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Geology and Ore Deposits

of the

Sandon Area, Slocan Mining Camp, British Columbia

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SUMMARY

Sandon has been a centre of production of silver-lead-zinc ores for sixty years. Mines in the Sandon area have contributed approximately half the entire output of silver and lead of the Slocan Mining Division. Mining activity has fluctuated widely with the condition of the metal market, and interest in the area has been renewed with the most recent rise in prices.

The area is 2 miles north of the northern boundary of the Nelson batholith and is underlain by sediments of the Slocan series, intruded by dykes and small stocks.

The Slocan series is of great thickness, only part of which is exposed within the Sandon area. In the area, tuff occurs in the upper part of the geologic column. The sediments are mainly argillites, quartzites, and limestones, or intimate admixtures of these rock types. For the most part the sediments are silty, estuarine deposits with rapid alternations in character; some are rhythmically banded. Cross-bedding and evidence of turbulent deposition are common in many parts of the geologic column. The rocks are locally slaty.

Intrusive bodies are for the most part sill-like and some stocks are elongated with the structure. The general rock type is a quartz diorite, with a highly variable texture. Lamprophyres of the same general composition, but relatively rich in biotite, are common and grade into the quartz diorites.

Metamorphism of contact type is not marked. The principal product, which occurs locally, is a brownish rock produced by the development of biotite in some of the argillite. Silicification is widespread, affecting the rocks patchily and chiefly in the southern and western parts of the area. The rock most affected is limestone, which may be converted to a product very similar in appearance to quartzite. Silicification is not related to the lodes but to the general process of intrusion, and is only locally related to specific dykes or sills.

The structure is of a type not heretofore described. It is more Alpine than has previously been recognized in British Columbia and has far-reaching regional implications, although the implications are not considered in this bulletin. Certain details of the structure are believed to be closely related to the emplacement of the Nelson batholith but, as time has prevented study of the batholith itself, the relationship has not been proved.

The folding of the Slocan sediments is of recumbent type, the individual folds having axial planes with little or no dip and axial lines with little or no plunge. The entire assemblage is involved in one huge recumbent fold, striking northwesterly, which is open or concave to the southwest. This is termed the Slocan fold, and includes many smaller folds of various sizes and degrees of complexity.

The large complex Slocan fold is wrapped round the northeastern end of the Nelson batholith, east of the Sandon area. South of the area, and also east of it, the rocks deviate markedly from the northwesterly strike along the general east-west course of the batholith. The folded rocks swing through a right angle in strike in a huge crumple that is termed down buckling, and ultimately meet the batholith tangentially. This folding of folded rocks is a modification of the Slocan fold structure, and there is no

evidence that it was produced by a second period or separate generation of orogeny; rather, it is believed to have resulted from a progressive change in stress application during late stages of the Slocan folding. A further modification of the Slocan fold is a broad cross-warp that extends across the entire structure from the vicinity of Idaho Peak to the vicinity of Retallack. The cross-warp is anticlinal, with low regional plunges to northwest and southeast on either side of it. It extends through the main productive belt of the Slocan mining camp.

Dragfolds of all sizes are developed in characteristic relation to the large folds. The geometry of recumbent folding is such that all upper beds have moved relatively downward, the reverse of the movement observed in upright folds. Cleavage is developed locally, and in the main Whitewater and Payne slate belts it is produced at least in part by excessive interbed slippage which amounts to shearing. Axial-plane cleavage and shear cleavage cannot be differentiated except by structural reference, and some cleavage is of dual origin.

There are many faults, all of which are related to the structural complex and the forces which produced it. Two general classes of faults are recognized: tangential and crosscutting. The tangential faults are parallel in strike to the formation and commonly are bedded. The crosscutting faults cross the regional strike at large angles. The two classes are closely related in time of origin. All faults appear to be normal, and most have a lateral as well as a normal component of movement. The displacement on the tangential faults is a consequence of the folding and bears the same relative movement as the interbed slippage of which the faults are, in a sense, an extreme expression. The crosscutting faults are tear faults with a component of underthrusting.

The lodes are almost without exception crosscutting faults, of small and large size. In the Sandon area they cut across the structure but, immediately to the south in the valley of Silverton Creek, they are tangential to the down-buckled strata. It is believed that the larger faults of this class originated parallel with the down-buckled rocks as an extreme of this late phase of folding and in partial relief of the stresses that produced it. The larger faults or lodes stemmed from a focal area in lower Silverton Creek with steep dips to the northwest, rolled with the down buckle to a southeasterly dip and, in the zone of maximum curvature, continued across the northwesterly striking rocks.

Most of the lodes are complex, inasmuch as they represent zones of rupture with more than one locus of movement. They are to a considerable extent influenced by the structure they cross, in both strike and dip. They are zones of both fracture and shear.

Orebodies are related to zones of fracture rather than of shearing and as a rule occur in places of decreased confining pressure. The factors which may be said to have controlled ore deposition are many, and most orebodies were formed as a result of the conjunction of a number of favourable circumstances.

Metal distribution within the area and within individual lodes is of great importance. Factors which might limit the occurrence of ore at depth and which might produce lateral or vertical segregation are vital to considerations of development. No marked pattern of zoning or segregation is recognized, except for the fact that the margins of orebodies are relatively richer in zinc than in lead. The control of ore deposition is structural, and temperature and load pressure due to depth are of minor importance. The most important single factor was probably that of local confining pressure in a structurally complex environment.

Plate I. Looking down upper Carpenter Creek valley; Sandon is at the mouth of Sandon Creek, in mid-distance; Cody Creek valley in left foreground. The single fir-tree points to Adams Peak.

Plate II. Sandon, 1947. Carpenter Creek flows through a covered flume under the main street.

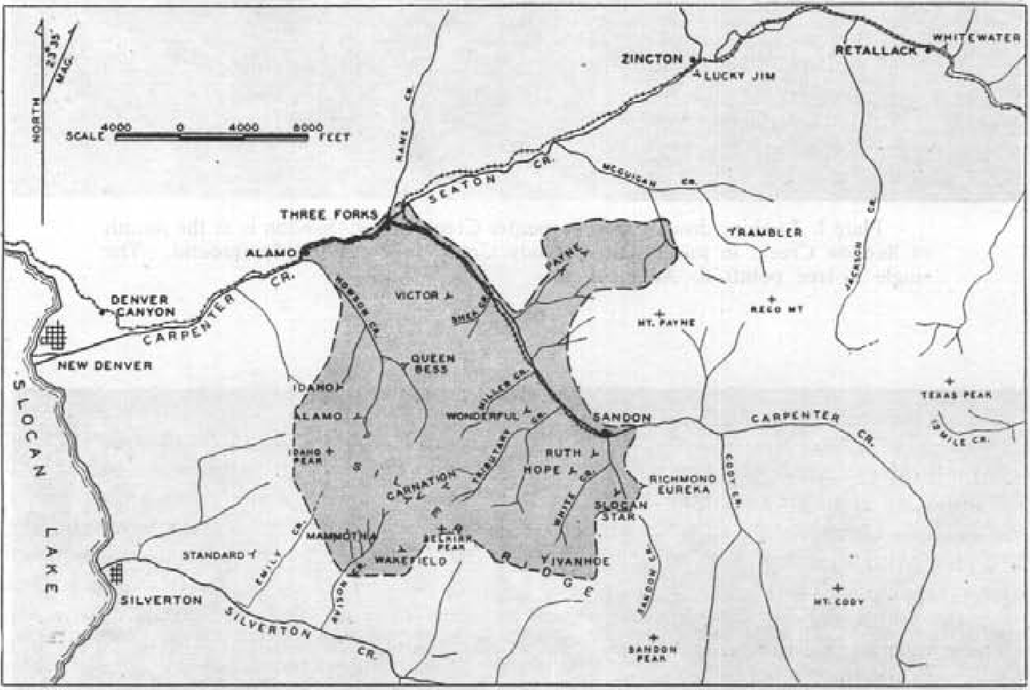

Fig. 1. Part of Slocan mining camp. Sandon area shaded.

CHAPTER I.—INTRODUCTION

Sandon is a small mining settlement in the Slocan Mining Division. It is situated in the Selkirk Mountains 6 miles east of Slocan Lake, 9 miles by road from New Denver.

The Sandon area as outlined in this bulletin (Fig. 1) comprises about 10 square miles southwest of Carpenter Creek, between Sandon and Three Forks, and an additional 1½ square miles northeast of Carpenter Creek. It includes many well-known mining properties, the more productive of which have been the Silversmith-Slocan Star, Ruth-Hope, Ivanhoe, Mammoth, Queen Bess, Payne, Wonderful, and Idaho-Alamo. The Standard mine is about 1 mile southwest of the area.

The total value of metal production from the Sandon area, combined with that from the nearby Standard mine, is roughly half the value of metal production from the entire Slocan Mining Division.

The area has a maximum relief of about 5,000 feet, from Alamo Siding on Carpenter Creek to Selkirk Peak, elevation about 7,650 feet. Slopes are precipitous at many points along Silver Ridge, which forms the height of land between the drainage basins of Carpenter and Silverton Creeks. Slopes of 30 degrees average inclination are common, and some are greater than 35 degrees. Most of the region can, however, be scaled, with the chief exception of bluffs on the north face of Selkirk Peak. Timber cover is heavy, mostly second growth or alpine, although much of the ground in the angle between Howson and Carpenter Creeks and on the slopes of Payne Mountain has not fully recovered from early forest fires and is thickly overgrown with brush. Few remnants of the original forest remain except in the alpine sections. Growth includes fir, hemlock, cedar, balsam, spruce, and tamarack, and brush consists of alder and willow at lower elevations and snowbrush and huckleberry at higher elevations.

The precipitation is heavy, and snow is a severe winter handicap. Snowslides are common during winter and spring months. June is commonly a wet and rather cold month, and snow can be expected to return to the summits in early October. The working season on the surface at higher elevations is short.

The area is served by a line of the Canadian Pacific Railway which runs between Nakusp on Upper Arrow Lake and Kaslo on Kootenay Lake. A branch extends from Three Forks to Sandon. The Kaslo–New Denver auto road passes through Three Forks, 4 miles by road from Sandon. The area is well served by mine roads, some of the extensions of which are in poor repair. In 1950 all roads were passable by auto from Sandon with the exception of that to the upper Ruth and Hope workings, which was passable by jeep. The road up Howson Creek was open as far as the Queen Bess. On the south slope a steep one-way road extends from the Standard to the Mammoth. There were at one time many trails, most of which can still be used, although some have not been brushed out for years.

HISTORY

Sandon is centrally situated in the most productive part of the Slocan silver-lead-zinc camp. Founded in 1892, it grew to be a headquarters and an outfitting point for a score of mines and many prospects, and was a thriving and lively community. Now, only about a dozen people live there permanently, and staffs and crews of current operations are quartered in the old buildings. J. M. Harris, who maintains the only hotel and store and supplies water and electricity to the community, has been a resident of Sandon since 1892.

The history of the Slocan camp is one of initial rapid growth and of subsequent booms and recessions reflecting the market price of silver, lead, and zinc. The first claim recorded was the Payne, located on September 9th, 1891, and before the end of the year some eighty locations were made in the district at large, including several in the vicinity of Sandon. The following year 750 locations were made, sixteen properties were in operation, and shipments were made by pack-horse from six properties, including the Freddie Lee, east of Sandon. The earliest locations were made under the Apex law, which provided a claim 600 feet by 1,500 feet, with extralateral rights, but this law was repealed in April, 1892.

In 1895 the Kaslo and Slocan narrow-gauge railway was completed between Kaslo and Cody, 1½ miles east of Sandon. The Canadian Pacific Railway started building from Nakusp in 1893, reached Three Forks in 1894, and later extended the line to Sandon. By the end of 1895 a total of thirty-five properties had shipped crude ore to American smelters, and the first concentrator was in operation, a semi-custom mill at Alamo. This was a time of rapid growth in the Kootenays in general, when there was a great influx of people, including many first-class prospectors. The Hall Mines smelter at Nelson and the smelter at Trail were blown in a month apart, in 1896. Both were copper smelters which soon installed lead furnaces and solicited custom ores.

It is a tribute to the early prospectors to record that in the general vicinity of Sandon most of the productive lodes were discovered before the end of 1892, and that relatively few discoveries have been made in the succeeding years.

Production increased, with some recessions, until an all-time peak was reached in 1918. Since then activity has been renewed with every rise in metal prices, but production has never equalled the 1918 figure. The most recent rise in metal prices started in 1946. At first this rise did not result in much increase in production, and because of high costs and general uncertainties in the post-war years little active interest was shown in exploration. The activities of lessees did increase, materially, with the unprecedented high prices of lead and zinc, and most of the readily available remnants of ore were extracted from many old properties.

Plate III. Part of the Sandon area as seen from the Payne No. 15 level. Valleys of Tributary Creek on left head below Adams and Selkirk Peaks, and valley of Shea Creek on right is in line with Idaho Peak. Lone Batchelor dumps on right. Silver Ridge forms the skyline.

Advances in metallurgy have greatly affected the camp. In the earliest years sphalerite was of no value and was regarded as gangue material. The first shipment of zinc ore was made in 1901 from the Bell and was soon followed by others from other properties. The first zinc concentrates were produced at the Payne in 1903 and at the Whitewater in 1904, but it was not until 1911 or 1912 that the production of both lead and zinc concentrates became the rule rather than the exception. In the early 1920's selective flotation was developed to the stage that greatly improved separation of sphalerite and galena could be made. Thus it became possible from most lead-zinc ores to recover most of the lead in a lead concentrate and at the same time to recover most of the zinc in a zinc concentrate. The grade of the flotation zinc concentrate was generally much better than could be made by gravity concentration, and the over-all recovery of silver, lead, and zinc was much better. The smelter rates were generally more favourable as the grade of zinc concentrate increased. Before the adoption of flotation milling much zinc was wasted. Penalties attached by the smelters to shipments of mixed lead-zinc ore have changed but have always been present to some degree. Establishment at Trail of a custom concentrating plant in 1925 made the shipping of mixed ores more profitable, but the plant was closed in 1930. Until recently the shipper received nothing for the zinc contained in an ore sent to a lead smelter, but now 50 per cent of the zinc content is paid for. Zinc ore shipped to the zinc plant must be of a grade seldom attained by hand cobbing.

More recent exploratory activity includes that of Silver Ridge Mining Company Limited from 1937 to the present, with a wartime cessation of activity. Kelowna Exploration Company Limited undertook a geological examination of the Payne and Washington groups from 1940 to 1942 and in 1946 acquired a large holding south of Sandon. On this latter ground an extensive geological examination was made which culminated in exploration on the Carnation lode in 1949. Violamac Mines (B.C.) Limited acquired the Victor property in 1948 and made the mine a steady producer. Work at the Mammoth stopped in 1944 when the orebody was mined out above No. 7 level, but a programme of deeper development started in 1948. Examination of the Queen Bess group by Bralorne Mines Limited and Kelowna Exploration Company Limited started in 1949.

In 1947 mining and milling of the Whitewater mine dumps commenced at Retallack, and in the following year custom ore from several properties was also treated. In 1950 Kootenay Belle Gold Mines Limited installed a sink-float plant in the Retallack mill to facilitate treatment of dump material. In 1951 the same company acquired several properties in the Sandon area and installed a second sink-float plant below the Richmond-Eureka dumps, the sink product being hauled to Retallack for further concentration.

PRODUCTION

Production figures of tonnage for the properties in the Sandon area are not quite correct, because in the earliest years of operation of some mills the proper distinction was not everywhere made between quantity of ore milled and quantity of concentrates shipped. Metal production figures are correct, inasmuch as they show the actual content of ores and concentrates by smelter settlement, as recorded by the British Columbia Department of Mines. Prior to 1925 gross metal content of ores and concentrates was recorded, and in 1925 and subsequent years the net metal content was recorded after deducting calculated smelter losses.

The following figures were obtained from the official records. From 1893 to 1950, inclusive, the mines in the Sandon area produced about 900,000 tons, containing 3,148 ounces of gold, 25,257,486 ounces of silver, 221,810,746 pounds of lead, and 44,825,365 pounds of zinc.

Production was from thirty-six properties, of which nine contributed 96 per cent of the tonnage.

By way of comparison, the entire Slocan Mining Division, from 1892 to 1950, produced 55,121,159 ounces of silver, 423,585,479 pounds of lead, and 307,991,427 pounds of zinc. It will be seen that the Sandon area contributed, approximately, 46 per cent of the silver, 52 per cent of the lead, and 14 per cent of the zinc of the division, the zinc produced at Zincton overshadowing that from all other sources.

The gross value has not been calculated. Unit metal prices have fluctuated widely but, as higher prices favoured production, the average unit price obtained for the quantities given was above the average for the period.

In comparison with current practice the zinc recovery throughout the life of the area has been low, owing to wastage in milling and to deliberate discarding of sphalerite.

It is probable that, were the ore represented mined under present-day milling and smelting practice, the zinc recovery would approximately equal that of the lead. In other words, the loss of zinc in tailings, on the dumps, or left in the mines may have been as much as 175,000,000 pounds. Recovery of some of this material from the dumps is now being undertaken. Retreatment of part of the tailings from the Standard mill at Silverton was effected from 1940 to 1942.

PREVIOUS WORK

The first geological work in the camp was done in 1894 and 1895 by R. G. McConnell, who incorporated his results in the West Kootenay Sheet issued in 1904. The Provincial Mineralogist, W. A. Carlyle, published the first technical account of the camp in 1896. The Zinc Commission published a lengthy report in 1906 containing many property descriptions. O. E. Leroy, commencing in 1908, made repeated visits to the camp, and his work was carried on by C. W. Drysdale. M. F. Bancroft made further investigations in 1917 and in 1919. C. E. Cairnes spent from 1925 to 1928 in geological mapping and in making property examinations in the Slocan camp. His report, published in two volumes, is the definitive work on the Slocan and contains a wealth of detailed observations that cannot be duplicated.

Plate IV. Sandon, 1947.

Geological work by private interests has not been extensive until comparatively recent years. One of the first serious attempts in the Sandon area to map mine workings in detail was that of J. J. O'Neil in the Ruth-Hope mine in 1927. In 1940 and 1941 Evans B. Mayo, for Kelowna Exploration Company Limited and under the direction of Paul Billingsley, mapped the Payne and Washington mines and a considerable portion of the ridge of Payne Mountain. Kelowna Exploration, starting in 1946, have carried out a campaign of extremely detailed geological investigation on holdings south of Sandon; since 1947 this work was under the active direction of Dr. Mayo and the general supervision of Mr. Billingsley. In 1949 the work was extended to cover the Queen Bess group.

Previous work by the writer includes a study of the Whitewater and Lucky Jim mine areas in 1944 and 1945, and property examinations in the camp at large.

The present bulletin is the result of field work done from 1946 to 1950. In this work the writer was assisted, in 1947 and 1948, by A. B. Irwin, who studied particularly the region of upper Howson Creek in connection with a Ph.D. thesis at McGill University. Other assistants included J. M. Black, M. C. Robinson, D. H. James, P. W. Richardson, and J. D. Paton.

The writer gratefully acknowledges assistance and information generously given him by many individuals, notably Paul Billingsley, Evans B. Mayo, J. W. Ambrose, R. H. Stewart, R. A. Grimes, A. M. Ham, R. A. Avison, and many others. In particular, it has been a great privilege to work in parallel and in complete harmony with Messrs. Billingsley and Mayo, whose ideas have contributed much to this work.

The Department of Mines has continued the work south of Silver Ridge down to and across Silverton Creek, under the direction of M. C. Robinson. This work, started in 1949, was almost completed in 1950 and will form the basis of a bulletin by Mr. Robinson.

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PRESENT MAPPING

The accompanying geological map (Fig. 2) is on a topographic base which is a compilation of the best data available. Most of the topography was obtained by the writer, using plane-table methods, on a scale of 200 feet to 1 inch, and in part was checked against acceptable mineral-claim surveys from Wild Goose basin to Three

Forks. Transit surveys, made by Kelowna Exploration over a good deal of the eastern part of the area, were used as checks wherever possible. The timing of the work was such, however, that much plane-tabling was done before the transit work was completed.

Topographic mapping was done by Kelowna Exploration on the Mammoth-Wakefield section, lower White Creek valley, and the Payne ridge. The southwestern part of the area, south of Idaho Peak, was mapped by Western Exploration in 1937. All this mapping has been incorporated with that of the writer to form the topographic base of Figure 2. Ties and adjustments were made by plane-table under the writer's direction.

The resultant map has not been checked for over-all accuracy, because master surveys of a precise nature have not been made, but for the purpose and on the published scale it is believed adequate. All contours were drawn in the field.

The datum used is geodetic. A tie was made (by plane-table closed traverse) between Sandon and a geodetic bench mark near Three Forks. This was checked against C.P.R. levelling over the same distance. There is a discrepancy in the higher levels, inasmuch as the writer's elevation of the summit of Idaho Peak is 7,411 feet, as compared to the triangulated elevation of 7,479 feet obtained by a Department of Lands survey. This discrepancy of 68 feet between Carpenter Creek and the summit of Silver Ridge is regrettable, but time and the survey method used did not permit its correction. Such an error in a vertical range of about 4,000 feet does not invalidate any of the geological conclusions. There is a corresponding error on the southern slope, between the Mammoth workings and the crest of Silver Ridge, but the elevations of the workings are approximately correct. All company surveys are on different datum planes, with a maximum variation between them of about 200 feet. The Kelowna Exploration datum is within 3 feet of being correct at Sandon.

The magnetic declination of approximately 23 degrees 35 minutes has been taken from the angle between the compass needle on the plane-table and the established meridian. This is slightly at variance with the published figure of 24 degrees 30 minutes (in 1932) but checks closely throughout the area and is the actual observed declination. Local magnetic attraction was not encountered north of Silver Ridge, but magnetic anomalies were detected on the summit at the head of Alamo basin and at points in the southwest part of the map-area.

The geological map shows the main facts of lithological distribution. No formational units are named because of uncertainties of correlation. Most of the contacts drawn are approximate, because the boundaries between most lithologic units are gradational and their exact positions may be matters of personal opinion. An attempt was made to follow the actual contacts and, wherever float clearly represented residual mantle and not drift, the evidence of float was taken between areas of outcrop.

As many dip and strike symbols as possible have been plotted in order to indicate the basis on which the cross-sections have been drawn. The symbols illustrate variations in trend lines and serve also to indicate the principal areas of outcrop. It has not been practicable to indicate stratigraphic tops of beds, but they are shown, at approximate points of determination, on the cross-sections.

Almost all the geology is the writer's. The work of his assistants was all checked in the field, at least as regards lithology. The Kelowna Exploration Company geologists were fully co-operative and made the results of their mapping available for field use. A great deal of time was saved thereby, but the writer has seen virtually all exposures himself throughout the entire area. It was deemed necessary for one man to see all rocks in all parts in order to plot the lithology with reasonable consistency. In most parts it was found advisable, if not necessary, to follow lithologic units through a structure indicated by observations of attitude, in order to test the validity of the structure. The structures at and near Idaho Peak were worked out only after all available details of rock distribution were known.

Some general and regional considerations have been based on Mr. Robinson's mapping south of the present map-area. In fact, structures in the basin of Silverton Creek have furnished several important clues regarding the origin and localization of the major lodes. Details of these structures must await publication of Mr. Robinson's bulletin, but some major conclusions are now presented, particularly as they affect the largest mineral belt in the Slocan.

CHAPTER II.—GENERAL GEOLOGY

GENERAL STATEMENT

The sedimentary rocks are members of the Slocan series,* considered to be Triassic in age.† They are cut by granitic dykes and by small stock-like masses closely related to the intrusion of the Nelson batholith, which is considered to be late Cretaceous in age.‡ The sediments include argillites, quartzites, and limestones, and every admixture of these as well as some tuff. They are characteristically non-slaty and have been subjected only locally to thermal metamorphism. There has been local silicification, particularly of limestone.

There is comparatively little pure argillite, pure quartzite, or pure limestone in the area. The most abundant rock type is a quartzitic argillite, dark in colour and commonly well bedded, consisting of alternating hard and soft beds or groups of beds, comparatively few of which can be classed as argillite or quartzite without qualification. The individual beds range in thickness from a fraction of an inch to 2 or 3 feet, and in the district the thicker bedded, more blocky assemblages are commonly referred to as quartzites.

Plate V. Idaho Peak from Selkirk Peak.

The rocks are fine grained and, with the exception of some argillite and limestone members, are silty. Quartzites showing a well-defined granular texture are rare, and most contain an admixture of argillaceous or limy material. The geological section is characteristically thinly bedded. Regular alternations of light- and dark-coloured beds from a fraction of an inch to 4 or 5 inches thick produce a striped rock that has been referred to in the district as "pyjama rock." Some of this rock is varved and represents cyclical deposition. More commonly, however, the bedding is less regular and alternations of rock type are not systematic. Intricacies of bedding are common, including cross-bedding, lenticularity, and swirls. The cross-bedding is sometimes very well developed and is in many instances diagnostic of tops and bottoms.

* Termed Slocan group by Little (1940).
† Cairnes, 1934, p. 61.
‡ Cairnes, 1934, p. 74.

The admixture and intergrading of the principal rock types make classification difficult. The succession has not been completely established, partly owing to intricacies of folding and partly owing to the fact that the amount of movement on the major lode systems has not been determined.

The map units chosen do not in all cases represent well-defined members but rather units which include rocks more limy, more argillaceous, or more quartzitic than others, and units which are heterogeneous in composition. Changes in general appearance caused by variation in lithology and thickness of bedding, or by varying degrees of deformation, make precise mapping of rock types next to impossible, and no single horizon has been recognized beyond doubt to extend throughout the area.

ARGILLITES

Several bands of argillite of uncertain correlation are known. This rock is soft to moderately hard, fine grained, and dark in colour; it possesses a blocky fracture and commonly weathers to a light-grey surface. It tends to form bluffs and, where well exposed and strongly weathered, closely resembles limestone, so much so that frequent application of acid is necessary to prove that it is not. Close inspection of the fractured surface shows a satin-like sheen, which is not seen in the dark limestones or limy argillites. The argillite is characteristically massive, though fine bedding structure is frequently present. The bedding planes, even where well defined by light-coloured silty or limy streaks, do not as a rule provide cleavage planes.

This massive argillite, with fine light-coloured silty beds, is seen to advantage on the ridge summit between the head of White Creek and the east fork of Tributary Creek, on the ridge west of Miller Creek, and on the bluffs north of Queen Bess mine. Internal deformation has locally been severe, and there is abundant evidence that the rock has flowed plastically, with contortion, squeezing, and fracture of the silty beds.

Argillite of similar appearance, but with limy as well as silty beds, underlies Alamo basin at the head of Howson Creek. In some parts the light-coloured limy and silty beds, from a fraction of an inch to 2 or 3 inches wide, are well developed and impart a striped appearance to the rock. Distortion, rupturing, and even comminution of these beds have taken place locally.

Predominantly argillaceous rocks, characteristically thin bedded, occur west of Miller Creek and in the vicinity of the Yakima claim. Alternations with quartzite and limestone beds are common, and in places alternations of argillite and limy material, as many as ten to 1 inch, produce a very finely striped rock in which the light-coloured limy beds weather buff. Intricate details of bedding may be well preserved in this rock, which possesses bedding cleavage.

Other rock mapped as argillite locally includes some quartzite and fewer limestone beds, up to about 25 per cent.

The argillite is characteristically blocky, although a very fine, incipient cleavage is locally present. Local development of flow cleavage and even conversion to phyllite is seen in a few, but by no means all, zones of extreme contortion. Argillites at and near Three Forks, along Carpenter Creek valley, and on the upper slopes of Payne Mountain have not been mapped owing to scarcity of outcrop. They are characteristically slaty.

QUARTZITES

The units mapped as quartzite include impure quartzite, quartzite, and single beds and narrow bands of argillite and limestone. The impure quartzite is typically a dark-grey to black silty rock that can be scratched only with difficulty by the point of a pick; it may be gritty or of fine, even grain. It is an argillaceous quartzite and in rare instances is limy. The quartzite is commonly a medium-grey to black, finely granular rock that consists almost entirely of quartz grains and is completely recrystallized. Some grey quartzite contains small dark vitreous grains, and the distribution of this rock might be valuable in future correlations. A small amount of the quartzite is light in colour and may even be white, and it is possible that some of the white rock is the product of silicification of limestone.

Single beds and narrow bands of argillite and less limestone have been mapped with the quartzite because they cannot be treated separately. Some are in sharp contact with the quartzite or impure quartzite and some are completely gradational with it, but the proportion of distinctly argillaceous and limy material does not exceed 25 per cent of the whole unit and in most instances is much less than 25 per cent.

The largest amount and the best exposures of quartzite are at the headwaters of Tributary Creek, on Selkirk Peak and adjacent high ground. Between the forks of Tributary Creek and on the eastern part of Selkirk Peak the bedding is relatively uniform, but contortion can be seen on the precipitous north face of the peak and west on Read Peak. It has not proved possible to trace this quartzite through the area or to account satisfactorily for the fact of greater abundance in this locality. In spite of apparent uniformity the quartzite may have been thickened by dragfolding, slice faulting, or other structural causes. In a few places some of the rock is similar in appearance to the products of silicification found elsewhere, but it is very unlikely that more than a small part of the quartzite is of this origin.

North of the Queen Bess mine a band of quartzite, relatively pure and moderately granular, extends down Howson Creek valley. This has not been correlated with other quartzites across the several lodes and may or may not be the equivalent of that on Selkirk Peak. It seems certain, however, that there have been changes in lithology along the strike of the quartzites that have affected both thickness and character.

LIMESTONE

The limestone ranges in colour from light grey to black and as a rule is light coloured on the weathered surface. It is fine grained to coarsely granular. Bands of relatively pure limestone about 100 feet thick occur, but the greater part is interbedded with quartzite and argillite. Impure limestones show every gradation into argillite and quartzite by straight admixture or, into some argillites, by ultra-fine interbedding.

Most of the limestone is well bedded, and fine bedding structures are well preserved. Cross-bedding is common in almost all cases, and its presence, even in fine-grained limestone, proves that the rocks were deposited by current action and not from solution. Some of the best examples of cross-bedding seen in the area were in granular limestone deposited as a lime sand with, in many instances, an admixture of quartz sand. Lenticularity of deposition in some limestones is more marked than in sandy and silty rocks.

The greatest development of limestone is in Wild Goose basin, on the east wall of Alamo basin, and on the south side of Idaho Peak. Mixed limy rocks predominate at the heads of the branches of Avison Creek. There is an apparent affinity between limestone and quartzite, and the relative amount of these rocks varies in some members. Silicification of limestone has in some instances produced a hard light-coloured granular rock, more or less limy, which can be differentiated only on structural evidence from quartzite of original deposition. The development of magnetite accompanies the silicification in places and produces anomalies affecting the compass needle. Other forms of alteration are rare, and only very small amounts of garnet and pyroxene were seen in Alamo basin and southwest of Idaho Peak, along dyke contacts.

MIXED, BANDED ROCKS

Under this heading are included alternations and admixtures of argillite, quartzite, and limestone. They include every gradation between the principal rock types, as well as relatively pure successions of beds, as much as 30 feet thick. They differ little in appearance from many interbedded argillites and quartzites except for the limy content of many beds in addition to beds of relatively pure limestone. The amount of lime can be judged only by the liberal use of acid in the field.

As a rule these rocks are well banded owing to alternations of beds of different colour, hardness, or texture, but banding is their only characteristic feature apart from the fact that they contain about 10 to 25 per cent of limy strata. They are transitional with argillite, limestone, or quartzite units laterally and also along the strike. Precise contacts are consequently a matter of doubt.

The mixed, banded rocks occur chiefly in the southwestern part of the area and denote a greater deposition of lime there than elsewhere. Rocks of similar character have been recognized on the shoulder of Payne Mountain but have not been mapped separately.

INTERBEDDED ARGILLITES AND QUARTZITES

These rocks extend along the slopes of Carpenter Creek and are rather characteristic of many parts of the Slocan camp. They have not been mapped as a distinct unit or units because of poor exposure, and they could perhaps be subdivided if they could be seen to better advantage. In any event they do not apparently contain enough limestone or limy strata to warrant classifying them as "mixed rocks."

Even where well exposed these rocks are hard to classify, because quartzite and argillite are relative terms and there are many silty intermediate types for which classification is at best arbitrary. Subdivisions can be made in the accessible Ruth and Silversmith workings, for instance, and also in the Silver Ridge crosscut, but it has proved impossible to correlate these with rocks on the surface. The latter rocks are poorly exposed, are weathered, and may have undergone more or less deformation than those in the mine workings.

Plate VI. Finely bedded silty rocks in diamond-drill core from Lookout crosscut.

The rocks west of lower Tributary Creek, through the Black Colt and Victor properties, are for the most part thin bedded, with most beds 3 inches or less thick. Many of these are fine, silty types in which primary cross-bedded structures are common. Many of the beds are relatively hard quartzites, but the rock as a whole is readily mashed by faults and behaves in response to deforming forces much as if it were composed of argillite alone.

TUFF

Tuff was found between the Standard and Mammoth mines and southwest of Idaho Peak, and has been noted west of the area and close to Slocan Lake. On fresh fracture there is little to suggest its origin, but on weathered surface light-coloured fragments contrast with the darker matrix. Were it not for its speckled appearance, somewhat resembling the texture of a fine-grained porphyry, the rock would be classed in the field as an argillaceous quartzite. It is interbedded with black argillite and a small amount of black limestone.

The matrix is a dark-grey to black silty material, and the fragments consist of both feldspar and rock. Many of the rock fragments are of acidic and even porphyritic igneous material, but a few fragments of sedimentary rock, including slate, were seen. The fragments are one-tenth of an inch or less in diameter, and many are much smaller.

The rock is a water-lain sediment, but the fragments strongly indicate volcanic affiliations. As Cairnes has remarked:* "Some of the rock fragments are fine-grained, dense, and of indeterminate origin, but others are porphyritic and distinctly resemble volcanic rocks. . . . The angular outlines and fresh appearance of the feldspar fragments is plainly indicative of no normal processes of erosion and deposition." It should be classed as a tuff even though it does not consist of preponderantly volcanic products.

SEDIMENTATION

The alternation and admixture of argillite, quartzite, and limestone throughout the geological section on a major and minor scale indicate considerable variation in sedimentation over a long period of time. The local but repeated deposition of beds as fine as ten to the inch and of contrasting materials, together with abundant cross-bedded structures, points to shallow water deposition. The known fossils are all marine except for plant remains found on Reco Mountain,† and it seems probable that the sediments were deposited under estuarine conditions.

Depositional structures are common, chiefly cross-bedding but including small-scale lenticularity, swirls, scour and fill, and possibly ripple marks. Superposed on these and readily confused with some of them are secondary structures, possibly the result of soft rock deformation to which the sediments were subjected before consolidation. Further distortions took place by flowage or crumpling during the long period of folding. In spite of widespread deformation the cross-bedding is in many instances well preserved.

A good deal of the cross-bedding clearly indicates tops and bottoms of beds, a fact which is invaluable in working out structures. Some merely shows stratification at an angle to the normal plane of sedimentation, but some consists of inclined beds which meet the underlying beds tangentially and are truncated by the overlying beds. The most conclusive cross-bedding is cuspate in form, in which case the lower tangency and upper truncation are most plainly seen.

Diagnostic cross-bedding occurs in strata from one-tenth of an inch to 5 or 6 inches thick. It may be present in any rock other than the finer argillites and limestones and is best developed in the silts and sandy limestones. Some of the limestone is

* Cairnes, 1934, p. 56. Cairnes does not mention the same locality, but the rock he refers to is undoubtedly the same.

† Cairnes, 1934, p. 59.

exceptionally well cross-bedded, and the structure is plainly visible on the weathered surface. In the silts and some quartzites the structure can be seen only on the weathered surface, unless there is a marked colour variation in the stratification.

Scour and fill structures have been seen but in only one or two instances were well enough developed to prove top and bottom. Possible ripple marks have been seen in Alamo basin. These structures are, as a rule, too easily distorted or destroyed by deformation to be of positive value.

Varving of some sediments is present as an alternation of beds of dark argillaceous and light silty to limy material from one-tenth of an inch to 2 or 3 inches thick. In some instances the light-coloured beds grade upward into the dark and so might provide evidence of tops and bottoms, but this systematic gradation is not sufficiently widespread to be a positive criterion, and in most instances there is no certain gradation. Pleistocene varved clays show this gradation, as do many varved or graded sediments of other ages (Pettijohn, F. J.: Sedimentary Rocks, pp. 467–470). Rhythmic alternation of argillaceous with silty or calcareous beds proves regular fluctuations in conditions of sedimentation and suggests an annual cycle, but the matter is hard to prove in pre-Pleistocene rocks. Many of the striped " pyjama rocks " in the district, such as those on Seaton Creek east of Three Forks and on the southern slopes of Reco Mountain, as well as some in the Sandon area, include truly varved members, but the apparent lack of graded couplets in most instances may disprove an origin through an annual cycle.

There are clearly recognizable changes in sedimentation along strike in distances of a mile, and changes are to be inferred in shorter distances. Cairnes* noted an increase in the amount of limestone to the southeast in the district, and the present writer noted the same thing in the Whitewater area.† In spite of the detailed nature of the present examination, measurement of the increase or decrease in thickness of a given type of sediment has proved impossible because of scarcity of outcrop and because of the influence of folding on the thickness of strata.

The accompanying map and sections illustrate some examples of changing sedimentation, in part observed, and in part inferred to account for discrepancies in succession. The main units of limy, argillaceous, or quartzitic rocks are relatively unchanged, inasmuch as the proportion of these dominant rock types may not vary to a marked degree, but a variation chiefly in the amount of lime in a mixed, banded unit may warrant its remapping as a limestone unit on one hand or as an argillite or quartzite unit on the other. Marked lenticularity, with drastic changes in sedimentation in a few hundreds of feet, was not observed, although extremely detailed study may prove that it exists in some places.

GEOLOGICAL SECTION

No close estimate of the thickness of the sedimentary column can be given because of the structural complexity of the area. Minor buckling within the major folds has undoubtedly affected the thickness of most members. Positive correlation across the major lodes has proved impossible, and movement along near-bedded faults has produced effects which cannot be measured. The only thing that can be said is that some thousands of feet of sediments are represented in the area, and that these sediments have undoubtedly been thickened and doubled up to an incalculable degree by folding and faulting. Cairnes has estimated the entire Slocan series to be 6,800 feet thick,* which in the light of additional work proves to be an underestimate. The entire thickness may possibly be several times that figure.

No attempt has been made to outline the succession in the Sandon area because of uncertainties in correlation. Rather than hazard opinion, it seems best to let the plan and sections speak for themselves and to allow future work to settle some of the problems, but it is of interest to emphasize a few main facts regarding the succession.

* Cairnes, 1934, p. 58.
† Hedley, 1945, p. 9.

Plate VII. " Pyjama rock " near Rambler mine. Banded rock of finely bedded argillite and quartzite. The rule is about 6 inches long.

Plate VIII. Irregular sedimentation in thin-bedded argillites in vicinity of Sunshine mine. The circular patches are lichen.

The highest rocks mapped, stratigraphically, are tuffs, in overturned position on the southwest side of Idaho Peak. The writer cannot claim complete knowledge of all rock types in the Slocan camp, but he has seen most of the rocks between Idaho Peak and the basal Slocan sediments on Whitewater Creek and can state that if tuffs are present in that interval they are extremely rare (a few conglomeratic horizons on and near Reco Mountain may be tuffaceous). It is safe to say that tuffs first appear in quantity well up in the succession of the Slocan series.

Stratigraphically below the tuffs there is a great thickness of limy strata, including two or more 100-foot bands of limestone. The apparent amount of the limy units is exaggerated in mapping by topography and by structural repetition, but the fact remains that limestones and mixed, banded rocks containing an appreciable amount of limestone are of widespread occurrence. Still lower stratigraphically, in the central and eastern parts of the Sandon area, argillites and quartzites predominate, with only a small amount of limestone.

INTRUSIVE ROCKS

Dykes, sills, and stock-like bodies of pre-mineral age are common. They are widespread through the entire district and have been well described by Cairnes,* who considers them to be related to and somewhat younger than the main intrusion of the Nelson batholith. In the Sandon area the relation to the batholith has not been determined, but a probably somewhat younger age may be deduced from the fact that they are, in general, younger than silicification, which is not restricted to nearness to specific dykes, and which possibly originated at the time of the main intrusion.

Cairnes mentions a great variety of dykes, ranging from acid pegmatite through granitic to dark basic types. He classifies them as salic or mafic depending on whether quartz and/or feldspars predominate or are subordinate to ferromagnesian minerals. In the Sandon area there is not the variety found in the district as a whole. The terms salic and mafic will be used, although strict differentiation between the two types is impossible, at least in the field.

Most of the intrusives are locally termed porphyries, although they are by no means all porphyritic. A few are of the " bird's-eye " variety, but well-developed porphyritic texture is not characteristic of the dykes and sills.

The largest stock, on the slopes of Payne Mountain, lies mostly outside the area; it is 2,000 feet wide where crossed by the Payne road. Dyke-like extensions of it continue for about 1 mile southwest of the Payne road, although outcrops are scarce and the details are uncertain. The next largest, north of the Idaho mine, is about 1,600 feet in cross-section and probably has dyke-like extensions. The edge of another stock lies on the west margin of the map. The Silversmith plug, about 1,500 feet long on the surface and with a maximum width of 600 feet, appears to be irregular and sill-like underground. From observations in various parts of the district it is likely that the smaller stocks and plugs are irregular in shape and vary considerably in cross-sectional outline. Some appear to be no more than local enlargements of dykes or sills.

Sills and dykes are widespread and only the larger have been mapped. Isolated outcrops of " dyke rock " of some size have been recognized in many places, but it has proved impossible to tell in some instances what shape or size of body is represented. The sills or dykes are as much as 100 feet or more thick or as little as 2 inches thick.

A great many of the intrusive sheets are sill-like and follow the bedding as a rule more faithfully on strike than on dip. The sills cross the bedding locally, split, pinch and swell, and cut through complex structures, but tend to follow the bedding wherever possible and in some cases follow the curvature of a fold. They are undeformed, and therefore were not directly involved in the processes of folding, but they are thought to have been intruded during the last stages of the folding, at a time when there was probably some flexing of the beds in order for them to have followed bedding planes to so great an extent. Other evidence will be adduced for the time of intrusion.

* Cairnes, 1934, pp. 69–73.

Cairnes notes in the district as a whole that the salic dykes tend to strike northwestward and the mafic dykes, which are younger, strike northeastward. In the Sandon area this rule is not evident, partly because salic and mafic dykes are not clearly separable, but it is in some measure correct. It has been noted that some of the smaller lamprophyres tend to be highly irregular and to have been intruded along fractures rather than bedding planes, a fact which indicates that they came in somewhat later than the salic dykes, after relaxation of the main folding stresses. Crosscutting relationships between salic and mafic dykes were not seen.

The salic dykes, sills, and stocks are light coloured and granitic in appearance. Some of the larger are bird's-eye porphyry like the Silversmith plug and some stocks on lower Carpenter Creek. Porphyritic texture is more or less well developed in some others but is far from universal. Ferromagnesian minerals include biotite and hornblende, which are present in relatively small amounts in most cases. There is great variation in grain size.

Mafic dykes are of two general sorts. One is a biotite-rich rock which, unless composed almost entirely of that mineral, has a texture no different from that of many of the salic dykes. There is apparently, from a field study, a complete gradation between salic dykes and the mafic dykes of this type, and microscopic study fails to indicate any clear-cut division. The darker, more biotite-rich individuals may be termed lamprophyres and characteristically weather readily.

The other sort of mafic dyke is a fine-grained light-coloured to brownish biotite-rich rock that weathers readily, and no completely fresh specimen has been available for microscopic study, even from drill core far removed from any lode. It contains many small egg-shaped bodies, which impart a porphyritic texture but which are so completely altered that they defy determination. These dykes are the most erratic in form and course and tend to cross bedding planes as much as follow them. They might be termed spotted lamprophyres.

All dykes are pre-mineral. Lenses or remnants of sheared and altered dyke rock are fairly common in the lodes, and it is not known in many instances whether they represent drag material or not. Several examples of such rock within lodes, however, represent dykes that were intruded along the course of the lode prior to mineralization and were sheared by subsequent movement.

A microscopic study of the dyke rocks was made by A. B. Irwin while at McGill University, from which the following observations have been made. With the exception of the spotted lamprophyres and one example of strongly altered, highly basic rock, the dykes are intergradational members of one family. The lighter-coloured rocks are quartz diorites and the darker are kersantites.

Of twenty-nine thin sections studied, all contained quartz and none contained orthoclase. Biotite is the dark mineral with, in three thin sections, some hornblende. The feldspar is andesine and albite, the phenocrysts being andesine. Most of the rocks contain a small amount of calcite, and this mineral is a prominent constituent in many of the biotite-rich rocks.

The spotted lamprophyre is highly altered and consists of biotite, chlorite, calcite, and quartz. The egg-shaped spots consist largely of carbonate.

One basic dyke of a knotted texture was found to be too highly altered for determination; it consisted of approximately 80 per cent biotite and chlorite and 20 per cent carbonate. This type of rock is very rare.

METAMORPHISM

All rocks are indurated and have been subjected to both dynamic and thermal metamorphism.

Some argillaceous rocks possess a slaty or flow cleavage of which part is axial plane flow cleavage and part has been produced by shearing forces. This matter will be discussed more fully in a later section. In zones of extreme deformation some rock has failed by combined fracture and flowage, and the fragments of harder beds are strewn, systematically or otherwise, through the softer material. This produces a conglomeratic texture in some instances. In several places the rock has been mashed, and all original textures and structures have been destroyed. An interesting example of this is seen on the south slope of Read Peak, where finely striped argillite consisting of an alternation of dark and light-coloured beds has been finely comminuted and recemented, producing a spotted rock in which many of the light-coloured fragments are no larger than peas, and fragments larger than a walnut are rare. Some of this rock is merely streaky, owing to intense interflowage of the different coloured materials. In the vicinity of the Carnation mine, argillite has been squeezed into fractures in the quartzite, and blocks of quartzite appear to float in the argillite. In a sharp flexure south of Queen Bess mine, quartzite in a small anticlinal crest is overlain by argillite; the quartzite in the crest contains no evidence of bedding and even includes small blocks of argillite.

The argillites are not characteristically rusty weathering, but in zones of close folding and of shearing they may be, owing to development of pyrite. In such situations they do not outcrop readily, and the presence of rusty argillaceous float, particularly if the fragments are splintery, may often be taken as evidence of more than ordinarily intense deformation. In other cases rusty float may be derived from rock in which pyrite and even pyrrhotite have been developed as the result of thermal or hydrothermal metamorphism near an intrusive body.

Although dynamic metamorphism does not alter the appearance of limestone and quartzite, the argillaceous sediments may differ in appearance with the degree of deformation they have undergone. Apart from development of cleavage and the growth of pyrite, the evidence of bedding may be increased or diminished, a fact which in some instances makes it difficult to decide whether two outcrops are lithologically the same or not.

The effects of thermal metamorphism are not intense. North and east of Sandon there is some recrystallization of argillite to a finely knotted rock with the development of staurolite, a type of alteration common farther east in the district. Finely recrystallized black argillites of various sorts are to be seen locally on the Payne road, near the Ruth mine, and elsewhere in the vicinity of Sandon, apparently restricted to beds of favourable composition more than to precise situations close to intrusive rock.

Dark-coloured massive argillite may undergo a change in colour to brownish shades with little or no coarsening in texture close to intrusive bodies, as near the Idaho mine. This is due to the development of fine unoriented biotite. The development of garnet in scattered grains in limestone was noticed locally on the east side of Alamo basin, close to an acidic dyke. Southwest of Idaho Peak there is local development of pyroxene, and some fine-grained silicified limestone has a greenish cast due to the presence of the same mineral. These phenomena are very local. A particular sort of metamorphism is seen in the 5480 adit of the Carnation mine. There a brown- and green-striped rock, with layers rich in biotite and pyroxene, is derived from what was perhaps originally a finely bedded silty sediment containing some lime. Exposures nearby are few in number, so it is not known just what the original rock was, nor how extensive is the alteration. A similar alteration of finely bedded silty argillite to a siliceous aggregate of variable greenish colour is seen locally on upper White Creek.

Silicification, principally of limestone, has been widespread. The effects are as a rule local, but between Avison and Emily Creeks silicification has been intense over an area measuring about 500 feet by 2,000 feet. The replacement by silica has been so faithful that in many instances primary structures, such as cross-bedding, have been perfectly preserved.

The silicification was accompanied by bleaching of the limestone which, in the extreme case, has been converted into a dense white hard granular rock with a fine sugary to chalcedonic texture. A small amount of pyroxene may be developed, as seen in several thin sections under the microscope, and it is presumed rather than proved that that mineral is responsible for a slight greenish tinge (in streaks) seen locally in several parts of the area but not thoroughly examined microscopically.

There is every gradation from bleached limestone to an end product consisting almost entirely of quartz, and for the most part the amount of lime present can be judged only by the application of acid. There is no direct proof of origin of some of this material in the field, because it resembles some limy quartzite or quartzose limestone. Microscopic study was made of a number of specimens and, although the examination was not exhaustive, there was little or nothing to suggest secondary origin in comparison with some rocks of undoubtedly primary nature.

Silicification is hard to prove in the field because it may affect whole beds through the extent of an outcrop, and along a single horizon it may be present in lenses which could as well be interpreted as products of sedimentation. Crosscutting relations are rare, and the best evidence is provided by interbeds of silty material, commonly dark in colour, which have been bleached along fractures and of which only remnants remain.

Bleaching and silicification may also affect silty or quartzitic beds across widths of several feet and not always in contact with or near limestone. Bleaching of these beds has as a rule been initiated along fractures, and some striking patterns of brecciated appearance have been observed. The end product may be indistinguishable from the silicified limestone, and some partly bleached dark silty rock may contain sufficient lime to effervesce with acid.

Magnetite was not observed in quantity and fine opaque specks seen were not determined. Pyrrhotite, with pyrite, may be present in amounts sufficient to produce rusty weathering of some silicified zones. Areas of magnetic anomaly associated with silicified zones may be produced by magnetite or pyrrhotite or both.

Silicification is directly associated in a few instances with sills or irregular dyke-like intrusives, but in most of the larger areas the relationship is not evident.

In several places, as on Idaho Peak and in the headwall of Alamo basin, silicification was locally seen to follow closely the contact of an intrusive body, but in no instance was the intrusive itself silicified. The only place a gradation between a dyke and silicified rock was seen is on No. 5 level of the Victor mine, where quartz diorite is excessively quartzose at a contact and grades insensibly into silicified rock.

In the majority of cases there is no apparent direct relationship between a dyke or sill and silicified rock, and the presence of inclusions, similar to nearby silicified zones, within dykes on the road between Avison and Emily Creeks suggests that silicification was initiated prior to intrusion of these dykes. Intense silicification near the Van Roi and Hewitt mines, close to the batholithic contact, suggests that the silicification accompanied the general period of intrusion rather than that it was related to specific dykes. Another reason for assigning the alteration to a time earlier than dyke intrusion is the fact that some dykes crossing silicified zones are more irregular and less sill-like than is common, apparently due to the fact that the silicified rock fractured more unevenly and with less influence by bedding planes than did the unaltered sediments.

Silicification is widespread, although quantitatively the amount is small. No attempt was made to map the silicified rocks as distinct units, chiefly because the areas affected are small and also because it was not everywhere possible to decide upon the limits. In some places "quartzite" was seen that looked very much like rock which was known elsewhere to be a silicified limy sediment, and it is probable that the apparent amount of quartzite in the area has been increased by this process. It is not believed, however, that silicification was on such a scale as to convert major thicknesses of limy sediments into rocks indistinguishable in the field from quartzite.

