

FIFTY-SEVENTH ANNUAL REPORT

OF THE

ONTARIO DEPARTMENT OF MINES

1948

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PROVINCE OF ONTARIO
DEPARTMENT OF MINES

Hon. WELLAND S. GEMMELL, *Minister of Mines*

H. C. RICKABY, *Deputy Minister*

FIFTY-SEVENTH ANNUAL REPORT
OF THE
ONTARIO DEPARTMENT OF MINES

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Geology of Teck Township and the Kenogami Lake Area, Kirk-
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*Plans and sections (Sheet A - Sheet S) referred to in this report have not been reproduced.

Geology of Teck Township and the Kenogami Lake Area, Kirkland Lake Gold Belt

By Jas. E. Thomson

INTRODUCTION

This report deals with the geology of Teck township and parts of Otto, Grenfell, and Eby townships, as shown on the accompanying geological maps, Nos. 1945-1 and 1946-1. The detailed geology of the main ore zone in the Kirkland Lake camp is described in another report in this volume. Only the general relationships of the main Kirkland Lake camp to the surrounding area

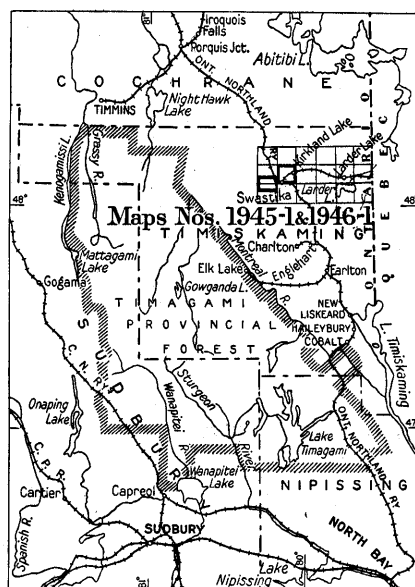


Fig. 1.—Key map showing the location of Teck township and the Kenogami Lake area. Scale, 60 miles to the inch.

are discussed here. Teck township and the Kenogami Lake area comprise the western section of the important gold-producing belt that extends eastward through the Larder Lake area and across the northwestern part of Quebec. The town of Kirkland Lake is the main community in the area; the village of Swastika lies five miles southwest of Kirkland Lake and is the junction point of the Nipissing Central railway and the Ontario Northland railway.¹ Highways Nos. 11 and 66 cross the map areas.

Kirkland Lake ranks as the second largest gold-producing camp in Ontario and in Canada. The bulk of the production has come from seven mines, which are located in the eastern part of Teck township along the main ore zone of the Kirkland Lake camp. Eight mines in Teck township produced bullion valued

¹Formerly the Temiskaming and Northern Ontario Railway.

at \$503,718,939 between the years 1913 and 1947, inclusive. Dividends paid by the seven producing mines along the main ore zone at Kirkland Lake from 1915 to 1947, inclusive, amounted to \$209,394,760.¹

The gradual expansion of the main part of the Kirkland Lake camp has led to an intensive search for gold throughout the surrounding country in various "boom" periods over the last thirty years. Widespread exploration has been carried out on a large number of mining properties within Teck township and the Kenogami Lake area at intermittent periods since the first staking rush into the country in 1906. There is scarcely a claim along the main belt that does not show indications of surface examination. To date, however, no large ore bodies have been found outside of the main camp, although there are several gold showings and a few small ore shoots. There is still a possibility that a more thorough exploration of some of these properties may reveal commercial gold deposits.

Scope of Maps and Report

In 1936, the Geological Branch of the Ontario Department of Mines commenced a detailed investigation of the entire Kirkland Lake-Larder Lake gold belt. This work has been carried on continuously to date (1948) but was on a restricted scale during the war years. The plan provided for the publication of separate geological maps for each township. It was decided that the maps should have a uniform scale and show a correlation of geological features throughout the entire mineral belt. It was hoped that this investigation would provide useful information concerning the nature of the known gold deposits and their relationship to geological features and thus aid in the search for new deposits. Much development work has been done by exploration and mining companies throughout the map areas since the last government reports were issued. As much as possible of this company information has been obtained and included in this volume.

The field work in Teck, Otto, Eby, and Grenfell townships was done by different field parties working at intervals from 1937 to 1944. During the seasons of 1937, 1938, and 1939, Wm. Gerrie was in charge of the field parties that mapped the geology along and adjacent to the belt of Timiskaming sediments from the west boundary of the property of Lake Shore Mines westward to the southwest end of Kenogami Lake; this mapping included the southwestern portion of Teck township west of that part of highway No. 11 that runs southeast of Kirkland cemetery and part of Otto township. The field maps covering this section were prepared on the scale of 200 feet to the inch. In this work, controls for the laying down of claim surveys were established by a transit survey along township lines, roads, rivers, power lines, etc. In cleared sections, the geological mapping was done by plane-table surveys. Throughout the bush-covered country, pace-and-compass traverses were made at 200-foot intervals across surveyed claims and tied to stations established by chaining along claim lines.

In 1937 and 1938 field parties under the direction of A. MacLean mapped the belt of Timiskaming rocks from the west boundary of the Lake Shore Mines property eastward to the Lebel township boundary. This survey was carried to the boundaries of map No. 37a of the Ontario Department of Mines, which was prepared by E. W. Todd to accompany his report on the Kirkland Lake Gold Area.² Professor MacLean's field parties made a plane-table survey of this section on the scale of 200 feet to the inch.

¹Data from Statistics Branch, Ontario Department of Mines.

²E. W. Todd, *Ont. Dept. Mines. Vol. XXXVII, 1928, pt. 2.*

The remainder of Teck township and the northwestern part of the Kenogami Lake area was surveyed in 1943 and 1944 by field parties under the direction of the writer. The field work was done on the scale of 500 feet to the inch. Pace-and-compass traverses were made across surveyed mining claims at about 400-foot intervals. These traverses were tied to stations established along claim lines, power lines, or picket lines.

The surface geology in the vicinity of the producing mines in the Kirkland Lake camp is taken from map No. 37a of the Ontario Department of Mines, by Todd¹; local revisions were made from maps prepared by geologists of the mining companies. In 1943, Harold Hopkins, geologist at the Wright-Hargreaves mine, undertook a detailed examination of the producing mines in Kirkland Lake for the mining companies. Mr. Hopkins compiled a surface geological map of the productive area and adjacent ground on the scale of 400 feet to the inch. A copy of this map was presented to the Ontario Department of Mines and as much information as the scale of publication would permit was incorporated in the accompanying geological map of Teck township (No. 1945-1).

The compilation of data from the above-mentioned geological surveys for the preparation of maps Nos. 1945-1 and 1946-1 was made by the writer in 1943 and 1944, and he must accept the responsibility for most of the interpretive geology shown on these sheets. The maps were completely redrawn on the scale of 500 feet to the inch. Some generalization and grouping of small outcrops and exaggeration in dimension of small geological features was necessary in order to show them on the published maps. Geological features were correlated as closely as possible with those of Lebel,² Gauthier,³ McVittie,⁴ and McGarry⁵ townships, maps of which had already been published.

In preparing this report, the author has attempted to integrate the information with that contained in the accompanying report on the main ore zone at Kirkland Lake. Reference is made from one report to the other in order to prevent too much duplication of description.

This report contains all the available information, to the end of the year 1948, on mining properties in the map areas with the exception of the seven producing mines on the main ore zone at Kirkland Lake, which are dealt with in the second report in this volume.

Acknowledgments

Much of the information in this report has been obtained from the mining companies in the area. The leaders of field parties are pleased to acknowledge the courtesy, assistance, and co-operation that they have received from these organizations. A complete list of companies and individuals to whom special acknowledgment is due cannot be fairly recorded here. Every organization that was approached for information willingly supplied it.

The leaders of field parties were ably assisted by graduate and undergraduate students from Ontario universities. Much of the geological mapping was done by the more experienced field assistants. The diligence and enthusiastic co-operation of all assistants is gratefully acknowledged. In 1937, A. MacLean was assisted by A. T. Griffis, W. A. Norfolk, N. Hogg, G. R. Casselman, and R. G. Rhodes; in 1938, N. Hogg, G. R. Casselman, D. P. Robertson,

¹E. W. Todd, *op. cit.*

²Ont. Dept. Mines, map No. 53a.

³Ont. Dept. Mines, Vol. L, 1941, pt. 8, map No. 50c.

⁴*Ibid.* pt. 7, map No. 50b.

⁵*Ibid.* map No. 50a.

J. O. Gorman, F. L. MacDonald, and G. E. Parsons acted as assistants. Assistants to Wm. Gerrie were as follows: W. P. Corking, O. S. Perry, Albert Hopkins, and Laurent Labbe in 1937; J. W. McBean, O. S. Perry, Peter Ginn, and D. G. Wilkinson in 1938; J. W. McBean, Peter Ginn, D. H. McGuire, and Dean Richard in 1939. The author was assisted by C. G. Clarke, R. B. Ferguson, D. F. Hewitt, Paul Hammond, J. W. M. Kerr, and L. M. O'Shaughnessy in 1943, and by C. G. Clarke, Clayton McAulay, and L. M. O'Shaughnessy in 1944.

Literature

The mineral resources of the map areas have been described by geologists and engineers at intervals dating back to the first prospecting activity in the country. A list of the main publications on the geology and mineral deposits of the areas is given below. Papers that deal more specifically with the mines at Kirkland Lake are listed in the second report in this volume.¹

- E. L. BRUCE, "The Swastika Gold Area," *Ont. Bur. Mines*, Vol. XXI, 1912, pt. 1, pp. 256-265.
- A. G. BURROWS and P. E. HOPKINS, "The Kirkland Lake and Swastika Gold Areas," *Ont. Bur. Mines*, Vol. XXIII, 1914, pt. 2, pp. 1-32.
- A. G. BURROWS and P. E. HOPKINS, "Kirkland Lake Gold Area" (Second Report), *Ont. Dept. Mines*, Vol. XXIX, 1920, pt. 4.
- A. G. BURROWS and P. E. HOPKINS, "Kirkland Lake Gold Area" (Revised Edition), *Ont. Dept. Mines*, Vol. XXXII, 1923, pt. 4, pp. 1-52.
- H. C. COOKE, "Kenogami, Round, and Larder Lake Areas," *Geol. Surv. Can., Mem.* 131.
- JAS. E. THOMSON, "The Keewatin-Timiskaming Unconformity in the Kirkland Lake District," *Trans. Roy. Soc. Can., 3rd series*, Vol. 40, pt. 1, sect. 4, 1946, pp. 113-124.
- JAS. E. THOMSON, "Regional Structure of the Kirkland Lake-Larder Lake Area," *Structural Geology of Canadian Ore Deposits*, *Can. Inst. Min. Met., Symposium volume*, 1948, pp. 627-632.
- E. W. TODD, "Kirkland Lake Gold Area" (A Detailed Study of the Central Ore Zone and Vicinity), *Ont. Dept. Mines*, Vol. XXXVII, 1928, pt. 2.

History and Development

The early history of the Kirkland Lake area has been discussed by other government geologists² and is only briefly summarized here.

Claims were first staked for gold around Swastika and Kirkland Lake during the Larder Lake gold rush of 1906, and most of them subsequently lapsed. Operations were carried on at the Swastika and Lucky Cross properties, now owned by Kirkland Golden Gate Mines, Limited, and small mills were erected, which produced some gold.

The history and development of the seven producing gold mines along the main ore zone at Kirkland Lake is given in the second part of this volume.³

This report describes in detail only those properties that lie outside the boundaries of the seven producing mines in the central ore zone. Production from these properties has been small in amount. The bulk of the output has come from the Kirkland Golden Gate mine, which has a recorded production of slightly over \$1,000,000. Very small ore shipments are recorded from the Baldwin Kirkland (Baldwin Consolidated), Ontario-Kirkland (Kirkland Gold Rand), and Trout Creek (Sahtram) properties.⁴

Most of the ground within the map areas has been intensively explored at the surface and by means of prospect shafts and test pits. Any important dis-

¹Pages 58, 60.

²A. G. Burrows and P. E. Hopkins, *Ont. Dept. Mines*, Vol. XXXII, 1923, pt. 4, pp. 2-3.

E. W. Todd, *Ont. Dept. Mines*, Vol. XXXVII, 1928, pt. 2, pp. 4-5.

³Pages 57 and 58 and chapters IV to X.

⁴*Ont. Dept. Mines*, Vol. LVII, 1948, pt. 1, Table II in pocket.

coveries in the future will in all probability be made by systematic drilling and underground development of favourably located ground.

Topography

The physical features of the area are typically Precambrian and are partly dependent upon the nature and structure of the rock formations. As indicated by the geological maps, rock outcrops cover the greater part of Teck township, but large areas of drift and swamp are found in the vicinity of Kenogami lake in Eby and Grenfell townships. In the northern part of Teck township, the topography becomes quite rugged in some localities, especially west of Amikougami lake, where a range of hills rises more than 400 feet above the lake level. The high ridges are generally found within the areas underlain by hard gabbro, diorite, or massive greenstone. The Cobalt series also tends to stand out prominently. Around Amikougami lake and to a lesser extent at Kenogami lake, the long dimension of the lake is about parallel to the strike of the lava flows.

In the Kenogami Lake area most of the country is covered with green forest, and a thin mantle of soil and moss covers most of the outcrops. In Teck township much of the forest has been cleared, especially around the populated areas. In the northwestern part of Teck township recent fires, wind storms, and logging operations have exposed large areas of rock, but slash and windfalls make bush travelling very difficult. The boundaries of mining claims are difficult to locate throughout most of Teck township.

From a practical viewpoint, the most interesting feature of the topography is the way in which sheared and faulted zones follow linear rock depressions. For this reason, streams sometimes mark the position of faults. The Blanche river at Swastika, Amikougami creek, and Murdock creek are fine examples of this relationship between topography and faulting. The most important structure in the country from an economic viewpoint, however, is the Kirkland Lake fault. It is only expressed topographically in the western part of Teck township; the productive part of the structure could never have been located by the use of aerial photographs.

GENERAL GEOLOGY

The consolidated rocks of the area are Precambrian in age; the formations of economic interest belong to the earlier Precambrian era and consist of volcanics, sediments, and intrusives. Stratigraphical and structural studies show that the early Precambrian volcanic and sedimentary formations are greatly deformed by folding and faulting. They are separated by a great erosional and structural unconformity into two main age groups. The older group consists of the volcanics that underlie the northern and southern parts of the area; these belong to the Keewatin period. The younger sedimentary-volcanic complex is classified as part of the Timiskaming series. It is predominantly sedimentary in character, but a number of horizons of volcanics and pyroclastics are interbedded with the sediments.

Throughout the Keewatin series there are bodies of gabbro and diorite. The larger masses are undoubtedly intrusive into the Keewatin series and appear to intrude the basal formations of the Timiskaming series. Some of the narrower bands assigned to this group may be coarse-grained phases of thick lava flows.

The above-mentioned formations are cut by irregular bodies and dikes of intrusives, which range from acid to basic in composition. These are classified as Algoman in age. A few post-Algoman diabase dikes are also found. Along certain zones of intense shearing in the volcanics and sediments there has been

replacement by siliceous carbonate solutions, forming the so-called carbonated rocks or "dolomite."

In the vicinity of Kenogami lake the relatively flat-lying sediments of the Cobalt series cover the older folded formations with great unconformity. The sand, gravel, and clay deposits, which form a thin mantle over the bed rock in depressions, were laid down during the continental glaciation of Pleistocene time.

The rock formations with their different members may be classified as follows, the oldest being placed at the bottom of the list:—

QUATERNARY

PLEISTOCENE: Clay, sand, gravel
Great unconformity

PRECAMBRIAN

HURONIAN (COBALT SERIES): Conglomerate; arkose, greywacke, slate.
Great unconformity

POST-ALGOMAN:¹ Diabase, lamprophyre

Intrusive contact

ALGOMAN: Syenite porphyry, quartz-feldspar porphyry, alaskite.
Quartz porphyry.
Basic syenite, augite syenite, and lamprophyre; augite porphyrite.
Hornblende, biotite, diorite.
Granite and syenite.
Carbonated rock or "dolomite."²
Diorite and gabbro; quartz diorite and quartz gabbro.³

Intrusive contact

TIMISKAMING: Trachyte; trachytic breccia.
Tuff and agglomerate; tuffaceous conglomerate.
Conglomerate, greywacke, basal grit.

Great unconformity

KEEWATIN: Tuff and iron formation.
Altered basic volcanics.
Intermediate and basic volcanics (greenstone).

Keewatin Series

The Keewatin series is largely composed of lavas ranging in composition from acid andesite to basalt; these are commonly called "greenstone" in the field. They are typically fine- to medium-grained, dark-green rocks, but the texture varies with the thickness of the flows. Throughout the greater part of the map areas the flows are massive and show such primary structure as vesicles, amygdulæ, spherules, and pillows. Fragmental volcanics are rather widely distributed in the vicinity of Perron lake in the western part of Teck township. Elsewhere narrow bands of volcanic breccia are found and probably represent the fragmental tops of lava flows. Pillows up to 15 feet in length have been observed in some of the larger flows. These show the later-formed pillows filling the surface irregularities of the earlier ones, and this feature has been used throughout the area to determine the tops of individual flows. Only in rare instances was it found possible to trace an individual flow for any distance along the strike. Local sheared zones in the volcanics are marked by the presence of talc-chlorite schists with accompanying carbonatization.

Throughout the Keewatin volcanics difficulty is encountered in distinguishing between the coarse-grained central parts of thick flows and the intrusive diorite and gabbro, especially where the field relationships cannot be seen. As

¹Some diabase dikes are known to be post-Cobalt series in age.

²The carbonate rocks are not intrusives, but were formed by replacement during the same general period as the Algoman intrusives.

³Some of the narrow bands indicated on the map may be coarse-grained phases of Keewatin lava flows.

the intrusives occur as sill-like masses injected parallel to the flows and become fine-grained towards the margin, the contacts are not easily defined unless the rock is well exposed.

Narrow bands of bedded cherty tuff and iron formation are interbedded with the lava flows in a few localities. The iron formation contains narrow seams of fine-grained magnetite, which causes local magnetic disturbance. The tuffs show differential weathering, are thinly bedded, and in places are sufficiently fer-ruginous to weather a rusty colour on surface exposures. They provide excellent marker horizons for structural studies.

South of the Kirkland cemetery (located at the junction of highways Nos. 11 and 66 northeast of Swastika), there is an area of highly altered Keewatin volcanics. These lie immediately off the west nose of a large body of syenite. The rocks consist of biotite and hornblende schists and gneisses, which are cut by masses of diorite, amphibolite, and syenite dikes. In the less altered phases of the rock, elongated pillow structures may be seen, proving that it was originally part of the basic volcanic group. There is a gradual transition from the altered to unaltered volcanics.

Timiskaming Series

The Timiskaming series consists of interbedded sedimentary and volcanic formations, which lie with great unconformity upon the Keewatin series, which is almost a purely volcanic group. Within the boundaries of the Timiskaming series the sedimentary rocks predominate in amount over the volcanics and associated pyroclastics. The Timiskaming rocks in the map areas represent only part of a continuous belt that extends eastward to Larder Lake and northwestern Quebec; it may also extend westward towards Matachewan under the cover of the Cobalt series.

In field mapping the Timiskaming series may be conveniently divided into two main lithological groups. These consist of (1) conglomerate and greywacke and (2) pyroclastics with a small amount of trachytic volcanics. The conglomerate and greywacke are sometimes so intimately associated that they have to be mapped as a unit, but in other localities definite horizons of conglomerate may be distinguished. The pyroclastics consist of agglomerates and water-laid tuffs.

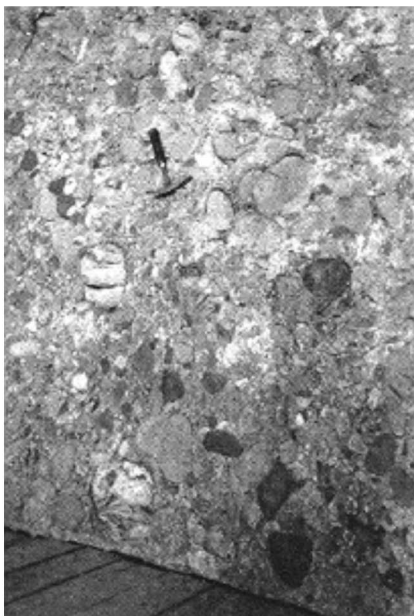
In Teck township the Timiskaming strata face south across the full width of the belt, except for a local fold in a wedge-shaped fault block in the south-eastern part of the township near Murdock creek. They rest unconformably on the Keewatin volcanics to the north and are in faulted contact with the same volcanics to the south. The stratigraphical succession is made up of progressively younger formations to the south, but the complete sequence and the possible south limb of the fold has been removed by faulting. The structure sections shown on sheet A (in map case) give a diagrammatic picture of the stratigraphical succession and the effects of faulting.

Basal Grit and Greywacke

Wm. Gerrie found a horizon of sediments along the north edge of the Timiskaming series in the western part of Teck township and the eastern part of Grenfell, which he has named basal grit and greywacke. These are designated as T1 on the maps. The pebbles of the basal grit are generally less than an inch in diameter and more angular than those in the normal conglomerate, although pebbles as much as 3 inches in length may occasionally be seen. Wherever the actual Keewatin-Timiskaming contact is exposed in an unfaulted condition on surface or in drill cores, the basal grit lies immediately adjacent to the basic lava and follows the irregularities of the older rock surface.

Conglomerate and Greywacke

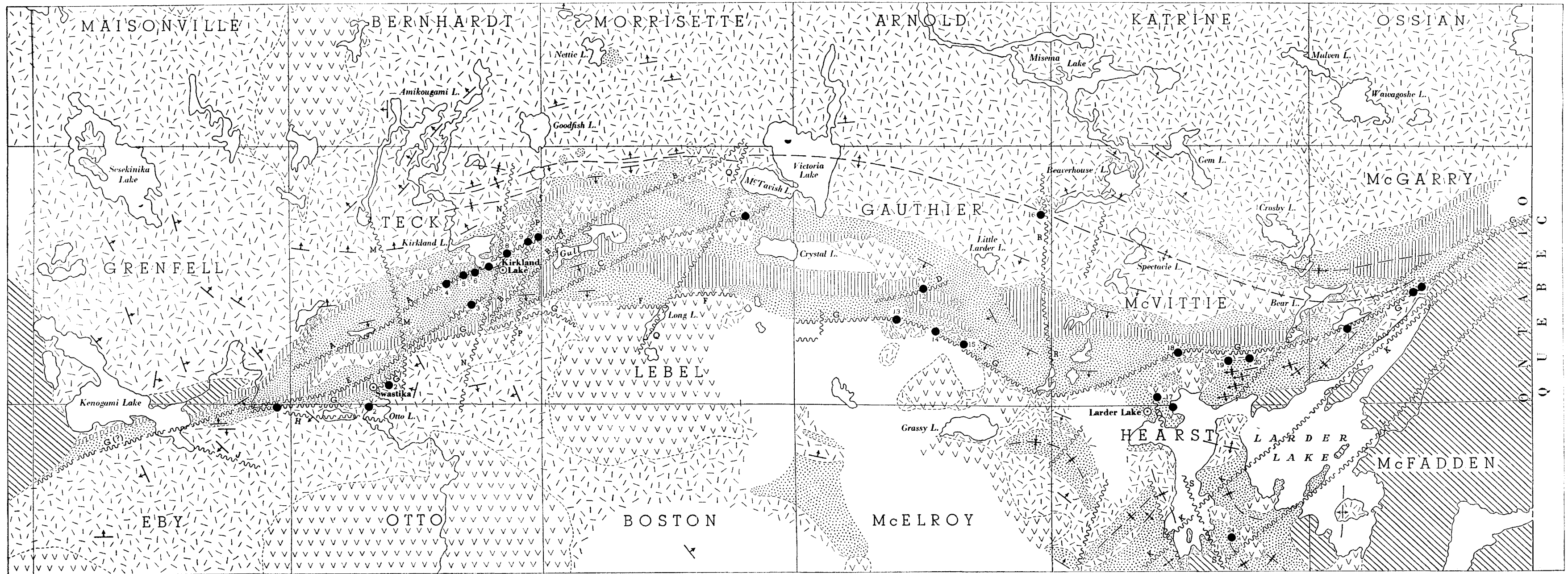
The bulk of the true sedimentary rocks in the area consists of interbedded conglomerate and greywacke. In some localities boulder and pebble conglomerate occur over considerable areas; in others greywacke, containing only occasional narrow bands of pebbles, is predominant; and in many places there is such an intimate association of greywacke and conglomerate beds that the two types have to be mapped as a single geological unit. On the geological maps the main bodies of conglomerate have been differentiated by a special marking.



Boulder conglomerate of the Timiskaming series, Chaput-Hughes.

The conglomerate everywhere contains rounded to ovoid boulders and pebbles. Sorting in the boulder conglomerate is fair to poor, but the thin bands of pebble conglomerate exhibit a fair degree of sorting. In certain areas there is a remarkably uniform alternation of clean-cut beds of well-sorted pebble conglomerate and greywacke. Pebbles and boulders of porphyries (acid to basic type), syenite, granite, felsite, rhyolite, trachyte, greenstone, diorite and gabbro, quartz, jasper, chert, and rhyolite are found in the conglomerate. Light-weathering types, such as porphyries, syenite, and rhyolite, predominate. Pink trachyte pebbles are abundant and closely resemble the typical trachytic volcanics of the map areas. Probably the most remarkable feature of the conglomerate is the consistent occurrence of red jasper pebbles both across and along the entire belt of Timiskaming sediments in the map areas. The jaspers scarcely ever constitute more than from 2 to 5 per cent. of the pebble content but are scarcely ever absent. The matrix of the conglomerate is usually a sandy greywacke or grit containing the same mineral assemblage as the normal greywacke.

Some of the coarsest and most extensive areas of boulder conglomerate in the map areas are found well up in the stratigraphical sequence in the vicinity of Chaput-Hughes (near the junction of the Goldthorpe road with highway No. 66).



LIST OF PROPERTIES

1. Baldwin Consolidated.
2. Golden Gate.
3. Amalgamated Kirkland.
4. Macassa.
5. Kirkland Lake Gold.
6. Teck-Hughes.
7. Lake Shore.
8. Wright-Hargreaves.
9. Sylvanite.
10. Toburn.
11. Bidgood Kirkland.
12. Upper Canada.
13. Anaki.
14. Queenston.
15. Ritoria.
16. Beaverhouse Lake (Argonaut).

17. Laguerre.
18. Onega.
19. Amalgamated Larder (Fernand).
20. Amalgamated Larder (Cheminis).
21. Amalgamated Larder (Barber Larder).
22. Kerr-Addison.
23. Chesterville.
24. Martin-Bird.

LIST OF FAULTS

- A. Kirkland Lake Fault.
- B. Mordock Creek Fault.
- C. Bidgood Fault.
- D. Upper Canada Fault.
- E. Amalgamated Kirkland-Blanche River Fault.
- F. Turtle Lake Fault.
- G. Larder Lake Fault.
- H. Vigraas Lake Fault.
- J. South Bay Fault.

- K. Northeast Arm Benson Creek Fault.
- L. Milky Creek Fault.
- M. Amikougami Creek Fault.
- N. Lake Shore Fault.
- O. Long Lake Fault.
- P. Sylvanite Fault.
- R. Misema River Fault.
- S. Sharp Creek Fault.

Scale of Miles



LEGEND

- Cobalt series (sediments).
- Intrusives.
- Older sediments.
- Trachytes and tuffs.
- Basic volcanics and diorites.

SYMBOLS

- Strike of flows or beds, together with direction in which they face.
- Synclinal axis.
- Anticlinal axis.
- Fault.
- Mine location.

FIG. 2—GENERALIZED GEOLOGICAL MAP OF THE KIRKLAND LAKE-LARDER LAKE GOLD BELT.

Scale, 1 inch = 2 miles

The boulders represent a great variety of rock types, including several varieties of porphyry. Narrow bands of greywacke are found throughout this boulder conglomerate.

