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NOTES ON THE GEOLOGY OF THE MONARCH MINE
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STRUCTURE: As has been previously stated, the orebodies lie on the east leg of a gentle anticline, the axis of which strikes approximately N 25° W and dips gently southward, on the north side of Mt. Stephens. Under the top of the mountain it is flat, and gradually turns to a south pitch on the south side of the mountain, making a dome under the crest of the mountain. It is located a little over a half mile west of the mine. (Bearing and location are approximate and subject to some change after more careful work). The average dips of the strata in the east limb are about 14° northeast; the strike is northwest and southeast.

Along the limb of the main anticline there are a number of minor anticlines and synclines, or wrinkles, which are parallel to its main axis.

Some three thousand feet east of the mine the Cathedral fault occurs, striking about parallel to the axis of the folding and to the known orebodies. The west side of the fault, containing the Monarch mine, has dropped some three thousand feet, relative to the east side. A number of fissures observable on the surface, are approximately parallel to the fault and the anticline, while a second series are approximately at right angles to them.

WRINKLES: Several wrinkles on the east limb of the anticline are definitely known, (1) At the East Monarch orebody, (2) 350 feet southwesterly from the East Monarch (3) At the West Monarch orebody, (4) 350 feet (estimated) southwest from the West Monarch orebody, (5) Twelve or fifteen hundred feet (estimated) west of the West Monarch.

Number (1) quite definitely forms a trough under the East Monarch orebody, which may be seen from the Kicking Horse side, and is well exposed in the recent southerly workings on the orebody underneath the stope and in the #102E raise. Number (2) shows on the surface and in the Main Incline between the two orebodies. It is essentially a steep up-roll westward, with a slight flattening on top. Number (3) occurs under the West Monarch orebody, and troughing is evident on the surface and especially in the Production Drift, although the exact shape of the fold is not exposed by the present workings. Number (4) shows a slight troughing when viewed from the Kicking Horse side; above it is apparently strongly brecciated, iron-stained rock. It is in an inaccessible position. Its position corresponds well with that of the main Kicking Horse orebody and the flattening (not troughing) of the strata there.

Number (5) is also inaccessible and rather indefinite. It is accompanied by a strong fissure which appears to extend to the north side of the valley. Nos. 1, 2, 3, and 5 do not definitely show on the north side of the river.

The projected position of Numbers 1 and 2 are under talus, but Number 3 should appear about at the diamond-drill station east of the No. 1 tunnel if it extends that far. It is not evident there.

FISSURING: Much of the fissuring, surface and underground, falls roughly into two systems nearly at right angles to each other. One system strikes S 15° to 35° E, about parallel to the orebodies and the main structures; the dip is steeply eastward. The cross-fissures strike S65° to 85° W and are vertical, or dip slightly northward.

There are occasional other fissures of random dip and strike. There are also seams, or parting planes, which are discernable throughout both the East and West Monarch workings, which strike from S 10° to 20° W and dip from 75° to 80° west. These seams have in general the appearance of joints, although it is difficult to explain the presence of joints in a brecciated mass, unless they formed after the brecciation had healed. There are also widespread traces of similar seams or partings approximately S 35° E. In general, surface fissures have similar trends. So far as observed there is no faulting on any of the fissures. Most of them, at least, are pre-mineral, although some have been opened in post-mineral time. Near the surface they are much more easily distinguished than further underground, since they are more open and more oxidised. At a distance underground, they are more or less obscured by the mineralization, but all of them which are strong enough to show in the underlying dolomite (so far as development in the dolomite has gone), have been first found within the orebody. Typically, the fissures close to, or in the edge of, the orebody show small seams of calcite, traces of iron oxides, and vugs or solution cavities; in the orebody, in predominantly zinc ore, the appearance is about the same but weaker; in predominantly lead ore they are sometimes indistinguishable, - sometimes represented by a white hairline seam. There is frequently also ~~an unusual~~ amount of calcite along the course of the fracture which breaks a little differently from the remainder of the ground and has a knobby appearance on the side of the drift.

