GEOLOGY OF THE BOREALIS GOLD DEPOSIT

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THE BOREALIS GOLD DEPOSIT CONTAINS RESERVES OF 2.1 MILLION TONS AT A GRADE OF 0.08 OUNCES OF GOLD AND 0.50 OUNCES OF SILVER PER TON. THE MINE IS LOCATED IN WEST-CENTRAL NEVADA, IN MINERAL COUNTY, 12 MILES SOUTH OF HAWTHORNE. BOREALIS WAS ACQUIRED BY HOUSTON INTERNATIONAL MINERALS IN APRIL, 1978 AND PLACED INTO PRODUCTION IN NOVEMBER, 1981. I WISH TO THANK HOUSTON INTERNATIONAL MINERALS MANAGEMENT FOR PERMISSION TO GIVE THIS TALK AND THE STAFF FOR THEIR MANY CONTRIBUTIONS DURING THE LAST FOUR YEARS.

SLIDE IL REGIONAL GEOLOGY

THIS FIRST SLIDE IS OF THE REGIONAL GEOLOGY AROUND BOREALIS. THE MAP COVERS AN AREA 30 MILES BY 20 MILES. THE PINK COLOR IS GRANITIC BASEMENT, BLUE IS ANDESITE, GRAY IS BASALT, AND YELLOW IS QUARTERNARY ALLUVIUM. THE REGIONAL GEOGRAPHIC SETTING OF BOREALIS IS DOMINATED BY FLETCHER BASIN, A TOPOGRAPHIC AND STRUCTURAL DEPRESSION 30 MILES LONG AND 12 MILES WIDE, ELONGATED IN AN EAST-WEST DIRECTION. STRUCTURAL RELIEF IN THE CENTER OF FLETCHER BASIN MAY BE ON THE ORDER OF 8,000 FEET.

THE STRATIGRAPHY OF THE BOREALIS REGION IS TYPICAL OF MUCH OF WESTERNMOST NEVADA. A MEZOZOIC CRYSTALLINE BASEMENT IS OVERLAIN BY OLIGOCENE ASHFLOW TUFFS AND MIOCENE ANDESITE FLOWS AND BRECCIAS. THE OLIGOCENE TERTIARY RHYOLITES AND MIOCENE ANDESITES ARE OVERLAIN IN TURN BY PLIOCENE TUFFACEOUS SEDIMENTS AND PLIESTOCENE GRAVELS. RHYOLITE DOMES, RHYOLITE ASHFLOWS, AND BASALT CONES AND FLOWS OF PLIOCENE AND PLEISTOCENE AGE ARE ALSO PRESENT ON THE SOUTH MARGIN OF FLETCHER BASIN. THE BOREALIS DEPOSIT IS ON THE NORTHEAST MARGIN OF FLETCHER BASIN, IN ROCKS DIPPING REGIONALLY TO THE SOUTHWEST.

SLIDE 2L

MINE GEOLOGY

THE SLIDE ON YOUR LEFT IS OF BOREALIS MINE SITE GEOLOGY. THE MAIN OREBODY IS THE LARGE PINK AREA IN THE CENTER. SEVERAL SUBSIDIARY OREBODIES LIE TO THE SOUTH OF THE MAIN OREBODY. THE BAR SCALE IN THE LOWER RIGHTHAND CORNER REPRESENTS 500 FEET.

THE STRUCTURE OF THE BOREALIS MINE SITE IS DOMINATED BY A NORTHEAST TREND OF HYDROTHERMAL BRECCIAS. NORTH-SOUTH FAULTS CUT THE NORTHEAST TREND AND BOUND THE BOREALIS DEPOSIT TO THE EAST AND THE WEST. THE NORTH-SOUTH FAULTS ARE DOWNDROPPED TO THE WEST IN A STAIRSTEP FASHION. BEDDING DIPS 10° TO THE SOUTHWEST AT BOREALIS, CONFORMING TO REGIONAL DIP ALONG THE NORTHEAST MARGIN OF FLETCHER BASIN.

