different salts. The solubility of NaCl is but little affected by changes of temperature, which have great influence on that of the sulphate and carbonates. The sulphate is not only more soluble than urao, but is also present in much smaller proportion in this water, hence it is not deposited to any extent until most of the urao has separated. Afterward the relative amount rapidly increases, as has been shown by the series of crystallizations of the water of Owen's and Mono Lakes.

The "crude," as already stated, is that portion of the first crystallization which was not redissolved. As the first crystallization was allowed to go on till NaCl had been deposited in some quantity, the increased amount of this salt is accounted for; but as the process was then interupted, little more sulphate is found in this than in the purest specimens.

The "twig" urao shows smaller differences from the theoretical proportions, than any of the others. The grass root on which it formed was suspended in the water of the shallow natural basin so that the crystallization proceeded evenly at all points. It was only when the decrease of the water left the specimen lying on a mud bank that the salt crystals and sand adhered to it. If these impurities are deducted, the remainder is a practically pure urao.

The "beach vat" made by spontaneous evaporation of a lye differing from the lake water in having a larger percentage of $NaHCO_3$ and a smaller proportion of Na_2SO_4, is also very close in the relations of the urao constituents.

Finally we have the "lagune" urao. This was found on the border of the small lagune which was then dry. It is apparently the result of an interchanging concentration and dilution of the mother-liquor in which it was formed. As the water in such a shallow basin evaporates, the tendency is to leave a crust of very pure urao at the edge of the basin, the deposit towards the center becoming more and more impure as the concentrating liquid deposits its salt and sulphate, and becomes, as the experiments show, a comparatively pure solution of monocarbonate. If then the basin be refilled by seepage, as would be the case when the lake rises, as it does in the spring, the solution would contain a larger proportion of the neutral carbonate, and in consequence, on reconcentration, leave on its edges a urao containing an excess of hydrated monocarbonate. If we calculate the amount of urao present in this sample we shall find that the excess of Na_2CO_3 and H_2O is almost exactly the amount required for $Na_2CO_3+2H_2O$.

"Lagune."			Urao.		$Na_2CO_3 + 2H_2O$.		
Na_2CO_3	48.73	=	39.73	+	9.00		....
$NaHCO_3$	31.49	=	31.49		....		....
H_2O	16.57	=	13.49	+	3.06	+	.02
Impurities	2.21	=	.....		....		2.21
	99.00	=	84,71	+	12.06	+	2 22

The deficiency of one per cent. in the analysis is in this respect unfortunate, but can not be easily explained. The analytical figures given are averages, derived from two or more closely agreeing determinations of each constituent, the list of which comprises everything that can be supposably present.

Artificial urao.—In order to determine the conditions under which urao is formed, and also to find out if, by spontaneous evaporation, the sesquicarbonate or any other combination of the mono and bicarbonate might be formed, the following series of experiments was undertaken.

Some of the analytical results already obtained appeared to give some indications of the existence of a mixed carbonate having a formula $2Na_2CO_3+NaHCO_3+x\,H_2O$. If this could be separated in a pure state and the sesquicarbonate also obtained, we should have the following series:

Na_2CO_3	Mono-carbonate.
$Na_2CO_3+\frac{1}{2}\,NaHCO_3$	Supposed salt.
$Na_2CO_3+NaHCO_3$	Urao.
$\frac{1}{2}Na_2CO_3+NaHCO_3$	Sesquicarbonate.
$NaHCO_3$	Bicarbonate

For this investigation a number of solutions were prepared, each of which contained Na_2CO_3, $NaHCO_3$, and NaCl, the amount of each salt employed having a certain definite relation to its molecular weight. NaCl was used because its presence appears to exert a favorable influence on the crystallization of the mixed carbonates.

Solution No. 1 was intended to produce the "supposed salt," and was therefore made up as follows: 10.5 grams $NaHCO_3$ ($=\frac{1}{8}$ molecule) 26.5 grams Na_2CO ($=\frac{1}{4}$ molecule) were dissolved in water. To this solution were added 26.5 grams Na_2CO_3 and 29.25 grams NaCl. These latter amounts are purely empirical, an excess of Na_2CO_3 seemed to be needed, so that a quantity equal to that already present was added, and as we then have half a molecule, 29.5 grams $=\frac{1}{2}$ mol. NaCl was used. The solutions as evaporated contained:

No. 1. 10.05 grams $NaHCO_3=\frac{1}{8}$ molecule.
53.00 grams $Na_2CO_3=\frac{1}{2}$ molecule.
29.25 grams $NaCl=\frac{1}{2}$ molecule.
No. 2. 21.00 grams $NaHCO_3=\frac{1}{4}$ molecule.
53.00 grams $Na_2CO_3=\frac{1}{2}$ molecule.
29.25 grams $NaCl=\frac{1}{2}$ molecule.

This proportion was expected to yield urao:

No. 3. 42.00 grams $NaHCO_3=\frac{1}{2}$ molecule.
53.00 grams $Na_2CO_3=\frac{1}{2}$ molecule.
29.25 grams $NaCl=\frac{1}{2}$ molecule.

The amount of $NaHCO_3$ being twice as great as in No. 2, there was a possibility of the formation of sesquicarbonate.

In the course of six weeks No. 1 had deposited a crop of acicular crystals. The mother liquor was poured off, leaving a large group of small but good crystals, and a number of smaller groups. These were collected and carefully dried between filter paper, remaining perfectly transparent and unaltered in the air. In the course of another week the mother liquor yielded a second crop of acicular crystals.

No. 2 deposited at first some crystalline scales, afterwards acicular crystals were formed; this material was collected, and the scales were carefully separated from the other crystals.

No. 3 behaved like No. 2, except that the crop of scales was larger.

The salts thus obtained were analyzed, giving the following results.

The figures for No. 1 are averages of two closely agreeing determinations of each constituent:

	No. 1, first crop acicular.	No. 2, first crop scales.
H_2O	19.58	11.78
CO_2	38.73	51.69
Na_2O	40.07	36.54
NaCl	1.46	.51
	99.84	100.52

Hypothetical combination.

H_2O	15.37	1.25
Na_2CO_3	43.69	.42
$NaHCO_3$	39.32	98.34
NaCl	1.46	.51
	99.84	100.52

By calculating the percentage of urao in each of these salts we find,

	No. 1.			No. 2.		
	Urao.	Bicarbonate.	Residue.	Urao.	Bicarbonate.	Residue.
H_2O	14.84		.53	.14		1.11
Na_2CO_3	43.69			.42		
Na_2HCO_3	34.62	4.70		.33	98.01	
NaCl			1.46			.51
	93.15	4.70	1.99	.89	98.01	1.62

We see therefore that No. 1, 1st crop, is urao, plus 4.70 $NaHCO_3$, while in No. 2, 1st crop, the scales are nearly pure bicarbonate.

The scales of No. 3 being in all respects similar to those of No. 2 and of No. 7 (to be described later), were considered as being $NaHCO_3$, and were not analyzed.

In the mean time other solutions had been prepared, in which not only the relative proportions of Na_2CO_3 and $NaHCO_3$ were varied, but also that of NaCl, in order that the proper proportions of a typical solution for the production of urao might be determined.

For this purpose a solution of Na_2CO_3 was prepared, 200 cm^3 of which contained 53 grams of the salt, the amount taken for each experiment, the other salts being added, together with sufficient water to effect complete solution.

Solution.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.
Na_2CO_3	53.00	53.0	53.0	53.0	53.00	53.00
$NaHCO_3$	21.00	10.5	10.5	42.0	5.25	5.25
NaCl	58.5	14.62	58.5	58.5	58.5	29.25

In preparing No. 4, the $NaHCO_3$ was added in portions to the 200 cm^3 of Na_2CO_3 solution, which was vigorously shaken after each addition, but to effect complete solution it was necessary to add water until the volume measured 250cm^3. To this, the NaCl was added, and the whole again shaken; an emulsion was formed which speedily became solid, so that the vessel could be inverted without loss. Portions of water were gradually added until a clear solution was obtained, the resulting liquid measuring 590cm^3. With No. 5 the $NaHCO_3$ dissolved completely without addition of water, but on putting in the NaCl and shaking a solid mass resulted, measuring 220cm^3. Water was then added, and the final solution measured 300cm^3. The same phenomenon was observed with each of the other preparations, and all were allowed to spontaneously evaporate.

No. 4 deposited at first a quantity of scales, but soon began to form urao. The mother was then poured off and subsequently produced a large crop of urao, the mother liquor of which deposited NaCl in small but very brilliant cubes.

No. 5 formed radiating wisps or sheaves of very good and quite stout acicular crystals (No. 5, 1st crop.) The mother liquor continued to form these crystals and after some time was poured off. This second mother liquor produced in time several large masses of apparently tabular crystals, together with a small quantity of fine needles. These masses were collected, and as they showed a strong tendency to effloresce and a portion placed in a small bottle became partially liquefied at the atmospheric temperature of 32° C. (90° F.), there is no reason to doubt that they were the ordinary decahydrated salt $Na_2CO_3+10H_2O$.

No. 6 yielded a large crop of beautiful groups of radiating acicular crystals (No. 6, 1st crop). The mother liquor continued to form small acicular crystals, finally NaCl in cubes.

No. 7 deposited crystalline scales, and when acicular crystals began to form the mother liquor was poured off and the needles carefully separated from the plates (No. 7, 1st crop). The mother liquor yielded acicular crystals and NaCl.

Nos. 8 and 9 each deposited acicular crystals, and the mother liquor was poured off. The mother liquor of No. 9 formed a quantity of fine needles so matted together as to present a woolly appearance. (No. 9, 2d crop).

	No. 5, first crop acicular.	No. 6, first crop acicular.	No. 7, first crop scales.	No. 9, second crop acicular, matted.
H_2O	19.54	19.42	11.63	18.91
CO_2	37.88	37.76	51.52	36.46
Na_2O	41.02	39.85	36.49	39.32
NaCl	1.72	2.88	Undet.	5.58
	100.16	99.91	99.64	100.27

Hypothetical composition.

H_2O	15.96	15.55	.92	15.41
Na_2CO_3	49.00	45.29	.64	46.60
$HaHCO_3$	33.48	36.19	98.08	32.68
NaCl	1.72	2.88	Undet.	5.58
	100.16	99.91	99.64	100.27

Calculating the amount of urao as before, we get

	No. 5, first crop.			No. 6, first crop.		
	Urao.	Na_2CO_3-H_2O.	Residue.	Urao.	$NaHCO_3$.	Residue.
H_2O	14.35	1.14	.47	15.38	...	.17
Na_2CO_3	42.25	6.75	...	45.29	...	...
$NaHCO_3$	33.48	...	...	35.89	.30	...
NaCl	...	...	1.72	...	...	2.88
	90.08	7.89	2.19	96.56	.30	3.05

	No. 7, first crop.			No. 9, second crop.		
	Urao.	+$NaHCO_3$.	+Residue.	Urao.	+Na_2CO_3-H_2O.	+Residue.
H_2O	.22	...	.70	14.00	.91	.50
Na_2CO_3	.64	...	...	41.24	5.36	...
$NaHCO_3$	.51	97.57	...	32.68	...	...
NaCl	...	...	Undet.	...	...	5.58
	1.37	97.57	.70	87.92	6.27	6.08

The early products of the other solutions did not differ in physical properties from those examined, and were therefore not analyzed. The mother liquors, however, if allowed to evaporate till all the urao and most of the NaCl had been deposited, yielded crops of the monohydrated carbonate Na_2CO_3, H_2O, as was shown by analysis; but any considerable fall in the temperature of the solution caused a crystallization of the decahydrated salt.[1]

From the results before us it is evident that no such compound as the sesquicarbonate is obtained from a solution of the two carbonates by spontaneous evaporation and crystallization, and no other compound carbonate but urao was produced in any of these experiments. If there is an excess of $NaHCO_3$ present this will separate first, but the next

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[1] An abstract of these results was published in a paper on "Urao," in Am. Jour. Sci., vol. 38, July, 1889, p. 59 seq. The crystals obtained as above were crystallographically examined by Mr. Edward F. Ayres, who published his results in the same number of the Journal. He shows that urao is monoclinic, but that the angles differ but slightly from those of orthorhombic forms, and quotes Zepharovich (Zeitschrift f. Kryst., vol. 13, p. 135, 1887), who obtained similar results on a urao formed accidentally by Reinitzer, whose analytical determinations agree with my own. Reinitzer gives as sp. g. 2.14, my own determination being 2.1473.

product will be urao. As the urao crystallizes upon and intermixed with the previously separated bicarbonate, it is clear that unless the two are carefully separated an analysis of the product may give results ranging all the way from pure bicarbonate to pure urao, or ultimately the neutral carbonate. The variations in the analyses of natural soda are thus explainable, since the bottom part of a cake of such soda should generally be richer in bicarbonates than the rest. This will be still more likely if much NaCl is present in the solution, since, as shown by No. 6, $NaHCO_3$ was separated, although the proportion of Na_2CO_3 present was four times that required for urao. In No. 5 the proportion of $NaHCO_3$ or of NaCl is too low, as shown by the presence of Na_2CO_3 in the first crystallization. No. 9, which was considered as a crucial test of the possibility of the formation of the "supposed salt," gave even as its second crop only urao, the amount of Na_2CO_3, H_2O being too small to be considered otherwise than as an impurity. The first products of No. 2 and No. 7 are $NaHCO_3$ almost pure, as was also No. 3, 1st crop, and No. 4, 1st. No. 2 differs from No. 4, as does No. 3 from No. 7, only in having one-half the quantity of NaCl; all of them deposited $NaHCO_3$, but No. 2 less than the others.

No. 1, which in amount of NaCl is midway between Nos. 5 and 6, shows more $NaHCO_3$ than No. 6, but less NaCl. In this case the amount of NaCl in the solution was not sufficient to separate $NaHCO_3$ until the solution had become sufficiently concentrated to deposit urao, when both salts crystallized together. This is indicated by No. 2, where the increase in the amount of $NaHCO_3$ had the effect of depositing a portion of it before the urao had formed.

That the presence of NaCl is not necessary for the formation of urao was proved by the following experiment. A saturated solution of chemically pure sodium carbonate was prepared, and into this pure carbonic acid was forced under pressure until a considerable amount of bicarbonate had been deposited. The solution was then filtered and put aside to evaporate spontaneously. No further separation of $NaHCO_3$ was observed, and in time a crop of acicular crystals was obtained which on analysis yielded the following results:

				Urao.	$Na_2Co_3H_2O$.	Residue.
H_2O.....	20.14	H_2O.......	16.33	= 15.21	+ .59	+ .53
Na_2O....	41.40	Na_2CO_3....	48.35	= 44.85	+ 3.50	..
CO_2.....	38.69	$NaHCO_3$...	35.55	= 35.55	....	..
	100.23		100.23	95.61	4.09	.53

The salt is therefore urao with a small proportion of Na_2CO_3, H_2O. The residue of water is very nearly sufficient for the dihydrated salt, but in view of what has been already shown it is more reasonable to consider it as an excess. It will be observed that no tendency to form sesquicarbonate is evinced, although it would seem that the circumstances were most favorable for its production.

Experiment has also shown that if a moderately concentrated solution of pure Na_2CO_3 be exposed to the air until crystallization begins, the first crystals obtained are urao, owing to the absorption of CO_2 from the air during the slow evaporation. It is therefore very remarkable that the voluminous literature of soda takes such slight notice of this salt, which must have been so frequently seen by those working with soda salts.[1] Even Lunge's great work mentions urao but once, and then only as a synonym for trona, although its nature and properties would appear to give valuable hints for technical work.

As has been already seen, Wallace had a suspicion that such a compound existed, but Mondesir[2] has the credit of being the first to publish a method for its production in a pure state. After alluding to the doubts concerning the nature of "sesquicarbonate," he gives an account of his work on the mineral waters of Royat, in the course of which he established the presence of urao. In describing it he says:

> This salt is very stable in saturated solutions of NaCl probably because it is only slightly soluble even with the aid of heat, and even on boiling loses its acid carbonic acid with excessive slowness. Nevertheless a certain excess of the neutral carbonate is necessary for its preservation.

His method of preparation is to dissolve 28 parts of NaCl and 28 parts of $Na_2CO_3 . 10H_2O$ in 100 parts of water. The solution is then heated nearly to boiling and a thoroughly incorporated mixture of 8 parts $NaHCO_3$ and 28 of $Na_2CO_3 . 10H_2O$ is gradually added in small portions, the liquid being continually stirred, and the loss by evaporation being made good by addition of distilled water. As soon as the solution is complete the liquid is allowed to cool slowly, when the urao crystallizes in fine needles. He advises that the temperature of the liquid should not be permitted to go below 20°C. (68°F). The salt crystallizes in fine needles matted together, and when treated with water, is decomposed, Na_2CO_3 going into solution, while $NaHCO_3$ is undissolved.

To this salt, which he recognizes as being the same as Boussingault's urao, he gives the name "carbonate quatre-tiers," or "four-thirds carbonate," on account of the relation of CO_2 to Na_2O. In the sesquicarbonate we have the relation of one and one-half equivalent of CO_2 to one equivalent of Na_2O, whence its name, while in urao the relation is four-thirds of an equivalent of acid to one of base. It might, therefore, be called the "tetra-trita" or "tetrita carbonate."

Mondesir's view that the presence of NaCl and excess of Na_2CO_3 is of value in the formation of the salt is in harmony with my own results, though my work shows that the NaCl is not absolutely necessary, and that the aid of artificial heat can be dispensed with unless the atmospheric temperature is below 20°C. If the solution is cooled down below that point, the excess of Na_2CO_3 is liable to crystallize out as the decahydrated salt.

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[1] See note on p. 82 concerning Reinitzer's work.

[2] Mondesir, Paul de; Comptes Rendus, Mai 31, 1887, civ. 22, p. 1505.

ANALYTICAL METHODS.

The analytical methods employed in these analyses are in general well known. The salts and solutions necessarily contain only traces of other bases beside alkalies, and those were determined in the usual manner. Silica may exist in some quantity, but the amount is usually small.

SO_3 and Cl were determined gravimetrically and in duplicate, the results agreeing in most cases very closely. When SO_3 is precipitated by $BaCl_2$ in such solutions containing alkaline salts only, and these in small quantities, and care is taken that the precipitant is in slight excess only, the precipitation is both rapid and complete and the precipitate is pure, the after treatment with HCl rarely showing a loss of any consequence.

The CO_2 was determined by distillation, the gas being collected and weighed in a Liebig potash bulb, and the apparatus and method are fully described in "Analyses of waters of the Yellowstone National Park." Gooch and Whitfield, Bulletin No. 47, U. S. Geol. Survey, p. 15. With care and experience the results agree very closely. For the boric acid, in the water of Owen's Lake, the excellent method of Gooch[1] was followed; for the Mono and Ragtown waters the process of Stromeyer, with modifications of my own, was used; but, though giving very fair results, the process can not be compared for ease, simplicity, and accuracy with the former method.

The determination of the alkalies in such very dense waters was, at first, found to be difficult, owing to the large quantities necessarily taken. To get determinations which shall be fairly accurate when referred to a liter, portions of not less than 50cm^3 should be taken, the water in all cases being carefully weighed. The amount of alkaline chlorides corresponding to 50cm^3 of such waters is very large, and, when the final evaporations are being made, there is great liability to loss, owing to the formation of a salt crust on the surface of the liquid and subsequent spirting, caused by steam and ammonia vapor produced under the crust. This takes place no matter how carefully the evaporation be carried on, and many determinations were thus lost.

The use of hydrochloric acid enables us, however, to completely obviate this difficulty. The purified alkaline chlorides are to be evaporated till crystallization begins; the platinum vessel is then removed from the water bath, and an equal bulk of very pure, highly concentrated hydrochloric acid added to the solution. A copious precipitation of finely granular salts at once ensues, and, on replacing the vessel on the water bath, evaporation goes on quietly and rapidly, no salt crust is formed, and when the final heating is given, little decrepitation occurs. In this manner it is as easy to handle several grams of

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[1] Gooch: Proc. Am. Acad. Sci., 1886, p. 167.

chlorides and to obtain accurate determinations as it is when we have to deal with the far smaller quantities usual in mineral analysis.

The water in the salts was determined by means of the apparatus figured. A is a combustion tube drawn out and bent at a right angle. The platinum boat B, containing the salt, rests upon the thin sheet of asbestos paper C, used to prevent adhesion between the platinum and the heated glass. D is a roll of asbestos paper wrapped with thin platinum wire, which fits loosely in the tube and prevents back currents of air during the heating. The bent end of the combustion tube enters one limb of the U tube E, which is my own form, and differs, as the drawing shows, materially from the forms now on the market, in having an especially large bulb at the bottom. The two limbs of this tube are filled with glass beads wet with strong sulphuric acid. Sufficient acid should be put in so that the narrow tubes are filled up to the bends and the air forced to bubble through.

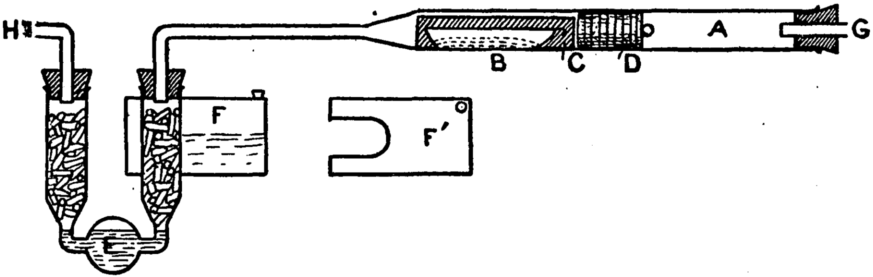

FIG. 4.—Apparatus for determination of water.

In using the apparatus the tube is thoroughly heated and then allowed to cool, a current of perfectly dried air being continually passed through it. The part of the tube where the boat is placed is protected by a semi-cylinder of sheet-iron lined with asbestos paper.

The U tube, having been weighed, is then attached to the combustion tube as shown and the air current regulated. The platinum boat which has been heated and then cooled in a desiccator, is now weighed and about one gram of the salt put into it and spread evenly along the bottom. The salt should be very finely pulverized to prevent decrepitation on heating. The boat with its contents having been weighed, it should at once be inserted into the tube and the asbestos plug D which has been highly heated and should still be hot, shoved in close behind the boat.

The tube is now heated gradually, beginning at the plug. As the water in such salts is driven out in great part at a low temperature the heating must be done cautiously and the air current watched, since, if it is too slow, water may condense in the cold part of the tube behind the plug. This regulation of the air current is the more difficult, since the acid CO_2 of the bicarbonate is set free simultaneously with the water, but upon it and the gradual heating depends the success of the operation.

The water bath F, of which F^1 is a top view, is now put into position, so that one limb of the U tube fits into the curved recess in the side of the bath. A small alcohol lamp keeps the bath hot, so that the water driven out of the salt may not condense in the upper part of the limb. By the use of this bath the time of the operation is much shortened.

As soon as that part of the tube containing the boat appears free from condensed water it should be highly heated until all the moisture has disappeared from the drawn-out portion. This will generally take from twenty minutes to half an hour, and when completed the water bath is removed and the apparatus allowed to cool, the air current being still kept up. As soon as the tube is cool the U tube is disconnected and the boat removed and placed in a small, well-stoppered glass tube, which has been weighed. The increase of weight of the U tube gives he amount of water in the sample, while the weight of the small tube containing the boat and calcined salt, if subtracted from the sum of the weights of the boat, the salt taken and the weighing tube shows a loss which is the water plus the acid CO_2 of the bicarbonate. The calcined salt which should be sintered together, but not fused, can then be used either for a determination of the residual CO_2 or, as is usually done, dissolved and the alkali determined by standard sulphuric acid, methyl orange being used as the indicator, the same portion being then used for the Cl determination.

Many attempts were made to collect and weigh the CO_2 driven off by heat, but it was found impracticable to do so without at the same time sacrificing the water determination. No matter how carefully the heat and air current are regulated, the CO_2 comes off too rapidly for proper absorption in the potash bulb, and if the air current is too slow, water condenses back of the plug and this determination is too low.

