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The Monte Cristo District, Washington.
From "Gold Ores of Washington and Oregon" by F:C:Lincoln,
EMJ 7-1-1911. p.13 ff.

Stratigraphy.

Eocene Sediments. Sveral thousand feet of arkoses, conglomerates and quartzites, probably derived from Tertiary erosion of the Mesozoinc granite core of the Cascades.

Miocene -Pleistocene Volcanics. Andesite
Younger Unonformity
Extensive olivene basalt
Sparse rhyolite. Before the extrusion was completed uplift occurred, with much ~~faulting and~~ fracturing and some faulting.
Unconformity
Tonalite flows
Older Andesite (older) flows.

Mineralization. The ore deposits are in joint cracks:gash veins. While jointing appears equally developed in all rocks, the ore is chiefly in the tonalite, less in the andesite and other igneous rocks. Very little in the sedimentary arkoses. The tonalite corresponds to the Republic latite, with which the Republic ores are generally related. The Monte Cristo ore formed since the last elevation of the district. Deposition began with the dissection of the plateau in the late Pliocene or the Pleistocene.

The ore is often localized at fracture intersections. Areas of great fracturing are generally areas of the greatest mineralization. The fissures are narrow, and replacement is more important than open fissure filling. The first stage of alteration of the tonalite comprizes the alteration of the feldspars to sericite,and that of the ferromagnesians to glaucophane. In the second stage, the quartz grains increase in size,feldspars and ferromagnesians go to calcite,kaolinite and sulphides. In the alteration of the andesites, the ferro-magnesians go to epidote instead of glaucophane.

Ores Mainly gold. Little silver. The deep ore carries 0.6 oz. Au, 7 Oz. Ag. The shoots are extremely irregular, and ore differs from country rock only in the increase of sulphides. Pyrite, pyrrhotite, arsenopyrite,sphalerite, galena ccpy. Minor chalcocite, bornite, molybdenite and stibnite. The oxidized minerals are malachite, limonite, hematite and melaconite. The gangue consists of altered country rock, now principally quartz and calcite. In the upper primary zones are Galena,sphalerite, ccpy,high gold and silver. In the lower zones, pyrite,arsenopyrite, and low gold and silver. The order of deposition was 1. arsenipyrite, pyrite and quartz. 2. ccpy, pyrrhotite,sphalerite, galena and quartz.3. Realgar ? stibnite,molybdenite, ccpy, quartz and calcite. The gold and silver are chiefly with the sulphides. Gold with the arsenopyrite. Silver with the pyrite and galena. The pyrrhotite and realgar are barren.

Gold Ores of Washington and Oregon

By Francis Church Lincoln *

A review of the geologic conditions in the Republic and Monte Cristo districts in Washington, and the North Pole shear zone in Oregon, which have furnished most of the gold produced by these States.

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Washington and Oregon rank ninth and tenth among the States as producers of gold, their respective productions for 1910 having been estimated[1] at $711,359 and $631,173. Washington contains two economic gold deposits of exceptional geologic interest, the seleniferous gold veins of the Republic district and the joint-crack deposits of the Monte Cristo district. Oregon has been an important source of gold, the eastern portion of the State having produced approximately $65,000,000[2]. The North Pole shear zone in argillite is the most important deposit.

Tertiary Propylitic Veins

The veins of the Republic district are of special interest on two accounts. In the first place, they constitute the northernmost economically important representative in the United States proper of the group of late Tertiary propylitic veins in effusive eruptive rocks which includes both gold and silver lodes and has numerous members to the south in the United States, Mexico and South America. North of the Republic district no deposit of importance is known until the Apollo lode on Unga island, Alaska[3] is reached. Across the Pacific similar goldfields occur in Japan, the Dutch East Indies and New Zealand. The other interesting point is the occurrence of a considerable amount of selenium with the gold. Selenium also occurs in association with the gold ores of Goldfield, Nev.; Redjang-Lebong, Dutch East Indies; Waihi and Great Barrier, New Zealand; and Falun, Sweden. With silver ores the gold of which is of subordinate value, it occurs at Tonopah, Nev., and in several Mexican and South American districts[4].

Republic Camp Opened in 1896

The Republic district[5] is situated in northeastern Washington 20 miles south of the Canadian boundary. It formed part of the Colville Indian reservation, which was opened to mineral entry, Feb. 21, 1896. George and John Welty, who had camped upon the ground all the previous winter, brought into the district Philip Creaser and Thomas Ryan, who had been grubstaked in Rossland, B. C. Creaser and Ryan located three claims on Feb. 29, and within two weeks all the important claims in the district had been staked. The New Republic ground was taken up on March 5, 1896.