1R

MINE GEOLOGY

MINE CROSS SECTION

THE SLIDE ON YOUR RIGHT IS A NORTHWEST CROSS SECTION THROUGH THE CENTER OF THE BOREALIS DEPOSIT. THE PINK COLOR IS ORE, BROWN IS OXIDIZED QUARTZ BRECCIA, ORANGE IS HOT SPRING APRON DISCHARGE DEPOSITS--INCLUDING A PECULIAR ALTERATION TYPE LOCALLY KNOWN AS "SPONGEROCK". PURPLE IS MUDSTONE, THE WHITE MASS NEXT TO THE MAIN OREBODY IS CONGLOMERATIC SANDY SILTSTONE, THE BLUE IS ANDESITE, THE WHITE LENSES ARE INTERFLOW SEDIMENTS, AND THE YELLOW IS PEDIMENT GRAVELS AND ALLUVIUM. EACH INCREMENT ON THE VERTICAL AND HORIZONTAL BAR SCALES IN THE LOWER LEFT CORNER REPRESENTS 100 FEET. SLIDES SHOWN ON THE LEFT HAND SCREEN THROUGHOUT THIS TALK WILL REFER TO THE CROSS SECTION.

STRATIGRAPHY AT THE BOREALIS MINE SITE IS SIMILAR TO THE REGIONAL STRATIGRAPHY AROUND FLETCHER BASIN. CRETACEOUS GRANODIORITE AND TRIASSIC ROOF PENDANT ROCKS ARE INFERRED AT DEPTH BUT HAVE NOT BEEN DRILLED. OLIGOCENE RHYOLITES ARE ALSO INFERRED. AT LEAST EIGHT HUNDRED FEET OF MIOCENE ANDESITE FLOWS, BRECCIAS AND INTERFLOW SEDIMENTS HAVE BEEN DRILLED BELOW BOREALIS. UNCONFORMABLY OVERLYING THE ANDESITES IS A 200 FOOT SECTION OF PLIOCENE HOT SPRING DISCHARGE APRON DEPOSITS, MUDSTONES, CONGLOMERATIC SANDY SILTSTONES, AND QUARTZ BRECCIA. THESE LATE PLIOCENE ROCKS WERE DEPOSITED AT THE SURFACE OF AN ACTIVE GEOTHERMAL FIELD. QUARTERNARY ALLUVIUM AND PEDIMENT GRAVELS FORM AN APRON AROUND THE TOPOGRAPHICALLY HIGHER GEOTHERMAL DEPOSITS.

SLIDE 3L MINE CROSS SECTION

STEAMBOAT SPRINGS

THE DISCHARGE APRON DEPOSITS (IN ORANGE) AND INTERBEDDED MUDSTONES (IN PURPLE) AT BOREALIS WERE DEPOSITED IN MUCH THE SAME MANNER AS THE TERRACE DEPOSITS OF STEAMBOAT SPRINGS, NEVADA, PICTURED IN THE SLIDE ON YOUR LEFT. LAYERS OF OPALINE BRECCIA ALTERNATING WITH WIND-BLOWN MATERIAL COMPRISE THE THICK, SILICEOUS, DISCHARGE APRONS AT STEAMBOAT. INDIVIDUAL SPRING VENT TRENDS AT STEAMBOAT UP TO TEN FEET WIDE AND SEVERAL HUNDRED FEET LONG CUT THE DISCHARGE APRON. FOSSIL SPRING VENTS AT BOREALIS EXHIBIT SIMILAR WIDTHS AND LINEARITY.

BOILING WATERS WITHIN THE PRESENT DAY DISCHARGE APRON AT STEAMBOAT ARE RICH IN SO_2. THE SO_2 OXIDIZES TO SULFURIC ACID IN VAPORS ABOVE THE BOILING WATER TABLE AND CONDENSES ON THE SURROUNDING ROCK. THE TEXTURAL AND MINERALOGIC RESULT OF THIS HOT SPRINGS GENERATED ACID ATTACK IS KNOWN AS "SPONGEROCK" AT BOREALIS.