When no attempt is made to absorb the CO_2 the results are very satisfactory. In the analysis of urao "best specimen" given on page 76, we have as the mean of three closely agreeing CO_2 determinations 38.13 per cent., while two determinations of the alkali gave 40.28 per cent., equivalent to 28.58 per cent. of CO_2 required to make monocarbonate. Deducting this amount from that of the total CO_2 we have 9.55 per cent. as the acid CO_2 of the bicarbonate present. The determinations with the above described apparatus gave the following results:

Salt taken.	Loss of boat.	H_2O.	Difference=CO_2.
1.0040	29.51	20.12	9.39
1.0490	29.58	20.09	9.49
1.1583	29.49	20.00	9.49
1.0638	29.53	20.07	9.46

We have therefore as average 9.46 per cent. CO_2 found, which being deducted from the calculated amount 9.55, leaves an excess of 0.09 per cent. not driven off.

In another sample of urao:

Salt taken.	Loss of boat.	H_2O.	Difference $=CO_2$.	CO_2 in residue.	Sum of CO_2.
1.1801	29.27	19.80	9.47	28.69	38.16
1.2297	29.35	19.83	9.52	28.64	38.16
1.2066	29.39	19.85	9.54	28.49	38.03
1.0880	29.26	19.80	9.46	28.67	38.13
1.1761	29.32	19.82	9.50	28.62	38.12

Two determinations of total CO_2 gave 38.17 and 38.22 per cent.—average 38.19. Two determinations of alkali gave 40.19 and 40.22 per cent. Na_2O, average 40.20—equivalent to 28.53 per cent. CO_2. Hence, as 28.62 per cent. CO_2 was found in the residue and only 28.53 was necessary for the combination Na_2CO_3, we have 28.62—28.53=0.09 per cent. CO_2 not driven off.

In a sample of Trommsdorff's C. P. sodium bicarbonate there was found:

Salt taken.	Loss of boat.	H_2O.	Difference $=CO_2$.	CO_2 in residue.	Sum of CO_2.
1.4265	36.68	10.91	25.77	....	....
1.5995	36.81	10.90	25.91	....	....
1.3200	36.71	10.91	25.80	26.25	52.05
1.3723	36.73	10.98	25.75	26.37	52.12
1.4296	36.73	10.92	25.81	26.31	52.09

Two determinations of total CO_2 gave 52.06 and 51.90, average 51.98 per cent. Two determinations of alkali gave 36.86 and 36.90, average 36.88 per cent. Na_2O, equivalent to 26.17 per cent. CO_2. Subtracting 26.17 from 26.31, the average amount in the residue, we have 0.14 per cent. CO_2 not expelled by heating to the sintering point.

Comparing these amounts of excess of CO_2 retained by the residues of the ignition, we find the following relation:

Sample.	Number of determinations.	Average weight taken.	Average excess, per cent.	Relation of excess to weight.
Urao, No. 1	3	1.0638	0.09	0.084
Urao, No. 2	4	1.1761	0.09	0.077
Bicarbonate	4	1.4296	0.14	0.091
Average	....	....	....	0.084

Hence we may say that if sodium bicarbonate, or a salt containing a large proportion of it, is heated till it sinters without fusing, and is kept at that temperature for one hour, it still retains CO_2 in excess of the amount required to form monocarbonate with the alkali present, and that for quantities of from 1 to 1.5 grams this excess may be considered as one-tenth of one per cent. of the weight of the salt taken.

For an analysis of sodium bicarbonate by means of this method it is therefore sufficient to determine the loss by ignition, the H_2O, and the alkali in the ignited residue to obtain the total amount of CO_2 in the sample, adding in an amount of CO_2 equal to 0.10 per cent. of the weight of the salt taken. This method for the analysis of bicarbonate or "baking soda" is much more rapid, far easier and quite as accurate as the distillation process, and may prove of value for technical purposes.

ORIGIN OF NATURAL SODA.

We have seen that this material occurs in many widely separated localities, which have, perhaps, but one characteristic in common, namely, a very dry climate. The presence of volcanic rocks belonging to late geologic periods, though proved in many instances, has not as yet been shown for a few of them, such as Hungary and Egypt.

Dryness of climate has no other effect, probably, than to retain within a given region its product of natural soda, which would otherwise be continually carried off to the sea through natural drainage, though the consequent inclusion of the drainage in closed basins may be necessary to permit of certain chemical after-reactions.

In an arid region like our Great Basin, but a small portion of the total rainfall reaches the ocean. Rivers of considerable magnitude terminate in "sinks" or lakes without outlet. Such lakes are naturally impregnated with salts, since each drop of inflow brings its quota, and the only loss that such a basin suffers is by evaporation, which carries off no solid matter.

Unless chemical changes occur in the lake itself, such a body of water represents a simple concentration of its inflowing streams, and if we find it to contain any given salt, it is evident that this salt has either been brought as such into the basin, or is a product of chemical after-reactions among the constituents of the lake water. If the salt has been brought as such it is a product of rock or soil decomposition, and is in solution as a result of a leaching process, whether the water came from a deep-seated spring or is a mere surface drainage.

The existence of springs carrying sodium carbonate is well-known, since many of them have a world-wide reputation for their medicinal qualities. Although most of them are weak solutions, a comparison of their compositions with those of the waters described in this paper will show that they would by sufficient evaporation yield a very pure natural soda. The sodium carbonate in such springs is produced by decomposition of the alkali-bearing rocks through which the water flows, and this decomposition is brought about by the combined action of air and moisture, aided in many instances by heat and pressure.

The air absorbed by water contains a much larger proportion of oxygen and carbonic acid than the normal atmosphere, the composition of which may be taken as

Oxygen	20.9512
Nitrogen	79.0073
Carbonic acid	0.0415

while the air absorbed by water at 15° C. (60° F.) contains, according to Bunsen,

Oxygen	34.12
Nitrogen	63.62
Carbonic acid	2.26

The alkali-bearing minerals are generally silicates, having for bases ferrous or ferric oxide, alumina, lime, magnesia, soda and potash in varying proportions according to the character of the mineral. Thus orthoclase feldspar is composed, essentially, of silica, alumina and potash; albite, of silica, alumina and soda; anorthite, of silica, alumina and lime, but they are rarely found pure and there exist many intermediate steps, so that orthoclase usually contains soda and lime in varying proportions, while magnesia and ferric oxide replace in part lime and alumina respectively.

By the action of water, containing carbonic acid, upon such minerals, the alkalies and alkaline earths are converted into carbonates and dissolve in the carbonated water. Hence they are leached out of the residue, which is rendered the more porous through the decomposition, and if the water so charged does not on its way to the surface meet with sulphates or chlorides of other metals which, by double decomposition, would produce alkaline sulphates or chlorides and non-alkaline carbonates, the alkaline carbonates make their appearance as constituents of a mineral spring. In such springs the salts of sodium are usually in much greater proportion than those of potassium, not only because the soda minerals are, in general, more easily decomposable, but also because soils have a strong tendency to take up and retain the potash salts from water percolating through them while readily giving up their contents of soda salts.

If the waters of such springs flow into basins without outlet and the rate of evaporation equals the inflow, a concentrated solution gradually results, and if the inflow be interrupted, we shall in time have a dry basin in which the salts have deposited as a crystallized mass. It is evident that if the geological character of a country is favorable to the production of such alkaline springs, the dryness of the climate or the excess of evaporation over rainfall determines the degree of concentration of the contents of their basins, the number of which is dependent on the topography, and the consequent productiveness of the region in natural soda.

We have so far considered original formation and simple evaporation only. There are, however, a number of instances in which the alkali appears to be the result of more complicated chemical reactions. We have already seen the views of Szabo and Moser as to the mode of origin of the Hungarian soda, in which the carbonate of lime is supposed to play a part. Lunge[1] refers to the fact that from a damp mixture of common salt and lime soda effloresces in the air after several weeks' time, and also states that "from a solution of common salt a solution of bicarbonate of lime precipitates sodium bicarbonate; apparently this reaction explains the formation of soda efflorescence in soils containing common salt." If the more soluble magnesium bicarbonate be substituted for the calcium salt we have Weldon's process for soda making.

It may therefore be said that if common salt and limestone or dolomite are present together in a soil, subject to the action of air, moisture and climate, all the conditions for the production of natural soda are at hand, and it is thus that the origin of the soda of Egypt may be explained. Russegger's description of this locality has already been cited. After ascribing the formation of the sodium carbonate to reactions occurring between the $CaCO_3$ Na_2SO_4 and NaCl, by which Na_2CO_3 $CaCl_2$ and $CaSO_4$ are formed, he says:

> The first two (Na_2CO_3 and $CaCl_2$) dissolve in the water of the lakes together with the undecomposed Na_2SO_4 and NaCl, and thus we have a lye containing NaCl, Na_2SO_4, Na_2Co_3 and $CaCl_2$.

A very slight knowledge of chemistry tells us that Na_2CO_3 and $CaCl_2$ cannot exist together in solution, since $CaCO_3$ must be precipitated at once, NaCl remaining in solution; so Karsten (loc. cit.) adds the following note:

> This transformation of the salts is undoubtedly a consequence of the oxydation of the pyrites in the clay to sulphates, followed by a double decomposition of these sulphates by the NaCl and $CaCO_3$ in the clay. The sodium and calcium sulphates so formed are then reduced to sodium and calcium sulphides and these are decomposed by means of NaCl and $CaCO_3$. The process must, therefore, be considered as very complicated and as demanding not only length of time but also a co-operation of special conditions, precisely as they occur in the Egyptian lakes. The organic matter here present may well be considered as the sole and only cause whereby the sulphates are reduced to sulphides, these being changed then to carbonates.

Abich, in his description of the Armenian localities, already given in part, ascribes the formation of the sodium carbonate there found more particularly to the action of plant life. The salt grasses and other plants which grow in that region yield an ash rich in soda salts, those from Armenia being richer in Na_2CO_3, while those from the Steppes contain a larger proportion of Na_2SO_4. The soil of the Steppes contains much Na_2SO_4, but is poor in NaCl, precisely the reverse of the soil of Armenia; hence the conclusion that the Na_2CO_3 is formed by the action of the plant on NaCl, comparable with the formation of potassium carbonate, which usually predominates in the ash of land plants. The growth, death and decomposition of successive crops of such plants would, under this view, continually increase the amount of sodium carbonate in the soil without taking into consideration the amount pro-

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[1] Lunge: Sulph. Acid and Alkali, Vol. 2, p. 310.

duced by direct weathering of the eruptive rocks so abundant in that region.

We have already seen that the deposits of Wyoming consist in great part of sulphates and chlorides, though occasionally the percentage of carbonate becomes sufficiently large to be of importance. This is also true of the Lake Bonneville region as described by King in the 40th Parallel report, already frequently quoted. In vol. 1, page 500, he shows that the salts are mainly chlorides and sulphates, the former largely predominating, while carbonates are generally absent. The water of the Great Salt Lake may therefore be taken as typical for the region. As one proceeds westwardly the occurrences of alkaline carbonates are more frequent and the percentage of this salt greater until we reach the Lahontan region of western Nevada, where the proportion of alkaline carbonate is usually greater than that of sulphate.

The cause of this chemical change in the nature of the salts, though much discussed, is not yet ascertained. So far as we know, there is no such difference between the rocks of the eastern and the western portion of the Great Basin as would account for this increase of the carbonate. In both sections the eruptive rocks are of similar character, and, by their decomposition, should yield the same products. It is possible that the fact that volcanic action has persisted to a much later date on the western border than on the eastern side may have some influence. Hot springs are much more common along the foot of the Sierra Nevada, and some of the volcanoes have been active at a comparatively recent date. The enormous volume and high temperatures of the heated waters of the Comstock Lode may also be considered as showing a probably greater activity in rock decomposition but not, necessarily, a difference in character of product.

Once formed through rock decomposition, a solution containing sodium chloride, sulphate and carbonate would afterwards lose none of its carbonate unless soluble earthy salts were added to it; on the contrary, when such a water reaches an enclosed basin, the proportion of sodium carbonate tends, following the views of Karsten, to increase through the reduction of the sulphate by organic matter and the subsequent action of the atmospheric carbonic acid on the sulphide; a reaction which requires a period of comparative rest, which such a basin affords. It has been already stated that the waters of springs carrying alkaline carbonate may lose the whole of it on the way to the surface by passing through formations containing non-alkaline soluble salts, such as gypsum, calcium chloride or magnesium salts, resulting in the formation of calcium or magnesium carbonate and alkaline sulphate or chloride. The same reaction would occur if the surface water percolates through soils containing these salts, or if water containing them be added to the streams or basins.

It is probable that an alkaline lake or the dry deposit resulting from its desiccation is in all cases the result of both primary rock decomposition and subsequent chemical change. The latter usually appears to be the subordinate agent, but still occupies a definite position, and in this connection the results of the examination of certain seepage waters from the shore of Owen's Lake are interesting. The analysis of the water of this lake shows that sulphides are absent, the most careful tests showing merely a doubtful trace. On page 76, a urao was described as having been produced from seepage water collected in a vat dug on the beach and for practical reasons it was desirable to study the nature of the seepage. To this end, small pits were dug in a line extending from the vat to a point much above the highest recent water mark of the lake. From each of these pits, beginning with the one most distant from the lake, a sample of the seepage water was taken and the specific gravity tested, as follows:

Sample.	Temperature.	Specific gravity.	Remarks.
	° C.		
No. 1	32	1.005	
No. 2	31	1.035	
No. 3	31	1.050	
No. 4	31	1.050	
No. 5	32	1.062	Analyzed.
No. 6	32	1.090	
No. 7	32	1.108	
No. 8	31	1.085	Analyzed.
No. 9 near vat	31	1.063	Do.
Lake water	25	1.062	

The soil of these pits showed no variety; in each case it was found that the surface sand was underlaid by a dark grey material similar to a very sandy clay and closely resembling the "volcanic ash" common in this section, and which it is considered to be. A sample was taken from pit No. 9 and analysed as follows, having been partially dried, when it became pulverulent and of a pale yellowish grey color.

H_2O at 110°	.65	H_2O		3.15
H_2O at red heat	2.50	*Soluble part.*		
CO_2 in soluble part	.87	NaCl	1.45	
CO_2 in insoluble part	6.35	Na_2SO_4	.80	
SO_3	.45	Na_2CO_3	2.09	
Cl	.88			4.34
SiO_2	55.81	*Insoluble part.*		
TiO_2	.80	$CaCO_3$		14.44
P_2O_5	.27	SiO_2	55.81	
Al_2O_3	10.07	TiO_2	.80	
Fe_2O_3	3.43	P_2O_5	.27	
FeO	.67	Al_2O_3	10.07	
MnO	.23	Fe_2O_3	3.43	
CaO	9.14	FeO	.67	
MgO	2.22	MnO	.23	
K_2O	2.98	CaO	1.05	
Na_2O	3.09	MgO	2.22	
	100.41	K_2O	2.98	
O=Cl	.20	Na_2O	.75	
				78.28
	100.21			100.21

Analyses of the samples of seepage water.

Specific gravity and temperature.	Pit No. 5.		Pit No. 8.		Pit No. 9.	
	1.06872 (22.5° C.)		1.0881 (24.1° C.)		1.07308 (21° C.)	
In 1 liter.	Weight.	Per cent.	Weight.	Per cent.	Weight.	Per cent.
Cl	24.316	27.92	29.412	25.87	23.808	25.84
SO_3	6.092	6.99	8.664	7.62	4.936	5.36
O	1.216	1.40	1.732	1.52	.988	1.08
S (sulphur)	trace...	....	.120	.11	.161	.17
CO_2	15.172	17.42	21.100	18.56	19.320	20.97
O	5.516	6.33	7.672	6.75	7.024	7.63
K	2.352	2.70	2.612	2.30	2.020	2.20
Na	32.064	36.82	41.896	36.85	33.426	36.24
SiO_2	0.296	.34	.316	.28	.260	.29
Al_2O_3	undet ..	....	.008	.007	.008	.01
Ca	undet ..	....	.020	.02	.014	.015
Mg	undet ..	....	.009	.008	undet ..	....
B_2O_3	present	....	undet ..	....	undet ..	....
H	.072	.08	.120	.105	.176	.20
	87.096	100.00	113.681	100.00	92.142	100.00

Hypothetical combination.

	Weight.	Per cent.	Weight.	Per cent.	Weight.	Per cent.
SiO_2	.296	.34	.316	.28	.260	.30
Al_2O_3	....	....	.008	.08	.008	.04
$CaCO_3$	....	....	.044		.032	
$MgCO_3$	....	....	.033		....	
KCl	4.487	5.15	4.991	4.39	3.864	4.19
NaCl	36.549	41.96	44.545	39.18	36.199	39.28
Na_2SO_4	10.812	12.41	15.376	13.52	8.757	9.49
Na_2S	trace.	....	.292	.26	.392	.43
Na_2CO_3	28.876	33.17	37.884	33.33	27.817	30.19
$NaHCO_3$	6.076	6.97	10.192	8.96	14.813	16.08
	87.096	100.00	113.681	100.00	92.142	100.00

In comparing these analyses we must remember that the water here examined is not the lake water, but the drainage from fresh springs along the base of the Inyo Range. As the water passes through the volcanic ash it gradually becomes laden with the salts produced by the decomposition of the soil as shown by No. 5. At this point the amount of sulphur or sulphuretted hydrogen present, though small, was unmistakable, showing that a reduction of sulphates had begun. In No. 8 the percentage of chlorides had diminished, and that of bicarbonate had increased, while the percentage of sulphates was somewhat larger, although sulphides were present in weighable quantities. No. 9 is very regular in its results if compared with No. 5. The chloride and sulphates have suffered a considerable decrease, while sulphides are in as large a proportion as we should expect, considering that they would be destroyed at once if in solution with bicarbonates. The sodium monocarbonate is apparently less in amount than in the first analysis, but we observe a great increase in bicarbonate, so the percentage of alkali in the last analysis shows a large gain over the first one. As the distance from one pit to the next was not more than a hundred yards, this process of alkali production is really quite a rapid one, and the solutions obtained are stronger and of better quality for practical purposes than the mass of the lake water.

CAUSE OF THE RED COLOR OF CONCENTRATED ALKALINE BRINES AND OF THE SALTS OBTAINED FROM THEM.

The red color which brines, particularly those of an alkaline character, are apt to assume when concentrated, and which is frequently taken up by the deposited salts, has often been noticed. The cause of this color has been studied by Payen,[1] who finds that it is due to the presence of the small crustacean, Artemia salina, Leach (Cancer salinus, Linn.), known in the West as the "alkali shrimp." In his experiments carried on at the Salines of Marignano, he found that the brine in concentrating to 15° B. becomes entirely clear and colorless, continuing until it reaches 20° B., at which point large numbers of small animals, grey or greenish grey in color, are observed swimming in the liquid. As the brine concentrates to nearly 25° B. all of these little crustaceans die, turn red, come to the surface and form a red foam, which is composed of the fragments of their bodies and gives a peculiar odor. Experiments showed that if the concentration of the brine did not exceed 20° B. the animals were healthy, provided that they had air and that the solution did not become acid. If the solution became acid, the animals became sluggish and moribund, but were revived as soon as the solution was rendered alkaline.

The same may be said of the brine at 15° B. For a short time the animals were very lively, but on the fourth day became sluggish. Rendering the solution alkaline revived them to some degree, and on reducing a portion of the solution to 3° B. the crustacea in it remained alive and vigorous up to the time when the paper was written.

Those in the solution at 20° B. were lively during two days, then began to die, and all were dead on the third day. In fresh water all died within four days. In solutions at 23° B. all died within twenty-four hours, having become much redder than in the weaker solutions, and settled on the bottom as a brown sediment. These experiments show that a certain degree of concentration and a certain degree of alkalinity are necessary for the life of these animals, and that greater concentration causes death and the consequent red coloration.

The letter of Audouin accompanying the paper gives the observa-

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[1] Payen: Ann. de Chimie, pt. 2, vol. 65, pp. 156–169.

tions of Schlosser made at Lymington, England, in October, 1755. The latter describes these animals as follows:

> The body is merely a tube, cylindrical or vermicular in form, very slender, and about one-third of an inch in length. At one end of this tube are two antennæ, very delicate and short, and two black eyes, round and elevated; between these eyes is a black spot, which may be a third eye. A curved mouth is placed under the eyes. The body is provided with 21 pairs of natatory legs, the longest being in the center of the body, the others becoming shorter as they approach the head and tail. The posterior part is bare, the anus being at the extremity. The females have posterior to the last pair of legs a sac, usually three or four times the diameter of the tube, containing eggs; the males have, anterior to the first pair of legs, two long flattened arms, with these they seize the females, and while attached to them appear to squeeze out several eggs. The animals thus attached swim together for some time.

D'Arcet observed the red color of the Egyptian lakes, but finding only a few artemia, did not consider that the color was due to them. In the West the artemia are very plentiful and the red color is very usual, though generally ascribed to some property of the salt grasses. It is probable that the opinion of Payen is the correct explanation.

LEACHING OF ALKALINE SOILS AND CLAYS.

A chemical examination of a soil always includes a leaching with water and the analysis of the soluble portion. This is especially necessary in the case of samples from alkaline terranes, where the percentage of soluble salts is often large, and unless these can be extracted without alteration, no correct conclusion can be drawn as to the character and agricultural possibilities of the soil. In such regions crops can seldom be grown without irrigation, which not only supplies the plants with the necessary moisture, but also improves the land by leaching out the surplus salts, which may, under exceptional circumstances, be profitably recovered from the leachings.

The extraction of the soluble constituents from such soils and clays is often difficult, because when the sample is mixed with water subsidence is exceedingly slow, and filtration, if at all practicable, yields a very turbid solution. Having to examine a number of such samples, experiments were made to find out the simplest method of securing a clear aqueous solution containing only the naturally soluble salts. The presistent turbidity seems to be in some way connected with the alkalinity of the solution, since if this is rendered slightly acid, subsidence is rapid and a clear liquid is easily obtained. By acidifying, however, all the carbonates are decomposed and the resulting solution tells us nothing concerning the character of the original material.

It is well known that sea water precipitates the finely divided suspended material from inflowing river waters, and experiments based on this observation have shown that the addition of a small proportion of pure sodium chloride is all that is needed to obtain a clear and unaltered solution. Three samples of so-called "clays" from Owen's Lake have been especially examined for this purpose.

In making vats at the soda works at this place it was found that some of them could not be rendered water tight without great expense, and the reason of this was sought. Sample No. 1 represents this class of ground, while the combination of Nos. 2 and 3 is "good ground," holding water without difficulty. If the samples are dried the difference is strongly marked, No. 1 becoming very friable, while the others are as tenacious as a brick clay of inferior quality. If the dried samples are mixed with a little water all become pasty, but if much water is added the emulsion of No. 1 subsides rapidly, a few hours being amply sufficient to give a clear supernatant liquid, which can be poured off without disturbing the compact underlying sediment. Under like conditions Nos. 2 and 3 remain turbid, and after the lapse of thirty days not more than one-tenth of the supernatant liquid was even approximately clear. By the addition of a sufficient amount of common salt the subsidence was rendered as rapid and as complete as in No. 1, and the sediments can be washed by decantation. For the determination of chlorine, dilute nitric acid is added till the solution becomes acid, producing the same effect as the addition of common salt.

No. 1 is from the "upper works" at Keeler, Owen's Lake. It is covered by the surface sand, is yellowish grey in color and, as stated, friable. No. 2 is "sandy clay" from the "central works." This is immediately under the surface sand, is about 12 to 18 inches thick, and is said to be the best for vat-making; underlying this is the "blue clay," No. 3, of undetermined depth and also very good. Analysis gave the following results:

	No. 1.	No. 2.	No. 3.
H_2O at 120°	4.02	1.41	2.05
H_2O at red heat	1.18	2.73	2.40
SiO_2	45.83	53.24	54.92
TiO_2	.30	.25	.30
Al_2O_3	8.05	10.84	11.25
Fe_2O_3	2.77	2.59	2.77
FeO	.43	.77	.94
MnO	.12	.10	.08
CaO	4.88	9.18	8.76
MgO	1.23	5.82	4.91
K_2O	2.86	2.64	2.77
Na_2O	14.21	2.06	2.10
SO_3	1.85	.08	trace.
Cl	7.33	.05	trace.
CO_2	6.44	8.75	7.21
	101.50	100.51	100.49
Deduct	1.65	.01	.49
	99.85	100.50	100.00

	No. 1.	No. 2.	No. 3.
Water	5.08	4.14	4.45
Soluble part	24.80	1.26	1.41
$CaCO_3$	6.18	19.07	15.34
Insoluble	63.79	76.03	79.29
	99.85	100.50	100.49

Composition of soluble part.