Greywacke is typically a massive, grey-weathering, medium- to fine-grained rock. The massive variety generally contains a few thin beds of grit or pebble conglomerate. Hand specimens of the greywacke generally show angular grains of quartz, and microscopic examination indicates that these may constitute from 10 to 50 per cent. of the rock. The remainder is largely composed of feldspar fragments, chlorite, and carbonate material. Thinly bedded greywacke, showing gradation across the beds from coarser sandy grains at the base to fine-grained clayey material at the top, is found only on rare occasions. It occurs at a few points along the south contact of the sedimentary series.

Where the conglomerate or greywacke has undergone intensive shearing it has been changed to a glossy, cream-coloured schist owing to the development of sericite and carbonate material.

Tuff, Agglomerate, and Tuffaceous Conglomerate

A feature of the Timiskaming series throughout the Kirkland Lake-Larder Lake belt is the intermingling of numerous horizons of trachytic volcanics and associated pyroclastics with normal sediments (see Fig. 2). In the area under discussion the pyroclastic members of the volcanics are predominant, and only a few outcrops of the typical trachytic lava have been found. In Lebel township the trachyte horizons become more prominent, and this condition continues eastward to the Quebec boundary. Throughout the map areas the typical pyroclastic member of this rock group is commonly referred to as tuff. On recently published geological maps of the Ontario Department of Mines of the Larder Lake country (Nos. 50a, 50b, and 50c), the same rock has been named trachytic agglomerate and tuff. Regardless of the name applied, the important point is that these pyroclastics are practically identical in appearance and field relationships along the entire belt from Kenogami lake to the Quebec boundary. Some of the bands are very persistent along the strike and thus serve a useful purpose as marker horizons for structural studies, especially in complexly folded and faulted sections.

Surface exposures of typical tuff show a pinkish or reddish colour owing to the abundance of grains, crystals, and fragments of pink feldspar or pink trachyte in the rock. Much of it is bedded, and crude cross-bedding is often seen; but cross-bedding sufficiently developed to indicate the tops of beds is rarely found. Fragments of pink trachyte are almost invariably present. In certain places these trachytic inclusions are as large as pebbles or boulders and are as well rounded as the boulders in an ordinary conglomerate. This variety has been named tuffaceous conglomerate by A. MacLean and Wm. Gerrie. The bedding, sorting, and rounding of fragments provide evidence that the tuff and tuffaceous conglomerate are water-laid deposits.

Tuff and tuffaceous conglomerate are distinguished from the true sediments by the fact that the former contain no quartz grains and the fragments or pebbles in the conglomerate consist almost entirely of trachyte. In contrast, the true conglomerate always contains a great variety of pebble types and normal greywacke shows numerous grains of clastic quartz. Owing to the absence of quartz, the tuff and tuffaceous conglomerate is a softer rock and does not have a gritty feel when scratched with a steel pick or hobnail.

Despite the above-mentioned characteristics, it is not always easy to distinguish between the tuffaceous sediments and the true sediments. On the bare

outcrops south of the town of Kirkland Lake, there are numerous exposures that show the interbedding and intermingling of these two types. For example, in the southern part of the former Kirkland Lake Victory Gardens, on claim L. 6,179, there is a bare ridge of typical tuff with trachytic fragments and a greenish igneous matrix, but a few widely separated well-rounded pebbles of iron forma-



Tuff and tuffaceous conglomerate exposed on the south side of the Goldthorpe road, claim L. 2,912, Teck township.

tion and granite porphyry may be seen in the exposure. Evidently a few pebbles of foreign rock material have been deposited in the bodies of water at the same time as the showers of volcanic ash were settling down and being sorted. When pebbles of foreign material are found in volcanic sediments, the safest criterion for rock identification is the lack of quartz grains in the tuff in contrast to its abundance in the normal greywacke and conglomerate.

A study of the accompanying geological maps will show that there are four main stratigraphical horizons of tuff in the area and also several small bands. The lowest horizon in the sequence lies at or near the north margin of the Timiskaming series and is fairly continuous across the western part of Teck township and the eastern part of Grenfell. A second band comes in above this in the western part of Teck township and extends along the north side of the main ore zone of Kirkland Lake; it is repeated on the south side of the ore zone owing to thrust-faulting along the Kirkland Lake fault.¹ The most continuous band extends from the southern part of the town of Kirkland Lake westward to the Blanche river, where it is cut off by faulting. In the eastern part of Teck township this horizon breaks up into a number of units that are interfingering and interbedded with normal sediments. In the general vicinity of Murdock creek the structure appears to be very complex, and there could be repetition of tuff horizons owing to faulting movements. The south horizon of tuffs extends westward from Swastika and lies south of the Blanche river. As the strata face south across the full width of the Timiskaming series in Teck township, most of the large tuff horizons are not repeated by folding. As mentioned above, how-

¹E. W. Todd, *Ont. Dept. Mines, op. cit.*, pp. 43-45.

ever, at least one is definitely repeated by strike-faulting, and there is a possibility that some of the other bands may have been similarly affected.

Trachyte and Trachytic Breccia

A few small bands of typical trachyte and trachytic breccia have been found throughout the area. The rock is massive and fine-grained and usually has a pinkish colour. It is intimately associated with the tuffaceous horizons and is identical with the trachyte of the Larder Lake country. The lack of any extensive bodies of trachyte in Teck township and the Kenogami Lake area would indicate that the source of Timiskaming volcanism was in the country to the east. If this surmise is correct, the volcanic ash and dust from these outpourings of lava must have been transported westward in large volume.

Keewatin-Timiskaming Unconformity

A great angular and erosional unconformity separates the Keewatin and Timiskaming series in the Kirkland Lake area. This fact was first noted by Burrows and Hopkins¹; recent detailed mapping has not only corroborated the fact but gives some indication of the magnitude of the unconformity. This subject has been discussed in detail in another publication.² A study of the maps of the Kenogami Lake area (No. 1946-1), Teck township (No. 1945-1), and Lebel township (No. 53a) will show that evidence of a major unconformity is found at several points along the north Keewatin-Timiskaming contact and at one point along the south contact in Eby township.

Where detailed information is available, it may be observed that the north Keewatin-Timiskaming contact is quite irregular with local embayments of sediments extending northward into the lavas and diorite. Three small irregular outliers of Timiskaming sediments are found in the Keewatin series in the northeastern part of Teck township and the northwestern part of Lebel, and a possible fourth outlier is found east of Nettie lake in Morrisette township (see Fig. 2 facing page 8). For reasons discussed elsewhere,³ these are believed to represent erosion remnants of the Timiskaming series lying with great unconformity on the Keewatin volcanics. Similarly, two inliers of volcanics are surrounded by sediments in the main body of the Timiskaming series, and the evidence again shows that these are eroded dome-like "islands" of Keewatin volcanics bounded with great unconformity by the sediments. One of these lies on claim L. S. 121 in the northwestern part of Lebel township; the other is found 7 miles to the southwest on claim L. 8,629 south of Perron lake in Teck township.

In a few places along the north shore of Kirkland lake the basal conglomerate, greywacke, and grit of the Timiskaming series is found in close proximity to or in actual contact with Keewatin pillow lavas and intrusive diorite. At one point on the north boundary of claim L. 6,446, basal grit is scattered irregularly over massive pillow lava, and the contact strikes at right angles to the strike of the lava flows. The contact has also been intersected by diamond-drill holes from the end of the 3,075-foot level crosscut from the Lake Shore mine through Kirkland Basin ground (see sheet D in map case). The contact, as seen in the drill-holes that crossed it, shows massive conglomerate and grit adjacent to massive lava. The basal grit is identical to that found at the contact at different localities on the surface. In one hole the contact is sharply defined as a fine line in an unbroken piece of core. In another, only a break in the core separates

¹A. G. Burrows and P. E. Hopkins. *op. cit.*, p. 10.

²Jas. E. Thomson, *Trans. Roy. Soc. Can.*, 3rd series, Vol. 40, sect. 4, 1946, pp. 113-124.

³*Ibid.*, pp. 116-118.

conglomerate and lava. The cores show definitely that there has been no movement along the contact. The Keewatin-Timiskaming contact would dip to the south at an angle of 86 degrees if the dip were uniform from the surface to the 3,075-foot horizon on Kirkland Basin claims. The numerous hills and valleys of the Keewatin topography, however, as revealed on the present surface, will undoubtedly occur down the dip, so that many contact irregularities may exist over a distance of 3,075 feet.

No top determinations have been made in the massive sediments at the contact in this vicinity, but to the northeast in Lebel township there is ample



Exposure of pillowed lava of the Keewatin series near the contact with Timiskaming conglomerate on claim L. 2,515, north shore of Kirkland lake.

evidence that the tops face south at the contact. Many excellent top determinations in the volcanics show that the lava flows consistently face north. On claim L. 2,515, on the north shore of Kirkland lake, two outcrops at the contact show excellent vertical sections across lavas that contain pillows up to 15 feet in length. These indicate that the flows dip north at about 65 degrees. This would mean that if the sediments were laid down in a horizontal position, or even with a considerable angle of initial dip, the volcanics would have undergone folding to an overturned position before sedimentation began. In other words an unconformity in dip of more than 90 degrees is almost certain in this vicinity.

The best visible evidence of the Keewatin-Timiskaming unconformity is found around the outliers of sediments and inliers of lava in the northwestern part of Lebel township. These are described elsewhere.¹

¹Jas. E. Thomson, *op. cit.*, pp. 116-118.

An inlier of pillowed lava occurs within the main belt of the Timiskaming series on claim L. 8,629, located on the south shore of Perron lake in the western part of Teck township. Fig. 3 shows details of the relationship of lavas to sediments at this place. The bedded sediments strike northeast, and the underlying pillowed lavas strike southeast, again indicating a major angular unconformity. A study of map No. 1946-1 will show that the same condition

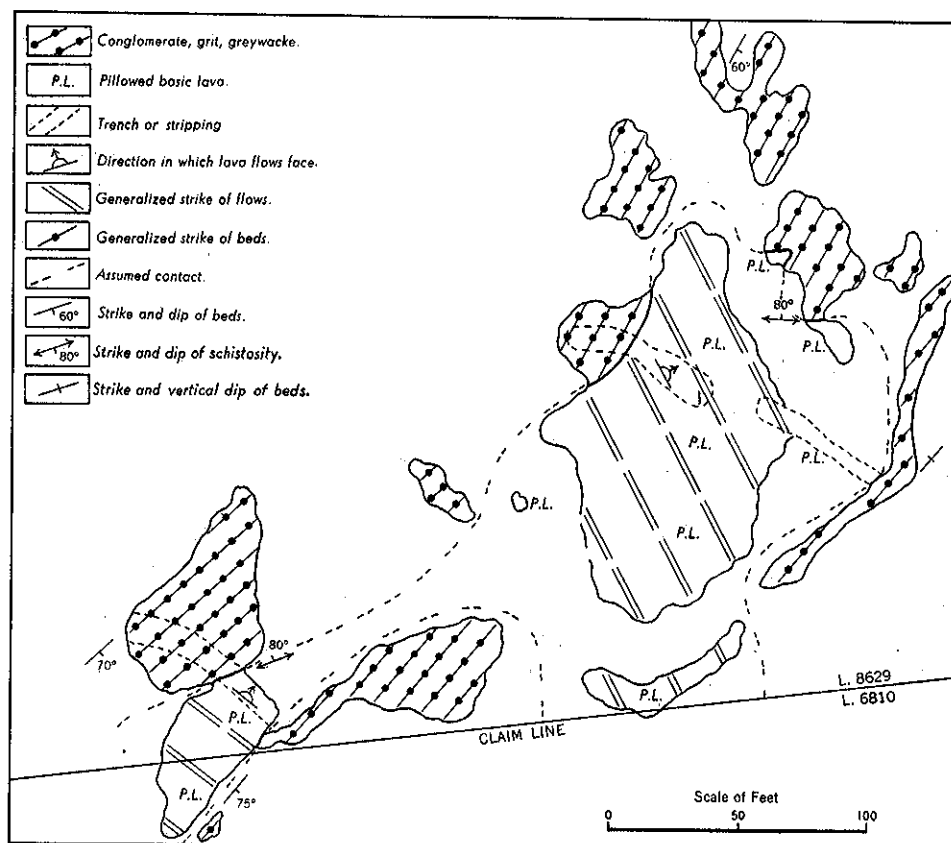


Fig. 3—Geological sketch map showing the unconformity between Keewatin lavas and Timiskaming sediments, south of Perron lake, near the west boundary of Teck township. (Geology by Wm. Gerrie.)

exists in the southern part of Grenfell township. Here, the lava flows of the Keewatin series strike almost at right angles to the different formations in the Timiskaming series.

It has been stated elsewhere that there are indications of a steeply dipping fault between the sediments and lavas along the north lava-sediments contact at Kirkland Lake.¹ The writer has checked the available evidence in consultation with other Department of Mines and mine geologists on various occasions and, to date (1948), can find no evidence of faulting along the contact in this

¹"The Gold Mines of Kirkland Lake," Structural Geology of Canadian Ore Deposits, Can. Inst. Min. Met., Symposium Volume, 1948, p. 645.

Harold Hopkins, "Structure at Kirkland Lake," Bull. Geol. Soc. Amer., Vol. 60, No. 5, 1949, pp. 912-913; and p. 162 of this report.

locality. Sheet D (in map case) shows a sheared zone and several faults of small displacement in the area south of the Keewatin contact at the 3,000-foot horizon. A gouge-filled slip is seen in old test pits south of the contact along the north boundary of claim L. 6,446 north of Kirkland lake. Local shearing and carbonatization is found along the contact in the southeast corner of claim L. 2,853 in the northwestern part of Lebel township. There is no question as to local faulting at and near the main lava-sediments contact, but this in no way nullifies the evidence of a great angular unconformity between the Keewatin and Timiskaming series. In an area so complexly faulted as that around Kirkland Lake it could not be expected that the lava-sediments contact zone would be devoid of these structural features. In the writer's opinion, however, there is no evidence that a major fault zone, comparable with the Larder Lake fault, which marks the south lava-sediments contact, is to be found along the north margin of the Timiskaming series.

In contrast to the conclusive evidence of a great unconformity along the north contact of the Timiskaming series, the south margin gives very little definite information. The reason for this is that the south contact is the locus of extensive faulting movements and is heavily sheared and carbonated. But in lots 2, 3, 4, and, 5, concession VI, Eby township, a small remnant of the Timiskaming series is found south of the regional fault. Immediately south of highway No. 11 in lot 3, concession VI, it was possible by surface-trenching and stripping to locate a point where the conglomerate and greywacke are exposed to within 6 feet of the adjacent pillow lava. As the rocks at the contact are massive and unsheared, there is little likelihood that any appreciable faulting occurred. Grain gradation in bedded greywacke about 10 feet from the contact shows that the tops face north. In the lava outcrop at the contact the shape of the pillows indicates that the lava flows face south. This would indicate an unconformity of equal magnitude to that observed along the north margin of the Timiskaming series. Despite much searching at other points along the unfaulted part of the south contact, no other definite information could be found to serve as a check on the above-mentioned observations.

The nature of the basal conglomerate and grit throughout the Timiskaming series is also indicative of an erosional unconformity. A large percentage of the boulders in the basal conglomerate is composed of the Keewatin type of greenstone. The rounding, sorting, and heterogeneity of the boulders and pebbles shows that they were deposited at long distances from their original outcrop. The source of certain pebble types, such as the jaspers that are found everywhere throughout the conglomerate, has always been a mystery. As no jasper-bearing iron formation has been found in the Keewatin series anywhere throughout the Kirkland Lake gold belt, the jasper pebbles must have been derived from some very distant source. The variety of pebble types in the conglomerate compared with the homogeneity of rock types in the immediately underlying volcanics shows that a very extensive terrain was undergoing erosion.

It is important to note that the angle of unconformity between the Keewatin and Timiskaming series varies greatly throughout the country, and it is only by obtaining the maximum angle of unconformity that the nature of the time interval is understood. In some places the Timiskaming series crosses the older folds at right angles, at other points it angles diagonally across the older structures, and in still others it runs parallel to Keewatin folds. Where Keewatin and Timiskaming folds happen to coincide, as in part of the Larder Lake area, there is little visible evidence of unconformity (see Fig. 2 facing page 8). The true magnitude of the unconformity becomes evident only in those parts of the

Kirkland Lake area where Keewatin and Timiskaming structures follow entirely independent courses at angles of 90 degrees or more to one another. When such a great angular discordance is known to exist, it is quite evident that the Keewatin and Timiskaming series should be regarded as independent structural units.

Algonian Intrusives

The rocks of the Keewatin and Timiskaming series are invaded by bodies of intrusives that vary greatly in composition, appearance, shape, and field relationships. Most of these rocks have been described in detail by Burrows and Hopkins,¹ and Todd.² In the present study, the intrusives have been divided into the five different groups, which are indicated in the legend on map No. 1945-1. In certain places the relative ages of certain members of the different intrusives may be observed, but in others the invading rock occurs in isolated masses and its relationship to other intrusives cannot be established.

The diorite and gabbro bodies associated with the Keewatin volcanics appear to be the oldest intrusive. Hornblende, biotite, and associated dioritic phases are found in the contact zone between large syenite bodies and older formations. They appear to have been formed by contact action and probably owe their composition to the large-scale assimilation around the outer margin of the stocks or batholiths. The augite syenite, basic syenite, and "lamprophyre" may also have been formed in this manner. In many parts of the area, and especially in the Kirkland Lake camp, the dark-coloured augite syenite ("lamprophyre") type grades into the syenite, but in certain places the syenite distinctly cuts the augite syenite. The syenite porphyry invades the more basic intrusives with a sharply defined contact. The long dimension of the smaller masses of the Algonian intrusives generally lies roughly parallel to the strike of the flows or sedimentary beds, but in detail crosscutting relationships are found in all three dimensions.

The carbonate bodies are discussed in this section of the report because they are believed to have been formed during the general period of Algonian intrusion. It should be clearly understood that the carbonate bodies are not intrusives but are secondary rocks produced by the replacement of the original rock by siliceous carbonate materials, often along lines of weakness produced by shearing movements. Throughout the Kirkland Lake-Larder Lake country the carbonate bodies are later than some syenitic bodies but are definitely older than the large syenite batholith lying in the southern parts of Lebel and Teck townships and other syenitic stocks of the same age.

Diorite and Gabbro, Quartz Diorite, and Quartz Gabbro

Bodies of altered basic intrusives are associated with the basic volcanics of the Keewatin series throughout the map areas. They have the composition of diorite or gabbro and quartz diorite or quartz gabbro, although the quartz-bearing variety is less frequently found. The rocks are characteristically massive, dark-green to greenish-black in colour, and of intermediate to coarse texture, but they become fine-grained at their boundaries. The hard, massive character of these basic intrusives has made them quite resistant to erosional agencies, and they generally stand out as rugged hills and ridges. The outline of some of the diorite and gabbro bodies suggests that they may be sills injected parallel to the lava flows. They may contain sufficient magnetite to disturb a compass needle

¹A. G. Burrows and P. E. Hopkins, *op. cit.*, pp. 13-18.

²E. W. Todd, *op. cit.*, pp. 25-38.

slightly. Microscopic examination of the basic intrusives shows that the constituent minerals are generally greatly altered.

These coarse-grained basic rocks often present certain field problems to the investigator, and it is not always possible to solve them satisfactorily. The basic intrusives are interbanded with massive lava flows, some of which are thick and become coarse-grained in the central portion. Wherever the coarse-grained dioritic rocks are poorly exposed it is often difficult to decide whether they are intrusive or extrusive. The fact that the diorite becomes fine-grained near the margin of the body makes it hard to delineate the contact with adjacent lavas. Then, the coarse-grained rocks sometimes closely resemble the later diabase, and unless contact relationships are found it is possible to confuse the "older gabbro" with the post-Algoman diabase. In the northwestern part of Teck township the basic intrusives in places occur in broad or irregular-shaped bands, which attain a width of more than half a mile. Here, definite contacts and crosscutting relationships with the lavas are found, and the intrusive nature is well established. In the vicinity of Armer lake in Teck township, there are places where the diorite seems to merge gradually into basic syenite and syenite, which suggests that the diorite and gabbro bodies are marginal phases of the Winnie Lake granite batholith. Syenite porphyry, which is the latest differentiate of the Algoman intrusives, cuts the diorite and gabbro bodies.

The exact relationship of the basic intrusives to the sediments of the Timiskaming series is not easily ascertained. Tongues of the intrusives extend into the north margin of the sediments in Teck and Lebel townships, which might suggest that the intrusives are post-Timiskaming, but when the great angular unconformity between the Keewatin and Timiskaming series is taken into consideration it is always possible that the unconformity could account for great irregularities in the contact. The actual contact between conglomerate and diorite is rarely seen, and even when seen does not provide satisfactory evidence for any definite conclusion. The contact may be observed on claim L. 1,824 or the south shore of the northwest bay of Kirkland lake. Burrows and Hopkins¹ have interpreted the relationship at this point as an unconformity because fragments of a dioritic rock are found in the conglomerate adjacent to the diorite. All the diorite pebbles in the conglomerate, however, are well rounded and must have been transported for long distances and their exact source is unknown, but it is very doubtful if they could have been derived from the immediately adjacent diorite. In summary, it might be said that the available evidence throughout the country would slightly favour a post-Timiskaming age for the diorite and gabbro bodies but the question is not definitely settled.

Granite and Syenite

The only true granite in the area occurs in the Winnie Lake batholith, which extends a short distance into the northwestern part of Teck township. Northwest of the lake the rock is a massive, medium-grained, pink granite with a considerable quartz content. South of the lake the granite appears to merge into syenite. The batholith that underlies the southern part of Lebel township and extends westward into the southeastern part of Teck township has the composition of syenite. Marginal phases of the syenite body in the southeastern part of Teck have the composition of basic syenite, hornblendite, diorite, or gabbro. Small erosion remnants of basic lava occur with the hybrid types. The normal syenite is a medium- to coarse-grained rock, which weathers to a light

¹A. G. Burrows and P. E. Hopkins, *Ont. Dept. Mines, op. cit.*, p. 10.

colour. Fresh samples contain dark-green and black hornblende and light-coloured to pink feldspar.

Hornblendite, Biotitite, and Diorite

As previously mentioned, the hornblendite, biotitite, and diorite are hybrid rock types that occur along the margin of the syenite batholith south of Kirkland Lake. They occur in small irregular bodies and show much variation in type. From mile post II on the Teck-Lebel boundary westward to claim L. 9,852, there are outcrops of a peculiar variety of hornblendite. The rock contains crystals of black hornblende up to half an inch in diameter and inclusions of greenstone and is probably produced by reaction between the batholithic magma and the assimilated lava. The hornblendite is cut by dikes of red syenite.

Basic Syenite, Augite Syenite, "Lamprophyre," and Augite Porphyrite

The basic syenite, augite syenite, and augite porphyrite are closely related to the so-called "lamprophyre" of the Kirkland Lake camp. These rocks are characteristically dark in colour owing to the content of ferromagnesian minerals. According to Todd,¹ the typical rock in the Kirkland Lake camp consists mainly of augite and alkali feldspar. The close association between the dark-coloured plutonic rock and the syenite into which it sometimes grades would indicate that the name augite syenite is more appropriate than lamprophyre. Since there are later narrow dikes of true lamprophyre in the area it is confusing to refer to the rock of this group by the same name. The term "lamprophyre," however, has been in popular use throughout the Kirkland Lake camp for a great many years and cannot easily be discarded from mine records. For this reason it is referred to as "lamprophyre" (with quotation marks) throughout this report to indicate the name in common use rather than the more accurate name of augite syenite. Basic syenite is a general descriptive term for the rock and indicates that it is the basic phase of a syenitic intrusive body. It may thus be seen that the names augite syenite, "lamprophyre," and basic syenite may all apply to the same rock exposure. Unfortunately, this confusing situation has developed over a period of many years and any attempt to rectify it now would only add to the confusion.

The basic syenite weathers to a rough, uneven or pitted surface owing to the leaching of the dark-coloured minerals. In some places it is cut by a series of narrow parallel dikes of red syenite, which stand out as little ridges on outcrops because they are more resistant to erosion than the basic rock.

About half a mile north of Swastika a band of basic intrusives averaging more than a quarter of a mile in width extends westward from Amikougami creek for about two miles. This rock has been termed augite porphyrite by Wm. Gerrie. It is a medium-textured, porphyritic rock, which shows on the weathered surface a mottling of grey feldspar and green ferromagnesian crystals in a slightly pinkish groundmass. The rock resembles in appearance certain porphyritic phases of the trachyte in the Larder Lake area. It is, however, definitely intrusive into the tuffs. Immediately west of Amikougami creek near the north boundary of claim L. 1,385, the contact between augite porphyrite and bedded tuff is well exposed. Small tongues and fingers of the augite porphyrite extend from the main body into the tuff. The augite porphyrite is cut by dikes of syenite porphyry and mica lamprophyre. It has not been observed in contact with the basic syenite and "lamprophyre," but the general field relationships would suggest that these dark-coloured intrusives may be closely related and they are grouped under one colour on map No. 1945-1.

¹E. W. Todd, *op. cit.*, p. 27.

Quartz Porphyry

Quartz porphyry is found in the northeast corner of Teck township. It contains large quartz phenocrysts in a fine-grained groundmass and is distinctly different from all other types of porphyry found throughout the area. The quartz porphyry occurs as dikes and irregular-shaped bodies. In places it is considerably sheared, especially along the contacts with basic lavas. On the north shore of Gami lake, it cuts through an outlier of Timiskaming conglomerate and so is definitely of Algonian age.

Syenite Porphyry, Quartz-Feldspar Porphyry, Alaskite

The latest members of the Algonian series in the area are syenite porphyry, quartz-feldspar porphyry, and alaskite. The porphyries may be exposed as dikes or small irregular-shaped bodies, or as large stock-like masses. The long dimension of these intrusive bodies tends to be parallel to the strike of the adjoining formations. Syenite porphyry is the most widespread member of the group, but occasionally phases are found that contain a few quartz "eyes," and this type may be classified as quartz-feldspar porphyry. Microscopic study shows that the quartz-feldspar porphyry is only a quartz-bearing phase of the syenite porphyry. A fine-grained, felsitic variety has been classified as alaskite by Wm. Gerrie.

The syenite porphyry is typically pink to bright-red in colour and is characterized by the presence of conspicuous crystals of feldspar. By diminution of the feldspar phenocrysts, the syenite porphyry grades into a syenite. The syenite porphyry is intimately associated with the basic syenite and "lamprophyre" throughout the Kirkland Lake camp, yet the porphyry always shows a sharply defined intrusive contact against the older rock type.

The reader is referred to the accompanying report on the mines of the Kirkland Lake camp for a further account of the porphyries.¹

Carbonated Rocks

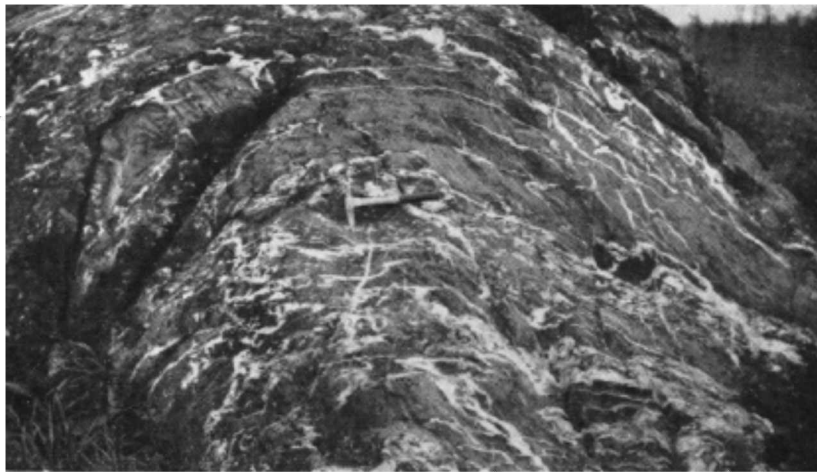
The carbonated rocks of the map areas are discussed in this place because they were formed during the general period of Algonian intrusion, although it must be clearly understood that they are not intrusive bodies. The carbonated rocks were formed by replacement of pre-existing rocks by siliceous carbonate materials. As in all replacement bodies, the amount or degree of alteration varies from place to place, and the carbonate bodies are therefore quite irregular in outline. There are all stages of development from slightly carbonated country rock to a siliceous carbonate body from which all vestiges of the original rock have disappeared. As the carbonatization diminishes gradually towards the margin of a body, an arbitrary boundary must often be drawn for the carbonate material on a geological map, and observers might easily differ in their classification of marginal areas.

