later origin than the feldspar, since it occurs in fractures running irregularly through the plagioclase. Such calcite-filled fractures not only cross the rare phenocrysts but traverse also the microlitic groundmass. Furthermore, the amygdules scattered through the rock are filled with calcite formed in two stages; the first formed being clear, colorless, and sometimes spherulitic, the second being cloudy and yellowish, probably from limonitic stain. On the other hand, there is not the slightest indication that the calcite is confined to, or is even more abundant near, fractures than in the rock as a whole. If the calcite, especially that in microscopic veinlets and amygdules, is the result of later alteration, that alteration must have occurred under conditions such that the plagioclase and magnetite were remarkably stable, while the rest of the rock was removed almost completely. It is well known that this will not occur under ordinary weathering conditions, and that, on the contrary, the plagioclase of the Columbia river basalts alters readily under such conditions, and that one of the products of such alteration is calcite. It is also true that ordinary rock samples illustrating the production of calcite from feldspathic rocks probably under conditions of moderately high

in cold acid and has indices somewhat higher than those of calcite. This rock seems to furnish another example of primary carbonate, since the fresh unaltered minerals include not only plagioclase and magnetite, but also brown hornblende and apatite. The carbonate seems to have ceased to crystallize after the magnetite, but as early as the feldspar. Quartz was the last mineral to complete its crystallization and fills interstices between the other minerals. The rock is a carbonated hornblende dacite. The relation of the carbonate to the other minerals of this rock is shown in Fig. 2.

The augite andesite of National has been often called basalt because it differs sharply in appearance from the hornblende andesite of the same district, while it resembles closely a true basalt. The rock is essentially different from a true andesite, and therefore the name augite andesite, which implies that the rock is a variety of andesite, is distinctly objectionable. I would suggest that such rocks be called auganite. The relation in chemical composition between andesite, auganite, and basalt may be shown by comparing the averages computed from all available complete analyses.

FIG. 1. UNALTERED LATH-SHAPED PLAGIOCLASE WITH SHARP CRYSTAL OUTLINES EMBEDDED IN CALCITE. FAIRVIEW CLAIM, NATIONAL, NEVADA. CROSSED NICOLS. × 30.
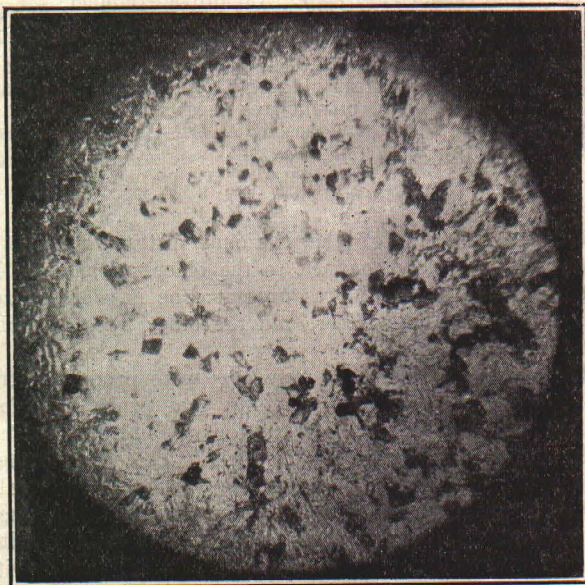

FIG. 2. DACITE, NATIONAL, NEVADA. THE BLACK MINERAL IS MAGNETITE OR ILMENITE, THE ELONGATED GRAY MINERAL WITH CLEAVAGE LINES IS BROWN HORNBLENDE, THE IRREGULAR GRAY GRAINS ARE ANKERITE, THE WHITE GROUNDMASS IS A MOSAIC OF PLAGIOCLASE AND QUARTZ. ONE NICOL. × 60.

pressure and temperature furnish nothing like the andesite found in National. On the contrary, in such rocks the calcite is clearly derived at least in part from the alteration of the feldspar. It seems probable, therefore, that the calcite in the andesite at National is largely of magmatic origin.

Andesite of the later series has not been studied microscopically, but it is relatively fresh, contains little or no calcite, and consists largely of plagioclase and hornblende, commonly with rock glass. Some of the samples contain fragments of an older andesite, of a basaltic rock, or of a rhyolite.