Soluble.	No. 1.	No. 2.	No. 3.
KCl	4.18	....	....
NaCl	11.15	.09	....
Na_2SO_4	3.30	.14	....
Na_2CO_3	7.50	.87	1.18
$NaHCO_3$	1.17	....	....
SiO_2	.39	.16	.23
Al_2O_3	.11	....	....
	24.80	1.26	1.41

No. 1 is evidently in great part sand, made up of quartz and small grains of eruptive rocks, and contains but little real clay. Hence it absorbs large quantities of soluble salts, but parts with them readily on leaching, leaving a porous residue, which, on account of its granular condition, subsides rapidly when mixed with water. Nos. 2 and 3 contain only small quantities of soluble salts, but chlorides are practically absent, and the residues containing considerable quantities of carbonate of lime may be viewed as marls.

The clarification by the use of NaCl must be considered as a physical phenomenon since, so far as our present knowledge extends, no chemical change is supposable under the conditions. In each of the following experiments, begun September 11, 1888, the air dried material was weighed out and put into a cylinder containing the given amount of salt dissolved in 50cm^3 of water. The cylinder was then corked, shaken vigorously and allowed to stand without further disturbance.

Exp. A: 10 grams clay No. 2 (sandy clay), no NaCl. Subsidence very slow. Nov. 28. Height of column 85mm, height of sediment 47mm, supernatant liquid slightly turbid.

A¼: 10 grams No. 2, 0.025 gramme NaCl. Subsidence much more rapid, having been, apparently, completed about Oct. 1st. On Nov. 28, height of column 85mm, sediment 33mm.

A½: 10 grams No. 2, 0.05 NaCl. Subsidence complete within forty-eight hours. Column 92mm, sediment 33mm, liquid clear and line of demarkation between sediment and liquid sharply defined. A1 and A2, containing 0.1 and 0.2 grams NaCl respectively, showed complete subsidence within 24 hours.

Series B: 10 grams No. 3 (blue clay) taken.

B: No NaCl. Nov. 28. Column 86mm, of which about 5mm could be called clear, the next 10mm, though translucent, was turbid, the rest opaque.

B¼: 0.025 grams NaCl. Nov. 28, column 88mm, sediment 50mm, demarcation fair.

B½: 0.05 grams NaCl. Nov. 28, column 81mm. Sediment 44mm, demarcation definite, solution clear.

B1: 0.1 gram NaCl. Nov. 28, column 84mm. Sediment 28mm. Sedimentation complete within a week.

B2: 0.2 grams NaCl. Nov. 28, column 87mm, sediment 28mm. Subsidence complete within 48 hours.

Two portions of each clay of 5 grams each with 0.025 and 0.05 gram NaCl, respectively, showed a rate of subsidence much more rapid than that of the corresponding 10 gram portions, and this rate seems to depend upon the salinity of the solution. The further investigation of this subject involves complicated problems in physics, and for practical purposes it is sufficient to know that by the use of small quantities of NaCl the soluble portion of such clays can be easily and completely extracted.

CONCLUSIONS.

The conclusions arrived at in the course of this work may be briefly summarized as follows:

First. Natural soda is formed partly by direct decomposition of rocks through the action of air and water, aided at times by heat and pressure, and partly by subsequent decompositions occurring either in soils or in closed basins. These reactions, especially those of the latter class, are much influenced by the action of organic matter, which not only reduces sulphates, but also, in the form of certain organic acids, has been found to be a powerful reagent in rock decomposition.

Second. Natural soda is, essentially, a definite compound of sodium monocarbonate and bicarbonate, and the other accompanying salts are to be considered only as impurities. The proportion of the two carbonates forming this compound is one molecule of each. Any excess of either carbonate above this ratio is considered to be merely accidental, and the existence of the so-called sesquicarbonate or combination of one molecule of monocarbonate with two molecules of bicarbonate is believed to be very doubtful; at present, the strongest proof of its existence is derived from certain crystallographic determinations.

Third. The mineral urao is the pure form of natural soda, and this compound, having a relation of four-thirds of a molecule of CO_2 to one molecule of Na_2O, may be called the "tetra trita" or "tetrita" carbonate. The sodium carbonates are therefore considered to be but three in number, namely: monocarbonate, tetrita carbonate and bicarbonate.

Fourth. The nature and properties of urao render it the most suitable form in which the natural sodium carbonates can be separated from accompanying salts. Hence any technical method devised for the manufacture of commercial soda from the natural material should be based on the formation and separation of this compound. The method described as being employed at Owen's Lake is, as far as it goes, simple and good, but the yield is not large, when the extent of the plant is considered. Owing to the small proportion of bicarbonate present in the original water, the crop is smaller than could be obtained if the amount of bicarbonate could be increased. Whether this can be economically done can be answered by practical experience only, but the following suggestions may be of value.

As the first step in the purification of a natural soda, it must be dissolved, and the solution should be clear. If such a solution be analyzed it will be found, in most cases, that the proportion of bicarbonate present is insufficient to give the largest practicable yield of urao. The amount of carbonate in the first crop depends upon the amount of bicarbonate in the solution, as this separates first and in separating takes with it a proportionate amount of monocarbonate. We have already seen that a soda ash of very good quality can be made at Owen's

Lake, but the yield under present conditions must be small in proportion to the amount of solution used. If the percentage of bicarbonate could be economically increased, the first crop should be much larger without detriment to its purity, and the increase may be effected either by the direct addition of bicarbonate or by its formation in the solution by causing the latter to absorb carbonic acid under pressure.

If the direct addition of bicarbonate is preferred, advantage may be taken of the fact noticed by Mondesir and others, that if urao is treated with an amount of water insufficient for its complete solution, it is decomposed, Na_2CO_3 going into solution, while $NaHCO_3$ is left behind. Heat increases the rapidity of the decomposition, but the temperature of the solution should not exceed 37.5° C. (100° F.). The $NaHCO_3$ thus obtained can then be dissolved in the raw solution of the natural soda, which for this purpose must not be too concentrated and, as the bicarbonate dissolves slowly, agitation of the salt with the liquid will hasten this stage of the process.

The solution of Na_2CO_3 obtained by this treatment of a portion of the urao may be utilized by converting it into bicarbonate, using, for this purpose, the carbonic acid given off during the calcining of the soda ash. The proper form of furnace for calcining such material is a continuously working muffle, in which the soda is mechanically fed, stirred and delivered, while the CO_2 is obtained in a pure condition and, when cooled, can be introduced at once into the solution of Na_2CO_3. For rapid absorption a pressure of about 25 to 30 pounds to the square inch is advisable, hence a pump must be used and the absorbing vessels should be made of light boiler iron. The absorption should not exceed the point at which bicarbonate begins to precipitate, and if the absorbing vessels are properly arranged in a series the carbonating will be a continuous operation and the plant required for quite extensive works will be found to be much smaller than would be supposed. The carbonated solution can be added directly to the raw solution.

If the formation of bicarbonate in the raw solution is preferred, a portion of this may be thoroughly carbonated and then added to the rest. This method has some advantages over the first one, but would probably require a somewhat larger carbonating plant for works of an equal capacity.

While the summer temperature is usually sufficiently high for the proper production of urao, the season is short, under the most favorable circumstances, and the output of works depending entirely upon natural heat correspondingly small. On the other hand, the temperature of the solutions should not be allowed to exceed 100° F. If it be possible to maintain the solution at this temperature during the crystallizing stage, in an economical manner, a great gain would be made, as the works could be run throughout the year, there being, usually, but little difficulty in obtaining and storing up an ample supply of concentrated raw solution. In this direction there is an extensive field for the exercise of educated ingenuity in the utilization of the waste heat of the calcining furnaces, as also in the economical application of heat derived from fuel burned for this purpose only. The description of the salt works at Pomeroy, Ohio, given in my paper on salt-making processes, in the Seventh Annual Report of the U. S. Geological Survey, shows a most ingenious and exceedingly close utilization of heat derived from fuel of very poor quality, and may give many hints to those desiring to work in this direction.

The utilization of the mother liquor of the first crop is a problem which can only be solved by the growth of this industry. Doubtless in time something can be done with the vast quantities of chlorides and sulphates which are waste products, but their value is too small to give much hope for their utilization under present conditions. The industry is in a preparatory stage only, but will surely become of great importance in the future; the present consumption of sodium carbonate in this country is probably not less than 250,000 tons and is increasing, and a large part of this amount could be supplied by the Great Basin if its resources were utilized. If those who may hereafter take up and prosecute this branch of chemical industry shall find the information given in these pages of value to them, the purpose of this paper will have been realized.

ANALYSES OF SIX NEW METEORITES.

By J. Edward Whitfield.

The Rockwood Meteorite.—This meteorite was found about the middle of March, 1887, by Mr. Elihu Humbree on the range of the Crab Orchard Mountains, in Tennessee. The field in which it was picked up is now owned by Mr. W. B. Lenoir, and is situated 8½ miles west from Rockwood, in Cumberland county. The material for analysis was received from Messrs. Ward and Howell, of Rochester, N. Y., the present owners of the meteorite, to whom I am indebted for the privilege of description.

Fig. 5.—The Rockwood Meteorite.

There were three pieces found, the smallest measuring 10cm × 8cm × 6cm, and weighing 1.65 kilos; the next larger, measuring 20cm × 16.4cm × 6.5cm, and weighing 2.64 kilos; and the largest, an irregular egg-shaped mass, a little flattened on one side, measuring 38cm × 25.3cm × 21.5cm, with a weight of about 38.5 kilos and specific gravity of 4.240. An idea of the appearance of this piece can be had from the foregoing cut, which is from a photograph reduced to $\frac{1}{6}$ natural size. The mass is quite brittle, very hard to saw, but easily broken by hammering. Cut slices show many irregularly shaped stony fragments with some nodules, the largest seen being about 1cm on the surface diameter. In the larger slices the stony part is so broken as to give the polished surface a brecciated appearance.

In analysis, the metallic portion was freed from the mineral part by crushing to rather fine particles and separating by the aid of a magnet.

This was again treated in the same manner, and the resulting metal washed with alcohol and quickly dried; by this method it was found possible to free the metal from all but the merest trace of stony substance.

The metallic portion proved to be an alloy, rich in nickel, as is shown by the following figures:

	Per cent.
Fe	87.59
Ni	12.09
Co	trace.
Cu	trace.
P	none.
S	none.
	99.68

The metallic grains seem to be quite evenly distributed through the mass. In but one instance does a nodule appear to have attained a size larger than that of a pea, and on the section of this nodule we were able to obtain the Widmannstätten figure by etching. Cut No. 2 shows the polished slice containing the nodule of natural size:

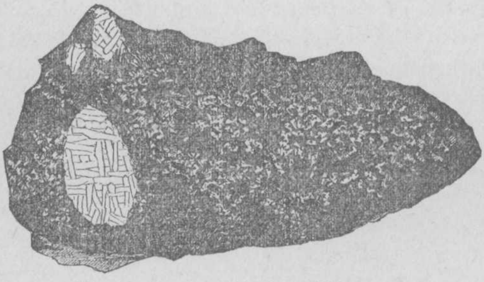

FIG. 6.—Section of Rockwood Meteorite.

The rocky part, after being freed as well as possible from metal, was finely ground and digested with dilute hydrochloric acid, and the resulting soluble and insoluble portions investigated separately, but from the fact of there being a number of minerals mixed together no satisfactory conclusions could be drawn from the examination. The mass was therefore analyzed as a whole with the following results:

	Per cent.
SiO_2	41.92
Al_2O_3	9.27
FeO	22.94
CaO	9.09
MgO	8.76
Fe	3.75
Ni	1.74
Cl	0.18 = 0.32 $FeCl_2$
P	0.65
S	1.58
	99.88

By the analysis of the portions soluble and insoluble in dilute acid it was found that the greater part of the lime and but a trace of the magnesia had gone into solution, proving the absence of olivine, and giving good grounds for the supposition that the rocky portion is mainly a mixture of anorthite and a silicate related to augite, but very rich in iron. It will be noticed that the ratio between the iron and nickel in the metallic portion is greater than that in the rock. This is accounted for by the fact that in the rocky part of the meteorite the iron, as metal, has been greatly oxidized, as is shown by the large amount of rust covering the specimen, caused no doubt by the chloride of iron present, and is reckoned as FeO, accounting for the large proportion of iron in the supposed augite.

Owing to the bad condition of the fragments subjected to analysis we have no grounds on which to compute the phosphorus and sulphur as schreibersite and troilite, but from the fact of these minerals being among the more common constituents of this class of meteorite, and also that in the main analysis of the rock portion phosphorus and sulphur were found, it is probable that the phosphide and sulphide of iron are two of the minerals present.

One of the polished slices contained a small nodule, which was sacrificed in order that its nature might be determined, and the following figures give the results of analysis. The mineral was finely ground, the metallic portion, if any, separated by aid of the magnet, and the residue was digested in dilute hydrochloric acid.

The insoluble portion was found to be 94 per cent., the composition of which is

	Per cent.
SiO_2	51.85
Al_2O_3	4.52
FeO	13.26
CaO	1.09
MgO	29.28
	100.00

This gives the ratio of $R''O$ to $SiO_2 = .93 : .86$, which corresponds well with the mineral enstatite, although in this case much of the magnesia is replaced by iron. The soluble portion consisted of iron with a slight trace of nickel, which tends to show that the nodule contained some metallic particles which it was impossible to extract with the magnet. During the digestion in acid, as no sulphuretted hydrogen could be detected, we infer the non-existence of sulphides in the nodule.

The total mineral was also analyzed with the following results:

	Per cent.
SiO_2	49.96
Al_2O_3	4.75
FeO	15.97
CoO + NiO	trace.
CaO	1.15
MgO	28.15
	99.98

This meteorite, then, is a lithosiderite, poor in metal, the metallic portion not exceeding 16 per cent. of the mass. The stony part is probably anorthite and enstatite.

Chattooga County Meteorite.—This mass of meteoric iron was found by Mr. W. J. Fox, about the 27th of March, 1887, on his farm near Holland's Store, Chattooga county, Ga. In all 12.5 kilos were found, but the mass was rather roughly handled, being broken into pieces and some of them worked into horseshoes and nails by the local blacksmiths. Three of the fragments were obtained by Mr. G. F. Kunz, of New York city, and described by him in the December, 1887, number of the American Journal of Science.

The material received from Mr. Kunz for analysis gave the following results:

	Per cent.
Fe	94.60
Ni	4.97
Co	.21
P	.21
Cl Ss	traces.
	99.99
Specific gravity	7.801

Taney County Meteorite.—We received from Mr. George F. Kunz, the present owner of this meteorite, the material for analysis. The description has been fully given by him in the December, 1887, number of the Am. Journal of Science.

This being one of the class termed stony meteorites, a number of analyses were made on the rocky portion, in order, if possible, to ascertain the character of the minerals present.

The analysis of the metallic part is as follows:

	Per cent.
Fe	89.41
Ni	10.41
Co	.29
P	.16
	100.27

Of the rock material separated from metallic grains the analysis gave

	Per cent.
SiO_2	45.88
Al_2O_3	7.89
FeO	19.73
CaO	6.02
MgO	17.96
NiS	1.67
FeS	.54
	99.69

The fragment as received gave a specific gravity of 4.484. As far as I can judge the insoluble mineral of the rocky portion is enstatite, and the soluble part a lime-iron silicate with considerable Al_2O_3. Of the portion insoluble in dilute hydrochloric acid the following figures are the results of analysis:

SiO_2	52.39	=.87	
Al_2O_3	7.11		
FeO	14.68	.20	.81
CaO	4.49	.08	
MgO	21.33	.53	
	100.00		

Ratio of $SiO_2 : R''O = .87 : .81$ which agrees pretty well with enstatite; but here the MgO is replaced by much FeO, and the presence of Al_2O_3 makes the ratio vary a little from the normal 1 : 1. Deducting all the S as NiS and the Fe to correspond to the remaining S from the soluble part, we have for the percentage of the soluble part:

	Per cent.
SiO_2	26.95
Al_2O_3	17.69
FeO	35.98
CaO	15.98
MgO	3.40
	100.00

The little MgO here probably comes from the slight solubility of the enstatite in the hydrochloric acid.

This meteorite is similar to the so-called Newton county, Ark., stone described by Dr. J. L. Smith,[1] and Mr. Kunz has found that the mass originally fell in Taney county, Mo., but that a fragment was broken off and taken to Newton county, Ark.

Linnville Mountain Meteorite.—About the year 1882 a mass of meteoric iron was found on Linnville Mountain, Burke county, N. C. Eventually it came into the hands of Mr. Kunz and was described by him in the American Journal of Science.[2]

Material for analysis was furnished by Mr. Kunz and gave the following results:

	Per cent.
Fe	84.56
Ni	14.95
Co	.33
Cu	none.
S	.12
C	trace.
P	trace.
	99.96

The Fayette County Meteorite.—The meteorite described below was found some ten years ago at Bluff, a settlement on the Colorado River about three miles southwest of the town of La Grange, in Fayette county, Tex. Bluff can not boast of being a village, as it is simply made up of a few farms scattered within a radius of two miles. The farmers are

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[1] Am. Jour. Science, vol. 40, 1865.

[2] Ibid., vol. 36, Oct., 1888.

mostly Germans or Bohemians, and as they are generally of the superstitious class, it is not strange that the finder, a Bohemian, named Raniosek, should have been struck by the appearance of the stone, and especially by its weight. As it is probable that he never heard of such a thing as a meteorite, it is safe to say that he did not know the nature of his find; still he seems to have come to the conclusion that it was something foreign to the soil.

There is a tradition in Fayette county that Santa Aña, at the time of his flight after the battle of San Jacinto, buried his war treasures somewhere near La Grange, and the belief has so fixed itself in the minds of the inhabitants that many fruitless attempts have been made to discover them. The finder of the meteorite, with the tradition fresh in his mind, reasoned that so large and heavy a stone must mark the place where some treasure was deposited; he therefore rolled the stone a few feet aside and dug a deep hole at the exact spot where the stone had been, without finding anything to pay him for his labor.

For several years the stone lay where the Bohemian had left it; then he sold the piece of land to Mr. C. Hensel, who still owns it; but before the latter had taken possession Raniosek removed the stone to his own farm, about a mile away, where for five years more it lay neglected in his yard. His reason for removing it was that its weight led him to suspect it contained some valuable metal.

About three years ago Mr. H. Hensoldt took charge of the school at Cedar, two and one-half miles from Bluff settlement. While spending his time in hunting for fossils, minerals, etc., the attention of the farmers was drawn to him, and in January, 1888, he was informed of the strange stone in Mr. Raniosek's yard. Immediately on seeing it he recognized it as a meteorite, and a very fine specimen of its kind.

After obtaining possession of the stone Mr. Hensoldt disposed of it to Messrs. Ward and Howell, of Rochester, N. Y., to whom we are indebted for the material for study and the privilege of description. On receiving the stone Mr. Howell published a notice in Science (February 3, 1888, p. 55) putting it on record as the "LaGrange Meteorite," but on finding that this name had already been applied to the Oldham County, Ky., Meteorite, agreed that it should be called the Fayette County Meteorite.

The stone possesses all the characteristics of a meteorite. The pittings are well marked, but the crust shows only in the deeper depressions; a freshly fractured surface shows, besides the grains of metal, a greenish-gray appearance not unlike some greenstones. A particularly interesting feature of the stone is the presence of a few dark-colored veins varying greatly in dimensions—the one in the specimen for examination being some 2mm in the greatest width and 60mm in length.

The three dimensions of the mass are 58cm × 46cm × 28cm, and the total weight about 146 kilos. A good idea of the appearance of the meteorite may be had from figure 7.

Before the specimen was pulverized for analysis the vein was carefully sawed out, so as to keep all the vein material from the mass. The rock was then ground as fine as possible, and a portion (1 gram) treated with iodine in cold water, to separate the metallic particles. The residue was filtered on a Gooch soluble filter and washed free from iodine. The rocky material, after being weighed, was treated with dilute hydrochloric acid and allowed to stand for some time, then filtered, and the residue weighed; in both cases the mineral being separated from the filter by using the proper solvent for the anthracene—washed with ether and alcohol and dried at 100° C. This temperature was not sufficient to drive all the water from the mineral part, which accounts for the discrepancy of about 2 per cent.

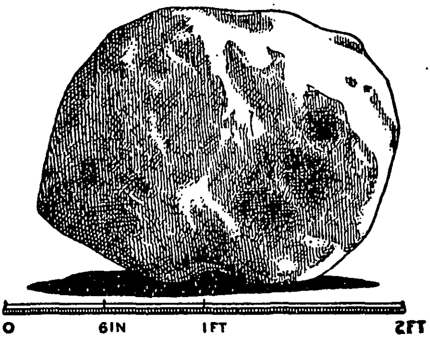

FIG. 7.—The Fayette County Meteorite.

The following figures will show the composition of the metal and the rock, soluble and insoluble, in hydrochloric acid; also the results of a complete analysis of the total mass:

	No. 1.	No. 2.	No. 3.	No. 4.
	Total mass.	5.67 per cent. of total (metal).	33.3 per cent. of total (insoluble in HCl).	60.62 per cent. of total (soluble in HCl).
SiO_2	37.70	....	49.64	33.59
Fe	3.47	82.42	....	....
FeO	23.82	....	15.56	31.12
Al_2O_3	2.17	....	4.12	1.34
P_2O_5	.25	....	....	.42
CaO	2.20	....	4.93	1.00
MnO	.45	....	.54	.43
MgO	25.94	....	25.21	28.08
NiO	1.59	....	trace.	2.66
Ni	.65	15.44	trace.	....
CoO	.16	....	trace.	.27
Co	.09	2.14	....	....
S	1.30	....	....	2.18
	99.79	100.00	100.00	101.09
Less O for S	.65	....	....	1.09
	99.14	....	....	100.00
Specific gravity	3.510	....	....	....

The percentages in all except the first are calculated from the weight found.

From these figures it will be seen that the minerals which go to make up the rocky portion of the meteorite are essentially olivine and enstatite, with considerable pyrrhotite, as is also shown by the microscopical description, for which I am indebted to Mr. G. P. Merrill, of the U. S. National Museum, by whom the paper was published in the American Journal of Science.[1]

The stone belongs to the class of meteorites to which G. Rose[2] has given the name "chondrites." To the unaided eye the chronditic structure is not distinctly marked, a broken surface showing a fine-grained and evidently crystalline granular rock, very compact, of a greenish-gray color, and thickly studded with small metallic points with a brassy luster. A polished surface shows the stone to be composed of small chondri rarely over 2mm in diameter, thickly and firmly compacted in a fine granular groundmass. Throughout the entire mass are thickly distributed innumerable small irregular flecks of a steel-gray, brassy, and bronze-yellow color, presumably native iron and pyrrhotite.

The striking feature of the stone is its fine and compact texture, which exceeds that of any chondritic meteorite with which we are acquainted, but which is perhaps most closely approached by the stones of Dhurmsala, India, and Cabarrus county, N. C.

Thin sections of the stone show, under the microscope, a confused aggregate of rounded and irregular, often fragmental, olivine and enstatite grains and chondri, embedded in a fine granular groundmass of the same mineral composition.

The chondri occur in both monosomatic and polysomatic forms composed either of olivine or enstatite alone or the two minerals associated. The peculiar grate-like or barred forms so characteristic of olivine chondri are here represented, as are the radiating fan-shaped forms of enstatite.