The carbonated rock is composed mainly of silica and carbonates of magnesium, calcium, and iron. Throughout the Kirkland Lake-Larder Lake country this rock used to be called "dolomite," and the name is still occasionally heard, although it is technically incorrect. The rock frequently contains a bright-green mica, either fuchsite or mariposite in composition, and this gives it a characteristic greenish colour. The carbonate bodies are frequently intersected by a network of quartz veinlets. Where quartz veinlets are few or lacking, the highly schistose nature of the carbonate rock is quite noticeable, and this type is sometimes referred to as carbonatized schist. Owing to their iron content the

¹Pages 66-71.

carbonates show a reddish-brown gossan on the weathered surface; the green mica is also prominently displayed on the surface of the gossan.

Most of the carbonate bodies occur as elongated bands and lenses along sheared zones that strike about parallel to the lava and sedimentary formations.



Exposure of carbonate rock containing a stockwork of quartz veinlets, claim T. 15,754, south of Kirkland Lake.

The strongest and most persistent sheared zone is localized along or near the south margin of the Timiskaming series in Teck township and in the Kenogami Lake area. Carbonate rocks are found along it at intervals from the boundary of Teck township to Kenogami lake. This sheared zone is very probably a westerly



Large body of carbonate rock with quartz veinlets exposed on claim L. 6,187, south of Kirkland Lake.

continuation of the Larder Lake "break," which extends across the Larder Lake country (see Fig. 2 facing page 8). The sheared zone and carbonates have been cut out through a large part of Lebel township and in certain places in the southern part of Teck township by bodies of intrusive syenite and porphyry.

South of Kirkland Lake a bare ridge of carbonate rocks extends from claim T. 15,753 to L. 6,187. Bodies of weathered green carbonates up to 400 feet in width are cut by a network of white quartz stringers (see photographs on page 19). Two hundred feet southeast of No. 3 post of claim L. 6,681, the contact between recognizable bedded greywacke of the Timiskaming series and the carbonates may be seen (see photograph below). The beds in the sediments are greatly contorted, drag-folded, and brecciated. Northward from the carbonates the first sediments to be recognized are in a band of hard, white, drag-folded beds, about 2 feet in thickness. These are followed by a narrow band of carbonated rock, probably altered sedimentary beds, and then by more recognizable bedded greywacke.

The original nature of the main carbonate bodies cannot be determined. They appear to pass gradually into sediments to the north and basic lavas to the south, although on the south side only a few small patches of lava remain in



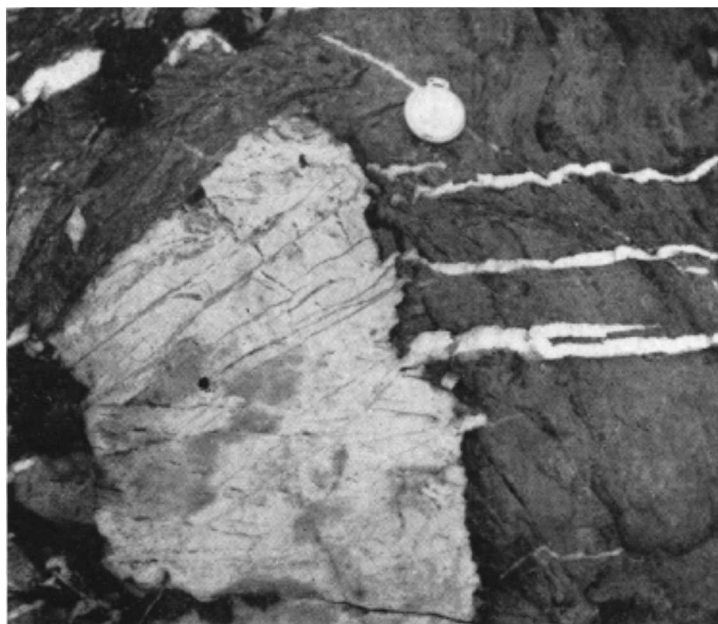
Contact between the green carbonates with quartz veinlets and recognizable sediments of the Timiskaming series, claim T. 15,754, south of Kirkland Lake. The hammer head rests on the contact. The sediments are drag-folded.

the syenitic intrusives. The highly schistose nature of the carbonate zone may be seen in places, but frequently the carbonatization has masked the original shearing. The relationship of the carbonates to the sediments and lavas is exactly similar to that in the Larder Lake country and is presumed to indicate extensive faulting movements along the contact. These would produce lines of weakness along which siliceous carbonate solutions could be injected.

Westward from the above-mentioned locality the carbonates are largely cut out by syenitic intrusives on claims T. 16,691 and T. 15,752. The carbonate zone is then presumably moved southward by a cross-fault underlying Murdock creek and west of the creek would follow a drift-covered depression if not cut out by the intrusives. Carbonates are found at an old shaft on claim L. 16,555. Drilling on claim T. 16,478 (Sahtram property) in 1945 after map No. 1945-1 was prepared showed that a 100-foot width of green carbonates and talc schist occurs along the lava-sediments contact. West of Amikougami creek the green carbonates are again encountered in a strong south-dipping fault in the northern part of the Golden Gate mine workings. At Swastika the carbonates are cut out by acid intrusives but may be followed at intervals along or near highway No. 11

to the Baldwin mine in concession VI, lot 2, Eby township. As indicated on map No. 1946-1, the ground between the Baldwin mine and Kenogami lake is mostly drift-covered, but green carbonates are exposed in the north half of lot 4, concession VI, Eby township. Another prominent band of carbonates occurs west of Vigrass lake in the northwestern part of Otto township. This has been traced westward to the west boundary of lot 1, concession VI, in Eby township. It is possible that another band of carbonates may extend southeastward from the southeast end of Kenogami lake.

There is ample evidence in the southern part of Lebel township and the southeastern part of Teck that the syenite batholith and its satellitic offshoots are intrusive into the carbonate rocks. In certain areas the carbonates have been completely cut out; in others fresh, massive dikes of syenite, syenite porphyry,



Late veinlets of quartz cutting syenite dike and carbonate schist, claim T. 15,754, south of Kirkland Lake.

and fine-grained, white aplite intersect the carbonates at different angles. Eastward along this carbonate band in the Larder Lake country, certain bands and dikes of syenite in or near the sheared zone are carbonated. The time of carbonatization is, therefore, fixed between the early and late phases of the syenitic intrusion. The quartz stockworks that frequently accompany the carbonate rocks cut across the carbonates, schists, and later syenite dikes. The main vein-fracturing and quartz-filling is then a very late or end phase of the Algonian period of intrusion.

The main economic interest in the carbonate rocks lies in the fact that eastward along the strike on the Larder Lake break and in certain sections of the Cadillac-Lake Bouzan fault in northwestern Quebec, gold deposits of commercial importance are localized within or adjacent to the carbonated zones. The economic possibilities of the carbonate zones are discussed in a later part of this report.¹

¹Pages 32-34.

Post-Algoman Intrusives

Dikes of diabase and lamprophyre intrude all the rock types with which they are associated. In the southern part of Grenfell township diabase also cuts the sediments of the Cobalt series. In most cases the age relationships of these later basic dikes to the Cobalt series is not known, and they can only be classified as post-Algoman in age. The diabase dikes in the Kirkland Lake camp are described¹ in the second report in this volume covering the main ore zone at Kirkland Lake.

Wm. Gerrie has traced a number of true lamprophyre dikes in the western part of Teck township. Unlike the so-called "lamprophyre" in the Kirkland Lake camp, these are clean-cut, dark-coloured dikes characterized by a high content of black biotite.

Cobalt Series

The relatively flat-lying strata of the Cobalt series occur east and west of Kenogami lake. The rocks are quite resistant to erosion and tend to show steep scarps and bluffs. The rocks of the Cobalt series consist of conglomerate, grey-wacke, arkose, and slate.

Excellent exposures of coarse boulder conglomerate may be seen in a road cut on highway No. 11 immediately southeast of the bridge over the Blanche river. Where bedding is found in the finer-grained clastics of the Cobalt series, the dip never exceeds 25 degrees from the horizontal. The dip of the beds provides the best criterion for distinguishing the Cobalt series from the older Timiskaming series. Compared with the Timiskaming strata, the sediments of the Cobalt series are fresh, massive, unsheared, and unaltered. Pebbles of jasper and iron formation, which are so characteristic of the Timiskaming conglomerate, are very rare in the conglomerate of the Cobalt series.

Pleistocene and Recent

The accompanying geological maps show the drift-covered and swamp-covered portions of the map areas. The drift consists of clay, sand, and gravel, all of which are products of the Pleistocene continental glaciation. Glacial striae and grooves show that the general trend of the ice-sheet was between S. 15° E. and S. 35° E.

STRUCTURAL GEOLOGY

All the data by which the geological structures of the area are determined have been shown on the accompanying geological maps. The strikes, dips, and tops of beds in the sediments and of the lava flows in the volcanics indicate the nature of the folding. Faults, sheared zones, and vein fractures are also marked on the map-sheets. The general interpretation of the regional and local structures is indicated by the lighter tints, which show the assumed extension and boundaries of formations under overburden. Sheet A (in map case) shows three generalized structure sections across the sedimentary belt in Teck township; two of these are located along long crosscuts on the 3,000-foot horizon at the Macassa and Lake Shore mines and therefore show the downward extension of structures and rock formations.

Fig. 2 (facing page 8) gives a simple picture of the main structural features within the map areas and their relationship to the entire Kirkland Lake-Larder

¹Pages 71-72.

Lake gold belt. It has been pointed out in a previous section of this report¹ that the Keewatin series is separated from the Timiskaming series by a great unconformity and that the two series are largely separate and independent structural units. In the northeastern part of Teck township the Keewatin series is, in part, buckled into east-west trending folds, but to the west the flows gradually swing around until in the vicinity of Kenogami lake they strike in a north-south direction and consistently face east and northeast. The Timiskaming series represents only the north limb of a syncline and for the most part is cut off along its south margin by a fault of regional extent. A small portion of the south limb of the syncline has been preserved south of the fault in concession VI, Eby township. The lavas south of the regional fault generally face south or southwest. A study of the accompanying geological maps will show that there are two main sets of faults. The older consists mainly of east-west trending shears, whereas the later faults frequently strike in a north-south or northeast-southwest direction. In the vicinity of the town of Kirkland Lake the faulting is very complex.

Methods of Studying Structure

Any attempt to solve the structure of the area requires that special attention be paid to (1) the tracing out of reliable marker horizons, (2) accurate determinations of the tops of lava flows and sedimentary beds, and (3) the location of sheared zones and cross-faults. The relative ages of the faults with respect to ore is most important because some are favourable pre-ore structures whereas others only displace the ore bodies; certain faults may show both pre-ore and post-ore movement.

Within the Keewatin volcanics individual flows could not be traced for any distance, although large bodies of diorite that are interbanded with the flows could readily be followed in certain parts of the area. A few narrow bands of tuff and iron formation are found locally in the volcanics and serve as excellent marker horizons. In the Timiskaming series the most reliable marker horizons are the bands of tuffs that are interbedded with the normal sediments.

The Keewatin and Timiskaming strata have been so closely folded that flows and beds generally have a very steep or vertical dip and in some cases are overturned. The direction of dip is thus useless in locating fold axes. In this report the interpretation of the folding and stratigraphy is based primarily on the determination of the tops of beds and flows. In the finer-grained sediments the tops of beds are determined by gradation in grain size across individual beds from the coarse-grained sand at the bottom to fine-grained clay at the top. Cross-bedding is developed in certain places throughout the tuffs. In the Keewatin lavas the tops of the flows were determined almost entirely by the shape of the pillowed structures. Throughout the map area large, well-developed pillows, up to 15 feet in length, are found in the basic volcanics, and the direction of the top of the flow is clearly marked although the error in determining the strike and dip of the flows by the average elongation of the pillows may be as great as 10 to 15 degrees.

For the sake of clarity folding, faulting, shearing, and fracturing are discussed here under separate headings, but it should be remembered that undoubtedly some of these structures were formed simultaneously, although adjustments on them probably continued throughout a long period of geological time.

¹Pages 11-15.

Folding

As pointed out previously in this report,¹ the folding of the Keewatin series is largely independent of the Timiskaming series; that is, much of the folding of the Keewatin series took place before the Timiskaming series was laid down. But as the Timiskaming series is also closely folded and faulted, the Keewatin series must have been affected by the deformation of Timiskamian time. The two periods of folding are discussed separately.

Keewatin Folding

Structural studies in the northeastern part of Teck township show that the volcanics have been closely folded into a central anticline flanked on either side by a syncline. The approximate positions of the fold axes are indicated on map No. 1945-1. At Gami lake, evidence of doming or cross-folding of the anticline shows that it pitches to the west on the west side of the lake. The anticlinal axis can be traced westward to the southeast arm of Amikougami lake; it may possibly continue eastward to McGarry township (see Fig. 2 facing page 8). The south syncline extends eastward off the nose of an elongated mass of basic intrusives. East of the Teck-Hughes slimes basin, the synclinal axis cannot be very accurately located. Near the Goodfish road south-facing flows are found, but the south limb of the fold was not found in Teck township. Immediately to the east in Lebel township, however, north-facing flows are found in an inlier of Keewatin lavas in the Timiskaming series on claim L. S. 121; consequently, the synclinal axis either passes beneath the Timiskaming series or follows near its north margin in Lebel township. The north syncline is a broad, open, westward-plunging fold lying east of Young lake.

The above-mentioned folds disappear to the west. In the northwestern part of Teck township the regional structure seems roughly to swing around parallel to the margin of the Winnie Lake batholith, and the flows uniformly face northwest and north. In the southern part of Grenfell township, the flows again swing around until the strike is west of north, but the tops are uniformly to the northeast.

In the southern part of Teck township the Keewatin lava flows strike about parallel to the margin of the adjacent intrusives. Thus, in the southeastern part of Teck township they fold around from an east-west strike to a northwest strike and face south or southwest. In a rock cut on the railway on claim L. 5,890, located on the south boundary of Teck township east of Swastika, the flows are very flat. They dip about 20 degrees to the north and plunge to the east at about 20 degrees. This point may be close to a synclinal axis. Around Vigrass lake in the northwestern part of Otto township, the flows strike northwest and face southwest. As the flows in this vicinity lie between two strong east-west trending fault zones, it is difficult to say whether the strike of the flows represents the normal regional trend or whether there has been some local folding associated with fault movements. Only a few top determinations have been made in the volcanics in the northern part of Eby township; they indicate a south- or south-west-facing structure.

Timiskaming Folding

Top determinations in the sediments and tuffs show that throughout Teck township the Timiskaming strata with few exceptions face south across the full width of the belt. On their north margin, they lie unconformably on Keewatin

¹Pages 11-15.

volcanics, whereas the south margin is greatly sheared and carbonated and is the locus of extensive faulting movements. In Teck township, therefore, the Timiskaming series represents only part of the north limb of a major synclinal fold. The remainder of the fold has presumably been removed by faulting.

There is one exception to the usual south-facing attitude of the Timiskaming series in Teck township. This is found east of the town of Kirkland Lake in a fault block lying south of Murdock creek on the property of Black Gold Mines. Here the beds face north. North-facing strata are also found along the continuation of this fault block south of the west end of Gull lake in Lebel township, but near the north shore of the lake the strata face south. There is thus a small synclinal fold within the narrow fault block that is not found elsewhere. The complexity of the faulting in this vicinity may in some way account for this unusual condition.

Few top determinations have been secured in the strata of the Timiskaming series in the Kenogami Lake area. This is particularly unfortunate in the case of that part of the Timiskaming series lying south of Kenogami lake because in this vicinity the sedimentary belt lies a short distance north of the assumed regional fault. Top determinations here could definitely establish the true nature of the regional folding in the Timiskaming series. The rocks, however, are mostly massive conglomerate and tuffs, and despite special efforts, no trustworthy top determinations could be found.

In lots 2 to 5, concession VI, Eby township, a small area of conglomerate and greywacke lies south of the regional fault. Much attention was paid to this area by the writer, and after a considerable search north-facing tops were located about 15 feet from the lava contact at a point where there is not much chance of faulting but considerable evidence of unconformity. The predominant rock along the margin of the Timiskaming series in this vicinity is a type of basal conglomerate very similar to that found along the north margin of the belt. It would therefore appear that a small remnant of the south limb of the major syncline of Timiskaming sediments has been preserved here.

Faulting

The known and assumed faults are indicated on the accompanying geological maps; some of the more important faults are also indicated and named on Fig. 2 (facing page 8). They may be roughly divided into three sets according to their trend with respect to the enclosing formations. These three groups are usually referred to as strike faults, diagonal faults, and cross faults. The terminology, however, is somewhat loose because a strike fault may swing around and become a diagonal or cross fault.

Faults are of great economic importance owing to the fact that the ore bodies in the seven producing mines at Kirkland Lake are located along a fault system. It is also very important to know the relative age of the faults with respect to the time of ore formation, but this information is not always readily obtained. It is known that certain faults with post-ore movement have the same strike as pre-ore faults. It is also known that different periods of movement may have taken place along the same fault plane both before and after the deposition of ore. Generally speaking, the strike faults are more liable to be pre-ore, and thus of economic interest, while many of the cross faults are known to be post-ore. The strike faults have a thrust displacement and probably originated during the long period of regional folding and igneous intrusion. In some places they are represented by a wide zone of shearing or brecciation, depending upon the type of rock traversed. In some instances the faulting has been followed by carbonatiz-

ation, silicification, and vein formation, all of which have tended to mask the original evidence of movement. The Kirkland Lake fault and the Larder Lake fault are examples of strike faults in the area.

The diagonal faults angle across the strike of the different rock formations. The Murdock Creek fault system would be classified with this group. There is evidence that this fault has post-ore movements and intersects the older Kirkland Lake fault. The cross faults have a general north-south strike and are definitely post-ore. These are most readily recognized by the way in which they offset marker rock horizons, older faults, veins, etc. In some cases diagonal and cross faults may be part of one post-ore fault system. For example, the Lake Shore cross fault merges with the diagonal Murdock Creek fault south of the town of Kirkland Lake.

CAUSE OF THE FAULTING

In the past the folding and faulting in the Kirkland Lake area has been attributed to a thrust movement from the vicinity of the syenitic batholith to the south.¹ Studies in recent years, however, have shown that this folding and faulting is not a local feature but is distributed over a belt more than 150 miles in length across Ontario and Quebec. This belt represents the roots of a range of ancient tectonic mountains. The fault pattern has been produced by crustal shortening on a grand scale in a great geosyncline during the mountain-building processes of early Precambrian time. The major line of weakness developed at that time was the Larder Lake Cadillac fault system. Adjustments on this structure were recurrent over a long period of time resulting in the different ages of faults in the system. The south side of the geosyncline was elevated by the thrust movements, and a series of more or less parallel, southward-dipping overthrusts were developed subsidiary to the main plane of movement.

In the area under discussion the main thrust movements were developed along the Larder Lake fault, which generally follows the south contact of the Timiskaming series, as presently exposed. On the other hand the ground in the vicinity of the north contact of the sedimentary series acted as a fairly stable buttress. Under these conditions the intervening area was cut into a series of slices by faulting, and each successive fault block rode upward over the block immediately to the north. The Kirkland Lake fault system, which was formed after the emplacement of an elongated stock of Algoman intrusives, may be an exception to this rule. The origin of the Kirkland Lake fault system is described elsewhere in this volume.²

Like most of the great thrust-fault systems throughout the world, the thrust faults are accompanied and displaced by normal faults. The normal faults run in almost every direction with relation to the strike of the thrust faults, but the majority tend to be at about right angles to the older structures. The usual explanation for this association is that thrust-faulting, under compression, has been followed by a relaxational period, during which the masses settled under gravity in order to regain the equilibrium disturbed by the compressive horizontal stresses.

STRIKE FAULTS

Kirkland Lake Fault System

The seven producing mines of the Kirkland Lake camp lie astride the Kirkland Lake fault system for a distance of more than 3 miles in the eastern

¹E. W. Todd, *Ont. Dept. Mines, op. cit.*, p. 41.

²Pages 86-91.

part of Teck township. West of the Macassa property the Kirkland Lake fault has been traced across the Tegren property by surface-trenching and shallow drill-holes. It has been displaced 900 feet to the south by the Amikougami Creek fault and then continues westward across the Kirkland Gateway and Murphy properties. The location of the fault has been fairly well established by diamond-drilling westward to the Teck-Grenfell township boundary. The structure has not been recognized in Grenfell township, although there is always a possibility that it might have been offset by cross-faulting near the Teck boundary and the western continuation thus lost under overburden and the Cobalt series.

The Kirkland Lake fault system strikes N. 60°-70° E. and dips to the south at 75 to 80 degrees. It is generally marked by a narrow zone of gouge accompanied by adjacent fracturing and rock alteration; vein-filling commonly follows the fault, especially in the eastern part of Teck township. It is a thrust fault with the south side being displaced upwards in a rotational movement. The Kirkland Lake fault system is described in greater detail in the accompanying report on the main ore zone at Kirkland Lake.¹

Amalgamated Kirkland-Blanche River Fault

It is assumed on the accompanying geological maps that the Amalgamated Kirkland-Blanche River fault is a continuous fault zone extending from a point near the northeast boundary of the property of Amalgamated Kirkland Mines westward to Kirkland Lake, where it may merge with the Larder Lake fault (see Fig. 2 facing page 8). The fault has been recognized at several points, but there has not been sufficient drilling to establish complete continuity across the country.

On Amalgamated Kirkland ground the fault has been traced out by surface-trenching and diamond-drilling. In the northwest corner of claim T. 16,621 a diabase dike has been offset about 200 feet by the fault. The fault was intersected by drilling near the east boundary of claim T. 16,480 (Sahtram Gold Mines) in 1945-46 by Toburn Gold Mines. The structure is offset to the south by the Amikougami Creek fault and extends through the underground workings at the old Trout Creek shaft in the southwest corner of claim T. 16,477. The fault has also been traced across the Ventura-Kirkland claims by diamond-drilling. From this property it is believed to extend westward under the bed of the Blanche river, thus accounting for the divergence in strike of the Timiskaming strata on either side of the river valley. Up to 1947 this section of the fault had been cut in only one drill-hole, which was put down beneath the river immediately north of the shaft on Baldwin Consolidated ground. According to G. L. Holbrooke,² it was indicated in the drill-hole by a zone of strong shearing, carbonatization, silicification, mineralization, and low gold values.

Wherever information is available this fault is known to have a southerly dip. It is probably a thrust fault, but the amount of the displacement is unknown. The drag of the beds and the displacement of the diabase in the southwestern part of Teck township shows that the south side probably moved west in post-diabase time, but an opposite direction of movement is indicated by the offset of a diabase dike at the east end of Amalgamated Kirkland ground.

Larder Lake Fault

A zone of intense shearing, frequently accompanied by silicification and carbonatization, is found along the south margin of the Timiskaming series.

¹Pages 74-81, 84.

²Preliminary Report on Baldwin Consolidated Mines, issued by Brewis and White, Toronto, 1946

This represents a faulted contact between the sediments and Keewatin volcanics. The fault extends across Teck township and probably continues westward through Eby township, but there is a great deal of low ground along its assumed position in the vicinity of Kenogami lake. As indicated in Fig. 2 (facing page 8), this fault is probably the westerly continuation of a structure named the Larder Lake "break" in McGarry, McVittie, and Gauthier townships.¹ The latter, in turn, is probably the continuation of the Malartic-Cadillac-Bouzan Lake fault in Quebec. There may thus be a continuous fault for more than 150 miles from a point beyond Louvicourt township in northwestern Quebec to Kenogami lake and possibly extending even to the Matachewan or Midlothian areas.²

In the Larder Lake area the Larder Lake fault is a strong sheared zone, along which the rocks have been altered to talc-chlorite schist over widths up to 700 feet; siliceous carbonate material has replaced the schist at many places. This condition is also found along the south boundary of the Timiskaming series in Teck township and part of Eby township. The Larder Lake fault has been traced westward from a point near the Quebec boundary to the edge of the syenite batholith in Lebel township, where it is cut out by the intrusives. At the west end of the Lebel syenite batholith the shearing and carbonatization are first found on claim L. 6,187, about half a mile south of the town of Kirkland Lake in Teck township. In the eastern part of this claim the structure disappears into a long narrow valley that trends southeastward into Lebel township to a dam on the Lake Shore slimes basin on claim L. 26,908.³ East of the slimes basin the syenite cuts out all the older structures.

Large bodies of green carbonates with quartz stockworks occur between claims L. 6,187 and T. 15,753 south of Kirkland Lake. Dikes and irregular offshoots of acid intrusives from the syenite body to the south invade the carbonate bodies. In the northeast corner of claim T. 15,754 the contact between the sediments and carbonates is exposed. It shows that the sediments have been much folded and contorted at the contact. In the vicinity of claim T. 15,752 the syenites have cut out all but small remnants of the carbonate bodies. The structure is thrown southwest about 600 feet by cross-faulting along Murdock creek. West of the creek there is a pronounced valley along the supposed location of the sheared zone. Carbonates were encountered in the underground workings at the old Highland-Kirkland shaft on claim L. 16,555. West of this shaft the ground is largely drift- and swamp-covered for a width of three claims, but strong shearing is found in the tuffs near the assumed position of the sheared zone in the northeast corner of claim L. 15,396. Immediately south of the highway on claim L. 2,634 a narrow valley separates the sediments from the lavas, and the sediments along the valley's edge are heavily carbonated.

A geophysical survey, made by A. A. Brant for the Department in 1945, indicated that the contact bends southwest through the Kirkland cemetery as indicated on map No. 1945-1. This location was checked by drilling in 1946 under the direction of Toburn Gold Mines on the property of Sahtram Gold Mines. Two sections drilled across the lava-sediments contact east of Amikougami creek indicated a sheared zone about 100 feet in width. This contains talc schist and green carbonates, both of which are cut by narrow syenite dikes.

A horizontal displacement of 700 feet on the Amikougami Creek fault would bring the Larder Lake sheared zone in line with a heavy fault containing green

¹Jas. E. Thomson, *Ont. Dept. Mines, Vol. L, 1941, pt. 7, pp. 36-37.*

²G. W. H. Norman, *Bull. Can. Inst. Min. Met., No. 406, Feb., 1946, pp. 137-140.*

M. E. Wilson, Trans. Roy. Soc. Can., 3rd series, Vol. 37, pt. 1, sect. 4, 1943, p. 131.

Jas. E. Thomson, op. cit., pp. 36-37.

³*Ont. Dept. Mines, map No. 53a.*

carbonates that has been traced along the southwestward-trending part of the same creek. It was located by diamond-drilling on claim L. 4,486 by Ventura Kirkland Mines. This fault dips at 60°S. at the Golden Gate mine and comes into the workings on the 975-foot level (see Fig. 4 on page 46). The faulting and carbonatization have been cut out by the porphyry intrusives at Swastika, but west of the intrusive body the carbonated schists are well exposed a few hundred feet north of highway No. 11 on the Crescent section of the property of Kirkland Golden Gate Mines.

Shearing and carbonatization are found in surface exposures along the lava-sediments contact from Swastika westward to the Kelmac shaft of Baldwin Consolidated Mines in Eby township. The fault appears to leave the contact at this point, and there is less certainty of its exact location to the west. Green carbonates outcrop north of No. 11 highway in lot 4, concession VI, and shearing and carbonatization are found in a road cut a little over half a mile southeast of the Blanche river bridge. This may mark the position of the main fault or it may lie slightly to the north.