In the East Monarch workings there are a number of small fissures, or enlarged joints, which run longitudinally to the orebody, but show little if at all in the dolomite. They appear more like shear-zones (without a shearing movement) than definite fissures. On the east side of the East Monarch #103 Stope, similar seams are fairly prominent, striking S 5° to 10° W. The cross-fissures are more definite and clear cut.

BRECCIATION: A zone of strong brecciation emerges from under the talus at the edge of the cliffs along the trail to the mine and follows through the East and West Monarch workings, and beyond to the Westward along the face of inaccessible cliffs. It is some three hundred feet in thickness and follows along the base of the Cathedral limestones (immediately on top of the dolomite) up to some four hundred feet west of the West Monarch orebody, and then diverges from the contact upward at an angle of fifteen or twenty degrees.

On the north side of the River about 1200 feet (estimated) northeast of the Kicking Horse Camp, the breccia zone emerges from under the talus in a very weakened condition, with large coarse fragments and the original bedding planes easily discernable; immediately on top of the dolomite there is scarcely any brecciation. Within a few hundred feet to the westward it again passes under the talus, emerging directly north of the Kicking Horse camp, still rather weak, and extends through the No. 1, 2, and 3 tunnel workings fairly strong. Just before reaching No. 4 tunnel it begins to diverge from the dolomite contact, passing into higher strata and becoming lost.

Underground, strong brecciation usually accompanies the ore, but occasionally ore occurs in comparatively weak, coarse brecciation. Ore also sometimes quits while the same degree of brecciation continues outside of the orebody. In various places, both on the margins of the orebody and within it, brecciated fragments which have been healed by calcite have acted as a unit in resisting replacement by ore. Apparently the dolomite, being soft and elastic as compared to the limestone above, has bent rather than fractured during the stresses that caused the brecciation in the limestone. Unbrecciated limestone a few feet above the dolomite is exceptionally hard and shows numerous thin bands of darker color; the two color fragments in much of the breccia is evidently derived from this.

ORE: The ore consists of galena and sphalerite with pyrite replacing limestone and filling fractures. A few spots of quartz have been noted, associated with sphalerite, in #207 Drift.

There is also some unknown black mineral, or association of minerals, which occurs in hair-line seams in and near the ore.

Sphalerite occurs largely as a replacement of limestone fragments, and to a limited extent in fractures and around the margins of fragments. It is accompanied by a little pyrite and a little calcite; it is essentially free from galena, except that it may border on galena.

Galena occurs, rather coarsely crystallized, intergrown with calcite and largely appearing to fill open fractures. If it has replaced limestone fragments at all, the replacement must have been complete since no fragments of partly replaced limestone were found. It occupies spaces between replacement-sphalerite fragments, between barren limestone fragments, etc. It is occasionally accompanied by small amounts of fine pyrite and sphalerite.

Pyrite occurs in minute grains throughout the whole brecciated area, in greater concentration it borders the orebody at some points, and is lacking in others, in irregular pockets in calcite, and occasionally closely associated with the galena; it is rarely in close association with sphalerite, though often close to it.

Calcite has apparently deposited from the time of the first brecciation up to the present.

GALENA IN DOLOMITE: Small amounts of galena have been found at a number of points in the dolomite, although never in commercial quantity. It usually occurs on or near fissures and between the edges of the bedding planes where they have been dragged apart. There appears to have been very little replacement of the rock. The typical occurrence is a thin layer of pyrite on the rock, followed by calcite, and then coarsely crystalline galena.

In a short tunnel below, and east of, the powder magazine galena is associated with a flat fissure and a quartz stringer. Widely scattered galena occurs in the East Monarch production drift, but none has yet been found in the West Monarch production drift.