The large greenish microscopic chondri are, under the miscroscope, seen to be made up of innumerable enstatite granules so arranged as to form oval or fan-shaped areas of radiating columns, inclosing large, quite perfectly outlined, crystals of the same mineral. These included forms are nearly colorless or merely gray through inclosures of innumerable dust-like particles, and show sharp and well-defined cleavages parallel to either prism and a parting parallel to the orthopinacoid. Both olivine and enstatite are nearly colorless or gray through inclosures of dust-like particles, and carry but few cavities.

In addition to the minerals above mentioned there were noticed occasional broad, irregular plates of a monoclinic mineral, light gray in color, but polarizing brilliantly in red and yellow colors, and which gave extinction angles varying from 25° to 31° Such are presumably augite or a closely allied pyroxene. Nothing that can be certainly identified as a feldspar was observed. Occasional small nearly colorless angular forms show faint indications of twin structure, and it is possible may

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[1] Whitfield & Merrill: Am Jour. of Science, vol. 36, Aug. 1888.

[2] Abhandl. der königl. Akad. d, Wissensch. zu Berlin, 1863, p. 1861.

be a plagioclase. In two sections were observed irregular outlined interstitial areas perfectly colorless and full of gas cavities. These in some cases remained quite dark during a complete revolution of the stage, and in others gave decided polarization in light and dark colors, and in converging light showed indistinct biaxial interference figures. The position of these areas relative to the other constituents is that of an interstitial glass or a secondary mineral like a zeolite. As they show neither cleavage nor crystallographic outlines, and moreover are to be found but rarely in the sections at hand, it is impossible to identify them satisfactorily.

The metallic iron occurs in the usual rounded and irregular masses one to two millimeters in diameter, and is apparently in about equal proportions with the pyrrhotite: the latter showing a bright brassy luster in strong contrast with the silvery white iron.

The black vein above noted traverses the stone in the form of an irregular fissure (often expanding and contracting abruptly, as is shown in Fig. 8), for a distance of about 60mm, and varies in width from a mere line up to 2mm. Near its lower end it bifurcates, and incloses a portion of the mass of the meteorite some 15mm long by 2mm wide.[1]

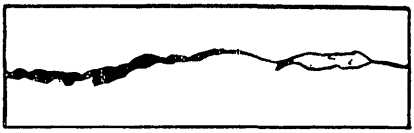

FIG. 8.—Vein in Fayette County Meteorite.—Natural size.

From a fragment containing a portion of the vein thin sections were prepared, and the remaining vein material, separated as clearly as possible from the inclosing rock, was subjected to chemical analysis, the process being essentially the same as in the analysis of the meteorite proper. Although the vein material is more compact and much darker in color, the analysis shows very little difference from that of the mass, the main apparent difference being the absence of the lime bearing mineral. The following are the figures obtained by analysis on material that weighed a little less than 0.4 grams:

	Metal.		44 per cent. of vein. Insoluble in HCl.	51 per cent. of vein. Soluble in HCl.
Fe	2.30	SiO_2	56.52	27.63
NiCo	trace.	FeO	12.35	34.31
		Al_2O_3	1.51	2.41
		CaO	trace.	trace.
		MgO	25.53	32.12
		(NiCo) O	4.09	3.27
		S		.52
			100.00	100.26
		Less O for S		.26
Specific gravity	3.585			100.00

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[1] Since the above was written Messrs. Ward and Howell have sliced the stone through the center and published in Science of June 1, 1888, a figure showing the full extent and width of the veins.

The same difficulty, with regard to water in the mineral, exists here as in the analysis of the mass.

From the figures it appears that the portion soluble in hydrochloric acid is essentially olivine in composition, while the insoluble is evidently a mixture of the same insoluble constituents as the mass of the meteorite. The filling material of the vein is, to the unaided eye, quite black and without luster; under the microscope it is seen to penetrate very irregularly and by innumerable minute vein-like ramifications into the stony mass on either side, and to carry numerous inclosures of a colorless mineral substance and blebs of metallic iron and pyrrhotite. The exact nature of the colorless inclosures can not be ascertained. On treating an uncovered slide with hydrochloric acid a part of these were dissolved, others were unacted upon. Under the microscope they are full of irregular rifts and fracture lines, but show no true cleavages. Some of them are in the form of single individuals, others have the structure of fragments of polysomatic chondri. Nearly all contain included black amorphous material, and many show distinctly included specks, giving the silvery white and brassy yellow reflections of the metallic iron and pyrrhotite. In many cases they are not separated from the black vein material by sharp lines, but seem to pass into it by gradations. Between crossed nicols many of them act like a gum, others remain always light, recalling the well-known crypto-crystalline structure of chalcedony, and still show here and there occasional small areas giving the characteristic polarization colors of olivine and enstatite. On examining the walls of the vein areas were observed where the gray and yellowish enstatites and olivines retained their normal properties at the distance of one or two millimeters, but at contact with the black-vein matter were reduced to the colorless non-polarizing condition of the inclosures.

The black matter of the vein when viewed in strong reflected light shows a dull bronze luster, less brilliant than that of the pyrrhotite particles which it incloses. The thinnest portions of the slide when examined with a power of 175 diameters show a brownish amorphous base through which are scattered abundant irregular dust-like particles and flecks of a perfectly black opaque material, the nature of which it is impossible to ascertain by the microscope alone.

The structure of the vein is shown in figure 9, in which the finely dotted portions represent the black amorphous vein matter with bronzy luster, the entirely black areas, the blebs of metal and pyrrhotite, and the irregularly rounded clear or partly clouded areas the colorless silicates.

From the study of these veins as above described we are inclined to consider the colorless particles as olivine and enstatite residuals which have been deprived of their normal optical properties by the forces active in forming the vein. What the exact character of the black and amorphous material may be still remains a matter of conjecture. It is unacted upon by acids, and when tested with a needle point it breaks up readily into earthy fragments which are not attracted by the magnet.

Mr. Howell informs me that the stone in his possession shows three of these veins, the largest exposure of any one on a broken surface being about four inches. The width and general character of all, he states, appear to be uniform throughout, though this can be ascertained definitely only by breaking the stone.[1]

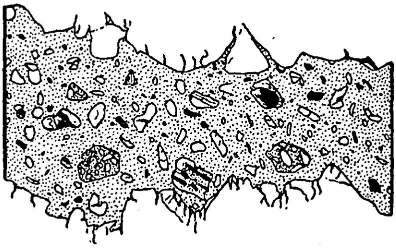

FIG. 9.—Portion of vein highly magnified.

Owing to the small amount of vein material which was available for chemical analysis and the impossibility of separating it completely from the inclosing rock, the results obtained can be regarded only as suggestive. The main points brought out can be best shown by reproducing here a comparison of the results:

	Mass of meteorite.	Vein material.
SiO_2	37.70	38.96
Fe	4.41	2.30
FeO	23.82	22.98
Al_2O_3	2.17	1.89
CaO	2.20	trace.
MnO	.45	....
MgO	25.94	27.52
Ni, Co	1.75	3.26
S	1.30	.26
Specific gravity	3.510	3.585

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[1] In structure these veins seem to only remotely resemble those described by Tschermak (Sitz. der kais. Akad. der Wiss., vol. 85, Part 1, p. 204) in the Mocs meteorite, and which, it will be remembered, he argued indicated an elevation of temperature since the consolidation of the stone, such as, aided by reducing vapors and gases, fused the iron and pyrrhotite without affecting the silicates. He describes the brown and black "Fullmasse" of the vein as an admixture of the same substance as the meteorite itself, and an opaque half glassy black admixture resembling the black vein-like material of the Orvinio stone. The silicates occur in the vein in the form of small sharp splinters, the iron in granules, and the pyrrhotite in the form of little leaves and small kernels, often so arranged as to give rise to a fluidal structure. Dr. Hans Reusch has described (N. Jahrb. für Min., IV Beil.-Band, 3 Heft, 1886, pp. 491–492) veins in the Ställdalen meteorite which present features in part common to those of the Fayette stone. To the unaided eye the filling material is black and opaque and carries metallic particles. Under the microscope it shows a brownish gray, isotropic and sometimes glassy substance densely crowded with rounded transparent fragments. The upper figure in his Plate XIV closely resembles in structure the vein matter of the Fayette stone, but as far as can be judged from his description the included particles seem to have retained their normal optical properties. Reusch regards this black vein material as the result of a partial refusion of the chrondite substance.

These differences are too slight to be considered of great value unless found to be constant by further investigation.

San Bernardino County Meteorite.—A prospector working in the San Emigdio Mountains, California, found this meteorite, and thinking it to be a lump of some valuable ore sent it to Mr. Thomas Price, of San Francisco, for assay. Unfortunately before the nature of the sample was discovered it was put through a crusher and hence only small pieces could be obtained. On finding that it was a meteorite, Mr. Price sent a few fragments to Mr. G. P. Merrill, of the U. S. National Museum, for investigation. Mr. Merrill has published a note on the subject in the June, 1888, number of the American Journal of Science, and later a full description in Vol. 11 of the Proceedings of the National Museum.

From Mr. Merrill we received material for analysis, but the bad condition of the fragments made a complete analysis almost impossible.

The mass consists of

	Per cent.
Metallic portion	6.21
Soluble in HCl	51.26
Insoluble in HCl	42.23

Of this the metallic portion gave as its composition—

	Per cent.
Fe	88.25
Ni	11.27
Co	.48

The soluble portion is presumably all olivine and pyrrhotite, with some secondary iron oxide. The analysis of this portion by separation with dilute hydrochloric acid was a failure. The insoluble part was separated by long digestion in dilute acid followed by boiling in sodium carbonate. The remaining powder showed, with the aid of the microscope, the presence of very pure enstatite and very little else, and the chemical composition upholds this view.

	Per cent.
SiO_2	54.42
FeO	14.03
CaO	2.46
MgO	29.11
	100.02

From these figures it will be seen that the mineral is a highly ferriferous enstatite (bronzite) with a small amount of a lime-bearing pyroxene mineral. The relative proportions of the various constituents as they exist in the first rock can not be estimated with any degree of certainty for the reasons already stated.

TWO SULPHANTIMONITES FROM COLORADO.

By L. G. Eakins.

The mineral first to be described was sent to the Denver laboratory of the U. S. Geological Survey in the latter part of 1885 by Mr. E. R. Warren, of Crested Butte, Colo.

At that time a hasty qualitative examination was made, establishing the fact that it was a sulphantimonite of lead, and since then nothing more has been done with it until the present analysis was made.

This mineral comes from the "Domingo" mine, on the ridge between Dark Cañon and Baxter Basin, Gunnison county, Colo., in which locality it is known as "mineral wool." It consists of aggregates of small acicular crystals, forming matted, wool-like masses in the cavities of a highly decomposed gangue rock of siliceous material mixed with some calcite. It is dull grayish-black in color, with occasional spots of iridescence, due undoubtedly to a slight superficial oxidation.

In procuring material for analysis a lot of loose material sent by Mr. Warren was slightly crushed and rubbed with water in a mortar and poured off, the fine needle-like crystals floating off readily; this was afterward purified by a retreatment in the same manner, and then subjected for a short time to the action of dilute hydrochloric acid to remove the slight amount of attached calcite. The material obtained in this manner appeared under the microscope to be perfectly pure and homogeneous, with the exception of a slight amount of gangue still remaining.

No crystalline form could be made out, and on account of its peculiar nature no attempt has been made to determine either specific gravity or hardness. Heated before the blow-pipe it fuses readily without decrepitation; in the closed tube it gives a slight sublimate of sulphur only; in the open tube it gives off sulphurous acid and dense white fumes of oxide of antimony; heated strongly the antimony all volatilizes, leaving a fused residue of sulphate of lead, slightly colored by the iron present; on charcoal it gives the lead and antimony coatings, and in the reducing flame with soda a lead button. It is soluble in hot strong hydrochloric acid with evolution of hydrogen sulphide.

The analysis is as follows:

		Atomic ratios.	
Ag	trace.		
Cu	trace.		
Pb	39.33	÷207 = .190	.222
Fe	1.77	÷ 56 = .032	
Mn	trace.		
Sb	36.34	÷120 =	.303
S	21.19	÷ 32 =	.662
Insoluble gangue	.52		
	99.15		

Dividing these atomic ratios by .222, we get:

Pb, Fe	1.00	= 3.00
Sb	1.36	4.08
S	2.98	8.94

Giving the formula: $(Pb, Fe)_3Sb_4S_9$, or $3(Pb, Fe) S, 2Sb_2S_3$.

This mineral, it is seen, fills a place in the group, $3RS, 2(As, Bi, Sb)_2S_3$, of which there are but few good examples, and which until now has not had an antimony representative.

The somewhat low summation of the analysis is probably due to two causes: First, a small amount of soluble gangue which was present and undetermined; second, the sulphur is about four-tenths of one per cent. less than required, due to the slight natural oxidation of the mineral together with an additional amount induced by treatment with dilute hydrochloric acid for the removal of calcite. In addition to the complete analysis given, there were additional determinations made of lead, antimony, and sulphur, the results obtained being in strict agreement with those given above.

The second of these sulphantimonites was collected in the summer of 1887, by Mr. Whitman Cross. It comes from a mine on Augusta Mountain, Gunnison county, Colo., this locality being about one mile east of the "Domingo" mine. Locally this mineral is also known as "mineral wool," and although differing considerably in appearance from the one just described, they were, on account of the similarity of occurrence, considered as probably identical.

It occurs in a siliceous gangue together with pyrite and sphalerite, and forms groups of acicular crystals, which are elongated prisms deeply striated, but whose form could not be determined.

The individual crystals of this mineral are considerably larger than those of the one previously described, and in consequence they do not tend so much to form matted aggregates. Its color is a bright, steely, grayish-black, with no tendency toward tarnish or iridescence. The separation of this mineral from the accompanying ones and the gangue was a matter of considerable difficulty. On account of their size the crystals could not be successfully washed out from the other material, but by the use of a rapid current of water and the Thoulet method a small quantity was finally procured perfectly free from everything except some pyrite, and that had no effect upon the analysis, as the mineral was dissolved in a mixture of hydrochloric and tartaric acids, leaving the pyrite unattacked. It was then filtered through a Gooch crucible, and the amount of pyrite determined and deducted from the material taken. The fact that but a trace of iron was found in the analysis is conclusive proof that the pyrite was practically unattacked.

Blow-pipe characteristics are the same as in the one before described. The analysis is as follows:

		Atomic ratios.
Ag	trace.	
Pb	55.52	÷207 = .268
Fe	trace.	
Sb	25.99	÷120 = .217
S, (calculated)	18.98	÷ 32 = .593
	100.49	

Dividing these atomic ratios by .217 we get:

Pb	1.24	= 4.96
Sb	1.00	4.00
S	2.74	10.96

Giving the formula:—$Pb_5Sb_4S_{11}$ or $5PbS, 2Sb_2S_3$.

We have here, in formula, a freieslebenite in which instead of lead and silver the silver has been completely replaced by lead, and although the crystallographic agreement of this mineral with freieslebenite has not been established, there seems to be no good reason for not referring it to that species. The first described of the above minerals, $3 (Pb, Fe) S, 2 Sb_2 S_3$, has been given the name "Warrenite," after the gentleman who brought it to our notice. The same mineral has been designated "domingite" by Groth.

COEFFICIENTS OF VOLATILITY FOR AQUEOUS CHLORHYDRIC ACID.

By ROBERT B. WARDER.

The various questions of physical chemistry are claiming more and more attention, and problems relating to states of aggregation seem to have a special interest. The art of fractional distillation on a manufacturing scale has developed a great variety of appliances, but much remains to place the theory on a satisfactory mathematical basis, especially in the case of bodies which exert a mutual affinity.

The term "coefficient of volatility" was introduced by Wanklyn[1] to indicate the relative readiness of different constituents to volatilize. Thus he found that when a very dilute solution of ammonia was distilled until $\frac{1}{10}$ of the water passed over, nearly $\frac{1}{2}$ of the ammonia had distilled with it. He estimated that a given quantity of water in any small fraction of the distillate was accompanied by 13 to 14 times as much ammonia as the same quantity of water in the boiling liquid. Expressed more formally, if a boiling liquid has the composition H_2O+nNH_3, and yields a mixed vapor represented by $H_2O+vnNH_3$, the factor v is the coeficicient of volatility, and in the case cited v equals about 13 or 14. Since this gas may be absorbed in indefinite proportions, of course the coefficients n and vn may be fractional, indicating the number of molecules of NH_3 divided by the number of molecules of H_2O.

In the case of chlorhydric acid, as is well known, when the liquid boils under the ordinary atmospheric pressure, it tends to acquire the constant composition $HCl+8H_2O$, or $H_2O+\frac{1}{8}HCl$. After a stronger or weaker acid has reached this composition, on further boiling $n=vn$ and the factor v=unity.

The well known researches of Roscoe and Dittmar[2] showed that an acid of higher composition will boil unchanged under diminished pressure; a similar result was observed upon evaporation in a current of air of given temperature to supplement the partial pressure exerted by acid and aqueous vapor. Hence it is clear that v depends not only upon the composition of the mixture, but also upon the pressure (or temperature) at which the distillation is conducted. The published

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[1] Philos. Magazine, [4] 45, 129 (1873). Pharm. J. Trans., [3] 3, 543 (1873).

[2] Jour. Chem. Soc., 12, 128.

data relate to the conditions under which $v=1$, but no attempt has yet been made to show the relation between v and n.

The more recent researches of Roozeboom show certain conditions of equilibrium among solid, liquid, and gaseous phases of aqueous chlorhydric acid[1] and other compounds which are illustrated by thermodynamical theory;[2] but the papers do not discuss the ordinary conditions of distillation.

Many operations of manufacturing, geological, and analytical chemistry depend upon the partial or complete separation of volatile constituents. Chlorhydric acid is typical of a large number of substances which have strong attraction for the solvent; and a more exact knowledge of its *volatility* as a function of the *composition* is the object of this research.

EXPERIMENTAL METHOD.

One hundred cubic centimeters of chlorhydric acid of known strength was subjected to fractional distillation in a boiling flask of $250 cm^3$ capacity. Successive portions of the distillate were conducted through a Liebig condenser and discharged near the bottom of receivers; a loosely fitting cork was used to hinder evaporation. The several fractions, after weighing in well stoppered vessels, were titrated with sodium hydrate, containing a little barium hydrate and carefully protected from the air by soda lime. Phenol phthalein was used as indicator. In some cases very weak distillates were evaporated with excess of ammonia, and titrated with centinormal silver solution and potassium chromate. The water was determined by deducting the acid from the total weight of the fraction. As a rule no reliance was placed upon specific gravity, the ordinary summer temperature of the room being far above that recognized in the tables; hence the acid used for each distillation was weighed. The residues in the boiling flask were also weighed and titrated for control.

When fractional distillation is conducted for the purpose of separating the constituents, this is promoted by some kind of dephlegmation; this may be accomplished by exceedingly simple means, as the walls of an ordinary boiling flask, by the complicated appliances of the manufacturers, or by the many devices for laboratory use. The object of the present work required the exclusion of dephlegmation, since this would introduce an element of great uncertainty. The flask was placed in a cylindrical air bath and covered with a conical hood of sheet copper. By means of a ring burner (as devised by Gibbs), with very gentle air blast, a circle of gas jets was thrown upon the copper cone, so as to keep the upper part of the flask heated far above the boiling point

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[1] Rec. Trav. Chim. Pays-Bas, 3, 84 (1884). Abstract in Zeitsch. physik. Chem., 1, 365 (1887) and 2, 459, (1888).

[2] Rec. Trav. Chim. Pays-Bas, 5, 335 (1886). Abstract in Zeitsch. physik. Chem., 2, 462 (1888).

of the fluid, while distillation was effected by a large Bunsen burner under the air bath. A thermometer in the vapor was usually kept at a temperature of 145° to 153°. The boiling point of the liquid was from 100° to 109 C. (varying with the concentration); and from the rate of distillation and the space above the liquid, it was estimated that the vapor would pass from the surface to the condenser in about six seconds; hence it is not to be supposed that the thermometer indicated the actual temperature of the vapor, but something between this and the temperature of the radiating surface of glass or copper. By this means the condensation of moisture upon the sides of the flask was prevented. In a preliminary experiment with $H_2O+.037HCl$, the first fifty per cent. distilled without the hood and ring burner contained no more acid than the 10 per cent. distilled with the precaution described; and this was only one-twentieth as much acid as distilled in the first 50 per cent. under the heated cover.

As the distillation proceeded, and the volume of vapor increased, the temperature had to be moderated by turning down the flame.

In the distillation of strong acid each receiver was weighed with $10cm^3$ water, to absorb the acid fumes.

CALCULATION OF RESULTS.

The weight of HCl found in each fraction of the distillate subtracted from the total weight, leaves the weight of water; and the weights of water and acid thus found in each fraction were subtracted successively from the water and acid taken to find the composition after the removal of this fraction. The mean composition of the boiling liquid during the removal of each fraction was expressed in the form $H_2O+nHCl$, the composition of the distillate being $H_2O+n'HCl$ or $H_2O+vnHCl$. The coefficient v was then found by dividing n' by n. Four distillations gave 25 pairs of values as follows:

I.		II.		III.		IV.	
n	*v*	*n*	*v*	*n*	*v*	*n*	*v*
.0952	.284	.0681	.140	.0666	.084	.1939	5.44
.1031	.423	.0759	.194	.0693	.111	.1853	3.71
.1107	.537	.0862	.282	.0730	.158	.1713	2.40
.1186	.645	.0984	.429	.0769	.172	.1567	1.66
.1231	.868	.1107	.597	.0806	.198	.1474	1.31
				.0844	.243		
				.0879	.247		
				.0911	.253		
				.0944	.300		
				.0970	.311		

DISCUSSION OF RESULTS.

Two points remain to be considered:

First. What formula will best express the values found for v as function of n?

Second. Do the relations here determined point to actual equilibrium between liquid and vapor?

No one equation was found to express all the values given above. When dilute acid ($n=.07$ to $.11$) was boiled rapidly (about one gram per minute) the results agreed with the equation

$$v=445n^3,$$

as in series II. When strong acid ($n=.15$ to $.20$) was boiled rapidly, the values of v were somewhat greater than would be indicated by the equation above; approximately,

$$v=3063n^4,$$

as in series IV. These two empirical curves, which occupy different parts of the field, are entirely consistent with each other, but must be regarded as a *first approximation only* to the function sought. When the dilute acid of Series I and III was boiled from 20 to 60 per cent. more slowly than that of Series II, the values of v were about 10 to 30 per cent. less than those indicated by the equation. There can be little doubt that v is a function of the rate of boiling as well as of the composition of the liquid. The problem appears to be dynamical, not a question of equilibrium merely, and I hope to investigate this point further.

ANALYSES OF JADE.

By F. W. Clarke.

In the ethnological collections of the U. S. National Museum there are many objects of jadeite, nephrite, and various jade-like stones. They represent a wide range of localities, especially as regards the North American specimens, and in their external characteristics they exhibit great variety of color, texture, and quality. Some came from regions which have already been well studied, but others, as in the series of articles from Alaska and Costa Rica, seemed to merit further investigation. At the earnest desire of the late Professor Baird, their mineralogical description was undertaken by Mr. G. P. Merrill and myself, and our joint paper, giving my analyses and his microscopic examinations, has already been published by the National Museum.[1] The present communication contains merely my own portion of the work, as part of the year's record of the chemical laboratory.

In Alaskan specimens of jade the museum is particularly rich. Since the acquisition of that territory by the United States it has been visited by many official expeditions, and their assembled collections represent the entire coast-line from Point Barrow to the southernmost extremity. If we except the remarkable hammers of jade-like pectolite described by me some years ago,[2] all of the Alaskan jades are true nephrites, undistinguishable in most particulars from the nephrites of Siberia, New Zealand, or the Swiss Lake Dwellings. In general this nephrite is coarse in quality; but occasionally objects are seen having high finish, some translucency, and great beauty. The following worked specimens were examined, the material for analysis being in each case carefully sawed off to avoid unnecessary damage to the object.