A possible location for the continuation of the fault southwest of Kenogami lake is shown on map No. 1946-1, but at the time the map was prepared there had been no drilling to check its existence. Early in 1948 Burtho Gold Mines drilled four holes along the assumed fault zone on the south half of lots 6 and 7, concession VI, Eby township. This work confirmed the presence of the fault on lot 7 approximately in the position shown on map No. 1946-1. The fault was traced northeastward across Kenogami lake, where its surface projection would lie about 100 feet south of the northwest corner of claim L. 18,312. In this vicinity the drilling revealed only one fault instead of the two indicated on map No. 1946-1. The fault zone consisted of a 50- to 75-foot width of strongly sheared, brecciated, and carbonated greenstone with local "mud seams" and quartz stringers. Where it passed through syenite porphyry, the rock was brecciated and veined with quartz.

The actual amount of displacement on the Larder Lake fault is unknown. The vertical component must have been sufficient to elevate most of the south limb of the syncline in the Timiskaming series above the present erosion level. The evidence of the direction of horizontal displacement is obscure. The drag of the beds adjacent to the fault in Teck township suggests that the south side moved east. This checks with a possible 1,500-foot displacement of conglomerate by the fault near the Kelmac shaft on the Baldwin Consolidated property. The only reliable information on the dip of the fault is found in the Golden Gate mine workings, where the inclination is 60°S. between the surface and the 1,000-foot horizon. In summary, this would mean that the structure is a thrust fault of great vertical displacement, along which the south side moved up and possibly to the east. This would agree with the information on the displacement in the Larder Lake country.¹

Vigrass Lake Fault

The Vigrass Lake fault strikes in an east-west direction across the north-western corner of Otto township and extends into Eby township. It is a zone of intense shearing with green siliceous carbonate alteration along certain sections. Diamond-drilling by Kirkland Golden Gate Mines along the creek that drains Vigrass lake into Otto lake has indicated a strong fault with a southerly dip. There is a pronounced scarp immediately south of the east end of Vigrass lake, which probably has been produced by the faulting movements. This strikes

¹ *Jas. E. Thomson, op. cit., p. 38.*

directly towards a zone of shearing and green carbonate, which has been traced westward to the boundary of the Baldwin Consolidated property in Eby township. At this point the carbonate zone ends abruptly at a southwestward-striking sheared zone.

The Vigrass Lake fault lies about 1,500 feet south of the Larder Lake fault, contains the same type of carbonate alteration, and has a similar dip to the south. It is presumed to be another thrust fault in the regional fault system.

South Bay Fault

Shearing with attendant green carbonate alteration is found along a zone striking S.70°E. through the southeast bay of Kenogami lake. Drilling on the Walters claims has indicated a zone of talc schist underlying the creek bed on claim L. 17,402. A hole was drilled across the assumed northwest extension of this fault 1,600 feet from shore in the bay by Burtho Gold Mines in 1948, but only weak shearing and a narrow mud seam were found. Strong shearing has been noted adjacent to the highway on lot 3, concession V of Eby township.

DIAGONAL FAULTS

Murdock Creek Fault

The term Murdock Creek fault is applied to a system of faults that underlie and run parallel to the valley of Murdock creek, south of the town of Kirkland Lake. The fault system has been traced northeastward across Lebel township. The main fault underlies Murdock creek on the property of Black Gold Mines and extends across the southern part of the town of Kirkland Lake. It is indicated on the surface by a marked topographical depression and the variation in character and strike of the adjoining formations. Drilling on the Black property shows that the fault dips from 70° to 75° N.W. The fault zone is indicated in the cores by broken rock replaced by quartz and calcite over widths of as much as 39 feet. Mylonite is developed in the fault zone, and in this respect the Murdock Creek fault resembles both the Kirkland Lake fault and the No. 5 strike fault of the Wright-Hargreaves and Sylvanite mines.

Assays up to \$2.65 per ton in gold are reported from the fault zone material. Hopkins¹ shows that this fault extends into the underground workings of the Wright-Hargreaves mine below the 4,000-foot level. Here, it is named the No. 5 strike fault. According to Hopkins, this structure has post-ore movement and displaces the productive veins as much as 700 feet. He believes that it is an underthrust with the southeast side moving downward. This fault is described in greater detail in the following report on the main ore zone at Kirkland Lake.² The available information suggests that the Murdock Creek fault may have undergone both pre-ore and post-ore movement.

From 700 to 1,000 feet southeast of the above-mentioned fault in Teck township, there is evidence of a more or less parallel fault. In Lebel township this is regarded as part of the Murdock Creek fault zone.³ On the Black property there is a marked change in strike and offset of tuff and sedimentary beds along it. The ground between these two faults constitutes a fault block, in which the strata face north in contrast to the east- and south-facing beds outside of it.

North Harvey Fault

The North Harvey fault is indicated near the Teck-Lebel boundary by the

¹See page 173

²Pages 86, 173.

³Ont. Dept. Mines, map No. 53a.

abrupt change in strike of adjoining formations. A prominent horizon of tuffs on claim L. 1,534 is cut off sharply by this structure. The drag of formations adjacent to the fault would indicate that the south side moved east; the schistosity adjacent to it dips to the south. It is possible that the wedge-shaped block between the North Harvey fault and the main Murdock Creek fault moved southwest.

Middle Harvey Fault

The Middle Harvey fault follows a marked topographical depression immediately north of the Harvey Kirkland shaft on claim L. 1,873 in Lebel township.¹ Its extension west into Teck township is assumed. There is strong shearing in conglomerate outcrops in the southwest corner of claim L. 6,682 on the Hudson-Rand (Kirkland Gold Rand) property. This may mark the position of the merging Middle and South Harvey fault zones. North of the Harvey Kirkland shaft the drag on the formations would suggest that the south side of the Middle Harvey fault moved west. In other words, the fault block between the North and Middle Harvey faults moved to the east.

South Harvey Fault

The South Harvey fault has been traced across the western part of Lebel township and is projected across the eastern part of Teck, where it may join the Middle Harvey fault. East of the merged Sylvanite and K cross faults, the South Harvey fault lies at or near the lava-sediments contact. This is an unusual condition, for the Larder Lake fault usually occupies such a position.

TRANSVERSE OR CROSS FAULTS

Transverse or cross faults strike in a general north-south direction and are normal faults produced by tensional adjustments following the regional folding and injection of the Algonian intrusives. They are the latest expression of faulting in the area and are thus post-ore. The position of the cross faults is indicated by the offset of marker horizons, contacts, older faults, veins, etc. They are often expressed topographically by narrow linear valleys. Hopkins² has pointed out that the movement on the fault plane on certain of the cross faults has been rotational with the axis of rotation somewhere north of the Kirkland Lake fault. Some of these faults are discussed in greater detail in the accompanying report on the main ore zone at Kirkland Lake.³

Shearing and Fracturing

Outcrops on which shearing has been observed are marked with the appropriate symbol on maps Nos. 1945-1 and 1946-1. Shearing with accompanying carbonatization is indicated by the colour for the carbonate rocks, and less intense alteration is shown by the V-shaped pattern in red. Study of the distribution of shearing on these maps will show that it is mainly concentrated along definite zones, which strike about parallel with the rock formations. The shearing may be limited to only a few feet in width, as in the case of the Kirkland Lake fault, or it may extend across hundreds of feet, as in certain sections along the Larder Lake fault. Subsidiary zones of shearing sometimes angle off the main sheared zones. In addition, there may be broad zones of moderate shearing that cannot be identified with any known faults but rather

¹see map No. 53a.

²Harold Hopkins, *Trans. Can. Inst. Min. Met.*, Vol. 43, 1940, p. 698.

³Pages 85, 86, 171, 174, 176.

lie in the contact zone where intrusives and intruded rocks are intermingled. The shearing is largely confined to certain zones in the volcanic and sedimentary rocks. Intrusive stocks, such as that along which the main ore zone of Kirkland Lake is located, are generally massive, except in the immediate vicinity of "breaks."

There is little information on rock fracturing and vein-fracture patterns except in the vicinity of the mine workings. These vein-fracture patterns are indicated on the geological plans and sections of the various mines described in this volume. A feature of the fracturing in the Golden Gate and Crescent workings of Kirkland Golden Gate Mines is that the vein fractures cut indiscriminately across intermingled massive lavas and syenite porphyry, each rock type being about equally competent. At the Baldwin Consolidated mine, gold values obtained to date are reported to be confined to those areas where cross-faulting and fracturing intersects the vein system. The fracturing along the main ore zone at Kirkland Lake is described in another part of this volume.¹

ECONOMIC GEOLOGY

During the past thirty years successful development of mines in Teck township and the Kenogami Lake area has been limited to the seven producing properties located on the main ore zone at Kirkland Lake. The large amount of exploration on many other properties has located only a few relatively small ore shoots. The Kirkland Golden Gate, with a gold production of approximately \$1,000,000, has the best record amongst these to date. Exploration has indicated that gold is widespread in occurrence; as interesting geological structures have been found at certain places, there is reason to believe that further development may reveal new gold ore bodies.

It should be noted that there is one small base metal occurrence (Winnie Lake) in the northwestern part of Teck township. The association of lavas and basic intrusives in the northern parts of Teck and Grenfell townships is suggestive of the possibility of finding base metal occurrences.

General Character of the Gold Occurrences

Gold-bearing veins have been found on more than half of the 24 properties described in this report, but, in most cases, the size and grade are below the current commercial level. In practically all the occurrences, gold is found in quartz veins or stringer zones. The veins lie in a variety of rock types, but syenite porphyry is almost invariably one of the rocks in the vein zone. A definite structure (break) such as a sheared zone or fault with gouge is generally present. Occasionally multiple structures form a structural pattern. Carbonate alteration adjacent to the structure is often noticeable.

The mineralization consists mainly of pyrite, but lesser amounts of chalcopyrite, galena, molybdenite, and specularite are sometimes found. In some places, high gold values are associated with patches of heavy sulphide mineralization in the veins. Native gold is reported at several of the occurrences.

Complex post-ore faulting adds to the exploration problems in certain parts of the area. This is particularly noticeable in the ground near the Larder Lake fault zone and at the east end of the Kirkland Lake camp.

Considerations in Future Exploration

Experience gained from widespread exploration throughout the Kirkland Lake-Larder Lake gold belt has shown that ore bodies have a closer relationship

¹ Pages 82-83.

to structures than to rock types. The main ore zone of the Kirkland Lake camp is an outstanding example of the close association between ore and a fault system. Emphasis has thus been placed on the tracing out and investigation of pre-ore fault structures. In the country under discussion there are three main strike faults or breaks of economic interest and several other lesser known parallel structures. From north to south the stronger faults are (1) the Kirkland Lake fault system, (2) the Amalgamated Kirkland-Blanche River fault, and (3) the Larder Lake fault. Possibly the Narrows break (see Fig. 7 facing page 82 and sheet D in map case) might be regarded as a separate gold-bearing structure from the Kirkland Lake fault system, especially to the west.

Naturally, the close association between the productive veins along the main ore zone and the Kirkland Lake fault system has focused attention on its extension westward across the country as an exploration "bet." The bulk of future exploration along this structure will probably have to be at considerable depth because near-surface probing to date has failed to indicate any ore. The development of important subsidiary veins on the south side of the Kirkland Lake fault in the west end of the camp suggests that similar interesting conditions might be found at other places along the fault system west of the Macassa mine.

The Amalgamated Kirkland-Blanche River fault zone has had some attention in recent years, and gold is known to occur at a few points along it. The structure has been traced across the western part of Teck township, but its possible continuation east of the Lake Shore cross-fault has not been definitely recognized. Considerable portions of this fault have not yet been drilled.

The Larder Lake fault is the most persistent strike fault in the country and generally follows the south margin of the Timiskaming series, although in the vicinity of Kenogami lake it appears to leave this horizon. Its importance lies in the fact that ore bodies have been found along and adjacent to it in the Larder Lake country to the east and gold is known to occur in its vicinity in the area under discussion. The Larder Lake fault is a very ancient structure, antedating the syenite and porphyry intrusives, but it appears to have been the main line of weakness across 150 or more miles along the Ontario-Quebec gold belt. In and adjacent to this structure, faults and fractures of different ages were formed as recurring adjustments took place over a long period of time. Some of these faults and fractures coincided with the period of gold mineralization and are ore-bearing, whereas others were formed at other times and are barren.

The Larder Lake fault zone has attracted the attention of prospectors for a long time. As early as 1920, Burrows and Hopkins described it as follows:¹—

In the southerly part of the sediments there is a band of carbonate rock traceable at intervals for several miles, which has been differentiated on the map. It is not definitely known whether the rock belongs to the Keewatin or Timiskaming. The rock is cut by numerous irregular veinlets of white quartz, and resembles the carbonate or ankerite bands frequently observed in the Porcupine and Larder Lake areas. Some of the material mineralized with iron pyrites and copper pyrites was found to yield traces and up to \$2.00 of gold to the ton.

Drilling and underground exploration have been done along or near the Larder Lake fault in recent years on the Florena, Sahtram, Kirkland Golden Gate, and Baldwin Consolidated properties. West of the Baldwin Consolidated, drilling at Kenogami lake by Burtho Gold Mines in 1948 along the assumed extension of this structure in the south half of lots 6 and 7, concession VI, Eby township, located the fault zone, but gold values were lacking. The Vigrass Lake fault and the South Bay fault at Kenogami lake are structures similar to the Larder Lake fault and have had only a limited amount of attention. Any un-

¹A. G. Burrows and P. E. Hopkins, *Ont. Dept. Mines, Vol. XXIX, 1920, pt. 4, p. 12.*

explored areas in the vicinity of the strike faults throughout the country might prove to be interesting ground for further investigation.

The experience gained from thirty years of mining operations along the main ore zone in the Kirkland Lake camp shows that intrusive stocks have a profound influence on ore localization. This fact should be considered in the exploration of the surrounding country. As pointed out in the second part of this volume,¹ the ore bodies of the Kirkland Lake camp are confined to an elongated, composite intrusive body and to the sediments in the contact zone. The combined intrusive body and fault system has controlled the strike, dip, pitch, and limitations of the ore zone. This was not the result of any known genetic relationship between the intrusives and the ore but was rather the result of some delicate difference in the physical nature of the intrusive body, which provided and maintained the necessary openings at the strategic time of gold deposition. The presence of intrusive stocks in the general vicinity of pre-ore faults in the area under discussion provides a theoretically ideal combination, but, of course, the vagaries of commercial gold deposition are so well known that only systematic exploration can reveal whether such areas contain any ore.

DESCRIPTION OF PROPERTIES

Amalgamated Kirkland Gold Mines, Limited

Amalgamated Kirkland Gold Mines, Limited, was formed in 1939 and acquired a group of claims in the southeastern part of Teck township adjoining the Teck-Hughes, Kirkland Lake Gold, and Macassa mines on the south. The property includes the former Kirkland-Kalgoorlie, Canadian Kirkland, and Kirkland-Hunton mines, on all of which underground work was done a number of years ago.² In 1939, 27 surface drill-holes were put down along a break that strikes northeastward across the northern part of the property. In 1940-41 it was planned to explore this structure at depth by driving a long crosscut south from the 3,000-foot level of the Macassa mine. The work was discontinued, however, when the drive had reached a point 135 feet from the Amalgamated Kirkland boundary. In 1944 two drill-holes were extended into Amalgamated Kirkland ground from the end of the crosscut. In 1945 some further surface-drilling was done.

Geology

The surface exposures on Amalgamated Kirkland ground consist of Timiskaming sediments and tuffs intruded by syenite, syenite porphyry, basic syenite, and diabase dikes. An elongated irregular-shaped body of syenite porphyry and basic syenite extends across the northern part of the property. The north margin of a syenite stock lies near the south boundary of the claims. Between these intrusive masses the interbedded sediments and tuffs have been greatly drag-folded and faulted, as indicated on map No. 1945-1.

A fault, referred to as the Amalgamated Kirkland-Blanche River fault in Fig. 2 (facing page 8), is believed to extend southwestward across the northern part of the property. It offsets a diabase dike in the northern part of claim T. 16,621 near the Teck-Hughes boundary. Elsewhere across the property it has been traced by drilling.

The carbonated fault zone that follows the main south sediments-volcanics contact may extend through low ground on claims L. 15,396, L. 5,689, and

¹Pages 73, 88, 89. See also sheets A, N, Q, and R in map case.

²A. G. Burrows and P. E. Hopkins, *Ont. Dept. Mines, Vol. XXXII, 1923, pt. 4, pp. 48-51. E. W. Todd, op. cit., pp. 148-149.*

L. 6,768. This is an older type of fault, which is part of the Larder Lake fault system. The Larder Lake fault is cut out by syenite and porphyry intrusives in many places throughout the country and this condition may also exist here.

Early Developments

Previous work on the Kirkland-Kalgoorlie claim, L. 5,433, is described by Burrows and Hopkins¹ as follows:—

Several quartz veins have been found, the principal one of which is in the southwest part of the claim. It has been traced about 300 feet and prospected by means of several pits and a shallow prospect shaft. It occurs in schistose sediment on the northwest side of a porphyry dike. Where seen in one pit, the structure shows a somewhat banded character of quartz veinlets in the sediment over a width of six feet, with the wider quartz bands towards the centre of the deposit. The quartz veins dip 70° to 80° S.E., and the best values are reported to occur in the footwall side in the narrow seams of quartz. The principal metallic sulphide is iron pyrites. A working shaft was being sunk near the northeast end of the exposure of the vein.

Developments on the Canadian Kirkland property are described as follows:²—

Two vertical shafts and several pits have been sunk on mineralized zones. The main shaft on claim L. 6,687, fifty feet from the north line, was sunk on a mineralized zone in the greywacke, consisting of quartz veinlets and greywacke impregnated with iron pyrites, copper pyrites, galena, and calcite. The strike of the mineralized zone is east-northeast and west-southwest. A section exposed in the shaft shows a series of quartz veinlets about one inch wide, dipping steeply to the south across the shaft to the 150-foot level. A short crosscut was made southward at the 100-foot level, and on the 150-foot level a crosscut was made to the north and south of the shaft. Promising assays were obtained for about eighty-five feet in the shaft, but no drifting was done to determine whether the mineralized zone pitched eastward or westward. The crosscut at the 150-foot level is in greywacke with fine-grained, slate-like rocks eighty-five feet south of the shaft.

The property was under option to the Crown Reserve Mining Company in 1919. At a later date the shaft was continued to a depth of 400 feet.

The following account of early developments at the Hunton (later Kirkland-Hunton) property is taken from the same report:³—

The Hunton property is situated nearly a mile south of the southwest end of Kirkland lake and consists of two claims, 16,621 and 16,620. A porphyry dike with strike N. 66° E. intrudes the schistose sedimentary rock near the line between the claims; most work has been done so far on the northerly claim, 16,621. A mineralization occurs along the south contact, extending into both formations. An open-cut was made along a series of narrow quartz veinlets one to three inches wide, which intersect the sediments and porphyry, the cut passing from the sediments to the porphyry to the northeast. A shaft was sunk to a depth of forty feet in the sediment with the porphyry on the north wall. The mineralization is reported to extend to the bottom of the shaft, while visible gold was encountered down to about thirty feet. Diamond-drilling indicated gold, in the core from a depth of 254 feet from the surface, vertically. By open-cuts and pits, the mineralization has been traced for 300 feet along the surface. Just northeast of the shaft, three quartz stringers dipping south are exposed in the open-cut; while twenty-five feet from the shaft there is a quartz vein two inches wide running diagonally across the trench, N. 30° E., in the porphyry, carrying extremely rich showings of gold with pyrite. The gold is very fine, almost like "mustard" gold, and shows as a yellow stain throughout the quartz. The porphyry and quartz along the rich streak carry abundant iron pyrites. This mineralization is adjacent to a fault plane that strikes in the same direction as the vein.

A vertical shaft has been sunk to a depth of 400 feet and stations cut at 125, 250, and 275 feet. The vein, which dips steeply to the south, has been drifted on at the first level for 250 feet and much quartz, pyrite, molybdenite, and films of specular hematite were observed. About 4,000 feet of diamond-drilling has been done from the third level in exploring the ground lying principally to the north of the shaft. A crosscut was driven northward to intersect a mineralized zone containing promising gold values, which had been discovered in the drilling operations. This crosscut is 1,050 feet in length and, for the greater part of this distance, is in conglomerate which replaces the porphyry 140 feet to the north of the shaft. At a point approximately 800 feet along the crosscut, the conglomerate is intruded by a dike of brecciated porphyry fifty feet in width. Movement has taken place along the plane of the dike, resulting in the development of sheared zones in the porphyry along which considerable mineralization, principally in the form of pyrite, is in evidence.

¹A. G. Burrows and P. E. Hopkins, *op. cit.*, p. 50.

²*Ibid.*

³*Ibid.*, pp. 48-50.

About 500 feet of drifting has been done along a narrow pyritized break in proximity to the conglomerate-porphry contact north of the shaft. A crosscut was also driven south from the shaft 200 feet to the southern contact of the porphyry with conglomerate. In all, the workings on the 375-foot level total about 1,800 feet.

Additional information on the Hunton property is taken from Todd's report:¹—

Recent work has been confined principally to the exploration of the sheared zone encountered on the north crosscut. A winze was sunk from the 300-foot crosscut to the 675-foot horizon, and considerable drifting was done at this level. An exploratory crosscut was also driven north to the vicinity of the boundary line between the Hunton and the Teck-Hughes.

The shear zone drifted on is a heavy fracture lying mostly in greywacke in which there are narrow beds of conglomerate. It is marked by a thick seam of clay selvage or gouge, and short patches of ore occur associated with the conglomerate bands. This break, if it had more favourable wall rock, would constitute an excellent vein structure.

The property was explored to greater depth by diamond-drilling, and a long drill-hole was put out across the south claim from the 300-foot level, the core of which consisted almost entirely of sediments.

In the spring of 1928 the shaft was extended to a depth of 500 feet, and lateral work was begun to explore a favourable vein structure, in the vicinity of the shaft, which had been indicated by diamond-drilling.

Baldwin Consolidated Mines, Limited

Baldwin Consolidated Mines, Limited, was incorporated in July, 1946, and acquired property from Baldwin-Kirkland Gold Mines, Limited, Kelmec Mines, Limited, Lucky Kirkland Gold Mines, Limited, and Sylvanite Gold Mines, Limited. The main property is located in the northeast corner of Eby township; four additional claims were held in the southwest corner of Teck township in 1946.

Development by previous owners consisted of surface-trenching, some 12,000 feet of surface and underground drilling, and underground exploration from a shaft located on the north half of lot 2, concession VI, Eby township. The 2-compartment shaft was sunk 420 feet, and four levels were opened at 100-foot intervals. Some 4,000 feet of drifting and crosscutting was done, mostly on the 200- and 300-foot levels. This work covered a 500-foot length of the lava-sediments contact zone. Crosscuts were driven 340 feet north on the 2nd level and 350 feet south on the 3rd level. An ore shoot, 60 feet in length, was located on the 3rd level and stoped to a height of 45 feet. A 20-foot length of ore on the 2nd level is considered to be the upward extension of the ore shoot on the 3rd level.

The earlier developments on the property have been described by Burrows and Hopkins² and Dyer.³

After acquiring the property in 1946, Baldwin Consolidated Mines de-watered and sampled the old workings; the surface and underground geology were mapped in detail, and a series of short underground holes, totalling 1,300 feet, were drilled. A considerable part of the information given below, including the plan and section facing this page, was obtained from a report by G. L. Holbrooke, consulting geologist of the company, dated July, 1947.

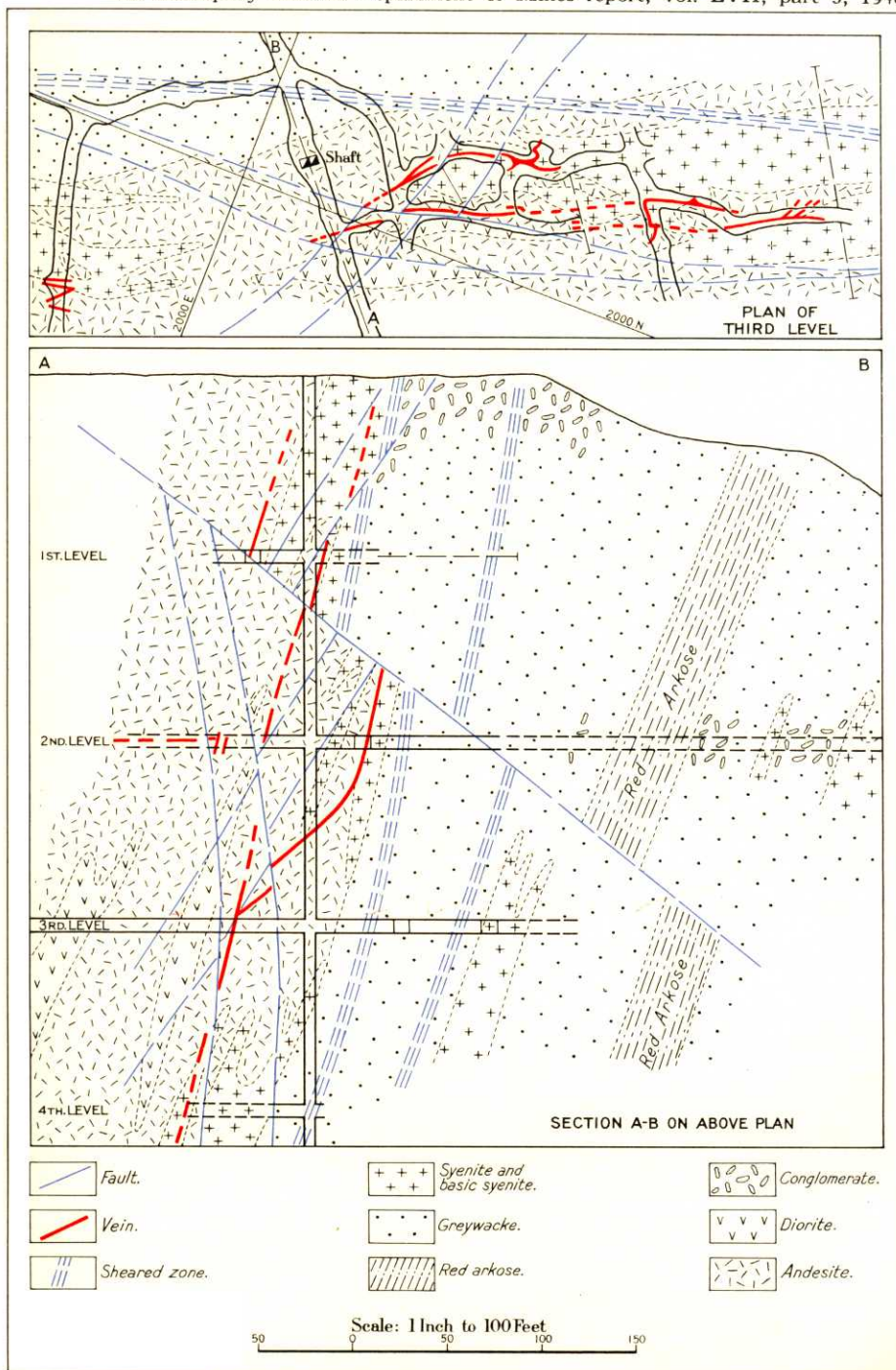
General Geology

The surface geology of the property is indicated on map No. 1946-1. Sediments of the Timiskaming series cover most of the northern part of the claims, and Keewatin volcanics and intrusive diorite lie to the south. The sediments consist mainly of interbedded conglomerate and greywacke; a band of red arkose forms a prominent marker horizon in this series. The Keewatin volcanics are

¹E. W. Todd, *op. cit.*, pp. 149-150.

²A. G. Burrows and P. E. Hopkins, *op. cit.*, p. 52.

³W. S. Dyer, *Ont. Dept. Mines, Vol. XLIV, 1935, pt. 2, pp. 52-53.*



GEOLOGICAL PLAN AND SECTION, BALDWIN CONSOLIDATED MINE.
Modified after mine plans, June, 1947

andesitic in composition and locally show poorly developed pillows. Bodies of syenite, basic syenite, and syenite porphyry are found along the lava-sediments contact zone. Underground these bodies show local alteration.