Metamorphism is older than the lodes, and the writer saw no evidence that silicification was related to them. On the contrary, the sequence of events is well enough known to make it certain that silicification took place before mineralization. Although the lodes are not characteristically quartz filled, it could have been possible in the long history of lode formation for an influx of silica to have followed the initial fissuring. That this did not take place is deduced from the fact that the zones of observed silicification are not localized along the lodes but are haphazard. The silicified rock seen underground in many workings is not different in character from that known to have been produced by the general processes of intrusion in the area, and it is not localized in such a manner as to suggest dependence on the lode fissure for a source of silica.

CHAPTER III.—STRUCTURAL GEOLOGY

GENERAL STATEMENT

The structural geology of the Sandon area is of Alpine type and is highly complex. Very little of the structure can be inferred from the map alone, but by comparing the map (Fig. 2) and the sections (Figs. 3 and 4) the extent of the present state of knowledge of the structure can be studied. An important modification of the structure is observed south of the present area, in the valley of Silverton Creek, and only a suggestion of that modification is to be seen in the Sandon area itself. Current work by Mr. Robinson along Silverton Creek, between Silver Ridge and the contact of the Nelson granite, is thus an important complement to the present work.

In order to discuss the structure of the Sandon area to best advantage it must first be considered in a regional frame of reference, namely, the region between the massive rocks of the Nelson batholith and the Kaslo greenstone. Further extrapolation of the structure, and consideration of its significance in the framework of a large part of the West Kootenay, is highly important from a regional point of view, but, since the present bulletin aims to describe the geology of a mineralized area and these broader implications serve no immediate purpose, they will not be discussed.

Future work between Kootenay and Arrow Lakes will throw much light on the larger regional framework of the West Kootenay. It is hoped that the material in the present bulletin will not only add to the stock of knowledge but will prove the necessity for detailed study in working out regional structures.

In the general section to follow, the writer draws on his own experience, which includes both detail and reconnaissance work in a large part of the Slocan. Mr. Robinson's work is used and some concepts of Messrs. Billingsley and Mayo. Some of Dr. Cairnes' geological compilations have kindly been made available.

Following this general section there are discussions of dragfolds and cleavage, particularly as these features may be useful in interpreting and integrating the structures of the Sandon area.

STRUCTURE OF THE DISTRICT

The sedimentary rocks of the Slocan series are strongly folded into a complex of asymmetrical and overturned folds. The central part of the sedimentary basin between Silverton and Kaslo Creeks has been greatly compressed, with the formation of structures more Alpine in type than have hitherto been recognized. The general form, if not the detail, of this folding is reasonably well understood in the Sandon and Silverton areas and has required a great deal of intensive study for its working out. Study in comparable detail elsewhere has not been possible, but enough is known of the more important features to warrant drawing the following conclusions regarding the cross-section of the basin between Nelson granite on the southwest and Kaslo greenstone on the northeast.

The Slocan sediments as a whole are well-bedded, typically blocky rocks in which little secondary cleavage has been developed. At the headwaters of Kaslo and Seaton Creeks, however, there is a belt of slate as much as 4 miles wide bordering the Kaslo greenstone, in which the dip of both bedding and cleavage is dominantly to the southwest. In a former bulletin (Hedley, 1945) the writer expressed the belief that this thickness of slaty rocks was a normal succession without duplication by major folding, but probably thickened to an incalculable degree by dragfolds, crumples, and possibly slicing faults. The cleavage was held to be of the axial plane variety in spite of its general, but not detailed, parallelism with bedding and in spite of the absence of isoclinal folding. This opinion is now modified by a change in concept that recognizes the possibility of the development of cleavage on so large a scale by an extreme of interbed slipping which amounts to shear (*see* section on cleavage, pp. 36–38). The Whitewater slate belt is thus considered to be a huge shear zone, localized by the buttress of Kaslo greenstone, which follows the bedding in general, and expresses an extreme of the same relative movement as the interbed slipping which accompanied folding. A second period of deformation, apparently related to faults, has deformed the cleavage near the head of Kaslo Creek.

A second slate belt crosses Payne Mountain and is known to extend from the vicinity of Cody to that of Three Forks. This is also a shear zone, as much as half a mile wide, possibly representing a major dislocation. It follows the regional trend and tends to be localized in argillaceous rocks, but it is not entirely a bedded structure and is not confined to an argillaceous horizon of relatively low competency.

Elsewhere, north and east of Silver Ridge, the rocks are complexly folded into an aggregate of poorly symmetrical forms with axial planes that are nearly horizontal and with low angles of plunge. The characteristic form is a recumbent fold, involving overturn of one limb and ranging in intensity from moderate curvature to isoclinal. This is a pattern of folding not often described, and during the course of the present work it was thought to be anomalous and that elsewhere there would be found a more conventional series of anticlines and synclines with steep axial planes. However, although differences in outline have been encountered in the Slocan camp, this fundamental form of the folding persists for a cross-sectional distance of 12½ miles and through a vertical range of 6,000 feet.

The Slocan sediments are involved in a zone of overturning of major proportions. The form is not completely outlined, because only the lower part remains and the full implication is not known, but a recumbent fold is indicated with an amplitude at Sandon of at least 5,000 feet and possibly twice that figure. Little is known of the roots or of the upper eroded limb.

With local and minor exceptions, strata which dip to the southwest are stratigraphically right side up, and strata which dip to the northeast are overturned. The lowermost, west-dipping strata steepen upwards and roll over to an overturned position in a huge crumpled arc, concave to the southwest. The full implication of this arc is not known because the complementary arc of recovery by which the overturned strata return to a right side up position is not seen anywhere in the district. The complete structure, no matter how complex, must in original outline have been in the form of a gigantic dragfold in which the higher, overriding strata moved relatively southwestward and the lower strata moved relatively northeastward, supposedly in response to tangential earth stresses. Only part of the lower arc has survived erosion, and an upper arc, the remainder of the "dragfold," must be sought elsewhere along the regional strike.

This structure, or rather the lower part of it that remains, is here called the Slocan fold. It cannot be seen anywhere in its entirety, but the general form is a recumbent fold open or concave to the southwest.

The simplest known outline exists on Twelvemile Creek, where steep southwesterly dipping rocks on Kaslo Creek steepen and roll over to northeasterly dips and maintain that dip in a panel that extends northwestward to the head of Jackson Creek. The details of the folding are not known, but the curvature itself is unmistakable.

The Sandon area is situated in perhaps one of the most complex parts of the structure. Repeated reversals of dip are the rule, and neither the southwest dipping roots nor the upper limit of overturning can be seen. The working out of this structure has involved integration of detail because none of the individual folds is clearly exposed. Determinations of top and bottom of strata by cross-bedding have been invaluable, proving in several instances the existence of tight folding that could not otherwise be distinguished.

The Slocan fold, extending from the Kaslo greenstone to the Nelson granite, may, and probably does, involve the Kaslo greenstone as well as the Slocan sediments. The cleavage in the sediments on Kaslo Creek is continuous with shearing in the greenstone, but whether the greenstone, which is conformable with the overlying sediments, steepens upwards and rolls over to a northeasterly dip is not definitely known. This latter point is important in assessing the size and regional implications of the fold, but the mass of the greenstone and the scarcity of evidence of internal structure make the matter very hard to determine. The answer may lie to the northwest, on upper Kane Creek, or perhaps on Upper Arrow Lake, although the evidence may have been destroyed by intrusion of the Kuskanax batholith.

The lower limb of the fold is apparently represented by the prevailing southwesterly dips on Kaslo, Seaton, and lower Carpenter Creeks, and the root zone lies below the level of Slocan Lake. Nothing is known of the ultimate base of the structure.

The Slocan fold is seen fragmentally in cross-sectional outline for about 12½ miles horizontally and about 1 mile vertically. It is not and probably never was a structure of simple or uniform curvature. The belt of slaty rocks, interpreted as a huge shear zone, along the edge of the Kaslo greenstone points to modification of the folded outline by shearing stresses. The Payne slate belt is similarly interpreted as being at least in part a shear zone along which adjustment took place. In order that a uniform outline be produced in the course of folding over so large an area, uniformity of application of stress and of response by layered rocks would have to have been of a high order. Actually the heterogeneously bedded sediments failed irregularly, and the application of stresses was far from uniform throughout the known dynamic history of the region.

The Slocan fold is a complex of structures whose present configuration is a result of changing stress application. The northwesterly trending complex, characterized by axial planes with little or no dip and by low plunge, is " humped " along a zone extending from near the Mammoth mine to the Whitewater at Retallack, and some members are buckled through approximately a right angle near the contact with Nelson granite.

The Slocan fold, referring to the entire complex of individual structures, is a composite structure. The individual folds are folded, a fact which on first thought suggests a second period of deformation, but, other than the marked curvature of fold axes, there is no evidence of two periods of deformation. On the other hand, there is evidence that folds were formed and then buckled in one more or less continuous process. The evidence is most abundant in the Silverton Creek area and will be discussed in Mr. Robinson's bulletin when field work is completed.

The general form of the Slocan fold is discussed in the following paragraphs inasmuch as it bears on problems of occurrence and genesis of the major lodes. It is thought that the Slocan fold developed along a basic recumbent pattern and, probably before the

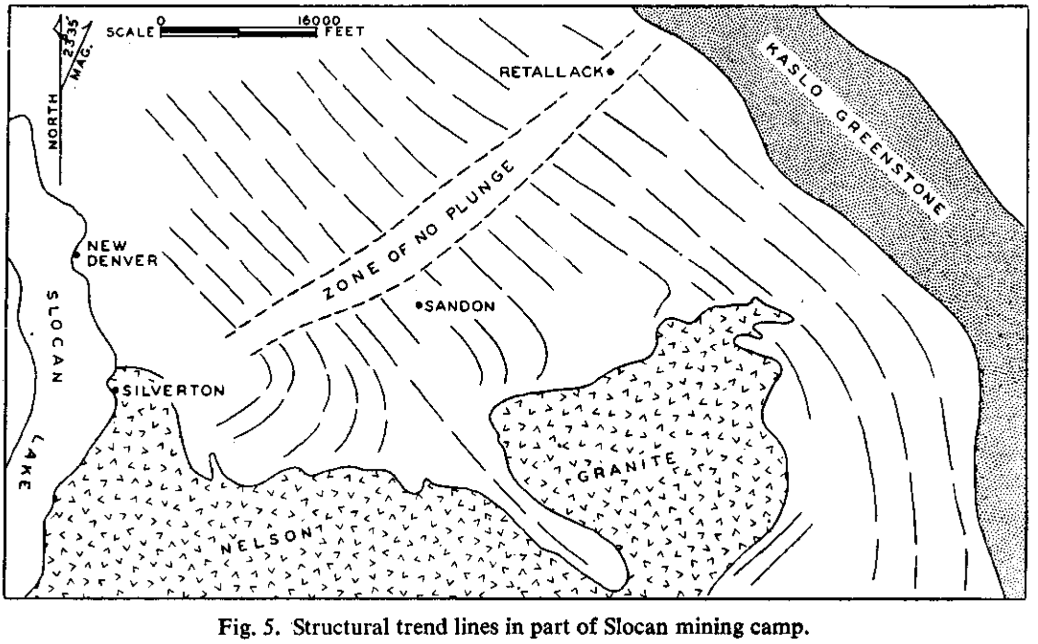


Fig. 5. Structural trend lines in part of Slocan mining camp.

present recumbent outlines were fully formed, a redistribution of stresses crowded and buckled some of the individual fold elements in the path of the growing Nelson batholith.

This crowding and buckling along the general granite margin must, obviously, bear some relation to the intrusive body. Speculation on the mechanics of intrusion are not considered here, particularly as study of the granite itself has not been possible. The preceding reference to crowding must, however, stand, whether the granite actively did the crowding or whether the sediments were warped against a granitic buttress. The writer believes, to express the matter in only the most general way, that the development of the complex Slocan fold and the emplacement of this part of the Nelson granite must have been interrelated.

Figure 5 shows the general outline of the northern extremity of the Nelson batholith and the marked swing in structural trend round the northeast edge of it, as mapped by Cairnes on the Sandon Sheet. Trend lines are also shown to illustrate how parts of the Slocan fold are buckled against the northern margin of the granite.

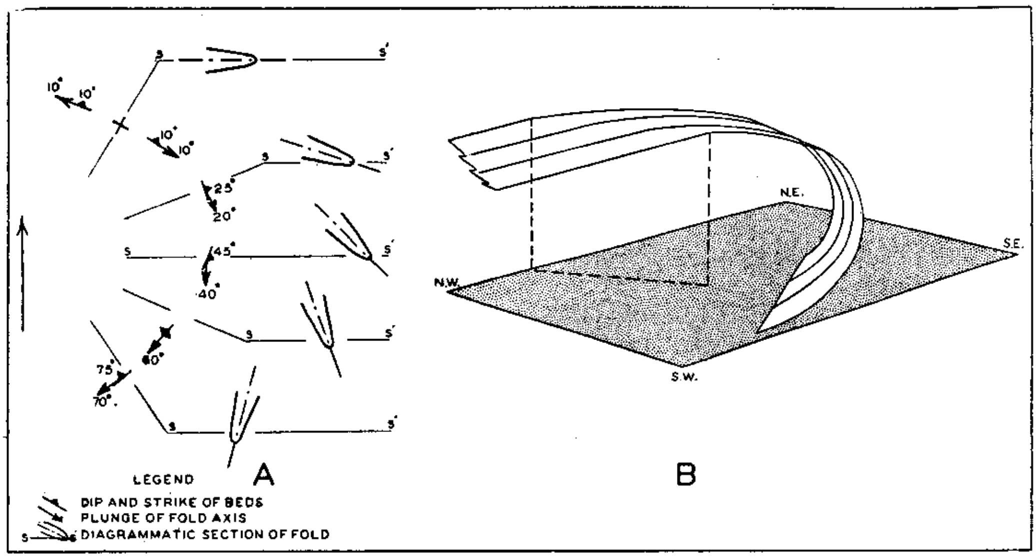


Fig. 6. Down buckling of Slocan fold between Idaho Peak and Silverton Creek (not to scale).

Figure 6 illustrates the nature of the down buckling as traced by an element of recumbent structure which passes through Idaho Peak and near the Mammoth mine, to show how it is deflected and rotated down across Silverton Creek. In detail, crumpling complicates the fold and its exact shape is not known, but the general pattern is clear. In A, Figure 6 is shown the dominant dip and strike of the sediments and the plunge of the larger fold axes in plan, and in section the dips of a single compressed fold. B is a perspective drawing of a single plane, essentially horizontal near Idaho Peak and warped down and around to a steep northwesterly dip near Silverton Creek. Only a plane is represented because it has proved too difficult to illustrate the assemblage of compressed folds actually involved in the down buckle. The sketches illustrate the general pattern of fold elements which have been almost continuously traced in this vicinity. Most, but not all, of the individual fold elements curve in this manner to meet the granite.

In curving from a northwesterly to a northeasterly strike the previously folded beds are rotated and are buckled downward to the south. The curvature is sharpest where seen on lower Silverton Creek and is apparently a broad open curve south of Adams Peak.

A broad cross-warp extends between the Mammoth mine and the Whitewater mine at Retallack, separating northwest plunges on the north and west from southeast plunges on the south and east. The area of the cross-warp, which extends across the entire sedimentary basin, is one of locally conflicting plunges. It is apparently associated with the down buckling only on lower Silverton Creek and may possibly stem from a focus of stresses in that locality. The actual boundaries of the cross-warp are vague, but this structure, in general, coincides roughly with the main productive area of the Slocan.

DRAGFOLDS

Dragfolds, as defined or implied in standard works on structural geology, are minor, systematically developed crumples in incompetent strata between more competent beds. They have been formed by the differential movement between beds during the process of folding, and friction has played an important part in their formation. The individual dragfolds may be irregular in outline but more commonly are S-shaped or Z-shaped. The relative direction of movement between beds may be deduced from the shape of the folds and from this, in turn, the direction of curvature of the beds in the nearest major fold can be determined.

In the Slocan, systematic development of small dragfolds in relatively soft beds or series of beds is not of common occurrence, possibly because of the heterogeneous character of the sediments. Such folds do occur locally and are useful in the working out of structure, but other structures are of more general importance and will also be called dragfolds in this bulletin. In so doing, current field practice is being followed, but inasmuch as the standard texts imply restriction of the term it is necessary to define this usage.

A dragfold is considered to represent the folded outline which has resulted from the overriding of any bed or series of beds by itself. It is not restricted in size or to any type of rock, other than that it is a product of stratiform folding;* it may be developed in a soft bed between harder beds, or it may be developed in a hard bed of rock which has buckled between softer beds which have flowed. It implies shortening of strata and thickening by repetition. The outline is as a rule S-shaped or Z-shaped, resulting from

* By stratiform folding is meant the formation of flexures in layered rocks. The deformation of massive, non-stratiform rock is not considered here.

Fig. 7. Diagrammatic cross-section of a recumbent fold. Cleavage represented by broken lines.

a small or moderate amount of self-overlap as measured on a single bed, but may include, as extremes, a flexure which has stopped just short of overriding, and an overlap measuring many times the thickness of the band involved. It is a result of partial failure of a rock band to transmit stress, and so may pass into a shear or fault.

In Figure 7 is shown diagrammatically the cross-section of a fold on which dragfolds of much smaller size are localized. The fold is drawn recumbent to illustrate some of the problems of structural study in the Slocan, but in principle it may just as well be viewed as an upright anticline or syncline by holding the page sideways. The principal axiom concerned is that in stratiform folding, which always involves some interbed slippage, the outer beds must move differentially toward any crest with respect to inner beds which are closer to the axial plane. It follows that dragfolds which have formed as a direct result of this interbed slippage must indicate the relative direction of movement.

Dragfolds measuring a few inches to a few tens of feet in amplitude are moderately plentiful in the Sandon area. Some are S-shaped and represent some overlap as measured on a single bed, but included with them are many flexures in beds which have not overlapped themselves. Some of these latter may be called dragfolds only by courtesy, but they indicate the same relative movement as do the others. Some irregular buckles are of uncertain derivation and consequently are of no other value than to prove that contortion has occurred. A structure should be termed a dragfold only when it is related to the general process of folding. Non-symmetrical buckles and rolls, and even some S- and Z-shapes, may simply represent loci of failure of the strata in relief of local stresses.

Dragfolds of both overriding and flexural type may be formed at some time other than that of the general folding and in response to quite different forces. They may, for instance, represent incipient shear zones, examples of which have been observed, particularly in the Whitewater area. In the heterogeneous strata in the Slocan, folded into complex outlines, the general forces of folding have not acted uniformly throughout the rock mass and many anomalous structures have been formed.

The foregoing remarks have by direct statement or inference referred to beds, and by so doing have put some measure on the possible size or limit of a dragfold. Actually there is believed to be no limit to the thickness of rocks that might be involved, nor to the size of the structure. In size then, a dragfold may be microscopic, or it may be only somewhat smaller than the largest structure of which it may form a part.

With the above definitions and qualifications in mind, it may be stated that dragfolds in the Sandon area may in the majority of cases be used with confidence in the working out of structure. The dip of the axial plane of a dragfold may be of little positive value in indicating the dip of the axial plane of the major fold, but the plunge is approximately that of the larger structure, and the integration of individual plunges is considered to be the most positive way of determining the major structural plunge.

The Sandon dragfolds indicate the direction of differential movement between beds, but this does not determine tops and bottoms of the beds. Owing to the nature of the folding, all beds have in general moved down dip relative to those beneath them. Reference to Figure 7 will show why this is so. In a recumbent fold the outermost beds move towards the crest relative to the innermost, as they must in all stratiform folding, but also the higher beds move down dip relative to the lower, the reverse of the differential movement seen in upright anticlines and synclines. A newcomer to the district, because of his experience with upright folds, at first may believe all beds are overturned. In fact, the only way to determine tops and bottoms is by study of cross-bedding. Dragfolds prove extremely useful in the field provided the stratigraphic top is known.

A few dragfolds are anomalous, in that they prove that the higher beds have moved relatively up the dip. This is easily explained in the case of warps on the limbs of some recumbent folds, but in a few particular cases is inexplicable. At the head of White Creek large and small dragfolds prove that the uppermost beds of a west-dipping panel moved relatively up the dip, the reverse of what is the rule for the remainder of the area. Knowing the general pattern of folding in the entire district, one explanation is that the dragfolds have been produced by later acting forces, for which there is no positive evidence; another explanation is that the west-dipping panel is part of a larger structure, to which the dragfolds are related.

One general consequence of the Sandon dragfolding is that it steepens the average or effective dip of a structural panel. Because higher beds override the lower, down the dip, each bed is in effect lowered each time it is dragfolded, and the average dip is increased.

CLEAVAGE

Cleavage is not prominent in the rocks of the Sandon area and is not characteristic of the Slocan as a whole. It is developed locally, however, and as its presence is a structural record open to interpretation it is worth discussing for the light it may throw on general and particular problems.

Cleavage is here taken to mean slaty cleavage, which involves orientation of platy minerals and which is generally considered to have resulted from rock-flowage. Since there is some difference of opinion on the origin and significance of slaty or flow cleavage, it is well to state the writer's point of view. The ideas of W. J. Mead (1940) are taken as setting forward in clearest language in a single paper the principle that cleavage may result from rock-flowage during the normal course of folding, given the right conditions of load, rate of deformation, and degree of compaction and dehydration of suitable rocks. Under these conditions cleavage may develop, regionally or selectively, approximately parallel to the axial planes of folds. Cleavage may also develop by rock-flowage in response to shearing stresses, in which case it may not be parallel to axial planes. The two products may be identical in appearance.

Fracture cleavage, implying more or less closely spaced fractures or joints with no orientation of platy minerals, is not considered separately. It is present in the district and may prove useful in structural determinations, but its implications are not believed to be as far reaching as those of flow cleavage. In many observed instances it is not possible in the field to differentiate between fracture and flow cleavage unless the fracture crosses the flow cleavage and was thus demonstrably formed at a different time. In fact, most of what the writer considers to be fracture cleavage in the field seems merely a less fissile form of flow cleavage with which it intergrades, the degree of fissility and the angle of dip varying with the rock traversed, unless the cleavage follows the bedding. The matter of mineral orientation, although important in the generally accepted classification of cleavage, cannot be determined in the field and for the present work is not believed to warrant the extensive laboratory study necessary for its determination.

The best development of flow cleavage is in the Whitewater-Lucky Jim area, described in an earlier bulletin (Hedley, 1945). The next largest development is in the slate belt on Payne Mountain that passes down the slopes of Reco Mountain to the vicinity of Cody and is important in mine development as Cairnes has shown (1935, p. 1), since it limits to the southwest a number of productive veins. Elsewhere, flow cleavage is of more random and frequently very local occurrence.

In 1945 the writer advanced the belief that the flow or slaty cleavage in the Whitewater-Lucky Jim belt was axial-plane cleavage developed in response to the forces of folding and endeavoured to reconcile the fact of the nearly universal parallelism with bedding by pointing to the great amount of interbed slippage on what was presumably the flank of a major fold against an underlying buttress of Kaslo greenstone. Since additional work has been done this view has been modified. It is now believed that in this belt rock-flowage, the evidence of which is slaty cleavage, was not produced as an over-all result of the general folding but in response to locally resolved stresses. It is believed that, specifically, the intensity of folding, and of flowage due to folding, may vary in such a heterogeneous rock-mass as the Slocan series so that flow cleavage will tend to develop in certain zones more than in others. If the zones of extreme folding become eventually zones of shear through continued application of the same stresses, flowage due to folding becomes progressively flowage due to shear, and the cleavage, which is the chief evidence remaining of that flowage, may be of dual origin.

In parts of the Payne slate belt flow cleavage is locally axial to fold elements, yet the belt itself transects formations. In the saddle abreast of the summit of Payne Mountain quartzite is very strongly cleaved, whereas in the common case of slate development quartzite is not as a rule affected. No fundamental difference in character of the cleavage is seen, and there is no positive evidence of more than one generation, yet it is believed that the Payne slate was formed under two essentially different conditions. A zone of folding developed which progressed through a condition of more than ordinary rock flowage and finally became a zone of shear rupture along which there was an unknown amount of displacement.

Such localization of deformation is not believed to be in any degree extraordinary but to be of likely occurrence in a complexly folded, heterogeneous assemblage such as the Slocan series. The concept involves more or less continuous deformation, with rupture occurring when and if the limit of capacity to accommodate by stratiform folding has been passed. Further consideration of processes and implications involves dealing with definitions of rock-flowage, shearing, and mineral orientation which are beyond the scope of this bulletin. The foregoing seems best to explain the field facts and is written for that purpose only.

The development of cleavage within the Sandon area has produced rocks that range from those with incipient slaty cleavage to phyllite and rarely to schist. In some instances cleavage has been produced by flowage in zones of extreme buckling and adjustment, and sharp flexures in the bedding may cross the cleavage. In minor folds of near-symmetrical outline the cleavage is axial. In some instances the cleavage is folded or at least crenulated, but not in such a manner that a second period of deformation is indicated; rather, it would seem that after the initial fold was formed further adjustment took place, and the cleavage was warped or buckled.

Plate IX. Bedding crossed by cleavage on Payne ridge. Right-side-up argillaceous beds dipping at a low angle to the right are crossed by nearly flat slaty cleavage, whereas harder quartzitic beds are crossed at a larger angle by widely spaced fracture cleavage. Note the minor thrusting on the fracture cleavage. The pencil gives the scale.

In one or two places such as an asymmetrical buckle in quartzite, argillite has been squeezed plastically into the fold or cavity and is cleaved in consequence of the squeezing. Such cleavage of strictly local formation can be recognized for what it is if the exposure is adequate, but in small outcrops the origin is hard to prove.

Care must be taken if cleavage-bedding relations are to be used to work out structure. The cleavage may not be axial-plane cleavage in the first place and even if it is, in relation to a single fold, it may be of no value without additional information. As was pointed out in the case of dragfolding (*see* Fig. 7), in any fold the peripheral beds move toward the crest and in recumbent folds the upper beds move relatively down the dip, regardless of stratigraphic tops and bottoms. The best illustration of axial-plane cleavage developed in a recumbent fold is on the slope of Payne ridge just southeast of the Slocan Boy (Plate IX). Here southwesterly dipping beds are cut by flatter cleavage, which fact, under conditions of upright folding, proves that the beds are overturned. Actually, the beds are known to be stratigraphically right side up from the evidence of cross-bedding, and the exposure is on the upper limb of a recumbent fold with nearly horizontal axis.

The fact that in many places cleavage is predominantly parallel to bedding is best explained by the large amount of interbed slippage which has occurred, and by the fact that many faults or shear zones follow the bedding. The cleavage may thus be produced by flowage caused by attenuation or by shearing, and may even be of dual origin.

On the Canadian Pacific track between Three Forks and Rambler Siding there is a greater width of slate in several places than occurs on strike of the formations on higher ground to the southeast. In some of the slate the bedding has been obliterated and blocks of harder rocks have migrated through softer. It is not known whether this slate is the product of extreme buckling alone, during which the rocks first shattered and then flowed, or whether it is the product of a major zone of shearing.

The Whitewater-Lucky Jim slate belt is probably the expression of rock-flowage more intense than that produced solely through the mechanics of folding. It is probably related in part to crowding of the argillaceous sediments against the Kaslo greenstone and involves a strong element of shearing. The fact that cleavage in the sediments is parallel with cleavage in the adjacent greenstone implies that a single cleavage has affected both rocks.

Another manifestation of cleavage, which seems to be of possible regional origin even though it is of local development, is worthy of mention. This is seen particularly in banded " pyjama rocks " in which the banding is between pale siliceous and dark argillaceous beds ranging in thickness from one-quarter of an inch to 3 or 4 inches. It is seen in other similarly alternating hard- and soft-bedded rocks whose regularity is less marked than in the " pyjama rock " type. In such alternations the softer beds possess a poor to good cleavage at a small angle to the bedding in plan and essentially parallel in section. It has been seen at enough widely scattered points and on enough different structures to imply that it is of possible regional significance. The orientation of this cleavage is such that it indicates a relative shift of the southwestern beds to the northwest.

STRUCTURE OF THE SANDON AREA

Summary.—The strata in the Sandon area are complexly and asymmetrically folded as part of a huge regional recumbent fold, the Slocan fold. The major Slocan fold cannot be seen, but its general nature is deduced from integration of the minor elements. The strata on the higher slopes of Silver Ridge are on the upper, overturned limb of the major fold, and the strata in the valley of Carpenter Creek follow round the crest zone of the major fold. The lower limb is not seen in the Sandon area, except perhaps west of Three Forks.

The strata are buckled on a large and small scale, and there are many reversals in dip about near-horizontal axial planes. Dragfolding is on a small and large scale, and some of the major buckles are considered to be huge dragfolds, the most prominent of which, on Idaho Peak, is semi-isoclinal in form. No complete folds can be directly observed in the field and in only a few localities can the curvature of part of a fold be traced in cross-section. The concept of the structure is built up by integration of all observations obtained by detailed scouring of all areas of outcrop and by close attention to distribution of rock type.

There are wide differences in character of the folding in different parts of the major structure. There are also wide differences in the manner of failure, and of accommodation to the major structure, of rocks differing in degree of competency and in degree of bedding fissility. Consequently, there are differences in outline of the folding both along strike and in a single cross-section. The large isoclinal fold on Idaho Peak is on the limb of the major structure, where differential movement has been extensive, and sharp reversals in dip in the area of Miller and Tributary Creeks are in the crest zone of the major structure. The actual form assumed may differ widely between argillite, quartzite, and thin-bedded rocks.

Most of the rocks in the Sandon area ultimately swing through an arc of about 90 degrees to meet the northern edge of the Nelson granite at a small angle (Fig. 5). One unexplained exception is the continuation of the northwest trend through a prominent re-entrant in the granite at the head of Sandon Creek. The curvature from northwest to northeast strike is seen in the Sandon area only in the vicinity of the Mammoth mine.

This curvature, shown in Figure 6, involves compression of the recumbent folds, a change in plunge from 10 to 15 degrees northwest to 20 degrees southeast, and a progressive steepening of the plunge through southerly, ultimately to about 70 degrees southwesterly. At the same time the tight recumbent folds are buckled down and under so that the axial planes dip steeply to the northwest.

In spite of the complexity in the Sandon area a few features make structural interpretation possible. Cross-bedding, though not everywhere present, has permitted frequent determination of stratigraphic tops and has been invaluable. Dragfolds, with few exceptions, serve to illustrate the form of the curvature. Cleavage has proved unreliable on the whole, although locally it shows the differential movement between beds.

As a general rule, invalidated only by flexures upon folds and by isoclinal dragfolds, southwest-dipping beds are right side up and northeast-dipping beds are overturned. The dominant pattern of folding is about near-horizontal axial planes, and the differential movement between beds has been that the upper beds moved down the dip relative to the lower.

The plunge of the axes of individual folds is at a low angle to the northwest in the northern and western parts of the area. The plunge is to the southeast in the southern and eastern parts. The Sandon area straddles a cross-warp of regional dimension.

Local observations at scattered points lead to the conclusion that southwestern beds moved relatively to the northwest. The evidence for this is the development of cleavage in softer interbeds (*see* p. 38) that is apparently not necessarily related to the major fold nor to minor folds alone, but which has resulted from a huge creep along the formational trend.

The folded rocks were metamorphosed, intruded by igneous masses, and dislocated by faults. All these events are believed to have taken place in one semi-continuous and overlapping process during the final stages of folding.

Some metamorphic effects, such as the growth of fine biotite in the argillites, is clearly related to individual intrusive bodies, but some are not related to any single apparent source. Silicification is a more important phase of metamorphism, because it involved an influx of silica in large quantities, and because it changed the competency of some of the rocks affected. Its presence makes correlation difficult in some instances.

The general sequence of events was silicification, intrusion of sills and dykes, faulting, and mineralization. Although silicification was in general prior to intrusion, it accompanied the intrusion of some bodies. It is impossible to determine the time of silicification relative to folding, but indirect evidence points to the fact that sills and dykes were intruded before the folds reached their ultimate form, presumably at a time when the folds were essentially complete but before the folding stresses were fully relieved. Joints of the principal crosscutting set came later, for had these abundant fractures existed at the time of intrusion, dykes following this direction would have been common, whereas the typical intrusive body throughout the area is a sill. Faulting started at about the same time, although before the last intrusion, and continued for a long period, probably in a series of pulsations with attendant relief of pressure. Mineralization took place before the faulting ceased.

The timing of intrusion and faulting is based on the fact that in much of the area the intrusive sheets follow the bedding more often than not, and some of the sills continue round broader folds. This is taken as evidence that bedding planes were easily spread by invading magma because the beds were still subject to flexure by regional compressive stresses. Tangential faults are so much influenced by the structure, are related to dragfolds and ruptured folds, and have the same relative movement as the interbed slippage, that the time of their formation is proved to be no later than the close of the period of folding. Crosscutting faults, some channeled along the joint system, formed at much the same time. The larger crosscutting faults developed finally into huge tear faults which involved some underthrusting, with a flatter dip and a more easterly strike than the smaller faults. They were major avenues for the relief of stresses, and the direction and amount of movement varied along their courses, influenced by deflections round and along some structures. In both classes of faults the movement locally passed from fault zone to bedding and even from one class of fault to another. Mineralization took place while the faults were still active and was restricted almost entirely to the crosscutting faults. Distinctly later faults, post-mineral and related to a possible period of relaxation, have not been recognized.

Folds.—The structure of the Sandon area involves a gradual upturning of southwesterly dipping strata at the lowest elevations and overturning to northeasterly dipping strata at the highest elevations. The simplified outline is that of a huge recumbent fold, open to the southwest, but the details of the folding are highly irregular and complex.

Complex as the structural detail is, and irregular in outline as many fold elements are, there is a basic pattern that is important to recognize. Strata are folded about nearly horizontal axial planes and along nearly horizontal axial lines; also, in general, beds dipping to the southwest are stratigraphically right side up and those dipping to the northeast are overturned.

The ten cross-sections (Figs. 3 and 4) illustrate better than words the known and inferred details of folding. These are drawn along vertical planes trending north 55 degrees east, at right angles to the average structural trend. It will at once be obvious that little enough is known of the full outline of the folding, and that in some parts both form and detail can be gathered only from mine workings. In some places the lack of outcrops and of mine workings in areas of relatively low topographic relief makes the drawing of sections almost impossible.

Equivalence of folds, like equivalence of strata, is sometimes in doubt due to the unknown amount of movement on the major lodes. This is made more uncertain by variations in outline of the individual folds. Furthermore, projection is made uncertain by local changes in plunge of the structures, and by warping of the axial planes of some folds. The following discussion of folding is of necessity, therefore, a discussion of form in relation to a major outline that can be recognized but not fully illustrated.

The most continuous structural element is the extensive overturned panel which dips down the northeast slope of Silver Ridge. At its upper edge it is thrown into a sharp fold in the vicinity of Idaho Peak, and at an elevation between 5,000 and 5,500 feet it rolls under in the first of a series of irregular folds. This panel is part of the upper limb of the Slocan fold. Before erosion produced the present topographic profile the limb extended for a considerable distance farther up the dip. The extension is deduced from the form of the fold on Idaho Peak, which is considered to be a tight dragfold. The strong closure of this fold and the amount of overlap are features more likely to be developed on a major limb than in the crest zone of a major fold.

The lower limb of the Slocan fold is not well exposed. The upper, overturned limb rolls under and passes down steeply in a zone of repeated reversals in dip along the crest of the major arc to the lower limit of observation at Sandon. The crest zone at Sandon is apparently of more complex outline than to the northwest, because the same zone is represented, in different strata, in the lower valley of Howson Creek and below Three Forks on the road to New Denver. The curvature there is apparently simple in outline, although interrupted by small buckles and dragfolds.

The lower limb of the Slocan fold is probably represented on Seaton Creek, where there is an extensive panel of southwest-dipping rocks, but without detailed study correlation of structures is difficult over large areas, owing to uncertainties regarding the precise plunge and the dip of the major axial plane. Possible dislocation along the Payne slate belt makes structural correlation with the valley of Seaton Creek a matter of doubt until the implications of the slate belt are understood.

The structural plunge of large and small fold elements is to the northwest at a low angle on Idaho Peak and in the basin of Howson Creek. The average inclination is not more than 15 degrees. In the vicinity of Sandon the plunge is at a low angle to the southeast, and it is to the southeast also on upper Avison Creek. Elsewhere, in intervening ground, individual determinations of plunge vary and, in spite of local reversals, the fold axes are on the average nearly horizontal. There is a general reversal of plunge in the central part of the area, representing a regional cross-warp.

In the southern part of the area, in the vicinity of the Mammoth mine, the southeasterly plunging folds become compressed and swing to a southerly strike and plunge, while at the same time the axial planes tilt downward to the east. The plunge on Idaho Peak is about 10 degrees to the northwest and on Avison Creek about 20 degrees to the south. A similar swing to a southerly strike is seen at Adams Peak, although the curvature is less abrupt. This is part of the down buckling, discussed in the regional structure, that has taken place along the northern margin of the Nelson granite. The curvature and down buckle are sharpest on Avison Creek and broaden to an open curve south of Adams Peak; in these localities the picture is complicated by the presence of the Mammoth and Adams lodes.

The axial planes of individual folds are not exactly horizontal, but on the average are nearly so, and dips do not, as a rule, exceed a few degrees. The axial planes are warped in some instances, a condition that is probably not the result of a second period of deformation but was caused by an extreme of folding in one period. As a result of this warping of the axial planes of some folds, shallow anticlines and synclines may be present on some limbs, whether the limbs are right side up or overturned. The degree of symmetry, on the whole, is not high, and the form of any fold may vary along its strike. The form may vary also in a single cross-section, across the different rock layers involved in the folding.

Variation in form of the folding is most marked across Silver Ridge and is best seen in Section G-G′, Figure 4. The nearly isoclinal folding with warped and puckered limbs on the southwest, in the valley of Avison Creek, is in contrast with the more open folding of smaller amplitude on the northeast, near Sandon. The difference is in part clearly related to the down buckling but may also in part be due to differences in lithology and to the relative position in the Slocan fold. This statement needs amplification.

The down buckling of folded elements takes place along an approximately east-west line, whereas the regional strike is northwest. Consequently, the northwesterly lying fold elements are affected progressively farther to the southeast, and any cross-section drawn at right angles to the regional strike may show compressed folds on the southwest and relatively open folds on the northeast. This is an important consideration in a study of the basic pattern of folding, as the complexity and amount of compression may be related not so much to position in the " throat " of the Slocan fold as to nearness to the axis of down buckling. The buckling is superposed on folds already formed, due to a late shift in application of compressive stresses rather than to a second period of folding following a period of quiescence.

In detail, variation in form may be directly related to the character of the rocks involved and to the degree of bedding cleavage. Strong, well-bedded quartzites may maintain a smooth outline, whereas alternating thin-bedded argillite and quartzite may fold with intricate outlines and rupture locally. The thicker bands of relatively massive argillite possess poor bedding fissility and, being soft, may be squeezed irregularly without regard to bedding planes. Evidence of plastic or semi-plastic flow, with acutely rumpled remnants of bedding planes, is in many places characteristic of the argillites.

Reference has been made to the large dragfold on Idaho Peak. This is a compressed and attenuated structure on the gently dipping and overturned limb of the Slocan fold. It is completely eroded on the northwest slopes of Idaho Peak and is not seen in similar form to the southeast, in spite of the change to southeasterly plunge. The Idaho Peak dragfold does, however, in changed attitude and somewhat changed form, pass through the northwest side of Adams Peak, having been removed by erosion north of Selkirk Peak. Complete mapping of the north side of Adams Peak was not accomplished, owing to the steepness of the ground, but parts of a fold can be recognized, partly obscured by faulting and by irregular dyke-like intrusion. This fold has an axial plane dipping eastward at possibly 40 degrees and is believed to have the outline of a dragfold. It cannot be seen on the south side of the peak because it is cut off by the Adams lode. Unfortunately, this fold, even in imperfect outline, cannot be shown on the cross-section, although a much smaller dragfold, possibly related to it, is illustrated in Section B-B′.

Little is known of the structure on the slopes northeast of Carpenter Creek, and the present stage of mapping does not permit structural correlation between Silver Ridge and Payne Mountain. A prominent overturn or recumbent fold occurs in the vicinity of the Payne mine, between No. 5 level and the crest of the ridge. It was first mapped by Mayo in 1941. The fold is open to the northeast, has a low plunge to the southeast, and an axial plane that possibly dips at a small angle to the northeast. It extends to the southeast through the shoulder of Payne Mountain and is removed by erosion 1,000 feet or more northwest of the Payne vein. It is one of the very few recumbent folds much of whose curvature can clearly be followed in the field along a single line of cross-section.

This fold is important, inasmuch as the Payne orebodies occurred where the beds curve sharply from southwest to northeast dips. A change in dip back to the southwest in a lower fold takes place somewhere above No. 15 level, and scanty observations indicate a further reversal below No. 15 level. Important ore was not found much below No. 5 level, and it is believed that the orebodies were localized because of lithology as well as structure (*see* pp. 97–98).

Two small, tightly compressed dragfolds are poorly exposed on the Queen Bess lower road, and two occur at the head of White Creek. It is quite possible that many more isoclinal dragfolds exist and have not been recognized. The curvature of such a fold may be so abrupt that it cannot always be detected, and if the amount of overriding of beds is comparatively large the fold may pass into a near-bedding shear. On the headwall of White Creek valley the remains of one sliced off, tight dragfold can be seen, and in one place on the same high ridge tight folding of beds was proved by cross-bedding although no folding was detected.

The reason for stressing this kind of fold is that if it is common it can account for some change in thickness of strata and, by repetition, the thickness can locally be greatly increased. Such a mechanism may account in part for the large amount of quartzites on Selkirk Peak. No tight dragfolds or overlaps were seen on the bare, precipitous slopes, but it is possible that some occur.

Folding in the southeast corner of the area, at the head of White Creek, presents a westerly dipping panel at a higher elevation than the main upper overturned panel. This panel lies south of the Adams and Ivanhoe lodes, and the dislocation represented by the lodes has brought widely separated structures into near conjunction. Southeast of the area a broad recumbent fold is plainly visible on the ridge between Sandon and Cody Creeks. In this fold, overturned rocks on Sandon Peak roll under to a westerly dip in the valley of upper Sandon Creek. Farther southeast, past Sandon Peak, the same recumbent fold continues into a prominent re-entrant in the granite, whereas the remainder of Silver Ridge is on the edge of the area of down buckling. Farther to the east, beyond the re-entrant, down buckling is resumed. (*See* Fig. 5).

Structural Sections.—Details of the structure can best be discussed by reference to individual cross-sections and comparison between them (Figs. 3 and 4). The areal map (Fig. 2) is of chief value in the present discussion to illustrate rock distribution and structural trends.

The cross-sections have been drawn on planes trending north 55 degrees east, at right angles to the average regional trend. This direction, which best illustrates the folding, is at a small angle to most of the lode faults, and consequently the sections do not illustrate the lodes, except in terms of greatly reduced dip, and fail to show the dislocative effects of the lodes in most instances.

For many of the sections there was not enough information along the actual section line to illustrate all the known or implied structure. In drawing the sections, contacts and attitudes were projected along the line of strike for distances as great as 300 feet and in rare instances 500 feet. Projection was made only of positive data in situations where uniformity of strike was indicated for the distance involved, and was carried on the line of plunge where known.

Section A-A′ is in the hangingwall of the Ivanhoe lode and for that reason is not directly comparable with other sections. The rocks well exposed around the headwall of White Creek are not correlated with those in the creek valley proper. The structure figured is more or less hypothetical, but there are irregular dragfold forms in an arc of overturning which involves differential flexure of a considerable thickness of rock. Dragfolds showing interbed slippage the reverse of that found in the area as a whole are illustrated and are unexplainable, except that they may represent abnormal take-up along some large curvature, of which this southwesterly dipping panel is a part.

Section B-B′ shows the principal overturned panel, dragfolded on Adams Peak. The dragfold is broken and apparently faulted and, although the full outline is not known, two dragfolds may be represented. The overturned limb rolls under sharply to an upright position. A lower overturned panel is encountered in Ruth No. 5 level, broken by tangential faults.

Section C-C′ shows no dragfold on Silver Ridge summit. The folding under, below the overturned panel, is as abrupt as in Section B-B′. The detail in the Ruth workings is in part diagramatic, but is a carefully drawn interpretation of the structure. This section illustrates the complexity in this part of the Slocan fold, where repeated overturning, with a form approaching that of accordion pleating, follows down the steep crest zone of the Slocan fold. Large tangential faults are localized within this zone.

As previously stated, folding believed to be of dragfold outline and of major importance passes through Adams Peak near the line of Section C-C′. It has not proved possible to illustrate this fold on the plane of section, even diagramatically, because of the inadequacy of mapping. The structure is disrupted by faults and apparently warped so that adequate portrayal on a single plane of cross-section would not be possible even if mapping were complete. This dragfold structure is possibly continuous with that on Idaho Peak, in spite of marked differences in outline, but since intervening parts have been entirely removed by erosion the fold cannot be shown on the succeeding three sections.

Section D-D′ illustrates the relatively undeformed overturned panel rolling under in the hangingwall of the Carnation lode zone. The southwest cliffs of Selkirk Peak have not been fully mapped, and projection of data near the Wakefield is not certain, so the structure may be more complex in that vicinity than the section indicates. The band of argillite on the north face of Selkirk Peak is believed to lie in the lower element of the Adams-Idaho Peak dragfold.

Plate X. Selkirk Peak from a point northwest of the Mammoth mine. Southwestern Carnation dumps on the left.

Section E-E′ illustrates the relationship between the Carnation, Wakefield, and Minniehaha lodes, even though the traces of the lodes on the plane of section are nearly horizontal. The points of juncture are not known. The folding under of the main overturned limb is deduced in the hangingwall of the Carnation lode and is projected in the footwall. A sharp fold is projected onto this plane of section from the northwest in the footwall of the Minniehaha lode, at an elevation of 4,000 feet.

Section F-F′ is the first section through the full structure. The main overturned panel is cut by the Carnation lode and rolls under at a point nearer to Silver Ridge than in the preceding sections. The first southwest-dipping panel beneath it rolls down in a steep, more or less crumpled arc at the level of the Lookout crosscut, and rolls back into an overturn below the nearby Wonderful adits. By analogy with Section C-C′ there are probably further reversals at lower horizons.

In the hangingwall of the Mammoth lode the first fold beneath the main overturned panel is more compressed than it is on the Carpenter Creek slope. The lower limb of this fold is crumpled and has a low average dip to the southwest.

Section G-G′ is in contrast with Section F-F′ and preceding sections. It is the first to illustrate the upper Idaho Peak dragfold on the main overturned panel, by projection from the northwest. It also illustrates the hypothetical outline of the Mammoth fold.

The Mammoth fold is considered to be of the general form and amplitude illustrated. Little of the fold can actually be seen, but it is drawn in comparison with the Idaho Peak dragfold and with a lower fold exposed on Avison Creek at the margin of the map area.

These folds are both of a strongly compressed, isoclinal type, a marked contrast in form with the folds of smaller amplitude and accordion-pleat type on the northeastern slopes. The adjustment pattern of strata in the inner part of the Slocan fold is different from that of strata in the outer or more peripheral part. There must be, in the intervening ground 2,000 feet beneath Silver Ridge, a zone of take-up or modification, the details of which cannot be surmised. The irregular and dragfolded apex of the Mammoth fold is drawn in the form shown in an attempt to indicate the possible complexity in this central zone, in the heart of the mountain. The meaning of the contrast in outline between the folds on the northeast and southwest slopes has already been discussed (pp. 41–42).

The form on the Carpenter Creek slope is not essentially different from that figured in the preceding sections. The structure crossed by the Silver Ridge Oregon crosscut is complex, in a zone of broken folds. Section G-G′ shows an interpretation of its over-all form. On the surface in this vicinity the overturned beds are involved in crumples and open folds which make interpretation of detail extremely difficult.

Section H-H′ shows the general form of the Idaho Peak fold, the highest fold known on the major overturned panel. It is a limb structure of attenuated, dragfold form. The outline of the compressed apex on Idaho Peak was traced with difficulty but is drawn accurately. The position and form of the complementary eastern apex is surmised, but its existence cannot be doubted in view of the tightly compressed form of the western apex.

The strata, as indicated by the argillite band, are dragfolded on a giant scale and, above the present erosion surface, they once continued up dip in an overturned position. If this were not so, an upper major complement to the Slocan fold would be represented, and the form of adjustment of strata within the apex would surely be different from that observed. In short, the amount of compression and attenuation of the Idaho Peak fold proves it to be part of a limb and not part of the crest of the larger structure.

Section I-I′ is complicated by the Alamo lode and by tangential faulting in the Queen Bess mine. The Idaho Peak fold is faulted so that overturned argillite beds in the lower part of the isoclinal fold are contiguous to right-side-up beds on the other side of the Alamo lode. The steep section of the lode, in which most of the mine workings lie, coincides nearly with the steeply dipping segment of the fold in this section. The lode deflected to follow the general course of bedding in this segment, past which it resumed its average attitude.

Dragfolds on the main overturned panel are drawn diagrammatically in the general form of several dragfolds observed on the east side of Alamo basin.

The apparent effect of tangential faulting in the Queen Bess mine is shown in diagrammatic form in this and the next section. Dominantly northeasterly dipping beds in the basin of Howson Creek are at the same elevation as dominantly southwesterly dipping beds in the mine area. The displacement on this zone of faulting is large.

Section J-J′ illustrates principally the main overturned panel, beneath the Idaho Peak fold and in the hangingwall of the Idaho lode. The general outline in the footwall of the Queen Bess lode seems to illustrate best the double nature of the Queen Bess major recumbent fold. The outline of this fold is crumpled as well as faulted, and the true nature of the fold cannot be seen by study of the surface alone.

Northwest of the Queen Bess mine, argillites and quartzites maintain a steep southwesterly dip almost to the main road near the Alamo mill (*see* Fig. 2), where they flatten rather abruptly. The vertical range is about 2,500 feet between the Queen Bess lode outcrop and the point of flattening above the main road. This does not mean, however, that the steep panel is 2,500 feet long on the dip, because the exposed depth is exaggerated by the northwesterly structural plunge, the exact amount of which is unknown. The slope of the line joining mine and mill is 18 degrees, and it follows that, assuming regularity along strike and a plunge approximating that figure, the steep panel may not be very extensive. The fact that the general direction of the curvature near the Alamo mill-site (Fig. 2) is the reverse of that illustrated below C level in Section J-J′ is not considered contradictory in the distance of nearly 2 miles.

Faults.—In the following discussion no fundamental distinction is made between faults and lodes. The emphasis here is on dislocation, and the lodes, which are mineralized faults, will be described in some detail in the chapter on economic geology.

Classification of faults is desirable in order to facilitate discussion, but it is not a simple matter. There is no positive evidence of more than one period of faulting, so a subdivision cannot be made on the basis of age. Subdivision on the basis of attitude is not entirely satisfactory because most faults in the Sandon area are more or less influenced by the structures which they transect, and wide variations may occur in the attitudes of individual faults. Two main classes of faults are, however, recognized, those that, in general, follow the formation and those that transect it. They are termed tangential and crosscutting, respectively. The tangential faults with local variations follow the formational strike, which in general is northwesterly, and dip with the formation. The crosscutting faults strike northeastward and with rare exceptions dip southeastward. All appear to represent normal displacement, in which the upper surface moved downward relative to the lower surface. The tangential faults are very seldom mineralized, and most of the crosscutting faults contain some evidence of mineralization.