A. Part of a small adze, Cape Prince of Wales. Yellowish-green, mottled. Specific gravity 2.989.

B. Material for a drill, St. Michael's. Siskin green, translucent, uniform in texture. Specific gravity 3.006.

C. Small knife, Diomede Island. Blackish-green, mottled and laminated. Specific gravity 3.010.

D. Adze, Point Barrow. Nearly black superficially, opaque. Specific gravity 2.922.

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[1] Proc. U. S. National Museum, 1888.

[2] Bull. U. S. Geological Survey, No. 9, p. 9.

The specific gravity determinations were made by Dr. William Hallock. The analyses, by myself, were as follows:

	A.	B.	C.	D.
Ignition	1.91	1.42	2.03	2.06
SiO_2	56.01	56.12	56.08	57.11
Al_2O_3	1.98	.63	1.01	2.57
FeO	6.34	7.45	7.67	5.15
MnO	trace.	trace.	trace.	trace.
CaO	12.54	12.72	13.35	11.54
MgO	21.57	20.92	19.96	21.38
	100.35	99.26	100.10	99.81

In each case the ferrous oxide represents the *total* iron. Ferric oxide was not discriminated, nor were alkalies looked for. So far the analyses are incomplete.

In addition to the above-named implements, another object of supposed jade was examined. It was a flaker from Point Barrow, of a dull bluish-green color, conchoidal fracture, considerable translucency, and specific gravity 2.654. These data, together with a partial analysis, identify the object as quartz. It contained 97.79 per cent. of silica.

Concerning the origin of the Alaskan jades there has been much discussion. Some early writers ascribed it to Siberian sources, but of late years evidence has been gathered pointing to a home locality. Native reports indicated a source known as the "Jade Mountain," which lies north of the Kowak River about 150 miles above its mouth, and after several efforts the spot has been actually visited by Lieut. G. M. Stoney. He collected specimens of jade *in situ*, and a number of specimens were submitted to me for analysis. They may be described as follows:

A. Greenish-gray, splintery-lamellar in structure.
B. Like A, but more granular.
C. Paler, nearly white, closer grained.
D. Brownish, highly foliated.

All four were analyzed with the subjoined results:

	A.	B.	C.	D.
Ignition	1.78	1.38	1.76	1.73
SiO_2	58.11	55.87	56.85	57.38
Al_2O_3	.24	2.07	.88	.19
Fe_2O_3	5.44	5.79	4.33	4.43
FeO	.38	.38	1.45	1.25
MnO	trace.	trace.	trace.	trace.
CaO	12.01	12.43	13.09	12.14
MgO	21.97	21.62	21.56	22.71
	99.93	99.54	99.92	99.83

If we connect this evidence with the microscopic evidence obtained by Mr. Merrill, it becomes clear that all the Alaskan jades are essentially identical, varying among themselves no more than specimens commonly vary from a single locality. This disposes of the theory that their presence in Alaska is to be accounted for upon the basis of trade with Siberia; which theory is also negatived by the discovery announced by Mr. G. M. Dawson ("Science," April 20, 1888, p. 186) of small nephrite bowlders on the upper part of the Lewes River, in British Columbia, not far from the eastern boundary of Alaska. But these nephrites are also strikingly like those from many other localities, and two of the latter have been included in my comparison. First, a dark green water-worn bowlder from New Zealand, sent to the Museum by Sir Julius Haast; and, second, a small implement from Robenhausen, Lake Pfäffikon, Switzerland, out of the collection of Mr. Thomas Wilson. The latter specimen, also green, had a specific gravity of 3.015, as determined by Dr. Hallock. The analyses are as follows:

	New Zealand.	Switzerland.
Ignition	.83	.63
SiO_2	56.73	56.87
Al_2O_3	3.22	1.50
FeO	5.96	6.33
CaO	13.24	13.45
MgO	19.42	21.06
	99.40	99.84

All the iron is here represented as ferrous. Traces of manganese were present, but alkalies were not sought for.

Of jade objects from Mexico the Museum has a large and fine series; but nearly all of the specimens are from the one State of Oaxaca. The greater number of them are true jadeite; but as jadeite from the same region has been described by Damour,[1] a very exhaustive review of the material did not seem to be necessary. No nephrite was found in the Mexican series. Two specimens were analyzed, which may be described as follows. The specific gravity determinations are by Dr. Hallock.

A. Light-colored bead, mottled with emerald green. Specific gravity, 3.007.

B. Carved head, light green, from Zaachita. Specific gravity, 3.190.

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[1] Bulletin de la Société Mineralogique, vol. 4, p. 157.

	A.	B.
Ignition	1.81	.53
SiO_2	58.88	58.18
Al_2O_3	25.93	23.53
Cr_2O_3	.12	....
FeO	.24	1.67
CaO	.40	2.35
MgO	.36	1.72
Na_2O	11.64	11.81
K_2O	.63	.77
	100.01	100.56

If the water (ignition) in A. be regarded as replacing alkalies, the mineral approximates closely to normal jadeite, $AlNaSi_2O_6$. Both analyses fit in well with Damour's work.

With Central American jade objects the Museum is well supplied. A few only are from Nicaragua and Guatemala. The finest are all Costa Rican. Here too jadeite is the dominant mineral species, although with the true jades are many articles of softer green stones, and occasionally an object of quartz or chalcedony. For analysis, four specimens were chosen, viz: two jadeites, one quartz-like mineral, and one of the softer minerals, as follows:

A. Polished fragment, green. Rio de Buena Vista, Costa Rica. Specific gravity, 2.71, Clarke.
B. Jadeite fragment. Sardinal, Costa Rica. Pale green, translucent. Specific gravity, 3.32, Clarke.
C. Jadeite fragment. Culebra, Costa Rica. Light green, very granular, opaque. Specific gravity, 3.27, Clarke.
D. Small ornament. Las Huacas, Costa Rica. Dark green, very soft. Specific gravity, 2.282, Hallock.

	A.	B.	C.	D.
Ignition	....	.90	.93	10.39
SiO_2	97.10	59.18	58.33	70.49
Al_2O_3	1.85	22.96	21.63	11.39
Fe_2O_3		1.87	1.71	2.39
FeO	....		.73	
MnO	....	....	....	trace.
CaO	none.	1.52	4.92	3.83
MgO	none.	.67	3.09	.57
Na_2O	....	12.71	8.13	undet.
K_2O	....	trace.	.22	undet.
	98.95	99.81	99.69	99.06

Of these analyses, A speaks for itself. In B and C we observe a difference in composition, which is in the line indicated by the appearance of the specimens; that from Sardinal being translucent and nearly homogeneous; that from Culebra being coarser, distinctly mottled, and evidently impure. Specimen C is plainly not jade in any sense. It was examined microscopically by Mr. Merrill, who pronounced it to be a highly altered volcanic tuff, containing a considerable amount of bright green chlorite.

Through the kindness of Mr. Thomas Wilson, whose collection furnished the Robenhausen nephrite already described, I have been enabled to examine several other worked specimens of minerals which are sometimes classed, though loosely, with jade. A massive "saussurite" from the Saas Valley in Switzerland, out of the Museum collection, may be conveniently included in this series.

A. Fibrolite implement from Brittany. Specific gravity, 3.147.
B. Black stone implement from Estavayer, Lake Neuchatel. Specific gravity, 3.132.
C. Dark green "saussurite" implement from Robenhausen. Specific gravity, 3.403.
D. Massive "saussurite," Saas Valley.

The specific gravity determinations are due to Dr. Hallock.

	A.	B.	C.	D.
Ignition	1.31	.65	.30	.54
SiO_2	34.66	45.13	46.90	48.29
Al_2O_3	63.24	16.55	29.76	27.65
Fe_2O_3	trace.	13.59	2.52	1.45
FeO	....	4.20		
MnO	....	trace.	....	....
CaO	none.	11.02	11.77	12.95
MgO	.37	5.48	5.80	5.36
Na_2O	....	3.89	3.21	3.57
K_2O	....	trace.	trace.	trace.
	99.58	100.51	100.26	99.81

Microscopically studied the second of the specimens was found by Mr. Merrill to be a mixture of various minerals. It is evidently a highly altered "basic rock," possibly a diorite. The saussurites need no special discussion.

MINERALOGICAL NOTES.

1. Petalite from Peru, Maine. By F. W. Clarke.

In the well-known spodumene locality at Peru, Maine, petalite has been found in abundance. The discoverer, Mr. N. H. Perry, of South Paris, Maine, kindly furnished me with a fine suite of specimens, upon which the following examination was made. The petalite is intimately and irregularly intergrown with the spodumene, and occurs in white, pearly, cleavable masses much resembling some varieties of albite. To some extent it is stained by dendritic manganese; but in general the mineral is exceedingly pure. An analysis gave the following results, the lithia being determined by Gooch's process:

Ignition	1.03
SiO_2	77.29
Al_2O_3	16.95
Fe_2O_3	trace.
MnO	trace.
Li_2O	2.62
Na_2O	2.39
K_2O	trace.
	100.28

2. Spessartite from Amelia County, Va. By F. W. Clarke.

This garnet, which is remarkable for its very high percentage of manganese, was analyzed at the request of Mr. G. F. Kunz. It occurs in the mica mines of Amelia county, in brilliant, brownish-red masses of considerable size. The specimen analyzed was very light in color, although some of the material was quite dark. The analysis was as follows:

Ignition	.27
SiO_2	35.35
Al_2O_3	20.41
Fe_2O_3	2.75
FeO	1.75
MnO	38.70
MgO	none.
CaO	.94
	100.17

3. Oligoclase from Bakersville, N. C. By F. W. Clarke.

This mineral, which was also received from Mr. Kunz, has been described by him[1] and also by Penfield and Sperry.[2] It occurs in color-

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[1] Amer. Journ. Sci. (3), vol. 36, p. 222.

[2] Amer. Journ. Sci. (3), vol. 36, p. 324.

less or nearly colorless fragments of extraordinary transparency. Indeed, it resembles glass so nearly that at first sight one can hardly realize that it is a feldspar. The composition of the sample analyzed was as follows:

Ignition	.25
SiO_2	62.92
Al_2O_3	25.32
Fe_2O_3	trace.
MnO	trace.
CaO	4.03
K_2O	.96
Na_2O	6.18
	99.66

4. Willemite from the Trotter Mine, Franklin, N. J. By F. W. Clarke.

Collected by Mr. W. S. Yeates, and at first thought to be a new mineral. The specimens obtained were nearly pure white, granular, and quite unlike ordinary willemite in appearance. The following partial analysis, however, served to determine the species:

Ignition	.25
SiO_2	27,41
ZnO	68.86
	96.52

A little manganese and iron are present, but were not determined.

5. Descloizite (?) from Beaverhead County, Mont. W. F. Hillebrand.

Through Messrs. W. H. Beck and George E. Lemon, of Washington, D. C., was received for examination a large lump of friable, uncrystallized material, having a dull yellow to pale orange color, and made up mainly of a vanadate, but carrying a large percentage of gangue. Two samples as pure as could be selected from different parts of the lump were analyzed with the following results:

	I.	II.	Mean.
PbO	56.02	55.84	55.93
CuO	1.16	1.13	1.15
FeO	0.70	0.70	0.70
ZnO	15.96	15.91	15.94
V_2O_5	....	20.80	20.80
As_2O_5	0.32	....	0.32
P_2O_5	0.27	....	0.27
H_2O	4.37	4.36	4.37
SiO_2	0.20	0.16	0.18
CaO	0.10	....	0.10
MgO	0.06	....	0.06
	....	....	99.82

From I 27.62 per cent. of gangue insoluble in cold dilute nitric has been deducted, and from II 22.20 per cent. Manganese was present in the gangue in small quantity, apparently as pyrolusite, but it was not dissolved by the acid. The insoluble portion was found also to retain very small quantities of lead and zinc, which were estimated and included in the analysis as probably belonging to the vanadate. The water had to be estimated indirectly by deducting from the total amount of water afforded by the dried mixture of vanadate and gangue that belonging to the latter alone, which was found as follows: The mixture dried at 100° C., was dissolved in cold dilute nitric acid, and the insoluble matter, collected in a Gooch crucible, was dried at the same temperature, and then ignited. The loss on ignition gave the water in the gangue, there being no ferrous iron in the latter to influence the result.

Neglecting the traces of SiO_2, CaO, and MgO, as probably derived from the gangue, the following molecular ratio is obtained:

PbO	.2508	.4718 or 4.02
CuO	.0145	
FeO	.0097	
ZnO	.1968	
V_2O_5	.1140	.1173 or 1.00
As_2O_5	.0014	
P_2O_5	.0019	
H_2O	.2428	or 2.07

The water it will be noticed is double that required by descloizite, $R^4(OH)^2(VO^4)^2$, but in view of the liability to error inherent in the method of water estimation employed, this is not deemed sufficient cause to separate the mineral from descloizite, although the close agreement of the two water determinations, made as they were on samples containing different proportions of gangue, would indicate the correctness of the formula $R^4(OH^2)(VO^4)^2+H^2O$, which is that of descloizite with a molecule of water of crystallization added.

This, so far as known, is the first observed occurrence of a lead vanadate in Montana. The precise locality of the mineral is the Mayflower Mine, in the Bald Mountain mining district.

6. PRELIMINARY REMARKS ON NORTH AMERICAN URANINITES

BY W. F. HILLEBRAND.

A large crystal nearly an inch in diameter from Andrews's formerly Hales's quarry, in South Glastonbury, a few miles northeast of Middletown, Conn., showing octahedral, cubical, and dedecahedral faces, having been identified as uraninite with about 10 per cent. of thoria, the question arose: Was this thoria an essential constituent of the mineral or was its presence due to admixture of some thorium mineral, as thorite or orangite? With a view to settling this point a careful analysis was made accompanied by a microscopical examination of a thin section of the crystal. The results were not conclusive, therefore other material from the same locality was sought for and obtained from Prof. W. N. Rice and Mr. E. F. Sheldon of Middletown, Conn. Analysis showed its chemical identity with the first specimen, and established beyond question that the thoria could not be derived from any thorium silicate. The observation was made that unless certain precautions were taken the estimation of UO_2 in the mineral was very unsatisfactory, and might be many per cent. too low. If a rather concentrated sulphuric acid is used for decomposing the mineral in sealed tubes, an insoluble uranous sulphate is formed which often crystalizes out in beautiful green crystals of considerable size, which dissolve very slowly when the contents of the tubes are emptied into cold water preliminary to titration with potassium permanganate. This defect was remedied by using a very dilute acid—1 vol. H_2SO_4 to 6 vols. H_2O—and the final reaction was then as sharp as could be desired. A more important precaution to be observed is the manner of filling the tubes with carbonic acid gas. This must invariably be done by introducing the gas from a generator and sealing during its introduction, and never by using sodium carbonate in the tubes themselves. In the latter case, before the seal can be made, outside air in greater or less amount is certain to enter and its oxygen is sufficient to lower the percentage of UO_2 found by several per cent., as repeatedly ascertained by actual experience.

The results thus obtained after employing every possible precaution to guard against oxidation of UO_2 or reduction of UO_3 during the process of decomposing the mineral and subsequent titration were perplexing to the last degree in view of the results arrived at by Comstock[1] and Blomstrand[2] independently of each other, which appeared to prove definitely that all varieties of uraninite could be considered as orthouranates of uranium and lead, in which thorium and other metals of the earths might replace basic uranium. The Glastonbury uraninite could by no possibility be referred to an orthouranate, but was a decidedly basic salt.

In extension of the investigation uraninite from Black Hawk, Colo., from North Carolina and from Branchville, Conn., was analyzed. The North Carolina material was so evidently in process of alteration, being seamed in every direction by very minute cracks filled with yellow decomposition products, that its analysis could give no clue to the relative proportions of the two oxides of uranium in the original fresh substance, but the presence of nearly 4 per cent. of rare earths—mainly thoria—was ascertained. The Branchville material was kindly given by Professors Brush and Dana, of New Haven, being the remainder of the stock from which the material for Comstock's analysis was taken. Its re-examination was undertaken with the view of ascertaining whether thoria had not been overlooked, as would almost certainly be the case had ammonium oxalate instead of oxalic acid been employed as a test

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[1] Am. Journ. Sci. (3), vol. 19, 1880, p. 220.

[2] Geol. För. Förh., VII, 59, 1884, and Journ. prak. Chem., XXIX, 191, 1884.

for the rare earths. This proved to be the fact, there being nearly 7 per cent. of thoria present in the mineral, which had undoubtedly been included in the UO_3 of Comstock's analysis. This alone would utterly invalidate the formula assigned by him, but in addition the UO_2 was found uniformly higher by many per cent. than his analysis showed. In different samples selected from the material at my disposal, however, the percentage was not the same, but differed by several units, and the density rose always with the percentage of UO_2. The Colorado mineral, which unlike that from Connecticut and North Carolina does not occur crystallized, is likewise not referable to an orthouranate, being as basic as that from Glastonbury, Conn. It is remarkable for the low percentage of lead—less than 1 per cent. of oxide—and for the absence of any other qualitatively similar element, as well as for the presence of about 7 per cent. of zirconia ; thoria being entirely wanting.

The question of the composition of this interesting mineral, which seemed so satisfactorily settled by the researches of Comstock and Blomstrand above referred to, must hence be considered as again opened for discussion. My own analyses and experiments are as yet too indecisive to admit of forming any conclusions entitled to weight as to the probable constitution of the mineral, but as opportunity offers they will be prosecuted, and extended to material from any other localities in this country or abroad that may become available, and will be published in detail at some future time.

Trifling amounts of rare earths other than thoria were found in the Glastonbury and Colorado specimens as well as in those from North Carolina.

7. DUMORTIERITE FROM NEW YORK AND ARIZONA. BY J. EDWARD WHITFIELD.

In the November (1887) number of the American Journal of Science Dr. R. B. Riggs published some observations, including a chemical analysis, on a mineral found at Harlem, N. Y., and generally supposed to be indicolite. The notice led to correspondence between Mr. J. S. Diller and Prof. E. S. Dana, the latter identifying it as dumortierite.

The composition, as determined by Dr. Riggs, conformed to no known mineral, and he was justified in provisionally calling it a new boro-silicate, but on further examination by Mr. Diller of a somewhat larger amount of material it was found that the mineral was associated with tourmaline, which no doubt accounts for the results of the analysis.

It was decided to analyze another portion which was known to be purer than that examined by Dr. Riggs. This was done, and the following figures are the results obtained: SiO_2 31.44 per cent.; Al_2O_3 68.91 per cent., with the smallest trace of boric acid. Their quantities compare fairly well with the theoretical amounts necessary to satisfy M. Damour's formula $Al_8Si_3O_{18}$ for dumortierite.

At about the time this work was being done on the New York mineral, a small piece of rock from Clip, Arizona, was sent to the National Museum for identification. Prof. F. W. Clarke recognized it as a specimen of dumortierite accompanying quartz, and it was subjected to analysis to confirm his opinion. Following are the results of the examination:

	Per cent.
SiO_2	31.52
Al_2O_3	63.66
CaO	none.
MgO	.52
Na_2O	.37
K_2O	.11
B_2O_3	2.62
Ignition	1.34
	100.14

These figures show that the mineral was rather impure, and it was thought advisable to obtain, if possible, more of the mineral, and endeavor to separate it as far as possible from the accompanying rock. Mrs. C. A. Bidwell, the sender of the first specimen, kindly furnished quite an amount of much better material, in which the only mineral associated with the dumortierite was quartz.

As dumortierite is not acted upon by hydrofluoric acid, the rock was crushed to small particles and digested in this acid for a length of time sufficient to remove most of the quartz. The mass was then washed with water, dried, and any quartz that might remain was separated by Thoulet's solution. After thorough washing, the material was examined with the aid of the microscope and found to be free from gangue.

After being ground exceedingly fine and dried at 104° C. for about three hours, the material was analyzed with the following results:

	Per cent.
SiO_2	27.99
Al_2O_3	64.49
P_2O_5	.20
CaO	none.
MgO	trace.
B_2O_3	4.95
H_2O	1.72
	99.35

These figures show less impurity than the first specimen analyzed; but if dumortierite is a simple silicate of alumina as stated, by M. Damour[1] these results either do not uphold his conclusions or they show the material to be a mixture of dumortierite and some other compound.

If we assume the formula of M. Damour to be correct and estimate all the SiO_2 in the analysis as belonging to the formula $Al_8Si_3O_{18}$, then there will be left unaccounted for a small amount of Al_2O_3, H_2O and

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[1] Bull. de la Soc. Min. de France, vol. 4, p. 6.

B_2O_3, and these are present in the proportions represented by the formula $AlB_3O_6,2H_2O$. If this mode of interpretation be correct, then the mineral from Arizona corresponds approximately to the formula,

$$3Al_8Si_3O_{18},$$
$$AlB_3O_6.2H_2O,$$

which requires Al_2O_3 65.2 per cent., SiO_2 27.6 per cent.; B_2O_3 5.4 per cent.; H_2O 1.8 per cent.; agreeing quite closely with the actual analysis. A borate of alumina corresponding to the above formula is, we believe, not actually known, and concerning its properties nothing can be predicated. If it exists, it is certainly remarkable that it should withstand the treatment with hydrofluoric acid which the Dumortierite received during the process of purification.

We are deeply indebted to Mrs. C. A. Bidwell for the supply of material for investigation, which at the cost of much personal labor she so liberally furnished.

8. XANTHITANE FROM NORTH CAROLINA. BY L. G. EAKINS.

Through the kindness of Mr. William Earl Hidden some fine specimens of xanthitane were obtained, the material coming from Green River, Henderson county, N. C. It was first described by C. U. Shepard in the American Journal of Science, 1856, vol. 22, p. 96.

The material I examined is evidently an alteration product of sphene, following the form very closely. It is light yellow, friable, and mixed with impurities which can not be removed, preventing the determination of whether or not it is a definite mineral; but it is interesting from the fact that it apparently represents a clay with the silica replaced by titanic oxide.

Specific gravity 2.941 at 24°. The air-dried material loses 6.02 per cent. of water at 100°. The following analysis is on material dried at 100°:

SiO_2	1.76
TiO_2	61.54
Al_2O_3	17.59
Fe_2O_3	4.46
CaO	0.90
MgO	trace.
P_2O_5	4.17
H_2O	9.92
	100.34

9. TRIPLITE FROM THE BLACK HILLS, DAKOTA. BY L. G. EAKINS.

The material for this analysis was taken from a large specimen of several pounds weight, in the collection of the National Museum. It comes from a tin mine near Rapid City, S. Dak. In reality it probably represents a mixture, but in general appearance it seems to be fairly homogeneous, and in composition it approaches closely to triplite.

It is brown in color, varying from light to dark, and translucent in thin pieces. In getting material for analysis any visible impurity was carefully picked out.

The composition is as follows:

SiO_2	.43
Al_2O_3	8.74
Fe_2O_3	2.36
FeO	1.97
MnO	29.13
CaO	6,72
MgO	trace.
K_2O	trace.
Na_2O	5.25
Li_2O	.13
P_2O_5	39.68
H_2O	3.67
F	2.35
Cl	.25
CO_2	.26
	100.94
Less O	1.05
	99.89

10. KAOLIN FROM THE WATERFALL MINE, GUNNISON COUNTY, COLO.

By L. G. EAKINS.

This mineral occurs in a large mass, filling a cavern which has been opened for mining purposes in Redwell Basin, Gunnison county, Colo. It is especially interesting on account of being the containing mass of aggregates of galena and pyrite crystals which are scattered irregularly through it.

It is very fine and white, and on slightly rubbing up with water the material as it comes from the mine it can easily be floated off in a pure condition.

The analysis is as follows:

SiO_2	47.28
Al_2O_3	36.19
Fe_2O_3	trace.
CaO	.42
MgO	trace.
K_2O	5.74
Na_2O	.51
H_2O	8.72
P_2O_5	.57
	99.43

11. NATIVE GOLD FROM PERSIA. BY CHARLES CATLETT.

The sample of gold, inclosing quartz, was submitted for assay through the State Department by the American minister to Persia, and was the property of the Persian Government. The specimen was of unusual interest as coming from a region so little known mineralogically. The native gold, which was of very light color, was analyzed with the following results:

Au	93.24
Ag	6.65
Fe	.11
Cu	none.
	100.00

12. PYROXENE AND SERPENTINE FROM MONTVILLE, N. J. BY CHARLES CATLETT.

The series in question was collected by Mr. G. P. Merrill, of the National Museum, and submitted to this laboratory for analysis. It consisted of a dark gray, and a white pyroxene (A and B), and a dark and a light serpentine (C and D), resulting from their respective alteration. An alteration product (E) closely related to the others was analyzed at the same time.