ORE IN #206 and #207 DRIFTS: In the first sixty feet of #206 drift nothing out of the ordinary was noted. Zinc ore extends well up to or into the back of the drift except close to the raise where the back is barren. There is very little lead except in the lower one third of the drift. S 15° E joints are plain and frequent. From 60 to 85 feet the ore has raised, but there is still little lead near the back. The brecciation is good in places and poor and coarse in places, and there are occasional traces of nearly horizontal bedding planes. The first fissure of importance is cut at 85 feet and the broken zone extends to 105 feet (to the south edge of the crosscuts). It consists of a ½" seam of iron-stained calcite, followed by less definite calcite seams, and an excess of calcite in differently brecciated ground. Ore continues throughout this area, but becomes more and more zincy to the south, and much more pyrite appears in the back of the drift. The top of the ore seems to be dropping down to the southward, and stops at the last, very faint, east-west seam above the floor of the drift. A drill hole shows that the ore crosses the seam below the floor of the drift, but it has only been traced a few feet. The faces of both crosscuts (#235 and #236) show white, coarsely crystalline limestone which is normally just above the ore. The brecciation in the west face is fairly good. From 105 feet to 165 feet there is no ore. The N 20° E seams are rather prominent, and similar seams S 35° E also show weakly, and there are traces of oxidation throughout. The brecciation is generally fair. From 165 feet to 305 feet (at the raise) ore is continuous and good. Ore comes in at 165 feet along an irregular line which has a general pitch of 65° North. The drift is probably close to the east edge of the orebody, and barren rock shows at intervals along the east bottom edge of the drift, showing traces of bedding planes dipping about 6° northward. The bottom of the ore is encountered in the drift at 25 feet from the raise. The brecciation through this section is fair to good.

No. 207 drift starts in the top of the orebody at the raise and runs along the east edge of it to 85 feet, where the ore ends. Ore shows in the east bottom of the drift for a short distance near the raise, and then barren rock to 65 feet; from there to 85 feet there is a little ore on the side. Strong pyrite often borders the ore on the east and top sides. On the west side of the drift the top of the ore has a wavy appearance nearly to the crosscut, where it passes into the back. In the crosscut ore stops along an irregular line having, on the whole, a steep westerly dip. South of the crosscut ore shows on the west wall of the drift for fifteen feet; it appears to pass out of the drift along a S 20° W seam.

On the east side of the drift at 85 feet the ore comes to a point along a S 20° W seam. Throughout the drift the N 20° E seams are exceptionally prominent and are close together; the S 35° E seams show weakly. The ore has a tendency to follow the N 20° E seams but along the edges keeps breaking back; in detail the boundary of the ore is therefore a scalloped line, while in general the usual course of the orebody is maintained. The brecciation is somewhat variable and in places in the ore is rather coarse; off the ore it has a tendency to be rather poor. There is a slight tendency toward an unusual amount of calcite above the ore. From 85 to 125 feet the drift is barren and the brecciation coarse; the N 20° E seams are quite noticeable. From 125 to 135 feet there is a fissured zone with fairly definite slips on the boundaries which show slight oxidation. Between them there is much calcite and the breccia fragments are far apart. Ore starts where the first slip cuts the east wall of the drift and runs to a point in the drift near the second slip; it does not extend to the bottom of the drift. It is bordered by strong pyrite to the north of the first slip. From 135 to 180 feet the ground is entirely barren; the brecciation is variable, but in places strong. At 180 feet a point of zinc ore begins in the middle of the drift and quickly widens to about drift size. It extends to 210 feet where it narrows and pinches out; it extends a little further in the top than in the bottom of the drift. Practically no lead shows in this lense of ore. The first quartz in the mine was found here in contact with zinc. Throughout the lense there are traces of a S 15° E fracture standing vertically. The face has never showed any slip or definite fracture but there was a continuous vertical arrangement of calcite and breccia fragments, and zinc has tended to be stronger along it. This is the second longitudinal fracture to be found in the WestMonarch workings, the first being the prominent slip along the west side of the stope. The two line up fairly well, but it is not safe to draw any conclusions from the fracture in #207 as it is too indefinite. It is, however, an interesting occurrence and may have some meaning.

<u>DEDUCTIONS DRAWN</u>:

WRINKLES: The two Monarch orebodies lie a few feet above distinct synclinal troughs, and the Kicking Horse orebody is above a distinct flattening , though not a trough.