Dacites are rare in the National district, but the two samples discovered seem to represent two periods of intrusion. One is closely associated with the later andesite, and, like the latter, is fresh and contains little or no calcite; it is a porphyritic rock containing small phenocrysts of quartz, andesine, and biotite in an extremely fine grained groundmass of the same minerals with much rock glass. It is a biotite dacite. The other is closely associated with the older andesite and like the latter contains abundant carbonate. Unlike those of the older andesite, the plagioclase phenocrysts and the smaller crystals of the groundmass are fresh and unaltered with sharp crystal outlines. The rock contains abundant feldspar, some quartz, light brown hornblende, magnetite (or ilmenite), apatite, and much carbonate, which is probably ankerite, since it does not effervesce

Auganite is a volcanic rock consisting essentially of basic plagioclase and pyroxene; the plagioclase is usually labradorite, but may be more basic; andesine marks a transition toward andesite. The pyroxene is often augite, but hypersthene, bronzite, diopside, and even enstatite replace the augite more or less completely in some types. Hornblende and mica are not common, nor abundant. Andesite consists of acid plagioclase (andesine or oligoclase) with hornblende or mica or pyroxene. Having provided the new name auganite for rocks ordinarily called augite andesite, it is possible to use the latter name for rocks which are actually varieties of andesite, and consist essentially of acid plagioclase and pyroxene. The close relationship in composition between augite andesite as thus defined and other andesites is clearly shown in the following table. Auganite at National forms dikes and flows which are dark colored and fine grained. In places they are amygdaloidal, the cavities being filled by layers of chlorite, calcite, and quartz, commonly formed in the order indicated. Rarely the rock contains accessory hornblende. Some samples contain abundant calcite and some pyrite. Part of the calcite seems to be of magmatic origin, but the evidence is not decisive.

Basalt is reported in flows stratigraphically above the foregoing rocks. I have not studied it.

Average Composition of Andesite, Auganite, and Basalt

	Hornblende and mica andesite.	Augite andesite.	All andesite.	Auganite.	Basalt.
SiO_2	61.31	61.33	61.30	54.97	48.78
Al_2O_3	17.16	16.47	16.88	16.69	15.85
Fe_2O_3	3.14	2.86	3.01	3.94	5.37
FeO	2.32	3.30	2.76	4.75	6.34
MgO	2.31	2.75	2.49	4.13	6.03
CaO	5.28	4.78	5.07	8.02	8.91
Na_2O	3.73	4.37	3.99	3.19	3.18
K_2O	1.94	1.81	1.89	1.45	1.68
H_2O	1.45	1.16	1.33	1.39	1.76
TiO_2	0.92	0.77	0.86	0.89	1.39
P_2O_5	0.26	0.24	0.25	0.28	0.47
MnO	0.18	0.16	0.17	0.30	0.29
	100.00	100.00	100.00	100.00	100.00

Hornblende and mica andesite: average of 34 analyses, from data of Daly, *Proc. Am. Acad.* XLV, 1910, p. 223.

Augite andesite: average of 23 analyses from data of F. W. Clarke, U. S. Geol. Surv. Bull. 419, 1910, Rosenbusch, 'Elem. Gest.,' 1910, p. 382, and Osann, 'Chem. Petrog.,' II, 1905. The name is here restricted to volcanic rocks containing acid plagioclase and pyroxene.

All andesite: average of 57 analyses, from data of R. A. Daly (*loc. cit.*), F. W. Clarke (*loc. cit.*), Rosenbusch (*loc. cit.*), and Osann (*loc. cit.*). Auganites excluded.

Auganite: average of 73 analyses, from data of F. W. Clarke, U. S. Geol. Surv. Bull. 419, 1910, Rosenbusch, 'Elem. Gest.' 1910, pp. 378, 382, and Osann, 'Chem Petrog.' II, 1905. Rocks containing acid plagioclase or orthoclase are excluded and 12 olivine-free basalts are included.

Basalt: average of 161 analyses, R. A. Daly, *Proc. Am. Acad.* XLV, 1910, p. 224.

Ore Deposits

The ore deposits of the National district are all in quartz veins largely confined to the older volcanic series. There are two types of ores present: one is characterized by copper, lead, and silver, and the other by gold (with silver).