Structure

In the vicinity of the mine workings the Keewatin-Timiskaming contact has been folded to an overturned position. The Larder Lake fault may follow this contact (see Fig. 2 facing page 8), but, according to map No. 1946-1, this structure leaves the contact east of the shaft and continues along the railway cut. If this is so, the contact as found in the mine workings and westward would represent an unconformity. On the surface the lava-sediments contact is not well exposed near the shaft or to the west, but it is seen in the mine workings. Here the contact shows a medium amount of carbonatization, but the alteration is erratically distributed. As indicated on the plan and section facing page 36, a sheared zone angles across the contact, but away from this disturbance at the west end of the mine the contact is tight and unfaulted.

The north crosscut on the 2nd level would not quite reach the assumed location of the Larder Lake fault, as shown on map No. 1946-1. A few hundred feet farther north a strong fault zone underlies the Blanche river. This has been investigated by one short drill-hole and shows strong shearing, carbonatization, silicification, and mineralization; several low gold values were reported. The work of the company geologists suggested that the Larder Lake fault may underlie the Blanche river rather than follow the zone of shearing along the railway cut. Additional development work will be necessary before it can be definitely stated which of these is the main fault zone.

Different sets of sheared zones and faults cut across the rock formations on surface and underground. Certain sheared zones strike about N. 65° E. and dip very steeply. In places, these contain zones of barren quartz-carbonate stringers but are probably pre-ore structures. Two sets of late post-vein faults are shown on the mine plans. One set strikes N. 15°-35° E. and dips steeply to the southeast; these faults show displacements of less than 10 feet. This set is cut by faults striking about N. 85° E. with a fairly flat northerly dip; horizontal displacements of 100 feet or more occur along these faults. The only gold values of economic importance found on the property to date occur where the N. 20° E. set of faults cut the vein system.

Veins

According to G. L. Holbrooke,¹ there are two different ages of vein material in the mine workings. The earlier consists of numerous irregular quartz-carbonate veinlets in a sheared zone. The later veins occur as a system of narrow quartz veins trending about N. 65° E. and dipping about 70° S. This vein system has a length of about 250 feet and rakes to the east. These veins contain a small amount of pyrite and range in width from a few inches to more than 2 feet. In detail the veins tend to roll and branch in both plan and section. It is in the principal vein of this system, where the N. 20° E. fracturing and faulting is prominent, that the best gold values are found. Native gold is seen in the stopes on the 2nd and 3rd levels. In addition, there is a set of small, poorly developed cross-veins that show a general north-south trend.

Black Gold Mines, Limited

Black Gold Mines, Limited, owns a group of six claims in Teck township

¹Private report.

located in the eastern part of the town of Kirkland Lake. These lie immediately south of the properties of Wright-Hargreaves Mines, Limited, and Toburn Gold Mines, Limited. Part of the property of the company has been subdivided for residential purposes. Much of the following information has been abstracted from private reports by Harold Hopkins in 1934 and J. A. Baker in 1937.

The rocks on the claims consist of greywacke, tuff, and conglomerate of the Timiskaming series, intruded by bodies of Algomian syenite porphyry.¹ The Murdock Creek fault strikes across the property in a northeasterly direction and dips to the northwest. The fault is indicated by a topographical depression and the variation in character and strike of the strata adjacent to it.

Work has been largely confined to claim L. 2,728. In the northern part of this claim three parallel veins are found within a width of 180 feet. These veins are numbered 1, 2, and 3 from north to south; they dip to the south. The wall rock at the surface is conglomerate, but drilling shows that No. 1 vein passes into a wide porphyry dike and that No. 3 vein lies close to another narrow porphyry dike.

About the year 1917, a shaft was sunk 125 feet on No. 1 vein and about 40 feet of drifting was done. No. 2 vein, 125 feet to the south, was opened up on the surface for a distance of about 320 feet. It is reported that visible gold could be seen on the outcrop of the vein. In 1932, No. 1 drill-hole was put down to section the claim from south to north and revealed gold values in Nos. 1 and 2 veins. In 1935, a crosscut was driven from the shaft to No. 2 vein and about 340 feet of drifting was done on the 125-foot level. The vein was followed for 200 feet east of the crosscut and 95 feet west of it. It contained gold values over an average width of about 6 inches. The vein material consists of fractured quartz stringers carrying auriferous pyrite. According to Hopkins,¹ the values are consistent over the exposed length of the vein, but when calculated to a mining width of 3 feet the average grade is quite low.

A total of 13 drill-holes has been put down to search for the possible extension of the veins in the shaft area and to investigate the Murdock Creek fault. Most of this drilling was done in 1937. No. 2 vein has been intersected in holes Nos. 1, 3, and 8, giving it a known over-all length of about 550 feet; this includes the exposure in the mine workings. In No. 8 hole, an 8-inch core length assayed 0.6 ounces gold per ton. This intersection would be about 50 feet east of the east end of the drift on the 125-foot level. Holes Nos. 9 and 10, which were drilled at 125-foot intervals to the east, failed to show vein material.

The Murdock Creek fault was cut in holes Nos. 1, 6, 7, 12, and 13. Hole No. 12 intersected the fault at a vertical depth of about 1,000 feet. According to the intersection of the fault in holes Nos. 1, 6, and 12, the dip of the Murdock Creek fault would be about 75° N. W. In hole No. 1 the fault was indicated by a 39-foot width of broken rock replaced by quartz and calcite; 8.5 feet of the core in the fault zone assayed \$2.65 per ton in gold. Similar widths of broken material and low gold assays were obtained in holes Nos. 6 and 7. Work on the property did not definitely determine whether the Murdock Creek fault is pre- or post-ore. In holes Nos. 7, 9, and 10, there are indications of other faults lying on the northwest side of the Murdock Creek fault.

Burtho Gold Mines, Limited

In 1947, Burtho Gold Mines, Limited, acquired the land on lots 6 and 7, concession VI, Eby township, and a number of water claims to the north in

¹Harold Hopkins, private report.

Kenogami lake. Eight diamond-drill holes, comprising 5,066 feet, were put down to test the ground in the vicinity of the fault zones that cross the property. Two fault zones striking north of east were encountered. These are shown on map No. 1946-1.

The most northerly sheared zone, which may be the Larder Lake fault, was cut in four holes, spaced at intervals over a 4,300-foot length. From 500 to 600 feet to the south a parallel fault and the adjoining porphyry and carbonate rock were probed by two holes. The fault zones were marked by shearing, brecciation, carbonatization, local mud seams, and some quartz veins and stringers. No gold values were obtained in the drilling programme.

Campbell Claims (Four Nations Consolidated Gold Mines, Limited)

In 1944, A. E. Campbell, of Stratford, Ont., owned a group of seven claims located west of Kenogami Lake Station in Grenfell township. These formerly belonged to the Four Nations Consolidated Gold Mines, Limited, but the company was adjudged to be bankrupt in 1935. Prior to 1933 a shaft was sunk to 500 feet on claim L. 14,821. Levels were opened at 125, 250, 375, and 500 feet, and considerable lateral work was done. Operations were resumed in November, 1933, and continued until November, 1934. During this time 1,065 feet of drifting and 1,451 feet of crosscutting were done.¹

The northern part of the property, including the mine workings, is underlain by interbanded diorite and basic volcanics of the Keewatin series. South of the shaft the relatively flat-lying sediments of the Cobalt series cover the older rock formations. A sheared zone near the Blanche river on claim L. 8,239 strikes towards the shaft but seems to be too far north to line up with the sheared zone found underground south of the shaft on the 500-foot level unless there is some folding or faulting between the two points.

The following information on the underground development is taken from the mine plans of the company and field notes of M. E. Hurst, Provincial Geologist of the Ontario Department of Mines, who examined the property in August, 1934.

In the vicinity of the shaft the veins strike N. 55°-60° E. and dip 65°-75° S. Here the country rock is basic lava with horizons of porphyritic lava, especially at the east end of the workings. Narrow dikes of felsite and pyroxenite cut the volcanics.

According to the mine plans, about 215 feet of drifting and 215 feet of crosscutting were done on the 125-foot level. Gold-bearing vein material is indicated on the plans in the crosscut about 60 feet southeast of the shaft. On the 250-foot level, No. 1 vein lies about 30 feet north of the shaft. According to Hurst, it consists of a 4-foot width of quartz veinlets and pyritized wall rock, the quartz being from 1 to 2 feet in width and very sparsely mineralized. The vein contains inclusions of pyritized greenstone in the quartz. An incomplete plan of this vein shows practically all assays to be less than 0.11 ounces per ton in gold across drift width. At 50 feet and 160 feet south of the shaft, short drifts were driven on low-grade vein material.

On the 375-foot level, the probable downward extension of No. 1 vein was followed for about 180 feet. According to the level plan, the vein may swing to the south at the west end of the workings. Scattered assays of medium grade over widths ranging from 10 to 43 inches are indicated along the drift.

¹*Ont. Dept. Mines, Vol. XLIV, 1935, pt. 1, pp. 94-95.*

Most of the underground exploration was done on the 500-foot level. A crosscut was driven 615 feet southeast from the shaft, and a little drifting was done at a number of different points along it. The bulk of the exploration was concentrated along a sheared zone lying about 250 feet southeast of the shaft. This strikes about N.70° E. and dips steeply to the south. More than 470 feet of drifting was done near the footwall of the sheared zone, and short crosscuts were driven across it at intervals. According to Hurst, the sheared zone is from 30 to 40 feet in width and contains some white quartz stringers, but values are generally low.

A long crosscut was driven north on the 500-foot level for the purpose of intersecting the possible downward extension of veins that outcrop on the north side of the Blanche river. Vein No. 554 was intersected at about 425 feet north of the shaft and explored by drifting for more than 300 feet. This vein consists of white quartz stringers and pyritized wall rock. The mine plans show a few assays of medium grade on this vein near the main crosscut. Some 230 feet north of vein No. 554, the so-called "Allen vein" was cut. This strikes N.36° W., which roughly corresponds to the strike of a vein that outcrops just north of the river. Underground it consists of quartz stringers and vein breccia with low gold values. Immediately northwest of the Allen vein a northwestward-striking fault was found. According to Hurst, this showed from 4 to 5 feet of gouged greenstone with soapstone adjacent to it. The crosscut was continued in a northwesterly direction in the hope of intersecting the downward extension of Nos. 2, 3, and 3a veins, which outcrop in the northern part of claim L. 7,937. Mine plans show that the crosscut was driven at least 450 feet beyond the fault in barren ground.

Casakirk Gold Mines, Limited

Casakirk Gold Mines, Limited, was organized in 1936 to consolidate a group of claims in the central part of Teck township located northwest of the property of Macassa Mines, Limited. In earlier operations a shaft had been sunk to a depth of 127 feet on claim L. 1,429. In 1940, Macassa Mines, Limited, in association with Hollinger Consolidated Gold Mines, Limited, undertook to drive a crosscut into the property from the 3,000-foot level of the Macassa mine (see sheet D in map case). The crosscut was driven 721 feet into Casakirk ground, but no ore bodies were located, although a gold-bearing vein was intersected about 50 feet north of the Macassa-Casakirk boundary. This was investigated by drifting.

The geology of the Casakirk claims is indicated on map No. 1945-1. The northern claims are underlain by massive diorite and gabbro and a small amount of greenstone. South of the basic intrusives there are horizons of tuffs and conglomerate followed by an irregular-shaped mass of syenite porphyry, basic syenite, and intermingled sediments and tuffs. In the general vicinity of the railway some veins and shear zones have been located by surface prospecting. There is also some shearing immediately north of the old shaft on claim L. 1,429.

Federal Kirkland Mining Company, Limited

The Federal Kirkland Mining Company, Limited, was organized in 1927 and took over claims of Kirkland Combined Mines, Limited, and Kirkland Federal Mines, Limited. The property consists of ten claims in Teck and Lebel townships; these adjoin the Sylvanite and Toburn mines on the north. The company sank a shaft on claim L. 6,527 to a depth of 740 feet and carried on

lateral work at the 200-, 550-, and 700-foot horizons. In December, 1938, the company made an agreement with Toburn Gold Mines, Limited, and Kirkland Combined Mines, Limited, for the purpose of carrying on further exploration. A crosscut was run from the 1,100-foot level of the Toburn mine and entered the Federal Kirkland property on claim L. 2,229. Later, a crosscut was driven northwestward from the 2,475-foot level of the Toburn mine, and at the end of 1944 this had penetrated 251 feet into Federal Kirkland ground.

Basic syenite and lamprophyre cover much of Federal Kirkland ground. A band of syenite porphyry about 500 feet in width crosses the property in an east-west direction. Patches of sediments and tuffs occur around the intrusive bodies.

Developments on the property up to 1928 are described by Todd¹ as follows:—

The two-compartment shaft, which was sunk to a depth of 200 feet by the Federal Kirkland company has been enlarged to three compartments and carried to a depth of 735 feet. Lateral work has been done on the 200-foot level and is progressing on the 700-foot horizon.

The shaft is adjacent to a vein on which considerable trenching was done on the surface. This vein is a structure showing some displacement and dips vertically for 70 feet, below which it is inclined towards the south, showing on the 200-foot level 25 feet from the shaft. There is 200 feet of drifting, mostly to the west of the shaft, and some crosscutting on this level, where the vein dips 60°S. and is bounded on the north by porphyry and on the south by lamprophyre. Some small masses of red tuff occur near the west end of the drift. On the 700-foot level this vein is reached by a crosscut about 80 feet long, which passed through another unimportant southward-dipping fracture.

Florena Gold Mines, Limited

In 1943, Florena Gold Mines, Limited, owned a group of fourteen claims located in the southeastern part of Teck township about 1 1/4 miles south of the town of Kirkland Lake. The property was formerly owned by Highland-Kirkland Mines, Limited. The older company carried out a programme of surface exploration and 3,200 feet of diamond-drilling. On claim L. 16,555 an inclined shaft was sunk to a depth of 100 feet, and 60 feet of crosscutting was done at that level. In 1936 and 1937, Florena Gold Mines had a geophysical survey made of the property, and 7 drill-holes, aggregating 7,860 feet, were put down.

The south boundary of the Timiskaming series extends for about 1 3/4 miles near the north boundary of the property. The southern part of the property is underlain by syenite and hybrid varieties of the Algoman intrusives with a few small remnants of Keewatin lavas. On the eastern claims there are numerous exposures of carbonate rocks with quartz stockworks. To the west these carbonates are partially cut out by the later syenitic intrusives. The carbonates are believed to be localized along an ancient sheared and faulted zone that can be traced for long distances across the Kirkland Lake-Larder Lake country and is called the Larder Lake fault (see Fig. 2 facing page 8). This sheared zone has probably been offset about 600 feet by cross-faulting along Murdock creek. West of the creek it may follow a marked topographical depression along the sediments-syenite contact. Carbonate rock is found on the dump at the old Highland-Kirkland shaft on the south side of this narrow valley.

M. T. Barney, manager for Highland-Kirkland Mines, reported assays of a few dollars per ton in gold from a number of veins on the property.² He also stated³ that values up to \$5.50 [0.15 ounces] per ton in gold were encountered in the crosscut at the Highland-Kirkland shaft and that a 30-foot width of low-

¹E. W. Todd, *op. cit.*, p. 151.

²A. G. Burrows and P. E. Hopkins, *Ont. Dept. Mines, op. cit.*, p. 51.

³M. T. Barney, *private report*.

grade vein matter was exposed. A few encouraging assays and several sections carrying low-grade values were reported from the earlier drilling. The drilling in 1936 and 1937, however, is reported to have revealed only values up to 0.06 ounces per ton in gold.

Goldbanks Mines, Limited

The property of Goldbanks Mines, Limited, consists of nine claims located in the western part of Teck township. Most of the development has been concentrated along a zone of shearing and porphyry intrusives trending north of east across claim L. 1,218 and the southeastern part of claim L. 24,284. This development consists of surface trenches, diamond-drilling, and two shafts. No. 1 shaft is 73 feet deep; about 200 feet of drifting and crosscutting has been done from the 60-foot level. No. 2 shaft is 45 feet deep.

The northern claims of the property are underlain by Keewatin volcanics. Timiskaming sediments and tuffs, intruded by syenite porphyry, lamprophyre, and diabase, occur on the southern claims.

Some shearing occurs adjacent to the porphyry in No. 1 and No. 2 shaft areas, and mineralized vein material occurs locally. Gold values are reported by the company from a number of places along this zone.

Hudson-Rand Gold Mines, Limited (Kirkland Gold Rand, Limited)

History and Development

Hudson-Rand Gold Mines, Limited, was incorporated in 1944 and acquired the property of Kirkland Gold Rand, Limited, in Teck township. Kirkland Gold Rand, Limited, was organized in 1931 and succeeded Kirkland-Premier Mines, Limited. In 1947, the property consisted of nine claims, totalling 315 acres, located in the southeastern part of the town of Kirkland Lake. Part of the ground was developed in the early days of the camp by Ontario Kirkland Gold Mines, Limited, and later by Montreal Ontario Mines, Limited, and Kirkland Rand, Limited. Ontario Kirkland Gold Mines deepened an old shaft on claim L. 2,679 to a depth of 450 feet and did lateral work on three levels. A 100-ton mill was erected on the property, and bullion valued at \$10,082 was produced in 1922 from 6,496 tons of ore milled.¹

When underground operations ceased at the Kirkland Gold Rand property in December, 1937, five levels had been opened to a depth of 800 feet, and 900 feet east of the main shaft a winze had been sunk to a depth of 636 feet below the 800-foot level; stations were cut in the winze at 125-foot intervals to the 1,425-foot level. In all, a total of 14,350 feet of lateral work and some 11,613 feet of underground diamond-drilling was done.

The mine was reopened by Hudson-Rand Gold Mines in September, 1946, and operations continued until the mine closed down in May, 1947. Some 1,399 feet of lateral work was done in this period. The 675- and 800-foot levels were resampled.

General Geology

The rocks on the northern part of the property consist of sediments and tuffs intruded by irregular-shaped bodies of syenite porphyry. The southern section is underlain by basic volcanics, tuffs, sediments, and carbonates, intruded by syenite and syenite porphyry.

¹*Ont. Dept. Mines, Vol. LVII, 1948, pt. 1, Table II in pocket.*

A number of faults, striking N. 55°–65° E., are believed to cross the property. The Murdock Creek fault zone is assumed to pass through the northwestern claims, and to the south are the assumed extensions of the North, Middle, and South Harvey faults. Todd¹ states that "a major eastward-trending fault showing in the upper workings dips at about 55° S. and lies beyond the workings on the 800-foot level."

The veins are 4,500 feet south of those being mined by the large Kirkland Lake producers. The strike of the veins in the porphyry and along inclusions of sediments is N. 87° E.; they dip from 75° N. to vertical. Veins in the sediments to the west of the intrusives strike N. 67° E. and dip 55° S. The veins have a small amount of quartz and fine-grained metallic minerals. The gold appears to be associated with pyrite and chalcopyrite; native gold is rarely seen. Cross-faults, which are known to occur in the Wright-Hargreaves and Sylvanite mines, apparently continue southward through the Kirkland Gold Rand claims. A published plan of the 300-foot level shows a cross-fault about 50 feet east of the shaft.²

Mine Geology

The rocks within the area of the mine workings consist of Timiskaming sediments intruded by syenite porphyry. Most of the gold-bearing zones found to date are in the syenite porphyry. In the annual report of the company for 1937, Chas. Spearman, consulting engineer, stated that diamond-drilling to a depth of 1,750 feet shows that the porphyry body may be more extensive at this horizon than in the mine workings.

According to Burrows and Hopkins,³ the ore on the 450-foot level consists of "fractured red feldspar porphyry with numerous quartz veinlets and much coarse-grained copper pyrites and smaller quantities of iron pyrites, molybdenite, and gold." Todd⁴ states:—

The ore produced by the Ontario Kirkland occurred in a shoot 60 feet long on the 150- and 300-foot levels, the vein being narrow, and the wall rock consisting of greywacke.

Ore Developments

The following statement of ore developments is taken from the annual report of the company, dated February 6, 1947, and prepared by E. J. Lees, mine manager:—

Ore has been opened up in the mine on seven veins. More extensive work may show some of these to be separate parts of a smaller number of veins.

Drifting by Hudson-Rand has opened up the following new ore lengths:—

Level	Vein	Length	Width	Ounces per ton
		feet	inches	
675-foot.....	No. 2.....	23	24	0.24
		90	27	.27
		35	22	.33
		133	57	.18
800-foot.....	No. 2.....	30	21	.16
		90	28	.33
	882.....	32	28	.31

The total ore opened up is 281 feet on the 675-foot level and 324 feet on the 800-foot level (including 172 feet developed by the former company) of an average width of 35 inches and grade

¹E. W. Todd, *op. cit.*, p. 152,

²A. G. Burrows and P. E. Hopkins, *op. cit.*, p. 49.

³*Ibid.*, p. 48.

⁴E. W. Todd, *op. cit.*, p. 151.

of 0.26 ounces (\$9.00) gold per ton. Comparable amounts of ore on levels above have been opened up by drifting by predecessor companies.

None of this ore has been raised on, so that no ore has definitely been blocked out. Assuming an expected continuity of ore between levels, a minimum stoping width of 36 inches and a dilution of 15 per cent., there is room to expect about 45,000 tons at \$8.00 grade, with gold valued at \$35.00 per ounce, could be mined. It must be reiterated that this estimate is only an expectation and that the ore has not been proved up by raising.

In addition to the sections of ore indicated by drifting, other veins have been indicated by diamond-drilling, and these will be further investigated. A diamond-drill hole from the 800-foot level intersected 105 inches, averaging 0.31 ounces, at 900 feet below that level, or a total of 1,700 feet below the surface.

A crosscut from Lake Shore Mines on the 4,450-foot level traverses the Kirkland-Hudson Bay property to within 640 feet of the common boundary with the Hudson-Rand property. A flat diamond-drill hole from the face of this crosscut intersected 18 inches, assaying 0.23 ounces, at the Hudson-Rand boundary.

Iroquois-Kirkland Mines Corporation, Limited

The Iroquois-Kirkland Mines Corporation, Limited, owns three claims in Teck township located near the northeast shore of Kirkland lake. Development consists of surface work and a small amount of diamond-drilling.

From north to south across the property the rocks consist of intrusive diorite, pillowed lavas, and conglomerate. Syenite porphyry occurs in the extreme southeast corner of claim L. 2,255. Zones of schisting occur in the conglomerate.

On the northern part of claim L. 2,255 a pit, 25 feet deep, has been sunk on a north-south trending vein that carries some mineralization.

In 1934, a drill-hole was put down to section the porphyry and conglomerate in the southern part of claim L. 2,255.

No gold values of commercial interest have been reported from exploration on the property.

Kirana Kirkland Gold Mines, Limited

Kirana Kirkland Gold Mines, Limited, holds some claims in the northeastern part of Teck township. On claim L. 1,571 there is an old shaft that was sunk to the 300-foot level by La Belle Kirkland Mines, Limited, in 1916. The showing has been described by Burrows and Hopkins as follows:¹—

The ore deposit occurs along the contact of quartz porphyry and basalt. The porphyry lies to the north, and forms the hanging wall of the deposit, which occurs in the altered basalt. The shaft, which includes 60° N. for 80 feet, and 70° N. below this level, is on the dip of the ore body, which is also approximately the angle of contact of the porphyry and basalt. The basalt near the contact is greatly altered to a greyish rock high in silica, calcite and other carbonates... In this altered basalt area there are streaks or bands of blackish material which form the higher grade portion of the deposit. These streaks contain films of molybdenite, to which the dark colour is due, and abundant iron pyrite, quartz and calcite, while visible gold is occasionally seen. A dark band near the foot wall was persistent in the shaft, while other bands towards the hanging wall are more lenticular, but have similar characteristics to the foot-wall streak. The silicified material between the streaks or bands carries low values in gold, but the values obtained in the high-grade streaks, which vary from a part of an inch to a foot in width, have indicated that the deposit is workable over a considerable width. The management is at present continuing the sinking of the shaft and drifting and crosscutting at several levels to determine the size of the ore body.

The narrow high-grade streaks or bands are reported to carry from \$20 to \$150 per ton in gold, while a probable value of from \$15 to \$18 per ton is given for a width of 7 feet to 10 feet, for some of the ore.

The deposit is evidently a replacement of the basalt near the contact with the porphyry. There is no evidence of the filling of open fissures with milky white quartz. Slickensides surfaces in the material of the streaks indicate some faulting along the dip of the deposit.

¹ A. G. Burrows and P. E. Hopkins, "Goodfish Lake Gold Area," *Ont. Bur. Mines, Vol. XXV, 1916, pt. 1, p. 262.*

Kirkland Basin Gold Mines, Limited

Kirkland Basin Gold Mines, Limited, owns a group of claims in Teck township adjoining the property of Lake Shore Mines on the north; most of the property underlies Kirkland lake. In 1938, Lake Shore Mines took an option to purchase the property and agreed to drive a crosscut through the property from the 3,075-foot level of the Lake Shore mine. This crosscut is shown on sheet D (in map case).

The following statement on results obtained is taken from the annual report of Lake Shore Mines for the year ending June 30, 1940:—

Total advances made on the property to date are as follows:—

	Feet
Crosscutting	2,402
Drifting	712
Diamond-drilling	12,049

The work exposed a number of gold-bearing fractures, but the values encountered were erratic and no payable ore was developed. It is considered that the property has been well tested at the 3,075-foot horizon and that additional work is not warranted by the results secured.

Kirkland Gateway Gold Mines, Limited

The property of Kirkland Gateway Gold Mines, Limited, consists of eleven claims in the southwestern part of Teck township located in the vicinity of Elsie lake about a mile west of the Macassa mine. In 1937 and 1938, the claims were explored by surface work and diamond-drilling. Twenty-seven holes, aggregating 15,281 feet, were completed. This work showed that a fault, believed to be the westerly continuation of the main Kirkland Lake break extends across the property. Some low gold values were obtained in a portion of the structure investigated.

The rocks on the property consist principally of Timiskaming tuff, grey-wacke, and conglomerate, intruded in places by narrow dikes of syenite porphyry, basic syenite, and lamprophyre. On the northern claims the outcrops are predominantly jasper-bearing conglomerate. The contact between the conglomerate and the volcanic tuff to the south is indistinct owing to interbanding of the two rock types in the transition zone. Several syenite porphyry dikes, ranging from 10 to 90 feet in width, intrude the sediments. These dikes are approximately parallel and strike about N. 60° E. with an average dip to the south of about 60 degrees. Dikes of basic syenite and lamprophyre have approximately the same strike and dip as the porphyry.

The most interesting structural feature of the property is the fault zone traced across claim L. 6,822. This probably extends to and beyond the west boundary of the property. It appears to be the continuation of the main Kirkland Lake break on the west side of the Amikougami Creek fault. The fault strikes north of east and dips about 80° S. It has been traced across the property by the topography, geology, and shearing. The fault is exposed on an outcrop on claim L. 6,822 and contains sparsely mineralized quartz in a brecciated porphyry. According to B. M. Arnott, engineer in charge of drilling operations in 1938, the fault zone was cut in 18 holes. It is marked by strong shearing and alteration and in some cases by a pronounced mud seam. One hole cut the structure at a vertical depth of 1,250 feet. On claim L. 6,822, the fault has displaced a porphyry dike. Throughout most of the drilled area sediments occur on both walls of the fault but sometimes are of different composition.