Faults are numerous, representing displacements of less than an inch to several hundred feet, but the offsetting of formations by them is not marked, except in the case of the larger crosscutting faults. Geological mapping on the surface can in many places disclose the approximate position of a large crosscutting fault but, in general, fails to indicate tangential faults. Most knowledge of the tangential faults is gained from mine workings.

Many faults which are not readily classifiable are seen in mine workings. As many of these may be branches of other faults, or may represent local divergencies, no generalizations can be made regarding them.

The direction or amount of displacement is not as a rule easily determined. In the case of faults of a few inches displacement, it may be possible to measure the offset of a bed or dyke, but in the case of faults with a displacement greater than the height or width of a mine working, indirect evidence must be looked for. The best evidence is as a rule the presence of dragfolds or rolls within the sheared material of the fault itself. Shingling or imbrication within the fault can be used, provided it does not represent merely bedding in a horse of uncrushed rock. Dragfolds or dragging in the walls in the direction of movement is useful, but the fact that many faults, particularly tangential ones, are localized along flexures in the bedding makes it obvious that not all flexures close to a fault were produced by the fault movement alone. The amount of displacement is even more in doubt as a rule than the direction. The width of the zone and the amount and character of the gouge vary widely in a single fault and provide only a very rough measure. Bedded faults—to be described in more detail later—are the most difficult; 2 or 3 inches of bedded clay, seen in a mine working, may represent a substantial fault or may represent merely a very soft bed along which a small amount of slipping has been localized.

As already stated, all faults are normal as far as the movement on them has been determined, and no reverse faults have been recognized. This does not mean, however, that they are gravity or relaxational breaks on which the hangingwall has merely dropped. A few may have that origin, but almost all show evidence of movement under conditions of compression and might be termed pressure faults to distinguish them from relaxational faults. This fact is of fundamental importance.

The tangential faults are closely related to the folding and are normal faults because of that fact. In all parts of the area these faults occur most frequently at changes in dip of the strata and in many instances are related to dragfolds or allied flexures. They are named tangential because they cross the bedding at a small rather than a large angle and tend to be parallel with the *average* attitude of the beds, though they are not strictly bedding faults in most instances. The weight of evidence is sufficient to prove that they were formed during the last stages of folding, and that they represent in large part failure of the beds to accommodate fully to compressive stresses by stratiform folding alone. It follows that in this area of recumbent folding, in which the upper beds moved relatively downward, bedded or nearly bedded faults related to the same forces that produced the folding must be normal, inasmuch as the upper or hangingwall blocks moved relatively downward.

No major tangential fault has been traced from one limb to another of a large recumbent fold, to determine whether it dies out in the crest of the fold or whether it continues in a crosscutting relation with the other limb. Some minor faults have been seen to extend beyond the limits of a single fold of small or moderate size, and many have been seen to pass into the bedding and lose their identity as faults. One fault of moderate size was seen to follow, from one steep limb to the other, round the curvature of a broad fold, with a consequent reversal in dip of the fault plane.

A distinct impression has been gained that there has been differential movement along some faults as though there had been some mechanism of take-up or absorption of movement along a single fault fissure. This matter is difficult to assess but can be important in some mining problems. Possible mechanics are indicated by the relation between faults and folds already cited and, by extension, between faulting and interbed slip in general. It is a fact that some faults do pass into the bedding and become " lost."

The largest known faults of tangential type are in the Silversmith and Ruth workings. They transect many structures in detail but follow the bedding in others. There are at least three major faults with interconnecting links, representing a total movement of several hundred feet at least. They are southwesterly dipping normal faults on which the horizontal component of movement was of the hangingwall relatively to the northwest but undetermined in amount. If the faults are tangential to a crumpled westerly dipping panel and are related to the interbed slippage on that panel, then this direction of horizontal component of movement is a natural one in view of the southeast structural plunge. The truth of this last statement is apparent when it is remembered that the interbed slip on any normal fold is at right angles to the axial *line* of that fold and, if the fold plunges, the interbed slip did not take place along the *present* dip of the beds.

Faults of the crosscutting class are normal faults, with a large lateral component of movement, that were formed as compressional and not relaxational breaks. They strike northeastward to nearly eastward and dip to the southeast. The upper block moved downward and northeastward relative to the lower block. They may be accurately termed tear faults but are referred to in this bulletin as crosscutting faults to stress their relation to the general formational trend.

The crosscutting faults include the lodes. Mineralization is not continuous in them but is localized in favourable situations along the zone of faulting, from wall to wall in some instances in the smaller faults and across part of the width in the larger faults.

The larger known faults, all of which are mineral bearing and are plotted as lodes on Figure 2, are zones of shearing and shattering from a few feet to about 100 feet in width. There is commonly one principal gouge zone, but there may be several, in addition to subparallel fractures and shears throughout the zone. A continuous zone of faulting, not a single fissure, extends through the Standard, Mammoth, Carnation, and Silversmith mines a known distance of about 6 miles. A branch just north of the Standard mine passes west of Idaho Peak, branching again to pass through the Alamo and Idaho mines. The main zone is joined at the Carnation by the flat-lying Wakefield fault which steepens down the Silverton Creek slope south of the area. A branch passes through the Minniehaha property. The Adams and Ivanhoe faults cross Silver Ridge farther to the southeast, and their combined offset is large. The Canadian fault is a steep connection between the Adams and Ivanhoe.

The most accurate estimate of displacement on a major fault is in the Mammoth mine, where the hangingwall of the lode has moved down and east a distance of several hundred feet relative to the footwall. This is a measure of the shift of a projected fold in limestone. In other places on the same fault zone the amount of movement appears to be more or less, although the basis of determination is not strong. The offset of a rock unit, say of argillite, is not an accurate measure of the displacement because variations in thickness and lithology combined with complex folding make correlation uncertain across a fault, and it is not always known which limb of a fold is being compared with which. The sum of evidence, which is often conflicting and seldom certain, is that the movement on the Standard-Silversmith fault varied both in direction and amount along the course of the fault zone.

Variation in the amount of movement along a fault is usually considered as evidence of hinging, but in the Sandon area variation is believed to be the result of complex adjustments. Movement is a measure of relief of stresses, and relief may be accomplished by unequal response in folded structures, particularly when the stresses of folding and faulting are closely related.

Although the large faults crosscut the structures, there is a marked local tendency to follow them where possible. There is a tendency in particular for the faults to flatten and follow the bedding of relatively flat panels, so that flat and steep sections of a lode, up to a point, reflect the attitude of the sedimentary rocks, in spite of the discordance in average strike between bedding and faults. The Wakefield fault is semi-bedded in a flat-lying panel and rolls up at the Carnation intersection and down southeast of the Wakefield workings. In the Ruth and Silversmith mines the fault or lode locally flattens into the bedding and also follows round folds on strike, while some of the movement passes into tangential faults. Although the Alamo mine was inaccessible, the attitude of the fault is clear from mine maps, and a major steep roll in the fault is related to an element of folding in argillites (p. 45).

Crosscutting faults of smaller but undetermined displacement along which offsets of strata were not measured, such as the Corinth, Sunshine, and Wonderful, are smaller examples of faults similar to the major faults just described. Others of steep dip and little displacement, such as the Victor, Black Colt, and Payne (in part), seem to be of different character and seem possibly to have a somewhat different origin. No subclassification is possible, however, because intermediate examples appear to provide evidence of complete gradation between faults of small and large size.

The smaller crosscutting faults strike more nearly northeast than do the larger and tend to cross the strata at an angle of 80 degrees. Thus, where the strata strike about north 40 degrees west the faults strike about north 40 degrees east. They dip steeply to the southeast and may be vertical and even dip locally to the northwest. They are normal faults, with a lateral component of movement in some determined instances of southern side eastward, but on the whole they display few of the characteristics of tear faults and the movement on some of them is very slight.

The fact that the smaller crosscutting faults are parallel with the most prominent regionally developed joints, and may be indistinguishable from them, is considered proof that they were initiated at about the same time and in response to much the same forces as the joints. Some ore-bearing fractures unquestionably are joints on which there has been little or no movement. The positive evidence of movement of say 20 to 70 feet on some faults is at variance with the concept of joints, but the Payne lode furnishes an example of a variable amount of movement on a single fracture. On the south side of the ridge on the surface the fracture is weak and there is no evidence of movement, while in the vicinity of No. 4 level the fracture is a mere crack and seems to disappear. On the north side of the ridge, in the workings from No. 8 level up to No. 5, there is evidence of movement sufficient to produce a shear zone as much as 5 feet wide. The only possible explanation is that some mechanism of take-up has produced a marked difference in the amount of movement along the lode in a distance of several hundred feet.

The concept that the large and small crosscutting faults belong in the same category and are related structures seems far fetched in view of the differences between them. No positive distinction, however, can be made, and while it is easy to conceive of different origins for, say, the Victor and Carnation faults, there appears to be a complete gradation in the Sandon area between even such divergent faults as these.

Future study may alter this concept, but at present it is believed that in a regionally developed set of joints some joints became faults of minor displacement, and that increasing movements were channeled along others. It can never be determined whether or not the larger crosscutting faults initially followed actual joint fractures, and it is not suggested that they did, because movement along them ultimately produced huge zones of dislocation that trend more nearly east and dip at lower angles than the joint system.

It has been stated (p. 46) that there is no positive evidence of age difference between the various faults. Some cut others, but there is enough ambiguity of relation to indicate that the tangential and crosscutting faults were essentially contemporaneous.

There are many ambiguous relations between tangential and crosscutting faults, and although one fault may be seen to cut another, faults elsewhere are seen to merge. The best example of inter-relationship is in the Silversmith-Ruth workings. Large tangential faults appear to offset the crosscutting fault or lode, but the lode also swings into the faults. Details will not be discussed here (*see* pp. 110–111), but dislocative movement definitely passes from one fault to another. In other instances, an offset in a lode is produced partly by flexure of the load and partly by shifting along a fault. The former B vein on the Queen Bess is now seen to be an offset part of the main lode, in which the lode in part swings from the crosscutting to tangential direction and back. Nearness in time of origin of tangential and crosscutting faults is indicated by the fact that they both may be mineralized, even though occurrence of ore within the tangential faults is rare. Nearness in time of origin is also indicated by the same time relations to the dykes. Whether the two classes of faults constitute in some instances a conjugate set of shears initiated simultaneously under the same conditions of stress is not known; the large amount of movement on them has obscured minor relations that might prove or disprove this point. A conjugate relationship is believed to exist in part of the Silversmith mine, but the particulars of stress-strain relationships must have varied greatly throughout the area as a whole.

There is evidence that the major crosscutting faults, or lodes, are related to the structural swing and down buckle in the lower basin of Silverton Creek. The lodes in this section are semi-bedded and dip steeply with the northeasterly striking strata. Furthermore, they appear to be related to dragfolds which plunge steeply to the southwest and show that the southeastern beds moved relatively to the northeast. The same relative direction of movement is indicated (1) by the displacement on the faults, (2) by the form of the dragfolds, and (3) by the interbed slippage necessarily produced in the course of swinging and down buckling of the strata.

A conclusion, which is at least logical, is that on lower Silverton Creek the lodes were initiated as bedded features in the northeasterly striking rocks in response to the intense forces of buckling. In the area of sharpest curvature the large tear faults passed across the strata with a crosscutting relation, and at the same time flattened. Farther east, where the curvature of the strata was less pronounced, it is possible that similar tear faults were initiated in the buckled rocks, but that they remained bedded, swung with the structure in a broad arc, and were finally dissipated.

There appears to have been a focussing of structural activity in the lower basin of Silverton Creek, namely sharper buckling, a concentration of tear faults (lodes), and a cross-warp marked by reversal in plunge of major axes. The structural features in the combined Sandon and Silverton areas, as previously stated, are believed to be the final outcome of one long period of folding, semi-continuous and with varying stress applications, the final form at least having been greatly influenced by granitic intrusion.

Joints.—Joints are numerous and on the whole form complex patterns which have not been unravelled. One set in particular is prominently developed throughout the greater part of the area and has great economic and structural significance. This is the crosscutting set already mentioned.

The crosscutting joints are most abundant in the northern and western parts of the area. They are found in all rocks but are less common in limestone. They strike approximately at right angles to the strata in which they occur, tending to be more nearly at 80 degrees, so that in beds that strike north 60 degrees west the joints strike north 20 degrees east. They dip southeastward at steep angles.

They are well developed in zones of close folding and are most prominent where they cross a sharp roll in the bedding. The dip in the northern and western parts of the area is nearly normal to the average northwesterly structural plunge. They appear to be joints of extension, developed as a result of elongation of the rock-mass along the axes of folding. Because of this origin they must have formed late in the period of folding and possibly before the final stages. If this reasoning is correct, it is possible that the joints were formed somewhat before the crosscutting faults.

Joints are abundant in the southwest-dipping panel of thin-bedded argillites and quartzites that extends from near Miller Creek past the Victor mine. These thin-bedded rocks of diverse competency are jointed more continuously over a larger area than is the rule elsewhere, partly because of the character of the rocks and partly because of the major uniformity of the structural panel. Bedded faults and slips are common, and the joints are not very continuous on the dip. Some joints terminate on bedded-clay seams which may not represent actual faults so much as thin shaly interbeds which have been reduced to a form of gouge.

Another possible origin of the joints should be considered, even though proof is not forthcoming: that is, that they were produced in the same manner as has been postulated for the larger crosscutting faults, namely in response to the late shift in stress application which caused the down buckling along the granite margin. Analysis of the stress-strain relationship, which was probably under continuous modification, probably cannot be made, but it is not impossible that the buckling along the granite front may have been accompanied by general stresses that were relieved in part by joint formation at greater distances from the granite.

Cleavage.—The previous general discussion of cleavage deals sufficiently with the apparent principles involved, and the following remarks are specific.

The Payne recumbent fold on the southern slope of Payne ridge is composed of slates and some quartzitic and limy bands. East of the Slocan Boy workings nearly flat axial-plane cleavage is well developed, with closely related fracture cleavage involving minor offsets of beds along cleavage planes. Farther west, in the vicinity of the Payne workings, cleavage is bedded for the most part and is not parallel to the axial plane of the recumbent fold. Slaty cleavage is seen also abreast of and below No. 15 level, and much slate is seen at the old Payne mill-site on the abandoned K. & S. Railway grade.

Slaty cleavage is strongly developed locally between the Sylverite and Victor properties. Few outcrops are seen, but float of slate and phyllite points to a concentration of deforming forces in this area.

The argillites both north and south of the Queen Bess mine all possess incipient cleavage. It is bedded in the steeply dipping limbs, but it is also bedded on the crests of some minor sharp crumples.

Through the area generally, points of sharp flexure may be marked by a local development of slate which in some instances is rusty. In field mapping the local occurrence of slate, either in place or as float, may provide evidence of a sharp flexure which might otherwise be overlooked. Float in the form of rods or splinters is often produced by the intersection of slaty and bedding cleavage and may indicate the presence of beds at some angle to the average attitude nearby.

CHAPTER IV.—ECONOMIC GEOLOGY

Silver-lead-zinc mineralization occurs in well-defined lodes of either simple or complex outline. The gangue minerals consist of calcite, siderite, or quartz in various proportions, with quartz the least abundant as a rule. Some ore is a simple fissure-filling, and some is a breccia of rock fragments cemented by gangue and sulphide mineral. The orebodies vary widely in size, outline, and continuity.

Very little replacement ore is known, in spite of the fact that limestones and limy rocks are cut by several lodes. Some replacement ore occurs in the Altoona mine northwest of Sandon, and an indication of replacement ore occurs on the Dixie Hummer claim at the head of Wild Goose basin, where surface workings show mineralization in limestone that is not obviously related to a lode fissure.

LODES

The term lode is used here in the general sense that it is a structure known to be mineralized. It may consist of a single fissure or a zone of multiple fissuring and, at the most complex, a zone of variable fracture and shear. The term fracture refers to any crack or break in the rock, whereas fissure refers to a continuous fracture of considerable length and depth. Vein refers to the mineralized part of a lode, whether it be the full width of the lode, one of a series of fissures, or a zone of fracturing. The term vein is used only in a particular sense, referring to a specific tabular orebody or oreshoot which has been explored.

Classification of lodes is not attempted. Single-fissure lodes and complex lodes are the only qualifying terms used and are self explanatory. They are more or less synonymous with the small and large lodes and faults, although not strictly so. The large or complex lodes vary in form along their length, largely in response to variations in rock type and folded structure. Definitions descriptive of form are useful inasmuch as they may save words in referring to the form of a lode, but terms relating to process of formation are hard to apply. The form of a lode results from the interaction of a number of factors, of which as a rule few are obvious, and the writer believes that study of process is more important than description of form in the task of ore-finding.

In a preceding section the lodes have been discussed as crosscutting faults in relation to the general structure. Evidence was given that the faults were initiated during the closing stages of the period of folding, and it was presumed that they served as avenues for the ultimate relief of essentially the same stresses as those that produced the folding. The larger faults formed as complex zones of dislocation along which the direction and amount of movement varied as the faults passed through complexly folded strata. The faults did not slice cleanly across the structure but swung " into " it in places. The total amount of movement along the course of a single major fault was not everywhere restricted to the fault zone itself but probably followed bedding in places where fault and bedding were more or less parallel. Some movement is considered to have passed from crosscutting to tangential faults, or vice versa.

These concepts are considered essential to a proper understanding of the behaviour of the lodes, an understanding that is vitally important in problems of mine exploration and development. Mineral deposition was dependent upon conditions within the lode being at the time favourable, and these favourable conditions were in many cases a function of the appropriate relation between lode and bedded structure, and not a function of rock type alone.

The only attempt at subdivision of the crosscutting lodes is to divide them into large, intermediate, and small individuals. As indicated in a foregoing section, the concept that all lodes (faults) formed at much the same time and in response to the same general stresses may ultimately prove to be wrong, but it has been impossible for the writer to make any valid distinction between them, except on the basis of size. The terms large and small are relative only, but in one given area they do describe physical appearance and, roughly, the amount of movement. Although the width of a zone or the amount of gouge in it do not always constitute an accurate measure of the amount of movement on a fault plane, yet in general they do, as in comparison between lodes such as those on the Black Colt and Victor properties with a displacement of a few inches or a few feet, and the Carnation lode with a displacement of probably several hundred feet.

The smaller lodes strike about north 30 to 70 degrees east and dip steeply to the southeast, and the larger strike about north 45 to 90 degrees east and dip at an average angle of about 45 degrees to the southeast. Lodes of other orientation are known, but it is probable that most of these represent parts of larger lodes with an anomalous attitude, branches between major planes of movement, or simply mineralized bodies that have formed along bedding planes at or near a lode zone.

One lode attitude is steep, with a northerly strike. The Canadian, the Buffalo, and two lodes which intersect the Adams lode on Adams Peaks are in this class. The Canadian may and probably does constitute a connecting link between the Adams and Ivanhoe lodes. The actual movement on these lodes is not known, but the Buffalo has a horizontal component of movement of about 30 feet. More detail will be given in property descriptions, but at present the structural significance of these north-south lodes is not well known.

The Carnation section of the Standard-Silversmith lode system may be cited as an example of the larger lodes. It is a zone 50 feet or more wide of subparallel fractures, shears, and breccia sheets. It is remarkably continuous and free of offset, to judge from its apparent surface trace. In the 6500 (formerly No. 2) adit, it is followed completely through the mountain for half a mile without offset and is as much as 100 feet wide. On the surface, on the west fork of Tributary Creek, the zone is at least 50 feet wide and contains coarse calcite in lenses as much as 15 to 20 feet thick. The lode continues to the east through the Hope workings to the Silversmith. It is more complex in the Silversmith mine, where it rolls in and out of the structure and bears conflicting relations with tangential faults of major size; one strand on Silversmith No. 5 level, probably not the main break, contains up to 12 or 15 feet of quartz.

The larger lodes include the Queen Bess-Idaho, which apparently joins the Alamo, which, in turn, continues through the Standard. Another branch of the Standard passes through the Mammoth, Carnation, Mascot, Hope, Silversmith, and Richmond-Eureka; it branches to form the Minniehaha and possibly the Jennie. Another lode on the Oakland, southeast of the map-area, branches to pass flatly through the Wakefield to join the Carnation. The main branch of the Oakland is continuous with the Adams lode. The Adams and Ivanhoe probably merge east of the map-area, and the Adams appears to be one of the largest single breaks in the area.

These lodes form a partly connected system of tear faulting and are the largest known in point of view of structural significance; some of the largest orebodies in the area have been found in them.

Although the lodes may contain widespread gangue minerals, orebodies have been shown by past exploration to be greatly restricted. It is clear that, although the lodes served as channelways for mineralizing solutions, it was only locally within them that conditions favoured the formation of an orebody.

Many details of the lodes will be discussed in property descriptions, but some general comments are in order here, so far as generalization is possible. The following remarks are based on observations in accessible workings of all mines in the area and of many nearby mines, and on observations of outcrops. Unfortunately, many of the underground workings in the ore zones of all properties are inaccessible, and drifts are on only one element of a lode so full examination is never possible.

The large lodes consist typically of one major and several subsidiary breaks, although several breaks of nearly equivalent appearance have been noted. Locally, all movement, with the exception of subparallel small fissures, has channeled through a single break. The principal locus of movement is usually marked by a gouge zone, 1 to locally 10 or more feet wide, the amount of gouge depending in some instances on the character of wallrock and in others on the angle between the plane of the lode and the bedding.

The distribution of planes of fracture and of shear within the limits of the lodes does not appear to show a regional pattern. Attention was paid to the possible existence of a conjugate system of shearing and associated tensional fracturing, but none was recognized with certainty. The distribution of minor or subsidiary planes of fracture and of shear may in one ore zone constitute a systematic relationship, but the pattern is different in another ore zone. The pattern may apparently be related only to internal failure within the lode itself, but in some instances it is related to contiguous structure in the wallrocks or to an intersection with another lode or fault.

Deflections from the average attitude of a lode are usually related to variations in competency and in structural form of the rocks transversed. The most striking deflection is that of the Alamo lode to follow the steeply dipping limb of the Idaho Peak fold. The relatively flat attitude of the Wakefield lode is directly related to the panel of low dips through which it slices at an acute angle. It is noteworthy that although the strikes of bedding and of lode are at a large angle to one another, yet the lode flattens to pass through the beds at an acute angle to the bedding planes and elements of the lode locally follow the bedding planes. Any section of a lode with a very low dip is almost certainly related to relatively flat structure in the rocks traversed. In fact, the average dip of the lodes of about 45 degrees is an average of flat stretches related to flat structure and steeper stretches which are, possibly, indicative of the "normal" dip of the lode.

More important than the form of a lode is its effect upon the rocks traversed. The relative amount of shattering and of shearing has in many instances a direct bearing on the occurrence of ore. Little enough is known of this subject, but the following remarks sum up a few important points. By and large, harder rocks may shatter whereas softer rocks may shear along any one element of a lode, but within the full width of one of the larger lode zones there may be both shattering and shearing of the same rock, by virtue of the fact that total movement is distributed unequally along a number of fissures. In general, the main locus of movement is a gouge zone in which the rock, regardless of original character, has been ground to a pulp. The remainder of the lode may consist of subparallel gouge seams in essentially undeformed rock. If the lode is nearly parallel with the bedding there still may be a principal gouge seam, but the number of subsidiary gouge seams increases and intermediate bands of rock may be comminuted and mixed with gouge. Other relationships will be discussed under the heading of ore controls.

All the foregoing remarks have referred to the large lodes. The small lodes, besides being smaller, trend more northerly and dip at steeper angles. They are as a rule simple in outline and commonly consist of a single fissure or of a set of fissures resembling closely spaced joints. As already mentioned, no sharp line of demarcation can be drawn between lodes and joints, and it appears to be a fact that some small lodes are mineralized joints of virtually no displacement, and others are joints along which displacive movement was later channeled.

The small lodes may contain relatively little gouge and sheared rock. They are little affected by the bedded structures inasmuch as they tend to follow relatively straight courses and not to deflect into the bedding. Ore occurs in them in lenses or sheets, influenced to some degree by the character of the wallrock or by the deflection accompanying passage from one rock type to another.

The small lodes are, like the crosscutting joint system of which they are believed a part, localized preferentially in certain structures. They are numerous in panels of thinly bedded relatively uniform rock, especially in or near a fold or a pronounced roll. Such a situation exists on the Payne ridge where, in the axial zone of folding, numerous joints and lodes are developed. Another situation is the southwest-dipping upright panel of interbedded argillites and quartzites northwest of Sandon, including the Black Colt, Victor, and other mines.

The small lodes and the joints are greatly affected by bedded-clay seams. Some of these are tangential faults which follow the average dip and may show clear evidence of substantial movement, but others represent soft, thin beds which have been reduced to a clay or gouge by the interbed slippage which was a normal accompaniment of the folding. In sharp flexures the interbed slippage tends to be abnormally large, and many clay seams may be considered faults only if it can be proved that the movement along them was greater than the extreme of interbed movement in contiguous rocks. The erratic behaviour of some small lodes relative to the clay slips seems further proof that they originated as joints, because cases have been observed of a lode stopping on a clay seam, with nothing to indicate former continuity with any fracture beyond the seam.

Intermediate lodes are, as the term implies, intermediate in character between the large and small lodes. As the term refers chiefly to the width and appearance of a lode on which the amount of movement has not accurately been determined, it is a general term, used loosely.

On the Payne lode, and on others, the apparent amount of movement varies markedly from one point to another in some way that is not understood except that it is not due to hinging action. Besides the obvious possibility of an intersection with another fissure, the writer considers it possible that movement can be transmitted along bedding planes, to be deflected into a fissure wherever relative attitudes permit. This is not different in principle from the passing of a fracture into the bedding, with consequent distribution of movement along many bedding planes.

ORE CONTROLS

Ore minerals are widely distributed throughout the area. Lodes are large and small, and many small fractures which do not merit being called lodes contain gangue and sulphide minerals in varying amounts. Mineralization has been widespread, and it is probable that mineralizing solutions had access to virtually all crosscutting fractures.

Most known orebodies occupy restricted positions in the lodes. If the search for ore is to be conducted efficiently, therefore, beyond the finding of an outcropping orebody, recognition must be given to the various factors that have influenced mineral deposition.

Factors of ore control have been discussed in many texts and papers. The following discussion deals only with those factors which appear to be of importance in the Sandon area, as observed in the area and in the Slocan camp at large. No single factor can be said to " account " for the presence of an orebody and, in the general case, an orebody formed only because a combination of several factors produced a favourable site for the deposition of ore minerals.

In investigating the subject of ore controls, it is well to pay close attention to the observations and beliefs of operators, miners, and prospectors who, over the years, have jointly accumulated a large store of facts and ideas. At the present time very many workings, particularly stopes, are inaccessible, and at probably no time in the history of the camp were all existing workings open to inspection. Any investigator is, therefore, continually seeking information about important workings which are caved, and this information is mostly verbal because of the scarcity of maps and records. There emerge several general beliefs or legends, some of which are well founded, and some merely express the cumulative effect of events over a period of almost sixty years. It is hardly surprising that some beliefs on ore occurrence are found to be a blend of observations on geology, mining practice, metallurgy, and the market price of metals.

The type of wallrock may be a very important factor, and the belief that ore is found mostly in the quartzites is widespread. This belief is not, in general, sound for diverse reasons, among which is the fact that the term "quartzite" is used very loosely. Actually, much ore has been found in the common rock of the district, a mixture of argillites and quartzites of a wide range of purity, and ore in the true quartzites is limited, partly because these rocks appear to have been too " hard " and partly, perhaps, because they are of limited occurrence. Examples of ore in " porphyry " have been cited as evidence that the sills, dykes, and stocks are favourable wallrocks as such, but close investigation proves that they are favourable only in particular situations.

One of the controls most widely referred to is the cross-fracture. There are good grounds for belief that cross-fractures may have an important bearing on the formation of orebodies, but there is little agreement on just what the term implies. A cross-fracture appears to be any fracture at an angle to the course of a lode and may be either systematic or random in occurrence. Mineralized cross-fractures may consist of: Joints crossing a band of limestone (in which case the band of limestone is the lode), planes of conjugate shear, tension cracks, bedded offshoots of a lode, crossover or linking fractures within a lode. The term is not used in this bulletin because of the uncertainty of meaning.

Perhaps the most fundamental fact is that ore is not as a rule deposited in or associated with strong gouge. Ore is reported to occur " right in the gouge " in the Standard mine, but such an occurrence is rare. The second most fundamental fact, related to the first, is that orebodies other than those of fissure-vein type occur in zones of shattering rather than of shear. A third fact, stemming from the other two, is that in the larger lodes orebodies do not as a rule form in the main plane of movement but in or associated with minor or accessory planes.

These facts are so important that, although exceptions and contradictions may be encountered, they should be kept uppermost in mind in the search for ore. It is true that conditions seldom can be foretold in detail but, in the broader field of exploration, settings which are apt to provide zones of shattering along a lode may sometimes be recognized in advance.

In general, sites that are apt to be marked by clean-cut fractures rather than by gouge may be listed as follows, although they are not necessarily in the following order of importance:—

(1) Intersection zones of fissures, whether that involves two lodes, connecting links between lodes, or crossover links between branches of a single lode. In such situations a wedge of ground may shatter or a set of subsidiary fractures may form in or along the margin of the dominant fissure.
(2) Where a bedded lode jumps across the bedding.
(3) Where a lode crosses a band of rock of the right degree of competency that rock may be cleanly shattered, whereas other bands of lower competency may be reduced to gouge. On the other hand, if the rock is excessively hard a complex lode may, in crossing it, be reduced to a single gouge-filled fissure. The optimum competency depends largely on the strength of the lode or of any particular plane of it.
(4) Where a lode crosses harder rocks in a pronounced roll.
(5) Where a lode crosses bedding at a large rather than a small angle and, more than that, the direction of movement on the lode is across rather than with the bedding. By extension, this proposition applies to subsidiary fractures within a complex lode or adjacent to a main plane of movement and may apply specifically to the angular relation between tension cracks and bedding.
(6) Where there is a component of tension in the lode movement, with the result that a zone of relatively low pressure occurs.

Propositions 1, 2, and 3 need no amplification. They are general principles, perhaps no more applicable to the Slocan than to any other camp. Propositions 4, 5, and 6 may involve situations that are not at once apparent, and for that reason merit some analysis.

Proposition 4 describes a situation involving several factors. As a rule a major lode rolls sharply only to approach parallelism with bedding, the most obvious example being a flattening of a lode to pass obliquely through a flat panel, in spite of the fact that the strikes of lode and bedding are normally at a comparatively large angle. The rolls, whether formed along dip or strike or both, may be accentuated by passage from hard to soft rock. A roll in a lode may be accompanied by shearing in soft rock, whereas hard rocks may shatter in response to tangential stresses in the zone of curvature. Many pronounced rolls or deflections in a lode occur where the lode either follows around or is deflected by some particular structure. This is a matter of direct observation in some instances, but in others there is no obvious structural influence, and it is to be inferred that a roll may be initiated locally by some specific structure and may carry through into a completely different environment.

Proposition 5 refers to the general condition that dislocative movement is least likely to produce openings if directed along planes of bedding. A bedded lode may have a relatively large movement distributed along many bedding planes, or it may be localized along one or more soft beds which are reduced to gouge. It is recognized that dislocative movement may pry beds apart to form openings of some size, but such effects are as a rule local and rare. Even though the plane of dislocation meets the beds at a moderate angle, movement in the general zone of the dislocation may channel in and out of bedding, shattering the rock it is perhaps true, but often with the production of much gouge. If the dislocation is at a large angle, only a single or multiple plane of gouge may be produced, but there may also be a clean-cut shattering, providing the rocks are of the proper competency.

A good example of the effect of bedding-lode relations is seen in parts of No. 7 level in the Standard mine. The lode crosses the beds at a moderate angle in strike, and the lode movement appears to bleed off into the hangingwall rocks along numerous gouge zones which closely follow the bedding. The rock in this section of the mine is physically no less favourable than elsewhere, but the angular relation between the bedding and the lode is unfavourable.

The mere size of angle between planes of dislocation and bedding is not enough to account for differences in the nature of rock failure. It is the size of angle between the direction of movement and the bedding planes that is important. If a fault crosses bedding at right angles in terms of strike and the fault dips 45 degrees southeast, there is the same interplane angle whether the beds dip 45 degrees southwest or 45 degrees northeast. Further, if the movement on the fault is one of dip-slip alone, the angular relation between the line of direction of movement and the bedding is the same, whether the beds dip southwest or northeast. In the Sandon area, however, the lode-faults have a component of strike-slip as well as of dip-slip, and the direction of movement is easterly to southeasterly. It follows that stresses along the major lodes were relieved in a direction at a small angle to northeasterly dipping beds and at a large angle to southwesterly dipping beds. If the direction of lode movement makes a small angle with bedding the rocks are mashed and bedded-clay seams are common, whereas if the angle is large the rocks break cleanly and may shatter adjacent to the principal plane or planes of displacement (Fig. 8). This principle accounts for the fact that in several situations ore makes in a lode where it crosses the southwest-dipping beds in one limb of a fold and does not extend into the northeast-dipping beds on the complementary limb.

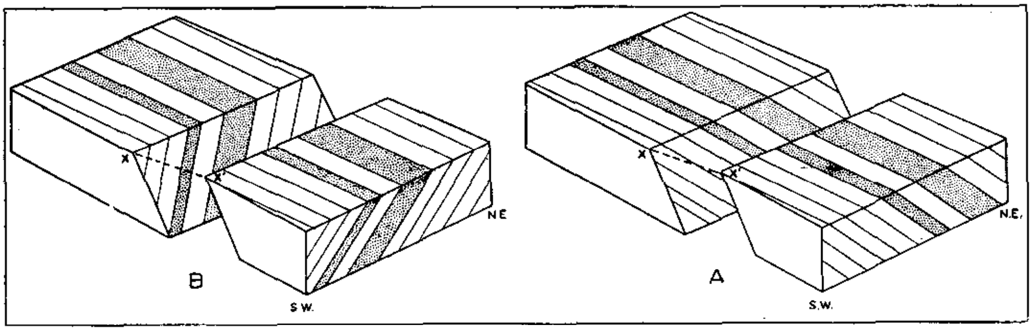


Fig. 8. Block diagram showing fault-bedding relationships.

The same principle is seen to affect ore deposition in a very different manner in the Noble Five mine. The normal movement on the lode, of hangingwall relatively down, tends to produce tension cracks in the hangingwall that dip steeply towards the lode. These tension cracks are commonly of little importance, but in one structural situation where thin brittle beds are approximately at right angles to the tension cracks the beds are much shattered and are mineralized sufficiently to provide stoping ground for several feet in the hangingwall of the lode. Although the character of the rock contributed to the formation of ore, it was the favourable structural situation that was the dominant control.

Proposition 6 refers to a much quoted fact that deflections from the average course of a lode in one direction are more apt to contain ore than those in another direction. The explanation commonly given is that movement between the walls of an irregular fracture produces physical openings (favourable) or pressure areas (unfavourable). The concept of the formation of physical openings is not a sound one, particularly in the case of the larger lodes in the Sandon area, on which there has been a relatively large amount of movement under considerable pressure, and a sounder explanation lies in the strain relationships of the rock-mass. A lode formed by shearing is, when viewed broadly, a plane of principal shear, to which is related a complementary plane of shear and an associated plane of tension. If a part of a lode follows nearly the ideal course of the plane of tension there is an element of tension in that part and, although there may be no physical openings and no actual tension cracks formed, there is a zone of lower containing pressure along which mineralizing solutions have found readier access.

Work by J. W. Ambrose in the Rambler mine has shown that ore is positively related to acidic sills because of their effect on the course of the lode. The steeply dipping lode, crossing the bedding at a moderately large angle, is deflected by each sill so as to pass through it more nearly at right angles, because of the relatively greater competency of the sill. The amount of movement on the lode is large enough to produce substantial displacement of the sills, but not so large as to prevent the deflection from remaining an integral part of the lode. It is interesting to note that such a situation may be met in many places, but, unless the deflection (a sort of refraction, actually) is towards the ideal tensional direction, the deflected section of the lode may not favour ore deposition.

In other properties igneous rock may be definitely unfavourable. In the Monitor a steep lode of small displacement crosses steep beds at a large angle. The lode zone may be several feet wide in the sediments but, in crossing an acidic sill, it contracts to a gouge zone a few inches to a foot or so wide that contains no ore.

OREBODIES

Orebodies occur either in fissures or in zones of shattering along the courses of the lodes. They may occupy the full width of a single-fissure lode or part of the width of complex lodes.

The size, form, and mineral content of orebodies vary widely. A large orebody may represent filling of a complex of fissures and fractures, in part breccia-filling and in part fissure-filling. The sulphide minerals are accompanied by more or less waste matter, in the form of gangue minerals or wallrock. Massive or nearly massive galena or sphalerite, or both, tend to occupy clean-cut fractures, but lenses, pods, and veins of relatively massive sulphides may occur anywhere within a larger orebody.

In the property descriptions the size and physical appearance of orebodies are described. The structural setting is described wherever possible, and there is discussion of the processes which have contributed to the formation of orebodies. It is difficult to summarize these remarks, here or elsewhere, because in no case is there a single controlling factor to which an orebody can be attributed. Rather, an orebody is where it is because several favourable factors have combined to form a site for the deposition of ore.

MINERALOGY

Cairnes, in his study of the Slocan camp, made many observations on the mineralogy and did much microscopic work. At that time many more workings were accessible, so there was better opportunity to study ores than at the present. The present bulletin stresses structure, and no detailed study of the mineralogy was attempted by the writer. The reader interested in details of mineralogy of the ores should consult Memoir 173, pages 118 to 132, and Memoir 184 for information which may be contained in the descriptions of individual properties.

Gangue minerals are calcite, siderite (spathic iron), and quartz. Other minerals are rarities. Quartz, on the average, is least abundant but locally is an important constituent of an oreshoot. On No. 5 level of the Silversmith mine an unmineralized quartz vein is locally more than 10 feet wide. Calcite forms lenses 15 to 20 feet thick in the Carnation lode and may be the dominant gangue mineral in some orebodies. Siderite is the most abundant in some properties.

These three gangue minerals, singly or together, fill fractures and fissures or cement zones of brecciation. Their relation to the ore is somewhat variable, inasmuch as there has been variation in the order of deposition. Cairnes (1934, pp. 91–95) gives an excellent summary of the evidence of composite mineralization. The field evidence points to a complex period of deposition in which the ore minerals, later than most of the gangue, were deposited before movement on the lodes had ceased, and before all gangue minerals had been deposited.

The principal ore minerals are galena and sphalerite, with sphalerite the more widespread. Grey copper (and, less often, ruby silver) occurs in many ores in small amounts. It is commonly associated with galena and in a few instances with sphalerite. Other sulphide minerals, not as a rule abundant, include pyrite, chalcopyrite, pyrrhotite, and arsenopyrite.

Galena ranges from steel-grained to coarsely cubic in texture. As a rule silver does not favour the finer-grained varieties. Galena of gneissic texture is common and provides evidence of movement contemporaneous with its deposition.

Sphalerite is medium to dark-brown in colour and is the common sulphide in the area, occurring in massive veins, disseminations, stringers, and as scattered single grains. There is sufficient cadmium in the zinc concentrates from some ores to be paid for by the smelters. A small amount of tin has been found in several zinc ores. It has long been known in the Payne ore, and random samples of sphalerite from the Hartney in recent years showed as much as 0.2 to 0.3 per cent tin. It is present in sphalerite from the Lucky Jim, Mammoth, and other properties. A considerable amount of investigation was done on Lucky Jim ore and concentrates during 1942 and 1943, but the tin was in too small a quantity and was separable with too great difficulty to be commercial. Isolation of the tin-bearing mineral was not satisfactory, owing to the fineness of grain, but although minute amounts of cassiterite may be present the tin apparently occurs for the most part as stannite.

Oxidation of ore was an important consideration in early mining in the district. Ore found near the surface was relatively low in zinc and high in silver compared with the unoxidized portion of the same orebody. No studies were made at the time of mining, and figures for bulk shipments provide the only available data on metal content. No oxidized ore has been mined for many years.

The amount of silver in an ore may contribute greatly to its value. Some closely sorted galena may assay 200 ounces in silver and some may assay a tenth as much. As a rule, careful visual study of most ores will reveal at least an occasional grain of grey copper, and the ores richest in silver contain the most. Ruby silver may also be present in small grains, but positive identification of it is difficult except in the laboratory. Much of the grey copper is intimately associated with the galena, but not universally so, and locally it may be associated with sphalerite.

A common expression is that a certain ore contains so much silver to the per cent of lead. This is often a useful concept but not always an accurate one. Some galena is probably truly argentiferous, but microscopic study shows much of it to contain tiny grains or blebs of grey copper and other silver-bearing sulphides sufficient to account, apparently, for all or most of the silver in the ore. If the silver-bearing sulphides are closely and uniformly associated with the galena then the ratio of ounces of silver to the per cent of lead has a real meaning, but if not it is an approximation which may at times be very misleading. Studies of carload shipments from some of the old properties show that the silver:lead ratio could be remarkably uniform, notably in ore shipped from the Ruth mine prior to 1900. The records from some other mines show that the ratio of silver to lead was much more variable.

METAL DISTRIBUTION

The relationship between lead, zinc, and silver has long been a matter of very great interest to all miners in the district. Silver-bearing and zinc-free lead ore has been sought from the time of the first discovery and, although galena and sphalerite are easily separable by modern milling methods, silver-lead ore is still the more valuable.

In the early days, zinc had no commercial value, and sphalerite was removed by cobbing or by gravity concentration and was wasted. In later years, zinc had value, but serious penalties were attached by the smelters to zinc content in the lead ore. Some mixed ores were non-economic despite the theoretical value of the contained metal. Still later, modern selective flotation made possible the relatively clean recovery of lead and zinc concentrates. At present the shipper's problem is that much of the zinc that goes to the lead smelter is wasted, and zinc ore is only acceptable above a minimum grade, hard to attain by hand sorting.

It follows that any information or any theory that may lead to the discovery of silver-lead ore, or to the discovery of silver-lead shoots in mixed orebodies, is of great importance. This applies to the search for any ore on any scale. Data for the formulation of a theory of distribution must be gained by direct observation or from the study of reliable records regarding metal distribution.

Unfortunately, opportunity for direct observation is limited. Many workings are inaccessible, and in the few currently accessible stopes it is almost impossible to estimate the character of ore that was mined. Records of grade of ore in individual oreshoots and stopes are so meagre as to be practically valueless, and about all that can be done at the present is to scan yearly production figures and endeavour to estimate from what part of a mine they came. Verbal reports from individuals are sometimes reliable but sometimes are not, and it is a fact that a single ton of massive galena will bulk as large in an individual memory as several tons of equally massive sphalerite.

The common belief in the camp is that the ore in general is rich in silver and lead at or near the surface, and increases in zinc content with depth. It is often stated of an old mine that "as they went down, the orebody turned to zinc and quit." This is true statistically, in terms of numbers of properties in which relatively high-grade material was mined at or close to surface and exploration at depth was disappointing. It is true also that zinc is more widespread than lead, and that the margins of orebodies, statistically, contain more zinc than lead. It is a fact that, the relative values of zinc and lead ore being what they have been, many working-faces have stopped while sphalerite was showing, but seldom have they stopped when galena was visible.

In a former bulletin the present writer (1945, pp. 23, 24, 41) showed that the change with depth from silver-lead-zinc ore to dominantly zinc ore in the Whitewater mine was a function of a marked change in geological environment and that a similar change in the Lucky Jim mine was possibly due to a change in the nature of fracturing. The Payne first shipped sorted silver-lead ore and later produced lead concentrates, and in the last two years of operation, before closing in 1903, produced a large amount of zinc concentrates. It might be believed, and is by many, that this record proves that the lower part of the orebody was zincy. Actually the best reconstruction of Payne history is that in early operations zincy ore was rejected and left in place as much as possible, or left as backfill after underground sorting. In the last stage of milling, old stopes were cleaned out and portions of the dumps were milled, and although some of this material may have come from lower levels most of it came from the main ore zone.

The belief of many in the camp that the zinc:lead ratio of most orebodies increases in depth has been stated more precisely by Cairnes, who recognized evidence of mineral zoning on a large scale. His treatment of the subject (1934, pp. 110–118) shows that he considered thermal gradient to be the most important controlling factor in the deposition of different types of ores. He believed the gradient to be steep, and that most silver-lead and silver-lead-zinc deposits were formed within a zone 1,000 to 2,000 feet thick. Since the boundaries of this zone are obviously not plane surfaces he formulated the "belief that mineralization at least of the silver-lead and silver-lead-zinc deposits formed in an undulating zone which over considerable areas accidentally parallels the present surface" (1934, p. 110).

Cairnes devoted much space to description of types of ore which he listed in terms of increasing temperature, evidence of which is conclusive, and is in full accord with generally accepted concepts of thermal scale. An ideal sequence grades from silver through silver-lead mineralization to dominantly zinc and finally to siliceous, pyritic mineralization. He believed this sequence to be represented in the thermal zone already referred to, and that the concept of mineral zoning was generally applicable throughout the Slocan camp.

The present writer agrees that some veins may show decrease in silver and lead and increase in zinc with depth but disagrees that the pattern of mineral distribution is such as to prove that a steep thermal gradient exists in as short a vertical range as that postulated by Cairnes. He has no quarrel with the concept of mineral zoning as such, nor with the importance of thermal gradient, inasmuch as different metals have demonstrably been deposited at different temperatures, but recognizes the fact that many orebodies in the Slocan are limited by structural conditions which have nothing to do with temperature or with depth below the present surface. In the Sandon area he sees no evidence for a temperature control of mineral deposition, but abundant evidence for structural control. The structural environment of lodes in the Sandon area is such that continuity of orebodies through great vertical ranges is not to be expected. On the other hand, there appears to be nothing to preclude the recurrence of favourable structural conditions at greater depths in the Sandon area and in most of the sedimentary rocks of the Slocan.

Changes in relative metal content can be seen, and can be deduced from reliable sources in many places. Small oreshoots have been observed to vary widely amongst themselves in terms of metal content within a space so small that thermal gradient cannot have been a deciding factor in the type of ore deposited. Rather, deposition of ore took place in sites that were structurally favourable, and the mineralogy of one site differed from another nearby for reasons that can conceivably include rate of passage of solution, confining pressure, or chemistry of wallrocks, none of which can be evaluated satisfactorily.

The writer has given considerable thought to the subject of the relative abundance of lead and zinc and the reasons why some oreshoots contain predominantly lead and others predominantly zinc. It is a recognized fact that sphalerite is a commoner mineral than galena, a fact that is sometimes overlooked owing to the fact that the net value of lead ore is higher than that of zinc ore and the fact that most of the silver in an ore is associated with the galena. If the two minerals were of equal value and specific gravity and were comparably associated with silver, the point of view of both miners and geologists would change, but as it is the economic factor strongly affects judgment.

To sum up what appears to be generally true, the following is put down as the result of direct personal observations in the Slocan camp and a culling of all reliable information. Galena is not only less abundant but is more restricted than sphalerite. The two minerals may be completely intergrown, and it is difficult to find a specimen of one completely free of the other, yet galena tends to be more segregated than sphalerite with respect to other mineral or rock matter in a lode. There is a tendency for galena to be deposited in greater relative abundance in the more open fractures, or in zones in which the confining pressure was relatively low, from solutions which supposedly carried an adequate amount of both minerals. In several important orebodies almost massive galena is reported to have occurred in masses of major size in or near the central part of the orebody. It appears to be a fact that, with the exception of the original Lucky Jim workings and the Bell mine in Jackson basin, vein widths of relatively massive galena have exceeded those of relatively massive sphalerite.

In general, a good summary of the situation is, in the words of R. H. Stewart, who has had fifty years of experience with the camp, " the lead tends to be central in the orebodies and the zinc peripheral." From the miner's point of view an oreshoot " gets ragged and zincy before it quits " in any direction.

In the Slocan camp in general and in the Sandon area in particular the relative abundance of lead and zinc is believed to be a problem of segregation rather than of zoning. Of the many factors affecting deposition of galena and sphalerite from solution, that of pressure was probably of great importance, namely effective pressure of the particular environment and not that theoretical confining pressure which is a function of depth alone.

As exploration proceeds, orebodies will be bottomed and probably will be zincy in the bottom parts. New orebodies will be found, it is to be hoped, and there seems no reason why other environments equally favourable to ore deposition do not exist, both laterally and at depth from those known at present. There seems no valid reason why these postulated orebodies should differ appreciably in tenor of metals from those already mined.

CHAPTER V.—DESCRIPTIONS OF PROPERTIES

In the following descriptions of properties, emphasis is placed upon the lodes and their geological settings rather than on property holdings. Some property has remained intact throughout the years, but there has been much change of ownership and many regroupings. Historical summaries accompanying the individual descriptions record in piecemeal fashion most of the company activity in the area, but sketches of several of the companies with extensive holdings are given as separate reports. These are Kelowna Exploration, Kootenay Belle, Silver Ridge, Western Exploration, and the Clarence Cunningham activity of former years. To aid reference the index lists the company holdings of present and former groups.

Figure 9 shows the larger blocks of ground held by the principal companies and lists Crown-granted and surveyed claims only. Claims are not enumerated in the property descriptions.

The notes on properties are arranged alphabetically, according to the property name generally used in the camp. Thus the name " Mascot " is retained for those workings on the former Mascot property which is now part of a much larger holding. Similarly the name " Victor " is retained for the principal lode and workings on the Violamac property. All but a few of the smallest properties are named on Figure 2, which shows all adit portals, most underground workings, and the courses of the principal lodes.

Maps of some of the more extensive workings accompany this chapter. The location and extent of other workings can be studied on Figure 2 sufficiently well, it is hoped, to illustrate the descriptions. Because of the scale of reduction of Figure 2, it was not possible to show all levels of the more extensive mines, but those which are shown are numbered according to the usage of each mine.

KEY LIST OF SURVEYED MINERAL CLAIMS TO ACCOMPANY FIGURE 9

215.	Queen Bess	C.G.
404.	Wanacott	C.G.
458.	Young Dominion	C.G.
472.	Idaho	C.G.
473.	St. John	C.G.
478.	Cumberland	C.G.
481.	Wonderful	C.G.
482.	Bluejay	C.G.
497.	Two Jacks	C.G.
498.	Mountain Chief	C.G.
499.	Payne	C.G.
500.	Maid of Erin	C.G.
541.	Washington	C.G.
545.	Slocan Star	C.G.
546.	Jennie	C.G.
547.	Slocan King	C.G.
548.	Great Western	C.G.
565.	Western	C.G.
572.	Anaconda	C.G.
575.	Carnation	C.G.
578.	Minneapolis	C.G.
596.	Day Dawn	C.G.
598.	Day Dawn Fr.	C.G.
626.	Slocan Boy	C.G.
674.	Buffalo	C.G.
698.	Britomarte	C.G.
699.	Chamblet	C.G.
727.	Lowdown	C.G.
737.	Alamo	C.G.
738.	Ivy Leaf	C.G.
742.	Elgin	C.G.
743.	Ivanhoe	C.G.
747.	Twin Lakes	C.G.
748.	Morn Fr.	C.G.
749.	V. Fr.	C.G.
750.	Adams	C.G.
751.	Brandon	C.G.
752.	Slater	C.G.
753.	Great Eastern	C.G.
754.	Wyoming	C.G.
840.	Despair	C.G.
841.	Ruth	C.G.
842.	Hope	C.G.
845.	Ruth Fr.	C.G.
859.	Elkhorn	C.G.
919.	Carbonate King	C.G.
920.	Snowstorm	C.G.
1009.	Emma	C.G.
1010.	Silversmith	C.G.
1017.	Ouray Fr.	C.G.
1018.	Return	C.G.
1247.	Read	C.G.
1248.	Tenderfoot	C.G.
1250.	Democrat	C.G.
1251.	Conductor	C.G.
1252.	Rabbit Paw	C.G.
1262.	Rienzi	C.G.
1263.	Wild Goose No. 2	C.G.
1264.	Corinth	C.G.
1265.	Mocking Bird	C.G.
1308.	Lookout No. 2	C.G.
1309.	Columbus	C.G.
1405.	Majestic	C.G.
1461.	Miantonomah	C.G.
1462.	Comet	C.G.
1463.	Defender	C.G.