SLIDE 4L

SPONGEROCK

THE SLIDE ON YOUR LEFT IS CLOSE-UP OF SPONGEROCK. DONALD WHITE DESCRIBES THE SPONGEROCK TEXTURAL TYPE AS THE RESULT OF ACID FLUIDS ABOVE THE WATER TABLE PERCOLATING DOWNWARDS IN A HOT SPRINGS ENVIRONMENT. THE ROCK RELATIONSHIPS AT BOREALIS TEND TO SUPPORT THIS HYPOTHESIS. SPONGEROCK AT BOREALIS IS DEVELOPED WITHIN SILICEOUS APRON DEPOSITS AND PERIPHERAL, INTERBEDDED MUDSTONES. THE NET RESULT OF THE DOWNWARD ACID LEACHING PROCESS HAS BEEN THE SAME FOR BOTH ROCK TYPES: A STRUCTURALLY COMPETENT ROCK WITH POROSITY OFTEN EXCEEDING 50%.

SLIDE 5L

CONTACT

MINE

CROSS SECTION

IN THE CROSS SECTION ON YOUR RIGHT, THE QUARTZ BRECCIA HAS THE SHAPE OF AN INVERTED CONE. ON YOUR LEFT IS A PICTURE OF THE SHALLOW DIPPING, SHARP CONTACT BETWEEN REDDISH QUARTZ BRECCIA AND UNDERLYING SPONGEROCK ON THE UPPER LEVEL, SOUTHEAST SIDE OF THE MAIN OREBODY. THE LITHOLOGY UNDERLYING QUARTZ BRECCIA ON THE NORTHWEST AND EAST SIDES OF THE MAIN OREBODY IS SEDIMENTARY BRECCIA, SHOWN IN WHITE. RECENTLY EXCAVATED PIT WALLS ON THE EAST SIDE OF THE DEPOSIT INDICATE THE SEDIMENTARY BRECCIA IS YOUNGER THAN BOTH THE SPONGEROCK AND THE HOT SPRING DISCHARGE APRON BUT OLDER THAN THE QUARTZ BRECCIA. THE SEDIMENTARY BRECCIA ON THE UPPER LEVELS, EAST SIDE, IS UNCONSOLIDATED AND FRIABLE, TESTIFYING TO A YOUTHFUL AGE FOR ITSELF AND THE QUARTZ BRECCIA. AVAILABLE EVIDENCE INDICATES THE QUARTZ BRECCIA WAS EMPLACED AT THE PALEOSURFACE AT THE END OF HOT SPRINGS DEPOSITION. AN ALUNITE DATE TAKEN BY FRANK KLEINHAMPL OF THE USGS INDICATES THE HOT SPRINGS WERE FORMING FOUR MILLION YEARS AGO. THE QUARTZ BRECCIA WILL BE SLIGHTLY YOUNGER.

BLANK

MINE

CROSS SECTION

HYDROTHERMAL ALTERATION AT BOREALIS IS DIVIDED INTO THE PYRITE AND OXIDE FACIES. THE PYRITE FACIES IS DEVELOPED IN THE UNDERLYING MIOCENE ANDESITES AND CONSISTS OF QUARTZ-PYRITE-ALUNITE, KAOLIN-PYRITE, MONTMORILLONITE-PYRITE, AND CHLORITE-CALCITE WITH PYRITE ON FRACTURES. THE HYDROTHERMAL OXIDE ASSEMBLAGE IS FOUND ABOVE THE REDOX INTERFACE AND CONSISTS OF QUARTZ-BARITE-HEMATITE WITH REMNANT SULFIDES, AND MONTMORILLONITE-HEMATITE. THE QUARTZ-BARITE-HEMATITE-REMNANT SULFIDE ASSEMBLAGE IS FOUND IN THE QUARTZ BRECCIA AND IN SPRING VENTS DEVELOPED IN THE DISCHARGE APRON. THE MONT-MORILLONITE-OXIDE ASSEMBLAGE IS DEVELOPED IN SEDIMENTARY BRECCIA ADJACENT TO, AND DOWN THE PALEO-GROUNDWATER GRADIENT FROM, THE QUARTZ BRECCIA.