It does not necessarily follow that where there is a trough there will be ore, and it is known that such is the case. However, a synclinal trough may safely be taken as a guide in extending known orebodies, and as a requisite condition to exploration for new ones. The theoretical reason for this is that the troughs (formed by a small adjacent syncline and anticline) are on lines of deformation of the strata, and therefore of moreintense brecciation than the average, forming more open channels for the ore solutions and less rapid circulation, giving more time for deposition of the metals.

The failure of either the East or West Monarch synclines to show on the Kicking Horse side near their projected position, when taken in conjunction with the poorly brecciated, unmineralized rocks, is discouraging and strongly indicates that the Monarch orebodies did not extend that far. It is a reasonable presumption that the Kicking Horse orebody may prove to be the same as the yet unproven orebody some three or four hundred feet west of the West Monarch.

FISSURING: It has generally been considered by geologists and miners that there was a close connection between the fissuring and the origin of the ore, and that the intersection of fissures was an extremely favorable place to find ore. From analogy with other mines in limestone such an assumption is entirely warranted, and it is possible that some evidence has been found locally which bears out such an assumption. However, in the East and West Monarch I have been unable to prove any connection whatever between the fissuring and the ore, and there are no strong indications of any. The fissures are certainly pre-mineral (with occasional slight re-opening) and are essentially without faulting, - perhaps somewhat in the nature of gigantic joints,- and it seems very doubtful if they extend to any great depth. Along the fissures themselves the ore is sometimes enriched, sometimes impoverished, and there is no evidence of a decrease in the metal content in the ore midway between fissures; neither is there any evidence either in the orebody, in the underlying barren dolomite, or in the overlying barren limestone, that they have acted as ore channels. Only one definite fissure longitudinal to the West Monarch orebody has been found; it borders the west edge of the orebody. In places the ore crosses it for a few feet, in others it fails to reach it by a few feet; this fissure has not been opened except along the edge of the orebody.

BRECCIATION: Fairly strong brecciation, though not nedessarily the most intense, seems to be necessary for the formation of ore. It does not follow, however, that ore always occurs where there is intense brecciation, since such brecciation without ore is known at a number of places, both in boulders of healed breccia within the orebody, on the margins of orebodies, and at some distance from known ore. It is evident that some factor besides the extent of brecciation governs the deposition of ore, since ore sometimes quits abruptly in the middle of an area of strong brecciation. The presence of brecciated fragments, healed by calcite and acting as a unit against ore deposition, which are frequently included in the orebody; the presence of highly brecciated barren points, healed by calcite and sometimes of considerable size, projecting into the orebody; and the sudden and sometimes sharply defined stopping of ore in a highly brecciated zone, are extremely difficult to explain except on the hypothesis of two stages of brecciation, of which the first was healed by barren calcite and the second by ore. It is also rather evident that some of the zinc ore has been brecciated and the interstices filled by calcite and galena, from which a third period of brecciation is predicated. While three stages of brecciation are not proven, nor indicated by indisputable evidence, yet I believe there is a very strong probability that there have been three stages, and that they have had an extremely important, - perhaps a governing effect, - in controling the location of the orebodies.

ORE: It may be considered as certain that calcite and pyrite have deposited throughout the whole range of the mineralization, although not always to the same extent.

Sphalerite and galena were largely deposited separately but apparently overlapped a little; the sphalerite deposition was first. The Zonal theory under which sphalerite tends to deposit lower down than galena, i.e., under conditions of greater temperature and pressure, seems to be inapplicable to the Monarch Mine.

The occurrence of an excess of zinc at the top of the orebodies is evidently not due to differences of temperature and pressure, since the range in elevation is too small; also the sphalerite and galena deposition were not in general concurrent.

GALENA IN DOLOMITE: No definite deductions can be made from these occurrences except that it is evident that the dolomite did not brecciate easily, nor was it easily replaced. The most reasonable hypothesis of the formation of the dolomite ore would seem to be that primary solutions of the galena stage of deposition had leaked downward from the brecciated areas in the overlying limestones and deposited their galena in open crevices. No zinc is known in the dolomite.