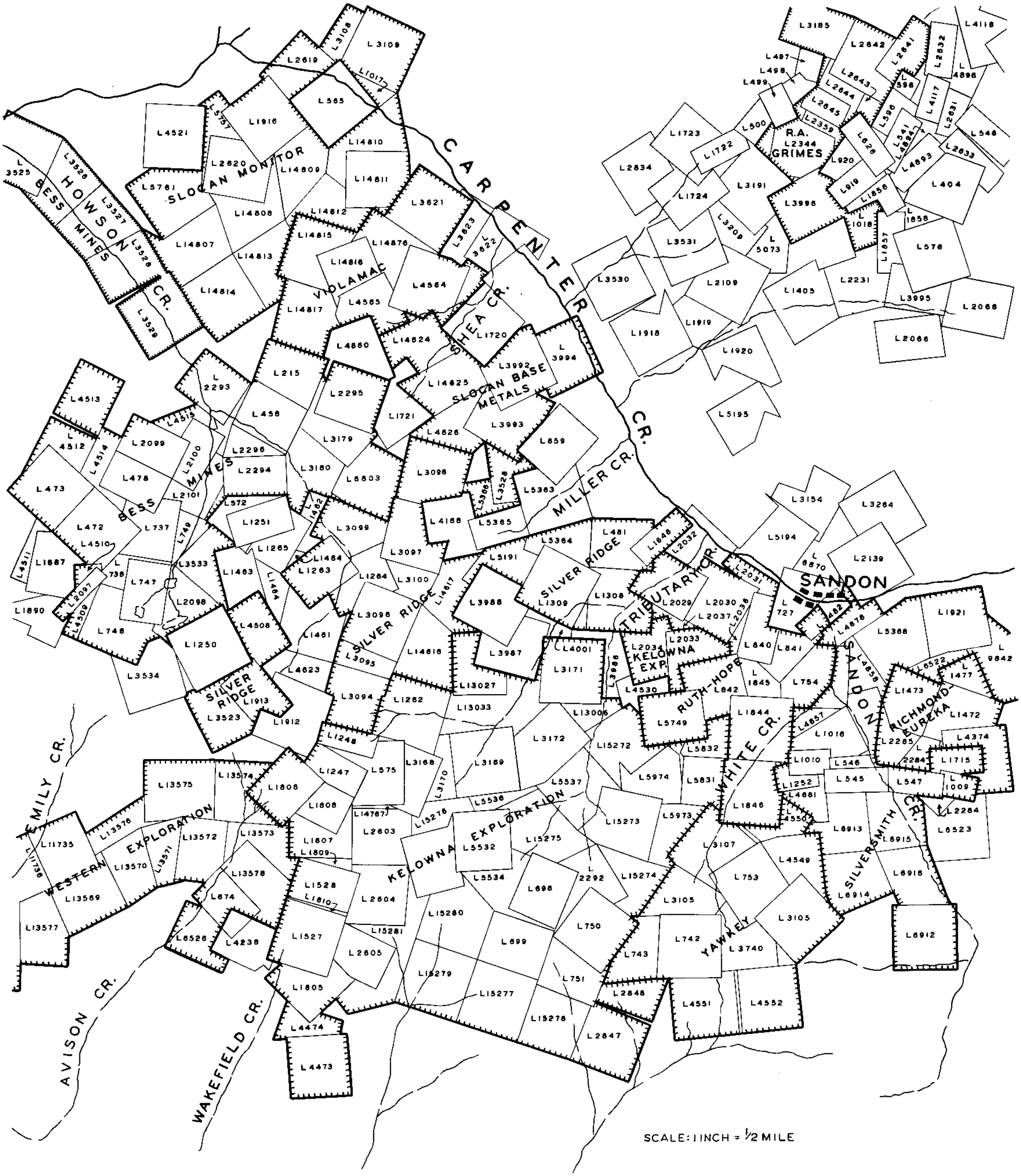


FIG. 9. SURVEYED MINERAL CLAIMS IN THE SANDON AREA AND OWNERSHIP OF THE LARGER GROUPS.

1464. Daybreak	C.G.
1472. Richmond	C.G.
1473. Starview	C.G.
1477. Empire	C.G.
1527. Wakefield	C.G.
1528. Cazabazua	C.G.
1648. Early Bird	C.G.
1715. Hidden Treasure No. 2	C.G.
1720. Hinckley	C.G.
1721. Black Colt	C.G.
1722. Reciprocity	C.G.
1723. Ocean	C.G.
1724. Lillian No. 4	C.G.
1805. Ottawa	C.G.
1806. Jenny Lind	C.G.
1807. Beaver	C.G.
1808. Robertson	C.G.
1809. Cazabazua Fr.	C.G.
1810. Wakefield Fr.	C.G.
1844. Lone Star	C.G.
1846. Blue Grouse	C.G.
1856. Lalla Rookh	C.G.
1857. Sapphire	C.G.
1858. Gem	C.G.
1887. Silver Bell	C.G.
1890. Sandow	C.G.
1912. Dixie Hummer	C.G.
1913. Mollie O	C.G.
1916. Monitor	C.G.
1918. Altoona	C.G.
1919. Bow Knot	C.G.
1920. Tawanda	C.G.
1921. Slocan Belle	C.G.
2029. Yuma	C.G.
2030. Aurora	C.G.
2031. Durban	C.G.
2032. Nighthawk Fr.	C.G.
2033. Badger State	C.G.
2034. Dorothy	C.G.
2066. General Sheridan	C.G.
2068. Rushford	C.G.
2097. Continental	C.G.
2098. Clarence	C.G.
2099. Daisy	C.G.
2100. Eastern	C.G.
2101. Cape Fr.	C.G.
2109. Emporium	C.G.
2139. Belt	C.G.
2231. Unexpected	C.G.
2284. Eureka No. 2	C.G.
2285. Mineral Hill	C.G.
2292. Midnight Fr.	C.G.
2293. Concord	C.G.
2294. First Extension	C.G.
2295. American Girl	C.G.
2296. Young Dominion Fr.	C.G.
2344. Good Day	C.G.
2345. Good Day Fr.	C.G.
2359. Tramp Planet Fr.	C.G.
2603. Dalkeith	C.G.
2604. Kelso	C.G.
2605. The Ben	C.G.
2619. Hustler Fr.	C.G.
2620. Portland No. 5	C.G.
2631. Charlotte	C.G.
2632. Herbert	C.G.
2633. Lone Jack	C.G.
2641. Dominion	C.G.
2642. St. Keverne	C.G.
2643. Felix No. 3	C.G.
2644. O.B.H.	C.G.
2645. Exeter	C.G.
2646. Payne Fr.	C.G.
2834. International Fr.	C.G.
2847. Sarah B	C.G.
2848. Katie D	C.G.
2849. Hilltop Fr.	C.G.
3094. Monday	C.G.
3095. Monday Fr.	C.G.
3096. Sunshine	C.G.
3097. Yakima	C.G.
3098. Oregon	C.G.
3099. Mine	C.G.
3100. Kasa Fr.	C.G.
3105. Admiral Nelson	C.G.
3107. Kitchener Fr.	C.G.
3108. Nellie Fr.	C.G.
3109. Ouray	C.G.
3154. Victoria No. 6	C.G.
3168. Violet	C.G.
3169. Evening	C.G.
3170. Violet Fr.	C.G.
3171. Minnie Ha-Ha	C.G.
3172. Jennie	C.G.
3179. Queen Fr.	C.G.
3180. Mentor Fr.	C.G.
3185. Telephone	C.G.
3191. Big Timber	C.G.
3192. Big Fr.	C.G.
3209. Redress Fr. No. 2	C.G.
3258. Sandon Chief	C.G.
3264. St. Charles	C.G.
3523. Opatunka	C.G.
3524. Thursday Fr.	C.G.
3525. Detroit	C.G.
3526. Rutland Fr.	C.G.
3527. Rugby Fr.	C.G.
3528. Cedar	C.G.
3529. Currant	C.G.
3530. Silver Bill	C.G.
3531. Mercury	C.G.
3533. Mary S. Fr.	C.G.
3534. Chetopha	C.G.
3621. Cinderella	C.G.
3622. Medford	C.G.
3623. Keyser Fr.	C.G.
3740. Bendigo	C.G.
3741. Bendigo Fr.	C.G.
3986. Ireland	C.G.
3987. New England	C.G.
3988. Scotland	C.G.
3992. Consolidated Verginia	C.G.
3993. Elk	C.G.
3994. Speculator	C.G.
3995. Erie	C.G.
3996. Silver Reef	C.G.
4001. Halifax Fr.	C.G.
4116. Cross Roads	C.G.
4117. Stormount	C.G.
4168. Cuba	C.G.
4238. Hellena	C.G.
4374. Summit	C.G.

4473. Edinburgh C.G.
4474. Essex Fr. C.G.
4508. Fairy C.G.
4509. Tonka Fr. C.G.
4510. Mazeppa C.G.
4512. Baldwin C.G.
4513. Amazon C.G.
4514. High Ore Fr. C.G.
4515. Thistle C.G.
4521. Newport C.G.
4530. Irene Fr. C.G.
4549. Tom Bowling C.G.
4550. Big Kanawka C.G.
4551. Ben Bow C.G.
4552. Triumph C.G.
4564. Lone Batchelor C.G.
4565. Victor C.G.
4681. Heber Fr. C.G.
4849. Triumph Fr. C.G.
4856. Morning Sun C.G.
4858. Echo Fr. C.G.
4878. Silver Star Fr. C.G.
4880. Palmita C.G.
4893. I.C. C.G.
4894. Washington Fr. C.G.
4896. Major Fr. C.G.
5073. Dumdum Fr. C.G.
5191. Miller Creek Fr. C.G.
5194. Galt C.G.
5195. Donnelly C.G.
5363. New Springfield C.G.
5364. Wonderful Fr. C.G.
5365. Sampson C.G.
5366. I.X.L. Fr. C.G.
5368. Ophir No. 3 C.G.
5532. Grace C.G.
5534. Little Stella Fr. C.G.
5535. Minnie C.G.
5536. Margaret Fr. C.G.
5537. Tornada C.G.
5749. Sunrise C.G.
5757. Friday Fr. C.G.
5761. Keewatis C.G.
5831. Orient Fr. C.G.
5832. Diamond Fr. C.G.
5973. Oom Paul C.G.
5974. C and K C.G.
6522. Eva Fr. C.G.
6523. Hillside C.G.
6526. Evelyn C.G.
6532. Carbajal Fr. C.G.
6803. Second Extension C.G.
6870. Marie Fr. C.G.
6912. Pembroke C.G.
6913. Bella Donna C.G.
6914. Millie C.G.
6915. Minnesota C.G.
6916. Whistle Fr. C.G.
8105. Morning No. 111 C.G.
9842. Edith Fr. C.G.
11735. Minoru C.G.
11736. Goodwin C.G.
13006. Minnie Ha-Ha Fr. C.G.
13027. Western Fr. No. 2 C.G.
13033. Western Fr. C.G.
13569. Mowich C.G.
13570. Monarch Fr. C.G.
13571. Monarch C.G.
13572. Mammoth C.G.
13573. Moose C.G.
13574. High Ore C.G.
13575. Hercules C.G.
13576. Hecla C.G.
13577. Tram C.G.
13578. Gem Fr. C.G.
14616. Peggy Fr. C.G.
14617. Kathie Fr. C.G.
14623. Minnesota Fr. C.G.
14624. Silver Ridge C.G.
14625. Silver Ridge Fr. C.G.
14626. G. Fr. C.G.
14767. Bay Fr. C.G.
14768. Amy Fr. C.G.
14807. Taw Fr. C.G.
14808. Horn Fr. C.G.
14809. Min Fr. C.G.
14810. West Fr. C.G.
14811. Cork C.G.
14812. Lope C.G.
14813. Tip C.G.
14814. Guf C.G.
14815. Hidden Treasure C.G.
14816. Clair C.G.
14817. Provident C.G.
14876. Archie C.G.
14877. D. Fr. C.G.
15272. Boss Fr.
15273. Best Fr.
15274. Basso Fr.
15275. Blimp Fr.
15276. Blot Fr.
15277. Amber.
15278. Anchor Fr.
15279. Abner.
15280. Alta Fr.
15281. Alma Fr.

Adams

The Adams showings are on Adams Peak, and the workings are on the northern and southern slopes. The ground is part of the holdings of Kelowna Exploration Company Limited. The Adams, Brandon, and Britomarte lodes were discovered very early in the history of the camp and were mentioned in some of the earliest reports. The details of the earlier work are not available, however, and it is not clear now, reading the reports, what lode was being referred to. There was probably some production from these lodes, but there is no positive record, and a small part of the production credited to the adjoining Canadian lode may have come from the Adams.

The present discussion refers to the Adams as the dominant lode of east-northeast strike and southerly dip, and the north and south Brandon lodes as those that strike nearly north, on either side of the Adams. The Adams is considered to be one of the largest lode-faults in the area and of great structural importance.

Adams Peak is, structurally, at the change from the regional northwest strike to a northerly strike. Toward Silverton Creek and the granite, the northerly strike swings in a broad arc to a northeasterly strike. Farther to the west the change in strike is more abrupt, in sharply down-buckled strata. To the east, beyond the map boundary, the strata are not buckled but pass into a prominent northwest-striking re-entrant in the granite (*see* Fig. 5). On the northeastern slopes of Adams Peak the strata maintain a steep, uniform easterly dip, but on the northwestern slopes they are sharply folded. There is an abrupt separation between the folded and unfolded rocks caused in part by faulting, but accentuated by irregular failure of a prominent intervening band of black argillites. As elsewhere stated (p. 42), it is probable that the Adams Peak folding is related, directly or indirectly, to the large recumbent dragfold on Idaho Peak. The structure on the steep north face of Adams Peak is hard to decipher, and there is no counterpart of it on the south slope south of the Adams lode.

The Adams lode has been traced to the southwest for most of the distance to the Oakland by noting discordance in strata, and undoubtedly it passes through the Oakland property, on which there is a prominent lode zone. To the east it passes into the basin at the head of White Creek, where there are few exposures, and apparently is represented in a series of old workings on the ridge beyond, at an elevation of about 6,400 feet. The Adams and Ivanhoe lodes probably merge somewhere east of White Creek.

Nothing is positively known of the Adams lode in the valley of Sandon Creek, east of the area, but it may be represented by a prominent zone of shearing and brecciation that crosses the high ridge between Sandon and Cody Creeks.

The Adams lode is a fault of major displacement. Strata north of the lode cannot be matched lithologically nor structurally with strata to the south. The displacement cannot be measured, but it must be greater than 1,000 feet. On the ridge between Sandon and Cody Creeks the structure north of the presumed Adams lode does not match the large and relatively simple recumbent fold clearly visible on the south side. The structure on the high ridge at the head of White Creek is anomalous and the lithology is not that to be expected from a moderate shift of hangingwall down and east. The direction of movement on the Adams lode has not been positively determined, but it is presumably the same as that on other major lodes, namely hangingwall down and to the east.

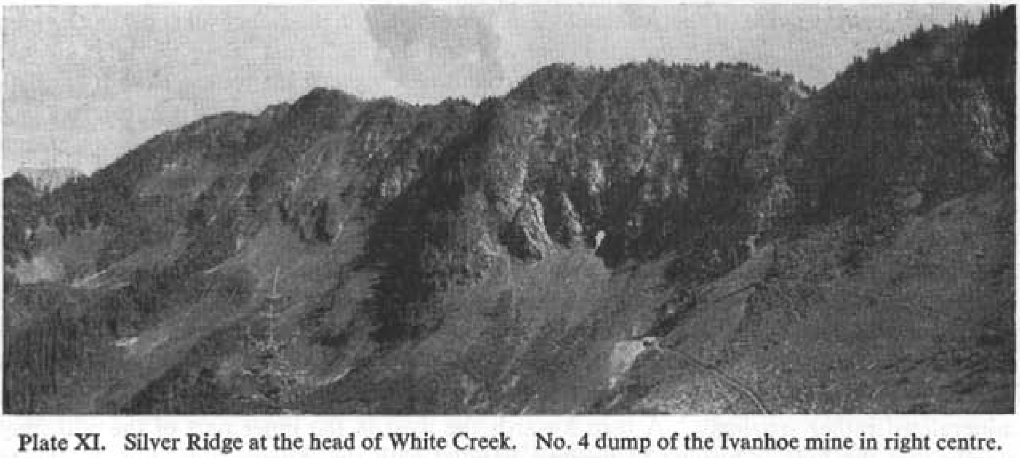


Plate XI. Silver Ridge at the head of White Creek. No. 4 dump of the Ivanhoe mine in right centre.

The relation between the Adams, Ivanhoe, Canadian, and the Brandon lodes is not clear. The main fact is that the Adams is the dominant break, a fact not so apparent by study of the lode itself but deduced from the amount of displacement along it. The Ivanhoe lode is subparallel and is a large fault zone with an apparent displacement of hangingwall down and east. It meets the Canadian lode at the crest of the ridge and is not recognized with certainty south or west of that point. The Ivanhoe appears to converge on the Adams lode to the east and presumably merges with it, perhaps in the basin of White Creek.

The Canadian is a steep lode, with a northerly to northeasterly strike, seen at the ridge crest and 100 feet or so lower on the north and south slopes. A northeasterly lode zone, imperfectly exposed on the south slope, may represent a branch of the Canadian, the Ivanhoe lode, or a connecting link between them. The Canadian is itself probably a connecting link between the Adams and Ivanhoe lodes and, if so, was probably initiated as a tensional break, although there is no apparent evidence of tensional character in the lode as it can now be seen.

The two Brandon lodes have a north to northeasterly strike. The one south of the Adams lode is seen only as an oxidized zone at the surface and the northern one is seen in two adits. The general area of intersection of these lodes with the Adams is sheared and brecciated. On the basis of attitude, they are similar to the Canadian and possibly, like it, were initiated as tensional breaks, although shearing stresses were later channeled along them. In any event, the Brandon lodes are subsidiary to the Adams lode.

Reduced to the limit of apparent simplicity, the lode pattern in this vicinity consists of the dominant and large Adams, with the subparallel Ivanhoe merging with it to the east. The Canadian is a steep cross-link between them, as is perhaps the south Brandon. The north Brandon is a lode subparallel to these latter and similar in origin, but extending to the north of the Adams lode.

The Adams lode crosses the ridge crest diagonally as a zone of shearing and brecciation about 30 feet wide. A caved adit on the southwest side of the ridge, about 200 feet below the crest, shows small amounts of quartz and calcite on the dump and a little sphalerite and galena. Another caved adit farther to the southwest, not shown on the map, is the site of a small spring. The actual lode is not seen on the southwest slopes.

The lode crosses a steep gully on the north slope a short distance below the crest. Strong shearing on an excessively steep slope makes a study of the actual limits of the lode difficult, particularly as the north Brandon lode meets it in the gully. Of two old adits the upper appears to be on the Adams lode, dipping southeastward, and the lower, 225 feet below the crest, is on the north Brandon, dipping eastward.

The general course of the Adams lode is traced by sloughed open-cuts down the east flank of Adams Peak, and a combined open-cut and short adit just above the talus slopes, at an elevation of 6,840 feet, provides the last and best view of the lode. Here it consists of 3 feet of quartz, strike north 62 degrees east, dip 65 degrees southeast, in the footwall of about 8 feet of shearing, perhaps not all of which is exposed. A 2-inch lens of galena was seen in the centre of the zone.

The south Brandon lode is seen only as a zone of sheared and oxidized rock on which three adits have been driven. The line of outcrop trends north, but the adits are caved and the attitude of the lode is not known.

The north Brandon lode strikes about north 25 degrees east and dips 45 to 70 degrees eastward. An adit about 225 feet below the ridge on the north slope is about 100 feet long, and a second adit, nearly 500 feet below the crest, is about 700 feet long. In the lower adit the lode is a well-defined but rather irregular zone of shearing locally mineralized rather sparingly. A turn towards the west in the inner part of the adit may signify that the lode is turning to become parallel with the Adams lode, but this point is not clear.

The two Brandon lodes are not well mineralized, judging from what can be seen and inferred from the old dumps. The zones of intersection with the Adams lode have not been explored.

The Adams lode has barely been investigated, which is odd considering its structural importance. However, the early prospectors would probably not have realized its importance, and the location is a difficult one. Except for surficial examination, most of the work done was confined to the two adits on the southern slope, and it is not known what length of the lode was explored. Some mineral was encountered, but it was predominantly zincy and supposedly not high in grade. Galena was encountered but not in quantity. In view of the structural importance of this lode, which extends along roughly the southeastern boundary of the main mineral belt, further geological investigation is warranted in more detail than that on which the present description is based. Trenching should expose the lode to the southwest without great difficulty.

Alamo.—See Idaho and Alamo, pages 79 to 82.

Altoona

This property, owned by Kootenay Belle Gold Mines Limited, is 1 mile northwest of Sandon on the northeast side of Carpenter Creek. No. 2 adit is on the old K. & S. Railway grade about 1,000 feet northwest of a small creek. The workings are not shown on Figure 2.

The property was first worked many years ago, but early details are lacking, and there was no production. It was acquired in 1949 by E. Doney, of New Denver, who sold it to Kootenay Belle Gold Mines Limited. The company first mined a shoot of replacement ore above No. 2 level and in 1951 was mining a fissure zone. About 400 tons was mined in 1950 but was not milled.

There are five adits, only the uppermost two of which have encountered mineralization. They are in argillites and quartzites which dip at moderate to steep angles to the northeast and are intruded by numerous sills and dykes in the vicinity of a large stock. Two principal fissures strike to the west and northwest and dip to the south and southwest respectively. Mineralization is mostly in the fissures but also occurs as replacement of limestone. Pyrite predominates in the ore with dark sphalerite and less galena.

No. 1 level is driven 100 feet to intersect a northwesterly striking fissure zone containing scant mineralization. This zone is followed for at least 200 feet, the full extent not being accessible. A second fissure east of the first and dipping to the south at 35 to 60 degrees has been followed to the east for 300 feet. Mineralization in this second fissure is sporadic, the best section, now under development, being about 75 feet long near the western end of the drift.

No. 2 level, 80 feet below No. 1, follows from near the portal a southerly dipping fissure for 200 feet. The fissure apparently swings to a southeast course for 90 feet and swings again to the east in a drift length of 190 feet. Ore is encountered in the first 100 feet of this latter drift and is presumably continuous with ore on No. 1 level. The ore is as much as 4 feet wide and as little as 1½ feet. It is pyritic and locally contains sufficient dark sphalerite to constitute an ore of good grade.

Ore was encountered replacing limestone 190 feet from the portal of No. 2 adit. A band of limestone and limy argillite about 25 feet wide is crossed at a large angle by the east-west lode, and on No. 2 level mineralization replaced the limestone for a maximum distance of 20 feet from the lode in the hangingwall. Stoping was carried out for 60 feet above No. 2 level, and a raise was continued to No. 1. The stope was much steeper than the lode and a little oxidized matter was seen on No. 1 at the top of the raise, in the hangingwall and possibly 100 feet south of the lode.

The two levels differ markedly in the apparent relation between the west- and northwest striking fissures. On No. 2 level the east-west fissure is clearly dominant, and the northwest direction constitutes a bend in it. On No. 1 level the ore-bearing east-west fissure is terminated by the northwest fissure, but on the same level, 30 feet north of the initial crosscut, a west-striking fissure possibly terminates the northwest one. It is plain that the two systems of fissuring were contemporaneous and that the fissure pattern varies from level to level. Ore occurs dominantly in the east-west fissures.

The limestone replacement appears to be a steep chimney apexing downward against a fissure on No. 2 level. An old open-cut east of No. 1 adit portal shows replacement ore which is probably the surface expression of this chimney which, to judge from the evidence on No. 1 level, is not continuous.

No. 3 level, about 80 feet below No. 2, is an exploratory drive, 120 feet long, in argillites and quartzites. No. 4 level, reported to contain several hundred feet of workings but no ore, was not examined. No. 5, a short adit, is below the Sandon–Three Forks road.

Aurora

The Aurora claim is part of the Ruth-Hope group. An old working on it not directly related to any others is dealt with here rather than as part of the Ruth or Hope. The showing is on an old trail at an elevation of about 4,100 feet, 250 feet west of the Ivanhoe tram-line.

A shaft about 100 feet higher than the trail is inclined at 38 degrees, south 20 degrees west. Water-level stood at 30 feet below the collar. The shaft is sunk on an irregular semi-bedded zone several feet wide consisting of masses and stringers of quartz containing a little sphalerite and galena. The dip is steep at the collar and is flat at water-level. An adit, 30 feet northwest of the shaft and 16 feet lower, is driven 72 feet at south 17 degrees west. It crosses an open synclinal roll, and no mineral was seen in it. A lower adit on the trail is caved.

The rocks are quartzites and argillites, locally crumpled but with a general southwesterly dip.

Black Colt

This claim is owned by Mrs. Clara Y. Robinson, 3703 North Twenty-ninth Street, Tacoma 7, Wash. It is at the head of Shea Creek, and its northern extremity is crossed by the main Silver Ridge road. The first shipment was made in 1919, and later work by E. J. Vandergrift, under lease and option, led to the claim being taken over as part of the Consolidated Queen Bess holdings in 1929. From then until 1937 work continued irregularly. A little exploratory work was done under option in 1949.

Production from 1919 to 1937 amounted to 983 tons containing 11 ounces of gold, 53,510 ounces of silver, 701,774 pounds of lead, and 208,866 pounds of zinc.

There are two adit levels 104 feet apart at elevations of approximately 4,650 and 4,750 feet. The portal of the lower is on the Silver Ridge claim. A third adit level on the Silver Ridge Fraction crosses into Black Colt ground. In 1949 the Black Colt levels were accessible by raises from the Silver Ridge Fraction adit.

The rocks are thin-bedded argillites and quartzites right side up and dipping at low angles to the southwest, although locally they are crumpled. They are cut by steeply dipping or vertical joints normal in strike to the bedding. Several faults dip at various angles to the southwest, and there are many fractures of random orientation. Most of the faults follow the bedding or cut it at small angles, and because of local crumpling of the beds it is not always certain whether a fault is parallel to the general bedded attitude, follows a crumpled zone, or is deflected from some other course by local crumples. The amount of movement on these faults is not known. It seems evident that in the thinly bedded rocks a small or moderate amount of movement can produce a prominent gougy zone, and it may be that the interbed movement involved in folding has locally reduced a single bed to a mass of clay or gouge which closely simulates a fault gouge. It follows that the amount of movement, if any, can hardly be estimated from the appearance of a gougy or sheared zone.

Mineralization follows fissures closely allied to the system of joints. A good deal of the workings is obscured by lagging, and it is not certain what the main ore zones looked like. Random mineralization occupies joint fractures and locally spreads along bedding planes and along small crumples; none of this mineralization is impressive. The chief ore zone was on No. 1 level near the Palmita boundary, and the ore on the latter claim was found in an attempt to locate the continuation of the Black Colt ore beyond a bounding flat fault. A second zone, on which some mining was done, is close to the Silver Ridge Fraction boundary on No. 2 level, but no downward continuation of it was found by the level driven below for that purpose. The best clearly visible showing is a steep vein up to 1 foot wide exposed for 140 feet in a drift on the American Girl claim of the Queen Bess group, 1,000 feet in a straight line from the portal of No. 2 adit. The vein in this drift is clean-walled, is composed of carbonate, and contains sphalerite and a trace of galena.

Buffalo

The Buffalo claim is owned by Western Exploration Company Limited and is part of the Mammoth group. The lode outcrops in Avison Creek gulch, and two adits are driven on it about 300 feet southeast of the portal of No. 9 Mammoth level. The lower adit, at an elevation of 4,358 feet, is a crosscut for 250 feet and follows the lode in an average direction of north 25 degrees east. The upper adit in a 60-foot crosscut intersects the lode about 50 feet above the middle part of the lower adit; it follows the lode for 195 feet at north 35 degrees east. A raise at about 55 degrees connects the two adits and a stope about 30 feet long extends between them. There is a stope of similar length above No. 1 adit.

The lode, as seen in the adits and in surface exposures, is a well-defined sinuous zone of shearing and fracturing up to several feet wide. It follows in general the bedding in black argillites. The horizontal component of movement is 30 feet, as measured by the offset of a vertical dyke, the eastern or hanging wall having moved relatively to the north. Observed mineralization was of small scattered amounts of sphalerite.

Between 1905 and 1928 these workings produced 113 tons of ore, containing 15,326 ounces of silver, 52,483 pounds of lead, and 23,612 pounds of zinc. In 1925 a shipment of 23 tons contained 40 ounces of silver per ton and 20 per cent zinc, the silver probably being contained in grey copper. (*See* description of the Mammoth lode for a discussion of the structural relations of the Buffalo lode.)

Canadian

The old Canadian group of Crown-granted claims—the Adams, Brandon, Hilltop Fraction, Katie D, and Sarah B—are held under lease from the Crown by Kelowna Exploration Company Limited and form part of that company's extensive holdings. The ground lies across Silver Ridge on the east flank of Adams Peak. It is reached by trail from the end of the narrow Ivanhoe wagon-road. A tram-line from No. 2 adit once connected with the head of the Ivanhoe tram.

Early reports are rather vague as to the naming of lodes on this and the adjoining Adams property, and the relation of the Canadian to the Adams and Ivanhoe lodes is not altogether clear. The apparent relationship is discussed under the Adams lode and workings. The Canadian is a steep north to northeasterly trending lode that passes through a saddle in the ridge crest. Two adits have been driven on it from the steep north slope.

Work started on this ground in 1895 or earlier. A report in 1896 mentions outcropping ribs of galena in oxidized ledge matter that must have been plainly visible to the first prospectors. Work commenced on both sides of the ridge but soon was restricted to the north slope. Small shipments of ore were made from 1904 to 1908 and were started again in 1918 when the property was optioned by the Rosebery Surprise Mining Company, who presumably built the aerial tram-line to connect No. 2 adit with the Ivanhoe tram. In 1920, 105 tons of concentrating ore was mined, but the option was dropped in May of that year. Leasing continued from 1921 to 1942, shipments being made in fourteen years of that period. The greatest activity was from 1926 to 1928, when shipments amounted to 357 tons for the three years.

Total production from 1904 to 1942 amounted to 452 tons, containing 9 ounces of gold, 77,732 ounces of silver, 792,083 pounds of lead, and 30,347 pounds of zinc.

The Canadian lode crosses the ridge at an elevation of about 7,050 feet. It is traceable down the north slope to No. 1 adit, elevation 6,857 feet, and on the south slope to a large oxidized stripping, elevation about 6,930 feet. No. 1 adit comes through the hill 150 feet southeast of this stripping and was not on the lode in the outer, southernmost part. The lode has an average strike of north 28 degrees east and a steep dip, locally of 75 degrees to the east. It is a zone of shearing and fissuring about 40 feet wide. A possible subparallel zone crosses the ridge about 100 feet to the west and has not been explored.

There is an apparent branch of the Canadian lode on the south slope, and there is stripping and a 30-foot adit on it about 325 feet west of and at almost the same elevation as the south portal of No. 1 adit. This branch is about 30 feet wide, is strongly oxidized, and strikes to the northeast and locally dips to the northwest, but neither the limits of the zone nor the main plane of movement can be determined. It is believed to be a branch of the Canadian lode but could possibly be the Ivanhoe lode, which meets the Canadian on the ridge crest and has not been recognized with certainty on the south slope. The Ivanhoe lode, projected upward from the southern extremity of No. 4 (Ivanhoe) level with a dip similar to that existing between Nos. 4 and 8 levels, would meet the surface near the zone in question.

No. 1 adit, elevation 6,857 feet, is caved 375 feet from the north portal. In the first 270 feet it follows at south 20 degrees west a vertical to steep easterly dipping fissure zone about 15 feet wide. The zone is oxidized but contains veins or remnants of sulphides, chiefly sphalerite but including some galena. A small amount of stoping has been done on central, footwall, or hangingwall vein sections. At 270 feet a crosscut 30 feet to the east encounters a subparallel ore-bearing fissure on which there is a north drift for about 40 feet and on which the drift to the south is caved 90 feet from the intersection. Stoping has been done in this section, and a raise extends down to No. 2 level.

The Canadian lode as seen in No. 1 adit is a zone of subparallel fissures at least 40 feet wide and may not have been fully explored. A crosscut extends to the west for 25 feet at the first turn, but there is a possibility of additional fissures to the west, especially in view of the indication of a western zone on the ridge crest.

Little can be learned on the south slope beyond the apparent fact of continuity of the general zone. The southern end of No. 1 adit is in bad condition and is caved in the supposed vicinity of the lode, about 50 feet west of the portal.

No. 2 adit, elevation 6,754 feet, is caved 200 feet from the portal. It is driven southwest for 140 feet to a face showing a zinc-mineralized fissure a few inches wide, striking north 15 degrees east and dipping 70 degrees to the east. At 120 feet from the portal the adit branches to the south and swings gradually to the southwest near the caved section. Some stoping has been done in the inner section on a fissure zone up to 3 feet wide containing narrow widths of sphalerite. It may be doubted that the lode in the accessible parts of the adit is the same lode as that in No. 1 adit, but the doubt may be created by variation in character and attitude of the lode. Plans of the full extent of the workings were not available.

No. 3 adit, elevation 6,525 feet, was driven in slide rock below the bluffs in search of the lode. It is caved, and there is no information concerning it.

The innermost parts of the Ivanhoe Nos. 4 and 8 levels are driven across the boundary of the Ivanhoe claim onto the Katie D claim, a member of the old Canadian group. The lode followed by these drifts strikes northeastward and dips 45 degrees to the southeast.

The structural setting and the possible relationship of the lodes in this vicinity are discussed in the treatment of the Adams lode (pp. 65–66).

Carnation

The old Carnation group, owned by Kelowna Exploration Company Limited, lies across the crest of Silver Ridge at the summit known locally as Read Peak. Workings are on both north and south slopes, and one adit, the 6500 level (formerly No. 2), passes through the ridge. On the north slope the 5480 adit (designated No. 9 on Fig. 2), in the basin of Tributary Creek, is reached by a new road, which was extended to the upper levels formerly reached by an old narrow wagon-road. The workings on the south slope are reached by trail from the 6500 level or by trail from the road in Wild Goose basin. Access in early years was from Silverton Creek via the Wakefield trail.

The Carnation lode was discovered in very early days, and work was done on it in the early 1890's. Details of ownership are not known, but the earliest work was on the Read and Robertson claims on the south slope, followed by work on the Carnation claim on the north slope. Work was done on the Carnation between 1917 and 1921 by G. W. Clark. The combined group was acquired under option by the Victoria Syndicate in 1925. The Victoria Syndicate pressed development and did some work on the south slope but concentrated on the Carnation workings on the north. In 1927 the Carnation 6500 (No. 2) adit was driven through the ridge, a distance of 2,800 feet, and a 10,000-foot aerial tram-line was built to connect with the Hewitt mill on Silverton Creek. The option was dropped in 1928.

Work on 6300 (No. 3) adit was continued by the owners, A. R. Mann and associates, but was stopped in 1930. The property was bought in 1946 by Kelowna Exploration.

A new low-level adit at an elevation of 5,480 feet was started in 1949, on the west fork of Tributary Creek and a second, 5480 east adit, was driven the following year. Two crosscuts were driven across the lode in the old 6300 adit and a new adit (6100) was driven after the lode had been uncovered at that level by stripping. The results of all of this work were disappointing, and the decision was made in June, 1951, to cease operations. Rail, pipe, and equipment were removed.

Surveys of the final work were not at hand when the map (Fig. 2) went to press. The 6100 and 5480 east adits are not shown, nor is the innermost part of the main or west 5480 adit.

The total recorded production from 1895 to 1928 is 677 tons with a metal content of 6 ounces of gold, 21,433 ounces of silver, 224,597 pounds of lead, and 36,491 pounds of zinc.

The Carnation lode is part of one of the largest crosscutting fault zones. One continuous zone of faulting extends from the Standard, through the Mammoth and Carnation properties to the Hope, Silversmith, and Richmond-Eureka, a distance of about 6 miles. It is not a single or simple break, but rather a major element of a system of faulting. The Wakefield lode is one major branch and the Minniehaha is another, while the relation of the Mammoth to the Standard lode is a complex one, to be described in a forthcoming bulletin. The lode structure is as much as 100 feet wide.

The structure crossed by the lode from the Wakefield intersection just below the southwest portal of the 6500 level to the portal of the 5480 adit is the principal overturned panel on the upper limb of the Slocan fold. These northeasterly dipping rocks on the high northern slopes of Silver Ridge roll down and under at elevations between 5,000 and 5,500 feet in the first of a series of recumbent folds. Such an inversion apparently takes place at some distance below the horizon of the 5480 adit, but the details of this fold may only be understood after additional development work is done. Exposures are few in the basin at the head of the west fork of Tributary Creek, and the structure cannot be well studied on the surface.

The rocks have been greatly deformed in the vicinity of Read Peak. Quartzites have shattered and argillites have flowed, and an extreme is seen in the argillite band that crosses the peak in the hangingwall of the lode. This argillite, originally finely banded, has been finely comminuted and has flowed, until the light-coloured beds remain as fragments and streaks; the band apparently pinches out close to the lode. In the headwall of Tributary Creek the structure is apparently uniform, although dragfolding is noticeable. If black argillite encountered in the hangingwall of the lode by the first crosscut on the 5480 adit may be correlated with the band crossing Read Peak, then an average northeasterly dip of the argillite of about 24 degrees is indicated for a horizontal distance of 3,000 feet.

On the south slope above the Wakefield intersection the lode does not cross southwesterly dipping rocks and is wholly in the overturned panel. On the north slope the steeply dipping footwall rocks at the 5480 adit portal are probably close to the uppermost recumbent fold, but the combined displacements on the Carnation and Minniehaha lodes make direct structural correlation with the hangingwall rocks very difficult.

The rocks traversed include all types, and the displacement, although of an unknown amount, is sufficient to bring widely differing rocks into juxtaposition across the lode. Igneous rocks are few, the largest being a sill at the portal of the 5480 adit. In this adit, metamorphism has produced a striped brown to green rock from banded argillaceous sediments.

On the south slope the lode is traced through a vertical distance of about 650 feet by the 6500 adit and three short adits above it, and by open-cuts. The exact point of branching of the Carnation and Wakefield lodes is not seen, but the lode elements explored by the adits flatten at the 6500 level from about a 50-degree to about a 30-degree dip with some strands nearly horizontal. The upper three adits may be on the hangingwall part of the combined lode. The lode is at least 50 feet wide and contains masses of calcite as much as 15 feet wide. Heavily oxidized sulphide, including galena, is exposed at the surface in places, and pods of ore are encountered underground. The 6500 level was caved at the intersection of the drift with a branch leading to the tram terminal.

The lode is not exposed on the crest of Read Peak, and only brecciated rock can be seen along its supposed course. Footwall strands cross the ridge 100 feet or more in the footwall of the main break and appear to diverge to the west. One such strand crosses the ridge 900 feet west of the main lode apex, and an adit (now caved) was driven on it on the south slope 100 feet below the crest of the ridge. The footwall strands contain small amounts of sulphides, as exposed at intervals by old open-cuts. Northeast of Read Peak open-cuts about 400 feet north of the main lode show mineral matter that may or may not be in place.

The uppermost workings on the north slope consist of a caved shaft on a broad zone of siderite and breccia. Below the shaft a crosscut (now caved) was driven southerly to the lode, but very little work was done on the lode itself. About 200 feet lower the 6500 adit is driven through the ridge along the lode for a strike-length of about 2,500 feet. This adit was inaccessible at the time of the writer's visits. The drift follows a nearly straight course, and numerous crosscuts were driven to right and left to explore the zone. The full horizontal width of fissuring is as much as 100 feet. Former reports state that " no ore was encountered " in this drift, but some mineralized sections were encountered. The amount and grade of mineralized matter are not known, but it is undoubtedly more attractive at current prices than it was in 1927 and 1928.

The innermost section of the 6300 adit (designated No. 3 in Fig. 2) explores the main lode, the hangingwall of which is a large zone of shearing containing much gouge and some calcite. Subsidiary footwall strands give a total width of about 50 feet. About 300 feet from the portal a northeasterly trending zone of fissuring and shearing may represent a fault or a flexure in the lode. In either case the main lode does not appear to have been reached by the initial crosscutting part of the adit. The exact behaviour of the lode in this section is important, because there is a complexity here that contrasts with the nearly straight course in the 6500 level above and to the west. Also, the Footwall branch encountered in the 5480 level and believed to be the Minniehaha lode is approaching the main lode in this section.

The 6100 adit, not shown on Figure 2, is driven 240 feet below the 6300 adit. The 6100 adit follows the lode along a general westerly course for 545 feet from the portal. Strata are crossed which in general dip with the lode or are inclined at small angles to it.

The lode dips at 30 to 35 degrees to the south, except at the face where the dip is 45 degrees to the south. The average dip from the face to the 6300 level is 48 degrees.

Neither the 6100 adit nor two recently driven crosscuts in the 6300 adit were examined. The company reported no favourable results from this work, in spite of the apparently encouraging situation. The fault or lode flexure in the 6300 adit, a feature possibly favouring the occurrence of ore, was not apparent on the 6100 level.

A condition of some interest exists in the 6300 and 6100 levels, where strata have a northeasterly strike and are rudely parallel to the lode. There are not sufficient exposures to explain the meaning of this panel at a large angle to the general trend. Three explanations seem possible: (1) the strata are dragged into near parallelism with the lode, (2) the lode follows the course of a dragfold, and (3) a wedge of different attitude is caught between branches of the lode.

The 5480 adit (No. 9 in Fig. 2) is driven into the hill for 230 feet and then as a crosscut for 1,380 feet. Lodes were encountered in the crosscut 680 feet and 1,080 feet from the turn. The first lode, a zone of shearing several feet wide, is probably the continuation of the Minniehaha and is referred to as the Footwall lode. The second, the Carnation lode, was followed to the west chiefly in the footwall for about 1,800 feet, and a second crosscut, 1,300 feet west of the first, was driven 330 feet into the hangingwall. In the explored length the lode was intersected by short crosscuts at a number of places. The lode follows in general an east-west course and dips at about 60 degrees to the south. The main break is several feet wide, and branches and subsidiary fissures make the actual limits of the lode zone rather indefinite. The movement in several observed places is of hangingwall down and east at a vertical angle of about 25 to 30 degrees. A very little sphalerite occurs locally.

The Footwall lode contained lenses of galena and sphalerite as much as 18 inches wide where first encountered. It was exposed by a drift for a total length of 340 feet and two short raises were driven on it, but there was not sufficient encouragement to do further work in this section. The lode is a zone of shearing and fissuring several feet wide that strikes northeastward and dips at a moderate angle to the southeast.

The position of the Footwall lode was determined by surface diamond drilling, and the apex at the 5480 level was found by stripping about 400 feet southeast of the main adit portal. A second 5480 adit was driven from a point 100 feet northwest of the lode apex and explored the lode for a total distance of 320 feet southwest of the apex. The face of the east adit is about 250 feet northeast of the drift on the Footwall lode in the main adit. The lode strikes north 10 degrees east at and for 100 feet from the surface and north 30 degrees east farther in the hill. It is weakly mineralized in several places.

The rocks traversed by the main crosscut dip steeply. Argillites in the main crosscut in the hangingwall of the lode dip southwesterly, with southeasterly axial plunges. These argillites are probably involved in a dragfold, because they cannot be structurally beneath the main overturned panel. The rocks in the immediate footwall of the Carnation lode are northeasterly dipping as a rule and include argillites and quartzites.

A sill or dyke 80 to 90 feet wide is crossed by the outermost section of the main 5480 adit. The same body is exposed on the surface in the small creek, part way to the 5480 east adit, and again in the footwall of the Footwall lode. Quartz dioritic rock also occurs in the hangingwall of the same lode and, if it is the same body as that in the footwall, a displacement of hangingwall to the northeast is indicated. Strata in both footwall and hangingwall of the Footwall lode dip to the east, in marked contrast to strata which dip to the southwest on the surface 200 feet vertically above.

The Footwall lode has been explored at the 5480 level for a total length of about 900 feet, including one gap of about 250 feet. The Carnation lode has been explored for a length of about 1,800 feet, from the main crosscut to a point due south of the inner end of 6300 level. The two lodes apparently join near the outer part of 6300 level, and what is supposedly the combined zone, the main Carnation lode, is explored for a strike distance of about 2,500 feet on 6500 level. These workings have failed to disclose an orebody.

In the area as a whole, although many factors may combine to form a site for ore deposition it is a rule that, statistically, orebodies favour southwesterly dipping rocks in which the lode movement is opposed to the bedding. Furthermore, orebodies on the larger lodes are found in areas of structural complexity more often than in areas of consistent dip. The 5480 level is driven near the base of the overturned northeasterly dipping panel, above the general zone of multiple recumbent folding in which most of the larger orebodies in the area are known to lie.

Far more information is available now than before the adit was driven, and in the light of that information the 5480 level appears to have been driven at a horizon somewhat high for ore formation. The southwest-dipping rocks already referred to on the surface 800 feet south of the main 5480 adit portal are now known to represent a dragfold in the lower part of the main overturned panel, and do not lie beneath that panel.

Another showing on the Carnation lode is on the north part of the Jennie claim, about 600 feet east of Tributary Creek. An adit 57 feet long was driven on part of the lode structure, which here is at least 50 feet wide and contains much calcite. No lead or zinc mineralization was seen.

The Carnation lode is also exposed where it crosses the west branch of Tributary Creek. The creek at this point falls rapidly in a cascade over quartzites and the lode, or part of it, is seen in the lower part of the cascade. Sheared and shattered ground occurs over a probable lode width of several tens of feet and contains some strands of siderite and a very little sphalerite.

Cinderella

The Cinderella is owned by Violamac Mines (B.C.) Limited. It is on the steep slope above Carpenter Creek and is reached by trail from the Victor road. The earliest shipment was in 1904, when 188 tons was shipped. Total production, in six years between 1904 and 1936, was 249 tons, containing 18,448 ounces of silver and 329,515 pounds of lead.

The rocks are argillaceous for the most part, although exposures are few and the full section cannot be seen. The structure is unknown. A stock of quartz diorite occupies the northern part of the claim and extends down to Carpenter Creek.

Steep northeasterly trending fissures, which are parallel to or are part of the joint system, are investigated in six adits. Two adits between 400 and 500 feet north of the Lone Batchelor adits, are driven on steep joints in thick-bedded argillite that dips southwestward into the hill. The upper adit is caved and the other, 60 feet lower, is about 200 feet long.

Two other adits are at the old camp, elevation about 3,420 feet. The upper adit is caved and is reported to be 650 feet long. The other adit, 100 feet lower, was recently opened; it is nearly 800 feet long. The workings are crooked and follow fissures of variable but general northeasterly strike that are offset or separated by faults. There is little evidence of mineralization, and continuity of lode is not established. The writer had no plan of this adit.

West of the camp on an old trail two adits are in quartz diorite. One about 180 feet west of the camp is caved. The other, about 800 feet west of the camp, is about 175 feet long and is driven on a fissure dipping 45 degrees to the southeast.

Conductor

This claim is owned by W. H. Elson, c/o George A. Richardson, 1829 Twelfth Avenue West, Vancouver. It is on the ridge east of lower Alamo basin. Old open-cuts trace the course of a lode over the ridge nose at an elevation of 5,800 feet, and an adit is driven from the western slope a short distance below the lode outcrop.

The adit is 150 feet long and crosses the lode 40 feet from the portal. A drift extends 72 feet at north 68 degrees east. The lode in the drift is oxidized in a streak about 6 inches wide which contains kernels of galena. On the surface the lode is not now well exposed, but galena was evidently found in it.

The lode crosses the main overturned panel and produces a marked offset, particularly noticeable in an argillite member. Except on the ridge, exposures are too few to trace the lode by noting the offset, and the course on Figure 2 is a projected one only; the approximate position on the east bank of Howson Creek seems fairly certain. An adit, now caved, was driven at the east margin of Alamo basin, apparently as a crosscut searching for the lode, but the objective was not reached.

There is no doubt that this is the Alamo lode. Projection is none too certain, particularly because the lode has an anomalous attitude in the Alamo workings, but a resumption of more normal attitude is reported to exist in the east part of No. 5 level. The displacement on the Conductor claim is comparable to that on Alamo ground, and no other evidence of displacement has been noted on the ridge.

Corinth

The former Corinth group is owned by Silver Ridge Mining Company Limited. The workings are on upper Howson Creek a short distance below Wild Goose basin, and are reached by road from Sandon. The property is an old one, first reported in 1896 and apparently worked until 1907. In 1925, under the ownership of the Corinth Silver Lead Mining Company Limited, of Seattle, Wash., a crosscut (No. 3 adit) was started to gain additional depth on the old workings. Nothing further was done from 1927 until 1948, when Maurice Ansaldo and partners shipped 35 tons sorted from old dumps and mined from surface showings. Later, Silver Ridge drove a crosscut beneath one of these showings. Total production from 1900 to 1949 amounted to 158 tons, containing 2.3 ounces of gold, 7,386 ounces of silver, 142,636 pounds of lead, and 7,533 pounds of zinc.

The workings are in mixed and limy strata which dip eastward at, on the average, about 50 degrees. Several small dragfolds have been detected, with horizontal axial planes and low plunges to the north. Dragfolding of moderately large amplitude, projected from the north, would underlie the lowest adit.

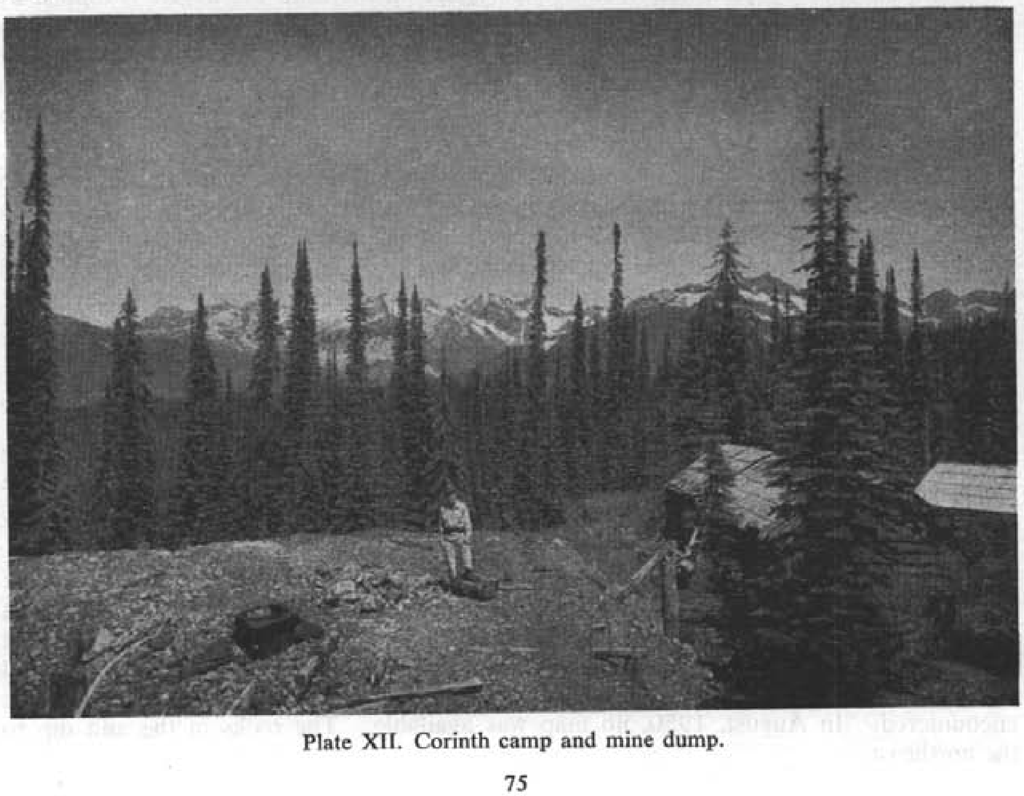


Plate XII. Corinth camp and mine dump.