The veins containing the base ores were produced after the extrusion of the older rhyolite, and probably before any of the later rocks; they cut the rhyolite and are not known to extend into the later rocks. The veins formed at this time contain a considerable variety of minerals; the chief gangue mineral is quartz accompanied in places by subordinate quantities of calcite and a little sericite; the chief ores include chalcopyrite, arsenopyrite, pyrite, bornite, stibnite, galena. They often contain an important amount of silver as well as copper and lead. Under favorable conditions they would yield fair returns, but on account of the comparative isolation of the district they have not yet produced any considerable amount of shipping ore.

Gold ore is the important resource of the district. The vein of the National mine contains phenomenally rich gold ore in quartz. It occupies a fissure which was produced later than the veins containing base ores, and later than the older andesite. Faulting along this fissure has lowered the andesite (which probably formerly overlay the older rhyolite) of the hanging wall to a position on a level with rhyolite in the foot-wall. The fissure was filled by quartz containing argentiferous gold or electrum with small amounts of pyrite and stibnite, and very little stephanite, native arsenic, galena, sphalerite, and chalcopyrite. After the formation of the ore, faulting continued along the vein; consequently, the ore is much broken and granulated, and rolled fragments are often found in the fault gouge. This post-mineral faulting movement along the vein occurred after the extrusion of the auganite, since fragments of this rock are now in the fault gouge. The metallic part of the ore consists of gold and silver usually in the ratio of about 1 to 1, as in electrum. The latter is intimately intergrown with finely granular quartz, and partly enclosed by elongated prisms of quartz rudely parallel or radial. Stibnite and native arsenic intergrown with the quartz give it in places a dark gray to black color. The sulphides in this vein are intergrown with the quartz, but (except stibnite in a few cases) are not so closely associated with the electrum. Even the pyrite is rarely if ever directly intergrown with the gold. In occasional samples the gold ore is broken and recemented by white quartz containing a little pyrite. There is little evidence of secondary enrichment, and no abundant formation of secondary minerals of any kind in the National vein, but small quantities of the following secondary minerals have been observed: calcite, orpiment, realgar, sericite, limonite, and pyrargyrite. Marcasite, native gold, and polybasite are reported as secondary minerals, but I have not observed them.

The ore occurs in a shoot of rather indefinite boundaries which has been proved to extend on the dip for a distance of about 700 ft. and on the strike for a distance of 400 ft. The shoot is not known to extend to the surface at any point, and for about 60 ft. from the surface downward the vein contained some silver, but no high-grade ore. No placer mines have been discovered in this vicinity, although erosion has been at work cutting down the surface and the outcrop of this vein for some time. It seems probable that the bonanza ore-shoot never reached the surface of the earth, and also that the upper portion of the vein which has been removed by erosion did not contain any similar lens of high-grade ore. Most of the ore from the mine is worth from $30 to $60 per pound, and the total production since the discovery of the lode in 1907 is reported to have been between $3,000,000 and $4,000,000.

Origin of the Ore

The problem of the origin of such ore is of great importance, as well as of a peculiar fascination, because it has engaged the attention of so many eminent students of ore deposits without receiving any satisfactory solution.

It is commonly believed that many ore deposits in veins have been formed by precipitation of metals, sulphides, or other compounds from flowing water or from flowing aqueous vapor. It seems reasonable to believe that such a mode of origin would produce a banding or crustification in the ore. At Steamboat Springs,[7] Nevada, where such a process is now forming deposits of stibnite, pyrite, metastibnite, and silica, and unrecognized minerals containing gold, silver, copper, lead, arsenic, and other metals, crustification on the walls of the fissure is distinctly visible through the recent sinter.

At National crustification is not uncommon in the quartz of the main vein, but it is wholly lacking in the high-grade gold-quartz, so far as I observed. It seems improbable, therefore, that precipitation occurred from a flowing fluid. I would suggest that the gold quartz was precipitated, not from a thin aqueous solution, but from a viscous, and perhaps gelatinous mass which occupied the fissure in much the same way as an igneous magma fills an opening in country rock. The amount of motion during crystallization may have been no greater in the former instance than in the case of the magma.

