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 Sicam 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 Bachelor 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 cobbng.

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'Neill 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.

BIBLIOGRAPHY


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 character-
istic 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 classifi-
cation 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

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* 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-beded 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.

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* 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.

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* Cairnes, 1934, pp. 69-73.
Cairnes notes in the district as a whole that the salic dykes tend to strike north-westward 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.