A caved adit is driven on a nearly east-west, southerly dipping lode that is stoped to surface across a low ridge west of the creek. A caved portal on the west side of the ridge indicates continuity of the lode for about 300 feet. No. 2, a slightly lower adit 175 feet to the northeast, is caved at the portal but was entered by a raise from below. An irregular southeast-dipping lode fissure 100 feet long in No. 2 adit is stoped to surface close to the creek; on the southwest it rolls into a bedded shear. Discontinuous mineralized fractures are encountered at intervals in a drift that extends 180 feet farther west. At the west end of this drift ore stringers are seen to follow the bedding round minor folds. About 75 feet southwest of this face in a sublevel 25 feet below No. 2 level, a 35-foot section of mineralized zone is about 2 feet wide and contains 2 to 3 inches of sphalerite and, locally, pods of galena. A crosscut, an additional 120 feet south in the sublevel, ends at a raise from No. 3 level below.

Continuity of ore is not indicated, in spite of surface evidence of a definite lode in the uppermost stope. There are two or more fractures in the lode direction, interrupted by bedded slips and minor folds.

No. 3 adit level is driven south for 1,215 feet. A narrow mineralized lode, as much as 2 feet wide, is crossed 100 feet from the portal. It is exposed in a drift to the west for a length of 65 feet and terminates against a flat-bedded slip. A raise extends to the surface. Small amounts of sphalerite and galena occur in this lode. At 405 feet from the portal a nearly flat carbonate stringer, bedded and containing sphalerite, is crossed. Quartz lenses in the crosscut dip from 50 to 70 degrees to the northwest and represent tensional fractures.

A strong east-west gougy unmineralized fissure is crossed 900 feet from the portal. It is followed to the west by a drift 195 feet long and for 260 feet east, to a point where it swings sharply into the bedding; the bedding flattens in an additional distance of 110 feet to the east. A raise west of the crosscut on this fissure extends at about 50 degrees to sublevels at 80 and 131 feet; the upper sublevel is 25 feet lower than the No. 2 adit level and has already been described. Ninety feet up the raise the fissure is topped by a fault dipping 40 degrees to the northeast. A strong gougy fissure dipping 65 degrees to the southwest is exposed 10 feet north of the raise in the upper sublevel and may be the same as the fissure below, faulted and with abnormal strike. However, it bears no known relation to the mineralized fissures already described that lie 100 and 180 feet to the north and east.

On the surface, 180 feet at north 60 degrees west from No. 3 adit portal, a trench has been dug on broken mineral-bearing ground. The trench is so badly sloughed that detail is obscure, but the line of the trench and of old open-cuts to the west indicates an east-west fissure or lode zone approximately at right angles to the prevailing local strike of the strata. The eastward projection of this fissure passes north of No. 3 portal.

Just below the main road, about 450 feet east of the creek, there are two old shallow workings on a curving lode. Some underhand stoping has been done from one of them. About 250 feet east of the creek a section of lode 55 feet long was uncovered in 1948, and lead ore was mined across a maximum width of 18 inches to a depth of 12 feet. These showings are possibly all on the lode structure that is stoped from No. 2 level to the surface and is seen crossing the creek, but there is no positive evidence of continuity and the lode, where seen, varies considerably in attitude along the generally east-west course.

An adit was driven in 1949 and 1950 from a point about 200 feet east of the creek and 75 feet lower than the 1948 surface showing. It had been driven south 272 feet when examined, the inner 30 feet being along an east-dipping fault. At a point 145 feet from the portal a drive had been made to the east, southeast, and finally south a total distance of 125 feet to get into the hangingwall of the fault, but no lode had been encountered. In August, 1950, no map was available. The rocks in the adit dip to the northeast.

Cunningham Clarence Cunningham, who died in 1938, built up a large holding, including many prominent Slocan mines. His first activity was at the Wonderful in 1915, and he subsequently extracted most of the ore won from that property. In 1916 he acquired the Queen Bess, under lease and bond, as well as other properties. After a short drive on the Queen Bess an orebody larger than any before known was encountered. It was rapidly mined and is reported to have shown net smelter returns of a million and a quarter dollars.

Cunningham controlled, in 1916, the Queen Bess, Wonderful, Idaho-Alamo, Van Roi, and Sovereign. Details of ownership or agreement are not clear at this date but, chiefly as Cunningham Mines Limited, he held these properties for many years, adding the Hewitt, Black Colt, and others to his list. Within the Sandon area a tram-line system was reinstalled from the Idaho and Queen Bess mines to Alamo Siding, where a mill was built on the site of the original Alamo mill. Ore was transported by tram from the Wonderful to the railway, whence it was shipped to the mill. The Queen Bess ore was shipped direct to the smelter. Consolidated Queen Bess Mines Limited was formed in 1928, in an amalgamation of the original Queen Bess and the Idaho and Alamo properties.

The Cunningham enterprises did not prosper as well in later years as in earlier, and at the time of Cunningham's death he was in debt. It was not until 1949 that most of the legal details could be untangled, and most of the properties have now passed into other hands. The Wonderful was bought by Silver Ridge Mining Company Limited, and the Consolidated Queen Bess holdings are controlled jointly by Bralorne and Kelowna Exploration through Bess Mines Limited.

Democrat The Democrat claim is on the east side of Alamo basin and extends a short distance over the ridge crest. It is owned by Mrs. Pearl McLean Stuart, 5508 East Fifty-fifth Street, Seattle, Wash.

There are three very short adits and several open-cuts, all sloughed. Evidence of mineralization is erratic and does not seem to indicate the presence of a throughgoing lode. The limestones and limy strata are involved in a large dragfold with an amplitude of about 200 feet, and the rocks are locally shattered or torn. The dragfold is plainly visible from the opposite side of the basin. Mineralizing solutions have followed, particularly in the steep limb of the dragfold, some of the fractures in these strongly deformed rocks.

Dixie Hummer This claim is on the crest of Silver Ridge at the head of Wild Goose basin. It is owned by Thomas A. Yawkey, 420 Lexington Avenue, New York, N.Y. A small amount of digging was done years ago on the ridge crest on a breccia zone in argillite. Surface work was also done in stripping limestone and limy rocks through a vertical range of about 50 feet on the steep north slope. This latter work is now partly caved, but a very small amount of sulphide mineralization was encountered, apparently a replacement in the limestone. Some very old open-cuts down the north slope show no more than a search for mineral but, 100 feet from the road, the writer discovered a few small pieces of galena in shattered rocks on which no work had been done. On the south slope a quartz " blowout " in argillite occurs about 200 feet below the ridge crest.

There is evidence of mineral in this locality, and the breccia zone on the ridge crest has the appearance of lode matter, but careful mapping shows no evidence of displacement such as would be produced by a lode of even moderate size. It seems rather that the observed mineral is erratic, following loci of shattering in limy and mixed rocks. The locality is not far removed from footwall fracturing of the Carnation lode zone, of which a strand of lode attitude crosses the ridge 600 feet southeast of the Dixie Hummer stripping and is exposed in an open-cut on the Carnation trail 400 feet from the same stripping. This open-cut shows about an inch of galena in a small shear zone, and an adit below the trail, now caved, was apparently driven on the shear.

Dorothy

The Dorothy claim is owned by Kelowna Exploration Company Limited. It is east of the east branch of Tributary Creek and is crossed by a number of trails. Several old workings are completely caved, and only a lower exploratory adit is open.

Cairnes reports (1935, p. 36): "On this claim, at an elevation of about 4,800 feet, an adit 400 feet long has explored a vein of high-grade silver-lead ore several inches wide. The vein occurs in a fault fissure striking nearly east, dipping 50 degrees south, and has been partly stoped out above the adit level. The fissure intersects banded argillites striking north 15 degrees west and dipping 75 degrees northeast, and is exposed in open-cuts and pits about 150 feet above the portal of the tunnel."

The adit referred to is on a small nose on the upper trail, uphill from which there are several old open-cuts, all badly sloughed. An exploratory adit below the lower trail is about 125 feet lower. It is driven 220 feet at south 60 degrees east to a raise driven upwards at 30 degrees. A 100-foot branch to the northeast ends in another short raise.

The rocks are thin bedded, predominantly argillites, and are fractured; exposures are poor. Other short adits in the vicinity were driven apparently on broken ground. The Minniehaha lode projects through this general area, and it is probable that the lode referred to by Cairnes is a part of the Minniehaha lode, of which there may be more than one fissure. The local structure is beneath the main overturned panel and is not known.

Elkhorn

The Elkhorn claim is held under lease from the Crown by Neil Tattrie, New Denver. The workings are on the west side of Miller Creek at and above the lower road crossing.

The workings are all caved and the early history is incomplete. George Gormley was one of the group owners for many years and leased the mine as early as 1907.

Cairnes (1935, pp. 39, 40) mentions five adits in addition to a shallow shaft, but the writer distinguished only four adits in the heavily overgrown area. The following quotations are from Cairnes.

Of about 2,000 feet of lineal work most was done on the two lowest adits. The second lowest adit exposes ". . . a strong zone of shearing along the contact of a porphyry sill and argillaceous sediments. The zone strikes north 55 degrees west, dips 75 degrees to the southwest, and averages several feet in width. It has been followed for over 200 feet in which distance some encouraging mineralization has been encountered, mostly in the form of small shoots. Raises and stopes connect with the surface workings 70 feet above, in which direction the shear zone flattens appreciably. The productive parts of the shear zone are at points where it is intersected by mineralized cross-fissures striking about north 65 degrees east and dipping from 40 to 70 degrees southeast.

"The lowest or No. 3 adit is a crosscut for about 460 feet to where it is reported to have intersected a fissure which may correspond with one of the mineralized cross-fissures encountered in the upper workings. . . . Judged from material on the dump from No. 3 level, the fissure at this depth carries abundant pyrite and considerable zinc blende in a gangue composed largely of siderite."

A production of 162 tons is recorded for the seven years from 1907 to 1936. This contained 1 ounce of gold, 5,440 ounces of silver, 111,468 pounds of lead, and 40,099 pounds of zinc.

Fairy

This claim, on the west side of Wild Goose basin, is part of the holdings of Silver Ridge Mining Company Limited. An adit on it is driven 250 feet westerly at an elevation of 6,690 feet. In the first 115 feet it follows a weak fracture in limestone and argillite at south 80 degrees west. From 115 to 190 feet the fracture is stronger and contains calcite and small amounts of sphalerite, in argillite. At 190 feet the drift turns to the southwest to follow light shearing into which the mineralized fracture swings. Two inches of calcite breccia containing sphalerite is seen near the face. Seventy feet from the portal a branch extends 65 feet to the south in limy rocks.

Hinckley The Hinckley claim, owned by W. D. Pengelly, of Silverton, is on Shea Creek and is crossed by the Victor road. Little is recorded of the history of this claim beyond that it was owned by the Hinckley & Black Colt Mining Company in 1898, was developed by R. A. Grimes in 1923, and by the Standard Silver-Lead Mining Company in 1924 and 1925. It was worked under lease in 1936 and 1937 when 3 tons was shipped, containing 85 ounces of silver per ton and 60 per cent lead.

Workings consist of four adits and a shaft. A fifth adit on the Bear Paw mineral claim, owned by Mrs. H. V. Dewis, of Silverton, passes into the Hinckley from the north. Exposures are few, and all that is known is that the rocks in Shea Creek valley dip steeply to the south and that a considerable thickness of quartzites occurs near the southernmost workings. A prominent dyke or sill of porphyritic quartz diorite, 150 feet wide as exposed in the creek, may extend to the east to connect ultimately with a prominent stock on the north side of Carpenter Creek.

Of three short adits at an elevation of nearly 3,800 feet at the edge of the creek one is caved and the others are driven southerly on both sides of the creek. They cross steeply dipping quartzites and argillaceous quartzites. The adit on the east bank is 150 feet long and at 70 feet from the portal encounters a semi-bedded crushed zone in which there is 6 to 8 inches of quartz and a little siderite and sphalerite.

About 250 feet northeast of this adit a series of small pits exposes an irregular mineralized fracture, and an adit a little lower in elevation explores what is presumably the same zone. The adit encounters a quartzose fracture, which dips 45 degrees east, 60 feet from the portal, and follows it for 40 feet, where it fades out in porphyry. Three short crosscuts into the hangingwall show broken ground in argillaceous rocks and porphyry.

An old shaft at an elevation of about 3,700 feet near the north edge of the claim is inaccessible. It is sunk on a fissure zone that strikes north 25 degrees east and dips 65 degrees eastward. Material on the dump is mainly gossan but includes a little siderite and glassy quartz. A small caved adit close to the shaft collar may be driven on a fault. An adit 150 feet lower and 350 feet to the northeast is driven southerly 260 feet from the Bear Paw claim into the Hinckley. This adit is driven in argillites for 180 feet, where it encounters an 80-foot sill. A crosscut 60 feet to the west encounters a fissure striking north 25 degrees east and dipping 55 to 70 degrees eastward. This fissure, which may be the same as that in the shaft, is followed to the south for 190 feet through the sill and into argillites. It is a gougy zone between porphyry walls, but in argillite it is a quartzose vein about 6 inches wide.

Idaho and Alamo These old mines on the headwaters of Howson Creek are controlled by Bess Mines Limited, 555 Burrard Street, Vancouver. Both early discoveries, the Alamo had the distinction of having the first mill in the Slocan, at Alamo Siding, in operation in 1895. The mines were at first worked separately but were amalgamated in 1904 or earlier, when an aerial tram-line was built up Howson Creek and a branch tram extended to the Idaho.

In 1904 most of the available ore was reportedly mined out from the Alamo upper four levels, and a fifth level was contemplated. Work in that year was concentrated on the Idaho.

Production in 1904 and 1905 amounted to 11,200 tons and for the next ten years never attained 300 tons per year. In this latter period it is presumed that the mines were worked under lease.

Clarence Cunningham acquired the combined property in 1916, as part of Cunningham Mines Limited. In 1917 and 1918 the main tram-line was rebuilt, with feeder trams to the Idaho and to Queen Bess Nos. 5 and 10 levels, and a mill was built on the site of the old one at Alamo. An amalgamation was made with the Queen Bess in 1928 and a new company, Consolidated Queen Bess Mines Limited, was formed.

In 1947 Harold Hemsworth and associates, of Vancouver, acquired rights to the Consolidated Queen Bess property after clearing the legal tangles which followed Cunningham's death. A lease and bond was taken by Bralorne Mines Limited who, jointly with Kelowna Exploration Company Limited, formed Bess Mines Limited as an operating company. A geological investigation was made in 1949 and 1950.

The record of production is not as informative as it might be because the output of the Idaho and Alamo was grouped. About 30,000 tons was mined altogether, with a metal content of about 1,625,000 ounces of silver and about 5,120,000 pounds of lead; zinc was recovered in 1905 and again subsequently to 1918. About 85 per cent of the ore was mined between 1895 and 1905. Dividends amounting to about $400,000 were paid. The last shipment recorded was 114 tons from the Alamo in 1928.

The Idaho and Alamo, two distinct lodes of major size, are continuations of the Standard lode system. They cross the high ridge northwest of Idaho Peak, the Alamo crossing the Sandow claim and the Idaho passing into bedding where last seen on the southern slope west of the Sandow. The two lodes may join before passing through Tiger and Echo ground farther to the south. The Idaho lode is continuous with the Queen Bess, although it cannot be traced between mines. The Alamo passes through the Conductor claim on the ridge east of Alamo basin, and its position is not known with certainty beyond that point. The projected position of the Alamo east of Howson Creek is shown in Figure 2.

Alamo.—The Alamo lode is exposed by five adit levels over a vertical range of about 500 feet. The adits are all caved, so the following underground detail is taken from published material or inferred from existing maps.

According to Cairnes (1935, p. 62): " The lode is a strong, mineralized fissure or fissured zone along the course of which the country rocks have been much crushed and brecciated. It varies in width from a few inches to over 9 feet and in its more productive parts had a filling composed in part of ore minerals, including at one point between 8 and 9 feet of solid galena and in part of quartz, siderite, calcite, and crushed country rock. Most of the available ore has been worked out. The principal shoot extended from the surface to 50 feet or more below No. 4 level and had a maximum length, between Nos. 1 and 2 levels, of about 500 feet. The shoot pitched in general towards the east and the length decreased downward to less than 200 feet on No. 4 level . . . On No. 5 level the lode is well defined, and contains much vein quartz, but has shown only traces or small lenses of lead and zinc minerals.

" Grey copper was a conspicuous constituent of the higher grade ore and a small amount of ruby silver was associated with the galena throughout the mine. Pyrite and chalcopyrite were also present, the latter, locally, in amounts rather unusual for ores of this district. Quartz was the most abundant gangue mineral. It was associated with a small proportion of siderite and calcite." It is reliably reported that high silver values were associated with " sugary " or finely crystalline vuggy quartz, in which the silver was contained in small grains of grey copper and ruby silver.

The Alamo lode crosses a prominent ridge at an elevation of 6,500 feet. The five adit portals are on the southeastern slope, but there is a second portal of No. 1 adit on the northwestern slope. The rocks in the mine area are argillites with a general low dip and minor warps and crumples. The rocks on the north or footwall side of the lode are overturned and those on the south are right side up. Although there is no evidence in the actual mine area, the displacement along the lode has brought into conjunction different limbs of a large compressed dragfold with a nearly horizontal axial plane (*see* p. 45 and Section I-I′, Fig. 4). The lode, where it passes through the steeply dipping axial part of the fold, deflects from its normal course to follow the bedding. In this section the lode, which normally has a moderate dip to the south, swings to a southeast course with a high dip to the southwest. Recovery to the normal east-northeast strike takes place in the vicinity of No. 5 level, and it is reported that the steep dip encountered in the higher workings decreases a short distance above No. 5. Most of the ore was mined from the steep part of the lode.

Most of the ore occurred above No. 2 level and was mined to 60 feet above No. 1, where the lode widened into a zone of stringers. The orebody lay in the upper part of the steep buckle in the lode, a situation very similar to that of the orebody in the Ivanhoe lode and not unlike that of the Queen Bess main orebody.

The general controlling factors which localized the Alamo orebody are well established. The pattern is more distinct than in most of the larger orebodies in the Sandon area and is not exactly duplicated anywhere, but there is enough similarity to make a further analysis valuable as a guide to exploration in the Sandon area.

In the Alamo mine area the lode, which in general crosscuts the formation, swings into parallelism with a panel of strata of anomalous attitude, producing a distinct buckle in the lode. The buckle is local on strike and probably is local on dip also, more sharply defined near its lower limit than its upper limit. The buckle or flexure on strike is in a shear direction but on dip is in a tensional direction relative to the lode along which the hangingwall moved relatively down and to the east.

The ore formed in or towards the upper part of the buckle. In the uppermost section the lode was wider and more diffused and was not favourable to the formation of ore in quantity—it is probable that, above the present erosion surface, the diffused elements of the lode regathered into a lode of more normal habit. It is not known whether there was a similar, lower diffusion and regathering. In the main part of the buckle the well-defined lode is presumed to have been gouge filled or to have contained a considerable amount of gouge, but where shattering and brecciation took place rather than grinding of the rock a site favourable for ore deposition was formed. In the case of the Alamo lode the influence of rock type was not important, and ore formed in argillite which in many circumstances is not a good host rock. In other cases of a similar buckle in a lode it may be presumed that the character of the rock might further localize ore deposition, depending on its susceptibility to brecciation or to shear.

It will be seen that such a buckle is governed by the folded structure and is, at least in the case of the Alamo, a bedded feature. It has been presented elsewhere as a general conclusion that bedded lodes are on the whole not favourable to ore formation. The conclusion is warranted, as a generality, but a distinction should be made between a general and a local following of bedding because in the latter case the buckle is the more important factor, and not the angular relation between lode and bedding. Also, a bedded warp or buckle may occur by reason of a bedded lode being deflected through an irregularity of bedding, but the tendency to rupture is less than in the case of a cross-cutting lode which is locally deflected into the bedding. Rupture, of the sort that produces brecciation, is not a prior necessity for ore deposition but is on the whole a very important contributing factor.

It is interesting to conjecture whether the Ivanhoe orebody formed for much the same reason as the Alamo, although in response to a structural environment of quite different over-all form. The answer is not forthcoming and might not be even after an exhaustive examination, but the form of the buckle in the lode is the same in both mines.

Idaho.—The Idaho lode outcrops in the small valley of a tributary of Howson Creek. There are few exposures along the course of the lode and most of the workings are caved. The rocks traversed are chiefly mixed, banded sediments and argillites. Two quartz diorite stocks lie north and west of the mine area. The structure is not known.

Two other lodes, the Cumberland and St. John, are branches of the Idaho lode on the northern or footwall side. The Cumberland joins the Idaho lode in the vicinity of the portal of No. 5 adit and diverges to the west. The St. John merges near the west end of the mine area and diverges to the northeast.

There are six adit levels on the Idaho lode in a vertical range of about 800 feet. No. 5 adit also explores the Cumberland lode. There are two small adits on the Cumberland and two on the St. John. All are caved except Idaho No. 5 adit. A sublevel between Nos. 5 and 6 was accessible in 1949 by a raise down from No. 5 level.

The Idaho has a maximum explored length of 2,500 feet. " The lode forms a strong shear or fracture zone varying in width from less than a foot to 25 feet. The principal tonnage was obtained in part from stopes between and above the upper two levels and in part from the surface about the portals of Nos. 1 and 2 adits. . . . The main shoot on the Idaho lode was up to 10 feet thick and included 2 feet of clean galena on the hanging-wall side. Besides this clean ore a large tonnage of milling ore was mined. Operations on and below the third level have, on the whole, met with only inferior results, and this in spite of every evidence of a strong lode carrying, down to the lowest level, a heavy filling of calcite gangue. Some stoping has been done from the lower levels and traces of ore mineralization are yet to be seen." (Cairnes, 1935, p. 60.)

Nothing is now known of the St. John lode. The workings on it were caved at the time of Cairnes' examination. The Cumberland has been explored over a length of 1,450 feet on No. 5 level. It is a steep well-defined fissure with little displacement. It cuts quartzites and argillites with moderate to low northeasterly dips. The best section seen contained up to 12 inches of siderite with seams of sphalerite and a little galena. One small section was stoped.

A length of 800 feet of the Idaho lode was seen on No. 5 level to a cave at the edge of a stoped section. A sublevel below No. 5, reached by a raise 500 feet from the portal, is about 700 feet long. The lode is a broad zone of shearing, not everywhere fully exposed, and locally contains 5 feet or more of calcite. It dips 50 degrees to the south but in places is steeper or vertical. There is some evidence that the hangingwall moved relatively down and to the east. The rocks are mixed, banded sediments, locally silicified.

Mineralization seen locally consisted of sphalerite in lenses and streaks and a little galena. One steep fissure containing sphalerite diverges from the hangingwall to the east.

The lode as a whole is gougy but locally is rather tight and almost free of gouge. It is as much as 20 feet wide and has the appearance of a strong shear zone.

Ivanhoe

The old Ivanhoe group, consisting of the Ivanhoe and Elgin claims, is owned by the Minnesota Silver Company, Limited, c/o Thomas A. Yawkey, 420 Lexington Avenue, New York, N.Y. Eight other claims and fractions are held by the Yawkey interests in an adjoining group. The combined property covers the basin at the head of White Creek and extends eastward to the Sandon Creek slope.

The Ivanhoe lode was discovered early in the history of the camp and received almost immediate attention. A mill was built on Carpenter Creek below Sandon in 1900 and an aerial tram was constructed to it from the mine. A total of 40,458 tons of ore was milled from 1901 to 1905, and activity then stopped for eight years. The mill was burnt down about 1914 and was rebuilt in 1916 by the Surprise Mining Company, who milled 1,105 tons in 1917. In 1918 the group was optioned by Rosebery Surprise Mining Company; 2,044 tons was milled in 1919, and Nos. 4 and 8 levels were advanced, but the option was dropped in 1920. The mill was bought by Silversmith Mines Limited in 1921.

Total production from 1895 to 1935 amounted to 44,416 tons, containing 456,295 ounces of silver, 5,211,395 pounds of lead, and 713,689 pounds of zinc. Ore was milled during seven years of this period and was shipped during fifteen.

The Ivanhoe lode is exposed in bluffs on the steep headwall of White Creek. It can be traced from talus on the east to a near junction with the Canadian lode on the west. The rocks on the bluffs are argillaceous and quartzitic, with a steep westerly dip. A few dragfolds east of the mine show that the upper beds moved relatively upwards, a movement the reverse of that common to the area. There is also some bedded faulting which has sliced other dragfolds. A discussion of the general structure and of the relationship between the Ivanhoe, Adams, and Canadian lodes is presented on pages 65 and 66, together with a description of the Adams property.

The Ivanhoe is a broad and rather irregular zone of faulting and shearing across a width of 40 feet or more on the bluffs, and the entire zone on No. 4 level appears to have a horizontal width of 150 feet of subparallel fissures and shears. Sulphides occur in very restricted parts of the zone.

The bluffs and underground workings were not mapped in detail. The principal working level, No. 4, was entered in 1948 to the main ore zone but was in poor condition, and the inner parts were caved. The lowest level, No. 8, was caved short of the lode. The uppermost workings were only partly accessible. Consequently the following description is very general.

The mine is developed by eight levels, of which Nos. 1, 2, 4, and 8 are adits, over a vertical range of 440 feet. Ore was stoped from No. 6 to 40 feet above No. 1 level, a vertical distance of 325 feet, but most of the stoping was done between Nos. 2 and 4 levels, a cross-sectional area of about 150 by 600 feet. Details of this stoping are not known.

No. 2 level, driven on parts of a large and complex lode, was partly accessible in 1948. The workings seen were irregular, and it appeared obvious that the existing outlines were the result of leasing operations in which almost all evidence of mineralization had been gouged out. Although the lode as a whole dips to the south in this part of the property, fissures were encountered in the outer part of No. 2 level dipping to the southeast at angles as low as 30 degrees. Some of these fissures and some small fractures locally form diagonal breaks between two stronger planes of movement. A little galena was seen at the two portals of No. 2 level.

On the bluffs near and above No. 2 portal a hangingwall branch of the lode diverges to the west and passes up the bluffs, possibly even to pass into the bedding, although the latter point was not established. The main zone may be traced to the west near the base of the bluffs and ultimately almost to the Canadian lode. In this interval some parts of the lode zone dip as low as 15 degrees and some dip at 50 degrees. The lode passes under talus a short distance east of No. 2 portal.

No. 4 adit reaches the lode 180 feet from the portal, crosses a branch of the lode 45 feet in the hangingwall, and continues to the south for 135 feet. The main part of the lode has been followed by drifting for 680 feet to the east and 1,450 feet to the west and southwest. The hangingwall branch has been followed for 390 feet. Three fissures up to 100 feet in the footwall of the main part of the lode have not been explored.

The drift on the main lode was accessible only for a short distance on either side of the crosscut. The workings on the hangingwall branch were open to the west and connected with a short open section of drift on the main branch of the lode. Stoping was largely restricted to the main part of the lode and a little exploratory stoping had been done on the hangingwall branch.

No. 8 adit was open as far as a cave, 600 feet from the portal, in massive argillaceous rocks dipping rather steeply to the east. Several southerly dipping faults were seen at 400 to 450 feet from the portal. A raise was driven on the main part of the lode up to No. 4 level, and No. 6 level was driven from the raise for a total length of 240 feet. Some stoping was done between Nos. 6 and 4 levels, but little evidence of mineralization seems to have been encountered below No. 6 level.

The Adams lode must cross the No. 8 crosscut and may be responsible for the caving 600 feet from the portal. If so it is possible that the southerly dipping faults 400 to 450 feet from the portal may represent footwall branches of the Adams lode zone.

The Ivanhoe lode swings to the southwest about 500 feet west of the mined area on No. 4 level and, to judge from the spacing between Nos. 4 and 8 levels, dips 45 degrees to the southeast. The inner parts of these drifts are on Canadian ground.

Little is known of the ore zone beyond the general limits deduced from an old mine plan and section. Study of the plan shows that the ore zone is related to a part of the lode with a dip of about 60 degrees to the south instead of the more general dip of 45 degrees. The steepening is accompanied by, and in fact was probably caused by, a flexure in the lode from a strike approximately east to southeast and back to east. The southeasterly striking part of the lode is nearly 200 feet long on No. 8 level, half that length on No. 4 level, and is barely perceptible on No. 3. The subdued upper part of the flexure is in the central part of the orebody, and ore was not found below No. 6 level where the flexure is most pronounced. The combined flexure and steepening of the lode passes above No. 4 level into an increased width of lode marked by many subsidiary fractures and fissures, a situation apparently favourable to the occurrence of ore.

There is some slight evidence of normal movement on fissures on No. 4 level as well as on fissures which are presumably in the footwall of the main Adams lode on No. 8 level. There is a suggestion also of a relative movement of hangingwall to the east in subsidiary fracture patterns near No. 2 level, so that the movement on the Ivanhoe and Adams lodes is indicated to be one of hangingwall down and east in conformity with other major lodes in the area. The amount of movement on the combined zone is undoubtedly very great.

Other workings presumably on the Ivanhoe lode and probably on the combined Adams-Ivanhoe lode are on the east side of the basin on the ridge between White and Sandon Creeks. A shallow stripping on the ridge crest marks the presence of brecciated and sheared rock, and a series of sloughed open-cuts down the west slope shows the zone to be a broad one. The dump of a caved adit indicates that several hundred feet of drifting may have been done on this zone. Carbonate is relatively abundant on the dump, but only a trace of sphalerite was seen.

Jennie

This lode on the Evening and Jennie claims is on Kelowna Exploration property on the ridge separating the two branches of Tributary Creek at an elevation of about 6,000 feet. One adit is on the bluffs on the western side of the ridge, and a second is on the eastern slope. Both are caved. Cairnes (1935, p. 40) states that the lode " cuts black argillaceous and quartzitic sediments of the Slocan series, strikes north 65 degrees east, and dips 45 degrees or more southeast. The productive part was about 300 feet long and 7 to 12 inches thick. In this the ore formed streaks of galena and oxidized products from one-eighth inch to 1 inch wide occurring, principally, in a gangue of quartz and calcite."

The only record of production shows that, in 1913 and 1914, 16 tons, containing 1,824 ounces of silver and 5,198 pounds of lead, was shipped.

As seen at the top of the bluffs the lode strikes north 65 degrees east and dips 50 degrees to the southeast. It appears to be a moderately strong zone of shattering and some shearing in quartzites, 10 to 20 feet wide. Its projected continuation passes through the saddle at the head of Tributary Creek west of Selkirk Peak.

The adit on the eastern slope may connect with that on the west. The dump shows some calcite and lode breccia, a little sphalerite, and a very little galena.

Kelowna Exploration Company Limited

The company name was changed in 1951 from Kelowna Exploration Company Limited to Kelowna Mines Hedley Limited. As all but a few of the many references to this company antedate the change in name the earlier name is used throughout the text. This company, operating the Nickel Plate mine at Hedley, is a subsidiary of South American Development Company Limited. Company office, 75 West Street, New York, N.Y. R. McLean Stewart, president; W. C. Douglass, general manager; Paul Billingsley, consulting geologist; George Mill, manager; Evans B. Mayo, geologist.

In 1939 the company began a campaign of investigation in the general vicinity of Sandon under the supervision of Paul Billingsley. Ground acquired included the Payne and Washington groups and various holdings south of Sandon. Mayo carried out a geological investigation of the Payne ridge in 1940 and 1941, and in 1942 the company did some stripping by bulldozer in search of the southerly continuation of the Washington lode. The time was not favourable for further investigation, and most of the ground was relinquished.

In 1946 most of the present ground south of Sandon (Fig. 9) was acquired, and the Ruth-Hope group was optioned. Quarters were established in Sandon, the Ruth No. 5 level was opened up, and crosscutting and diamond drilling were done. This work was extended in 1947, but the option on the Ruth-Hope was dropped in 1948.

In 1947 an ambitious programme of geological mapping was started by Mayo and carried on through 1948 and 1949, extending from Sandon, over Silver Ridge, to Silverton Creek, past the Oakland property, which was optioned in 1948. The mapping was later extended to cover the former Consolidated Queen Bess property. This geological mapping, done on a scale of 100 feet to 1 inch, stands out as the most extensive and detailed examination made by a private company in the Province.

As a final result of the geological mapping a decision was made to explore the Carnation lode at depth. A tunnel site at an elevation of approximately 5,500 feet was selected on Tributary Creek, and a crosscut adit to tap the lode was started in August, 1949.

A subsidiary company, Bess Mines Limited, was formed jointly with Bralorne Mines Limited to develop the former Consolidated Queen Bess property. Work in 1949, 1950, and 1951 was done on and near the surface at the Queen Bess mine.

All activity in the Sandon area was suspended in the summer of 1951.

Kootenay Belle Gold Mines Limited

Head office, 475 Howe Street, Vancouver. J. L. Trumbull, president; J. A. Clark, secretary; Vere McDowall, mine manager. This company owns a 60-per-cent interest in Retallack Mines Limited, which owns the Whitewater mine and mill at Retallack. The mill at Retallack treated ore from the Whitewater dumps from 1947 to 1950 and custom ore from various sources from 1948 on. A sink-float plant was installed in 1950.

In 1950, Kootenay Belle began milling ore from various sources on a royalty basis, and later acquired several properties in the Sandon area. These included the Altoona, Elkhorn, Monitor, Payne, Richmond-Eureka, and Ruth-Hope, which were acquired on a cash-instalment or cash-option basis. The Altoona was mined in 1950 and 1951 and the Monitor in 1951. A second sink-float plant was installed on the Richmond-Eureka to treat dump ore, and Nos. 5 and 6 adits on that property were reclaimed. Some exploratory work was done in the Ruth mine and the lower Elkhorn portal was reclaimed. Ore and sink-float concentrates were hauled by truck to the mill at Retallack.

Lone Batchelor

The Lone Batchelor claim is owned by Violamac Mines (B.C.) Limited and adjoins the Victor group. The No. 2 adit portal is on the Victor road. The claim was owned in 1901 by G. A. Petty and in later years was included in the Victor group. It was worked under lease by several individuals during seven years from 1905 to 1914, in 1917, and in 1923. Total production for the entire period was 1,068 tons, containing 25 ounces of gold, 117,570 ounces of silver, 927,038 pounds of lead, and 21,427 pounds of zinc.

There are three adits, Nos. 1 to 3, in a vertical range of about 180 feet, and one higher "A" adit. None of these was open at the time of examination.

The structural setting is the same as for the Victor lode 1,200 feet to the northwest. "The lode is a fissured zone as much as 5 or 6 feet wide composed of crushed fragments of wall-rock, gouge, and, more locally, vein matter. The vein matter included paystreaks that varied from an inch or less to 1 foot in width and followed the hanging-wall of the lode. The ore was composed chiefly of galena, but, particularly in the lower levels, was associated with varying amounts of zinc blende. The gangue was chiefly calcite." (Cairnes, 1935, p. 69.)

In 1951 No. 4 adit was started from a point below the Victor road, with the intention of crosscutting to the lode a distance of 700 to 800 feet to the northwest along the bedding.

Mammoth — The Mammoth mine is owned by Western Exploration Company Limited and is worked jointly with the Standard. It is reached from the Standard camp by a steep one-way road. The ore is delivered to the mill at Silverton by a 16,000-foot aerial tram.

The present Mammoth ground must have been located many years ago, but the first mention of the group in 1922 (then known as the Monarch) implied a recent discovery at the apex of the lode above the present ore zone. The Standard Silver-Lead Mining Company did some work under option in 1923. Porcupine Goldfields Development & Finance Company Limited worked under option through R. A. Grimes in 1926, in which year the first four adits were started. In 1927 Grimes interested Western Exploration, who acquired the property and made immediate plans to bring it into production. During 1929 mill and tram-line were completed, air was delivered to the mine from the Standard power plant on Silverton Creek, and the orebody was opened up between Nos. 7 and 4 levels. The new equipment was given a trial run in 1930, and the property was then shut down pending better metal prices.

After a period in which lessees made small shipments, the mine was brought into production in 1935 at a rate of about 100 tons a day and was operated, with one major shut-down, through 1937. Following a period of inactivity when company attention was directed to reopening the Standard and reclaiming tailings from Slocan Lake, the mine again came into production in 1942. By 1944 the orebody between Nos. 7 and 5 levels was mined out, and a considerable amount of exploratory drilling was done, much of it below No. 7. The same year a new adit, the Monarch, was started to investigate intersections obtained by surface drilling. All work ceased in 1945.

In September, 1948, No. 9 level was started. The work stopped during the winter, but the crosscut to the lode was completed, and a raise in the footwall of the lode was driven to No. 7 level in 1949. In 1950 the tram-line was repaired, and production started late in the year from No. 8 level, which was driven from the raise.

The Mammoth is at about 4,650 to 5,700 feet elevation on a steep hillside subject to snowslides, which have impeded winter work in the past. No. 9 adit is collared on a bluff face between gullies in a situation so exposed to slides that winter work is impossible. No. 9 crosscut was driven to the lode and a raise was put through to No. 7 level in the summer. In the future, hoisting and servicing will be done from No. 7.

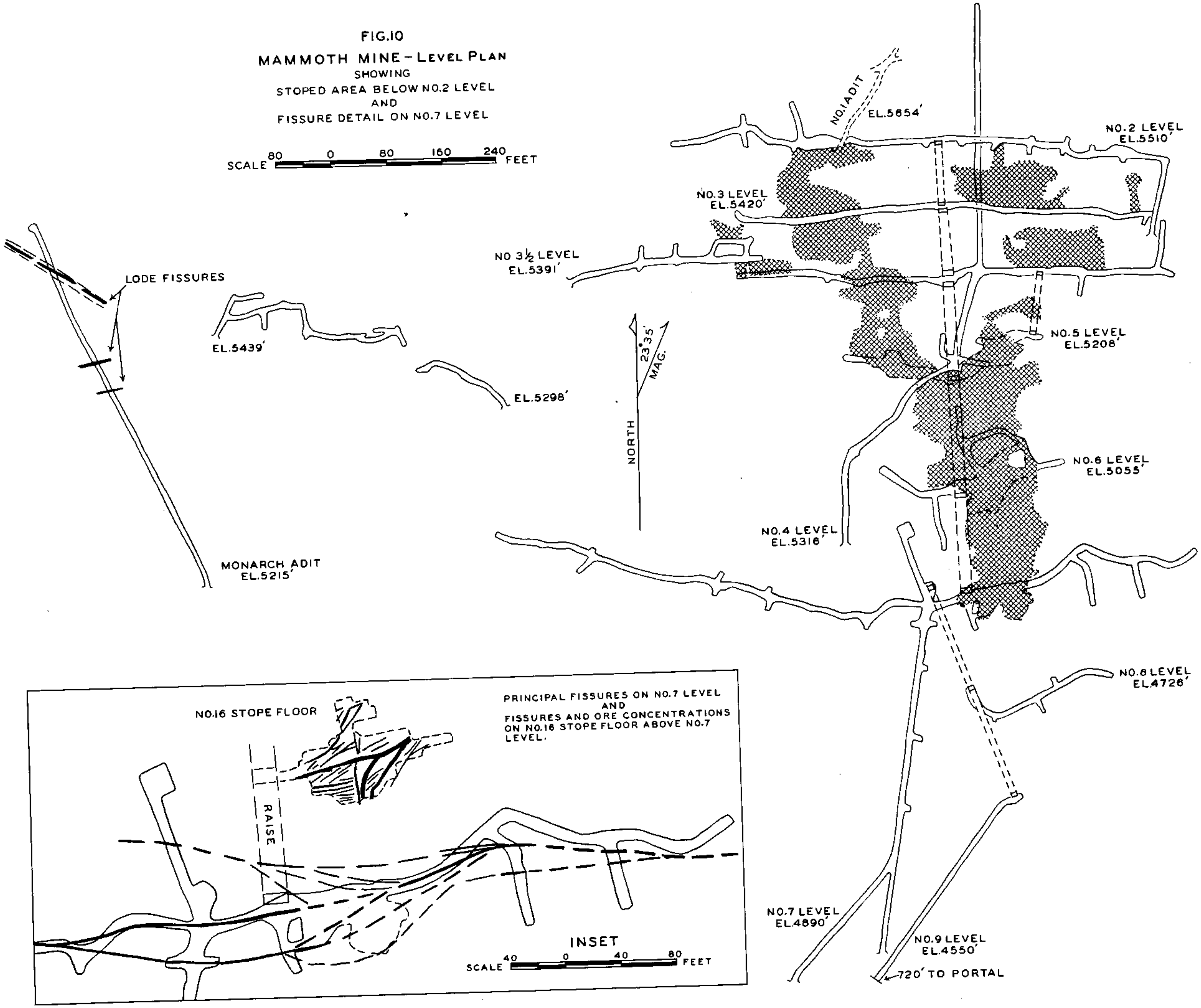
The orebody is developed by five adits, Nos. 1, 2, 4, 7, and 9. No. 3½ and two other short adits lie to the west of the main orebody, and an exploratory crosscut, the Monarch adit, lies farther to the west (*see* Fig. 10).

Complete production figures are not available because the ore has been milled jointly with that from the Standard and Enterprise. About 1,400 tons of ore was shipped prior to the start of milling in 1935. The total amount milled from 1935 to 1945 was 109,068 tons, with an average grade of about 12 ounces of silver per ton, 4 per cent lead, and 7 per cent zinc, according to company figures kindly supplied by Mr. Ham.

The main structural feature at the Mammoth mine is a compressed recumbent fold, concave to the west (Section F-F′, Fig. 4). The axis of the fold, in the hangingwall of the lode, is just below No. 4 level. The axis in the footwall of the lode is hidden from view at a somewhat higher elevation, possibly 100 feet higher. The outline of the fold is not that of a simple arc, and because there has been strike-slip as well as dip-slip on the lode (the hangingwall moved down and east an undetermined distance) direct comparison across the lode of the two faulted segments of the fold is impossible.

Below the Mammoth workings a second compressed fold, concave to the east, plunges to the south and southeast at about 20 degrees. This fold can be seen in plan on the areal map but is not shown in section. This complementary pair of compressed

FIG.10
MAMMOTH MINE – LEVEL PLAN
SHOWING
STOPED AREA BELOW NO.2 LEVEL
AND
FISSURE DETAIL ON NO.7 LEVEL



folds appears to have an amplitude, measured parallel to the low-dipping axial planes, of about 2,000 feet.

Regionally, these folds, beneath which there may be others, are plications within the major Slocan fold. Their plunge to the southeast is in contrast with the slight northwest plunge in the vicinity of Idaho Peak and in the drainage area of Howson Creek, and they are, consequently, on the southeast edge of the cross-warp that extends through much of the major productive part of the Slocan camp.

Regionally, also, the Mammoth is at the edge of the down buckle described on page 33 and illustrated diagrammatically in Figures 5 and 6. The compressed recumbent folding on Idaho Peak, with a northwesterly strike, swings through Mammoth ground to a northerly strike. At the same time the axial plane dips at a low but increasing angle to the east. Farther south the compressed folds continue to swing and steepen until they strike northeastward and dip steeply to the northwest.

The Mammoth, consequently, is situated in a focal area of extreme deformation, in which recumbent folds are warped round, down, and under into a spiral form. It is remarkable that elements of tightly folded strata which have been traced through this structure showed comparatively little evidence of brecciation. The down buckling is considered to be the result not of a second period of folding but of a change in stress application at the close of the general period of folding. If this were not so it is hard to conceive how, under conditions of a second period of folding, entire fold elements could be compressed and spirally twisted and still maintain their identity.

The fact of this down buckling is firmly established, but details on a scale directly affecting the course of mine development are very difficult to work out. The continuity of fold elements, just referred to, is interrupted in detail by warps and crumples which, being rudely parallel to different parts of the major structure, may be at considerable angles to one another. In the mine workings there are crumples with opposed attitudes that would be merely confusing if they were not understood to be reflections of the larger dual environment. The presence of these opposed crumples has contributed in part to the existence of an orebody.

The rocks cut by the Mammoth lode are for the most part of mixed, banded type. Limestone of average flat dip, but locally much crumpled, occurs at the portal of No. 7 level, and about a 100-foot thicknes is represented in the outer part of that level. Dark siliceous argillite, underlying the limestone, occurs in the hangingwall of the lode on No. 7 level, and No. 9 level is driven entirely in that rock. On No. 7 level limestone occurs in the footwall on the west edge of the orebody; otherwise the footwall rocks are mostly argillites. The size and nature of the orebody do not vary materially with the character of the rock.

The amount of displacement on the lode is not accurately known. In the workings it has not proved possible to match the footwall and hangingwall structure, but it is certain from evidence of dragging within the lode that the hangingwall moved relatively down and east, with changes in direction during the course of movement. Study of rock distribution in the mine area indicates that the amount of movement was probably about 300 or 400 feet.

In view of the postulated amount of movement, no single structural element or panel of bedding is large or continuous enough to be matched directly across the lode, particularly because the larger elements are interrupted by opposed crumples.

The orebody on the whole is pipe-like in form and has a known vertical range of about 1,000 feet. Above No. 5 level it divides into two tabular masses in a comparatively straight fissure. On No. 8 level there is a tabular continuation east of the main orebody that is not yet fully explored. There is no development on No. 9 level as yet.

When the mine was first opened the orebody was considered to lie at the intersection of the Mammoth and Buffalo lodes. No. 1 level (now inaccessible) was driven on what was believed to be the Buffalo lode, as was No. 4, and No. 7 level was driven along the projected course of the Buffalo, although no actual fissure was encountered. There is now no positive evidence of the Buffalo lode in any of the levels above No. 8. On No. 8 level and on the first four stope floors above, a strong fissure with the same attitude as that of the Buffalo meets the Mammoth lode. This fissure, without doubt the continuation of the Buffalo lode, terminates the hangingwall of the Mammoth lode to the east and is itself terminated by the footwall. The Mammoth lode, or rather the principal part of it that is exposed, is about 40 feet wide horizontally west of the Buffalo intersection and a few feet wide to the east of it.

The Buffalo is a lode fissure dipping southeastward with a horizontal component of movement of east side north of about 30 feet. It is well exposed in the draw below the Mammoth and has been followed for 200 feet in a drift, and it seems extraordinary that it is not recognized throughout the vertical length of the Mammoth orebody. The only explanation is that it passes locally into the bedding.

In the discussion of regional structure the belief has been advanced that some or all of the lodes (considered as major crosscutting faults, p. 49) originated as bedded structures in the steep northeasterly trending rocks and became crosscutting as they broke out of and across the tight arc of down buckling. The movement on the lodes was in the same direction as the interbed slippage necessitated by the buckling. This concept is supported by the occurrence of dragfolds of secondary origin in the valley of Silverton Creek, related to the down buckling and presenting evidence of considerable interbed movement during the late stage of folding. Expressed differently, the larger crosscutting faults of the Sandon area were initiated as faults tangential to the steep northeast panel of downbuckled rocks, and their relationships to their environment were much the same as those of the tangential northwesterly faults elsewhere described.

The northeasterly striking Buffalo lode meets the easterly striking Mammoth lode and merges with it, in part through a bedded zone. The two lode movements were in the same direction and were additive. Although they were contemporaneous, the influence of the Buffalo was to produce a swelling and slight jog in the Mammoth lode on No. 7 level and above, that contributed to the formation of a site for ore deposition in the master lode.

The detail of the ore zone on No. 7 level is shown in inset in Figure 10. The lode broadens, and there is a jog or offset in it, in a direction favouring the formation of a low-pressure area under the known conditions of fault movement. The direction of the jog is in accord with the Buffalo movement.

In the main part of the orebody there were abundant northeasterly slips and ore masses between Nos. 7 and 6 levels, as mapped on floor plans by C. C. Starr. Figure 10 shows the distribution of slips and ore on stope floor No. 16 above No. 7 level. The principal concentrations of ore are for the most part parallel to the average course of the lode. Northeasterly trending concentrations are common, and a few trend northward, across the lode; these last are not seen above the eighteenth stope floor above No. 7 level.

The influence of the northeasterly direction of fissuring seems plain, the Buffalo lode being a focal accentuation of the systematic interbed movement of the northeasterly striking rocks. The Mammoth lode, at some point to the west, had left the bedding and broken across the structure as a dominant crosscutting fissure. The northeast flexure or jog in the lode that has localized the orebody is undoubtedly related to bedding structure, even if more directly to a northeasterly direction of fissuring. It is believed that the flexure was initiated in a panel with northeast strike and persisted beyond the actual limits of that panel.

The foregoing is a lengthy treatment of matters in which interpretation overshadows obvious fact, but the localization of an orebody of major importance is worth more than passing attention. If it is the aim to recognize combinations of circumstance which have favoured the deposition of ore, one must, in the Slocan, delve into structural relationships beyond the limits of mine workings.

The Mammoth lode is not seen on the surface east of No. 2 level, but it plainly follows a steep timbered area east of a prominent gully to the Carnation workings. The existence of the lode in this area is proved by an offsetting of the formation (Fig. 2). The Wakefield lode joins the Mammoth just below the Carnation 6500 level, although the actual intersection cannot be seen.

To the west the lode has been explored by short adits and by diamond drilling as far as the Monarch adit. It splits at some point east of the Monarch adit and crosses the next ridge to the west, and Emily Creek, in two members, the southernmost of which passes through the Robin claim to the vicinity of the Alpha workings of the Standard mine. The Mammoth is a branch of the Standard lode.

The ore consists of masses and disseminations of sphalerite and galena in a gangue of rock, calcite, and siderite. Quartz is present locally. The ore minerals are in many instances concentrated in pods and tabular masses which may be parallel to the walls of the lode, dip flatter than the lode, or lie along northeasterly trending slips, and may be of random attitude and distribution within the ore zone. It is the observation of R. A. Avison, mine superintendent, that an individual mass of ore commonly shows a segregation of galena in its central and upper part. The uppermost surface of the galena mass may be rimmed by a concentration of sphalerite, but this is seldom as thick as the marginal concentration at bottom and sides. There is thus a rude zoning of galena and sphalerite within individual minor oreshoots of the orebody, but zoning of the orebody as a whole is not indicated.

A full description of ore occurrence is at present impossible because the mine is worked out above No. 7 level, and at the last time of examination, in 1951, No. 8 level did not fully outline the ore zone. The square-set stope floor plans of C. C. Starr provided all detail in the stopes and showed variations in the limits and distribution of ore from floor to floor. The stopes above No. 4 level were not entered. Figure 10 shows the limits of stoping.