Five drill-holes (Nos. 12, 21, 23, 24, and 26) cut fine-grained pyrite mineralization and veining in the fault zone. The mineralization occurs in altered

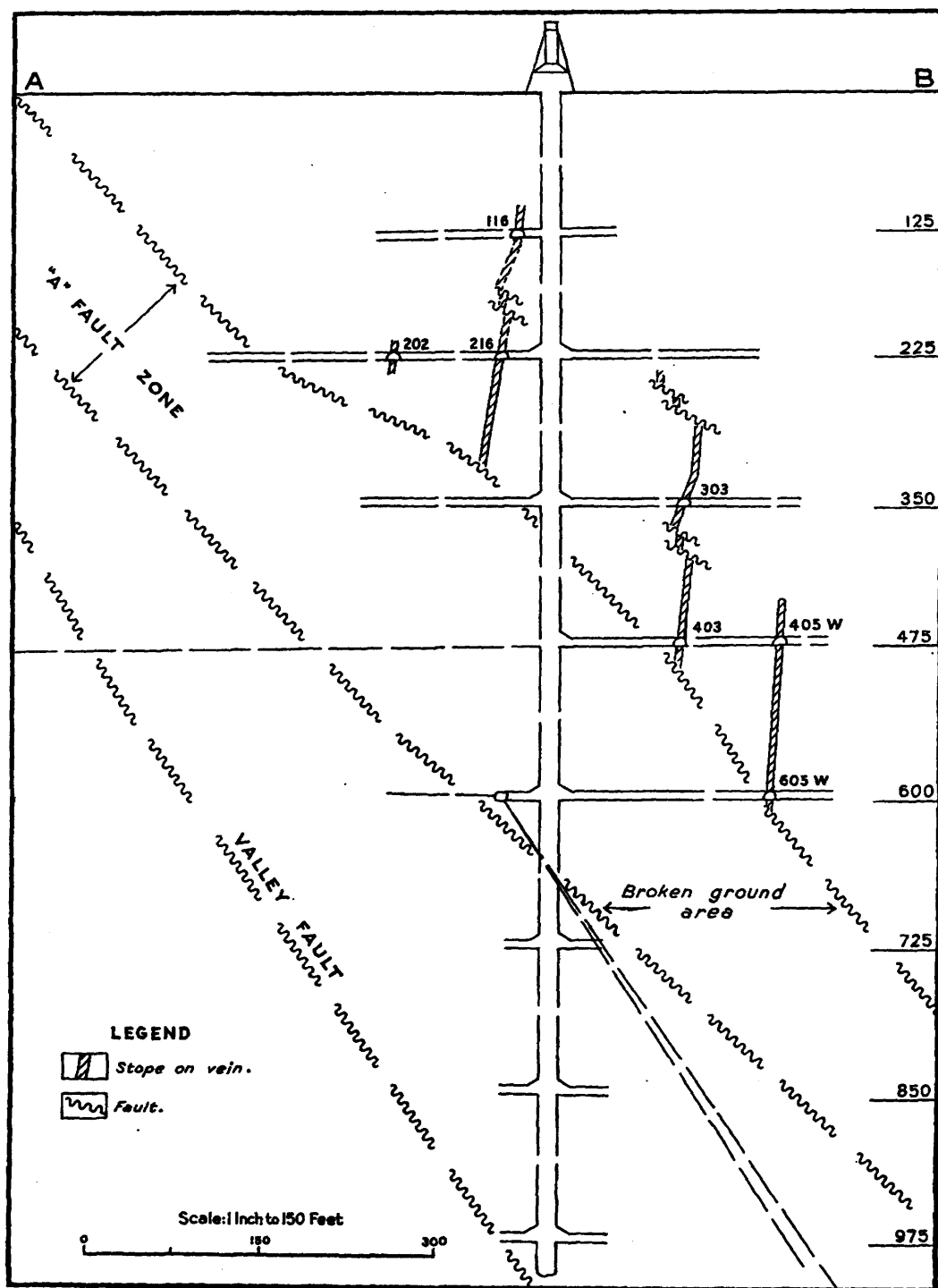
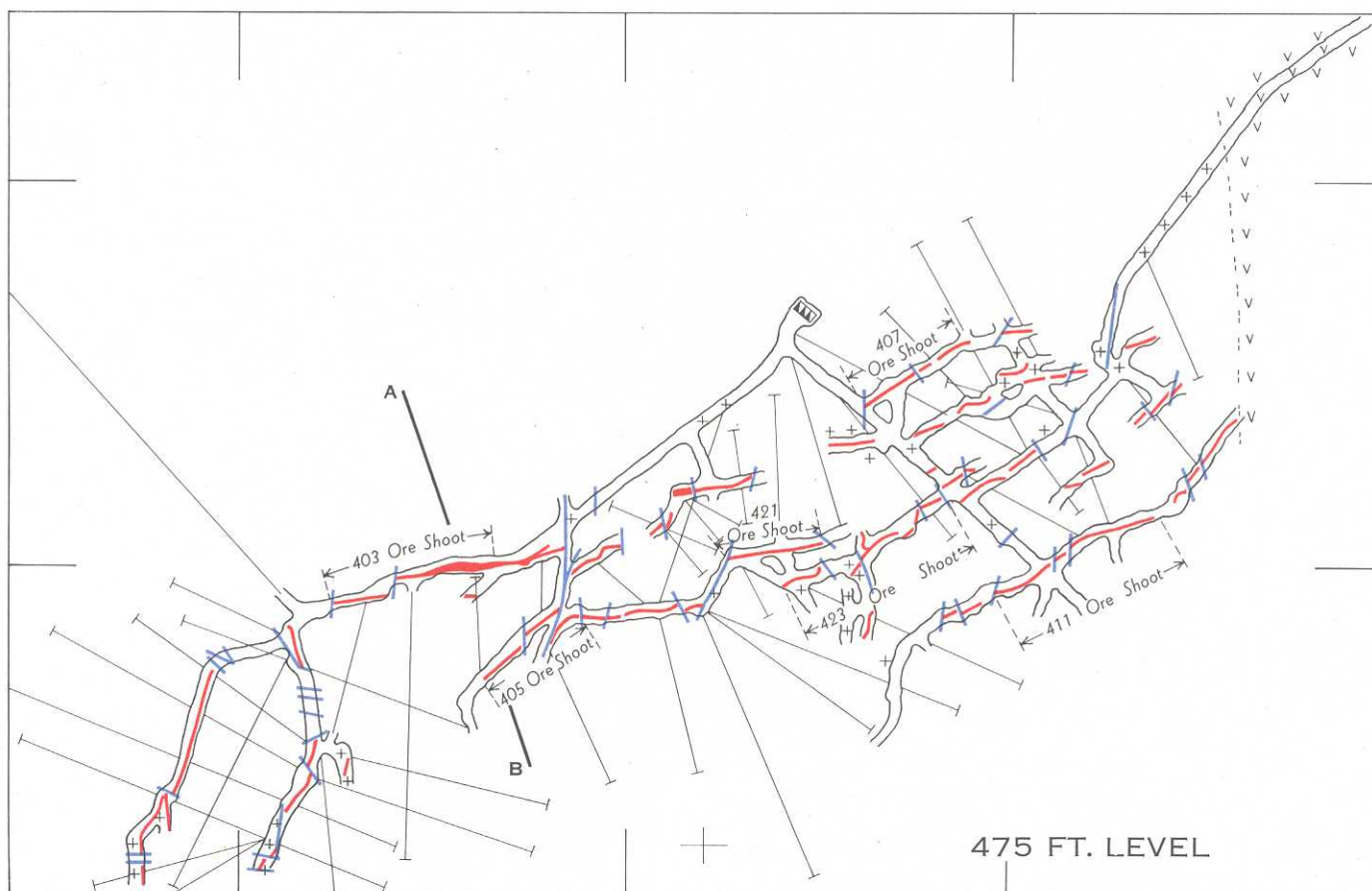
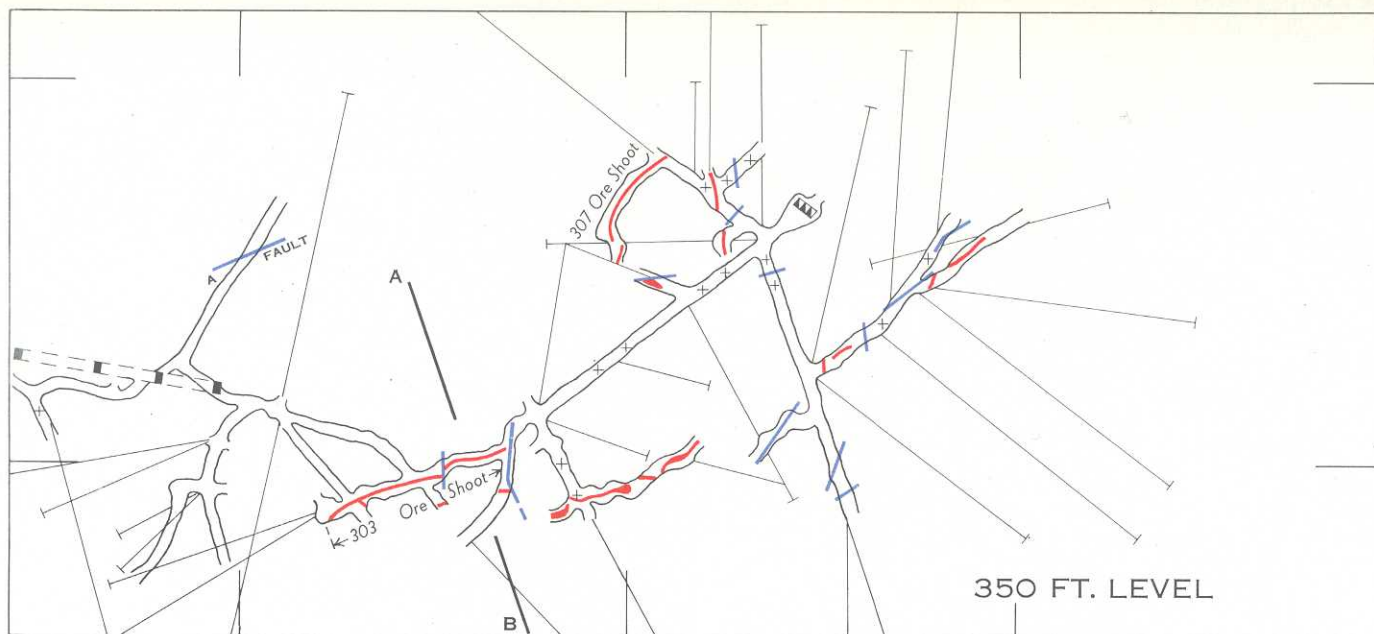


FIG. 4--VERTICAL SECTION THROUGH THE KIRKLAND GOLDEN GATE MINE.
(After mine plans, 1944.)



v v v
v v v Diabase

— Fault

+ + +
+ + + Syenite porphyry and syenite

Basic lava

— Quartz vein

Scale, 1 Inch to 150 Feet

150 75 0 150 300

Modified after Mine Plans, June, 1944.

GEOLOGICAL PLANS OF THE 350- AND 475-FT. LEVELS, KIRKLAND GOLDEN GATE MINE.

conglomerate in association with quartz and carbonate stringers. Gold values in this material are reported to range from 0.04 ounces per ton in gold over 3.5 feet of core in hole No. 26 to 0.14 ounces per ton over 1.2 feet in hole No. 23. When these intersections are plotted on a longitudinal section of the break, they indicate the possibility of a mineralized gold-bearing zone plunging westward and having a length of from 250 to 300 feet. Low gold values over narrow widths were intersected in holes Nos. 1 and 2.

Kirkland Golden Gate Mines, Limited

History and Development

Kirkland Golden Gate Mines, Limited, took over the assets of the Golden Gate Mining Company, Limited, in 1947. In 1945, the Golden Gate Mining Company owned a group of 23 claims in Teck and Otto townships adjacent to Swastika township. The original property of the company was acquired from the Kirkland Gateway Gold Mines, Limited, which had worked the old Lucky Cross mine (claim T. 2,692), where gold had been found as early as 1910. In 1913, bullion valued at \$14,006 was produced from 2,500 tons of ore milled.¹ The Golden Gate Mining Company developed the main workings on claims T. 2,692 and 2,696 to a depth of 1,000 feet. A 150-ton mill was erected and commenced production in May, 1938. It operated at from 60 to 70 tons daily until the middle of 1942. In June, 1940, the company acquired the neighbouring property of Crescent Kirkland Gold Mines, Limited, where underground workings had previously been opened to a depth of 400 feet in the old Swastika mine (claim L. 9,592 in Otto township). In 1911 and 1913, the Swastika mine produced bullion valued at \$11,172 from 2,160 tons of ore milled.² A small amount of ore was milled from the Crescent Kirkland section in 1941 and 1942. The mine was closed down in May, 1942. Total production from the combined properties by the company and previous operators to that date amounted to \$1,001,920 from 83,195 tons milled. From 1943 to 1945 a large amount of surface diamond-drilling was done on the Crescent Kirkland section of the property. Late in 1945 the Crescent shaft was dewatered and underground work was resumed. The shaft was deepened to 663 feet and lateral work was done on the 525- and 650-foot levels. Both these levels were driven eastward to develop veins that lie beneath the ground near the dance hall in Culver Park. Development work was carried on until April, 1949, when the mine was closed.

General Geology

The rocks on the property consist of Keewatin volcanics, Timiskaming sediments and tuffs, carbonates, various types of acid intrusives, and later diabase and lamprophyre dikes. The acid intrusives generally occur as small irregular-shaped bodies and have the composition of syenite, syenite porphyry, and basic syenite.

The rock formations on the property have been considerably disturbed by faulting movements. At least four faults are known to extend across the property, and innumerable weaker faults have been found in underground operations. In the northern part of the property a strong sheared zone with siliceous carbonate alteration occurs at or near the Timiskaming-Keewatin contact. This is the continuation of the Larder Lake fault west of the Amikougami Creek cross-fault (see Fig. 2 facing page 8). As it follows the southwestward-trending

¹Ont. Dept. Mines, Vol. LVII, 1948, pt. 1, Table II in pocket.

²Ont. Dept. Mines, Vol. XLIX, 1940, pt. 1, table facing p. 14.

portion of Amikougami creek and dips about 60° S. E., it approaches the underground workings of the Golden Gate mine, where it is called the "valley fault" (see Fig. 4). Green carbonates occur along this fault zone. Green carbonates again occur in the lava-sediments contact zone immediately north of highway No. 11 just west of Swastika. This is the continuation of the fault west of the intrusive body of porphyry in Swastika townsite.

The A fault at the Golden Gate mine is a wide zone of broken ground, on which there has been post-ore movement (see Fig. 4). On map No. 1945-1 it is assumed to bend southward and pass through the Crescent Kirkland mine workings, but there has not been sufficient drilling to date to prove the continuity of the faulting.

An east-west fault zone lies along the creek that flows from Vigrass to Otto lake. Diamond-drilling in this vicinity has intersected the fault and indicates that it dips to the south.

The Amikougami Creek cross-fault follows a long narrow valley near the east boundary of the property.

Golden Gate Mine

Mine Geology.— Fig. 4 and the plans facing page 46 show the geology in the vicinity of the ore shoots that have been mined. The veins lie in an area where many irregular-shaped bodies of syenite porphyry intrude the basic volcanics. The veins have a general strike of about N.53° E. and dip steeply to the north. They have been cut off by the A fault, which dips to the south at about 45 degrees. This fault has also offset a diabase dike so that the hanging-wall side has moved horizontally about 450 feet to the east. The diabase dike dips almost vertically from the surface to the 475-foot level, but below this horizon it is offset by the A fault, so that on the 600-foot level it is found from 450 to 500 feet farther west. The productive veins have not been located on the foot-wall side of the A fault.

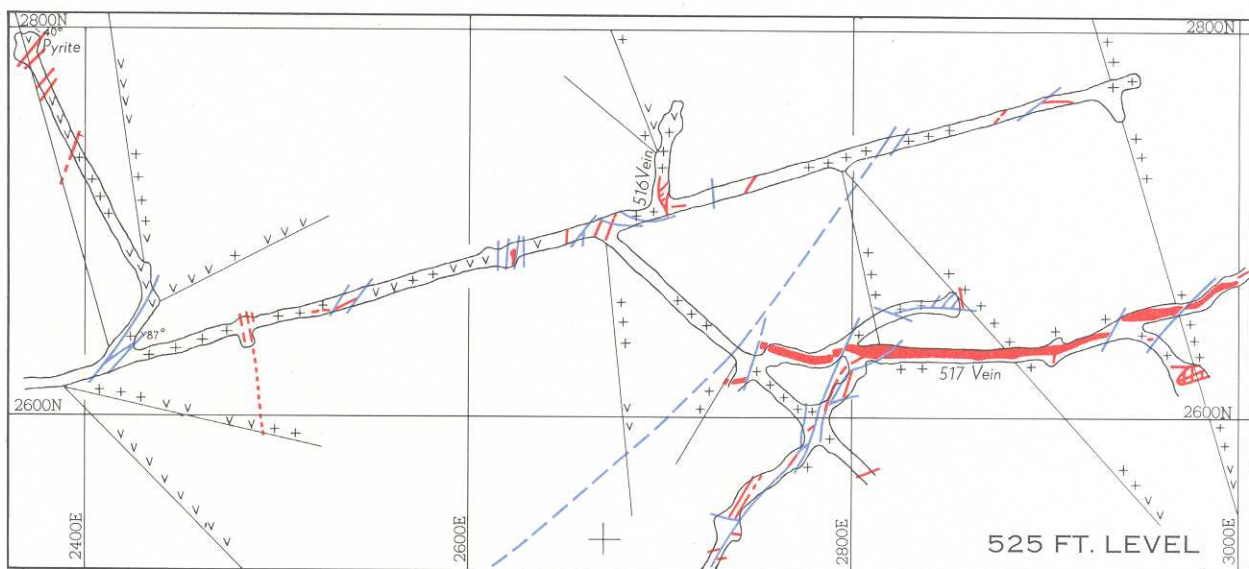
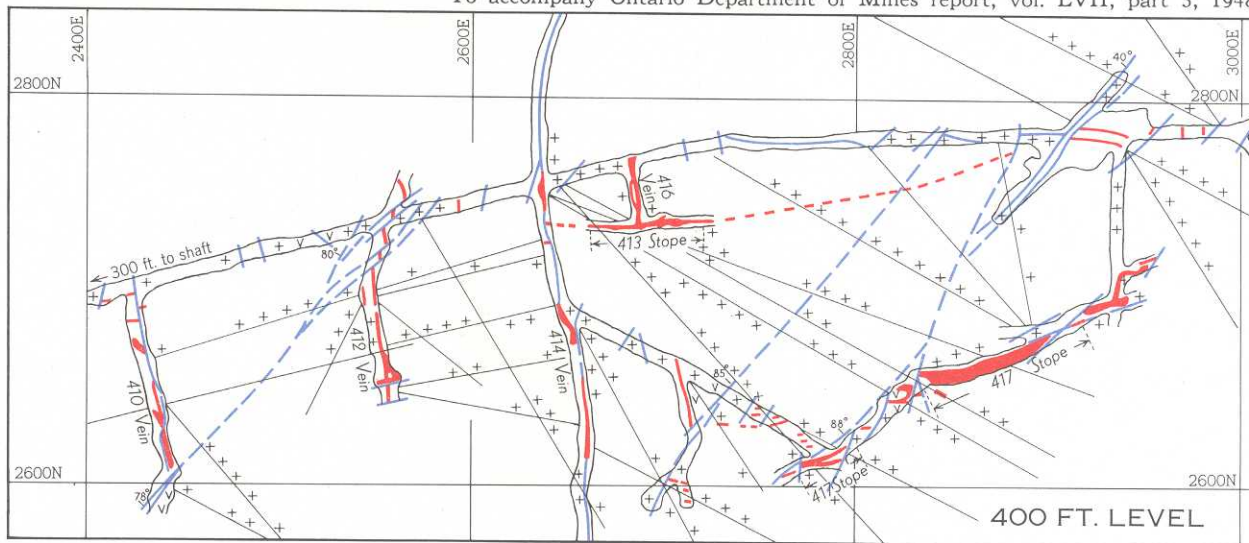
The "valley fault" strikes about parallel to the A fault but has a slightly steeper dip. Where cut by a drill-hole (No. 33) from the 600-foot level, it showed green carbonates and quartz stringers with low gold values over a core length of 43 feet. This fault zone was again intersected in the north crosscut from the 975-foot level.

The ore shoots at the mine have been found largely in certain portions of quartz veins (see insert facing page 46). The most profitable source of ore has been No. 11 vein. This was stoped to the 725-foot level, where it is cut off by the A fault.

Production, Grade, Costs, Etc.— The following information on operating results from 1939 to 1942 is taken from the annual report of S. A. Pain, manager, to the company in August, 1943.

	9 months ending Nov. 30, 1939	12 months ending Nov. 30, 1940	12 months ending Nov. 30, 1941	5 months ending April 30, 1942
Tons milled.....	18,012	25,551	23,906	8,324
Average tons per day.....	65.5	69.8	65.5	63.5
Recovery per ton.....	\$11.24	\$10.01	\$9.21	\$10.53
Operating costs per ton.....	\$8.69	\$8.38	\$9.56	\$10.22
Operating profit per ton.....	\$2.55	\$1.63	-\$0.35	\$0.31

To accompany Ontario Department of Mines report, vol. LVII, part 5, 1948



Scale: 1 Inch to 100 Feet
0 50 100 150

GEOLOGICAL PLANS OF THE 400- AND 525-FT. LEVELS, CRESCENT SECTION, KIRKLAND GOLDEN GATE MINE.
Modified after mine plans, August, 1948.

Crescent Kirkland Mine

Mine Geology.—Geological conditions at the Crescent Kirkland mine are quite similar to those at the Golden Gate mine. This similarity has led to some speculation as to whether part of the Crescent Kirkland area could represent the faulted portion of the Golden Gate mine below the A fault. If this were the case, most of the movement must have been pre-diabase because the dike has only a horizontal displacement of 450 feet.

The rocks in the mine workings consist of Keewatin lavas intruded by irregular-shaped bodies of syenite porphyry, and smaller amounts of diorite, granodiorite, and lamprophyre. Quartz veins intersect all these formations.

The geological plans facing page 48 show the vein and fault pattern in part of the underground workings on the 400- and 525-foot levels. In places there are two distinct sets of steeply dipping veins, which strike almost at right angles to one another; in addition, there are a few flat-lying veins. Different generations of quartz cut one another with very sharp contacts. The vein quartz shows a great deal of banding, brecciation, and fracturing. Most of the veins contain intermingled white and greasy quartz, but at least two veins of heavy sulphides have been found. The vein quartz is locally mineralized with pyrite and small amounts of galena and molybdenite. Visible gold occurs in places along fractures in the quartz. High gold values are found where there are heavy concentrations of fractured pyrite and galena in the veins.

No. 17 is the strongest vein and was stoped upward from the 400-foot level until cut off by a south-dipping fault. It is also found on the 525- and 650-foot levels.

The entire vein zone has been rather badly disturbed by a system of post-ore faults. Although some of these offset the veins only a short distance, they nevertheless add to the problems of development. The strongest set of faults strike northeast and have a steep dip. As there are low gold values along certain of these structures, some of the movement may have been pre-ore, or else there was some gold deposition later than that of the main veins.

Production.—Some gold was produced in 1941 from the Adit workings located south of the Crescent shaft on the shore of Otto lake. This was obtained from small, rich, flat-lying veins near the surface.

In 1947, 6,288 tons of ore from the Crescent workings were milled and bullion valued at \$42,507 was recovered.

Kirkland-Hudson Bay Gold Mines, Limited

Kirkland-Hudson Bay Gold Mines, Limited, owns a group of six claims in the eastern part of Teck township, adjoining the property of Lake Shore Mines on the south and east. A considerable part of Kirkland Lake townsite is built on the property. Between 1926 and 1928, surface-trenching and diamond-drilling revealed some veins, and two long holes were drilled into the property from the east end of the drift on the 1,000-foot level on the Lake Shore South vein. In 1933 a crosscut from the east drift on the 2,700-foot level of Lake Shore mine was extended 500 feet into Kirkland-Hudson Bay ground. About 200 feet south of the boundary a 6-foot vein was cut which gave encouraging values, but no ore shoot was developed. In 1938, a crosscut from No. 1 vein on the 4,450-foot level of the Lake Shore mine was driven to within 640 feet of the south boundary of the property and diamond-drill holes were extended the remainder of the distance (see sheet E in map case). A number of veins and breaks carrying low values were found. In 1944, Kirkland-Hudson Bay Gold Mines made an

agreement with Kirkland Gold Rand, Limited, whereby a new company, Hudson-Rand Gold Mines, Limited, was formed to develop the Kirkland Gold Rand property.¹

The rocks on the property consist of Timiskaming greywacke, conglomerate, and tuff with syenite porphyry intrusives and small patches of lamprophyre. Some of the north-south faults that generally offset the veins in the producing mines cross Kirkland-Hudson Bay ground. The Murdock Creek fault, which dips northwest and is also believed to offset the ore bodies in the Wright-Hargreaves mine, crosses the southeast corner of the property on the surface.

Kirkland Townsite Gold Mines, Limited

Kirkland Townsite Gold Mines, Limited, owns three claims located within the town of Kirkland Lake, adjoining the Wright-Hargreaves mine on the south. No work has been done on the property since 1931. In that year the shaft was enlarged from two to three compartments to a depth of 150 feet.²

Early operations on the property are described by Burrows and Hopkins³ as follows:—

During the greater part of 1924, the Anglo-Canadian Explorers, Limited, continued operations at the Townsite mine, situated at the east end of Kirkland lake. From a shaft 317 feet in depth, lateral work was done on the 150- and 300-foot levels.

A northwest-southeast crosscut 645 feet in length was run at right angles to the general trend of the formations on the 300-foot level. This cut two narrow bands of feldspar porphyry and penetrated the large mass of feldspar porphyry which extends across the Wright-Hargreaves property near the north line; short drifts were also run on vein structures from the crosscut. The most promising of these lies thirty feet south of the shaft in drift No. 304, which extends southwesterly for 120 feet in sediments. Two shallow winzes were sunk on the vein material, which contains fine-grained pyrite and shows some gold values over widths up to thirty-five inches. The structure dips 45° S. E. The rocks exposed underground are dominantly Timiskaming sediments intruded by bands of massive feldspar porphyry. Some diamond drilling was done from the surface.

Todd⁴ mentions the following later developments:—

Since this report⁵ was issued the shaft has been carried to the 675-foot level, and a long crosscut was run into the south part of the property at this horizon. A considerable amount of diamond-drilling was done from the surface and from the various underground levels. A long hole was also extended into the property from the 1,250-foot level drift in the Wright-Hargreaves mine.

As indicated on map No. 1945-1, the surface exposures on the property consist of Timiskaming greywacke cut by dikes and irregular-shaped bodies of syenite porphyry.

McIvor Gold Mines, Limited

The property of McIvor Gold Mines, Limited, consists of six claims located in the west central part of Teck township. It is crossed by the Goldthorpe road. No work has been done on the property in recent years. There is an old shaft on claim L. 2,911.

The claims are underlain by Keewatin lavas, Timiskaming sediments and tuffs, porphyry intrusives, and diabase dikes. A wide band of porphyry crosses the northern part of the property. A porphyry dike may also be continuous across the southern claims; the north contact of this dike is marked by a zone of shearing. Shearing is also in evidence at the old shaft.

¹For a description of this property, see pages 42-44.

²Ont. Dept. Mines, Vol. XLI, 1932, pt. I, p. 75.

³A. G. Burrows and P. E. Hopkins, *op. cit.*, p. 47.

⁴E. W. Todd, *op. cit.*, p. 150.

⁵The one quoted above.

Murphy Claims

The Murphy group of 13 claims is located in the southwestern part of Teck township immediately west of the Kirkland Gateway property and north of the Blanche river. The property boundaries are outlined in heavy lines on map No. 1945-1. The claims are underlain by Timiskaming sediments and tuffs, which have been intruded by basic syenite, syenite porphyry, lamprophyre, and diabase. The claims were optioned by M. J. O'Brien, Limited, in 1937 and drilled under the supervision of W. S. Dyer, geologist for the company. Twelve drill-holes, aggregating 4,559 feet, were put down along the probable west extension of the main Kirkland Lake break. No ore was found, and the option was dropped.

The drilling confirmed the geological and topographical evidence of faulting along the sediments-tuff contact on claims L. 6,863 and L. 6,842. Two holes, which sectioned the structure near the southeast corner of claim L. 6,863, indicated that the fault has a dip to the southeast of about 62 degrees, but to the west it appears to steepen. Fault gouge, ranging from half an inch to 4 inches in width, was intersected in some of the holes. The rocks adjacent to the fault are carbonated and silicified and contain quartz and calcite stringers but scarcely any mineralization. Nothing better than traces of gold was reported from drilling operations. The deepest hole cut the fault at a vertical depth of 580 feet.