In the early days of the camp, the high-grade ore was hauled 80 miles to the railroad at Marcus. Attempts to treat the low-grade ore on the ground were not wholly successful. A 30-ton Pelatin-Clerici cyanide mill was installed in 1898, and the following year this plant was dismantled to make room for 200-ton mill designed for cyaniding roasted ore, which latter plant was in operation less than a year. Both mills were expensive to operate and did not make satisfactory recoveries. After the abandonment of milling operations, there was a temporary revival of mining due to the advent of the railroads in 1902 and 1903, but smelting rates were so high that it was not until 1909, when contracts for a period of years were made with the smelters, that operations were resumed on a large scale.

The total production of the camp up to 1910 was approximately $2,000,000, of which 90 per cent. was gold. The New Republic mine produced about $1,400,000 of this amount, mostly between 1897 and 1902. The town of Republic has a population of 1500 and is the county seat of Ferry county. It is accessible by two railroads—the Republic & Kettle Valley Railroad and a branch of the Great Northern system. The camp is situated on Granite creek near its confluence with the San Poil river and at an elevation of 2500 ft. The New Republic mine is just south of the town and at the same altitude.

The surface in the Republic district is rugged. Many branching streams flow through valleys from 2500 to 3000 ft., deep. From these stream valleys steep slopes lead up to the mountains, which are of fairly uniform elevation and all have rounded tops. The New Republic vein outcrops at the crest of an elongated mound on the east slope of Copper mountain, which lies on the west side of Granite creek. The climate is semi-arid and neither winter nor summer temperature is extreme. The rainfall is about 18 in. and the streams carry sufficient water for mining and domestic purposes. A forest growth of evergreen trees covers the greater part of the district.

Rocks of the Republic District

The oldest rocks exposed in the Republic district are the metamorphic equivalents of a great series of shales, sandstones, limestones and lava flows of Paleozoic, (perhaps Carboniferous), age. These rocks were metamorphosed and raised above sea level and either during this crustal disturbance or shortly thereafter great batholithic masses of granodiorite were intruded into them. The intrusions took place in early or middle Mesozoic time and were succeeded by a long erosion period lasting till the middle Tertiary and divisible into two stages, one by which the entire area was reduced to base level in Eocene time, (now shown by the general accordance of mountain summits), and a second by which after reëlevation of the Eocene peneplain broad valleys at least 2500 ft. in depth were developed.

One of these valleys was occupied by dacite flows and included stream gravels of Oligocene age. Overlying these, unconformably, are andesite breccias, lake beds and andesite flows. These early Miocene deposits form the wall rock at the New Republic mine. Next in order of age come intrusive latite porphyries with which the ore deposits are thought to be genetically related. Erosion ensued, interrupted by a short period of basaltic eruption. In Pleistocene time the entire area was covered by Cordilleran ice.

Two Contemporaneous Vein Systems

The fissure veins of the Republic district occur in Tertiary dacite flow conglomerate, andesite flow breccia and latite porphyry. They were formed in Miocene or Pliocene time, susequent to and probably in connection with the intrusion of the latite porphyry, by hot ascending waters rich in silica, lime and potash, and carried subordinate amounts of sulphur, iron, copper, gold, silver, selenium, tellurium and fluorine. The productive belt is about five miles in length in a north-south direction and one mile in breadth. Within this belt there are two vein systems: a north-south system of which all but one dip east, and a northeast-southwest system most of which dip southeast. The veins of the first system vary in length from less than 100 to 4000 ft., while those of the second never exceed 1500 ft. in length. The two systems are thought to be approximately contemporaneous, since the northeast-southwest lodes abut against the north-south lodes but in no case continue on the opposite side.

The New Republic vein strikes north 4 deg. east. At the north end of the

[1] Eng. and Min. Journ., Jan. 7, 1911, p. 3.
[2] Eng. and Min. Journ., Jan. 7, 1911, p. 55.
[3] Eng. and Min. Journ., Sept. 17, 1910, p. 551.
[4] *Professional Paper*, 42 (1905), p. 281, U. S. Geol. Surv.
[5] *Bull. I*, 1910, Washington Geol. Surv.