The tabular or vein-like part of the orebody above No. 5 level persisted to the apex of the lode, but the heavily oxidized uppermost part was not mined. The main stope above No. 7 level had a maximum horizontal area of about 3,500 square feet, with a maximum length of about 180 feet and a maximum horizontal width of 75 feet. The horizontal area on No. 8 level of about 2,000 square feet is comparable to that above, and a downward constriction is not indicated. On No. 8 level, in addition to the main pipe-like orebody, ore extends eastward on the footwall Mammoth fissure for an undetermined distance, at least 80 feet east of the Buffalo intersection.

On No. 7 level the explored part of the lode, apart from the orebody, is not mineralized, and diamond drilling of both footwall and hangingwall did not encounter mineralization. In the crosscut leading to the hoist station on No. 7 a subparallel fissure, in limestone, was encountered about 55 feet in the footwall of the lode. This fissure, seen also in the rope-raise above, dips at 65 to 70 degrees and is sparsely mineralized. It is a downward diverging split in the lode and warrants investigation at lower levels.

Near-surface adits to the west contain some irregular mineralization. An interesting intersection was obtained in a surface diamond-drill hole and led to driving the Monarch adit in 1944. The lode, or rather the branch that was mineralized in the drill-hole, is encountered at 490 feet from the portal, and the main hangingwall branch at 355 feet. The footwall branch follows a bedded northwesterly course in the adit, and short holes drilled horizontally from the adit substantiate this attitude for a length of 150 feet. Only a small amount of mineralization was encountered in this branch, and the hangingwall branch was unmineralized where cut by the crosscut.

All that is known of the lower limit of the Mammoth orebody is that mineralization was intersected at the approximate horizon of No. 9 level by diamond drilling from the surface. At the time of writing there has been no development of the lode on No. 9 level. The occurrence of ore east of the main orebody on No. 8 and the knowledge that a mineralized fissure exists farther in the footwall indicate that extensive development is warranted on No. 9 level.

Mascot

The Mascot showing is on the Boss claim, part of the holdings of Kelowna Exploration Company Limited. The workings are on the east branch of Tributary Creek at an elevation of 5,050 feet. Two short adits close to the trail and one adit a short distance below the trail explore a southerly dipping lode. The lode is undoubtedly part of the same lode that extends from the Carnation to the Hope workings. It is exposed 400 feet to the east in an old sloughed working and 800 feet to the west on the edge of the creek.

A shipment of 1 ton in 1913 contained 52 ounces of silver and 612 pounds of lead. This was presumably from the two short adits, the lower adit having been driven under a lease from 1923 to 1925.

The two upper adits at the side of the trail and 60 feet apart are driven into a shattered zone dipping 30 to 40 degrees to the south, in quartzite. They are 35 and 60 feet long. The lower adit encounters the lode about 140 feet from the portal and follows it 50 feet to the east and 260 feet to the west beneath the upper adits. The lode dips 65 degrees to the south at the eastern face and 30 degrees at the western. It is a zone more of shattering than of shearing, and no mineral was seen in it. The lode is sinuous, and a branch at the face of the main crosscut was not intersected by a crosscut driven 60 feet into the hangingwall from the west drift.

The apparent weakness of the lode and the lack of gouge are in contrast with its known size and strength elsewhere. Possibly this is a footwall branch or element of the Hope-Carnation lode.

Some of the rock referred to as quartzite may be a product of silicification. West of the adits, on the trail, there is an extensive exposure of siliceous rock which could in part represent intense silicification.

Minnesota

The Minnesota Fraction in Wild Goose basin, at the head of Howson Creek, is owned by R. A. Grimes, of Nelson. It was once owned by Al. Holmquist. Silver-bearing galena float was found near the base of the steep hillside on the east side of the basin, and three short adits were driven just above the present road in search of the source of the float. This work was unsuccessful and the adits are caved. A fourth adit, about 40 feet lower, was driven under light cover in the bottom of the basin. This was driven southward 185 feet, and at the face a raise was put up an unknown distance. The rocks traversed are flat-lying limy sediments and no mineralization is seen. Some stripping was recently done by Silver Ridge Mining Company Limited along the side of the road in an unsuccessful attempt to locate a lode.

Minniehaha

The Minniehaha claim, owned by Kelowna Exploration Company Limited, is on the ridge between the two branches of Tributary Creek. The workings are on the western slope at an elevation of about 4,900 feet. The claim is an old one but was not seriously developed until 1924 when G. W. Clark did a large amount of trenching along the course of the lode and started the main adit. In 1926 it was developed by the Victoria Syndicate in conjunction with the Carnation and other claims in a large group. The work continued through 1927 when 99 tons of ore was shipped. No work was done after 1927. The main adit and most surface workings are now caved or sloughed. One adit on a subsidiary lode fissure is accessible.

The Annual Report of the Minister of Mines for 1924, page 196, stated that the lode had been traced on the surface for a length of 1,000 feet and that " a strong outcrop of galena along a length of 40 or 50 feet " had been disclosed. Cairnes (1935, p. 85) reported that: " Surface trenching exposed an attractive showing at a point about 70 feet above the portal of the present main working-adit. This showing is part of a shear or crushed zone from 15 to 20 feet wide striking north 35 degrees east and dipping 60 degrees southeast. It carried considerable quartz and calcite and, near the footwall, from 2 to 8 feet of oxidized matter containing bunches and disseminations of galena. The main working-adit, driven as a crosscut, intersected this lode at a distance of 125 feet from the portal. At this point the lode carried about 2 feet of calcite with some siderite and a little galena. Subsequent work consisted of attempts to follow this lode, which proved most elusive as a result of both pre-mineral and post-mineral movements."

Structurally, the lode crosses quartzite and strong argillite in the zone of repeated folding immediately beneath the main overturned panel. The lode zone has produced a marked offset of the strata, and correlation across it is not certain, particularly because there is more than one plane of movement in an area of complex folding. Silicification to a degree that is hard to assess makes recognition of original rock types difficult.

The surface workings show one dominant mineralized zone and two subsidiary fissures, all part of the same lode which is explored at a depth of about 70 feet by the main adit. A second adit, 330 feet to the northeast, follows a subparallel fissure in the footwall of the main zone.

The main adit, now caved, has an aggregate length of about 800 feet and is very irregular. Company data indicate that Cairnes' remarks on the elusiveness of the lode were well founded. More complexity was encountered underground than is apparent on the surface, and one interpretation is that elements of the lode zone locally follow fault fissures and bedding.

The northeastern adit is driven 112 feet along a lode striking north 60 degrees east and dipping at about 30 degrees to the southeast, in quartzites. The lode in the face contains 20 inches of siderite, and in the outer part of the adit is about 3 feet wide, containing strands of quartz and carbonate and a little sphalerite.

The Minniehaha lode is a broad and rather complex zone of faulting, including several subparallel elements. The displacement along it, in the vicinity of the workings and about 1,000 feet to the west, shows the fault to be a large one in the Sandon scale of values. It passes through the Carnation 5480 levels and approaches the Carnation lode in the vicinity of the 6300 level. To the east it passes through the Dorothy claim, possibly as more than one zone of fissuring.

Monitor

The Monitor group of seventeen claims is owned by Slocan Monitor Mines Limited, 640 Pender Street West, Vancouver. The property is southeast of Three Forks and includes the old Monitor group and the Min and Cork group. The first shipment of ore from the Monitor was made in 1896. In 1900 an English company, Monitor and Ajax Fraction, Limited, acquired the property and shipped about 2,500 tons prior to building a mill at Rosebery. The mill, completed at the end of 1905, was intended partly as a custom plant and was designed to recover zinc concentrates, but the only record of production was 325 tons of zinc concentrates, containing 30 per cent zinc, in 1909. The mine plant was burnt by a forest fire in 1910.

In 1917 the mill was taken over by Surprise Mining Company, and in 1922 the mine was acquired by Rosebery Surprise Mining Company. The mine was leased from 1922 to 1929 by George Gormley, who shipped 1,331 tons. Slocan Monitor Silver Mines Limited was formed in 1934 and was reorganized in 1939 as Slocan Monitor Mines Limited. Small shipments were made from 1936 to 1941. During this last period of activity work was concentrated on the Min and Cork section of the property.

Total production of shipping ore from 1896 to 1941 was 4,307 tons, containing 982 ounces of gold, 373,894 ounces of silver, 2,726,857 pounds of lead, and 375,351 pounds of zinc. The 325 tons of zinc concentrates already referred to contained 227,500 pounds of zinc.

The ore from the Monitor lode contains more gold on the average than ore from any other lode in the area. The best yearly shipment was 446 tons, in 1901, and contained 0.41 ounce of gold per ton. The gold is associated with pyrite in a siliceous gangue; a sample taken by the writer of almost massive pyrite from one of the dumps assayed 1.03 ounces of gold per ton.

The rocks underlying the property are argillites with some quartzite as local beds or as bands 10 to 30 feet or more thick. The dip is predominantly to the southwest at moderate to steep angles. Slaty cleavage is fairly well developed in most of the argillites. There are a few sills, mostly but not all of quartz diorite type.

The major structure is not known, because exposures are too few to illustrate more than the fact of the general southwesterly dip. Local crumples and anomalies are small and perhaps not persistent.

Monitor.—The Monitor lode is a steep northeasterly fissure of small displacement, offsetting steeply dipping sills a maximum of 6 feet. It is locally a sheeted zone and is related in origin to the prevailing joint system. Only a small part of the stoped ground is accessible, and it is not known what conditions favoured ore deposition. The lode is offset by bedded or near-bedded faults for distances up to 60 feet to the right. Variation in the amount of offset from level to level, on at least one fault, indicates a complex or variable fault movement that may be the result of interbed take-up during the latest stages of the period of folding.

The Monitor lode is developed by five adit levels through a vertical range of 468 feet. The greatest length on the lode is 1,300 feet on No. 5 level. Only No. 3 level, part of No. 4, and the crosscut on No. 5 were accessible in 1948. The best stoping area was above No. 2 level, consisting of a nearly continuous block 400 feet long by 100 to 120 feet high, stoped to surface. A second block 200 feet long at the portal of No. 3 level and a third 130 feet long at the inner end of No. 3 were stoped to No. 2 level. A fourth block 290 feet long in the inner part of No. 4 level was stoped to a sublevel and in part to No. 3. A little stoping was done at the portal of No. 4 and a little on No. 5 on both sides of a fault where the lode was first encountered. There is no apparent pattern or rake to the ore.

The mine is worked out above No. 4 level. The ore is terminated on Nos. 2 and 3 levels by a southwest-dipping fault beyond which the lode has not been found. Exploration beyond the fault was done on No. 2 level only, crosscuts 140 feet to the left and 100 feet to the right failing to find the lode. The lack of ore on the main part of No. 5 level may mean that the ore does not extend downward from the mineral zone, or it may mean that the ore-bearing fissure has not been followed; the interval of 212 feet between Nos. 4 and 5 levels is a long one for as irregular and weak a fissure as the Monitor lode. No. 5 level stops about 150 feet short of the projected downward position of the bounding fault.

The ore control is not understood. The occurrence of ore does not appear to be related to the bedding except in a general way. The character of the lode is not greatly influenced by the character of rock traversed, although there is a distinct tendency for the width to decrease and more gouge to form where the lode crosses a sill. There is a suggestion, although faint, that ore follows the faults, and it may be that fault movement tended to open the lode fissure. If, as is presumed, the lode and fault fissures formed at much the same time, during the close of the period of folding, an interrelationship between lode and faults is to be expected, and it is even possible that the fissure known as the Monitor lode is a discontinuous break or series of breaks across interfault blocks, with continuity more apparent than real.

Kootenay Belle Gold Mines Limited mined 5,488 tons of dump rock in 1950, and late in the year obtained an option on the property. In 1951 mining commenced on No. 5 level.

Min and Cork.—The Min and Cork workings are 1,900 and 2,400 feet southeast of the Monitor lode at elevations of 3,800 and 3,600 feet respectively. They are short exploratory drives which were started about 1937.

The Min adit is driven south for 140 feet and then for 70 feet to the southeast along a sheared argillite-porphyry contact. There is no evidence of mineralization.

There are two Cork adits, one 75 feet higher than the other. The upper adit, elevation about 3,640 feet, is 285 feet long. It is driven to the southwest along discontinuous fissuring of lode direction, interrupted by several bedded faults in slaty argillite. The fissure zone is strongly oxidized and contains up to 6 inches of gouge, some carbonate, and a small amount of ore minerals. A sublevel 60 feet long is 35 feet below No. 1 adit, and some stoping was done from it. No. 2 adit was caved in 1948. It was driven a total of 240 feet to the southwest, and in an inner stretch 50 feet long apparently followed the same mineralized fissure encountered above. The fissure dips 45 degrees to the southeast.

New Springfield

The New Springfield claim, owned by E. H. Petersen, of Sandon, and H. Ekeblad, is on Miller Creek on the main road leading from Sandon to Wild Goose basin. Development on this property began prior to 1900, and although a considerable amount of work was done at several points few of the workings are now accessible.

The structure of this area is not well understood because there are few exposures, except in the upper basin of the creek. Conflicting attitudes in argillites and quartzites are seen in the creek bed close to the workings, but remarkable continuity on strike is demonstrated by a branch of the Lookout crosscut that approaches Miller Creek from the south (*see* p. 125). The general structure is shown in Section G-G′, Figure 4.

The longest adit is on the road close to the creek, and a smaller adit is 27 feet higher. Small adits upstream and downstream are caved, and it is not certain what they followed. Local folds are present, and it is probable that mineralizing solutions entered some fractures which were associated with sharp folds and were not necessarily parts of the general lode system.

The main adit at road level crosses a lode 55 feet from the portal. Drifts follow the lode 50 feet to the southeast and 255 feet to the west to caves. Heavy lagging makes study of the lode difficult. It is sinuous, appears to be a moderately strong break, and contains as much as 2 feet of quartz and siderite and local sphalerite. The dip is 35 degrees to the south at several observed points. In the west drift the lode crosses argillite and quartzite with low easterly dips, lower than at the surface or in the crosscut part of the adit, and is cut by a strong fault dipping 40 degrees to the southwest at the point of caving. There are several short raises in the west drift.

The adit 27 feet above is 50 feet long, and its face is vertically above the lower drift 30 feet west of the crosscut. The inner half of this adit exposes quartz, carbonate, sphalerite, and galena in irregular widths as great as several feet. From this some zinc ore of excellent grade has been cobbed.

The relationship between the mineral in the two adits is not clear. The indicated dip in the lower adit would bring the lode into the outer part of the upper, or even outside the portal, and whereas the lode below is gougy the ore in the upper adit seems not to occur in so well defined a lode. In any event, the amount of work done on the ore in the upper adit is small.

Production from 1897 to 1937 amounted to 85 tons, containing 8,565 ounces of silver, 97,084 pounds of lead, and 4,843 pounds of zinc. Production in 1944 was 97 tons, containing 776 ounces of silver, 5,415 pounds of lead, and 39,822 pounds of zinc. The 1944 production, of a shipping grade of almost 23 per cent zinc, came from the upper adit.

Oregon, Jan, Belle

Exploratory surface work on the Oregon, Cuba, and adjoining claims was started in 1937 by Silver Ridge Mining Company Limited. This was the first extensive stripping done by bulldozer in alpine topography in the Slocan. The ground is west of the upper stretch of Miller Creek at elevations between 5,100 feet and 5,900 feet, on slopes locally in excess of 35 degrees.

Many hundreds of feet of trenches were dug in an attempt to locate possible lodes in addition to the Sunshine and Yakima lodes already known. The work resulted in the finding of mineralization on which were later driven the Jan and Belle adits, although no major lode was discovered. Late in 1938 the Oregon adit crosscut was started with the object of intersecting the Jan and Belle mineralization, and possibly the downward continuation of the Yakima and Sunshine lodes.

The area is structurally at the lower edge of the main overturned panel. Section G-G′ illustrates the general structure, the details of which are complex. Two bands of quartzite are involved, between and stratigraphically below which are thin-bedded argillites and some quartzites, including thin, silty beds which weather a buff colour and are limy. The thin-bedded rocks are caught up in local crumples and sharp plications, and there are open folds in the overturned panel itself.

Mapping of this area has not been altogether satisfactory, partly because of the complexity of detail and partly because the ground drops rapidly into Miller Creek, exposing lower structures in a short lateral distance. Continuity has not been proved to the west along the flank of the ridge between Howson Creek and Carpenter Creek drainage, a stretch very poor in rock exposures. Continuity of the rock units is affected by the possible course of the Alamo lode, which may pass not far west of the Oregon adit.

The bulldozer stripping uncovered two showings known as the Jan and the Belle and, farther south, a little erratic mineralization apparently more related to a sharply crumpled zone than to any well-defined fissure.

On the original Jan discovery a shaft was sunk 50 feet to a point where the lode was cut off by a flat fault. An adit was driven at an elevation 10 feet below the bottom of the shaft and picked up the lode below the fault at a point 125 feet from the portal. The lode was followed for a total length of 135 feet in an average direction of north 55 degrees west. The dip is from 50 to 70 degrees southwest. This lode is a narrow oxidized fracture crossing beds that dip about 20 degrees to the northeast; in the portal section dips are low to the southwest. The lode ranges from a crack to a reported 20 inches in a short underhand stope a few feet deep. For the most part it is 2 to 6 inches wide and contains some scattered galena. The fault referred to is a bedded-clay slip, and the lode terminates on the northwest end against a similar slip. It was noted at one point that bedded clay is terminated by the lode.

The Belle adit, about 100 feet lower than the Jan and 200 feet to the northeast, is nearly 400 feet long in a general west-northwest direction, driven in flatly dipping warped beds. The adit discloses several oxidized fractures locally containing galena. The fractures strike nearly east and dip from 50 to 70 degrees to the south. According to one interpretation they are parts of a single lode interrupted by flat bedded faults, but the writer considers them to be mineralized fractures terminated by bedded-clay seams which may not represent appreciable movement.

In more than one place a mineralized fracture terminates on a bedding plane, and the mineralization turns into and follows the bedding for as much as 3 to 4 feet. In one place mineralization follows steep fractures and flat bedding in a series of steps, with no evidence either of bedding slip or continuity of fracture. Where a fracture terminates beneath bedded clay and a similar fracture is found at a short distance above the same clay seam it may be possible that faulting of a single fracture has occurred, but the foregoing relation to bedding proves generally the existence of a system of discontinuous joints, some of which may terminate against and others transect thin plastic (clayey) beds.

The occurrence at and near the adits of a system of southward-dipping joints, several of which contain traces of mineral matter, leads to the conclusion that the Jan and Belle mineralization is directly related to the joint system.

The Oregon adit is an exploratory crosscut driven 2,150 feet in a general direction of south 22 degrees west. The total amount of work in it is about 2,750 feet. Heavy ground 925 feet from the portal necessitated an offset in the drive 20 feet to the east. At 1,650 feet the crosscut was offset 100 feet to the west to avoid a very wet section.

The adit was started late in 1938. Work was suspended for most of the war years and resumed in 1945. Excessively wet ground forced abandonment in the spring of 1946. Flow of water was from fractured thin-bedded and flat-lying siliceous rocks, containing irregular fractured dykes. After work stopped the working quickly became inaccessible, owing to bad air that did not permit entry for more than a few hundred feet. The air is deficient in oxygen, a condition fairly common in the Slocan, particularly in wet workings.

The Oregon adit was mapped at the time of closing before the general structural pattern of the district was understood, and there has been no opportunity to re-enter the workings. Much timbered ground was encountered, so that a more than ordinary amount of interpretation was needed to analyse the structure in the crosscut. The broad interpretation is figured in Section G-G′, Figure 4, involving sharp reversals in a zone of recumbent folding. The amount of movement on the faults is not known. Only two faults, apparently the largest of many, are shown in the section, one 925 and the other 1,760 feet from the portal.

Mineralization was encountered in three places, apart from two or three apparently random occurrences of barren quartz. The first, 220 feet from the portal, was entirely mined from a drift 80 feet long at south 80 degrees west. Recovery of a few tons of lead ore from this drift has been reported, but no evidence of ore remains. Possibly masses of galena occurred in the shattered rock with no definite lode structure. A joint system in quartzites farther in the adit, striking about north 40 degrees east and dipping 50 to 75 degrees southeast, is not mineralized. The second mineralization, at 900 feet, is a narrow lode zone containing quartz, siderite, and sphalerite. The lode was followed westward in a drift, the inner part of which was caved. It is in shattered ground near the first major southwest-dipping fault.

The third mineralization, 1,650 feet from the portal, is a gougy fissure zone containing a little quartz, striking north 70 degrees east and dipping 55 degrees to the southeast. It was followed 110 feet westward to where it was intersected by the second major southwesterly dipping fault. The hangingwall side of the fault was followed for 280 feet to the northwest, and a diamond-drill hole was driven ahead for an unknown distance without results. Heavy lagging in the vicinity of both fault and fissure obscured much detail, and it was not certain that the assumption of a right-hand offset was correct. The " lode " fissure is apparently a strong one, with an attitude common to that of many known lodes.

Palmita

The Palmita claim is owned by G. W. Robinson, 9933 Thirteenth Street, Edmonton. It is at the head of Shea Creek at an elevation of about 5,000 feet. The earliest development on the Palmita was on the eastward extension of the Queen Bess lode, and several short adits were driven on the general lode zone. Later development, starting about 1928, was initiated by E. J. Vandergrift from the upper Black Colt adit, and mining was later carried out by Clarence Cunningham when the Palmita claim was part of the Consolidated Queen Bess holdings.

In 1949 a discovery was made on the main road crossing the claim, and an option was taken by Kelowna Exploration, but the option was dropped.

Total recorded production in the six years from 1934 to 1939 was 582 tons, containing 6 ounces of gold, 38,457 ounces of silver, 597,835 pounds of lead, and 37,318 pounds of zinc.

Four short adits on the steep hillside between the two branches of the main road were driven many years ago. One adit was cleaned out by Kelowna Exploration and the others remained caved. These adits and several open-cuts on the upper branch of the road are all in broken and crumpled argillite and quartzite. No definite lode or shear zone is to be seen, and it seems probable that the Queen Bess lode passes through here in more than one plane of movement. There is some zinc mineralization in the open-cuts.

Workings on the Palmita claim, driven from the Black Colt No. 1 adit, were in poor condition and only partly accessible in 1949. A raise almost on the boundary line reaches a level 34 feet above Black Colt No. 1 level. A crosscut 105 feet long leads to a northeasterly drift section 240 feet long. A second raise reaches a level 45 feet higher on the same zone and a level 30 feet still higher 50 feet long. The ore, mined locally to widths of 10 feet, has all been taken out to fault boundaries.

The Palmita orebody is supposedly an extension of one of the Black Colt orebodies, above a rather flat fault. Detailed mapping was not attempted, and a brief examination of the accessible parts of the workings showed only that ore occurred in badly broken ground and that exploration would be difficult.

In 1949 a discovery was made on the main road 45 feet from the eastern boundary of the claim. This was stripped to show an 8-foot length of galena 4 to 10 inches wide, striking north 75 degrees east and dipping vertical. This block of ore was topped by a flat bedded slip above which, 7 feet to the north, an erratically mineralized block 12 inches wide by 4 feet high showed in the bank. The showing represented joint filling with no definite correlation with ore known elsewhere. It was mined under a lease in 1951.

Payne

The Payne group is owned by R. A. Grimes, of Nelson. The lode crosses the ridge extending northwestward from Payne Mountain, and the workings are on both sides of the ridge through a vertical range of 1,450 feet. A road from Sandon passes the portal of No. 15, the lowest level, and extends to an old camp at No. 5 level on the southwest side of the ridge. No. 8 level, on the northeast slope, is reached by a trail that extends from this road to the Rambler road on McGuigan Creek.

The Payne lode was located on September 9, 1891, and was the first discovery in the Sandon area. The property was acquired in 1896 by A. W. McCune, who took out a large amount of high-grade ore, and sold the property to Payne Consolidated Mining Company, of Montreal, in 1900. The latter, in 1902, erected a mill on the Kaslo & Slocan Railway. The mill, which had a capacity of 200 tons per day, was connected with the mine by surface tramway. The mill operated through 1903 until late in 1904, chiefly on stope filling and dump material, when it closed down. The mill operated again in 1905 and 1906, when it was apparently operated by the company for the benefit of lessees. Since 1906 a total of some 200 tons has been shipped by lessees.

The original development was by five adits, the upper three of which passed through the ridge. A winze was sunk from No. 5 to No. 8 level, and No. 8 adit level was driven from the surface to tap the bottom of the winze. Almost all shipping ore had been extracted by the McCune operation, during the course of which the stopes were back filled with sorted waste, including sphalerite, which was not shipped. The company found only a moderate amount of lower-grade ore below No. 5 level.

The property was sold at auction in 1907 to Payne Mines Limited. In 1911 the property was under lease and bond to W. E. Zwicky *et al.* No. 15 adit was apparently driven by Spokane interests. After No. 15 level was completed, a 750-foot raise was driven to connect with No. 8, and Nos. 9 and 10 levels were driven, all by the end of 1916, but the only record of production from this work is 53 tons in 1916. Between that year and 1939 about 80 tons was shipped by various lessees. The property was bought by R. A. Grimes in 1948.

The Payne has produced a total of 4,989,156 ounces of silver, 50,244,955 pounds of lead, and 2,258,322 pounds of zinc. During the period from 1897 to 1900 inclusive, when ore was sorted underground, 45,085 tons was shipped, containing 4,269,993 ounces of silver and 43,104,179 pounds of lead. During the period of milling, from 1902 to 1906 inclusive, a total of about 6,640 tons of concentrates was produced, containing 348,131 ounces of silver, 3,555,689 pounds of lead, and 2,257,524 pounds of zinc. The tonnage milled during this period is not known, but assuming an average ratio of reduction of 17 to 1, such as was obtained in 1904, about 113,000 tons was milled, a large part of which was apparently stope filling and dump material. The total ore shipped and milled was not more than 160,000 tons. The total value of production has been estimated at approximately $5,000,000. Dividends of $1,438,000 were paid, largely from profits made from shipping ore.

It should be stated that, from the meagre information available, it is impossible to hazard a guess as to the probable zinc content of any of the ore as it was mined.

The writer has not examined the mine but has merely walked through the few accessible parts, namely Nos. 8, 6, 7, and 15 levels and the outermost part of No. 5. The following notes embody a condensation from Cairnes' description and data from various other sources. Statements regarding ore control are the writer's.

The mine is developed by seven adits and four intermediate levels (Nos. 6, 7, 9, and 10) to a depth below the outcrop of 1,450 feet. No. 5 was the main haulage level to the head of the tram in early years; waste was trammed out through No. 8 level on the McGuigan Creek slope, and ore above No. 8 was hoisted to No. 5. No. 15 level, 600 feet below No. 8, is connected to No. 8 by raise.

The main oreshoot, averaging about 1,000 feet long and attaining a maximum length of 1,250 feet, was mined from a little below No. 5 level to the surface. Only low-grade and sporadic ore was found below this oreshoot, although some stoping was done as far down as No. 10 level. The position of the main lode on No. 15 is not known, but it is quite possible no single fissure continues throughout the range of mine workings.

No. 15 level was driven in the general direction of the course of the lode and has a total length of more than 4,000 feet. The raise to No. 8 is 3,500 feet from the portal. Mineralization near the inner end of the level and on Nos. 9 and 10 levels was disappointing, and little exploration was done. The lode was traced on the surface from the ridge crest to No. 4 level but not below.

The lode crosses a variety of rocks, including argillites and limy and quartzitic types. The rocks are all somewhat slaty, but slate is best developed below No. 4 level on the Carpenter Creek slope and about at the level of No. 8 portal on the McGuigan Creek slope. The structure of the upper part of the mine is a recumbent fold, first recognized by Mayo, which has an almost horizontal axial plane and probably plunges a few degrees to the southeast. The oreshoot lies in the zone of maximum curvature, in relatively favourable rocks.

Southwesterly dipping rocks at the ridge crest are seen to roll down and under in the tops of those stopes which reached surface. They dip steeply at No. 3 level and flatten to moderate northeasterly dips at No. 5 level. As the rocks in No. 15 level again dip to the southwest, another fold is indicated, but the position of the axis has not been determined. The amplitude of the folding as measured from the upper apex, which is open to the northeast, to the lower apex, which is open to the southwest, is possibly about 1,000 feet. Another fold, open to the northeast, is believed to lie an unknown distance below No. 15 level.

The Payne lode passes through the folded rocks in an irregular manner. At the surface, as seen in tops of stopes and in surface openings down to No. 4 level, the ore-bearing structure has the appearance of being a joint or series of closely spaced joints, part of the crosscutting system which is well developed on Payne ridge. Cairnes mentions a converging of stringers with depth below No. 3 level. At the portal of No. 4 level what appears to be the lode is no more than a crack in the slates, and it has not been traced to No. 5 level although bedrock is exposed continuously in that area. A bedded fault is reported to cut off the lode, but it could as well be said that the lode ends in the slates. The lode was reportedly picked up on No. 5 level by driving for its downward continuation some distance from the portal, a point that is now inaccessible. On No. 8 level and up to No. 6 the lode has a very different appearance, being a shear zone as much as 6 to 8 feet wide, including considerable gouge in places. Faults are reported to have bounded the oreshoot on the northeast, but mine plans indicate that the amount of offset of the lode is variable.

The lode on the surface near No. 4 level and the lode on Nos. 6 and 7 levels are so different in appearance that it may be doubted that they are parts of the same fissure. However, the indicated continuity of mine workings is such that it is probable that the fissuring was continuous but was variable in intensity. In other words, the movement on the lode fissure varied in amount from place to place and, in spite of the fact that the fissure crossed the structure at a large angle, there was absorption of movement on bedding planes and on tangential faults.

The lode dips steeply to the southeast and is reported to have carried a paystreak of an inch to 8 feet of galena, averaging perhaps 4 to 6 inches. Bands of siderite and sphalerite made up the remainder of the lode-filling. As far as can be judged from surface evidence, the walls of the orebody were gouge free. Below No. 5 level the lode was more irregular, siderite increased, the walls were sheared, and gouge was locally abundant. A dyke closely follows the lode on Nos. 6 and 7 levels.

The oreshoot is considered to have occurred in response to a conjunction of the following factors: (1) The occurrence of gouge-free fractures in the zone of maximum curvature in a pronounced fold, a condition which favoured maintenance of openings, and (2) the existence of relatively competent rocks, including bands of quartzites. It has been reported by an eye-witness of many years ago that the oreshoot was in reality made up of eighteen shoots localized in or close to quartzite bands, a condition that strongly suggests deflections of a fissure of small displacement in crossing rocks of different competency (*see* p. 57 in connection with the Rambler mine). The topmost part of the oreshoot has been removed by erosion. The lower termination of ore may, in part, be governed by the northeasterly dip of the enclosing rocks, but it is certainly due in part to the existence of slates beneath the more competent rocks of the ore zone. A change in character of the lode to a fissure of greater movement, occupied by a variable amount of gouge, also served to reduce the occurrence of ore.

About 100 feet east of No. 2 portal an adit, known as the Wilson, is about 400 feet long. It was driven on a mineralized fracture parallel to the Payne lode. Other, unmineralized fractures occur in the general vicinity. They are members of the prominent set of joints with which the Payne lode is parallel.

In 1948 and 1949 Maurice Ansaldo and partners, under lease, cleaned out the portal of No. 5 level in an attempt to locate the lode and started an adit 33 feet east of the portal. R. A. Grimes stripped by bulldozer near the crest of the ridge in search of parallel fractures, but did not succeed in finding any that were mineralized. On the McGuigan slope, on a steep surface on the St. Keverne claim, two almost forgotten adits were investigated. The upper adit is reported to be about 200 feet long and the lower about 30 feet below it, is about 35 feet long. A lode similar in attitude to the Payne, as much as 6 inches wide and containing galena, is exposed only at the portals, where it is broken by tangential faults.

The property was optioned in 1951 by Kootenay Belle Gold Mines Limited, who reopened No. 15 level and drove an adit on the St. Keverne claim.

Queen Bess

The Queen Bess workings are on the steep southwestern slope of a prominent ridge that flanks Howson Creek, at elevations between 4,900 and 5,500 feet. The workings are reached by a road about 4 miles long from the New Denver–Kaslo highway. A truck-road was built in 1950 from the Corinth road to provide access from Sandon down the length of the ridge. Surface and near-surface workings on the northeast side of the ridge explore the lode structure on Queen Bess and Palmita ground.

The property is under lease and bond to Bess Mines Limited, 555 Burrard Street, Vancouver, a company formed jointly by Bralorne Mines Limited and Kelowna Exploration Company Limited to develop the Queen Bess, Idaho, and Alamo ground.

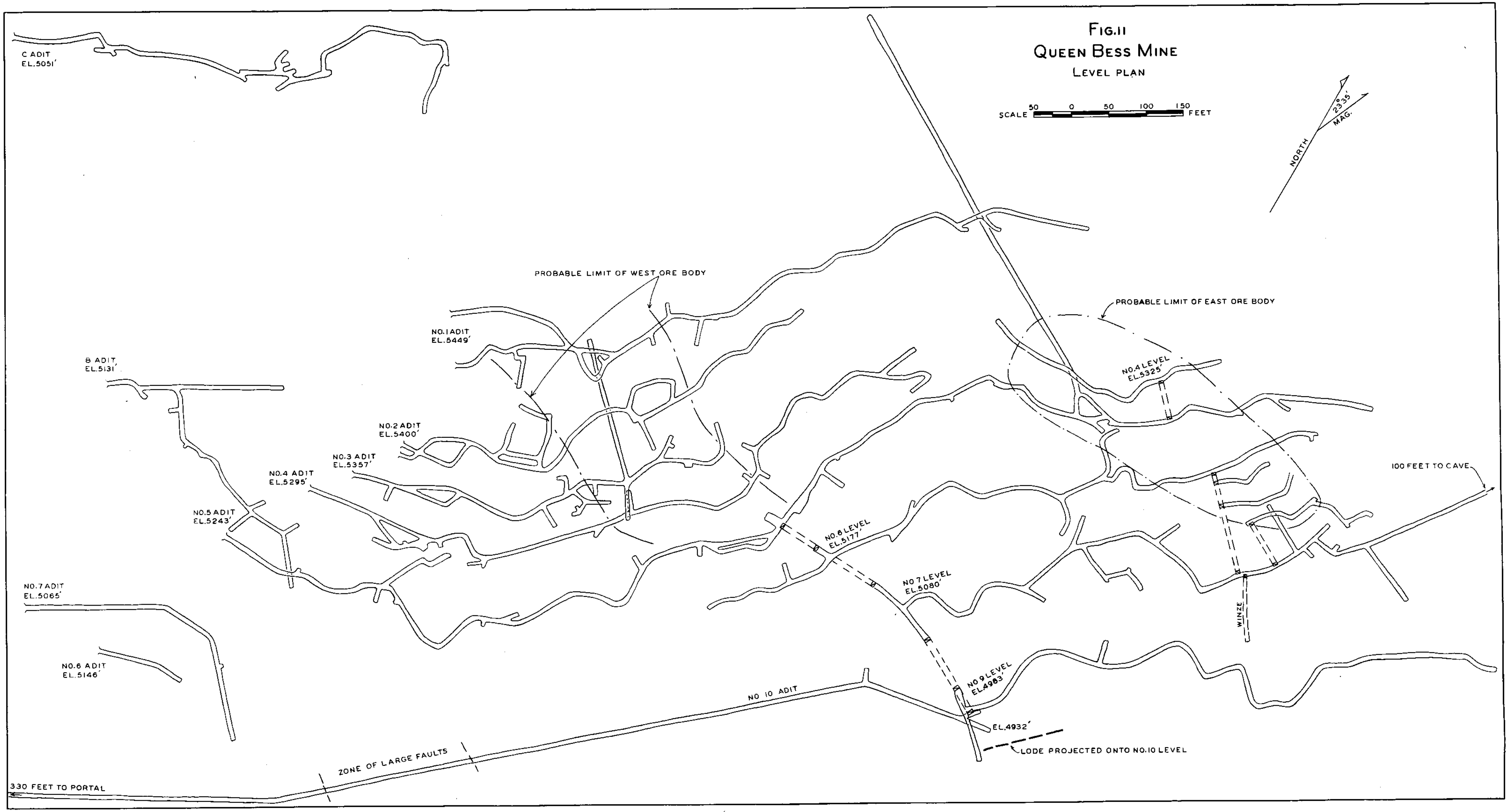


FIG. 11
QUEEN BESS MINE
LEVEL PLAN
SCALE 50 0 50 100 150 FEET
NORTH
23°35'
MAG.
C ADIT
EL. 5051'
PROBABLE LIMIT OF WEST ORE BODY
PROBABLE LIMIT OF EAST ORE BODY
NO. 1 ADIT
EL. 5449'
8 ADIT
EL. 5131'
NO. 2 ADIT
EL. 5400'
NO. 3 ADIT
EL. 5357'
NO. 4 ADIT
EL. 5295'
NO. 5 ADIT
EL. 5243'
NO. 4 LEVEL
EL. 5325'
NO. 8 LEVEL
EL. 5177'
NO 7 LEVEL
EL. 5080'
100 FEET TO CAVE
NO. 7 ADIT
EL. 5065'
NO. 6 ADIT
EL. 5146'
WINZE
NO 9 LEVEL
EL. 4983'
NO 10 ADIT
EL. 4932'
LODE PROJECTED ONTO NO. 10 LEVEL
ZONE OF LARGE FAULTS
330 FEET TO PORTAL

Plate XIII. Queen Bess mine dumps in centre foreground and Payne mine dumps beyond, in centre distance. Seaton Creek valley in left distance.

The Queen Bess was located in 1892, and a shipment of 40 tons was made in 1893. It was acquired in 1897 by the Queen Bess Proprietary Company, of England, who controlled it until 1903, when it was taken over by the Bank of Montreal. From 1898 to 1902 production amounted to 5,903 tons, with a content of 418,148 ounces of silver and 5,929,761 pounds of lead. The property then passed into the hands of Queen Dominion Mining Company Limited, of Vancouver, but little work was done for many years.

In 1916 Clarence Cunningham acquired a lease and bond on the property and, after driving about 20 feet on No. 5 level, encountered a rich orebody. Between 1918 and 1920 this orebody produced about 11,680 tons, with a net smelter value of about $1,250,000. Small shipments by lessees were made from that time until 1937, when Cunningham died. The Queen Bess, Idaho, and Alamo properties had been combined in 1928 as Consolidated Queen Bess Mines Limited and finally came into the hands of H. H. Hemsworth and associates, of Vancouver, in 1948, when the Cunningham estate had been cleared up.

Alamo Silver Lead Mining Company Limited was formed in order to obtain an option on the combined property in 1948, and in the same year an examination was made which involved a certain amount of rehabilitation, but the option was dropped.

The combined holdings were acquired under lease and bond jointly by Bralorne Mines Limited and Kelowna Exploration Company Limited in 1949, and the present Bess Mines Limited was formed as an operating company, with work under the direction of Kelowna Exploration. The geological examination of the area south of Sandon, begun in 1947, was extended to cover Howson Creek drainage area, and in 1950 bulldozing, diamond drilling, and drifting were done under the direction of Paul Billingsley and the supervision of W. M. Sharp and J. C. Black, of Sandon.

Production of the Queen Bess from 1893 to 1937 has amounted to 18,247 tons of shipping ore, which contained 27 ounces of gold, 1,377,873 ounces of silver, 18,809,857 pounds of lead, and 35,727 pounds of zinc. Zinc was recovered only from a small tonnage subsequent to 1924. None of this ore was milled because it was more economical to sort and ship a 50-per-cent lead product.

Structurally, the mine is situated in a recumbent fold, open to the southwest, immediately below the main panel of overturned strata that flanks Silver Ridge (*see* Section I-I′, Fig. 4). The fold is broken by tangential faulting, and its full outline cannot be seen. Minor crumpling is locally intense.

The rocks include argillite, quartzite, and interbedded argillite and quartzite, but details of distribution are not clear. The combination of crosscutting (lode) and tangential faults in an area of generally poor outcrop in the mine area makes it difficult to determine the amount of individual movement and the equivalence of strata. Figure 2 shows the distribution of major rock types and the effect of the faulting on them, the clearest detail being the slicing of a band of quartzite south of the mine area. Lack of outcrop on the northern nose of the ridge prevents tracing of other quartzite bands north of the lode. The intermediate band of quartzite on the southeastern side of the lode is projected from mine workings and does not outcrop.

Queen Bess Lode.—The Queen Bess lode is traceable, with reasonable certainty, over the ridge to the northeast onto the Palmita claim. A shear zone poorly exposed in a gully on the Victor road is probably on the Queen Bess lode or a branch of it. The lode is broken by faulting southwest of No. 5 portal and is present in a short adit west of Howson Creek. There is no positive information concerning it farther to the southwest, but projection and the known facts of rock distribution prove the Queen Bess and Idaho lodes to be the same.

There were at one time believed to be three lodes on the Queen Bess property, known as the A, B, and C veins, the principal one being named A. It is now known that the B vein is in reality a faulted segment of the main lode. The C vein, explored by a series of adits to the northwest, is a fissure of minor size following the direction of the steep joints which are locally abundant.

The mine was opened by six main adits, Nos. 1 to 5, now all caved, and No. 10, which is accessible (*see* Fig. 11). A raise from No. 10 level leads up to No. 5, but that level is caved. Nos. 9, 7, and 6 levels were accessible from the raise in 1950, but the upper two levels were in poor condition. A short adit, No. 7, not accessible at the time of examination, did not encounter the lode, and neither did No. 6, an even shorter adit. B vein adit was driven on a fault segment of the main lode. Another adit, driven from near the lower road on the supposed course of the B vein, is in the hangingwall of the lode. Only the lowest of the series of C vein adits is accessible, about 400 feet northwest of the main lode.

The lode was followed by each of the five uppermost adits. No. 10, driven roughly parallel to the lode, although supposedly in the footwall was actually started in the hangingwall and came into the footwall after crossing a prominent zone of faulting. The lode was not encountered by No. 10 adit but was intersected at No. 9 level by a raise. No. 10 adit is 1,650 feet long.

The rich Cunningham shoot (east orebody) was encountered on No. 5 level and developed by a series of internal levels. It was possibly 300 feet long on No. 5 level and extended from the vicinity of No. 6 upwards for a vertical distance of about 300 feet. The workings on this oreshoot have been caved for many years, and stope outlines are not known.

The lode is a very irregular structure, as may be judged from the level plan (Fig. 11). It was followed on No. 5 level from a point about 350 feet from the portal through the east orebody, according to mapping by E. B. Mayo in 1941 and A.B. Irwin in 1948 before the workings caved. In this distance marked changes in strike were in part caused by structures in the rocks traversed, although abundant lagging in the workings prevented thorough study. The long crosscut to the northwest on No. 5 is entirely in the lode footwall. No. 6 level was caved 280 feet from the main raise, and lode detail in the accessible section was obscure.

The lode was followed on No. 7 level for about 350 feet from the main raise, and the inner workings, beneath the orebody, were on a mineralized fissure dipping at about 20 degrees. A winze was sunk on this fissure which nearly follows the bedding. The innermost 200 feet of accessible level followed a shear zone dipping about 45 degrees to the southeast in argillites.

No. 9 level followed the lode for 300 feet from the raise and then worked out into the hangingwall. In the innermost part of the level, irregular ore-bearing fissures with a zonal dip of about 35 degrees are explored by two raises. This zone is apparently the same as that on which the winze was sunk from No. 7 level at an angle of 20 degrees.

The east orebody was on the lode at and above No. 5 level, with a dip of 45 to 50 degrees, and below No. 6 level the roots of the orebody were on a flatter, hangingwall branch of the lode. Very little is known of the sedimentary structure in this part of the mine, but there is an indication that the flatter hangingwall branch slices through the bedding at a comparatively small angle, and most ore was found at and above the intersection with the main lode. The hangingwall branch is mineralized to a known depth of about 150 feet below the orebody proper.

The west orebody occurred above No. 5 level. " Within this block of ground the ore formed one composite shoot commencing at the portal of No. 1 adit and raking to the northeast. The shoot had a maximum length of about 200 feet along No. 4 level. Below No. 2 adit it included much lean and barren vein matter " (Cairnes, 1935, p. 102).

Any further remarks concerning localization are speculative beyond the fact that: " Each of the orebodies lies within a bend in the vein from an easterly to a northeasterly direction, a peculiarity of ore deposition not uncommon in Slocan " (*ibid.*). The lode between the oreshoots is flatter than normal. This feature Cairnes ascribes to the passage through softer rocks, a view not held by the writer.

Both orebodies were localized by flexures in the lode. The flexures were apparently marked by more breccia and less gouge than elsewhere. The presence of " as much as 16 feet of clean galena " in the east orebody implies, if not the presence of physical openings, then the existence of a zone of relatively low confining pressure. The factor or factors which produced each flexure are not known, but the northeast strike and relatively steep dip both favour the existence of a site of lowered confining pressure in a lode on which the hangingwall moved down and to the east.

The sedimentary structure in the mine workings is not known beyond the fact of general southwesterly dip, which steepens on No. 10 level and is complicated by minor dragfolds, and nothing can be said of the structural setting of the orebodies. An upper reversal in dip to an overturned position undoubtedly occurs, but whether or not the reversal takes place in any of the upper levels is not known.

The zone of tangential faulting which is crossed by No. 10 adit passes through the outermost part of No. 5 adit and a branch passes through B adit. The main part of the zone is thought to pass east of the face of the lowest C adit. One branch passes through No. 7 adit.

The lode in the outer part of B adit is a broad breccia zone, sparsely mineralized. It swings into a southeast strike and, 80 to 90 feet south of the main body of the adit, contains several feet of low-grade zinc mineralization. It is followed southeast and south-southeast to a point about 110 feet below No. 5 level and contains a little siderite and sparse sphalerite through much of that distance. This is undoubtedly the main Queen Bess lode with anomalous strike. It appears that tangential fault members swing into the lode rather than that the lode is faulted, but the main part of the faulting seen on No. 10 level and on the surface must lie east of the present face of B adit and pass through the outer part of No. 5 level.

An adit 300 feet long driven beneath the road, 450 feet southwest of B adit, is in the hangingwall of the lode. This adit crosses steeply dipping quartzites and argillites that are continuous across No. 10 adit, 400 feet distant. The lode is probably faulted or deflected at some point between this adit and B adit.

An adit on the road 750 feet west of No. 10 portal is driven southeastward and encounters a lode zone 150 feet from the portal. This is the Queen Bess lode or a major branch of it. As seen in a drift length of 230 feet, it is a gougy zone as much as 5 feet wide dipping 50 to 60 degrees to the southeast. Where first encountered the gouge is of porphyry and is not mineralized, but elsewhere, in argillite, there is as much as 2½ feet of siderite on the hangingwall of the gouge, containing small amounts of sphalerite. A broad sill or dyke is offset to the left by the lode a distance of about 90 feet.

Trenching between this adit and the Idaho adits failed to disclose the position of the Queen Bess-Idaho lode.

The lode has been traced on the northeast side of Queen Bess ridge down to an elevation of about 4,900 feet on the Palmita claim. Several small open-cuts on the upper road and four short adits explore what appears to be a broad zone of fracturing and shearing. Lode material is present, but the evidence of mineralization is not strong. The possible continuation of the lode is shown in Figure 2, based on projection and on the assumption that an unexplored shear zone on the Victor road is part of the Queen Bess lode.

C Vein.—Only the lowest and by far the longest of the series of adits on the C vein is accessible. It is driven for the first 360 feet on a small mineralized fissure which differs little in appearance from numerous joints in the general vicinity. The inner part of the adit does not follow the same fissure and is a crosscut near the face.

The C vein was apparently as much as several inches wide, and a small amount of stoping was done on it. One winze was sunk 140 feet from the portal and another was sunk on the best section of vein 355 feet from the portal. The best section was about 50 feet long and contained galena and sphalerite with quartz. The winze was inaccessible when the workings were examined.

All work on the property ceased in midsummer of 1951.

Richmond-Eureka

This group of seven claims on the east side of Sandon Creek about 1 mile from Sandon is owned by The Consolidated Mining and Smelting Company of Canada, Limited. The group was optioned by R. Crowe-Swords, of Vancouver, and from him was optioned by Kootenay Belle Gold Mines Limited in 1950.

The lode is the eastern continuation of the Silversmith lode. It was discovered in 1891, and 70 tons of ore was shipped in 1896. In 1908, shipments started that in five years totalled 13,678 tons, averaging 48 ounces of silver per ton and 15 per cent lead. After 1912 production dwindled, but in 1919, a year of high silver price, 4,300 tons was shipped, containing 5.8 ounces of silver per ton, 1.8 per cent lead, and 2.8 per cent zinc. The last ore shipped was 59 tons in 1926.

Total production was 19,446 tons, containing 743,066 ounces of silver, 4,702,772 pounds of lead, and 241,956 pounds of zinc.

In 1951 Kootenay Belle built a sink-float plant at the bottom of No. 6 dump with the intention of treating all available dump material. Nos. 5 and 6, the two lowest adits, were reopened after having been caved at the portals for many years.

The lode was developed by six adits and some higher near-surface workings. Only the two lowest were accessible in 1951. In addition, the Slocan King adit was driven from near the creek into Richmond-Eureka ground. This adit was caved not far from the portal.

A complete study of the workings was not made, and areal mapping was halted at Sandon Creek, so no attempt is made at detailed discussion. A general treatment of the lode is included in that of the Silversmith (p. 111). Particular reference is to be found in Cairnes (1935, pp. 113–115), and the following remarks are limited.