SLIDE 6L

QUARTZ BRECCIA

MINE

CROSS SECTION

THE SLIDE ON YOUR LEFT IS A CLOSE-UP OF THE QUARTZ BRECCIA TAKEN FROM THE CENTER OF THE OREBODY. THE BRECCIA MATRIX OWES ITS GRAY COLOR TO ABUNDANT, FINE SULFIDES PRECIPITATED DURING BRECCIA EMPLACEMENT. THE SULFIDE ASSEMBLAGE AT BOREALIS CONSISTS OF INTER-GROWN PYRITE, CHALCOPYRITE, BRAVOITE ($(Fe, Ni)S_2$) AND COBALTITE ((Co, Ni)AsS) AND IS SIMILAR TO THE PYRITE, CHALCOPYRITE, BRAVOITE, AND SIEGENITE ($(CO, Ni)_3S_4$) ASSEMBLAGE DESCRIBED FOR COPPER-BEARING ZONES IN SOME MISSISSIPPI VALLEY DEPOSITS.

HYDROTHERMAL OXIDATION DURING BRECCIA EMPLACEMENT PARTIALLY DESTROYED THE SULFIDES AND PRECIPITATED QUARTZ-BARITE-HEMATITE. BRECCIATION AND SOME ROCK FLOWAGE OF PREVIOUSLY SILICIFIED ROCK WAS ACCOMPLISHED BY SHORT-LIVED, EXPLOSIVE, THERMAL FLUID STREAMING EVENTS. UPON REACHING THE PALEOSURFACE, HYDROTHERMAL FLUIDS OF THE QUARTZ BRECCIA PRECIPITATED SULFIDES CONTAINING PRECIOUS METALS. WEAKER STAGES OF THIS EVENT WERE CHARACTERIZED BY A FLUID THAT OXIDIZED SULFIDE AND MOBILIZED PRECIOUS METALS, COARSENING THE GOLD IN THE QUARTZ BRECCIA AND DEPOSITING A MINOR PORTION OF IT DOWN GRADIENT IN MONTMORILLONITE-HEMATITE ALTERED SEDIMENTARY BRECCIA.

SLIDE 7L

QTZ-BARITE-HEMATITE

MINE

CROSS SECTION

THE SLIDE ON YOUR LEFT IS A CLOSE UP OF A QUARTZ-BARITE-HEMATITE VUG DEVELOPED IN THE CENTER OF THE QUARTZ BRECCIA ORES. THE LARGEST BARITE CRYSTALS ARE 2 MILLIMETERS ACROSS. VERY FINE HEMATITE GRAINS BOTH COAT, AND DISSEMINATE THROUGH, SOME OF THE BARITE CRYSTALS. THIS ASSEMBLAGE IS EVIDENCE OF A LATE HYDROTHERMAL OXIDE EVENT, A MECHANISM THAT MAY HAVE LEACHED THE GOLD FROM SULFIDES AND RAISED THE GRADE WITHIN THE QUARTZ BRECCIA.