	A.	B.	C.	D.	E.
SiO_2	51.45	48.17	40.23	42.38	4.32
Ignition	1.08	*.12	14.24	14.12	*1.26
CaO	24.02	21.96	trace.	....	....
$CaCO_3$	....	10.44	....	....	87.75
MgO	18.43	17.61	39.46	42.14	4.07
$MgCO_3$	....	.71	....	....	1.67
Al_2O_3	2.94	.52	2.18	.07	.10
Fe_2O_3	1.06	.18	4.02	.97	
FeO	.96	.24	trace.	.17	....
MnO	trace.	....	....	....	....
SO_3	trace.	trace.	....	....	.13
K_2O	undet.	undet.	undet.	undet.	.12
Na_2O	undet.	undet.	undet.	undet.	.28
	99.94	99.95	100.13	99.85	99.70

* H_2O.

THE SUBSIDENCE OF FINE SOLID PARTICLES IN LIQUIDS.

[Second Paper.]

By Carl Barus.

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(1) In my earlier work I endeavored to analyze the phenomenon of sedimentation into parts such that the conditions under which subsidence is to be explained from a chemical, or from a physical point of view, may be better discernible.[1] To do this I first considered the question in its purely mechanical aspects.[2] If P is the resistance encountered by a solid spherule of radius r, moving through a viscous liquid at a rate x, and if k be the frictional coefficient, then $P=6\pi krx$. Again, the effective part of the weight of the particle is $P'=\frac{4}{3}\pi r^3(\rho-\rho')g$, where g is the acceleration of gravity and ρ and ρ' the density of the solid particle and the liquid, respectively. In case of steady motion $P=P'$. Hence

$$x=\frac{2}{9k}r^2(\rho-\rho')g \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (1)$$

In any given case of thoroughly triturated material, the particles vary in size from a very small to a relatively large value; but by far the greater number approach a certain mean figure and dimension. An example of this condition of things may be formulated. To avoid mathematical entanglement I will select

$$y= ax^{3|2}e^{-x^2} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

where y is the probable occurrence of the rate of subsidence x. If now the turbidity of the liquid (avoiding optical considerations) be

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[1] The present article, being a continuation of Bull. U. S. G. S., No. 36, 1886, is largely based on the experimental evidence there tabulated. Mr. William Durham (Chem. News, vol. 30, 1874, p. 57; *id.*, vol. 37, 1878, p. 47), was the first to give an incentive to this class of experiments. Much of our knowledge of the effect of precipitants is due to him. Moreover, the theoretical views at which he ultimately arrives may be regarded as a definite point of departure. In this country, Prof. T. S. Hunt (Proc. Boston Soc. Nat. Hist., Feb., 1874), Prof. W. H. Brewer (National Acad. Sc. 1883; American Journ. Sci., series 3, vol. 29, 1885, p. 1), and Prof. C. R. Stuntz (Cincinnati Soc. Nat. Hist., Feb., 1886), have occupied themselves with similar work. Professor Stuntz's paper contains further references among others to Waldie's results (Journal Asiatic Soc., Bengal, 1873; Chem. News, 1873). Meanwhile Mr. William Hallock has made experiments on the subsidence of lamp-black in connection with his work on the density of that substance. (Cf. Bull. U. S. G. S., No. 42, 1887, p. 132) I may add that my own experiments were suggested by Professor Brewer's memoir.

[2] Cf. Kirchhoff: Mathematische Physik, lecture 26, § 4, 1876.

defined as the mass of solid material per unit of volume of liquid, then the degree of turbidity which the given ydx particles add to the liquid is, caet. par., proportional to r^3ydx, where r is the mean radius. Hence the turbidity T, at the outset of the experiment (immediately after shaking), is

$$T = T_0 \int_0^\infty r^3 y dx = T_0$$

where equations (1) and (2) have been incorporated.

If the plane at a depth, d, below the surface be regarded, then at a time, t, after shaking, the residual turbidity there is

$$T = T_0 \int_0^{\frac{d}{t}} r^3 y dx = \mathrm{T}_0 \left(1 - e\frac{d^2}{t^2} \left(1 + \frac{d^2}{t^2}\right) \right) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

This equation describes the observed occurrences fairly well. In proportion as the time of subsidence is greater, the tube shows opacity at the bottom, shading off gradually upward, through translucency, into clearness at the top. If, instead of equation (2), there be introduced the condition of a more abrupt maximum; if, in other words, the particles be very nearly of the same size, then subsidence must take place in unbroken column, capped by a plane surface which at the time zero coincided with the free surface of the liquid. Again, suppose one-half of the particles of this column differ in some way uniformly from the other half. Then at the outset there are two continuous columns coinciding, or, as it were, interpenetrating throughout their extent. But the rate of subsidence of these two columns is necessarily different, since the particles, each for each, differ in density, radius, and frictional qualities by given fixed amounts. Hence the two surfaces of demarkation, which at the time zero coincided with the free surface. In general, if there be n groups of particles uniformly distributed, then at the time zero n continuous columns interpenetrate and coincide throughout their extent. At the time t, the free surface will be represented by n consecutive surfaces of demarkation, below it, each of which caps a column, the particles of which form a distinct group. This phenomenon is Professor Brewer's stratified subsidence. In the case of particles which have undergone an earlier fractionated sedimentation, either in nature or in the arts, the occurrence of groups possessing the distinctive characteristics here discussed is not improbable. On the other hand, when during subsidence the surfaces of demarkation follow each other in regular succession, one is tempted to look for something more than an adventitious cause for the phenomenon. An orderly arrangement of groups of particles, might for instance, indicate successive stages of hydration. (Cf. § 6.) In case of stratified subsidence it is convenient to speak of orders of surfaces, numbering them from the top downward. It is not uncommon to observe seven or even ten consecutive orders.

(2) With these deductions as a point of departure, I then attempted to find relations between rates of subsidence, the viscous and capillary properties of the liquid, and its electrical behavior under analogous conditions of concentration and of temperature. This general survey proved that the phenomenon of sedimentation is unique; that the frictional resistances encountered by the particles are apparently different from the viscosities of the liquids in which subsidence takes place; that many of the occurrences observed are closely allied to the electrolytic and the capillary properties of this liquid. Finally, utilizing Professor Brewer's stratified subsidence, which I obtained very clearly with certain kinds of tripoli, I commenced a series of more rigorously quantitative measurements, showing that, caet. par., rate of subsidence is primarily dependent on the turbidity of the mixture.

In my experiments with tripoli, the observed rates of subsidence ($^{cm}/(sec \times 10^6)$) in ether, alcohol, water, glycerine, were 7500, 1300, 3, 0.9, respectively; but, owing to the difference in character of the divers precipitates, these figures have no further signification than to emphasize the said difference in character. (Cf. §§ 5, 6.) Let water and ether be mixed so that there shall be equal bulks of etherized water below and aqueous ether above, and then let the dust (bole) be added. If now the mixture is violently shaken and then allowed to subside, the ether is washed clean of particles in a few minutes, whereas the sediments remain suspended in the water for weeks and even months. Here, however, the separation and subsidence are promoted by the surface energy of water. On the other hand, if dry tripoli be added to ether dried over $CaCl_2$, in a test tube, and if the tube be held obliquely after shaking, subsidence is so rapid that the upward current of ether along the upper line of the tube is almost tempestuous.

The close relation of the present phenomena to electrolytic phenomena appears at once by observing that so little as a single molecule of HCl (for instance) added to 10,000 or even to 50,000 molecules of H_2O, produces appreciable increase of the rate of subsidence. Remembering that the arrangement is in three dimensions, and supposing the molecule HCl as large as the molecule[1] H_2O, the effect of the molecule HCl must be appreciated at a distance of at least 30 times its own radius, and extend much beyond this asymptotically. Quincke's radius of capillary attraction, $.000005^{cm}$, being about 100 times the molecular radius H^2O, it appears that the striking effect of the molecule HCl in accelerating subsidence is not an abnormal occurrence, at least when considered physically. Other points of view are given in the Bulletin.

(3) To account for these phenomena as a whole, Mr. Durham in his second paper (l. c.) proposes a hypothesis in virtue of which the scope of the action of affinity is enlarged, and suspension regarded as the lower limit of solution. This view is fast gaining ground; nevertheless,

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[1] The estimated diameter of H_2O, distance between centers of adjacent molecules $=40/10^{9 cm}$. Kohlrausch. Wied. Ann., vol. 6, 1819, p. 209.

without concise experimental reference to the density and size of the solid particles, and the viscosity of the liquid, Mr. Durham's explanation contains no sufficient reason for the observed suspension, nor for changes of rate of subsidence. Prof. Brewer's ingenious hypothesis of colloidal hydrates, so constituted that the particles may ultimately swell up and float, something like gelatinous silica, or even like starch grains, is more direct; and before further reasons of the cause of suspension are sought, the validity of this inference must be tested. This test is feasible, I think. If the phenomenal difference of rate with which the same particles subside in water and in ether is due to volume changes of the particles, then a marked difference in the density of the sediment (clay or tripoli) in water and in ether, respectively, must be experimentally demonstrable. Cf. Equation (1). I made these experiments with both solids, using two nearly identical density flasks, one for water and the other for ether, in the usual way. The powders were sampled and dried at 200° in an air bath, for half a day, transferred to the pycnometers, dried and weighed when cold. They were then left in a desiccator for 18 hours and again weighed; and finally dried in vacuo, and weighed. The results throughout were satisfactorily constant. By aid of an apparatus specially devised for the purpose, the two flasks were once more thoroughly exhausted (mercury air-pump), and then filled with water and with ether, respectively, in vacuo, over sulphuric acid. In both cases (experiments made consecutively) the vacuum ebullition was kept up for some time to give full assurance of the expulsion of air, etc. The density of the ether had been previously determined by the same flasks, once for each experiment.

I thus obtained for tripoli

In water, density $=\Delta_w=2.672$,
In ether, density $=\Delta_e=2.697$.

Again I obtained for white bole

In water, $\Delta_w=2.639$,
In ether, $\Delta_e=2.663$.

The manipulation being somewhat difficult, the observed differences of Δ_w and Δ_e are no larger than the many sources of error led me to anticipate, particularly in view of the fact that the two samples, for ether and for water, may not have been absolutely identical. The concentrated ether used was the same commercial reagent with which I obtained the subsidence phenomena. In consequence of the high but normal values of both Δ_w and Δ_e, I saw no need of specially purifying it. I add finally that after calcination the dry tripoli lost 1.2 per cent. in weight, and the dry bole about 11.4 per cent. In both cases this is probably water of constitution, the elimination of which was of course not permissible. It is well to note that in spite of differences of chemical composition, bole particles are about equally well suspended before and after calcination, and the phenomena with ether dried over $CaCl_2$ are identical with the above.

(4) These results show that the densities in the two cases (sediment in water and in ether respectively) are not essentially different. Moreover, the density of tripoli is so near that of quartz, and the density of bole so near that of kaolinite, as to leave the hydration hypothesis very seriously in the lurch, so far as favorable evidence is concerned. It is improbable that the addition of water to the dry powder is accompanied by sufficiently marked volume changes; it is certain that the enormous variation of rates of subsidence actually observed, when the particles descend in water, in solutions, and in ether, must be referred to some general cause apart from the density of the particles and the viscosity of the liquids.

(5) This premised, the explanation of sedimentation may, I think, be satisfactorily based on the following principle: If particles of a comminuted solid are shaken up in a liquid, the distribution of parts after shaking will take place in such a way that the potential energy of the system of solid particles and liquid, at every stage of subsidence, is the minimum compatible with the given conditions. In the case of solid particles and pure water the configuration answering these conditions is schematically

Particle, water.... particle, water.

In the case of solid particles and ether, or of solid particles and solutions, this configuration is schematically

Particle, particle.... ether, ether.

For the truth of this inference, my paper contains abundant experimental evidence. The principle asserts that in case of water the sediment is graded and the suspended material granular, whereas in ether the sediment is apparently homogeneous, as I found; that the bulk of sediment is necessarily less in water than in ether, being compact in the first instance and of a microscopically arched or castellated internal structure, in the second instance, as I found; that the effect of a precipitant is particularly marked when the mixture is densely turbid with relatively coarse particles, as I found; that, finally, the phenomenon of sedimentation must be of a distinct and special kind, and by no means the immediate converse of capillary viscous transpiration. The inferences are thus based on equation (1) above, and follow at once when k and ρ are constant. In the Bulletin I computed the relative size (radii) of the particles of tripoli subsiding in water, alcohol, ether, to be 1, 19, and 24, respectively.[1] It is exceedingly curious to note in case of water,

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[1] This is the first hypothesis developed in detail in Bull. U. S. Geol. Survey, No. 36, pp. 34, 35, 37. In a recalculation since made with more accurate value of k (water 0° to 100°, Slotte's data, in Wied. Ann. vol. 20, 1883, p. 262; ethyl and methyl alcohol, Graham's data in Phil. Mag. (4), vol. 24, 1861, p. 238; ether datum from Landolt and Boernstein's tables, p. 153; glycerine $\eta=10.0\text{g cm.}^{1}\text{ sec.}^{1}$, estimated roughly), the radii of the particles in water, ethyl alcohol, methyl alcohol, ether and glycerine are found to be $r=0.000009^{cm}$, 0.00019^{cm}, 0.00018^{cm}, 0.00020^{cm} and 0.00005^{cm}, respectively. In case of bole suspended in water at 15° and at 100°, the radii were approximately $<0.000010^{cm}$ and $>0.000020^{cm}$, respectively. Section 6

despite the phenomenally large surface energy of the liquid, the subsidence takes place in such a way that for a given mass of suspended sediment the surfaces of separation are a maximum. On the other hand, in case of subsidence in ether, or in salt solutions, the solid particles behave much like the capillary spherules of a heavy liquid shaken up in a lighter liquid with which it does not mix. In other words, the tendency is to reduce surfaces of separation to the least possible value, large particles growing in mass and bulk mechanically, at the expense of the smaller particles. Finally it is clear that the condition of stratified sedimentation is very slow subsidence of a granular precipitate.

(6) The experimental evidence adduced bears directly on the size of the particles of any precipitate. A given mass of small solid particles presupposed, the observations of the foregoing paragraphs make it probable that the potential energy of the system of solid particles and liquid increases with the radius of the particle. These observations also show that the potential energy of the system of solid particles alone decreases as the size of the particles increases, a state of things due both to the immediate action between solid particles and probably also to the surface energy of the liquid in which suspension takes place. Under these conflicting conditions it is probable that there is a critical shell within which the energy solid-liquid decreases less rapidly than the energy solid-solid; and beyond which shell the energy solid liquid increases more rapidly than the energy solid-solid. This critical shell being compatible with the conditions of minimum potential energy of the subsiding system, as a whole, is the size of the precipitated particles; for any change of the radius of a particle bounded by the critical shell, implies an expenditure of work, which under the usual conditions of subsidence is not available.

(7) I have finally to endeavor to assign some value to the radius of the critical shell for the case of the above water suspensions. In my experiments with tripoli, rates of subsidence, x in $\text{cm}/(\text{sec}\times 10^6)$, varied from $x=1$ to $x=20$, according as higher orders of surfaces or turbidities of lower degree were chosen. Taking the more usual value $x=3$, the radius of the particles subsiding was probably not less than 400 times the molecular radius of water. The bole particles under analogous conditions of suspension in H_2O, were smaller, probably only 100 water radii. In Professor Brewer's indefinitely suspended clays, the limit of comminution can not be estimated at all, except perhaps from purely optical consideration.[1] Whether in this extreme case colloidal hydra-

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points out, that whereas these dimensions may be called in question when considered absolutely, the relative values of radius are probably true.

The fact that particles so extremely light descend at all is a most striking result, showing the extreme delicacy of these experiments. In case of tripoli-water, for instance, the estimated weight of particles is only $1/10^{11}$ milligram. Being invisible microscopically it must weigh less than $1/10^{10}$ milligram.

[1] The optical properties of light reflected from particles small in comparison with the wave length of light are discussed by Stokes (Phil. Trans., 1852, p. 530). How large a particle may be without interfering with optical clearness, I can not say.

tion with concomitant volume changes is still demonstrably absent, remains to be seen. To test it, a sufficient quantity of the extremely fine material would have to be collected and dried by low temperature evaporation, an excessively tedious task.

Again, in Bulletin No. 35, p. 21, I point out at some length that "when the particles decrease (in size) from some estimable mean value indefinitely," liquid viscosity, being at least partially, if not largely kinetic in character, can no longer be considered constant; that therefore a particle may descend, or in other words the continuous and constant action of gravity produce an effect even when the weight of the particle is below the mean or physically measurable value of the friction encountered; that the limits of time-variation of viscosity will increase as the radius of the circumscribed space decreases. In such a case the particle to be stationary must weigh less than the lower limit of the variable viscosity—a quantity which may reasonably be conceived to approach zero very nearly. I carried these inferences one step further by supposing, rationally I think, that the limits within which this *elementary* viscosity (say) varies, will increase with the degree of molecular agitation of the liquid. On the basis of this postulate I then endeavored to explain sedimentation kinetically, both in its relation to temperature and the effect of precipitants.

One point which antagonizes this hypothesis in part must not be lost sight of. Two or more particles sufficiently near together tend to screen each other, and, receiving impact mainly on their outer surfaces, will be held in permanent coherence so long as the conditions of pronounced molecular agitation last. This is observed to some extent in solution suspensions, ether suspensions, and in water suspensions at high temperatures (100°). There is therefore some difficulty in preserving the granular state (Bull. 36, p. 38).

To pass judgment on the validity of such an explanation, it is necessary to have in hand better statistics of the size of the particles relatively to the water molecules than are now available. Indeed whether the liquid water molecule is simply H_2O and not some more complex form can not at the present state of science be decided. Inasmuch as the particles in pure water are individualized and granular, it is apparently at once permissible to infer the size of the particles from the observed rates of subsidence. But my observations show that the said rates decrease in marked degree with the turbidity of the mixture. Hence the known formulæ for a single particle are not rigorously applicable though it can not be asserted whether the cause of discrepancy is physical or mathematical in kind. It follows that special deductions must be made for stated groups of particles before an estimate of their mean size can be fairly obtained.

A NEW METHOD OF MAKING ALLOYS.[1]

By William Hallock.

While occupied with a careful study of an article by W. Spring[2] on the production of Wood's alloy, and seeking the forces possibly brought to bear in his experiments, the following explanation occurred to me, and was subsequently verified by critical experiments. The method of production used by Mr. Spring was to mix filings of the four metals in the proper proportions, subject the mass to a pressure of 6,000 atmospheres, file up the block thus produced and compress it a second time, obtaining as an end result a block of Wood's alloy.

Now, if at any time during the various operations, be it the first compression, the subsequent filing, or the second compression, or if anywhere in the whole mass, the original metals came in contact all together, then at that point we should have a particle, a molecule as it were, of Wood's alloy. If thereafter the temperature ever rose to 70° C., that particle would melt and dissolve down its immediate neighbors until finally the whole mass was liquefied and converted into a homogeneous mass of alloy. Without waiting to consider how improbable it was that the three or four metals could be brought simultaneously into perfect enough contact to act as a real alloy, I tried the experiment and it proved an easy success.

The metals were filed to fine grains and mixed in the proper proportions, one part cadmium, one part tin, two parts lead, and four parts bismuth. A glass tube of 5^{mm} inner diameter and 70^{mm} length, sealed at one end, served as containing vessel. About 6 grams of the mixed filings were placed in this tube and packed down, an iron wire 3^{mm} diameter, held between the thumb and finger, being used as a packer; which certainly eliminated the possibility of any considerable pressure. The tube was thereupon so placed upon the water-bath that the sealed end containing the metals projected downward into the boiling water. In this way the filings remained dry and were kept at a temperature of 98° to 100° C. After remaining in this position for eighteen hours (over night) the filings showed signs of sinking together, which would

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[1] Read before the Philosophical Society of Washington, D. C., at the meeting of February 18, 1888.

[2] W. Spring: Ber. der Chem. Gesell., vol. 15, 1882, pp. 595–597.

indicate a beginning of the reaction. The tube was jarred upon the table to assist the condensation and again placed on the bath. Two hours later the tube contained a *homogeneous liquid globule of Wood's alloy.* The experiment was repeated, using two larger tubes, into which the metals were packed with a lead pencil, and producing some 30 grams of alloy. Of course when the operation is once started there is no limit to the quantity which can be produced. One tube remained on the water-bath over a week without signs of a solution and yet finally dissolved.

In further application of the same principle lead and tin were melted together at 190° to 200° C. by simply laying a piece of tin upon a carefully cleaned piece of lead and placing the whole in an air-bath at 190° C. A few hours suffice for this experiment. The melting points of the above metals are—cadmium 315° C., tin 230° C., bismuth 267° C., lead 325° C. Potassium and sodium were also used, melting at 62° 5′ C. and 95° 6′ C. respectively.

A very interesting and striking experiment is the production of the alloy of equal parts of potassium and sodium, which is liquid at temperatures above 6° C. Pieces of the two metals are simply placed with freshly cut surfaces in contact and slightly pressed together; in a few seconds the liquid alloy, which resembles mercury, is visible in drops around the contact surface, and an hour or two suffices to produce several cubic centimeters of the fluid.

It is my intention in the near future to follow up these observations by a series of experiments intended to establish and extend the principle here illustrated. The heat phenomena which doubtless accompany these reactions will also be investigated. Possibly also some electrical manifestations may be discovered, and perhaps some facts bearing upon the origin of contact electricity may be developed. In the mean time I would propose the following law: An alloy can be produced out of its original constituents without considerable pressure if the temperature be above the melting point of the alloy, even though it be far below the melting point of the most easily fusible constituent.

Probably this law will also be found applicable wherever under the existing circumstances the product is a liquid, even though the original substances be solids.

MISCELLANEOUS ANALYSES.

ROCKS COLLECTED BY R. D. IRVING.

A. Separations from the gabbro of Ashland County, Wis.: 1, Feldspar; 2, diallage; 3, magnetite, partial.

[Analyses by W. F. Hillebrand.]

	No. 1.	No. 2.	No. 3.
H_2O	.23	.33	
SiO_2	53.30	49.80	
TiO_2	trace.	1.29	8.47
P_2O_5	trace.	trace.	
Al_2O_3	29.03	2.86	
Fe_2O_3	.55	2.48	50.29
FeO	.23	10.82	30.70
MnO	none.	.37	
SrO, BaO	traces.	none.	
CaO	11.40	16.50	
MgO	.13	15.33	
K_2O	.40	.12	
Na_2O	4.87	.51	
Li_2O	none.	trace?	
	100.14	100.41	89.46

B. Garnet, separated from the garnetiferous actinolite schist of Penokee Gap, Wis.:

[Incomplete analysis on only 0.54 gram, by T. M. Chatard.]

SiO_2	39.31
Al_2O_3	12.86
Fe_2O_3 (total iron)	46.66
MnO	1.03
CaO	1.88
MgO	1.90
	103.64

The excess, 3.64, is oxygen added to ferrous iron. Correcting, we have approximately Fe_2O_3, 10.21; FeO, 32.81.

C. Limestones and iron carbonates: 1, Limestone, near Sunday Lake, Gogebic district, Mich.; 2, Limestone, Penokee region, Wis.; 3, cherty iron carbonate, Gogebic district; 4, iron carbonate, outlet of Sunday Lake; 5, iron carbonate, Palms mine, Gogebic district.

[Analyses by W. F. Hillebrand.]