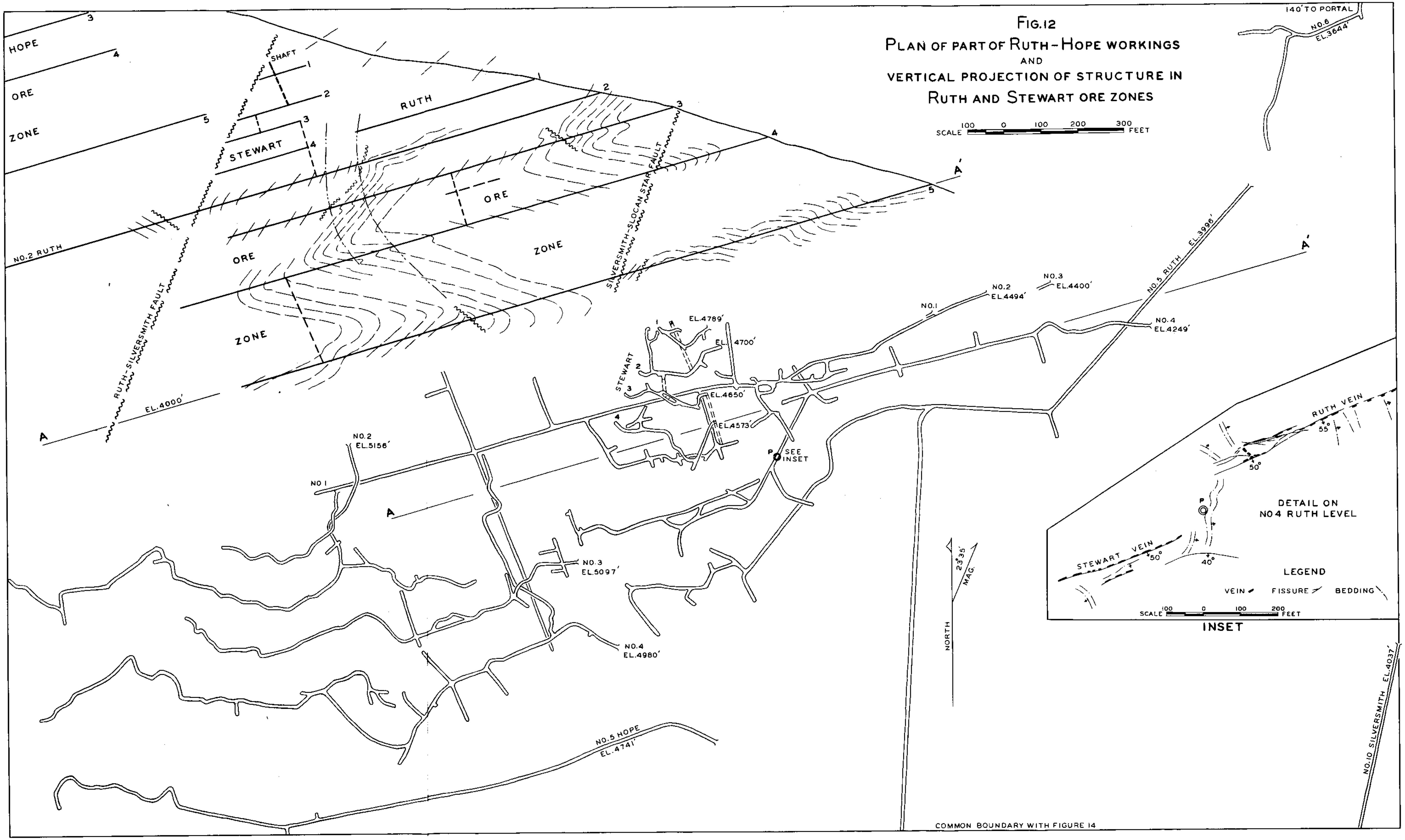


Fig. 12
Plan of part of Ruth-Hope workings
and
vertical projection of structure in
Ruth and Stewart ore zones
SCALE 100 0 100 200 300 FEET
HOPE ORE ZONE
STEWART
RUTH
ORE ZONE
ORE ZONE
SHAFT
NO.2 RUTH
RUTH-SILVERSMITH FAULT
SILVERSMITH-SLOCAN STAR FAULT
EL.4000'
A
A'
140' TO PORTAL
NO.6 EL.3644'
NO.5 RUTH EL.3996'
NO.4 EL.4249'
NO.3 EL.4400'
NO.2 EL.4494'
NO.1
EL.4789'
EL.4700'
EL.4650'
EL.4573'
STEWART
P SEE INSET
NO.2 EL.5156'
NO 1
NO.3 EL.5097'
NO.4 EL.4980'
NO.5 HOPE EL.4741'
NORTH
MAG.
23°35'
NO.10 SILVERSMITH EL.4037'
COMMON BOUNDARY WITH FIGURE 14
RUTH VEIN
55°
50°
DETAIL ON NO 4 RUTH LEVEL
STEWART VEIN
50°
40°
LEGEND
VEIN
FISSURE
BEDDING
SCALE 100 0 100 200 FEET
INSET

The lode in No. 5 level dips between 35 and 65 degrees to the southeast and is a rather irregular fissure zone consisting locally of several planes but in some places a single gouge zone 6 inches wide. The hangingwall moved down and to the east. In the drift length of about 1,400 feet there was 500 feet of stoping, but only one length of 100 feet and two shorter lengths were, according to an old map, carried up to No. 4 level. Between 625 and 1,000 feet from the portal three sublevels were driven below No. 5 level. Some mineralization was seen in addition to that in the stoped sections, but the possibilities of developing more ore on the level are not impressive.

No. 6 adit is about 1,250 feet long on the course of the lode. Ore possibilities are not impressive in the outer half of the adit, but beyond the main raise to No. 5 level siderite is locally abundant and there are some sections containing interesting amounts of sphalerite. The position of the main lode is not certain in much of this inner part, and the full width or extent of the mineralization has not been determined. Some exploration could well be carried out in the inner 600 feet of the adit, beneath the general ore zone on No. 5 level.

Ruth-Hope

This property is owned by Ruth-Hope Mines Limited, 736 Granville Street, Vancouver. R. H. Stewart, president. The property is immediately south of Sandon, and the mill is on the edge of the townsite. The original claims were located in 1892, and development was undertaken soon after. In the three-year period from 1896 to 1898 about 12,500 tons was shipped, containing about 1,000,000 ounces of silver and about 10,800,000 pounds of lead, all from the Ruth lode. The Hope lode apparently did not produce until 1906.

A mill was constructed in 1899 and was modified to recover zinc in 1904. Although the Zinc Commission Report states (p. 191) that a quantity of zinc concentrates was on hand in 1905, there is no record of zinc production until 1917 and 1918, after which time production of zinc was not the rule until 1925. Early records are not complete, but it is probable that a large part of the Ruth ore zone was mined prior to construction of the mill, because from 1900 to 1905 total production is credited as being only 4,277 tons, much of which apparently was of shipping grade. All levels on the Ruth lode were essentially the same in 1905 as they are to-day.

The Hope lode was mined from 1906 to 1919, the ore being mostly of shipping grade.

The present owners acquired the property in 1924, and a long drive was made to reach the continuation of the Silversmith orebodies across the property-line. At about the same time the Stewart lode, formerly known as Ruth No. 2, was investigated, four internal levels being driven from a shaft and from a raise above Ruth No. 2 level. The mill was rebuilt, and this phase of activity culminated in a yearly production of more than 13,000 tons in 1928 and 1929. The drop in metal prices closed the property in 1930.

Since 1930 the property was worked under lease almost continuously until 1940 and again in 1949 and 1950. It was optioned by Kelowna Exploration Company from 1946 until July, 1948, and development work was done on No. 5 level during that period. In 1951 Kootenay Belle optioned the property and drilled on No. 5 level in search of a fault block of the Ruth lode.

Production figures cannot be broken down, but the total production credited to the Ruth, Stewart, Hope, and Silversmith lodes to the end of 1949 is *about* 65,000 tons, containing, in ore and concentrates, 240 ounces of gold, 3,000,000 ounces of silver, 22,650,000 pounds of lead, and 3,100,000 pounds of zinc.

Ruth Lode.—The Ruth lode strikes north 75 degrees east and is nearly vertical above No. 3 level. It flattens downwards to a 50- to 55-degree dip on No. 4 level. The most productive part of the lode lay above No. 3 level, and little was mined between Nos. 3 and 4. No stope maps are available, and it is not known what proportion of the explored vein was stoped. Access in 1950 was by way of No. 4 level and up raises to Nos. 3 and 2; No. 1 level was inaccessible.

Production figures for 1897 show that oxidized ore assaying 35 to 40 per cent lead was shipped as well as ore assaying about 70 per cent lead. Figures are unfortunately incomplete; the relative amounts of oxidized and unoxidized ore are not known, nor are full production figures available for the Ruth lode alone. Average figures of grade are unobtainable, but it is of interest to note that from 1896 to 1898 about 12,500 tons contained an average of approximately 80 ounces of silver per ton and 44 per cent lead. Most of the Ruth zone appears to have been mined before construction of the mill in 1899.

The following remarks sum up the salient apparent facts concerning the geology of the lode. Reference is made to Figure 12, which is a composite plan from which No. 3 level has been omitted for clarity. The vertical projection illustrates the general structure as indicated by study of the levels alone, and the inset shows lode fissure-bedding detail on No. 4 level.

The lode appears to have been continuous for 700 feet from near the portal of No. 3 adit to the point where it terminates. The end of the lode on No. 2 is almost vertically above, and the end on No. 1 is apparently on the same line. On No. 4 level the lode is weaker and was not followed to its western termination, nor was it explored to the Silversmith-Slocan Star fault on the east. It was drifted on for a length of about 250 feet, and a crosscut intersects what is probably the same lode fissure about 225 feet farther to the east. On No. 5 level the lode is followed to the west for about 300 feet to a northeast-dipping fault.

In the section, Figure 12, the Ruth ore zone is shown bounded on the west by a curving line, beyond which is the Stewart vein. This line, according to old reports, was believed to be a fault zone, although the relationship was ambiguous. On No. 5 level the lode is terminated by a strong-appearing fault which dips northeast but cannot be recognized at higher levels. On No. 4 level (*see* inset) the lode structure has not been completely followed, but there is no possible fault that could separate the Ruth and Stewart as segments of one lode. On No. 3 level the lode ends in a drag-folded zone where the lode is cut by small flat faults. On No. 2 level the steep lode crosses flat beds and ends where they roll down to a steep westerly dip. There are on No. 2 some bedding slips that do not project through to No. 3 and are probably local. The behaviour on No. 1 level is not known.

The Ruth is a weak fissure with probably a few feet and certainly not more than a few tens of feet of displacement of hangingwall down and east. At its western end it splits on Nos. 2, 3, and 4 levels (*see* inset) and terminates in a zone which is not a fault but is probably a locus of marked interbed adjustment. This latter concept should be explained.

The explored part of the lode is in the axial region of a recumbent fold, convex to the west. There is evidence of crumpling of beds and of interbed and near-bedded slippage in the general crest zone. The eastward-dipping fault on No. 5 level appears there to be large, but it does not reach the higher levels. It is believed to penetrate to the general crest zone, where it is distributed through the bedding planes and possibly is absorbed by dragfolds and crumples. There may exist a similar but west-dipping fault in the west-dipping panel above the fold axis, which fault is similarly absorbed in the bedding on Nos. 2 and 3 levels. This condition is diagrammed in Section C-C′ of Figure 3, which is drawn at a different angle and on a smaller scale.

It is apparently a fact that the Ruth lode fissure was not strong enough to persist through this apical zone of crumpling and more than ordinary interbed slippage and, although there may have been some post-lode movement, the lode was not faulted but ended. The split and frayed condition of the west end of the Ruth lode fissure supports this concept, as does the fact that elements of the fissure tend to become bedded wherever discrepancies in attitude between bedding and fissuring are reduced. The Ruth and Stewart are similar lodes, not segments of a single lode.

It is significant that almost all ore was mined in the upper half of the recumbent fold, where the down and eastward movement on the lode fissure was opposed to the westward-dipping bedding planes. It is also significant that ore in the vicinity of No. 2 level, and supposedly including some of the better ore in the mine, is in a nearly vertical lode crossing nearly flat beds. In both cases the rocks fractured more cleanly and with less gouge than in situations (1) where the lode fissure crossed the beds at a small angle or (2) where the directions of fissure movement and of bedding dip nearly coincided.

In the vicinity of Nos. 2 and 3 levels the lode is offset a foot to a few feet by flat faults which step the upper segments to the south. One or two of these faults seem clearly post-mineral, but others, more or less bedded, contain a small amount of mineral matter and merge with the lode. This is in the part where footwall and hangingwall of the lode zone are about 30 feet apart and, in detail, there is a rather complex pattern of fracturing involving lode branches both steep and flat.

The rock distribution was not carefully studied. As a whole, a mixture of moderate to thin-bedded argillites and quartzites is represented, and it is not known whether the occurrence of ore may be locally related to the competency of some particular band of sediments. Several dykes were seen, but these had no apparent effect on the ore.

The ore zone is mined out except for remnants. Lessees were mining in 1949 on a sublevel about 30 feet below No. 3 level, on a block of ground which is possibly the last readily available. A winze below No. 4 level and two raises above No. 5 apparently did not encounter worthwhile mineralization.

In view of the weakness of the lode fissure and what has been said regarding its western continuation there may be doubt as to the possible continuation to the east, past the Silversmith-Slocan Star fault, a possibility never explored on No. 5 level. A general reversal in dip of bedding in the form of a second recumbent fold, convex to the east, takes place a short distance below No. 5 level, a fact which could be taken as favouring the existence of a second, lower ore zone.

No. 6 level was driven for a total length of about 800 feet, from a point immediately behind the mill. A narrow mineralized fissure, dipping 30 degrees to the southeast, was followed for a distance of 140 feet, but no attempt was made to search for continuations of it. This fissure, in eastward-dipping beds, bears no relation to the Ruth lode. The adit is now caved.

Stewart Lode.—This lode was first termed the Ruth No. 2 lode, but in later years became known as the Stewart lode because of its development at higher levels by R. H. Stewart. It is considered to have formed contemporaneously with but separately from the Ruth lode.

Little is known of this lode. The upper four Stewart levels and the shaft are inaccessible, and the workings on the Ruth Nos. 2, 3, and 4 levels are in poor condition. It is represented on Ruth No. 5 as an irregular semi-bedded and branching zone containing little evidence of mineralization. A sublevel between Nos. 4 and 5 levels was not examined.

Study of the level plans, a few points of direct observation, and company data make the following observations and deductions reasonably sound.

The Stewart lode is a moderately weak structure merging with and locally dominated by elements of northwest or tangential faulting. It is less a fissure lode than a zone of fissuring, a zone consisting of crosscutting and tangential elements, both of which are greatly influenced by bedding. The irregularity of the zone is apparent from study of the level plans. The lode is curved in the four Stewart levels, more nearly straight on Ruth No. 2, was not encountered on Ruth No. 3, and is split on Ruth No. 4 and in the sublevel below.

The lode terminates to the east in a zone of interbed slippage, much as the Ruth lode terminates to the west. On the west end the Stewart lode is bounded by the Ruth-Silversmith fault, which is seen only on Ruth No. 2 level. The lode length between these limits is about 250 feet on the Stewart levels and increases to about 800 feet on Ruth No. 5.

Where imperfectly seen on Ruth No. 2 level the zone is irregular, the general east-northeast direction being interrupted by two northwest stretches, which may or may not represent post-mineral faulting. Some stoping was done, but the ground is heavily timbered and little detail of the lode can be seen. On No. 4 level a small accessible section of the lode zone shows a footwall and hangingwall split; the footwall is the stronger, and some stoping was done on it. In one place a 20- to 30-inch zone of quartz, siderite, and sphalerite was seen. Bedding between the splits is nearly parallel in strike and is flatter in dip; some bedded slips are present. On No. 5 level the Stewart lode has flattened to pass obliquely through rather flat bedding, in spite of discordance in strike between lode and beds.

The Stewart lode in the inner part of Ruth No. 2 level swings into the southwest-dipping fault zone which is believed to be the continuation of the Ruth-Silversmith fault. Long crosscuts driven to the north and south on this level failed to locate a positive continuation of the lode west of the fault, and it is possible that the lode terminated at the fault and was not displaced by it.

A comparison beween the Stewart and Ruth lodes is interesting, because these are two subparallel lodes which pass through the same general structural zone. Production from the Stewart lode was largely from the Stewart levels; little was mined on Ruth No. 2 and below. This is in the same upper westerly dipping panel as the productive section of the Ruth lode. The Stewart was far more irregular in plan and had a variable dip of 35 to 60 degrees, influenced probably by a more irregular structural environment than the Ruth lode. Below, in the easterly dipping panel, the Stewart lode was unproductive, like the Ruth lode. On No. 5 level the Stewart lode is in the lower westerly dipping panel, not reached by the Ruth vein. In this panel, favourable in theory, the observed part of the Stewart zone is flatter and crosses the low-dipping beds obliquely.

This last situation, that of a lode passing flatly through relatively flat beds, in spite of divergence in strike, is a condition more productive of an irregular gougy shear zone than of an ore-bearing zone. The mere flatness of beds is not in itself an unfavourable condition, as witness the situation on Ruth No. 2 level, where the steep lode crossing flat beds makes ore. Apart from questions of refraction of a fissure as it passes from rock of one degree of competency to rock of another, a matter that of itself may account for variations in attitude of the fissure, it may be that below a limiting angular relation to bedding a fissure *tends* to follow the bedding, whereas above the limiting angle it is unaffected by bedding but maintains a uniform course. The magnitude of the sedimentary structure has also some influence on the course of the fissure, because minor structural flats could not conceivably have much effect on the attitude of a fissure, unless it were very weak indeed.

Hope Lode.—Little can be said of the Hope lode other than to repeat material already published. The portals are all caved, and data other than the level plans are not available.

The lode is almost certainly the westerly continuation of the Silversmith lode, beyond the Ruth-Silversmith fault, and possibly beyond a second fault subparallel to it. The relationship underground can be studied by aid of the fact that the south border of Figure 12 is the same as the north border of Figure 14.

Because of this correlation the Hope is a major lode according to the scale of values used in this bulletin. The observation by Cairnes (1935, pp. 119, 120) that the lode is a " productive zone rather than a well-marked fissure " as much as 40 feet wide substantiates this.

Cairnes further points out that the dip varies between 25 and 40 degrees and that the steeper parts as a rule are " better defined and are coincident with the intersection of the more competent rock members, particularly where the lode cuts most abruptly across them." Also, " The principal productive area was in the eastern section of the mine workings and extended from the surface to a little below No. 4 level. It had a maximum length on No. 2 level of about 550 feet and pitched to the east, out of the hill. The lode filling consisted of crushed rock, calcite, siderite, quartz, and ore. . . . The oreshoots were irregular in form, pinching, swelling, and in places abruptly terminating at their greatest thickness against a cross-fissure. . . . They varied in thickness from a fraction of an inch to 2½ feet and averaged, probably, about 100 feet in length.

" The ore as mined was clean galena and blende with comparatively little concentrating material. . . . The steel and fine cube galena ore carried from 155 to 170 ounces of silver to the ton and 60 per cent lead. Some of the zincblende carried high values in silver." Grey copper was present in the ore.

Anything further than these salient facts can only be derived from study of the level plan, Figure 12, from which raises, a sublevel between Nos. 3 and 4 levels, and a sublevel between Nos. 4 and 5 have been omitted for clarity. There is a northwest-trending section of the workings that probably represents a southwest-dipping fault west of the productive zone. If No. 5 level was driven on the lode, the lode must be much straighter on it than on the upper levels.

The dip of the ore zone is lower than is common, and speculation on the significance of this fact is profitless. Rock exposures in the vicinity of the mine are too few to form any accurate opinion of the structure.

Silversmith Lode.—Workings on the Silversmith lode on Ruth-Hope ground are shown in Figure 14. They are 3,750 feet from the portal of No. 5 level. The mineralized sections of the lode are inaccessible, and only the northern part of the older workings can be entered from a crosscut driven westerly by Kelowna Exploration in 1946 and 1947. The geology of this section is described under Silversmith-Slocan Star, pages 113 and 114.

Sandow

The Sandow claim is owned by the estate of T. Avison; R. A. Avison, Silverton, executor. It is 1,800 feet northwest of Idaho Peak on a steep southwesterly slope. The rocks are poorly exposed limestones and mixed rocks on the lower limb of the Idaho Peak dragfold. A short blocked adit and a 15-foot adit at an elevation of about 6,500 feet disclose a prominent shear zone, continuous with the Alamo lode which crosses the ridge crest 600 feet to the north. The main adit is driven on a shear zone 5 feet wide, striking north 75 degrees east and dipping 70 degrees southward. The smaller, 15-foot adit, 25 feet to the northwest, is on a similar zone. These are the southernmost known points on the Alamo lode.

Silver Ridge Mining Company Limited

Head office, 373 Baker Street, Nelson; mine office, Sandon. W. Dale Bost, president: R. A. Grimes, vice president; John R. Kenney, managing director. The Sunshine Silver Lead Company Limited was organized on December 22, 1935, and the name was changed to Silver Ridge Mining Company Limited on February 14, 1936. The prime mover was R. A. Grimes, who had in view the development of the Sunshine and other lodes at upper elevations of Silver Ridge.

The first work was an adit at the head of Miller Creek driven to locate the extension of the Sunshine lode. In 1937 and 1938 a great deal of bulldozing was done, the Jan and Belle adits were driven, and the Oregon adit was started. Work stopped in March, 1940, and was resumed in November, 1945. The Oregon adit was abandoned in July, 1946, and a site was selected on the Lookout No. 2 claim for a new crosscut at a much lower elevation. Collared late in 1946, this adit was advanced for a length of 2,200 feet and, in 1948 when the Wonderful property was purchased, a crosscut was driven northwestward in search of the Wonderful lode. A lease was granted on the Corinth the same year.

As a result of bulldozing on the Wonderful, the Pearson adit was driven to intersect the lode, and drifting was done on it in 1949. Late in the same year a crosscut was driven at shallow depth to reach the Corinth lode beneath a surface showing developed by lessees the year before.

Silversmith-Slocan Star

This property is owned by Silversmith Mines Limited, head office, 526 Lakeside Avenue South, Seattle 44, Wash. B. P. von Andersen, president. The company owns twenty-four claims on lower Sandon Creek, a consolidation of former groups. This was the largest and richest mine in the Sandon area and second to the Standard in the Slocan district. The tonnage of the Lucky Jim is greater than either, but the grade of ore is lower.

The Slocan Star oreshoot was located in October, 1891, and first produced ore in 1893. The first operating company was Byron N. White Company, of Spokane, Wash., and the property was controlled and managed by the White family for many years. A concentrator was built in 1896 and was remodelled for zinc recovery in 1904, and the Slocan Star mine was, in early years, the outstanding producer of the district. In 1904 litigation began which involved extralateral rights of the Rabbit Paw claim, owned by the Star Milling and Mining Company, in which company J. M. Harris was especially prominent. The suit lasted about seven years, being finally carried to the Privy Council, and was settled against the Whites. The two companies were amalgamated as the Slocan Star Mining Company in 1911, and production was resumed following a period of relative inactivity since 1906.

With the Slocan Star orebody exhausted and other development not very productive, the company got into financial difficulties in 1917 and was reorganized the following year as Silversmith Mines Limited. R. H. Stewart was called in as consultant, and the rich Silversmith orebody was found and was mined until 1926. In 1921 the old Ivanhoe mill was bought and remodelled, and a tram-line was built to the site below Sandon. Mining was sharply curtailed in 1927, and from then until 1936 production amounted to only about 15,000 tons. The company has been inactive since 1940.

In the mid-thirties a considerable amount of development and examination work was done, including diamond drilling. Slocan King Mines Limited was formed in 1926 under the same control as Silversmith Mines Limited. Development of this property, which lay to the east of the Slocan Star and consisted of ground formerly part of the Slocan Star group, was carried out on Nos. 8 and 10 levels of the Silversmith workings, but no orebody was found. In 1937 Slocan King Mines Limited was purchased by the Silversmith Company.

In 1948 and 1949 the Slocan Star dumps were leased to E. H. Petersen, who hand-sorted material mined in the earlier operations.

In 1948 an agreement of purchase was entered into with Carnegie Mines Limited, of Montreal. In 1950 a large part of No. 3 dump was hauled to Retallack for concentration in the Whitewater mill. Under the direction of R. Crowe-Swords about 250 tons was mined in the Rabbit Paw zone. In 1951 No. 5 level crosscut was reclaimed under the management of T. R. Buckham.

The Silversmith-Slocan Star is credited with a production of about 344,600 tons, containing 1,129 ounces of gold, 7,393,000 ounces of silver, 76,587,000 pounds of lead, and 16,390,000 pounds of zinc. The tonnage figures are subject to question, inasmuch as early records were of lot shipments without regard to whether they represented crude ore or concentrates.

An attempt has been made to estimate the production of the two main orebodies, but the record of mining is not sufficient for accurate figures. The Slocan Star orebody produced about 3,464,000 ounces of silver and 43,650,000 pounds of lead from a total of possibly 100,000 tons mined. The Silversmith orebody, including that part on contiguous Ruth-Hope ground, produced an estimated 1,000 ounces of gold, 3,550,000 ounces of silver, 26,800,000 pounds of lead, and 14,450,000 pounds of zinc from about 220,000 tons of ore mined. About 90 per cent of this total is believed to have come from the Silversmith mine.

A total of $1,267,600 has been paid in dividends throughout the life of the property.

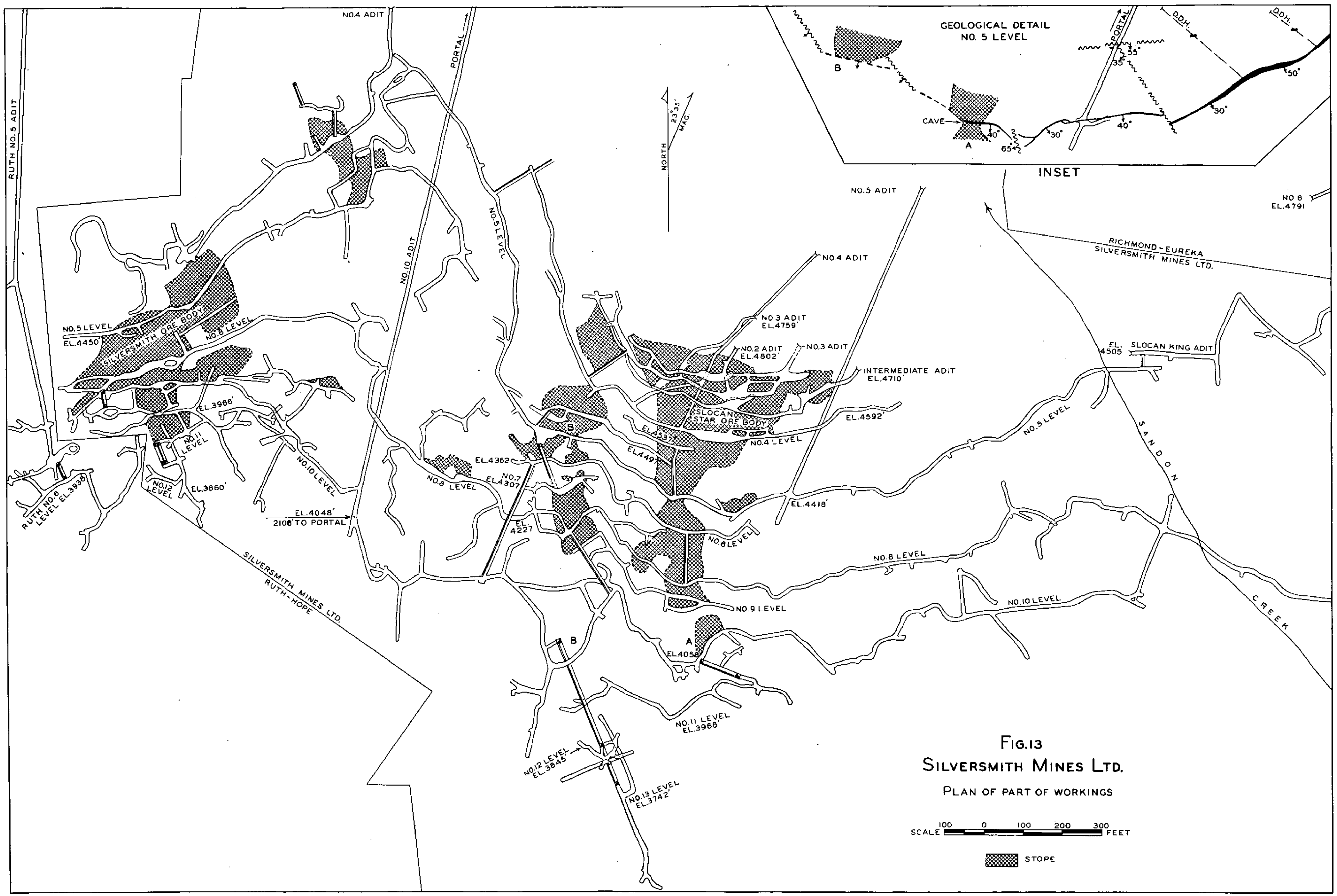


FIG. 13
SILVERSMITH MINES LTD.
PLAN OF PART OF WORKINGS

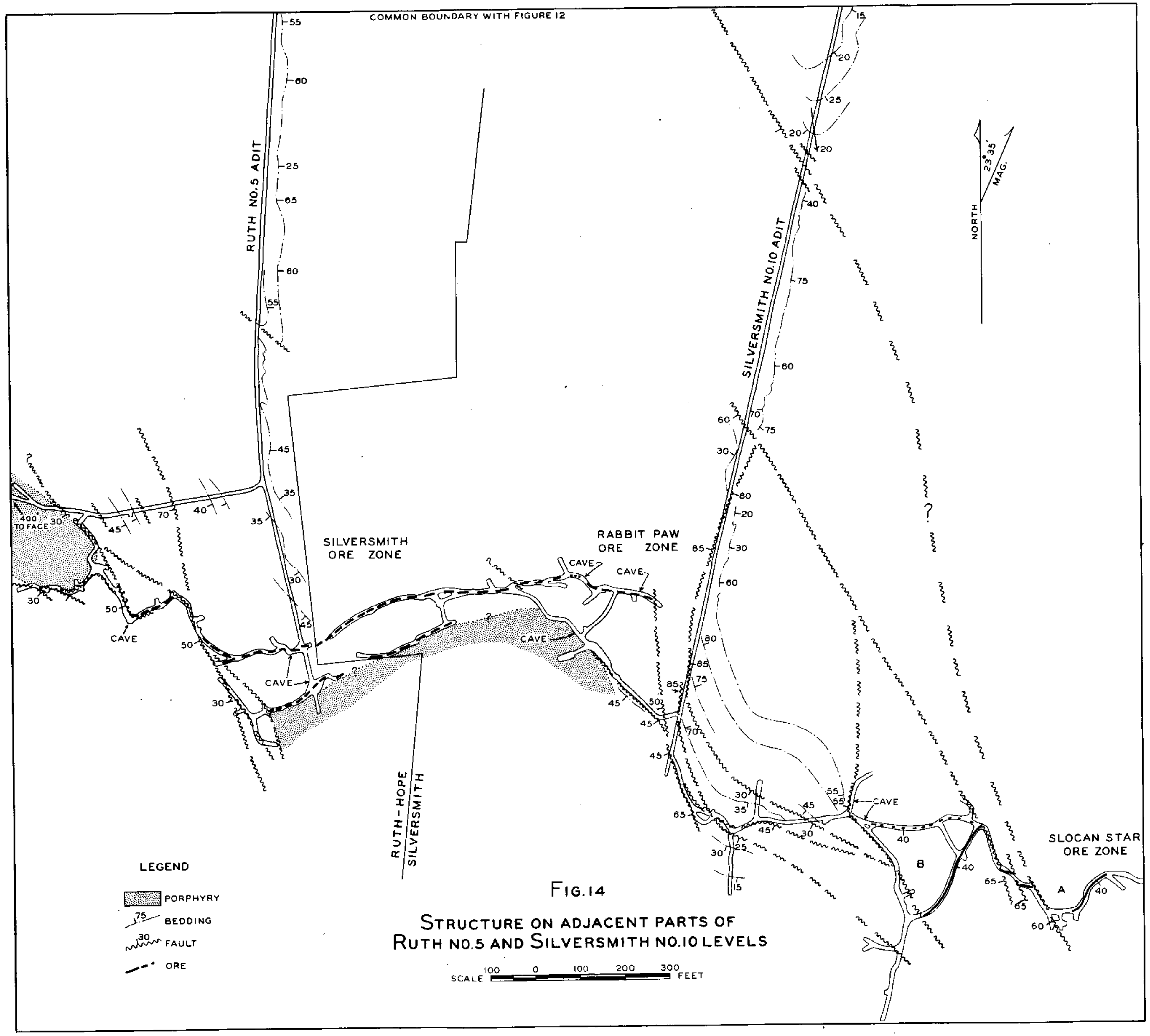


FIG. 14

STRUCTURE ON ADJACENT PARTS OF RUTH NO.5 AND SILVERSMITH NO.10 LEVELS

Until the recent lease on the dumps, no leasing was permitted on the property. Very little of the mine is currently accessible, except No. 10 crosscut and nearby workings, and No. 5 level east of the Slocan Star oreshoot.

The accompanying map, Figure 13, shows the extent of the workings west of the Slocan King portal. A few minor details have been omitted for clarity, and No. 9 level in the west end of the mine has been omitted for the same reason. The additional extent of the workings in the Slocan King part of the property may be judged from the areal map (Fig. 2).

In the following descriptions the Silversmith lode is treated without regard to property boundaries. It is continuously developed from Richmond-Eureka ground, through the Silversmith, to the Ruth-Hope, the boundary between the latter properties crossing one of the main productive sections of the lode. The Ruth No. 5 and Silversmith No. 10 levels differ in elevation by about 30 feet, so that the geology of these levels may be directly compared. The connection between properties is caved.

Ruth No. 5 level is accessible except for the main productive zone on the Silversmith lode. Only the fringes of the ore zone can be studied directly.

The lode strikes on the average a little north of east and dips about 45 degrees to the south. It is a major crosscutting zone of fracturing and shearing as much as 50 feet and more wide. It is a locus of tear faulting along which movement of the hangingwall was down and to the east at a moderate or low angle. It is interrupted by several southwest-dipping faults whose cumulative effect produced an apparent offsetting of the lode to the right of about 1,000 feet. The ambiguous relation between the lode and some faults makes it clear that they were closely related in time and origin, and that some displacive movement passed directly from lode to fault. Mineralization is not entirely restricted to the lode fissures, and some mineralization is continuous between lode and fault. It was partly this relation that made the litigation on extralateral rights such a lengthy procedure, because expert testimony was of divided opinion as to the relation between "fault" and "vein."

Structural Setting.—The structure of the Silversmith ground is not well known because of inaccessibility of workings and scarcity of good surface exposures. The outline of Section B-B[1], Figure 3, provided largely by workings on the Ruth lode, is comparable, but the details of that section are partly inferred, and the angle of southeasterly plunge is not known well enough for accurate projection onto Silversmith ground. The workings lie in a zone of recumbent folding which involves three or more main reversals in dip. Regionally, the site is in the crest zone of the major Slocan fold. The rocks consist of argillites and quartzites with few limy beds and have not been subdivided.

The mine area is cut by a number of acidic sills and dykes a few of which, locally, were intruded into the lode fissures prior to mineralization. The largest mass of "porphyry" outcrops in the hangingwall of the lode on the steep hillside near the west portal of No. 4 level and was long considered to be a stock or plug. Opportunity for study of the surface expression of this body is lessened by the dense cover and the fact that many surface workings are now obscured. It can be seen underground in only a few places. Diamond drilling on Ruth ground suggests that the body is sill-like, with continuity to the northwest, and that it is irregular in shape. Available information leads to the conclusion that the Silversmith "plug" is a local swelling of a sill-like body which varies in cross-sectional outline and whose form is locally influenced by the nature of the structural environment. Judging by exposures of similar rock in the bed of Sandon Creek, it is probable that there is a swarm of sill-like porphyry bodies in the general vicinity.

The foregoing remarks of a general nature are all that can be offered on the structural setting. They, and more detailed descriptions to follow, serve to illustrate both the difficulty and importance of the problems involved, and should point to the necessity for detailed geological mapping at the time of mining if the structure of this or any similar section is to be understood. To judge from the report of an examining engineer who complained, in 1905, of the inaccessibility of many workings, the situation is not new.

Figure 14 shows, diagrammatically, structural relationships in the principal accessible parts of the Silversmith lode. No. 10 Silversmith level and No. 5 Ruth levels are 25 feet apart vertically at their closest points. The workings are caved in the parts indicated. The geology of the accessible parts has been plotted from direct observation and that in the caved parts has been plotted from company records, wherever available.

The easternmost section of the lode at A has been stoped upward; and mineralization is continuous from it up through the Slocan Star orebody. Farther east, beyond the margin of the figure, the position of the lode is uncertain. West of this section the lode is interrupted by a large and complex zone of faulting, west of which lies the Silversmith ore zone and a second irregular zone of faulting.

In the Ruth and Silversmith crosscuts the beds dip to the east and are involved in a minor amount of dragfolding. Near the southern end of the Silversmith crosscut the beds steepen upwards and roll over to a southwesterly dip, in a recumbent fold open to the northeast and plunging to the southeast at 20 degrees or less. A similar fold may account for a change in dip in the Ruth workings, but details are obscured by crushing of the rock at the crest of the supposed fold.

The Silversmith-Slocan Star faults form a branching tangential system that appears to converge to the southeast and may also converge to the northwest. The movement on the various members is not known. In the area of the workings on No. 10 level there is an obvious relation between several fault planes and the fold structure. Part of the over-all fault movement has followed the bedding round the curvature of the strata, and part has cut across the strata with an abnormal strike of about north 20 degrees east. The complex of faults diagrammed in Figure 14 cannot be projected upward through the mine satisfactorily, but it is more than probable that the fault pattern changes from level to level.

The Rabbit Paw zone lies west of the Silversmith-Slocan Star faults and is separated from the Silversmith zone by what appears to be a barren and gouge-filled flexure in the lode. The Silversmith ore zone continues without serious break into Ruth-Hope ground, where it is terminated by the Ruth-Silversmith fault zone. Some stoping was done west of the main Ruth-Silversmith fault on a pronounced roll in the vein, beyond which only scattered mineralization has been discovered.

East of the Slocan Star shoot, beyond the margin of Figure 14, ore was apparently not encountered in drifting for a length of 2,600 feet on No. 10 level. Mineralization was found in places, but study of old maps indicates that the workings were not everywhere on the lode.

At B the northeast striking lode was stoped from No. 9 level to No. 7, above which the strike became more nearly east. This lode segment ended below No. 4 level, and stoping above No. 4 was on northwest-trending mineralization continuous with the main Slocan Star shoot. Old reports mention that ore was continuous from the " vein " for 90 feet along the " fault " in one part of the mine and doubtless refer to this condition (*see* Fig. 13). Nos. 11, 12, and 13 levels did not succeed in finding ore on this segment of " cross-vein," and it is possible that it lost its identity below No. 10. Similarly, the " cross-vein " segment at A, which is the lowest expression of the main Slocan Star orebody, was followed in a sublevel drift between Nos. 10 and 11 levels but was apparently not recognized on No. 11.

The complex of curving, partly bedded faults between B and the Rabbit Paw zone, in which the lode is missing for a strike-length of about 500 feet, straightened out up the dip to a northwest fault zone involving an apparent offset of the lode of about 750 feet. Expressed differently, the northwest fault zone, which separates the Slocan Star and Rabbit Paw zones and is itself locally mineralized, spreads out down the dip below No. 4 level, and hangingwall members of it follow bedding in the recumbent fold on No. 10 level. At the same time, the vein segment B forms between fault members, rotates to a northeast strike, and apparently loses its identity below No. 10 level.

The relation between the lode and the tangential faults is somewhat ambiguous. There is no doubt that the lode fissure and the fault fissures formed prior to mineralization and prior to some of the dyke intrusion. On the west side of the Slocan Star orebody, ore was reported to be continuous from lode to fault and, in places now accessible, not only are parts of some faults sparingly mineralized but lode fissures swing into the fault direction. There is thus implied an original relationship between fault and lode fissuring.

The most specific evidence of this relationship is seen on No. 5 level and is shown in inset on Figure 13. There are two branches of the lode, of which only the hangingwall branch has been explored. A fault ending against the footwall branch offsets the hangingwall branch. A second fault, between the crosscut and the Slocan Star shoot at A, interrupts the lode or hangingwall branch, which swings and splits as the fault is approached. A caved drift driven northwest beneath this fault shows evidence of mineralization related, apparently, to both lode and fault. East of No. 5 crosscut a wide section of the lode trends more northeasterly than the normal direction. The mineralization is quartz between walls that are frozen or carry a small amount of gouge, the latter fact proving that shearing was relatively light in this section. The conclusion is inescapable that the northeasterly direction favoured opening of the lode fissure under conditions of lessened confining pressure.

The foregoing analysis indicates the possibility that the east-northeast lode and the northwest faults may have initiated as co-ordinate shears with related northeast tension fractures. This possibility cannot be established as fact owing to insufficient evidence. The amount of displacement along the shear fractures (fissures) of both lode and faults and the general absence of fractures which possess direct evidence of being tensional in origin make it difficult to analyze an ideal stress-strain relationship that was initiated before rupturing. It may only be pointed out that the general established movement of hangingwall of lode down and east, and hangingwall of at least some faults down and northwest is not contrary to a co-ordinate origin. The later channeling of considerable movement along the initial fracturing and the interrelationship of fractures and folds make the study a very difficult one.

The structure in other parts of the mine zone is only conjectural. East of the Slocan Star shoot, development was unproductive, and apparently the character and position of the lode were uncertain. As will be discussed in the next section under "Slocan Star," the lode splits, probably near No. 4 level, and the hangingwall branch becomes erratic below No. 5 level. The vein and fault pattern deducible from old maps on No. 10 level is erratic and bears little resemblance to that in the Slocan King adit, 460 feet vertically higher. There can be little doubt that details of the lode structure change with depth.

The Slocan King adit starts as a drift and is caved at the first fault, about 240 feet from the portal. This is the first significant offset of the lode in a distance of more than 900 feet east of the Slocan Star orebody. This fault dips to the northeast, and other faults farther to the east dip in various directions eastward. The question arises why in the western part of the mine zone do the faults almost without exception dip generally westward and several in the eastern part dip generally eastward? The answer probably is that the average prevailing dip of the strata, in spite of complexity of folding, is westerly and easterly, respectively.

The Richmond-Eureka Nos. 5 and 6 adits are the only ones accessible. Stoping was done above No. 5 level over a total length of lode of about 500 feet. The lode on this level is moderately regular and is not offset appreciably by faults.

Slocan Star Orebody.—The Slocan Star orebody was one of the earliest discoveries and was probably the largest surface showing in the Slocan. It was also one of the richest bodies. Cairnes has calculated the value of mine production from 1894 to 1905 to have been $2,675,430, a figure which probably approximates the output of the Slocan Star shoot.

Parts of No. 3 workings are accessible, and the edge of the ore zone can be reached on No. 5 level. The remainder of the workings are inaccessible.

The body was longest and widest at and near the surface and funnelled down to No. 5 level. On the intermediate level between Nos. 3 and 4, elevation 4,710 feet, it was 750 feet long measured on the curve of lode and fault; on No. 4 level, elevation 4,592 feet, it was 300 feet long; on No. 5 level, elevation 4,418 feet, it was 100 feet long; this length of 100 feet was maintained through almost continuous stopes to No. 10 level, elevation 4,058 feet. A western body, continuous with the main Slocan Star shoot on top levels, was separated from it apparently as a fault segment (B, Fig. 13) about 100 feet long and was stoped above No. 9 level. The total vertical range of ore was about 800 feet at an average dip of about 45 degrees.

The average width of the orebody is not known. The total horizontal width of the combined ore-bearing structure is about 40 feet on No. 3 level, but it was not mined to the full width. Cairnes reports a maximum width of 80 feet. A northeast-trending vein structure in the west portal of No. 3 level, containing zincy ore and locally stoped to surface, may be considered the extreme footwall or else a "cross vein" in the footwall of the lode; its behaviour or even location at greater depth is not known.

The bending of the ore-bearing structure from west to northwest strike on the upper levels may account for the greater width. There are three principal planes of movement on No. 3 level and possibly more. Two fissures were apparently encountered on the east end of No. 4. Mining appears to have been carried out on a hangingwall branch of the lode below No. 4 level.

The Slocan Star orebody was widest in a broad complex lode zone, and its downward continuation was on a hangingwall branch of the lode that apparently weakened and became irregular down the dip. The footwall of the zone is not known for certain, but it was apparently explored and partly mined on No. 3 level and perhaps on No. 4. On No. 5 level (*see* inset, Figure 13) the lode followed by the drift appears to be too weak to be the main lode, and a semi-parallel shear, observable at a cave in the crosscut, is almost certainly a footwall element of the lode. Two diamond-drill holes, from information on an old map, intersected mineral on the line of projection of this shear to the east, and there is, furthermore, mineralization closely associated with the shear in the crosscut.

The lode element followed by No. 5 level, including the Slocan Star shoot, is a flatter hangingwall "blister," at this elevation as much as 175 feet from what is apparently the footwall and possibly the main element of the lode. Mineralization in the crosscut is sparse and that in the diamond-drill holes was apparently zincy, which accounts for the fact that this structure was not further prospected.

The northeast-trending vein-like section about 600 feet long in the eastern part of No. 5 level is from 3 to 4 feet wide to more than drift width and locally attains a width of about 20 feet, with a dip of 30 to 45 degrees at the wesern end and a dip of 60 degrees at the eastern end. Mineralization consists almost entirely of quartz, with local siderite, especially on the hangingwall. It contains little or no sulphides.

The western segment (B) of the Slocan Star orebody is not known, except from the drift and stope outlines as shown. It is definitely part of the main orebody at higher levels. It probably should not be considered merely as a faulted (hinged) part of the main body, but as on ore channelway in the lode-fault fissure system.

Rabbit Paw Ore Zone.—The Rabbit Paw ore zone on No. 10 level is a lode segment east of the Silversmith zone and is separated from it by a bend in the lode along a northwest course. The drift is partly caved and details are not known. The ore appears to be on a major branch of the lode in a situation structurally different from the Silversmith. A sublevel above No. 10 shows ore faces above stoped ground, but it was not fully examined by the writer. Stoped ground farther up the dip, above No. 5 level, may represent part of the same zone, but exploration on No. 8 and No. 9 levels (the latter is omitted from Figure 13) was unproductive, and continuity of the ore zone has not been proved.

The sublevel is 57 feet above No. 10 level and is midway between Nos. 10 and 9. It is 200 feet long on a lode dipping 60 degrees or more and including nearly flat and nearly vertical elements. The relation of this to a sparsely mineralized northwest fissure, dipping 45 degrees and following in part the under side of the porphyry body, is not known. The two should come together up the dip, and the question naturally arises as to what was found on Nos. 9 and 8 levels. The sublevel contains the only readily available ore in the Silversmith mine.

Silversmith Ore Zone.—This ore zone of major proportion extends from the Rabbit Paw section into Ruth-Hope ground, where it ends at a prominent zone of tangential faulting, called here the Ruth-Silversmith fault zone. All workings on ore are now caved, and for much of the following data the writer is indebted to R. H. Stewart who, in conversation, kindly drew on his extensive knowledge of the mines.

The hangingwall of the lode in much of this section is feldspar porphyry. The Silversmith plug, as it has been called, outcrops in the hangingwall of the lode, principally along the surface trace of the Silversmith-Slocan Star fault zone. Old open-cuts have now sloughed, and heavy brush cover makes it difficult to outline the porphyry on the surface. It is probable, however, that the body is sill-like and variable in cross-section, the variation being due to the influence of folded structures. The hangingwall or southern surface of the porphyry has never been investigated in the Silversmith mine.

Although most of the Silversmith ore was near the porphyry, little was in actual contact with it. The porphyry bears no genetic relation to the ore and any function of control is probably due to the fact that it contributed to the rigidity of the rock-mass as a whole and tended to deflect some fissures. In the few places observed it was noted that the actual contacts are not fault contacts, although some slip or faulting is commonly present at the border of the porphyry.

The Silversmith zone consists of two subparallel oreshoots in branches steeper than the main lode fissure. On the west end the zone is terminated by the Ruth-Silversmith fault, and no reason is known for the eastern termination. The footwall branch was the larger and more persistent.

Stoping was carried out over a total length of about 700 feet on the two properties. From No. 10 level, stoping extended up to No. 4 west level and down to No. 11 level (Silversmith) on the footwall branch, a vertical distance of 625 feet. Development on No. 12 level was disappointing.

Most of the ore occurred in two fractures steeper than the hangingwall, which was supposedly the main element of the lode. The steep orebodies were widest next to the hangingwall, against which they terminated, and narrowed downward and finally pinched out. Minor offsets were produced by fault planes which were parallel to the hangingwall and which showed normal displacement. The ore occurred in " quartzites." Some ore was mined from the main hangingwall part of the lode, beneath the porphyry but not everywhere in contact with it.

The foregoing suggests that the steep ore-bearing lode fractures formed tensionally in the footwall, in response to the normal component of movement on the lode. They formed in relatively competent rocks whose attitude is not known.

On Ruth-Hope ground, ore was mined up to No. 4 level and down to No. 6 (Ruth), a total vertical distance of 220 feet. The footwall branch was the better and is reported to have flattened at the top of the stope. Development on this property was interrupted by the decline in metal prices in 1930. Company maps show that the branches swing to the north to meet the Ruth-Silversmith fault zone tangentially, implying a right-hand displacement. In the Ruth as in Silversmith ground the lode in general cuts the formation.

Ruth, West Section.—Ore was encountered in one lode branch west of the Ruth-Silversmith fault zone (see Fig. 14). It is not definitely known whether this is the footwall or hangingwall branch, but it is probably the latter. Ore was stoped in this section from No. 6 level to some distance above No. 5. The ore-bearing structure swings abruptly from west to northwest, forming a sharp nose that plunges to the southwest. At the point of curvature, in partly caved workings, it is hard to be certain whether the lode fissure takes so sharp a bend along bedding planes in argillite or whether there has been some dragging of the beds into parallelism with the fissure at the point of curvature. This nose was followed down to No. 6 level, where it had a more pronounced curvature in plan than on No. 5. The orebody flattened sharply in the vicinity of No. 6 level and lay beneath porphyry.

The ore-bearing fissure, mineralized principally in that part striking eastward, was clearly deflected by folded strata and is in part bedded. The evidence at the only present point of observation is ambiguous, however, as there may be some dragging or flowage of argillite into a laminar product that simulates bedding.

The western mass of porphyry is probably related to the eastern, but there is no clear evidence that one body is divided into a series of fault blocks. The western body at the margin of Figure 14 narrows down, however, even if it does not terminate, because the faults do not for the most part cut the porphyry, and parts of the intrusive contact may be seen. It extends about 700 feet to the northwest, as followed for that distance by one diamond-drill hole drilled north 45 degrees west. A crosscut driven 400 feet westward from the west edge of Figure 14 was still in porphyry.

In 1946 and 1948 Kelowna Exploration Company drove a little south of west from the main No. 5 crosscut to tap the north end of the former workings and continued into the porphyry. East of the porphyry mass, diamond drilling disclosed mineralization in the footwall of the stoped ground west of the main Ruth-Silversmith fault, in a much broken area. Drilling was done along the porphyry to the northwest to test the ground along strike and, as already mentioned, followed porphyry for about 700 feet. Drilling to south and west, through the porphyry, showed the body to be highly irregular in cross-sectional outline and to have a pronounced roll or sag in its hangingwall surface; all holes were drilled upward. One strong intersection of zinc mineralization was encountered in the sag on the hangingwall of the porphyry.

This mineralization, in addition to indications in the old drift round the southern end of the western mass of porphyry, proves the existence of mineral on the hangingwall side, nowhere else explored. It is doubtful whether this can be directly related to the Silversmith lode.

The western continuation of the Silversmith lode is not known. In the vicinity of the Ruth-Silversmith fault and of the western porphyry the lode is irregular, is offset by the main fault, and is deflected into a northwesterly direction partly or wholly in response to the local structure. The evidence of only one drill-hole would indicate that the lode zone follows the northeastern or footwall side of the porphyry for some 700 feet. Perhaps part of the lode movement is distributed along the hangingwall side of the porphyry.

Correlation with the lowest workings on the Hope lode, 1,400 feet to the northwest and 715 feet higher, is unsatisfactory because little is known of the Hope lode and nothing of the intervening ground. If the Silversmith and Hope lodes are the same, then another fault zone probably lies west of the Ruth-Silversmith fault, and there is an intervening block of potentially favourable ground. It is of course impossible to say definitely whether the fault-lode complex, last seen in the Ruth workings and trending to the northwest, perhaps straightens out to a west- or southwest-striking zone which may contain ore.

It is believed that the Hope and Silversmith lodes are one, interrupted by faulting and involved in a complex of folded strata. The surface geology indicates that the Hope lode represents a crosscutting fault of major displacement in the district. Less is known regarding the Silversmith lode, and although the complexity disclosed in the mine workings shows the possibility of much take-up or variation in amount of displacement, the entire lode, ignoring detail, must represent a substantial crosscutting movement. The lode-fault pattern on the surface (Fig. 2) illustrates a general condition that is probably correctly interpreted, although branching and variations in strike and dip of all fissures produce a fissure pattern that, in detail, varies with every horizon.

Summary.—The changing pattern from place to place in this complex mine area makes both description and summary of detail very difficult. Rules learned by the miner in one part of the mine may not apply in the next. An understanding of the general processes, forms, and tendencies of the structural complex will, however, prove of value in reducing the costs of exploration.