SLIDE 8L

MINE GEOLOGY

MINE

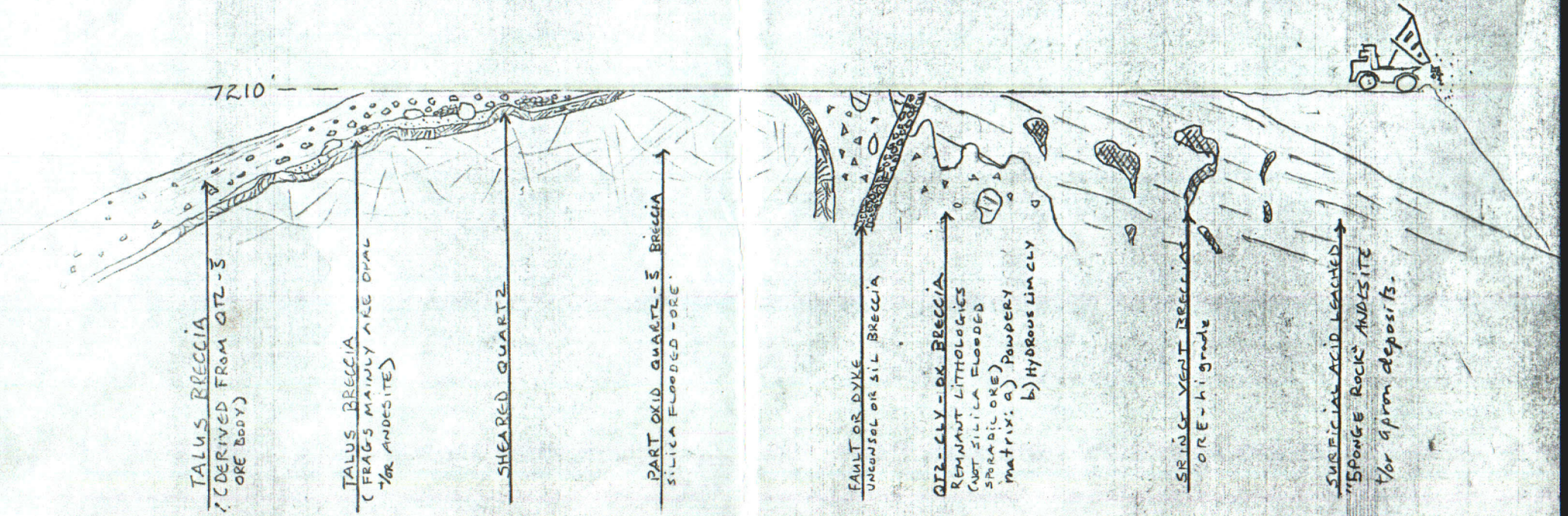
CROSS SECTION

ECONOMIC MINERALIZATION IS FOUND IN TWO ROCK TYPES AT BOREALIS. THE MAIN OREBODY, RESPONSIBLE FOR MOST OF THE PUBLISHED RESERVES, IS HOSTED BY THE QUARTZ BRECCIA. GOLD IN THE QUARTZ BRECCIA OCCURS AS SUB-MICRON GRAINS IN MATRIX SULFIDES AND AS 2 MICRON TO 25 MICRON GRAINS IN THE LATE STAGE QUARTZ-BARITE-HEMATITE ASSEMBLAGE. SUB-SIDIARY ORES ON THE SOUTH SIDE OF THE DEPOSIT ARE IN FOSSIL HOT SPRING VENTS. GOLD IN THE VENT BRECCIAS IS IN LAYERED SULFIDE AND QUARTZ-BARITE-HEMATITE MUDS. SELECTED GRAB SAMPLES OF BOTH THE QUARTZ BRECCIA AND SPRING VENT ORES WILL ASSAY IN EXCESS OF ONE OUNCE GOLD, BUT OVERALL AVERAGE GRADE FOR THE DEPOSIT IS LESS THAN 0.10 OUNCE.

IN CONCLUSION, BOREALIS IS A LATE PLIOCENE GOLD DEPOSIT ON THE MARGIN OF A LARGE STRUCTURAL BASIN OF SIMILAR AGE. THE DEPOSIT IS HOSTED BY A QUARTZ BRECCIA, ADJACENT SEDIMENTS, AND HOT SPRING VENT SEDIMENTS. THE QUARTZ BRECCIA AND ACCOMPANYING ORES WERE EMPLACED AT THE END OF HOT SPRINGS ACTIVITY BY A SHORT-LIVED SERIES OF EXPLOSIVE, FLUID STREAMING EVENTS, MAKING BOREALIS AN ATYPICAL HOT SPRINGS-ASSOCIATED GOLD DEPOSIT.

X-section

LOOKING NORTHEAST



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GENERALIZED GEOLOGY AND INTERPERTATIONS

SCALE: NONE

BY: RFR