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claim it splits into stringers, but at the south end it continues well defined beyond the limits of the property. Its dip is 60 deg. east, and it has been explored to a depth of 400 ft. The width varies from 2 to 8 ft. Spur veins narrower than the main vein occur in the foot-wall. They never extend more than 15 ft. from the main vein, and when they differ in dip always diverge upward like the limbs of a tree. The vein is crustified, the bands being roughly parallel with the walls. In detail, however, the banding is found to be somewhat irregular and concentric crustifications occur from a fraction of an inch to several feet in diameter. Sharply defined angular fragments of country rock occur in the vein. Silicification of the wall rock has taken place near the vein and calcification farther away. Calcite has been developed after feldspar and hornblende, and chlorite after hornblende and biotite, while secondary pyrite has been formed extensively.

Republic Ore Is of Medium Grade

The district contains large deposits of $7 ore and comparatively limited amounts of $12 ore. Some high-grade rock is said to have been taken from the New Republic mine. The ore does not amalgamate nor cyanide well and smelting seems to be the best method of treatment. The ore occurs in shoots pitching steeply to the south and containing kidneys and ribbons of high-grade ore lying parallel to the walls. Rich ore occurs in the spurs as well as in the main vein. In the unoxidized portions of the veins ore may be distinguished from waste by its appearance. Where gold and silver occur, there are found intermixed with the wavy ribbons of bluish-gray vein filling other ribbons of bluish-black color and sub-metallic to metallic luster.

Ninety per cent. of the vein filling is quartz. A considerable amount of adularia (the vein variety of orthoclase) is found, mainly in the form of microscopic crystals. There is also some calcite present and occasionally gypsum and an acicular calcium-magnesium salt. The bluish-black ore ribbons viewed under the microscope are found to contain disseminated aggregates of small opaque specks which as a rule are indeterminable. Pyrite and chalcopyrite are the principal exceptions, although one small crystal of fluorite and two resembling titanite have been observed. A dark metallic mineral present in these bands is thought to be silver-antimony sulphide. Selenium in some form is also present.

The ratio of gold to silver is 1:1 at the surface and 1:6 on the lower level. All of the gold which is not free, and some of the silver, is thought to be associated with the selenium. In this connection it may be of interest to recall that the form of the gold at Tonopah, where selenium occurs in the ore, is an as yet unsolved problem, but that at Goldfield the selenium is present in the mineral goldfieldite, which has been found intergrown with native gold[6]. Again, the form in which the gold occurs in the seleniferous ore of the Redjang-Lebong mine, Sumatra[7], has never been ascertained, but in the Falun mine, Sweden[8], it is intimately associated with seleniferous galenite.

Joint Crack Deposits of Monte Cristo

Monte Cristo[9] lies in the heart of the Cascade range in central Washington, 40 miles east of the city of Everett on Puget sound. The two principal mines, the Mystery and Pride, are owned by a single company which is controlled by the capitalists who built the smelter at Everett and the Everett & Monte Cristo Railroad which connects Monte Cristo with the outside world. The camp has not been very active recently, owing to the lowering of the grade of the ore with depth. The town lies in the valley of the head waters of the Sauk river on the western slope of the Cascade mountains at an elevation of about 3000 ft. above sea level, while the mines are about a thousand feet higher up the slope. Deep, narrow gulches are tributary to the valley basin, and the slopes of the mountains are quite steep. The higher mountains contain fields of perpetual snow and small glaciers.

The country rocks exposed in the Monte Cristo district are of Tertiary and Quaternary age and consist of an Eocene sedimentary series and a later series of volcanic rocks ranging in age from Miocene to Pleistocene. The sedimentary series comprise several thousand feet of arkoses, conglomerates and quartzites believed to have been derived by the erosion during early Tertiary time of the Mesozoic granite rock which in the Republic and other districts has been found to make up the core of the Cascade range. Following the deposition of the sedimentaries came a long period of volcanic activity. This began by the extrusion of andesite, followed by tonalite intrusion, which was succeeded by a period of erosion. Scanty rhyolite was then extruded, followed by abundant olivine-basalt flows. The rocks were then folded and eroded and a later andesite flowed out upon the erosion plain. Before the completion of the extrusion of the later andesite, the region was elevated. Profound fracturing and slight faulting accompanied the uplift. A period of erosion followed.

Gash Veins Prevalent

The ore deposits of Monte Cristo occur mainly in joint cracks and, therefore, belong to the class commonly termed "gash veins." While jointing is developed equally in all the rocks of the district, the ore has been deposited chiefly in or near the tonalite and to a less extent in the andesite and other igneous rocks, while the sedimentary arkoses contain little. It is of interest to note that the Monte Cristo tonalite is of similar geological age and chemical composition to the Republic latite to which the ores of that district are genetically related. The Monte Cristo ore is believed to have been formed since the last elevation of the district, deposition having begun with the dissection of the plateau in late Pliocene or Pleistocene time and continued until the present day. According to Spurr's hypothesis, the ores have been leached from the surrounding rocks by downward percolating waters, which have later precipitated their mineral contents in favorable localities. The ore is often especially localized at the intersections of fractures and areas of profound fracturing are generally the areas of greatest mineralization.