ORE IN #206 and #207 DRIFTS: All indications point to the West Monarch orebody narrowing east and west and gradually pinching out to the southward in a wedge shape. The ridh ore found in #204, #205, and #206 would then be accounted for on the hypothesis that the ore solutions were comparatively stagnant and more time was afforded for complete precipitation. There is a fair possibility that the break in the ore in #206 drift is more apparent than real and that there may be a dip in the orebody which has carried it below the level of the drift, to rise again further on. It seems probable that at least some connection between the orebodies will be found during the course of stoping, although it may or may not be ore of commercial size or grade.

There is extremely little data available that has any bearing on the probability of finding ore again further to the southward. It is not known whether the synclinal trough is still continuing strong or if it has faded out. The surface can hardly give any information of value. The brecciation at the present face is very poor, but whether this is a local condition only, or widespread to the southward, cannot be foretold.

Analogy with other limestone orebodies would encourage the expectation of again finding sizable orebodies if the proper course is kept, and it is possible that the faint S 15° E seam that is following along the drift may be of considerable significance in indicating the direction of further ore, if it can be followed.

SOURCE OF ORE-SOLUTIONS: Nothing was observed which seems to have a definite bearing on this question; what little data might bear on it slightly is of a negative nature. This subject was touched upon under (1) "Fissuring" and it was concluded that there was absolutely no evidence that mineralizing solutions had come through the fissures, except from analogy with some other deposits. Other conceivable ways in which the solutions might have arrived are (2)longitudinally upward along the wrinkles and through the brecciated zone in a southerly direction, or (3) upward through the brecciated zone and across the wrinkles in a westerly direction.

If the solutions came upward <u>along</u> the wrinkles, it would require explaning how they passed through comparatively unbrecciated rock below where the wrinkles fade out (as on the Kicking Horse side, in line with the two Monarch orebodies). It would also assume a source in igneous rocks presumed to be in depth near marbles in Yoho Valley. If the solutions rose <u>across</u> the wrinkles, more or less in the same way as a river finds its way through a delta, there would hardly be as many difficulties to explain away. The brecciation might be expected to be, if anything, more intense to the eastward (down toward the Cathedral fault) and to connect with the highly fissured and brecciated plane of the fault itself, which undoubtedly extends to great depth, and might reasonably be presumed to extend to a hypothetical source in underlying igneous rocks. It has already been suggested by an eminent geologist that the doming of the strata under Mt. Stephens might be due to a batholith below.

To me, this (3) seems to be the most reasonable hypothesis for the formation of the orebodies, and it is the most favorable one for the finding of further large orebodies south of the present faces.

SUMMARY AND CONCLUSION: The summary of the deductions outlined above may be tabulated somewhat as follows, which seems to be a logical hypothesis to explain observed conditions:

1. Folding - with regional brecciation in the more brittle beds, and partial healing with calcite and a little pyrite.

2. Cathedral Fault began - with strong brecciation and crushing somewhat localized.

3. Mineralization, 1st stage - essentially a zinc deposition, with a little calcite and pyrite.

4. Cathedral fault continued - with strong brecciation largely in areas weakened by (2)

5. Mineralization, 2nd stage - essentially a lead deposition with strong calcite and a little pyrite and zinc. Probably lower temperatures than in (3).

I consider the chances of finding further important ore south of the present faces as distinctly good provided the synclinal troughs continue strong, and poor if they do not. It necessitates development to determine this point, but not to any prohibitive extent. The proven presence of the continuation of a strong trough under barren ground would direct and encourage the exploration for new ore.

Theoretical reasoning would suggest the probability that the area around the apex of the dome under Mt. Stephens should be favorable ground.

If any given wrinkle flattens out and disappears it seems probable that others might be expected to form a short distance away en echelon.

I consider the chances of encountering a new orebody within some fourhundred feet southwest of the West Monarch to be fairly good, and well worth the cost of exploration.

Respectfully submitted,

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