The constituents of the viscous mass which formed the National vein may be inferred (from the components of the vein) to have been silica, gold, silver, and very little antimony, arsenic, iron, and sulphur. In accordance with generally accepted views, it is believed that these constituents did not exist merely in mutual solution, like those of a magma, but that they existed in solution in water or aqueous vapor. It is considered probable that the amount of water present was small, and that supersaturation was prevented by the presence of certain compounds which increase the solvent power of water, or may be themselves efficient solvents. Such compounds are carbon dioxide and alkaline sulphides. The present condition of the wall rocks, with abundant carbonates apparently both primary and secondary in origin, renders it very probable that carbon dioxide existed in the ore-forming solution. It is from chemical considerations that a belief in the existence of alkaline sulphides in the solution is derived.

In seeking for a solvent of gold in the National vein

[7] G. F. Becker, U. S. Geol. Surv. Mon. XIII, 1888, p. 331-353; W. Lindgren, *Trans. Am. Inst. Min. Eng.* XXXVI, 1906, pp. 27-31; J. C. Jones, *Science,* XXXV, 1912, p. 775.

it must be remembered that the ore contains not only gold, but also silver. It is clear that the two metals solidified simultaneously, and therefore from a single solution. Consequently it is necessary to find a solvent for both. Hydrochloric acid under pressure less than 100 lb. per square inch and at moderately high temperatures (about 120°C.) dissolves gold,[8] but is not a solvent for silver. Nitric acid dissolves silver, but does not affect gold. Sulphuric acid attacks silver, but is not a good solvent for gold. In short, there is no common mineral acid which is a solvent for both metals. On the contrary, alkaline sulphides, even when present in small amounts, are efficient solvents for gold, while silver sulphide is soluble in water[9] alone at temperatures as low as 89°C. Such solutions are also solvents of iron, antimony, arsenic, lead,[10] zinc, and copper, all of which are found in the National vein in sparse to rare primary minerals. Moreover, Lenher, of the University of Wisconsin, finds that an alkaline sulphide solution of gold is stable[11] under a considerable variety of conditions, whereas most other solutions are relatively very unstable, especially in the absence of oxidizing conditions.

Accordingly, it is probable that the solutions which filled the National fissure contained alkaline sulphides, and that these sulphides kept the gold and silver in solution.

If such a vein-magma did at one time fill the National fissure it would certainly slowly cool, and perhaps at the same time slowly come under decreasing pressure on account of slight upward movement and surface erosion. Supersaturation would finally ensue, and centres of crystallization would be established. On account of the high tenor of silica, quartz would probably be one of the earliest products of crystallization. The immediate result of the formation of quartz would be the liberation of water, previously combined with the silica in the condition of unconsolidated opal. Under suitable conditions of temperature and pressure, the water would promptly combine with carbon dioxide to form carbonic acid. Alkaline sulphides are wholly unstable in the presence of any mineral acid, including carbonic acid. Alkaline carbonates and hydrogen sulphide would probably be produced. The destruction of the alkaline sulphides would remove the solute for the gold and silver, and these would be precipitated. In the absence of gold the silver would probably combine with sulphur of hydrogen sulphide to form argentite. But in the presence of gold it seems to form an alloy (electrum) with the latter, rather than to decompose the sulphide.

Whether the precise chemical processes[12] involved have been correctly stated or not, it seems clear from the mode of occurrence that the electrum was precipitated from a solution containing large proportions of the precious metals, and that it was precipitated with the earliest products of crystallization from that solution. Alkaline sulphides are known to be remarkably efficient solvents, and they are regarded as the most probable solvents in this case; their destruction, probably to form carbonates, is believed to have caused the precipitation of the electrum.

The existence of pockets or lenses of high-grade ore (electrum quartz) may be due, in part at least, to the process of crystallization. The electrum must be precipitated around those spots where centres of crystallization liberate the water. The noble metals may have been fairly uniformly distributed through the vein magma at the beginning of crystallization. As soon as crystallization commenced the metals would diffuse toward the centres of crystallization. Thus the electrum would form local masses in a vein quartz elsewhere nearly or wholly barren. After the precipitation of the electrum, the alkaline carbonates and sulphuretted hydrogen would escape from the crystallizing mass upward through the unsolidified portion (if any still existed) and outward into the adjoining rocks. These compounds would produce the secondary carbonates (calcite, ankerite, siderite) and sulphides (pyrite) which are found in the country rocks.