On account of the narrowness of the fissures, replacement has been of much greater importance than fissure filling. The first stage of alteration of the tonalite is represented by the change of feldspar to sericite and ferromagnesian minerals to glaucophane. In a more advanced stage the quartz grains increase in size and the feldspars and ferromagnesian minerals are replaced by calcite, kaolinite and sulphides. The changes in the andesite are somewhat similar, save that epidote develops in preference to glaucophane.

Gold and Silver Occur with Sulphides

The ores carry small amounts of gold and silver. The surface ore from the Monte Cristo mine contained 0.95 oz. gold and 12 oz. silver per ton and the deep ore 0.6 oz. gold and 7 oz. silver. Owing to the nature of the deposit, the shoots are extremely irregular in shape. The ore differs from the altered country only in its increased sulphide content.

The principal ore minerals are pyrite, pyrrhotite, arsenopyrite, sphalerite, galenite and chalcopyrite, while the rarer ones include chalcocite, bornite, molybdenite and stibnite. Realgar has been produced by the alteration of arsenopyrite and among the oxidation products of the sulphides occur malachite, limonite, hematite, melaconite and scorodite. The gangue minerals are the minerals of the altered country rock, quartz and calcite being the most important.

There is a rough succession of the minerals in the order of their solubility which from the surface down is galenite, sphalerite, chalcopyrite, pyrite and arsenopyrite. The upper zones, characterized by galenite, sphalerite and chalcopyrite carry more gold and silver than the lower ones characterized by pyrite

[6] *Professional Paper*, 66 (1909), U. S. Geol. Surv.

[7] *Trans.* I. M. M., 10 (1902), pp. 53 and 12 (1903), p. 341.

[8] "Gold," Maclaren, p. 197.

[9] *Annual Report*, 22, Part II (1901), pp. 777-865, U. S. Geol. Surv.

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and arsenopyrite. The order of deposition of the minerals was as follows: First, arsenopyrite, pyrite and quartz were deposited; then chalcopyrite, pyrhotite, sphalerite, galenite and quartz; and finally realgar, stibnite, molybdenite, chalcopyrite, quartz and calcite. The gold and silver occur chiefly in the sulphides. Of these, arsenopyrite carries the most gold and pyrite and galenite the most silver. Pyrrhotite is comparatively barren, while realgar contains neither gold nor silver.

North Pole Shear Zone in Argillite

The most important goldfield of Oregon is situated in the Blue mountains in the northeastern part of the State. The best known mines of the Blue Mountain belt are situated on the North Pole shear zone[10] in the Cracker Creek district. The principal settlement is Bourne, six miles north of Sumpter, which is on a branch of the Oregon Railroad and Navigation Company's line from Baker City. The placer deposits of the Blue mountains were discovered by a prospector named Griffin and a party of men in 1861. In 1862, D. Littlefield and his party discovered the rich placers of Auburn. Notwithstanding the difficulty of access at that time, the population grew to 5000 in less than a year. Using Auburn as an outfitting point, prospectors scoured the Blue mountains and discovered practically all the mining districts by 1864. Quartz mines were found early, the Virtue being discovered in 1862.

The country was first made readily accessible by the construction of the transcontinental railroad in 1885, and its active development dates from that year. In 1889 the lode mines first made a notable production, and it was in the same year that the Cracker Creek district was first considered worthy of exploitation. There are four mines on the North Pole lode in this district which, in order from northeast to southwest, are the North Pole, Eureka and Excelsior, Columbia, and Golconda. Previous to 1880 the production of the Blue Mountain belt is but imperfectly known, and even since that date there have been many blanks in the records. The goldfield is located in Baker, Grant and Union counties, and the production of gold from both deep mines and placers in these counties from 1880 to 1908, inclusive, was approximately $24,000,000. The total production of the North Pole shear zone, known locally as the "Mother Lode," was estimated in 1908 to have been at least $7,000,000.

The Cracker Creek district is mountainous. The valleys, generally V-shaped, are sometimes U-shaped in their upper courses. They are separated by steep rugged ridges from 1000 to 2000 ft. in hight, which have narrow, somewhat serrate summits. The elevations range from 5000 to 8400 ft. above sea level. At Baker City the temperature is moderate and the climate dry. Going west toward Cracker creek rain fall and snow fall increase rapidly with the elevation until summer showers become frequent and winter snows are from 5 to 15 ft. in depth. The timber is of poor quality, consisting mainly of black pine and tamarack.