Rogick-Clark Claims

In 1946, Martin Rogick, of Kirkland Lake, and Mrs. Amelia Clark, of Swastika, owned a group of 5 claims (L. 18,312, 18,837, 18,227, 8,803, and 8,950), located in lots 4 and 5, concession VI, Eby township. In 1938 a large angular piece of gold-bearing float was found on claim L. 18,227. Surface work in this vicinity resulted in the discovery of gold. Pioneer Gold Mines drilled a number of holes in an east-west direction in the vicinity of the showing and obtained a number of low gold values. In 1944, the property was optioned to Siscoe Gold Mines, Limited, and four holes were drilled in a north-south direction. Two of these were put down in Kenogami lake near the small point of land on claim L. 18,312. Nothing of interest was found.

Outcrops in the vicinity of the workings on claim L. 18,227 consist of intermingled basic volcanics and porphyry intrusives. At one point on the right-of-way of No. 11 highway the pillowed lavas strike S.35° E. and face southwest.

Sahtram Gold Mines, Limited

Sahtram Gold Mines, Limited, was incorporated in 1945 and acquired the property of the Trout Creek Gold Mining Company, Limited. The latter company was organized in 1927 to develop a group of four claims located about a mile northeast of Swastika station. In the summer of 1928 a gold discovery was made in the southwest corner of claim T. 16,477. A shaft was sunk on the showing, and about 200 feet of lateral work was done from the 76-foot level. One ton of ore, valued at \$1,662, was shipped from the property in 1931.¹ In 1945-46, Toburn Gold Mines, Limited, drilled 16 surface holes on the property without any success. Some underground drilling was also done from the 76-foot level.

The claims are underlain by Keewatin volcanics, Timiskaming sediments and tuffs, and two main types of intrusives, augite porphyrite and syenite porphyry. Two fault zones strike north of east across the claims. These have been offset by the Amikougami Creek fault. A fault indicated by a narrow mud

¹Ont. Dept. Mines, Vol. LVII, 1948, pt. 1, Table II in pocket.

seam occurs in the underground workings on claim T. 16,477 and was traced northeastward by drilling. East of the Amikougami Creek fault, it was cut by drilling near the east boundary of claim T. 16,480. It probably represents a southwesterly extension of the Amalgamated Kirkland-Blanche River fault. Another parallel fault lies about 600 feet to the southeast along the volcanics-sediments contact. Drilling across this fault in 1946 indicated a sheared zone, about 100 feet in width, containing talc schist and green carbonates cut by narrow syenite dikes. The structure has all the characteristics of the Larder Lake fault (see Fig. 2 facing page 8), which follows the main south contact of the Timiskaming series.

Tegren Gold Mines, Limited

Tegren Gold Mines, Limited, owns the group of claims in Teck township formerly held by Harry Oakes. The main group is located immediately west of the property of Macassa Mines, and two additional small groups lie west and south of the McIvor property. The claims have been developed by surface prospecting and a limited amount of shallow drilling along the Kirkland Lake fault.

Practically all the Tegren ground lies within the belt of Timiskaming sediments. A considerable number of dikes and irregular-shaped bodies of syenite porphyry and basic syenite occur on the property. The most interesting feature of the Tegren claims is the Kirkland Lake fault, which has been traced from the Macassa boundary west to Amikougami creek, where it is offset southward by a cross-fault. A parallel zone of faulting has been found about 500 feet north and extends into the property on claim L. 2,762.

Ventura Kirkland Mines, Limited

Ventura Kirkland Mines, Limited, holds a group of five claims located northeast of Swastika townsite in Teck township. In 1928 a gold discovery was made on the adjacent property of Trout Creek Gold Mines about 50 feet from the Ventura Kirkland boundary. Following this discovery, the Ventura Kirkland property was explored on the surface and by 8 diamond-drill holes under the direction of R. J. Henry, but nothing of importance was found.

The rocks on the claims consist of Timiskaming sediments and tuffs cut by a body of syenite porphyry in the central section of the property and by augite porphyrite on the northwest claim. A diabase dike extends northeastward from the highway and was picked up in drill-holes.

A fault extends from the Sahtram shaft workings in a southwesterly direction across the property, and the porphyry adjacent to it is altered and sheared. Narrow quartz veins are found in the altered porphyry and adjacent sediments. These carry small quantities of pyrite, chalcopyrite, molybdenite, and galena, and traces of gold. Another strong southwestward-trending fault was intersected by drilling under Amikougami creek on claim L. 4,486. This is probably part of a strong fault (Larder Lake fault) which lies along the south margin of the Timiskaming series and which is believed to extend across Teck township (see Fig. 2 facing page 8). Another fault was found near the bottom of the hole, and this may represent the north-south striking Amikougami Creek fault.

According to a report on the property by R. J. Henry in 1928, the highest reliable assay obtained from surface sampling was 0.1 ounces gold per ton. The drilling operations did not yield any encouraging gold values.

Walters Claims

In 1946, the Walters group consisted of claims L. 17,402, 17,403, and 17,404 in lot 5, concessions V and VI, Eby township. The property and the

adjoining Reed claim were developed in 1938 by D. M. Hogarth, of Toronto, and associates. Surface work indicated the presence of gold on claim L. 17,404. Eight drill-holes, totalling about 3,000 feet, were put down to test the carbonate areas.

Outcrops on the property consist of basic volcanics, green carbonates, and a few syenite and lamprophyre dikes. The carbonate zone on the south boundary of claim L. 17,402 lines up with other carbonate outcrops along a zone striking S.70°E., which is probably a regional fault. Drilling indicated a zone of talc schist underlying the creek valley immediately north of the carbonate body on claim L. 17,402.

According to T. L. Wells, engineer in charge of development in 1938, bulk sampling from No. 1 trench at the east end of the carbonate body on claim L. 17,404 gave returns of 2.74 ounces and 0.06 ounces gold per ton from narrow quartz stringers containing finely divided visible gold. A drill-hole under this trench failed to reveal interesting values; some of the other holes gave low values.

Winnie Lake Mining Company, Limited

The Winnie Lake Mining Company, Limited, was organized in 1929 to develop a copper-zinc-gold showing exposed on claim L. 1,899 in the northwest corner of Teck township near the south side of Winnie lake. About the year 1912, a shaft was sunk 27 feet on a mineralized zone and, according to reports, a few tons of ore were shipped.

The main sulphide showing is located in the southwest corner of claim L. 1,899. The sulphides occur in siliceous lava near the contact with syenite intrusives. The sulphide zone strikes in an east-west direction and is exposed over a length of about 70 feet near the shaft but is only a few feet in width. The rock on the dump shows some heavy sulphide mineralization of pyrrhotite, pyrite, chalcopyrite, sphalerite, and traces of galena. Small lenses of magnetite occur with the sulphides. Analyses of selected grab samples of sulphide material from the dump at the shaft have indicated a considerable content of copper and zinc with gold values as high as \$2.10 per ton.

An electrical survey of the property was made in 1927 by Hans Lundberg. In 1938, the property was optioned by Erie Canadian Mines, Limited, and 4 short diamond-drill holes were put down along the main sulphide zone. These revealed only a few scattered patches of copper-zinc mineralization. The best material indicated 4.2 per cent. copper across 2.7 feet of core in hole No. 2. Two additional holes were put down by the Winnie Lake Mining Company to test the ground east of the shaft. Hole No. 5, located 450 feet east of the shaft, cut a 5-foot width that showed 0.01 ounces gold per ton, 1.03 per cent. copper, and 0.24 per cent. zinc.



**VEIN BRECCIA IN A WELL-FRACTURED ZONE ALONG THE NORTH
(No. 2) VEIN, LAKE SHORE MINE.**

GEOLOGY OF THE MAIN ORE ZONE AT KIRKLAND LAKE

CHAPTER I

Introduction

By Jas. E. Thomson

Introductory Remarks

This report deals with the underground geology of the seven producing gold mines in the Kirkland Lake camp. These mines are located on contiguous properties, which cover a length of about 3 1/2 miles along the main ore zone. From west to east the operating mines are Macassa, Kirkland Lake Gold, Teck-Hughes, Lake Shore, Wright-Hargreaves, Sylvanite, and Toburn. These mines are operating on a continuous gold-bearing structure, which is commonly referred to as the Kirkland Lake "break." The productive portion of this ore zone lies largely in the eastern part of Teck township but extends a short distance into Lebel township.

Kirkland Lake ranks as the second largest gold-producing camp in the Province of Ontario and in Canada, being second only to the Porcupine camp in the total amount of gold produced. Some of the mines at Kirkland Lake have been in continuous operation for more than thirty years. Most of the mines have been opened to great depth, and at present the camp holds the record for the deepest underground development on the North American continent. To the end of 1948, the seven mines mentioned above had milled 34,000,288 tons of ore and produced 16,871,063 ounces of gold and 2,969,434 ounces of silver, valued at \$516,743,288. From 1915 to 1948, inclusive, the total dividends paid amounted to \$212,863,367.

The production of such mineral wealth made Kirkland Lake one of the most flourishing communities in Ontario during the decade immediately preceding the Second World War. Throughout the war years, however, operations were greatly hampered owing to the shortage of labour. Since the end of the war, steadily mounting costs have considerably reduced the operating profit. The town of Kirkland Lake is the business centre of the community and is well connected by highway and railway with other parts of Ontario and Quebec. The township of Teck has a population of about 19,000 (1948), and most of these people are directly or indirectly dependent upon the gold-mining industry for their living.

Scope of Report and Acknowledgments

This report is the result of a co-operative effort on the part of the operating companies at Kirkland Lake and the Geological Branch of the Ontario Department of Mines. The mining companies have provided the bulk of the information, and their geologists have collaborated with the writer in preparing the reports on the individual mines. The writer has assumed the responsibility of co-ordinating the information and preparing it for publication. He spent the field

season of 1947 in examining the underground geology in company with the mine geologists, but in the time available was able to see only part of the accessible mine workings. The collaborating geologists have brought to this report the results of many years of underground study, and an opportunity has been provided to present their various points of view in the individual mine reports. The writer is responsible for Chapters I and II of this report, which summarize and discuss the data on the entire camp. Most of the reports in Chapters IV to X represent a joint effort, the actual writing being largely the work of the Government geologist with the information being provided by the mine geologist.

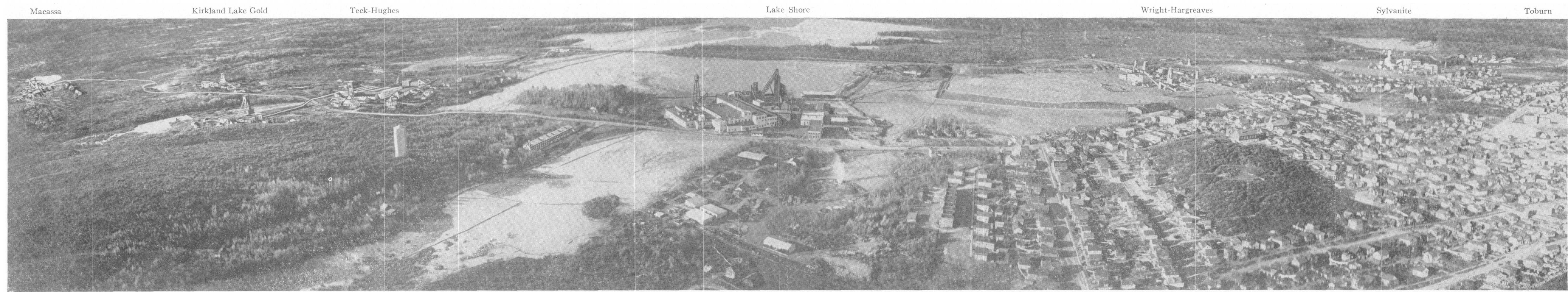
In preparing the accompanying maps, plans, and sections, an attempt has been made to correlate surface and underground information by the use of a uniform colour scheme. The source of the information is credited on each of the map-sheets, generally to the company rather than individuals because of the number of men who have contributed to it over a period of many years. In some cases a slight modification from the exact mine plan was necessary to conform with the standard system adopted for the camp. As this report has also been integrated with the first part of this volume, which covers Teck township and the Kenogami Lake area, there is a minimum of repetition in the description of rock formations, structures, and other features.

It was decided that the underground geology and ore bodies of the Kirkland Lake camp could be shown to greatest advantage by the publication of a set of coloured composite level plans and cross-sections. Likewise, several plans and sections that illustrate in detail certain local structural conditions or features of ore bodies are included in the report. It has recently been suggested that a longitudinal section along the "main break" of the camp would be of great public interest.¹ Investigations showed, however, that no single longitudinal section, or even a limited set of such sections, would give an accurate picture of the complex system of branching, parallel, and overlapping ore shoots that occur along the main ore zone. After discussing this matter with the various companies, it was decided to omit longitudinal sections through the camp, although a few that illustrate local conditions are included.

Part of this project has been a study of some of the more scientific aspects of the mine geology by Dr. J. E. Hawley, professor of mineralogy at Queen's University. This study was made on a suite of rocks and ores collected by the writer from the seven producing mines in the Kirkland Lake camp. A summary of the research by Dr. Hawley is incorporated in this report as Chapter III. These investigations included laboratory work on the mineralogy, paragenesis, and wall-rock alteration of the gold deposits. The research was sponsored in part by the Geological Branch of the Ontario Department of Mines, and the results have been integrated with the observations of the mine and Government geologists. Most of Dr. Hawley's work is credited to him throughout this report, but he also provided some additional help in the microscopic study of rocks; all his assistance is hereby gratefully acknowledged.

The Geological Branch of the Ontario Department of Mines wishes to record its gratitude and appreciation to the operating companies at Kirkland Lake for their co-operation and assistance in the preparation of this report. The companies have been exceedingly generous with their information and provided everything that could reasonably be given to the public. The pooling of their information for the benefit of all is a fine example of co-operation in the mining industry.

¹H. E. McKinstry, "A Review of Structural Geology of Canadian Ore Deposits," *Can. Min. Jour.*, Dec., 1948, p. 65.



AERIAL PANORAMA OF THE KIRKLAND LAKE MINES
(Photo by Airmaps Limited, Toronto.)

Town of Kirkland Lake

The writer was shown the greatest courtesy and hospitality by the officials and staff of the various mines. Particular thanks are due to the collaborating geologists for their contribution to this project. In addition, W. S. Savage, resident geologist of the Ontario Department of Mines at Swastika, assisted with the work in many ways and helped the writer with much of the underground examination. Acknowledgment should also be made to the Drafting Division of the Ontario Department of Mines for their painstaking efforts in the reproduction of the many detailed maps that accompany this report.

History and Development

The fascinating story of the discovery and gradual expansion of the Kirkland Lake camp has been well described in several publications, to which the reader is referred for details.¹ Only some general observations are recorded here.

Gold was first discovered at Kirkland Lake by W. H. Wright in the autumn of 1911 on what is now the east claim of the Wright-Hargreaves mine. In January, 1912, gold was found on the Tough-Oakes claims, and developments on that property started a great prospecting rush in 1913, following which the mines of the camp were gradually developed. Shipments of high-grade ore from the Tough-Oakes (later Tough-Oakes Burnside and then Toburn) mine commenced in 1913, and milling operations were begun in 1915. Production began at the Teck-Hughes in 1917, at the Lake Shore in 1918, at the Kirkland Lake Gold in 1919, at the Wright-Hargreaves in 1921, at the Sylvanite in 1927, and at the Macassa in 1933. These mines continued to prosper until the commencement of the Second World War. In the year 1939 the combined output of the seven mines in Kirkland Lake amounted to \$32,742,661, and almost \$16,000,000 was paid in dividends. During the war and post-war periods the production of the camp decreased owing to the shortage of labour and the increase of operating costs.

The record shows that most of the mines at Kirkland Lake attained success after considerable discouragement in the early stages of development. There were only a few surface exposures of the vein system as it is known today, but fortunately some of these were very high grade. The main surface showings, in order of discovery, were on the South vein at the Wright-Hargreaves, where some short ore shoots were uncovered; at the Tough-Oakes, where several rich veins were found; and on the South vein at the Lake Shore mine. Visible gold was found in stringers of quartz at several places on the surface at the Teck-Hughes, but the results of sampling were not encouraging. At the Sylvanite and Kirkland Lake Gold, native gold was found in surface exploration, but apparently no ore shoots were in evidence.

The results of the first few years of underground work were not too encouraging at some of the mines, and only after an arduous struggle was prosperity attained. The chief incentive during this period was the success of neighbouring properties. Tough-Oakes Gold Mines, Limited, (later Tough-Oakes Burnside Gold Mines, Limited) failed to locate the downward extension of the rich veins located at surface and eventually went through bankruptcy. The property was later acquired by Toburn Gold Mines, Limited, and the mine has

¹A. G. Burrows and P. E. Hopkins, *Ont. Dept. Mines, Vol. XXXII, 1923, pt. 4, pp. 2-5.*

E. W. Todd, *Ont. Dept. Mines, Vol. XXXVII, 1928, pt. 2, pp. 4-5.*

Thos. W. Gibson, "Mining in Ontario," *Ont. Dept. Mines, 1937, pp. 22-27.*

B. F. Townsley, "Mine-finders," *Saturday Night Press, Toronto, 1935, pp. 109-117.*

J. B. MacDougall, "Two Thousand Miles of Gold," *McClelland and Stewart, Limited, Toronto, 1946.*

Arnold Hoffman, "Free Gold," *Rinehart and Company, Inc., Toronto, 1947.*

been in continuous operation by this company since 1932. Harry Oakes had to struggle with the financing of Lake Shore Mines, Limited, until production was commenced, and then ore of a richness and extent probably never before seen in Canada was encountered, making the Lake Shore one of the outstanding dividend-payers of the country. The Kirkland Lake Gold Mining Company, Limited, was incorporated in 1915 but did not commence to pay dividends until 1934. Teck-Hughes Gold Mines, Limited, was a small struggling producer for the first eight years. Wright-Hargreaves was known at first as the "mine with a mill without ore"¹ but later showed spectacular developments. Sylvanite Gold Mines, Limited, was organized in 1913 but did not commence to produce gold until 1927. After years of effort, Macassa Mines, Limited, first discovered ore by drifting into the property from the 2,475-foot level of the adjoining Kirkland Lake Gold mine. These facts plainly show that the Kirkland Lake camp attained prosperity the hard way through the courage, tenacity, and hard work of the pioneer developers.

As the mines gradually became profitable operations, underground exploration was naturally extended, resulting in a better understanding of the geology of the gold deposits. It was found that the main ore bodies, especially in the west end of the camp, were located along a strong fault, and it was predicted that structure favourable for ore deposition would extend to great depth.² Further exploration resulted in the discovery of ore bodies off the so-called "main break" and sometimes in host rocks, which were at first thought to be unfavourable for the occurrence of ore. In the western part of the camp, subsidiary veins on the hanging wall of the Main break, or Kirkland Lake fault, became increasingly important as ore producers, and at the east end a broad zone of vein-fracturing was developed. In the early days the syenite and syenite porphyry were regarded as the favourable host rocks for ore, and the so-called "lamprophyre" was believed to be unfavourable. In recent years excellent ore has been found in the once-despised "lamprophyre." In fact, ore is now found in all the rock types of the camp with the exception of a few late diabase dikes, and the operators are willing to explore any promising pre-ore structure, regardless of the nature of the country rock.

After thirty years of steady production, during which time more than half a billion dollars worth of precious metals have been recovered under the varying world conditions that affect gold-mining, the camp has reached maturity. Ore is being stoped from all horizons to a depth of well below one mile. The deepest current (1948) ore developments are on the 6,800-foot level at the Lake Shore mine, and the deepest underground workings are at a depth of 7,200 feet at the Wright-Hargreaves mine.³ The backlog of experience gained through the years will be used to good advantage in thoroughly examining every structure along and adjacent to the main ore zone. The camp should continue to produce for many years to come, provided that world conditions are such that there is an incentive to mine gold.

Bibliography

A list of the reports and papers covering the geology of the producing mines at Kirkland Lake is given below in chronological order of publication.

A. G. BURROWS and P. E. HOPKINS, "The Kirkland Lake and Swastika Gold Areas," *Ont. Bur. Mines*, Vol. XXIII, 1914, pt. 2.

¹Arnold Hoffman, "Free Gold," *Rinehart and Company, Inc.*, Toronto, 1947, p. 59.

²E. W. Todd, *Ont. Dept. Mines*, Vol. XXXVII, 1928, pt. 2, p. 92.

³The annual report of Wright-Hargreaves Mines for the year ending August 31, 1949, states: "Of the 1,911 feet of drifting on the 6,600-, 6,900-, and 7,200-foot levels, mostly on the North vein or its subsidiaries, 624 feet was on profitable ore over drift width."

TABLE 1—DIVIDENDS AND BONUSES PAID BY GOLD-MINING COMPANIES
IN THE KIRKLAND LAKE CAMP, 1915-1947

Year	Tough- Oakes Gold Mines	Lake Shore Mines	Tech- Hughes Gold Mines	Wright- Har- greaves Mines	Sylvan- ite Gold Mines	Toburn Gold Mines	Kirkland Lake Gold Mining Co.	Macassa Mines	Total
1915	\$ 132,875								\$ 132,875.00
1916	265,750								265,750.00
1917									
1918		100,000							100,000.00
1919		100,000							100,000.00
1920		80,000							80,000.00
1921		120,000							120,000.00
1922		80,000	412,500.00						492,500.00
1923		160,000	206,250.00						366,250.00
1924		380,000							586,250.00
1925		600,000		206,250					1,150,000.00
1926		1,000,000		550,000					2,308,464.40
1927		1,400,000	474,714.40	893,750					3,351,071.60
1928		2,000,000	713,571.60	1,237,500					5,685,286.40
1929		2,200,000	2,866,286.40	825,000					5,938,276.40
1930		3,000,000	2,872,286.40						8,875,123.60
1931		4,800,000	3,118,143.60		65,990				10,011,761.40
1932		6,000,000	2,884,286.40	825,000	131,980				10,561,761.40
1933		6,000,000	2,884,286.40	962,500	164,975				13,930,381.29
1934		7,000,000	2,643,929.20	1,512,500	824,875	148,000	157,173.69	131,403.40	14,584,641.49
1935		8,000,000	1,922,857.60	3,025,000	659,900	148,000	157,173.69	396,710.20	16,989,799.66
1936		10,000,000	2,163,214.80	3,300,000	659,900	166,500	316,974.66	401,710.20	20,259,983.51
1937		12,000,000	2,403,572.00	3,850,000	824,875	259,000	479,402.91	535,613.60	20,259,983.51
1938		8,000,000	2,163,214.80	3,850,000	824,875	259,000	532,669.90	669,517.00	16,298,276.70
1939		7,500,000	2,067,071.92	3,850,000	824,875	296,000	532,669.90	870,372.10	15,940,988.92
1940		4,000,000	2,163,214.80	3,850,000	989,850	370,000	639,203.88	937,323.80	12,949,592.48
1941		3,100,000	1,922,857.60	4,001,250	923,860	333,000	585,936.89	937,323.80	11,804,228.29
1942		1,600,000	1,442,143.20	2,475,000	494,925	240,500	319,601.94	803,420.40	7,375,590.54
1943		1,600,000	1,442,143.20	1,925,000	395,940	74,000	213,067.96	642,736.32	6,292,887.48
1944		1,600,000	1,201,786.00	1,375,000	395,940	74,000	213,067.96	482,052.24	5,341,846.20
1945		1,600,000	721,071.60	1,100,000	395,940	55,500	213,067.96	321,368.16	4,406,947.72
1946		1,520,000	721,071.60	1,100,000	395,940	37,000	159,800.97	321,368.16	4,255,180.73
1947		1,440,000	721,071.60	880,000	296,955		213,067.96	160,894.08	3,711,778.64
Total	398,625	96,980,000	42,373,081.52	45,512,500	9,436,570	2,349,500	4,732,880.27	7,611,603.46	209,394,760.25

- A. G. BURROWS and P. E. HOPKINS, "Kirkland Lake Gold Area" (Revised Edition), Ont. Dept. Mines, Vol. XXXII, 1923, pt. 4, pp. 1-52.
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- W. WARD, O. S. PERRY, K. GRIFFIN, G. H. CHARLEWOOD, H. HOPKINS, G. MACINTOSH; and S. P. OGRYZLO, "The Gold Mines of Kirkland Lake," Structural Geology of Canadian Ore Deposits, Can. Inst. Min. Met., Symposium volume, 1948, pp. 644-653.
- HAROLD HOPKINS, "Structure at Kirkland Lake," Bull. Geol. Soc. Amer., Vol. 60, No. 5, 1949, pp. 909-922.

Statistics

The main statistics of the Kirkland Lake camp are presented on the following pages in tabular and graphic form. Detailed figures covering yearly and total tonnages of ore milled and the value of the bullion recovered to the end of 1947 are given in Table 3 (facing this page). Yearly and total dividends are listed in Table 1 (page 59). Table 4 (facing this page) shows the gold and silver production in ounces per calendar year for each mine. The total number of wage-earners (exclusive of salaried workers) in the seven mines and the average yearly wage for the period 1939 to 1948 is given in Table 2. Fig. 1 (facing this page) shows in graphic form the relation between tons milled, production, and dividends from the seven mines taken collectively for each year from 1913 to 1947.

TABLE 2--NUMBER OF WAGE-EARNERS AND AVERAGE YEARLY WAGE
IN THE KIRKLAND LAKE CAMP, 1939-1948

Year	Total no. wage-earners	Average yearly wage
1939	4,438	\$1,693
1940	3,927	1,730
1941	3,618	1,765
1942	2,337	1,892
1943	2,005	1,973
1944	1,800	2,005
1945	1,859	1,939
1946	2,207	1,968
1947	2,266	2,192
1948	2,336	2,467

The data given in Table 3 show that the average recovery from all ore milled by the seven mines for the period 1913 to 1947, inclusive, amounted to \$15.24 per ton. Similarly, from Tables 3 and 4, it is calculated that the average recovery for the mines taken collectively has been 0.499 ounces of gold and 0.087 ounces of silver per ton milled. The average ratio of gold to silver recovered from the entire camp for the period is 5.7 to 1.

A more detailed analysis of production, recovery, costs, ore reserves, profits, and dividends for a 10-year period is given in the reports covering most of the mines.

Tables 1 to 4 have been supplied by the Statistics Branch of the Ontario Department of Mines.