The process here outlined as a possible mode of origin of the electrum quartz of the National vein would have as consequences the crystallization of electrum with the earliest quartz formed, and the existence of cavities in the ore due to the escape of water and gases. As a matter of fact, a careful study of the ore makes it plain that the electrum crystallized with the first formed quartz which is finely granular, and is scanty or absent in the quartz of later crystallization, including that which lines vugs. Also, it is a fact that vugs are fairly abundant in the high-grade ore.

As a result of a study of the National vein, I have one other suggestion to offer in regard to the origin of the ore. Geologists and engineers often speculate regarding the origin of ore-shoots. As I interpret the National vein, it furnishes an excellent illustration of a paragenetic[13] ore-shoot due to a structural feature, but not a structure cited by Van Hise.[14] It is a 'shoot of variation'[15] not due to any chemical effect of wall rock nor to intersecting veins. The National vein strikes about north and south and dips about 50° to the west. Near the middle of the West Virginia claim the course changes, going southerly from nearly due south to south 25 to 30° east. The opening of the mine on different levels to a depth of about 500 ft. shows that this bend in the course of the vein pitches to the south so as to make an angle of perhaps 20° with the line of dip of the vein. Careful study of the striations on the walls of the vein has shown that the general direction of the faulting motion was nearly straight down the dip. Therefore, the direction of motion of the hanging wall makes an angle of about 20° with the pitch of the curve in the vein. It may readily be seen that the result of such conditions would be a tendency to relieve the pressure of the hanging wall, to produce less fault gouge, and to make an open space in the fissure north of the bend. Another result to be expected is a breaking of the hanging wall. All of these results are realized in the National vein. And it is in the open space thus produced that the ore-shoot of the mine is found. This shoot pitches in the same direction as the bend in the vein; it terminates to the south near the bend, and extends rather indefinitely to the north for a horizontal distance of about 400 ft. Since the pitch of the ore-shoot is not parallel with the direction of faulting motion along the vein as shown by striation, this shoot is not n harmony with Clayton's law[16] that such parallelism usually exists.

ACCORDING to the United States Geological Survey, there was no production of cobalt, molybdenum, nickel, rutile, or tantalum in this country during 1911. The United States cobalt supply comes from Cobalt, in Canada, imports for last year being 579,520 lb., worth $48,104. Imports of molybdenum and ferro-molybdenum were 8.5 tons, valued at $11,409. All nickel used comes from Sudbury, in Canada, the imports being 29,829,268 lb., valued at $4,022,716. Ferro-titanium amounting to 51.17 tons, and worth $22,700, was imported for consumption. A considerable quantity of tantalum wire was imported from Germany in 1911, for making incandescent electric lamps, but the quantity and value is not published.

PRODUCTION of gold in Russia during the last four years has increased over 50%, or from 22,275 poods to 35,084 poods per year, a pood (36.11 lb.) of gold being worth about $9000 according to the fineness.

[8]Victor Lenher, *Econ. Geol.*, IV, 1909, p. 562.
[9]P. DeClermont and J. Frommel, *Ann. Chim. Phys.*, 5th ser., Vol. 18, 1879, p. 189.
[10]C. Doelter, *Tsch. Min. Petr. Mitth.*, Vol. II, 1890, p. 319; G. A. Binder, *idem.*, Vol. 12, 1892, p. 332.
[11]Victor Lenher, unpublished manuscript, 1912.
[12]It is quite possible that the chemical reactions were more complicated and involved other substances, such as NaSH and KSH. It may be questioned, also, whether CO_2 alone would not destroy the alkaline sulphides.

[13]H. V. Winchell, *Econ. Geol.*, III, 1908, p. 425.
[14]C. R. Van Hise, *Trans.* Am. Inst. Min. Eng., XXX, 1900, p. 166.
[15]J. D. Irving, *Econ. Geol.*, III, 1908, p. 143.
[16]J. F. Kemp, 'Ore Deposits of the United States and Canada,' 1900, p. 49.