The Sedimentary Rocks

The country rock consists of sediments probably of Paleozoic, perhaps Carboniferous, age, which form an apparently conformable series. The members of this series range from cherts to clay slates and either grade into one another or occur interlaminated. An interbedded greenstone, 600 ft. in thickness, is also present. To the north and northwest the sediments are cut off by intrusive granodiorite. Altered feldspar-porphyry dikes cut both granodiorite and sedimentary rocks. A few aplitic dikes and serpentine masses also occur. Pleistocene morainal deposits have been formed in the creek valleys.

The North Pole lode is a mineralized shear zone in hard, black, silicious argillite. The lode was probably formed in early Cretaceous time by hot ascending waters of magmatic origin containing a considerable amount of carbon dioxide and alkaline carbonates. It belongs to a system of linked lodes, the Elkhorn-Cracker Creek-Cable Cove system. The lode has a general northeast-southwest strike, but is curved. It is continuous for at least four miles and occupies a normal fault which extends beyond the limits of the district. It dips 70 deg. to the southeast and displaces the country 400 ft. vertically and 1800 ft. horizontally, the movement having taken place along a line in the vein pitching gently southwest. In width it varies from 5 to 500 ft. with an average of about 25 ft., but although it occupies a shattered area of such variable width, the North Pole shear zone commonly has well defined walls. Fractures and fissures have been filled and in some instances the filling exhibits comb structure. Metasomatism of the country rocks has taken place, the slates having been pyritized and to a slight extent silicified and the porphyry dikes in the slates sericitized and carbonated. Faulting has taken place within the vein subsequent to its formation.

Character of Gold Ore Varies

The character of the ore varies considerably in the different mines on the lode. In value it averages from $6 to $15 per ton with occasional carloads running as high as $1000 per ton. From 6 to 50 per cent. of the gold is readily amalgamable. Concentrates make up about 10 per cent. of the ore and range in value up to $200 per ton. The pyrite formed metasomatically in the country rock is always poor in gold and silver, so that the core consists mainly of cavity fillings. Four large ore-bearing shoots are known, three of which had been explored at the time of Lindgren's examination. These were each several hundred feet in stope length, from 2 to 12 ft. in width, and were separated by long stretches of barren ground. Two of these shoots pitched from 20 to 30 deg. to the southwest and the third was irregular, insofar as explored. The gentle southwest pitch common to both fault movement and oreshoots is suggestive.

Within the large ore-bearing shoots, the ore is confined to smaller and more definite oreshoots which usually have a width of from 1 to 4 ft. These may occur on either the foot or the hanging wall, cross diagonally from one wall to the other, or form several distinct stringers. These oreshoots are lens-shaped, frequently overlapping, and bounded by fault planes filled with thinly laminated, striated, black gouge.

The Principal Minerals

A small amount of sulphides is present in the ore and lacking in the waste, but otherwise there is no apparent difference between the two. The ore minerals occur finely divided in quartz. Arsenopyrite, marcasite and pyrite are by far the most important. Chalcopyrite, galenite and sphalerite are uncommon. Among the rarer minerals are cinnabar, tetrahedrite, mercurial tetrahedrite, stibnite, hessite, sylvanite, native copper and pyrargyrite. A small amount of calcite occurs with quartz as a gangue, and more rarely chrome mica and vanadium mica are found. Examination of the ore shows that primary quartz and arsenopyrite were crushed and recemented by quartz containing sharply defined pyritohedrons of pyrite. In narrow cracks in quartz of both ages, calcite pyrite and arsenopyrite occur.

Gold Mostly in Sulphides

The finely divided sulphides are usually rich in gold. Native gold is seldom seen. Rich pockets contain pyrite, chalcopyrite, tetrahedrite, native gold and sometimes telluride, in a gangue of quartz and roscoelite (vanadium mica). Rich ore from the North Pole mine shows hessite filling cavities in quartz which are sometimes lined, next the quartz, with native gold and more rarely with a pale yellow telluride which, in one instance, adjoins the gold. These three minerals seem to be contemporaneous and are said to occur in apparently primary quartz. In the Columbia mine native gold occurs intergrown with colorless or brownish sphalerite and with tetrahedrite but not with pyrite, and is also found intergrown with roscoelite.

[10] *Annual Report* 22, Part II (1901), pp. 561-776; *Bull.* 380 (1909), pp. 85-93, U. S. Geol. Surv.

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