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
H_2O	.30	.27	.54	.68	.60
CO_2	45.31	46.27	41.10	25.21	19.24
SiO_2	3.07	.63	3.16	28.86	46.47
TiO_2	....	....	....	.20	.10
P_2O_5	....	....	.06	trace.	trace.
Cl	trace.	trace.	trace.	....	(?)
Al_2O_3	....	....	.08	1.29	.70
Fe_2O_3	.09	.03	.93	1.01	.86
FeO	.86	.75	15.18	37.37	28.57
MnO	.15	.08	1.15	.97	.40
CaO	29.72	30.94	26.65	.74	.49
MgO	19.95	20.68	11.01	3.64	2.30
FeS_2	....	....	.34	....	....
Organic matter	....	....	....	undet.	undet.
	99.45	99.65	100.20	99.97	99.73

(Same series continued): 6, Iron carbonate, Miner and Wells' option, Sec. 13, T. 47 N., R. 46 W., Michigan; 7, "iron carbonate," bed of Slate Creek, Huron Bay slate quarries, Michigan; 8, iron carbonate, northwest ¼ Sec. 18, T. 47, R. 45 W., Minnesota; 9, slaty rock, supposed iron carbonate, bed of Cross River, near Gunflint Lake, Michigan.

[Analyses by T. M. Chatard.]

	No. 6.	No. 7.	No. 8.	No. 9.
H_2O	1.71	.25	1.52	1.99
CO_2	17.72	39.68	22.44	.41
SiO_2	46.01	7.05	36.73	64.77
TiO_2	.12	none?	.19	.60
P_2O_5	.07	.27	.01	.20
SO_3	.15	.21	.16	.60
Al_2O_3	.83	.48	.38	14.45
Fe_2O_3	1.35	1.33	.98	1.84
FeO	26.07	undet.	34.81	4.54
MnO	2.04	.19	.52	.11
CaO	.63	50.08	.48	2.33
MgO	2.86	.57	2.74	2.34
Alkalies	undet.	undet.	undet.	K_2O. 5.03 Na_2O. 1.37
	99.61	100.11	100.96	100.58

(Same series continued): 10, Iron carbonate, west end of Gunflint Lake, Minnesota; 11, iron carbonate, north side of lake; 12, limestone, east end of Ogiskemannissi Lake, Minnesota; 13, limestone, north side of Gunflint Lake, Canada.

[Analyses by T. M. Chatard.]

	No. 10.	No. 11.	No. 12.	No. 13.
H_2O	2.08	1.22	1.07	.99
CO_2	5.22	19.96	24.70	32.42
SiO_2	58.23	46.46	41.99	23.90
TiO_2	trace?	trace?	trace?	none.
P_2O_5	.03	.13	.05	trace?
SO_3	.19	.14	.32	.17
Al_2O_3	.06	.24	1.24	.07
Fe_2O_3	5.01	.64	.42	.44
FeO	18.48	26.34	4.77	10.72
MnO	.25	.21	.26	.28
CaO	.38	1.87	16.85	22.25
MgO	9.59	3.10	8.41	8.52
Alkalies	undet.	undet.	undet.	undet.
	99.52	100.31	100.08	99.76

NOVACULITE FORM MARQUETTE, MICH.

[Collected by G. H. Williams; analyzed by W. F. Hillebrand.]

H_2O	2.35
SiO_2	76.99
P_2O_5	trace.
Al_2O_3	13.92
Fe_2O_3	.45
FeO	.77
MnO	trace.
CaO	.32
MgO	1.12
K_2O	3.65
Na_2O	.56
Li_2O	trace.
	100.13

BRICK-CLAY FROM NEW ULM, MINN.

Color greenish-gray. Brick made from it is reddish-brown, strongly sintered, somewhat fractured. Received from Hon. John Lind.

[Analyzed by T. M. Chatard.]

Ignition	10.73
SiO_2	61.32
TiO_2	.66
P_2O_5	.27
SO_3	.19
Al_2O_3	12.27
Fe_2O_3	3.62
FeO	4.18
MnO	.27
BaO	.05
CaO	.99
MgO	1.76
K_2O	3.59
Na_2O	.42
	100.32

ROCKS FROM MONTANA.

[Collected by A. C. Peale and G. P. Merrill.]

A. From hills east of Fort Ellis: 1, Rock, analysis by T. M. Chatard; 2, ground mass; and 3, portion soluble in hydrochloric acid, analyzed by L. G. Eakins.

	A. 1.	A. 2.	A. 3.
H_2O	5.42	1.90	....
SiO_2	46.90	65.23	20.88
TiO_2	.41	....	....
P_2O_5	.44	....	....
Al_2O_3	10.17	17.48	3.89
Cr_2O_3	.33	....	....
Fe_2O_3	1.22	.98	2.21
FeO	5.17	....	4.28
MnO	.10	....	trace.
CaO	6.20	3.08	1.01
MgO	20.98	2.02	16.44
K_2O	2.04	4.63	trace.
Na_2O	1.16	3.79	trace.
Insoluble	....	....	51.29
	100.54	99.11	100.00

B. From hills north of Camp 6 (Peale), East Gallatin River.

C. Partial analysis of vein from rock north of East Gallatin River.

[Analyses by L. G. Eakins.]

	B.	C.
H_2O	4.14	....
SiO_2	49.47	65.19
TiO_2	.21	....
P_2O_5	.37	....
CO_2	3.31	....
Al_2O_3	12.15	16.38
Cr_2O_3	trace	....
Fe_2O_3	1.93	2.31
FeO	4.07	....
MnO	.10	....
BaO	.03	....
CaO	9.30	.56
MgO	10.86	....
K_2O	2.42	8.09
Na_2O	2.08	1.71
	100.44	94.24

D. From Cottonwood Creek: 1, Rock, analysis by T. M. Chatard; 2, portion soluble in dilute hydrochloric acid, analysis by L. G. Eakins.

	D. 1.	D. 2.
H_2O	3.19	
SiO_2	51.65	12.94
TiO_2	.55	
P_2O_5	.21	
SO_3	.19	
Al_2O_3	13.89	2.93
Cr_2O_3	.08	
Fe_2O_3	2.70	5.07
FeO	4.80	
MnO	.15	trace.
BaO	.19	
CaO	4.07	.96
MgO	11.56	8.28
K_2O	4.15	.33
Na_2O	2.99	.39
	100.37	30.90

E. Porphyrite, Cottonwood Creek: 1, Complete; 2, portion soluble in dilute hydrochloric acid.

[Analyses by L. G. Eakins.]

	E. 1.	E. 2.
H_2O	2.68	
SiO_2	52.33	13.62
TiO_2	.14	
P_2O_5	1.02	
Al_2O_3	15.09	5.93
Fe_2O_3	4.31	
FeO	4.03	
MnO	.09	
BaO	.07	
CaO	7.06	
MgO	6.73	
K_2O	3.76	.08
Na_2O	3.14	.78
	100.45	20.41

F. and G. Two rocks from northwest of Cottonwood Creek.

[Partial analyses, as requested, by L. G. Eakins.]

	F.	G.
SiO_2	62.98	54.29
Al_2O_3	18.44	18.47
Fe_2O_3	2.49	5.67
CaO	1.79	3.69
MgO		3.98
K_2O	4.35	5.92
Na_2O	5.58	4.13
	95.63	96.15

H. Eight carboniferous limestones. Analyses by C. Catlett: 1, north of East Gallatin River; 2, west of North Bowlder River; 3, 4, north of East Gallatin River; 5, west side of Bridger Range, base of carboniferous; 6, north of Gallatin River, middle formation; 7, 8, north of Gallatin River, upper formation.

	H. 1.	H. 2.	H. 3.	H. 4.	H. 5.	H. 6.	H. 7.	H. 8.
$CaCO_3$	54.54	54.54	67.85	59.11	88.50	91.96	32.28	40.21
$MgCO_3$	43.63	42.62	6.18	1.96	.95	1.35	13.91	25.25
Fe_2O_3 Al_2O_3	.22	.40	2.50	1.92	.38	.58	.30	5.30
Insoluble	.34	1.78	23.50	35.26	9.98	5.99	50.74	25.24
Water, etc.	undet.	undet.	undet.	undet.	undet.	undet.	undet.	undet.
	98.73	99.34	100.03	98.25	99.81	99.88	97.23	96.00

ERUPTIVE ROCK FROM THE HENRY MOUNTAINS, UTAH.

[Received from J. S. Diller; analyzed by R. B. Riggs.]

H_2O	.69
SiO_2	63.16
TiO_2	.21
P_2O_5	.12
SO_3	trace.
Al_2O_3	17.21
Fe_2O_3	2.43
FeO	2.30
MnO	trace.
CaO	6.27
MgO	1.27
SrO	trace?
BaO	.09
Li_2O	trace
Na_2O	4.70
K_2O	1.84
	100.29

ROCKS FROM NEW MEXICO.

[Collected by J. W. Powell; analyzed by L. G. Eakins.]

A. Obsidian from Obsidian Hill Camp.

H_2O	.33
SiO_2	76.20
TiO_2	trace.
Al_2O_3	13.17
Fe_2O_3	.34
FeO	.73
MnO	.10
CaO	.42
MgO	.19
K_2O	4.46
Na_2O	4.31
	100.25
Specific gravity	2.352, 23° 5′

B, C, D, and E. Four basalts, Rio Grande Cañon.

	B.	C.	D.	E.
H_2O	.82	.64	1.29	.53
CO_2	trace.	.58	.37	
SiO_2	52.27	51.57	52.37	52.38
TiO_2	1.49	1.43	1.60	1.22
P_2O_5				.56
Cl	trace.		trace.	
Al_2O_3	17.68	17.72	17.01	18.79
Fe_2O_3	2.51	6.24	1.44	2.88
FeO	5.00	1.78	5.89	4.90
MnO	.23	.45	.32	.18
BaO	.06	.16	.06	.11
CaO	8.39	8.82	7.59	7.70
MgO	6.05	4.91	6.86	4.91
K_2O	1.58	1.99	1.59	1.76
Na_2O	4.19	3.59	3.51	3.99
	100.27	99.88	99.90	99.91

LAVAS FROM NEAR LASSEN PEAK, CALIFORNIA.

[Series collected by J. S. Diller.]

1. West end of Lake Bidwell.
2. Silver Lake.
3. Volcanic sand, half-mile northeast of Cinder Cone, 10 miles northeast of Lassen Peak.
4. Inclusion in lava of Cinder Cone.
5. Lava of volcanic bomb, from Cinder Cone.
6. One-third of a mile south of Cinder Cone, on border of lava field.
7. Lapilli from Cinder Cone.

8. Timber line, west base of Lassen Peak.
9. Lava enveloping No. 8.
10. East end of Chaos, northwest base of Lassen Peak.
11. East end of Chaos, northwest base of Lassen Peak.
12. Two miles south of Luffan's Mountain, Llana County.
13. Two miles south of Luffan's Mountain, Llana County.
14. Northwest base of Luffan's Mountain, at base of high cliffs near Lassen Peak.
15. West side of old crater near Thumb, head of Mill Creek.
16. One mile southwest of Thumb, at head of Bailey Creek.
17. Lava resting on dacite, near west base of Lassen Peak.
18. One and one-half miles northeast of Clipper Mills, on tramway to Rock Creek, Shasta County.
19. West summit of Crater Mountain.
20. North slope of Crater Mountain.
21. Nodule from No. 20.
22. Near eastern end of rim, Crater Mountain.
23. South base of Burney Butte.
24. Cone at south base of Burney Butte.
25. Northwest summit in rim about the head of Burney Creek.

[Analysis 1 to 21 by W. F. Hillebrand; 22 to 25 by R. B. Riggs.]

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
H_2O	.42	.86	.26	.68	.30	.28	.27	.91
SiO_2	56.18	57.59	55.93	79.49	56.70	54.56	56.53	55.14
TiO_2					.65	.53	.54	.52
P_2O_5					.20	.18	.15	.18
Al_2O_3	16.59	16.49	17.34	11.60	15.75	16.04	17.50	19.10
Cr_2O_3	....	....	....	....	trace.	trace.	trace.	none.
Fe_2O_3	1.51	1.22	1.50	.33	1.29	.95	1.35	6.16
FeO	5.51	4.89	5.20	.49	5.32	6.07	5.03	.54
MnO	undet.	undet.	undet.	none.	.19	.17	.12	.11
BaO	(?)	(?)	(?)	(?)	.03	.03	trace.	trace.
SrO	(?)	(?)	(?)	(?)	trace.	trace.	(?)	.07
CaO	7.64	7.40	8.04	1.64	7.67	8.89	8.07	8.36
MgO	7.26	7.72	7.29	.09	7.16	8.71	5.94	4.23
K_2O	1.47	.99	1.35	1.52	1.56	1.18	1.55	1.04
Na_2O	3.58	3.62	3.32	4.04	3.36	3.05	3.51	3.71
Li_2O	(?)	(?)	(?)	(?)	trace.	trace.	trace.	trace.
	100.16	100.78	100.23	99.88	100.18	100.64	100.56	100.07

	No. 9.	No. 10.	No. 11.	No. 12.	No. 13.	No. 14.	No. 15.	No. 16.
H_2O	1.37	.74	.77	.55	1.09	1.09	1.03	1.04
SiO_3	68.32	68.72	53.35	63.47	57.04	58.08	63.81	59.84
TiO_2	.31	.31	.56	.37	.47	.44	.38	.57
P_2O_5	.12	.09	.10	.13	.08	.16	.10	.19
Al_2O_3	15.26	15.15	19.22	16.75	19.11	18.37	17.07	16.81
Cr_2O_3	none.	none.	none.	trace?	none.	none.	none.	trace?
Fe_2O_3	1.66	1.16	3.28	2.15	4.37	2.92	2.11	1.88
FeO	1.26	1.76	4.48	2.75	2.48	3.38	2.15	3.60
MnO	.04	.11	.15	.09	.12	.13	.09	.14
BaO	.07	.07	(?)	.04	trace?	.03	.04	.07
SrO	trace.	.03	.03	.04	.02	.02	.03	.02
CaO	3.26	3.30	9.76	5.72	7.34	7.05	4.97	6.30
MgO	1.32	1.28	4.86	3.04	3.94	3,35	2.28	3.85
K_2O	2.81	2.78	.99	1.62	1.16	1.33	1.96	2.13
Na_2O	4.27	4.26	2.89	3.94	3.48	3.66	4.08	3.63
Li_2O	trace.	trace.	trace.	trace.	trace.	trace.	trace.	trace.
	100.07	99.76	100.44	100.66	100.70	100.01	100.10	100.07

	No. 17.	No. 18	No. 19.	No. 20.	No. 21.	No. 22.	No. 23.	No. 24.	No. 25.
H_2O	.69	.85	.40	.83	.45	1.47	1.02	.79	.90
SiO_2	56.51	74.60	68.12	61.17	53.85	52.95	62.44	52.63	60.04
TiO_2	.48	.16	.25	.45	.50	.66	.31	.07	.49
P_2O_5	.14	.03	.14	.14	.05	trace.	.05	.47	.04
SO_3	....	....	....	....	....	trace.	trace.	trace.	trace.
Al_2O_3	18.10	13.41	16.24	17.74	18.53	18.25	16.39	17.62	17.43
Cr_2O_3	trace.	none.	none.	none.	trace.	....	....	....	....
Fe_2O_3	4.26	1.28	1.26	1.78	1.96	4.36	4.66	6.49	5.39
FeO	2.68	.30	2.08	3.51	5.30	4.19	1.00	3.10	.53
MnO	.11	.06	.10	.12	.12	.12	Trace.	Trace.	.08
BaO	.04	.11	.09	.06	.03	.01	.03	.04	.04
SrO	.04	none.	.02	.04	.01	trace.	trace.	trace.	(?)
CaO	8.15	1.08	3.80	5.90	9.66	8.73	6.22	8.62	6.65
MgO	4.52	.26	1.35	2.76	5.88	4.93	2.65	5.64	3.51
K_2O	1.15	4.50	2.54	1.71	.74	.77	2.25	1.73	1.24
Na_2O	3.23	3.38	3.89	3.79	2.98	3.57	3.16	3.38	4.15
Li_2O	trace.	trace.	trace.	trace.	trace.	(?)	trace.	trace.	trace.
	100.10	100.02	100.28	100.00	100.09	100.01	100.18	100.58	100.49

BASALT, ISLAND OF MYTILENE, ASIA MINOR.

[Collected by J. S. Diller; analyzed by T. M. Chatard.]

H_2O	2.12
CO_2	2.32
SiO_2	56.58
TiO_2	.77
P_2O_5	.15
Al_2O_3	14.88
Cr_2O_3	trace?
Fe_2O_3	2.31
FeO	3.04
MnO	.16
CaO	8.69
BaO	.07
MgO	3.76
K_2O	2.18
Na_2O	3.36
	100.39

INCLUSION IN DIORITE FROM CRUGER'S STATION, NEAR PEEKSKILL, NEW YORK.

[Collected by G. H. Williams; analyzed by T. M. Chatard.]

H_2O	4.61
SiO_2	32.73
Al_2O_3	46.58
FeO	5.12
CaO	11.04
MgO	1.00
	101.08

Analysis made on only 0.4212 gramme. The mineral is margarite.

WHITE EARTH FROM TALLADEGA, ALA.

[Received from R. A. Moseley, jr.; analyzed by C. Catlett.

Ignition	1.94
SiO_2	88.92
Al_2O_3	7.47
Fe_2O_3	trace.
CaO	.18
MgO	trace.
Alkalies	undet.
	98.51

SANDSTONE, BEREA, OHIO.

[Extensively quarried; analyzed by L. G. Eakins.]

H_2O	1.19
SiO_2	92.91
Al_2O_3	3.78
Fe_2O_3	trace.
FeO	.91
CaO	.31
MgO	trace.
K_2O	.61
Na_2O	.34
	100.05

KNOX DOLOMITE AND RESIDUAL CLAY.

[From Morrisville, Ala.; collected by I. C. Russell; analyzed by W. F. Hillebrand.]

	Dolomite.	Clay.
SiO_2	3.24	55.42
Al_2O_3	.17	22.17
Fe_2O_3	.17	8.30
FeO	.06	trace.
CaO	29.58	.15
MgO	20.84	1.45
K_2O	....	2.32
Na_2O	....	.17
H_2O	.30	9.86
CO_2	45.54	....
	99.90	99.84

Of the water in the clay 2.10 per cent. was expelled at 100°.

DOLOMITE FROM TUCKAHOE, WESTCHESTER COUNTY, N. Y.

The so-called "Tuckahoe marble." Extensively used as a building stone. White, highly crystalline.

[Analysis by W. F. Hillebrand.]

Insoluble	1.33
H_2O	.16
Fe_2O_3	.21
CaO	30.68
MgO	20.71
CO_2	46.66
	99.75

Of the insoluble portion, 0.71 is silica. The iron is probably in part FeO.

WHITE DOLOMITE MARBLE, COCKEYSVILLE, MD.

[Analysis by J. E. Whitfield.]

SiO_2	.44
Al_2O_3	1.22
FeO	trace.
CaO	30.73
MgO	20.87
CO_2	45.85
Ignition	1.22
	100.33

MARBLE FROM LOUISIANA.

From sections 19 and 20, T. 11 N., R. 3 W., five miles west of Winnfield. White, abundantly streaked with black. Received from the Supervising Architect of the Treasury.

[Analyzed by W. F. Hillebrand.]

Insoluble	.65
H_2O	.13
CaO	55.01
MgO	.60
MnO	.10
CO_2	43.43
SO_3	.27
	100.19

Traces of Al_2O_3, FeO, BaO, SrO, Cl, and organic matter.

LIMESTONES FROM OHIO AND INDIANA.

Trenton limestones and Utica shales, collected by Professor Edward Orton in the course of an investigation of the oil and gas wells of the two States. Partial analyses, as called for.

A. From New Vienna, Ohio. Analyses by F. W. Clarke and R. B. Riggs, jointly. 1, 2, 3, Utica shales. 4, 5, 6, 7, Trenton limestones.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
CO_2	15.24	27.16	27.40	36.20	37.64	42.04	30.82
CaO	17.11	33.43	35.27	46.16	49.04	51.18	23.00
MgO	1.25	2.16	1.32	1.52	.58	3.08	12.90
Insoluble	60.17	29.51	25.80	8.47	9.93	2.12	28.43
	93.77	92.26	89.79	92.35	97.19	98.42	95.15

Iron and alumina present in the soluble portions.

B. Trenton limestones from Ohio. Analyses by Clarke and Riggs. 8, Arcadia, Hancock County; 9, Air-line Junction, Toledo; 10, gas rock, St. Henry's well, Mercer County; 11, oil-rock, Lima.

	No. 8.	No. 9.	No. 10.	No. 11.
CO_2	38.54	42.84	40.96	43.92
CaO	47.17	30.64	50.34	32.24
MgO	2.59	18.05	2.86	17.36
Insoluble	8.56	3.52	2.27	1.64
	96.86	95.03	96.43	95.16

Iron and alumina present in the soluble portions.

C. Seven Trenton limestones from Ohio. Analyzed by F. W. Clarke. 12, well No. 3, Bryan, gas rock; 13, McElree well, Kenton; 14, Huntsville; 15, Prospect; 16, Findlay street well, Dayton; 17, Xenia; 18, New Madison. Air-dried samples.

	No. 12.	No. 13.	No. 14.	No. 15.	No. 16.	No. 17.	No. 18.
Insoluble...	9.22	5.26	4.41	26.12	12.34	9.23	11.11
Fe_2O_3, Al_2O_3.	1.51	1.10	3.15	2.57	.58	.18	3.60
$CaCO_3$......	49.00	84.32	57.23	66.02	82.36	86.54	64.91
$MgCO_3$.....	38.59	8.43	33.16	3.77	1.67	2.99	17.98
	98.32	99.11	97.95	98.48	96.95	98.94	97.60

In 14 and 18 ferrous carbonate was present.

D. Seventeen Trenton limestones from Ohio. Analyses by C. Catlett. 19, Air-line Junction, Toledo, depth 1,415 feet; 20, Upper Sandusky, city well No. 2; 21, Sandusky, depth 2,260 feet; 22, St. Mary's township, Auglaize County, gas-rock, Pauck well; 23, same locality, gas-rock, Bennett well; 24, Carey, first city well, depth about 1,350 feet; 25, Fort Recovery well No. 2, depth 1,065 feet; 26, Loomis and Nyman well, Tiffin, depth 1,470 to 1,481 feet; 27, Loomis and Nyman well, Tiffin, 1,488 to 1,494 feet; 28, gas-rock, Waggoner well, 6 miles west of Fremont; 29, London, depth 1,594 feet; 30, Celina, depth 1,112 feet; 31, Port Clinton, 1,660 to 1,700 feet; 32, Wauseon, 2,135 feet; 33, Napoleon, 1,830 feet; 34, oil rock, Kossuth, Allen County; 35, Franklin Township, Mercer County; Doenze's well, 1,107 feet.

	No. 19.	No. 20.	No. 21.	No. 22.	No. 23.	No. 24.	No. 25.	No. 26.
Insoluble............	2.88	8.18	3.65	3.18	1.66	5.72	1.89	5.66
Fe_2O_3, Al_2O_3.........	8.68	4.31	4.58	3.12	2.48	3.08	1.57	4.86
$CaCO_3$..............	54.68	64.25	54.62	52.18	56.94	80.11	87.88	52.89
$MgCO_3$..............	25.73	15.93	33.67	38.42	35.55	8.09	7.43	33.46
	91.97	92.67	96.52	96.90	96.63	97.00	98.77	96.87

	No. 27.	No. 28.	No. 29.	No. 30.	No. 31.	No. 32.	No. 33.	No. 34.	No. 35.
Insoluble...	9.88	5.22	15.90	2,95	7.46	18.24	2.66	1.08	3.68
Fe_2O_3, Al_2O_3.	1.46	6.32	1.84	2.95	4.16	7.28	2.14	.66	8.38
$CaCO_3$......	79.39	52.93	77.69	68.41	71.96	42.82	53.85	90.72	69.53
$MgCO_3$.....	6.20	32.75	1.89	24.18	14.34	28.11	37.33	6.69	10.68
	96.93	97.22	97.32	98.49	97.92	96.45	95.98	99.15	92.27

E. Six Trenton limestones from Indiana. 1, Union City, 1,160 feet; 2, Bluffton, 1,062 to 1,067 feet; 3, Muncie, 920 feet; 4, Greensburg, 867 feet; 5, Vernon, 905 feet; 6, Wabash, about 900 feet.