The rule is that the lode hangingwall moved down and east, at a rather low angle in some places but probably not at the same angle throughout. The faults for the most part have a movement of hangingwall down and northwest at unknown but perhaps moderate angles. As these two directions of movement are at a large angle to one another, it follows that when an element of the lode swings into a fault direction, or vice versa, the actual direction of displacement of fissure walls may be in apparent contradiction to the foregoing rule.

It is a general fact that all fissures express normal and not overthrust movement. They are not, however, relaxational faults, but were formed under conditions of pressure, as a result of underthrusting and lateral tear.

There is a tendency for known elements or branches of the lode to converge upward and a tendency for at least some faults to converge upward. The physical expression of this is that the Silversmith-Slocan Star mine appears to become more " ragged " with depth, a condition that cannot of course continue indefinitely.

The two largest ore zones formed in response to different sets of conditions. What is perhaps most important, and one of the few factors in common, is that they formed partly in subsidiary fissures and not in the main element of the lode. The Slocan Star orebody was widest and most extensive in the zone of intersection of subsidiary fissuring with the main lode.

A word may be said regarding the possible future of the mine, or rather the chances for further exploration. In the first place, inaccessibility makes for expense in extending or even examining most existing workings. Driving blind through some general area has little chance for success in the face of the amount of work already done. It should by now be the plea, not only of the geologist, that geological mapping and investigation should keep abreast of the working-faces, and not be left to an indefinite future.

The indications of splitting of the lode on the dip provide perhaps the best clue to exploration, because overlooked segments of ore along the course of the main drifts may not amount to very much.

Lack of knowledge prevents estimation of continuity of the lode down the dip in most parts of the mine. No. 5 level, with indications of ore on a footwall split, is perhaps the easiest to investigate, from the adit crosscut.

Mineralization relatively rich in zinc was reportedly left in the eastern end of No. 4 level and might constitute ore at present prices. There is apparently a split condition in the lode in this part of No. 4 level.

At present the only block of ore observable, and also accessible without much difficulty, is in the Rabbit Paw zone above No. 10 level.

The reclaiming of No. 10 level from the adit crosscut to any point east of the Slocan Star oreshoot would be a major job roughly equivalent to driving a new heading for the same distance.

On the west end of the lode zone on Ruth-Hope ground, apart from pumping out No. 6 (Ruth) level with a view to lateral exploration or further sinking, the immediate goal would be testing the hangingwall of the porphyry, a task already begun. Testing of the footwall of the porphyry would probably involve several hundred feet of preliminary driving.

Sunshine and Yakima

The Sunshine and Yakima group now forms part of the property of Silver Ridge Mining Company Limited, being under option from the Thomas A. Yawkey interests, 420 Lexington Avenue, New York, N.Y. It lies across the ridge between Miller and Howson Creeks. The ground is in the upper overturned panel in argillites and quartzites.

Sunshine.—The Sunshine lode is explored by a series of adits crossing the ridge, two of which on the west slope are accessible. The lower adit on the west slope, the longest on the lode, was entered in 1946 for a length of 530 feet. It crosses east-dipping quartzites and argillites in a southeast direction for 220 feet to the lode; a drift follows the lode in an average direction of south 66 degrees east for 310 feet to a cave. The lode appears to be a moderate to strong fissure zone up to several feet wide containing gouge and as much as 2½ feet of calcite. The average dip is about 50 degrees to the southwest. Sphalerite and galena are present locally, although the condition of the working was such that close investigation was not everywhere possible. One stoped section 25 feet long is 180 feet from where the lode was first encountered, and a second stope commences at the cave.

The upper adit is a drift on the lode 205 feet long, and a connection exists with the lower adit, nearly 100 feet below. The lode is a gougy zone dipping between 55 and 70 degrees.

Small caved adits near the ridge crest and down the eastern slope may or may not be all on the same lode. Nothing can be learned from them except that sheared rock and some carbonate may be seen on the dumps, which appear to be very old. An adit was started in 1936 on the western side of the Miller Creek basin to intersect the lode at a lower level. This adit encountered broken ground and, when entered in 1946, was caved 150 feet from the portal.

Yakima.—Three adits on the Yakima claim at an elevation of nearly 6,000 feet are all caved. One lode, striking north 70 degrees west and dipping about 50 degrees to the south, is exposed at the southernmost portal and by stripping near by. It is a zone of fracture and shear containing some carbonate. Two other adits a short distance to the north may be on a subparallel lode 50 feet or so in the footwall of the first and diverging to the east, but the only positive evidence of a second lode is the presence of lode matter on the dumps.

Still another adit, completely caved but with a large dump, is at the fork of the road on the east side of the claim. This is known locally as the Granville adit. It is not known why it was driven, perhaps to explore the lodes already described.

Most of the work on the Sunshine and Yakima was done prior to 1905, although details are lacking. There was a little activity in 1928, evidence of which is a recorded shipment of 9 tons in that year. Total production from 1895 to 1928 amounted to 116 tons, containing 1 ounce of gold, 9,329 ounces of silver, and 117,416 pounds of lead.

Sylverite

This group of six claims is owned by Slocan Base Metals Mines Limited, 602 Hastings Street West, Vancouver. It is on upper Shea Creek and is reached from the main Silver Ridge road. The ground was prospected in early years, and an adit was driven in 1929 on the Silver Ridge Fraction claim to search for the downward continuation of ore on the Black Colt. Mining was done under lease by Clarence Cunningham in 1938, and by others in 1939, 1940, and 1942. Excelda Mines Limited, under Lloyd N. Smith, of Vernon, rehabilitated the camp in 1945 and Sylverite Mines Limited was formed in 1946 to take over the property. When Slocan Base Metals Mines was formed in 1950 the property was acquired from Excelda and Sylverite.

Production has amounted to 61 tons, containing 1 ounce of gold, 4,701 ounces of silver, 65,702 pounds of lead, and 5,925 pounds of zinc.

Structurally the ground is part of an extensive southwesterly dipping panel of commonly thinly bedded argillites and quartzites. The average dip is probably less than 30 degrees, but crumpling has produced local steep dips. Open folds may occur in areas of very low dip. The rocks are cut by steep joints at right angles to the structural trend. There is no well-defined lode in evidence.

The principal working is an adit just above the camp road, driven about 450 feet in a general westerly direction. From the end of this adit, on Black Colt ground, a raise extends to the Black Colt No. 2 level 75 feet above. A northerly crosscut extends 175 feet into Black Colt ground. Just short of the main raise the level for 45 feet crosses a north-dipping porphyry dyke, and mineralization was encountered in local shearing on the footwall of the porphyry.

A second adit on the main road, 400 feet northwest of the Black Colt No. 1 portal, is driven 200 feet to the west in broken ground, which contains a few fractures bearing evidence of mineralization. Shallow sloughed workings of an earlier generation lie just below the road.

Bulldozing done in 1949 above and below the main road between the Palmita and Black Colt claims disclosed local mineralization in a stringer zone a maximum of 30 inches wide associated with a gouge seam parallel to flat bedding. The mineralization is believed to be related to the joint system. Additional stripping in 1951 disclosed fissuring probably related to the Queen Bess lode.

Victor Violamac Mines (B.C.) Limited, head office, 67 Yonge Street, Toronto, owns the former Victor group and the Lone Batchelor and Cinderella claims. The property is on the southwest side of Carpenter Creek and is reached by 2½ miles of road from the Silversmith mill.

The original discovery on the Victor was made in 1921 by G. A. Petty as the result of trenching and ground-sluicing on a hillside almost completely covered with overburden. No. 1 adit was driven 50 feet below the discovery and four lower adits

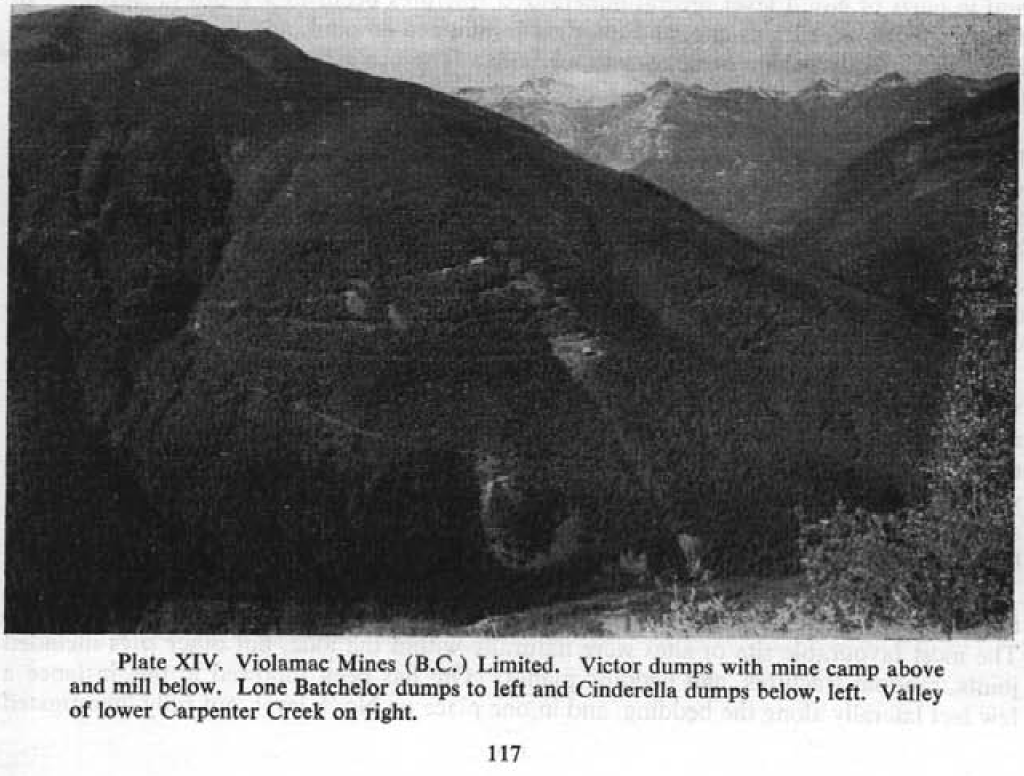


Plate XIV. Violamac Mines (B.C.) Limited. Victor dumps with mine camp above and mill below. Lone Batchelor dumps to left and Cinderella dumps below, left. Valley of lower Carpenter Creek on right.

were subsequently driven. Shipments between 1923 and 1929 amounted to 402 tons. The property was leased in 1931 by E. Doney, who shipped ore each year from 1932 to 1947. The total production to the end of 1947 was 1,424 tons, containing 132 ounces of gold, 254,419 ounces of silver, 1,298,664 pounds of lead, and 309,222 pounds of zinc.

In 1948 Violamac Mines Limited, of Toronto, purchased the property and Mr. Doney's lease and formed the present company, a wholly owned subsidiary. Production continued on a hand-sorting basis, but the rate increased when the downward continuation of the main orebody was located on No. 4 level. In 1950 a small mill was built to concentrate low-grade material and also to obviate the zinc loss incurred in shipping ore to the lead smelter.

From 1948 to 1950 the production of crude ore was 4,355 tons, containing 194 ounces of gold, 368,042 ounces of silver, 3,948,726 pounds of lead, and 1,496,336 pounds of zinc.

The rocks are interbedded argillites and quartzites, commonly rather thinly bedded. There are many sills in the mine workings. The structure is an extensive southwesterly dipping panel, right side up stratigraphically, with an average dip into the hillside estimated to be 40 degrees. Many individual dips are flatter than this figure, but the effect of minor crumples and dragfolds is to steepen the effective dip of the panel as a whole. The limits of the panel are not known, particularly of the zone where the strata must steepen and roll down and under to an overturned position, in accordance with known structure to the southeast.

The rocks are cut by a system of northeasterly trending steep joints that may dip either way but on the average dip to the southeast. The joints cut the strata approximately at right angles. The lode is parallel to the joint system and in fact appears to be an accentuated joint on which there has been only a small amount of displacement. The joints may be mineralized, and even fractures of local or non-systematic development may contain small amounts of lode matter.

The lode varies in appearance from place to place. It may be a single or multiple fracture, from a barely perceptible crack to a sheeted or crushed zone several feet wide, and in parts of No. 3 level several mineralized fractures occur in a width of 20 feet. In the oreshoots, siderite, calcite, and quartz are minor in amount, and the lode matter may be predominantly galena or sphalerite, or both. The ore averages about 1 foot wide in the ore zone, and widths of 5 feet of almost massive galena have been seen.

Faults are abundant; they are as a rule bedded and may cut the strata on dip but less often on strike. The larger faults are prominent gougy zones up to 2 feet and more wide. The movement on them is normal, inasmuch as the hangingwall moved down. Some are related to dragfolds formed as a result of folding, and it seems that here, as in other parts of the area, the bedded normal faults formed at a late stage of the folding, as an extreme of interbed slippage. The amount of movement on the faults cannot be determined, but it is believed to have been relatively small in spite of the prominent development of gouge.

The relation between faults and lode is ambiguous. The lode is offset not at all by some faults, a few inches to a few feet in either direction by others, or an as yet undetermined distance by a few, without regard to the apparent size of the fault. It is probable that the movement on many of the faults was slight, but it is a fact that lode and faults were to some degree contemporaneous. The ore widens close to a fault, proving at once an opening of the lode at the fault and a damming effect by the fault gouge. It is possible that the lode formed as a rupture in interfault blocks and not as a single continuous fissure.

The ore solutions clearly penetrated any fracture available to them and deposited ore in response to local physical opening or lowered pressure, wherever a site was present. The most favourable site or sites were naturally within the lode, but other sites included joints, random fractures, and bedding planes. Ore has been followed in one instance a few feet laterally along the bedding, and in one place on No. 5 level, not fully investigated at the time of writing, a "hump" of ore in the floor of the drift appeared to be the result of ore filling between beds in a local roll or dome.

The lode is developed by six adits. The upper five cover a range of a little more than 400 feet. No. 7, 220 feet below No. 5, was started in 1950. An old adit above No. 1 was driven as a prospect working in the early years of development.

No. 1 adit contained ore in an upper oreshoot which was topped by a flat fault and presumably was bottomed by a fault that, close to the portal, offset the lode about 15 feet to the right. On No. 2 adit no well-defined lode was seen.

No. 3 adit, near the top of the main orebody, is mined out. There was one orebody between Nos. 2 and 3 levels, but the main body lay below No. 3. No. 4 adit was not driven originally on the lode, but a short crosscut in 1949 reached the lode and drifts were driven both ways on it. The main ore on No. 4 is 160 feet long, with some additional length on the southeast.

The ore on No. 5 level is 380 feet long at least, and may be considerably longer. Most of the block between Nos. 4 and 3 and about half that between Nos. 5 and 4 was mined by the end of 1950.

No. 7 adit is driven along the course of the joint system and reaches the lode 1,040 feet from the portal. The lode strikes nearly west in the first 80 feet of drift; it is mineralized, and is similar in appearance to stretches of comparable length on the levels above. The ground is very wet on the course of the lode. The ground crossed by the adit is structurally similar to that above, with fewer faults in evidence. Lode matter was seen in several joints and minor erratic fractures. The lode was encountered in May, 1951.

The following remarks, not all sequential, refer to observations relative to geology and ore control. Some observations are the writer's, and for others he is grateful to J. W. Ambrose and W. S. Ellis.

A swarm of porphyry sills is noticeable at camp level and passes through the mine below No. 3 level. Sills are present in the outer part of No. 5 adit but are comparatively rare in No. 7 adit. They range in thickness from a few inches to 15 feet. The sills are not as good host rocks as the sediments, the lode forming in them a gougy zone or else a relatively tight fissure, rather than the sheeted or blocky fractured zone characteristic in the sediments.

The structure on No. 7 level, as far as known, is very similar to that on the levels above. The average dip is flatter, and the beds are more argillaceous and somewhat thicker. The contact with a stock of quartz diorite lies at most a few hundred feet down the hillside from No. 7, but no effects attributable to this body have been detected in the new level.

On No. 5 level there is much broken, mashed ground, and the lode matter is crushed. Some of the sills are shattered, although few faults were seen crossing them. The shattering is possibly caused by late folding, affecting the sills and the lode. There is some silicification on No. 5 level of sediments and locally of a sill or dyke. It is the only observed example of an intrusive body having been silicified, probably at the time of intrusion.

There is no obvious rake to the orebodies or shoots. The distribution of ore is controlled in part by faults which are about parallel to the bedding, but there is no conclusive evidence that the oreshoots rake with the bedding.

The ore shows abundant evidence of movement apart from the crushed condition on No. 5 level. A good deal of the galena is gneissic, some is slickensided, and some shows the gneissic bands to be dragfolded.

Striæ on the lode walls pitch with the bedding. A little dragging suggests a normal movement. Lenses or spurs from the lode dip to the northwest and may be tensional in origin. There is a tendency for bends to the right to make ore. All this evidence points to the southeast side of the lode having moved down and to the southwest, a direction parallel rather than opposed to both fault and bedding-slip movement.

Where a good face of ore is seen the walls are commonly sheeted.

Some faults persist as clay seams through massive ore without offsetting the lode. Ore tends to enlarge or blossom near and particularly beneath a fault, and the enlargement contains principally galena. Some of the larger ore pods persist to the actual fault, but in many instances ore blossoms near the fault and pinches again immediately at or beneath it. The ore may be of different character on either side of a fault on which there has been no apparent displacement.

Where an oreshoot or pod pinches, it characteristically contains more sphalerite. The greater widths contain predominantly galena, but constrictions and terminations, and stringers in general, contain mostly sphalerite. Where an oreshoot pinches the galena may become sheathed with sphalerite before giving way to sphalerite almost entirely. These observations are similar to others made in different parts of the area, reliably reported by men who have done much mining on other properties. The occurrence of large and central masses of galena apexing in and locally completely sheathed by sphalerite is common of the relationship between the two minerals.

Wakefield

The former Wakefield group is owned by Kelowna Exploration Company Limited. It is on the steep hillside on the southwest flank of Selkirk Peak at an elevation of about 5,800 to 6,000 feet. Access is by trail from the Carnation or by overgrown trail from the Mammoth.

The Wakefield was developed by an English company, Wakefield Mines Limited, who built a 100-ton mill on Silverton Creek and an aerial tram-line to it from the mine. This company suspended operations in 1902, and for five years thereafter the property was worked under lease by various interests. Shipments recorded in 1915, 1919, and 1929 show leasing activity in those years. Options were taken by Clarence Cunningham in 1918, and later by the Victoria Syndicate, but the workings at the time of writing are essentially as they were in 1905. The mill burned down in 1912 and was replaced by the present Hewitt mill.

The first shipment, made in 1899, amounted to more than 500 tons, containing 120 ounces of silver per ton and 48 per cent lead. About 8,000 tons of ore milled in 1900 and 1904 contained 9.5 ounces of silver per ton and 8 per cent lead. Reference is made in early reports to a considerable content of zinc in the ore, but although zinc concentrates were made at one time there is no record of their shipment. The small amount of zinc recorded came from 40 tons shipped in 1929. The total recorded production was 9,858 tons, containing 193,930 ounces of silver, 2,449,159 pounds of lead, and 10,435 pounds of zinc.

The Wakefield lode joins the Carnation lode to the north immediately below the 6300 west portal and passes through the Oakland property to the southeast. It has a low average dip to the southeast. The lode slices at a small angle through an overturned panel consisting predominantly of mixed banded rocks which dip at moderate to low angles to the east.

The low average dip of the lode is governed by the low dip of the strata traversed, and the lode tends to be bedded in spite of the marked divergence in strike. In the few accessible workings there is a wide variation in lode attitude, and sketches of the lode published in the Zinc Commission Report in 1906 show even greater variations in parts of the now inaccessible workings.

The Wakefield is a connecting link between the major Adams-Oakland and Carnation-Mammoth lode zones. It passes through a thick low-dipping panel, locally paralleling the beds and locally crossing them abruptly. Considerable variations in the attitude, width, and character of the lode are consequently to be expected.

The trace of the lode on the hillside pitches to the south at a low angle, and seven adits were driven on the lode in an outcrop distance of 850 feet and a difference in elevation of 177 feet, the average dip of the lode being about 13 degrees. The longest adit, No. 2, is 850 feet long according to an old plan. Most of the ore mined came from Nos. 1 and 2 adits, now inaccessible.

Only Nos. 5 and 7 adits were entered, each being about 500 feet long. The lode at its broadest shows about 3 or 4 feet of shearing and in places appears to be only a foot wide, although there may be additional unexplored parts of the lode. Imbrication indicates that the hangingwall moved down and east. The lode is irregular, is bedded in many places, and may follow local bends in the strata.

There is not much gouge in Nos. 5 and 7 adits, and the filling of quartz and calcite is not abundant. Sphalerite is common as grains and pods or as stringers as much as 3 inches wide. The best width of zinc-bearing quartz seen in No. 5 adit was 18 inches wide. Only a little galena was seen.

Between No. 7, the southernmost adit, and the Carnation 6300 adit, a distance of about 4,000 feet, there are in addition to the seven main adits a few surface and near-surface workings. These are all sloughed, and the full width of the lode cannot be seen clearly anywhere. A little sphalerite is to be seen in some of the dump material.

Washington and Slocan Boy

This property is owned by Washington Mine Limited, c/o Clark and Clark, 475 Howe Street, Vancouver. It crosses Payne ridge southeast of the Payne mine, and the main workings are on the northeastern slope. The workings can be reached by trail from the Rambler road on McGuigan Creek or from the end of the Payne Road.

The Washington was located in 1891 and by the end of 1894 had shipped a total of 2,060 tons of ore with an average content of 140 ounces of silver per ton and 60 per cent lead. A mill was completed at the end of 1895 near McGuigan Creek and was connected with the mine by a tram-line. In 1896, 6,000 tons was milled, and subsequently 431 tons was shipped from 1901 to 1939. Total recorded production was 8,491 tons, containing 2,318,738 ounces of silver, 4,256,797 pounds of lead, and 2,353 pounds of zinc.

The Slocan Boy was located in the same year as the Washington and was developed in the early 1890's. The recorded production from 1896 to 1905 was 381 tons, containing 44,188 ounces of silver and 491,246 pounds of lead.

In 1940 the Washington, Slocan Boy, and the Payne were optioned by Kelowna Exploration Company Limited, and the combined area was geologically mapped by Evans B. Mayo. The company did some bulldozer stripping in 1942 to locate the southern extension of the Washington lode and later relinquished the option.

The workings were not examined by the writer. The Slocan Boy adits were all caved, and it was reported that only a very small part of the Washington workings was accessible. The property was reported on by Cairnes (1935, pp. 159–162), from whose description the following remarks are abstracted.

The Washington workings, consisting of a shaft near the ridge crest and six adits on the McGuigan slope, develop the lode for a total length of about 1,000 feet. The lode is " a mineralized fault fissure zone, along which considerable shearing has occurred. The zone has a general strike of north 50 degrees east, and in most places dips steeply southeast, but locally is vertical, or, as in places between Nos. 1 and 2 levels, dips northwest. The principal productive section outcropped on the McGuigan Creek slope from above the highest adit to below No. 2 adit, a vertical distance of about 350 feet. This section has been largely stoped to the surface. It had an average pitch of about 48 degrees northeast; a maximum length, on the pitch, of about 750 feet; and a maximum width across the pitch of about 250 feet. In this section the lode varied in thickness from a few inches to 12 feet and was composed of crushed rock, quartz and a little siderite, galena, zinc blende, and pyrite.

" Ore and vein mineralization has been controlled by both bedding and jointing structures. The general course of the main lode follows the latter. It appears, however, that no one fissure is continuously mineralized, but that mineralization has been diverted from one to another by other fissures conforming closely with the bedding structure.

Such cross-fissures are common in these workings and in many places contain a little ore. They may cut across both walls of the main lode or lodes, but commonly stop at the hangingwall and run into the footwall rocks."

Workings on the Slocan Boy include three adits about 200 feet long extending to a depth of about 300 feet below the crest of the ridge. Early reports state that the lode was rich but narrow.

The rocks cut by the lodes are southwesterly dipping argillites with some quartzitic and limy strata. The workings are in the upper, right-side-up limb of the Payne recumbent fold, and the lower, overturned limb has not been recognized in the McGuigan Creek basin, as far down as the road crossing at an elevation of 5,200 feet. The axis of the fold on the Carpenter Creek slope is at an elevation of about 6,150 feet on the line of projection of the Washington lode.

To judge merely from surface exposures at the upper adit portals, the Washington lode is not everywhere a strong, well-defined zone, and the movement on it probably was not large in amount. At the portal of No. 2 adit it would appear that the movement was normal in character and possibly a few tens of feet in amount. To judge from Cairnes' remarks on variability of the lode, and to compare it with the nearby Payne lode, it is possible that there was considerable take-up along the course of the lode, and that the amount of movement on it varied from place to place.

The bulldozer stripping done in 1942 on the southwest slope was examined in 1948, after the banks had sloughed. An old 20-foot adit encountered at an elevation of about 6,300 feet was driven on brecciated material which may represent the extension of the Washington lode. The amount of breccia is, however, variable and is more widely distributed in the soil than would be possible if it all came from one lode zone. The structure is locally complex, with small rolls and strongly cleaved zones a short distance above the axis of the main fold, a situation which would probably strongly affect the course and behaviour of the lode and make its positive identification difficult.

Western Exploration Company Limited

Head office, 38 South Dearborn Street, Chicago, Ill. M. P. McCullough, president; A. M. Ham, managing director; C. C. Starr, consulting engineer; R. A. Avison, superintendent. This company, with mill and offices at Silverton, bought the Mammoth and Standard mines in 1928 through R. A. Grimes, at a time when the Mammoth orebody was being developed and the Standard was being worked by lessees. A mill was built at Silverton and a 16,000-foot aerial tram-line was built to the mine under the management of Grimes. The new equipment was given a trial run early in 1930 before low metal prices forced closure.

Later, the Standard was rehabilitated and ore from the two properties was milled. The Enterprise on Enterprise Creek was bought in 1944 at about the time that the Mammoth orebody above No. 7 level was exhausted.

Recent development has again brought the Mammoth into production, and the three properties are being operated. Ore is transported by tram from the Mammoth and by truck from the Standard and Enterprise.

Wonderful

The Wonderful property, 1 mile west of Sandon, was purchased in 1948 by Silver Ridge Mining Company Limited and added to that company's already extensive holdings. The Wonderful was among the earliest locations. Discovery of galena float led to ground-sluicing in 1894 and the uncovering of a train of boulders of almost massive galena. Total production of ground-sluicing operations, to the end of 1896, amounted to 400 tons, containing 120 ounces of silver per ton and 70 per cent lead.

Early development underground was not satisfactory. The first workings were purely exploratory, and apparently no definite lode was encountered by them. Some ore was mined, but it seemed doubtful whether the lode, which supposedly produced the large amount of detrital galena, had been discovered.

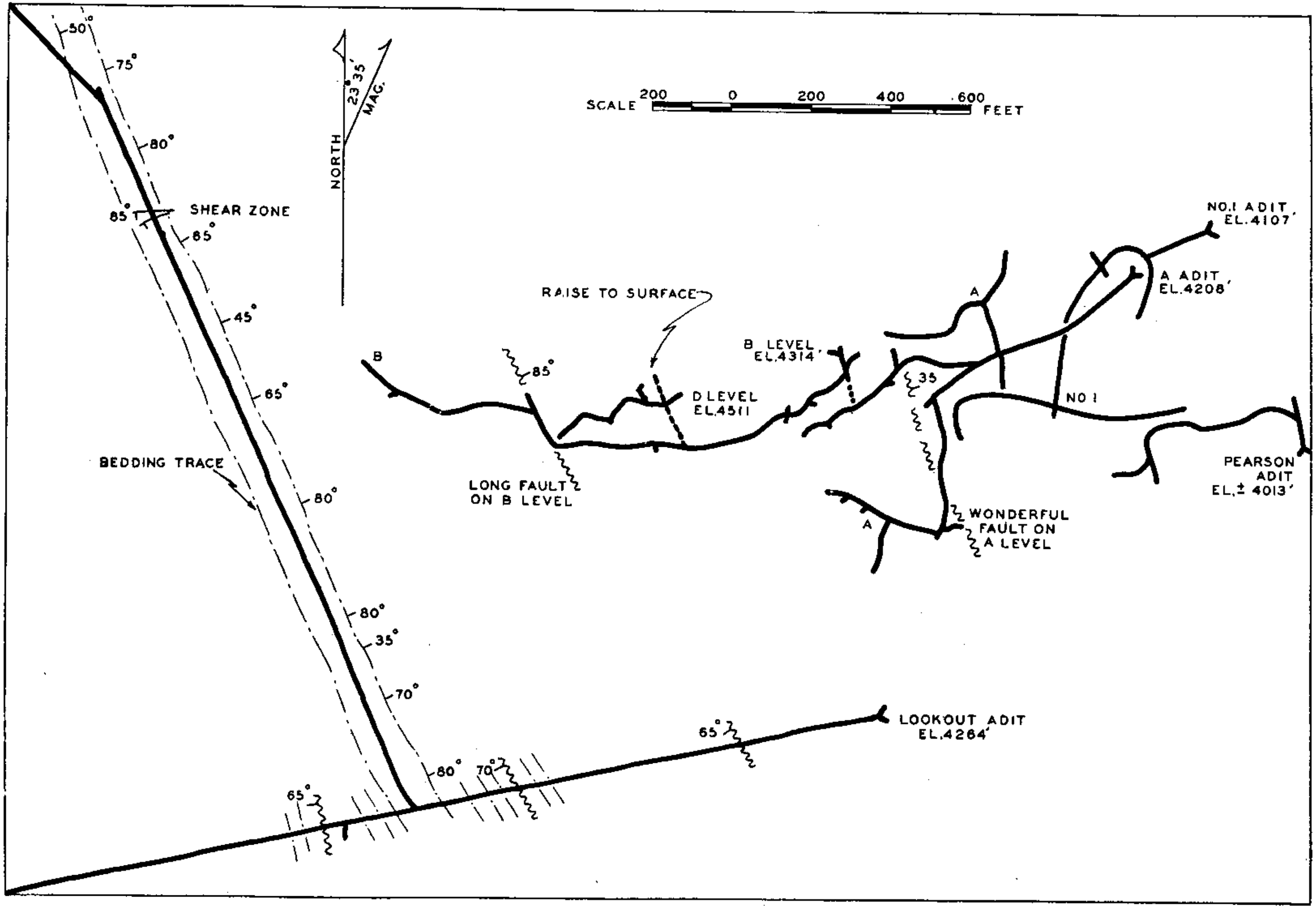


Fig. 15. Silver Ridge Mining Company Limited: Plan of part of Wonderful workings and of Lookout and Pearson adits.

The property was acquired by Clarence Cunningham in 1915, who established continuity of ore and drove most of the existing workings. In 1918 Cunningham built a 150-ton concentrator at Alamo Siding, on the site of the original Alamo mill, to treat the ores from his various properties. A tram-line was built to transport the Wonderful ore to the railroad. Ore of shipping grade gave place to concentrating ore. The peak year was 1923, when 10,663 tons of ore was mined, carrying a small amount of gold, 11.6 ounces of silver per ton, 5.1 per cent lead, and 3.3 per cent zinc. Work stopped in 1928, and an option was taken on the property by the Standard Silver-Lead Mining Company, who did exploratory work on No. 1 level.

The Wonderful is credited with a production of 31,273 tons, with a metal content of 221 ounces of gold, 415,156 ounces of silver, 3,530,291 pounds of lead, and 2,559,629 pounds of zinc. From 1896 to 1918 shipping ore, amounting to 1,630 tons, carried 92 ounces of silver per ton and 52.4 per cent lead. Concentrating ore, between 1919 and 1927, amounting to 29,604 tons, contained 9 ounces of silver per ton, 3.06 per cent lead, and 4.3 per cent zinc, in lead and zinc concentrates.

The Wonderful mine is opened by two adit levels, the A, elevation 4,208 feet, and the No. 1, elevation 4,107 feet (Fig. 15). Elevations are taken from old company plans and are close to the datum used in this bulletin. The productive level, A, connected by raise with six interior levels which, with approximate heights above A level, were named B, 100 feet; B½, 140 feet; C, 200 feet; C½, 242 feet; D, 295 feet; E, 417 feet. There were also several small sublevels. In Figure 15 only No. 1, A, B, and D levels are shown, because the full level plan is too complex to illustrate at any convenient scale. The mine is inaccessible.

All the following information is taken from an old company map containing some geological data. The Wonderful lode was first encountered on A level 35 feet east of the Wonderful fault, which dips 35 degrees eastward and flattens upwards to a 30-degree dip above B and as far as C level; the lode was displaced 30 to 35 feet by this fault. A second, known as the Long fault, strikes northwest and dips very steeply to the northeast. This fault displaced the lode about 160 feet.

East of the Wonderful fault a lode segment was partly stoped over a length of 35 to 80 feet. What is presumed to be the same segment, but not apparently stoped, was followed for 500 feet on No. 1 level. The inter-fault block, 725 feet long on B level and shortening upwards to about half that length on D level, was very irregular. About 50 feet of lode is indicated west of the Long fault on C level, and possibly as much as 250 feet on B level, the only levels which crossed that fault. Farther west B level trends northwestward, to a total distance of about 500 feet west of the long fault.

Complete stope maps are not available, but some stoping was done on the eastern block from A to the vicinity of B½ level, east of the Wonderful fault. Some stoping was done in the western block from B level to above C level, west of the Long fault. The central block, between the two faults, was partly stoped between B and D levels.

The lode structure is irregular, to judge from the record, particularly in the central block. The strike and dip are variable, and the lode is interrupted by discontinuous fault and gouge zones whose origin or relation to the lode are uncertain. In the eastern block the dip above A level is 55 degrees to the south and is somewhat flatter down to No. 1. In the western block it is about 70 degrees. In the central block the dip ranges between 55 degrees and vertical, while there is considerable variation in the direction of strike.

Cairnes reports (1935, p. 164): " The principal ore shoots, now mostly exhausted, have been found in the central and western mine workings, little mineralization having been encountered elsewhere. In the more productive sections the lode filling varied up to 8 or more feet in width and consisted of less crushed wall-rock, quartz, spathic iron, and ore minerals. The ore is brecciated and consists of fragments of galena, blende, and country rock in a gangue largely of quartz but containing, in places, quite a large proportion of spathic iron. In the less productive section the lode is marked by a few inches or so of gouge and crushed wall-rock with, here and there, bunches of quartz and traces of ore minerals. Pyrite and pyrrhotite are rather common and, in places, are quite abundant in both the productive and lean portions of the lode."

The Pearson adit, approximately 195 feet below A level and 94 feet below No. 1 level, was driven in 1948 and 1949 on a lode uncovered by stripping on the projection of the drift on No. 1 level. The finding of this lode on the surface and the tracing of it in the Pearson adit proves the existence of a segment of the Wonderful lode about 750 feet long east of the Wonderful fault. This lode segment averages about 45 degrees in dip in its eastern part and about 20 degrees in its western, in marked contrast with the average dip of nearly 55 degrees above A level.

In the Pearson adit the lode is intersected 100 feet from the portal and is followed to the west for 580 feet; a section of drift 140 feet long was detoured into the footwall to avoid bad ground. The lode is a strong gougy zone, slicing at an acute angle argillites and quartzites which dip at about 15 to 20 degrees for the most part. Where first encountered the lode contained some sphalerite and galena, between the hangingwall and a steeper footwall branch. In 1951 a nearly vertical fissure was encountered 35 feet in the footwall of the lode at a point 260 feet west of the crosscut. In the first 100 feet of drift this footwall branch is mineralized sporadically and contains as much as 3 feet of sphalerite of moderate grade, as well as local masses of galena.

The Lookout adit, elevation 4,264 feet, is driven as a crosscut for 2,252 feet at south 78 degrees west on the Lookout No. 2 mineral claim. At a point 1,200 feet from the portal a branch extends for 2,285 feet about north 24 degrees west; the inner 300 feet of the branch is deflected nearly 20 degrees westerly.

The main course of the adit was started in 1946 as a general exploratory tunnel, with a view to later lateral investigation. The branch was driven northward to intersect the Wonderful lode and was continued in an attempt to intersect the New Springfield lode. A great deal of water was encountered beneath Miller Creek, in the bedding and in minor fractures, at a depth of nearly 400 feet below the creek.

The only mineralized structure, apart from one or two thin seams containing calcite and a little siderite, was a zone 1,625 feet northwest of the main crosscut. This zone consists of two subparallel fissures 20 feet apart, dipping steeply to the south. The hangingwall fissure, containing up to 30 inches of calcite, strikes north 55 degrees east. The footwall branch is 1 to 2 feet wide, strikes east, and contains as much as 3 inches of calcite and siderite. This zone or pair of fissures has not been explored. Crosscutting joints, normal in strike to the bedding and dipping steeply to the southeast, are common through most of this branch of the adit, but are not mineralized.

The sedimentary structure is illustrated in Figure 3, Section E-E′. The main body of the Lookout adit is driven close to the nearly horizontal axial plane of a recumbent fold. In the first 800 feet detailed complexity of folding masks the outline, but in the inner section the nearly vertical beds are interrupted by flat sections which represent open dragfolds of Z form. The structure has remarkable horizontal continuity, as shown by the uniformity of strike for the known distance of 2,300 feet in the northern branch (Fig. 15); in this distance the dip is consistently to the east, with only minor open rolls. The plunge on these rolls averages probably a few degrees to the northwest. The rocks in this section are moderately strong and well-bedded argillites and quartzites.

A different picture is presented in the region of the Wonderful and Pearson adits. Thin to moderately thin bedded heterogeneous argillites and quartzites dip at moderate to low angles, predominantly to the east. The beds are overturned, and local open warps have formed in the overturned panel. Details are unknown because of the scarcity of exposures and of accessible mine workings. Most of the workings are in the lower limb of the same fold penetrated axially by the inner part of the Lookout adit. The fold is faulted upwards by the Long and possibly by other faults. Projection of attitudes farther down Tributary Creek shows a reversal to a westward-dipping panel at a lower elevation.

The structure may be complicated by granitic intrusion, of which two bodies, possibly large but of unknown attitude, are exposed in the creek bed. Dykes within the workings are few in number.

The Wonderful lode in the Pearson adit, the only place where it can now be seen, appears to be a strong fissure zone passing obliquely through low-dipping beds. In the Wonderful ore zone it passes more steeply through probably complex structure, near the crest zone of the main fold. West of the Long fault it apparently swings into a steeply dipping zone of shearing which is probably bedded. It is not known whether the lode is actually faulted at this point or merely passes into the bedding.

The Wonderful lode is a complex fissure in which the occurrence of ore may be related to character of wallrock, steepness of dip, and nearness to tangential faults. The particular favourable conditions in other parts of the ground are difficult to tell, but the condition in the Pearson adit, where a flattened lode passes obliquely through beds of low dip, is not a generally favourable one. The low-dipping panel penetrated by the Pearson adit is succeeded at depth by a steepening and a reversal of dip round the crest of a lower recumbent fold and, although such a situation should be a favourable one, knowledge is insufficient to indicate a suitable horizon for further work. The situation on the level of the Lookout crosscut is considered to be theoretically a favourable one.

An old adit on the Early Bird claim at an elevation of about 3,700 feet is entirely in quartz diorite. The size and continuity of this intrusive body are not known, beyond the fact that it measures at least 130 by 200 feet on the adit level, because there are practically no exposures on the thickly wooded hillside.

The adit extends 86 feet southwestward from the portal to a gouge zone dipping 60 degrees to the northeast. It then follows for 140 feet at south 15 degrees east a narrow fissure dipping 60 degrees to the west. A subparallel gouge-filled fissure 40 feet to the west is explored for a length of 40 feet. A small fissure 120 feet from the portal dips south at 45 degrees and is followed for 125 feet, mostly to the west. It is semicontinuously filled with calcite.

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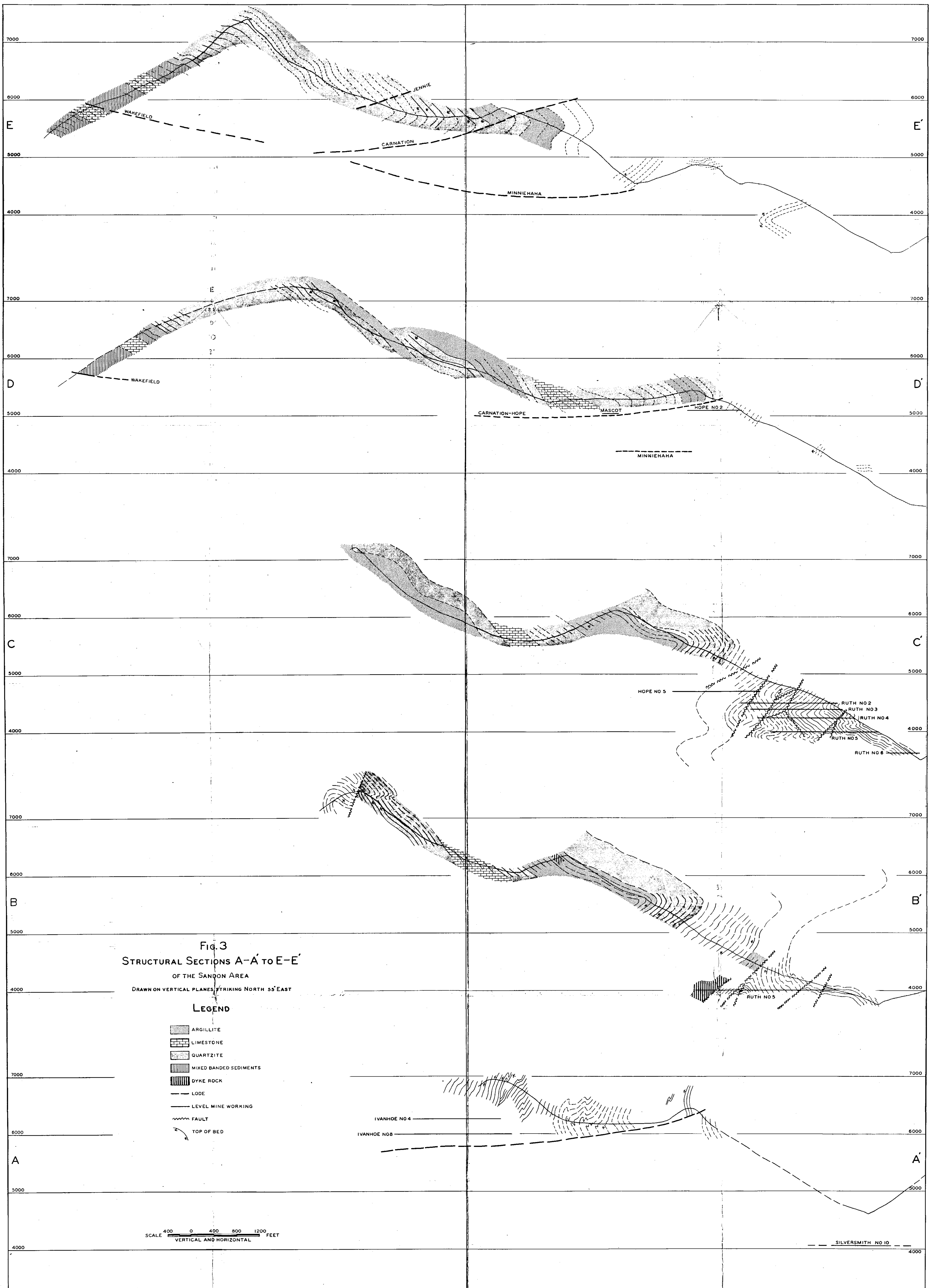

Fig. 3
Structural Sections A–A' to E–E'
of the Sandon Area
Drawn on vertical planes striking North 55° East

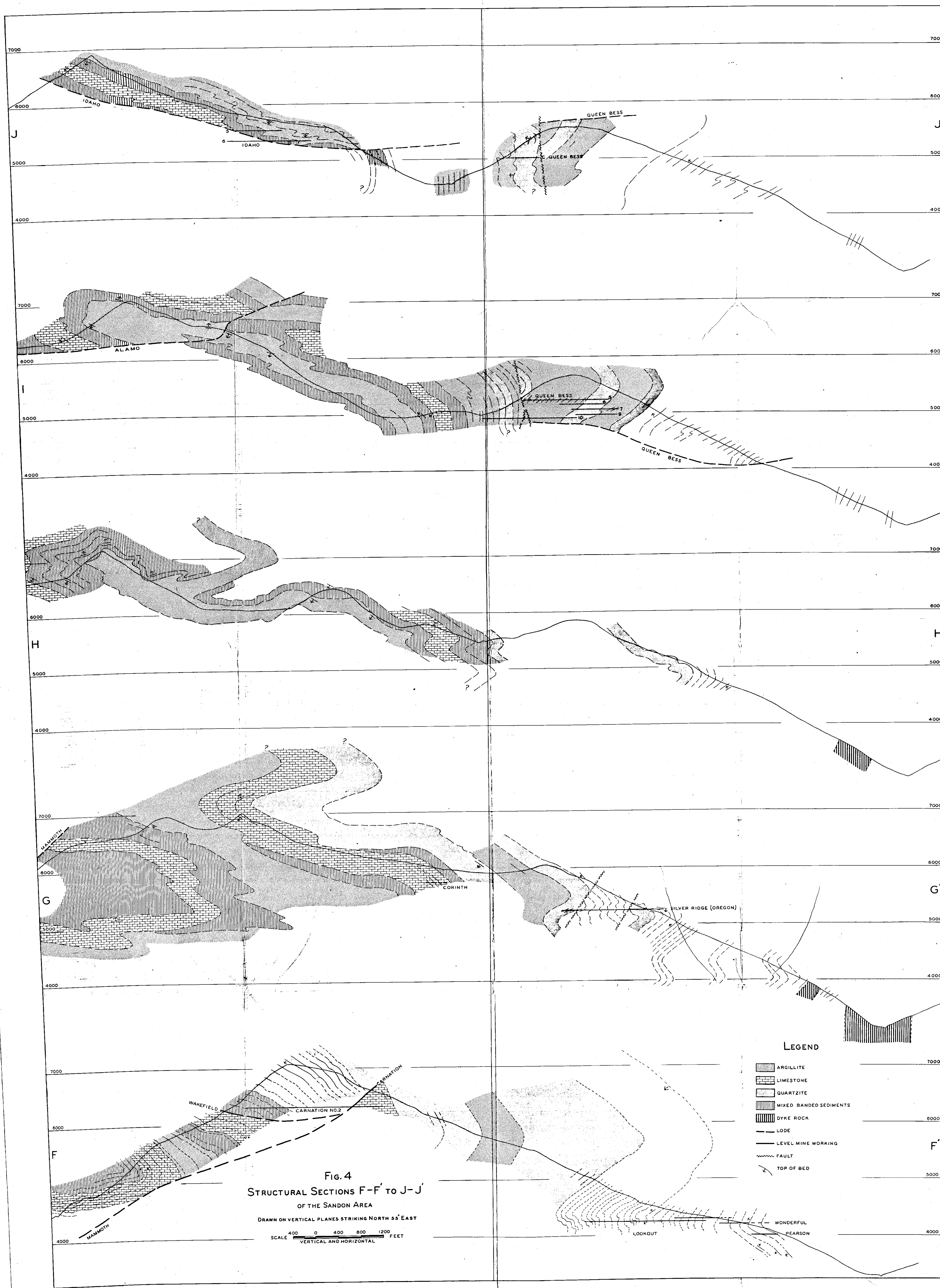

FIG. 4
STRUCTURAL SECTIONS F-F' TO J-J'
OF THE SANDON AREA
DRAWN ON VERTICAL PLANES STRIKING NORTH 55° EAST

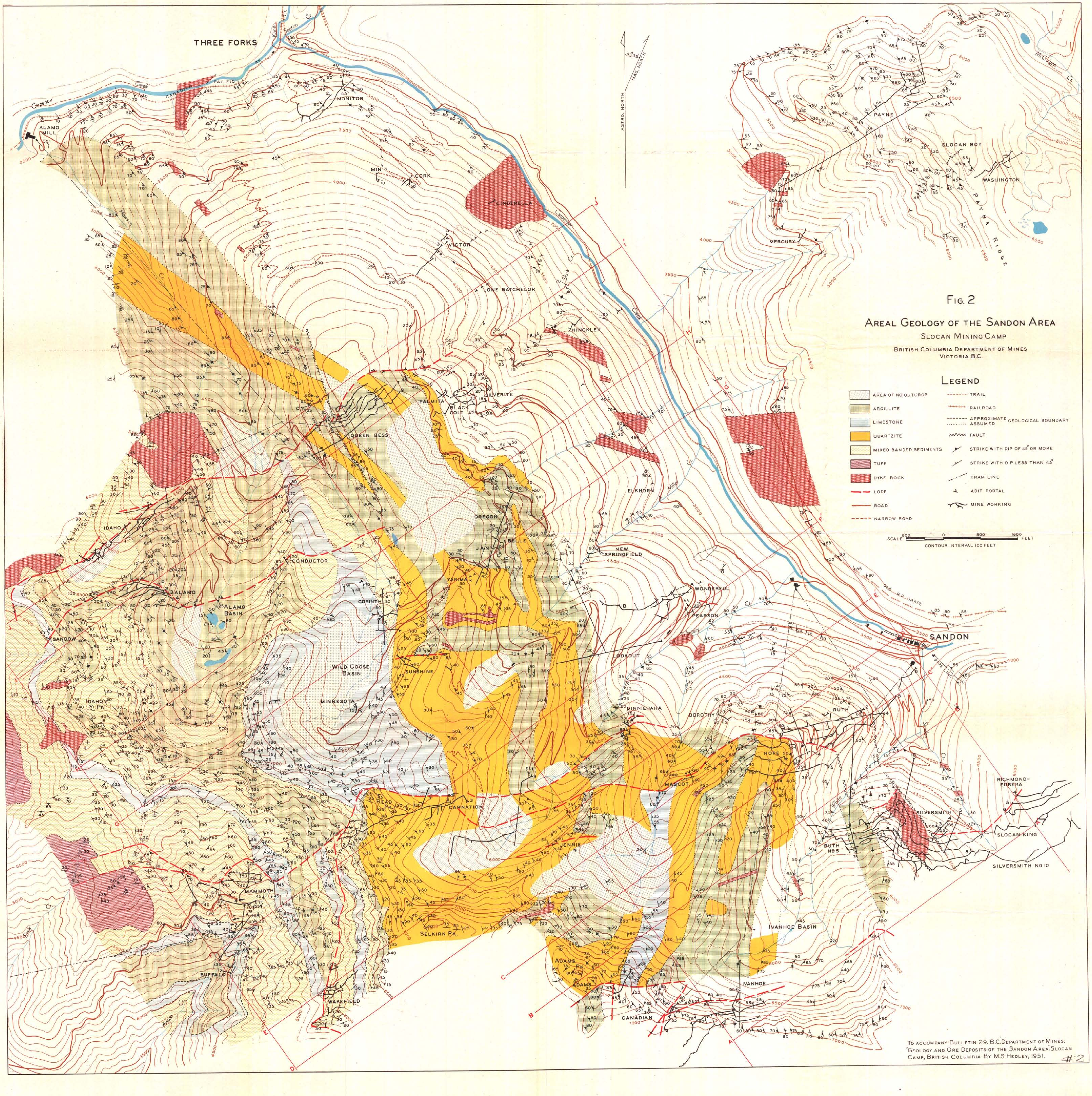

Fig. 2

Areal Geology of the Sandon Area

Slocan Mining Camp

British Columbia Department of Mines
Victoria B.C.

To accompany Bulletin 29. B.C. Department of Mines. "Geology and Ore Deposits of the Sandon Area", Slocan Camp, British Columbia. By M.S. Hedley, 1951.

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