[Analyses, 1, by F. W. Clarke; 2, 3, 4, 5, 6, by C. Catlett.]

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Insoluble	2.14	2.37	3.30	.87	8.00	3.52
Fe_2O_3, Al_2O_3	1.23	4.48	3.72	.55	.60	7.58
$CaCO_3$	83.21	53.43	51.96	94.60	85.56	53.18
$MgCO_3$	12.48	37.47	38.11	.36	trace.	30.53
	99.06	97.75	97.09	96.38	94.16	94.81

COQUINA, CORAL, CORAL ROCKS, ETC.

Collected by Professor N. S. Shaler in an investigation of coral reefs. Partial analyses, as called for.

A. Five coquina gravels from Florida; 1, 2, 3, 4, Tortugas; 5, Key West; samples air-dried.

[Analyses by F. W. Clarke.]

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Moisture	3.27	3.57	5.12	3.07	3.19
CO_2	41.46	41.07	40.39	41.53	41.58
SiO_2	.19	.22	.32	.21	.25
Al_2O_3, Fe_2O_3	.19	.47	.56	.76	.56
CaO	52.24	51.24	49.38	51.95	51.52
MgO	1.53	2.09	1.93	1.44	2.08
	98.88	98.66	97.70	98.96	99.18

Chlorides and sulphates present; phosphates not looked for.

B. Five coral and shell rocks from Florida; 6, near Fort Worth; 7, east side of St. John's River, near Seville; 8, corroded surface, Miami Reef; 9, near Oak Hill; 10, near Melborne.

[Analyses by F. W. Clarke.]

	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.
Moisture	2.64	3.37	2.33	3.21	2.53
CO_2	41.59	39.00	41.22	39.62	34.31
SiO_2	2.94	8.50	2.99	5.87	17.83
Al_2O_3, Fe_2O_3	.23	.73	.65	.95	1.18
CaO	51.51	47.29	51.22	50.34	43.85
MgO	.71	1.51	.06	.37	.26
	99.62	100.40	98.37	100.36	99.96

C. Three coquinas from Florida; 11, coarse shell mass, Senote; 12, Salt Key Bank, coral rock; 13, Loggerhead Key.

[Analyses by L. G. Eakins.]

	No. 11.	No. 12.	No. 13.
H_2O	.11	1.13	.81
CO_2	43.89	43.87	43.71
SiO_2	.22	.11	.20
Al_2O_3, Fe_2O_3	.18	.04	.22
CaO	54.87	53.54	53.54
MgO	.64	.71	.78
	99.91	99.40	99.26

D. Hammock clay, Melborne Creek, Florida.
E. Incrustation formed by evaporating waters, Everglades, Florida.
F. Ochreous deposit, Paint Rock, Dade County, Fla.

[Analyses by L. G. Eakins.]

	D.	E.	F.
H_2O	23.61	19.56	.31
CO_2		25.38	41.30
Organic matter	....	19.68	
SiO_2	38.04	1.59	1.32
Al_2O_3	27.19	1.11	.30
Fe_2O_3			7.26
FeO	....	....	.68
MnO	....	....	trace.
CaO	10.73	31.32	48.96
MgO	.46	.30	.41
Alkalies	undet.	undet.	....
	100.03	98.94	100.54

G. Phosphatic deposit, Island of Sombrero, West Indies.
H. Coralline bottom, Barbados.
I. Recent coral (Siderostria), Bermuda.

[Analyses by L. G. Eakins.]

	G.	H.	I.
H_2O	3.05	2.73	.54
CO_2	3.47	43.40	43.74
Cl	.66	....	....
P_2O_5	39.12	....	....
SiO_2	.14	1.17	.23
Al_2O_3	.29	.31	trace.
CaO	51.15	46.45	55.16
MgO	trace.	5.15	.20
	97.88	99.21	99.87

Alkalies not looked for.

J. Fourteen coral rocks and one soil from the Hawaiian Islands. Analyzed by L. G. Eakins. 1, Laie; 2, 3, Kohuku Bluff; 4, Kohuku coral flat; 5, point near coral flat; 6, modern chalk, Oahu; 7, Diamond Head; 8, under lava, Honolulu; 9, near Pearl River lagoon; 10, old reef, Waialua; 11, Campbell's Ranch quarry, Waianea, Oahu; 12, Wailuku Bay; 13, Reef Three, Honolulu; 14, Prison Knoll, Honolulu; 15, Lava soil, Diamond Head.

[Analyses by L. G. Eakins.]

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
H_2O	4.74	.40	.79	.93	.70	9.84	1.86
CO_2	41.89	44.33	43.64	43.89	43.95	11.09	40.81
SiO_2	.35	.19	.67	.25	.26	33.25	2.97
Al_2O_3	.19	.52	.73	.49	.21	19.53	2.88
Fe_2O_3						10.71	
CaO	49.38	49.34	51.09	53.34	52.17	11.37	44.82
MgO	1.74	4.60	2.50	.67	1.51	3.06	5.32
	98.29	99.38	99.42	99.57	98.80	98.85	98.66

	No. 8.	No. 9.	No. 10.	No. 11.	No. 12.	No. 13.	No. 14.	No. 15.
H_2O	1.61	16.84	1.33	.46	1.93	2.75	1.24	5.30
CO_2	38.71	none.	42.68	43.96	42.80	40.59	42.81	11.41
P_2O_5	....	....	....	....	....	....	....	.24
Cl	....	....	....	....	....	....	....	.91
SiO_2	5.34	46.22	1.05	.53	.45	3.53	.81	32.88
Al_2O_3	5.11	19.16	1.26	.62	1.82	2.26	1.19	12.02
Fe_2O_3		12.94						11.52
MnO	....	....	....	....	....	....	....	trace.
CaO	42.24	1.72	51.07	50.69	50.54	46.52	52.67	12.20
MgO	5.95	2.24	.11	2.98	1.83	2.45	.42	11.70
Alkalies	....	....	....	....	....	....	....	undet.
	98.96	99.12	97.50	99.24	99.37	98.10	59.14	98.18

IRON AND MANGANESE ORES.

Two iron ores and two ochres from the Lucas farm, Jefferson County, W. Va. Received from D. B. Lucas.

[Analyzed by C. Catlett.]

	Ore.		Ochre.	
	A.	B.	C.	D.
SiO_2	1.18	4.03	92.07	93.57
Fe	58.72	59.31	2.72	2.24
Mn	none.	none.	undet.	undet.
P	.075	trace.	undet.	undet.
S	.293	trace.	undet.	undet.

Iron ore, Little's ore bank, Jefferson County, W. Va., and Hostler's ore bank, same county. From D. B. Lucas.

[Examined by C. Catlett.]

	Little's.	Hostler's.
SiO_2	55. 67	67. 34
Fe	23. 21	22. 73

Also from D. B. Lucas, iron ore from Cool Spring ore bank, Clarke County, Va., and from Bear Pond, top of Blue Ridge, Va.

[Analyses by C. Catlett.]

	Cool Spring.	Bear Pond.
SiO_2	29. 63	7. 11
Fe	36. 50	48. 24
Mn	trace.	1. 625
P	. 175	. 941
S	. 232	. 156

Three manganese ores, from Elkton, Rockingham County, Va. Received from C. E. Creecy.

[Analyzed by C. Catlett.]

	A.	B.	C.
Mn	43. 94	49. 66	48. 75
SiO_2	15. 88	1. 80	15. 08
Fe	3. 43	8. 53	2. 79
P	. 166	. 076	. 085
S	. 07	. 089	trace.

Four iron and manganese ores, Stuart estate, Lick Mountain, near Wytheville, Va. From J. W. Reardin.

[Analyses by J. E. Whitfield.]

	A.	B.	C.	D.
Fe	2. 92	2. 57	1. 98	48. 988
Mn	51. 05	41. 89	57. 67	4. 54
P	. 161	. 035	. 009	. 394
S	trace.	. 09	. 067	. 056
Insoluble	4. 32	4. 05	1. 85	10. 34

Also three ores from the same estate, sent in by P. B. Thompson, jr. Same analyst.

	A.	B.	C.
Fe	34.05	38.01	3.96
Mn	4.93	15.23	44.60
P	.118	.05	0.45
S	.083	.088	trace.
Insoluble	34.59	9.31	15.81

Ores collected by Prof. J. R. Procter. Analyses partly by J. E. Whitfield, partly by C. Catlett.

A. From Scott County, Va.: 1, Anderson lands, near top of Clinch Mountain, southern slope, 1,150 feet above the railroad water-tank; 2, James Boatwright's land, east side of Stony Creek, Buffalo Ridge; 3, Clinch River Hills, land of J. C. Taylor's heirs, north side of the river, 3½ miles above Stock Creek; 4, Slip Hill ore, where North Fork of Clinch River cuts through Purchase Ridge.

[Analyses 1, Catlett; 2, 3, 4, Whitfield.]

	No. 1.	No. 2.	No. 3.	No. 4.
Fe	51.98	47.22	49.79	11.543
Mn	4.60	trace.	trace.	none.
P	1.406	.093	.205	.275
S	.086	.119	.008	.08
Insoluble	2.07	25.56	17.332	59.306

B. From Wise County, Va.: 1, 2, 3, Big Stone Gap, top, middle, and bottom layers; 4, 1¼ miles from Big Stone Gap; 5, lands of Virginia Coal and Iron Company. All the deposits are on the south slope of Wallen's Ridge.

[Analyses by Whitfield.]

	1, top.	2, middle.	3, bottom.	4.	5.
Fe	6.65	49.44	49.44	39.76	52.00
Mn	.30	trace.	none.	.47	trace.
P	.096	.015	.122	.260	.165
S	.136	.132	.135	.085	.08
Insoluble	80.38	21.75	24.52	36.64	11.17

C. From Lee County, Va.: 1, A. J. Ely's land, north slope of Poor Valley Ridge, near Pennington Gap; 2, land of W. M. Pennington, near Pennington Gap.

[Whitfield, analyst.]

	No. 1.	No. 2.
Fe	52.82	20.76
Mn	trace.	trace.
P	.124	.33
S	.115	.079
Insoluble	17.92	64.43

D. Iron ore, three miles east of Pineville, on north slope of Pine Mountain, Bell county, Ky.

[Analysis by Catlett.]

Fe	43.32
Mn	1.27
P	.120
S	.342
SiO_2	13.48

E. Supposed iron ore, one-half mile west of top of Flint Hill, two and one-half miles from North Carolina line, on the waters of Elk, Carter County, Tenn.

[Whitfield, analyst.]

Insoluble	88.48
Fe	5.83
Mn	1.35
P	.043
S	.039

F. Iron ores from Claiborne County, Tenn.: 1, outcrops 100 yards east of the Russell shaft, four miles southwest of Cumberland Gap; 2, Oty shaft, east end of Double Mountain, one and one half miles west of Cumberland Mountain; 3, Van shaft, southern slope of Double Mountain, one-half mile west of Gap Creek, two and one-half miles southwest of Cumberland Gap; 4, red fossil ore, three miles east of Big Creek Gap, southern slope of Cumberland Mountain; 5, red fossil ore, 200 yards east of Big Creek, 175 feet above creek, on southern slope of mountain, Big Creek Gap.

[Analyses by Catlett.]

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
SiO_2	4.28	7.43	19.79	6.70	5.66
Fe	55.16	54.94	44.71	54.54	53.83
Mn	.09	.30	trace.	.43	.53
P	.910	.124	.108	.72	.243
S	.162	.087	.269	.214	.187

G. Ores from Unicoi County, Tenn.: 1, Garland land, on ridge between Rock and Martin's Creeks; 2, land of W. and M. Peebles, northern slope of Little Iron Mountain, near top of spur; 3, northwest spur of Unaka Mountains, one and one-half miles south of Irwin; 4, old mine on the Farnum land, at base of hill opposite mouth of Sciatha Creek; 5, divide between the waters of Rock and Dix Creeks, Hann tract; 6, Bell lands, on ridge west of Rock Creek, one and one-half miles east of Irwin, 700 feet above Irwin; 7, land of W. F. Norris, six miles from Johnson City, three-fourths of a mile southeast of Buffalo Creek; 8, west end of Little Iron Mountain, about one mile west of mill, near top of hill; 9, one-fourth mile southeast from Blue Spring, on waters of Indian Creek.

[Analyses by Whitfield.]

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Fe	46.41	54.69	2.70	23.55	41.63	56.32
Mn	3.47	trace.	44.94	32.98	12.13	trace.
P	.741	1.102	.282	.551	1.237	1.432
S	.077	none.	none.	none.	.057	.059
Insoluble	5.06	6.51	3.14	5.11	3.85	3.32

[Analyses by Catlett.]

	No. 7.	No. 8.	No. 9.
Fe	2.04	46.37	51.40
Mn	39.37	.38	3.01
P	.116	.509	.761
S	trace.	.106	.092
SO_2	18.10	3.77	6.26

Iron ore, Cranberry Bed, Mitchell County, N. C.

[Analysis by Whitfield.]

Fe	51.65
Mn	.36
P	trace.
S	.081
Insoluble	19.95
TiO_2, Ni	traces.

Ores collected by L. C. Johnson in Louisiana: 1, Miller's Bluff, Bossier Parish; 2, Aubrey, Claiborne Parish; 3, Gilmer field, Phelps Lake, Bossier Parish.

[Analyses by Catlett.]

	No. 1.	No. 2.	No. 3.
Fe	38.35	43.17	49.97
P	.18	1.65	.62
S	.34	.056	.08
Insoluble	21.40	11.42	12.15

Ores from Arkansas, received from Hon. W. C. Whitthorne, from a mountain ridge crossing the line between Polk and Montgomery Counties, between the two Salinas Creeks: A, manganese; B, iron ore.

[Analyses by C. Catlett.]

	A.	B.
SiO_2	4.64	.94
Mn	38.33	1.32
Fe	18.68	54.30
S	.170	.162
P	.561	1.826

Iron ore from Wood County, Wisconsin. Section 32, T. 24, R. 4 E. Received from T. E. Nash.

[Analyzed by J. E. Whitfield.]

Fe	22.15
Mn	trace.
S	.008
P	.030
Insoluble	57.70

Manganese ore (impure rhodochrosite), from Llanbedr, Harlech, Merionethshire, Wales. Analyzed by T. M. Chatard, at request of Dr. D. T. Day, for purposes of comparison with certain American material.

CO_2	19.04
Mn	31.12
Al_2O_3	7.63
Fe	4.02
SiO_2	21.69

COAL AND COKE.

Two samples of coke from near Piedmont, W. Va. Received from G. W. Harrison.

[Analyses by C. Catlett.]

	Thomas mine.	Davis mine.
Moisture	.47	.25
Volatile carbon	2.39	2.24
Fixed carbon	87.14	89.23
Ash	10.00	8.28
	100.00	100.00
S	.721	.645

Two samples of coal from near Piedmont, W. Va. Received from Hon. H. G. Davis.

[Analyses by C. Catlett.]

	Elk Garden mine.	Davis mine.
Moisture	.76	.70
Volatile carbon	19.39	22.03
Fixed carbon	72.99	70.53
Ash	6.86	6.74
	100.00	100.00
S	.880	.924

Ash white, coke silver gray and porous.

Supposed anthracite from near Romney, W. Va. Received from A. W. Kercheval. A shale.

[Analyzed by C. Catlett.]

Moisture	.68
Volatile carbon	7.32
Fixed carbon	5.37
Ash	86.63

Three samples coal, Sharp bank, East Fork of Big Creek, Claiborne County, Tenn. Received from J. R. Procter.

[Analyzed by C. Catlett.]

	Top.	Middle.	Bottom.
Moisture	2.40	2.10	1.78
Volatile carbon	36.81	33.76	39.14
Fixed carbon	57.88	51.29	56.00
Ash	2.91	12.85	3.08
	100.00	100.00	100.00
S	1.087	1.15	2.30

Coke hard to burn; dark in color; ash brown.

Coal from Pend d'Oreille, Oregon. From Hon. J. K. Jones.

[Analysis by C. Catlett.]

Moisture	7.56
Volatile carbon	52.55
Fixed carbon	30.43
Ash	9.46
	100.00
S	.65

EFFLORESCENCE ON SANDSTONE, FROM CLIFF CREEK, GUNNISON COUNTY, COLO.

[Collected by Whitman Cross; analyzed by L. G. Eakins.]

	Soluble in water.		Insoluble.
Al_2O_3	trace.	SiO_2	55.09
CaO	trace.	Al_2O_3	9.75
MgO	5.42	Fe_2O_3	1.23
SO_3	10.31	CaO	.30
		MgO	.39
		Alkalies	undet.
	15.73		66.76

Water	16.88
Soluble	15.73
Insoluble	66.76
	99.37

The soluble part is essentially $MgSO_4$, $7H_2O$.

COMMON SALT, FROM HUTCHINSON, KANSAS.

[Received from Hon. P. B. Plumb, analyzed by T. M. Chatard.]

H_2O	.92
Insoluble	.09
$CaSO_4$	1.47
$MgCl_2$	.25
NaCl	97.27
	100.00

WATER FROM LINCOLN COUNTY, N. C.

Spring on the farm of Willis E. Hall, 3 miles from Lowesville post-office, and 20 miles from Charlotte.

[Analysis by F. W. Clarke. Stated in grammes per litre. Total solids, 0.642 gram.]

	Found.	Per cent. of total solids.		Hypothetical combination.
SiO_2	.0385	5.99	SiO_2	.0385
Cl	.0029	.45	$CaSO_4$	.4716
SO_4	.3329	51.86	$CaCO_3$	.0318
Ca	.1514	23.58	$MgCO_3$	.0328
Mg	.0094	1.47	KCl	.0042
Na	.0267	4.16	NaCl	.0015
K	.0022	.34	Na_2CO_3	.0601
CO_3, difference	.0780	12.15		.6405
	.6420	100.00		99.77 per cent. of total.

SURFACE DRAINAGE WATER, ST. AUGUSTINE, FLA.

[Collected by William Kennish; analyzed by T. M. Chatard. Stated in grammes per liter.]

	Found.	Per cent. of total solids.		Hypothetical combination.
SiO_2	.0146	2.40	SiO_2	.0146
$Al_2O_3+Fe_2O_3$	.0015	.25	Fe_2O_3	.0015
Ca	.0796	13.12	Al_2O_3	
Mg	.0166	2.74	NaCl	.1625
Na	.0639	10.53	KCl	.0188
K	.0098	1.61	$CaSO_4$	.0742
SO_4	.0524	8.64	$CaH_2C_2O_6$	.2341
Cl	.1076	17.74	$MgH_2C_2O_6$	.1009
CO_3	.2450	40.40		
H in bicarbonates	.0042	.69		
	.5952			
Deficit of CO_3	.0114	1.88		
	.6066	100.00		.6066

WATER FROM SPRING AT M'LEANSBOROUGH, ILL.

[Received from S. W. Heard; analyzed by R. B. Riggs. Stated in grammes per liter.]

	Found.	Per cent. of total solids.		Hypothetical combination.
SO_4	3.0040	59.59	KCl	.0220
CO_3	.7008	13.90	$NaCl$	.0396
Cl	.0345	.68	Na_2SO_4	.8433
SiO_2	.0142	.28	$MgSO_4$	2.2340
Al_2O_3	trace.		$CaSO_4$	.9166
Ca	.5420	10.75	$CaCO_3$	.1924
Mg	.4468	8.86	$CaH_2C_2O_6$	.7903
Na	.2888	5.73	SiO_2	.0142
K	.0115	.21		
	5.0426	100.00		5.0524
H, bicarbonate	.0098			
	5.0524			

WATER FROM LEBANON, LACLEDE COUNTY, MO.

[From a well 1,000 feet deep. Received from Hon. R. P. Bland; analyzed by L. G. Eakins. Stated in grammes per liter.]

	Found.	Per cent. of total solids.		Hypothetical combination.
SiO_2	.0112	3.90	SiO_2	.0112
Al_2O_3	.0032	1.11	Al_2O_3	.0032
Fe	trace.		$NaCl$	trace.
Ca	.0326	11.35	$MgSO_4$	.0060
Mg	.0163	5.68	$FeH_2C_2O_6$	trace.
Na	.0127	4.42	$MgH_2C_2O_6$	.0917
SO_4	.0048	1.67	$CaH_2C_2O_6$	.1315
Cl	trace.		$NaHCO_3$	.0370
CO_3	.2030	70.69	Na_2CO_3	.0066
H, bicarbonate	.0034	1.18		
	.2872	100.00		.2872

TWO SPRINGS AT HOMINY HILL, ARK.

[Received from Hon. A. H. Garland. Analyses by J. E. Whitfield. Stated in grammes per liter.]

A. OLD OR UPPER SPRING.

	Found.	Per cent. of total solids.		Hypothetical combination.
SiO_2	.0122	7.21	SiO_2	.0122
Fe, Al	traces.	....	$CaSO_4$	.0058
Br, I	none.	....	$CaH_2C_2O_6$	.0984
B_2O_3	none.	....	$MgH_2C_2O_6$	.0207
Cl	trace.	....	$KHCO_3$	.0103
SO_4	.0041	2.42	$NaHCO_3$	.0219
CO_3	.1117	65.98		
Ca	.0260	15.36		
Mg	.0034	2.01		
K	.0040	2.36		
Na	.0060	3.54		
Li	trace.	....		
NH_4	none.	....		
H, bicarbonate	.0019	1.12		
	.1693	100.00		.1693
Free CO_2	.0276		Free CO_2	.0276

B. NEW OR LOWER SPRING.

	Found.	Per cent. of total solids.		Hypothetical combination.
SiO_2	.0100	9.39	SiO_2	.0100
Fe	trace.	....	$CaSO_4$	.0121
Al	none.	....	$CaH_2C_2O_6$	.0535
Br, I, B_2O_3	none.	....	$MgH_2C_2O_6$	.0146
Cl	trace.	....	$KHCO_3$	.0031
SO_4	.0085	7.98	$NaHCO_3$	.0131
CO_3	.0629	59.13		
Ca	.0168	15.79		
Mg	.0024	2.25		
K	.0012	1.13		
Na	.0036	3.39		
Li	trace.	....		
NH_4	none.	....		
H, bicarbonate	.0010	.94		
	.1064	100.00		.1064
Free CO_2	.0091	....	Free CO_2	.0091

WATER FROM A SPRING NEAR DENVER, COLO.

[Received from Sidney Williams; analyzed by L. G. Eakins. Stated in grammes per kilo. Specific gravity 1.063, at 20°.8.]

	Found.	Per cent. of total solids.		Hypothetical combination.
SiO_2	.0290	.05	KCl	.2542
Cl	1.5862	2.62	$NaCl$	2.4143
SO_4	43.9675	72.56	Na_2SO_4	18.0629
Al, Fe	traces.	....	$MgSO_4$	38.7306
Ca	.3214	.53	$CaSO_4$	1.0929
Mg	7.7461	12.79	SiO_2	.0290
K	.1331	.22		
Na	6.8006	11.23		
Li	trace.	....		
	60.5839	100.00		60.5839
CO_2	.2101			
Album. NH_3	.0050			
Free NH_3	trace.			

MATILIJA HOT SPRINGS, NEAR SAN BUENAVENTURA, CAL.

[Received from Dr. Stephen Bowers; analysis by R. B. Riggs. Stated in grammes per liter.]

	Found.	Per cent. of total solids.		Hypothetical combination.
SiO_2	.0088	.53	KCl	.0622
SiO_3	.0412	2.51	$NaCl$	1.3876
Cl	.8768	53.20	$MgCl_2$	.0068
SO_4	.0169	1.02	$MgSO_4$	.0073
CO_3	.0579	3.51	$CaSO_4$	.0160
Ca	.0650	3.94	$CaCO_3$	.0965
Mg	.0034	.21	$CaSiO_3$	.0629
Na	.5456	33.11	SiO_2	.0088
K	.0325	1.97		
	1.6481	100.00		1.6481