Geothermal Gradient

In view of the fact that the workings of the Kirkland Lake mines extend to great depth and that the Lake Shore and Wright-Hargreaves mines have at

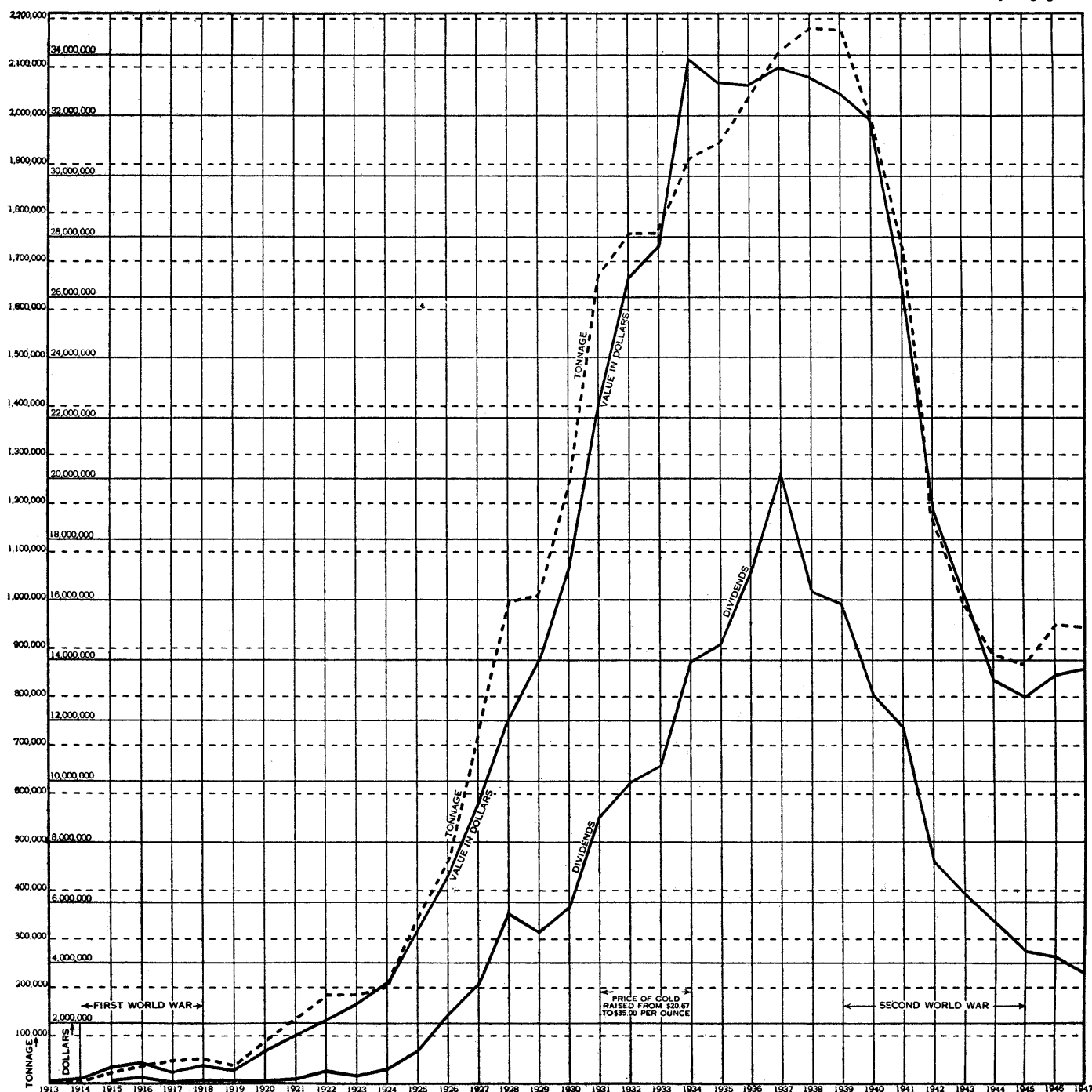


FIG. 1—GRAPH SHOWING THE RELATION BETWEEN THE VALUE OF BULLION PRODUCED, NUMBER OF TONS MILLED, AND VALUE OF DIVIDENDS PAID, KIRKLAND LAKE CAMP, 1913-1947.

TABLE 3—PRODUCTION STATISTICS OF THE GOLD MINES IN THE KIRKLAND LAKE CAMP, 1913-1947
(Value includes gold and silver, and exchange premium and equalization have been added since 1920)

Insert to face page 80.

Year	Toburn (Tough-Oakes Burnside)		Wright- Hargreaves		Teck-Hughes		Lake Shore		Kirkland Lake Gold		Sylvanite		Macassa		Total	
	tons	\$	tons	\$	tons	\$	tons	\$	tons	\$	tons	\$	tons	\$	tons	\$
1913	2,220	66,632	3	1,127											2,223	67,759
1914	3,734	117,644													3,734	117,644
1915	26,196	555,539													26,196	555,539
1916	39,865	711,626													39,865	711,626
1917	38,695	342,830			11,257	66,722									49,952	409,552
1918	22,000	139,683			14,774	80,570	16,749	416,414							53,523	636,667
1919					18,387	169,590	11,081	263,354	11,324	56,263					40,792	489,207
1920					30,646	277,878	19,779	545,311	40,812	322,533					91,237	1,145,722
1921			36,053	481,892	34,693	359,844	21,817	540,450	43,966	268,566					136,529	1,650,752
1922	16,108	107,617	66,181	767,445	41,194	604,006	24,279	476,461	37,489	226,527					185,251	2,182,056
1923	1,803	12,174	79,242	762,761	38,314	1,137,523	23,203	557,186	45,449	223,990					188,011	2,693,634
1924	8,438	47,548	84,487	1,094,462	44,209	1,035,338	56,168	1,104,550	8,091	46,513					201,393	3,328,411
1925	34,152	263,064	147,939	1,913,468	55,220	996,645	109,273	1,958,720							346,584	5,131,897
1926	43,871	309,709	153,392	2,150,844	87,074	1,600,613	171,197	2,775,000	10,829	126,999					466,363	6,963,165
1927	38,999	153,215	209,164	2,151,916	153,881	2,781,962	236,818	3,375,053	52,648	473,673	40,479	429,424			731,989	9,365,243
1928	14,396	82,316	256,331	1,838,510	317,213	4,951,707	279,661	4,073,965	57,883	414,596	69,791	738,146			995,275	12,099,240
1929			188,238	1,734,728	330,340	5,081,078	430,170	6,126,688	53,595	353,915	74,523	689,465			1,076,866	13,985,874
1930			220,430	2,432,888	338,555	5,403,030	550,501	7,847,508	52,106	534,154	81,213	794,459			1,242,805	17,012,039
1931			266,352	3,078,754	444,410	6,286,668	816,580	11,650,281	52,628	615,882	91,621	921,216			1,671,591	22,552,801
1932	14,689	227,956	295,525	3,984,125	475,700	6,631,755	818,698	14,317,113	56,492	592,451	96,891	930,305			1,757,995	26,683,705
1933	36,913	666,894	285,465	4,955,960	474,700	6,166,619	808,917	14,377,716	49,487	400,622	96,937	1,072,977	8,101	110,172	1,760,520	27,750,960
1934	36,230	708,119	354,418	7,572,292	442,745	5,801,691	836,023	16,305,819	64,952	703,300	111,767	1,740,384	66,557	1,111,098	1,912,692	33,942,703
1935	35,360	714,261	361,149	7,528,563	417,917	4,901,862	836,322	16,259,720	71,920	777,430	152,281	1,917,606	68,627	1,067,196	1,943,576	33,166,638
1936	34,440	723,295	400,310	7,588,550	403,712	4,747,833	887,571	15,882,078	84,679	746,189	162,185	2,099,128	70,878	1,260,414	2,043,775	33,047,487
1937	37,465	920,351	436,500	7,855,856	412,430	4,381,676	900,321	15,546,656	84,886	1,249,724	174,566	2,222,815	90,617	1,464,561	2,136,785	33,641,630
1938	52,434	1,112,385	434,650	7,800,875	380,215	3,625,284	921,837	15,149,635	92,665	1,483,769	190,714	2,419,784	110,718	1,769,951	2,183,233	33,361,633
1939	55,272	1,225,340	438,710	8,219,961	379,175	3,444,668	856,586	13,318,622	99,401	1,729,237	201,331	2,486,848	148,085	2,317,985	2,178,560	32,742,661
1940	59,524	1,296,428	442,920	8,688,806	317,560	3,577,194	647,426	10,930,962	137,986	2,051,790	212,519	2,658,723	150,674	2,680,188	1,968,609	31,884,091
1941	60,715	1,095,779	411,760	8,061,343	258,100	2,534,139	530,368	7,925,692	136,613	1,879,727	197,293	2,589,635	142,332	2,521,389	1,737,181	26,607,704
1942	43,635	730,350	283,580	5,669,063	93,335	1,365,513	347,951	5,560,188	100,854	1,458,823	175,745	2,021,506	120,400	2,144,501	1,165,500	18,949,944
1943	40,905	609,517	225,710	4,372,734	100,705	1,251,047	293,398	5,166,738	83,987	1,189,478	148,190	2,025,005	103,259	1,652,643	996,154	16,267,162
1944	39,940	493,270	184,520	3,494,958	102,920	989,004	258,544	4,223,731	77,457	1,053,156	137,822	1,722,722	83,392	1,398,011	884,595	13,374,852
1945	41,655	488,624	156,320	3,069,368	106,006	1,098,532	291,854	4,524,101	85,358	1,086,212	114,227	1,452,360	71,988	1,086,302	867,408	12,805,499
1946	40,753	483,496	174,314	3,147,009	91,302	1,093,701	310,968	4,744,166	91,443	1,094,837	154,562	1,693,581	87,383	1,325,491	950,725	13,582,281
1947	41,849	512,484	183,059	3,007,888	71,360	1,049,025	309,717	4,745,200	91,171	1,613,857	151,140	1,450,334	97,507	1,381,202	945,803	13,759,990
Total	962,256	14,918,146	6,776,722	113,426,146	6,488,049	83,492,717	12,623,777	210,689,078	1,876,171	22,774,213	2,835,797	34,076,373	1,420,518	23,291,104	32,983,290	502,667,777
Aver. recovery per ton	15.50		16.73		12.87		16.69		12.14		11.99		16.39		15.24	

TABLE 4—GOLD AND SILVER PRODUCTION IN OUNCES OF THE GOLD MINES
IN THE KIRKLAND LAKE CAMP, 1913-1947

Insert to face page 80.

Year	Macassa		Kirkland Lake Gold		Teck-Hughes		Lake Shore		Wright-Hargreaves		Sylvanite		Toburn	
	Gold	Silver	Gold	Silver	Gold	Silver	Gold	Silver	Gold	Silver	Gold	Silver	Gold	Silver
1913.....									43	404			3,164	3,890
1914.....													5,524	6,634
1915.....													26,658	8,922
1916.....													33,991	13,051
1917.....					3,181	1,155							16,384	5,257
1918.....					3,869	670	20,031	1,189					6,620	3,007
1919.....			2,675	379	8,156	930	12,696	932						
1920.....			13,795	1,853	11,910	1,508	24,292	1,723						
1921.....			11,678	1,665	15,582	1,305	23,896	2,025	22,617	2,066				
1922.....			10,814	1,279	28,780	2,322	22,737	1,974	36,748	4,866			5,144	1,870
1923.....			10,747	1,472	53,954	4,075	26,431	1,918	36,370	4,968			580	294
1924.....			2,236	453	49,350	4,117	53,053	4,225	52,465	6,413			2,281	583
1925.....					48,077	4,518	94,456	8,890	92,286	8,519			12,625	3,047
1926.....			6,112	1,260	77,266	6,450	133,893	11,935	103,793	8,912			14,819	2,114
1927.....			22,778	4,971	134,279	11,020	162,829	15,652	103,799	11,378	20,596	6,608	7,391	759
1928.....			19,962	3,390	238,887	18,453	196,533	19,557	88,580	12,778	35,452	9,263	3,967	540
1929.....			16,999	2,677	243,745	18,733	203,587	39,902	83,631	11,823	33,168	7,242		
1930.....			25,764	3,526	260,775	20,243	377,831	69,629	117,455	13,090	38,303	7,181		
1931.....			28,315	3,317	294,422	24,686	533,757	113,087	140,520	17,759	43,437	11,222		
1932.....			25,323	3,169	282,882	28,799	610,463	101,436	171,299	25,948	39,919	11,499	9,841	842
1933.....	3,683	302	18,465	2,332	220,036	27,792	499,800	95,941	177,190	27,372	44,607	8,791	23,020	3,430
1934.....	32,056	3,684	20,316	2,853	167,412	23,837	471,762	96,940	218,203	39,962	50,337	8,298	20,401	4,874
1935.....	30,272	3,498	22,051	3,391	138,987	22,795	461,109	112,678	213,471	33,556	54,356	9,030	20,200	5,630
1936.....	35,894	6,293	21,256	3,679	135,262	22,640	451,847	117,210	216,210	34,830	59,789	10,296	20,577	5,654
1937.....	41,762	6,527	35,666	4,421	124,999	20,089	443,160	109,040	224,092	37,174	63,393	11,958	26,243	5,247
1938.....	50,213	8,266	42,103	4,046	102,815	17,654	429,182	105,254	221,204	38,078	68,623	11,922	31,553	5,270
1939.....	63,886	12,085	47,323	4,764	94,775	15,540	368,320	89,065	225,907	42,944	68,249	11,877	33,506	6,738
1940.....	69,486	11,661	53,229	6,683	92,764	15,559	283,349	59,295	225,238	46,490	68,930	13,233	33,619	5,598
1941.....	65,875	10,209	48,767	5,913	65,714	11,154	205,334	54,597	208,937	46,449	67,160	10,716	28,422	4,112
1942.....	55,582	11,630	37,846	4,471	35,427	3,974	144,101	31,328	146,959	28,544	52,418	8,731	18,915	5,533
1943.....	42,854	7,141	30,863	3,280	32,456	3,901	133,906	29,089	113,343	23,166	52,515	8,253	15,799	3,294
1944.....	36,241	7,122	27,326	2,864	25,660	2,797	109,469	23,709	90,614	16,291	44,662	8,339	12,780	3,210
1945.....	28,154	5,801	28,179	3,340	28,506	2,621	117,249	25,183	79,590	12,922	37,648	7,397	12,648	4,151
1946.....	35,931	7,071	29,876	3,404	29,831	3,572	128,094	35,073	85,143	16,742	45,740	8,942	13,071	4,041
1947.....	39,319	7,036	46,042	3,323	29,885	4,281	134,847	36,283	85,576	17,593	41,231	9,792	14,588	2,665
Total....	630,708	108,326	706,506	88,175	3,079,644	347,190	6,968,014	1,414,759	3,581,280	500,537	1,030,533	200,590	474,331	120,256
Gold-silver ratio	5.8 to 1		8.0 to 1		8.9 to 1		4.9 to 1		6.1 to 1		5.2 to 1		3.9 to 1	
Aver. fineness of bullion	853		889		899		831		858		837		798	

present the deepest workings on the North American continent, the geothermal gradient in the camp is of general interest.

In 1933 Cleland¹ determined the following average geothermal gradients at Kirkland Lake: one degree Fahrenheit per 135 feet of depth at the Kirkland Lake Gold and Teck-Hughes mines; one degree per 163 feet at the Lake Shore mine; one degree per 167 feet at the Wright-Hargreaves mine; and one degree per 145 feet at the Sylvanite mine.

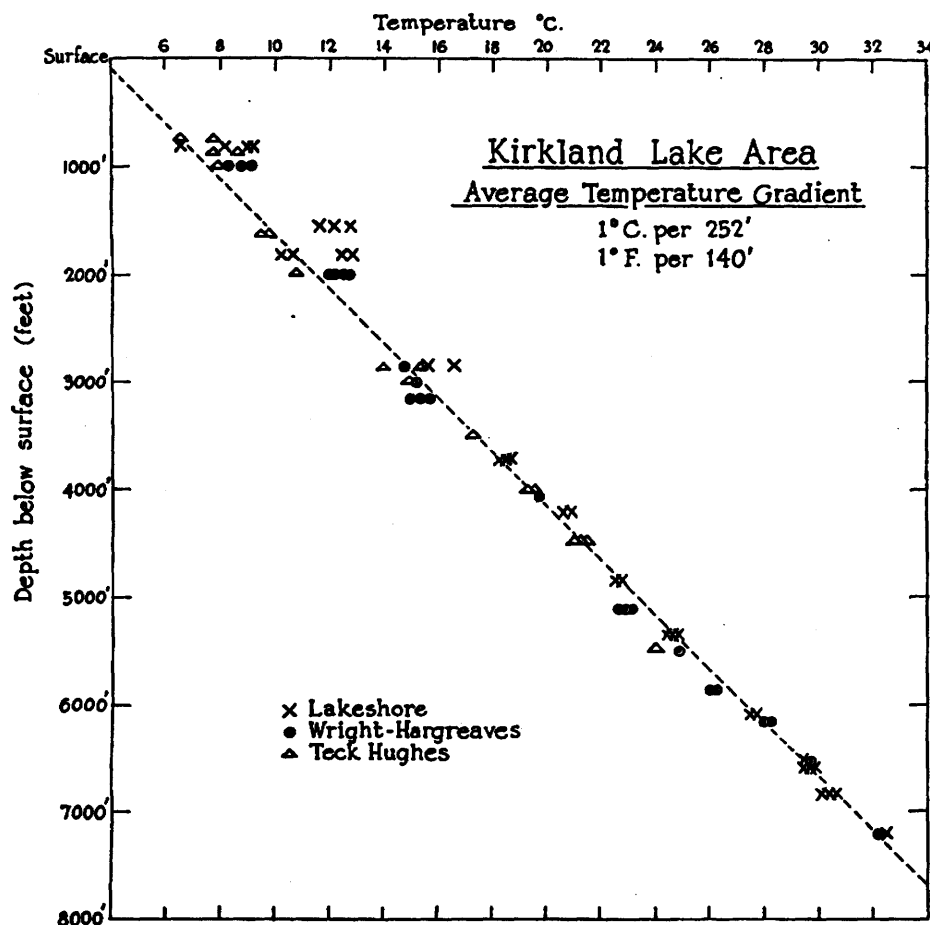


Fig. 2—Graph showing the average temperature gradient in the Lake Shore, Wright-Hargreaves, and Teck-Hughes mines. (After A. D. Misener.⁴)

Recently Misener² made a detailed study of rock temperatures and geothermal gradients in the Wright-Hargreaves, Lake Shore, and Teck-Hughes mines.³ A method of measuring the true underground rock temperatures with an accuracy of $\pm 0.1^\circ \text{F.}$ was applied, and readings were taken to a depth of 7,200 feet. The results show that the average points of equal temperature do not

¹R. H. Cleland, "Rock Temperatures and Some Ventilation Conditions in the Mines of Northern Ontario," *Trans Can. Inst. Min. Met.*, Vol. 36, 1933, pp. 379-407.

²A. D. Misener, "Temperature Gradients in the Canadian Shield," *Bull. Can. Inst. Min. Met.*, June, 1949, p. 281.

³This study was made possible by grants from the Research Council of Ontario.

⁴A. D. Misener, *op. cit.*, p. 281.

lie on planes parallel to the surface for depths of less than 3,500 feet. This means that the heat flow is not strictly perpendicular to the surface, and temperature gradients may be quite different at nearby points. Below 3,500 feet the points of equal temperature do lie on parallel planes, and reliable temperature gradients may be calculated. The average temperature gradient below a depth of 3,500 feet was found to be one degree Fahrenheit per 140 feet, or one degree Centigrade per 252 feet (see Fig. 2).

CHAPTER II

General Description of the Main Ore Zone

By Jas. E. Thomson

INTRODUCTION

In this chapter the main ore zone at Kirkland Lake is treated as a geological unit, regardless of property boundaries. The different rock formations, structures, and veins of the camp are discussed systematically. The following descriptions apply mainly to the block of ground through which the underground workings of the camp extend. This block is roughly 3 miles in length and 1 1/4 miles in maximum width, and reaches a maximum depth of more than 1 1/3 miles. Much of the written description is an explanation and interpretation of the accompanying underground plans and sections (in map case), and frequent references are made to these maps. The part of this chapter that deals with the causes of the faulting and fracturing must be considered as a theoretical discussion of the age-old question of "why is ore where it is?"; this is a departure from the main purpose of the report, which is to provide factual data to the public. The summary of principal geological events is intended for those readers who have a general interest in the geology of the Kirkland Lake camp but are not concerned about the details.

GENERAL GEOLOGY

The following description of rock formations is limited to the block of ground covered by the accompanying underground plans and sections (see sheets A to S in map case). This means that only the rocks along the main ore zone through the seven producing mines are discussed here. These consist of two main groups: (1) the older sedimentary and pyroclastic series of Timiskaming age, and (2) the later intrusive complex, which belongs to the Algonian period of plutonic invasion. These rocks have all been described in some detail in the earlier part of this volume covering Teck township. To avoid repetition the discussion here is limited to bare essentials, and the reader is referred to the earlier report and to the descriptions of individual mines for supplementary information on rock types.

The rocks along the main ore zone are classified according to age in the following table. The main periods of structural deformation and ore deposition are indicated in parentheses; these subjects are discussed in later sections of the report.

PRECAMBRIAN

(Post-ore faulting)

POST-ALGOMAN: Quartz diabase and minette dikes.

Intrusive contact

(Ore deposition)

(Wall rock alteration)

(Pre-ore faulting)

ALGOMAN:

Syenite porphyry,

Quartz-feldspar porphyry.

Syenite.

Augite syenite (including "basic syenite and lamprophyre").

Intrusive contact

(Folding)	
TIMISKAMING:	Tuff; small amount of trachyte. Conglomerate, greywacke; small amount of arkose and basal grit.

Great unconformity

(Folding)	
KEEWATIN:	Intermediate to basic volcanics: andesite, basalt, and pillow lava.

Keewatin

Keewatin volcanics have been found at only one place in the underground workings of the camp. Two long diamond-drill holes directed northward from the end of the long crosscut on the 3,075-foot level of the Lake Shore mine into Kirkland Basin ground intersected basic lava (see section No. 3 on sheet A and sheet D). The core showed massive Keewatin andesite in contact with basal grit of the Timiskaming series. The Keewatin-Timiskaming contact relationships have been discussed elsewhere in this volume.¹

Sections Nos. 2 and 3 on sheet A show that the most southerly of the underground workings in the camp are far from the Keewatin volcanics that lie south of the sedimentary belt.

Timiskaming**Lithology**

The rocks of the Timiskaming series in the mine workings are conglomerate, greywacke, and tuff, with small amounts of basal grit, arkose, and trachyte. Throughout the camp all the fine-grained clastics are generally classified as greywacke. It generally contains narrow bands of grit or pebble conglomerate, which reveal the stratification, although rude cross-bedding is also seen. The tuffs are typically well-bedded, fine-grained, cherty rocks; agglomeratic phases contain trachyte fragments. The tuffs are characteristically reddish in colour on the surface, but this feature is not so noticeable underground, except in the vicinity of breaks marked by wall-rock alteration. The essential mineralogical difference between the greywacke and tuff is the abundance in the former of clastic quartz, which is very scarce or entirely lacking in the latter. In thin section the fragmental nature of the tuff is generally noticed; it contains appreciable amounts of altered feldspathic material, apatite, and secondary carbonates. For a detailed description of the tuff and greywacke the reader is referred to Todd's report.² Analyses of the tuff and greywacke are shown in Table 5 (facing page 70).

A rather unusual type of tuff or trachyte is found at a few places on the south side of the main ore zone. It is best exposed near No. 1 winze on the 4,500-foot level of the Macassa mine, but also occurs at the Kirkland Lake Gold and the Teck-Hughes mines. Locally, the rock has been given such names as spotted trachyte, amygdaloidal trachyte, sericitic syenite, or tuff breccia. In hand samples, it is similar in appearance to the spotted porphyritic trachyte of Lebel township. Microscopic examination shows that the spots are pseudomorphs of feldspar; hence, the rock was originally porphyritic. The close association with tuffs would suggest that this rock is a porphyritic trachyte rather than an intrusive.

Boulder and pebble conglomerate are found in all the mines, especially in the long lateral crosscuts and drill-holes. It is known to extend to a depth of at least 7,200 feet below the surface at the Lake Shore and Wright-Hargreaves mines. Considerable widths of boulder conglomerate are exposed in crosscuts in the northern parts of the Lake Shore (Kirkland Basin ground), Sylvanite, and

¹Pages 11-15.

²E. W. Todd, *op. cit.*, pp. 16-20.

Toburn workings and in the long drive towards the Amalgamated Kirkland property on the 3,000-foot level at the Macassa mine. The last-mentioned locality shows the downward extension of the rather spectacular boulder conglomerate exposed on the surface in Chaput-Hughes townsite. This conglomerate contains a great variety of large rounded boulders. Most of the greywacke is exposed in the mines at the east end of the camp. Certain phases of this are arkosic in composition.

The basal grit is a pebbly sediment featured by the presence of small angular fragments. It lies adjacent to the Keewatin volcanics along the north side of the sedimentary belt on the surface and has been cut in underground drill-holes in Kirkland Basin ground (see sheet D in map case). A few narrow bands of a sediment similar to the basal grit are locally interbedded with tuffs in the mine workings and are especially noticeable at certain places in the long south crosscut on the 3,000-foot level at the Macassa mine.

Distribution

The accompanying plans and sections indicate the extent and distribution of the sediments and tuffs of the Timiskaming series throughout the underground workings of the entire camp. These formations are most commonly found on the north and south flanks of the elongated composite stock in which the main ore zone of the camp generally lies. An exception to this general rule is furnished by the so-called anticlinal structure at the Kirkland Lake Gold mine, where remnants of the sediments and tuffs occur well within the intrusive complex. In addition, patches of these rocks are found along the main ore zone on the upper levels at most of the mines.

Stratigraphy

The general stratigraphical sequence at the west end of the camp shows south-dipping horizons of tuff overlain by coarse boulder conglomerate, which passes upward into greywacke with some pebbly beds. At certain places on the surface the tuff-conglomerate sequence on the south side of the Kirkland Lake fault is an upthrust repetition of the tuff and conglomerate bands lying on the north side of the structure. The general stratigraphical sequence across the full width of the sedimentary belt is illustrated by the sections on sheet A. The steep pitch to the west of the main intrusive complex at Kirkland Lake affects the distribution of sediments and tuffs in longitudinal section through the camp, as shown in Fig. 3 (page 70). The sediments off either end of the elongated intrusive body plunge steeply westward. Any such longitudinal section must be very diagrammatic because of the complex interfingering of intrusive and intruded rock in the contact zone.

Algoman

All the intrusive rocks in the Kirkland Lake camp, with the exception of a few late diabase and minette dikes, are classified as Algoman in age. They act as host rocks for the gold deposits along most of the main ore zone and are, therefore, the rocks that are commonly seen in the underground workings. The main intrusive complex is in the form of an elongated and slightly wedge-shaped stock, which widens to the east. This composite body also dips steeply to the south, widens with depth, and has a steep over-all pitch to the west. In detail, it is, of course, a very irregular-shaped body with no definite boundaries and shows intermingled intrusive and intruded rock in the broad periphery zone.

The main intrusive stock and satellitic bodies are of variable composition, although all of the rock types are probably derived from the same parent magma

and represent phases of one general period of intrusion. In general, the more basic varieties are confined to the outer and upper parts of the intrusive mass, where they represent the earliest differentiate from the magma. The more acid phases intrude the earlier-formed rock types, resulting in a complex mixture in the transition zones but showing more uniformity of type in the interior of individual bodies.

The three main intrusive rock types throughout the camp are augite syenite, syenite, and syenite porphyry, intruded in that order. Augite syenite is the name now used throughout the camp for the rock formerly classified as "lamprophyre" or basic syenite. As these older names are well established in the mine records, they will continue to be used. The reader should, therefore, understand that the names augite syenite, basic syenite, and "lamprophyre" all refer to the same rock type.

AUGITE SYENITE

Fresh augite syenite is characteristically a dark-coloured rock with a coarser and more granitoid texture than the other intrusives. The chief ferromagnesian mineral in the rock is augite, although this is generally seen in varying stages of alteration to secondary amphibole (actinolite), chlorite, and carbonates. The feldspar was originally about $\text{Ab}_{90}\text{An}_{10}$ (oligoclase) in composition, but is replaced by some fine, mosaic orthoclase. Accessory minerals are magnetite, apatite, and minor amounts of titanite.

Much of the augite syenite seen in the mine workings is along the walls of veins and breaks and is, therefore, considerably altered. In this process the granular nature of the rock is obscured by brecciation, reddish discoloration, and the formation of buff-coloured mylonite. Microscopic examination shows that the alteration has produced a highly sheared rock with a cataclastic structure. The breccia fragments are highly carbonated and cemented by chlorite. The colour change in the rock may be due to the development of iron oxides and leucoxene.

SYENITE

The syenite is normally a medium-grained, pinkish-coloured rock, which becomes quite red adjacent to veins and fractures. It occurs as an irregular pipe-like body, which outcrops on the Teck-Hughes property and pitches westward through the Kirkland Lake Gold and Macassa mines (see Fig. 3 on page 70). The Kirkland Lake fault has sliced this body along its long dimension into an upper hanging wall and a lower footwall segment (see sections in map case).

In drill cores, syenite may show a transition into augite syenite or may exhibit a well-defined intrusive contact. In thin section, the rock shows a granitic texture and consists mainly of orthoclase with a small amount of intergrown oligoclase; secondary chlorite, carbonate, leucoxene, and sericite are present, and accessory minerals are magnetite, ilmenite, and apatite.

SYENITE PORPHYRY

The main body of syenite porphyry at and near the surface extends eastward from about the centre of the Lake Shore property; it crosses the Wright-Hargreaves, Sylvanite, and part of the Toburn properties. At the west end of the camp syenite porphyry occurs as dikes and small irregular-shaped bodies, which cut through the syenite and augite syenite with a well-defined intrusive contact. A diagrammatic picture of the general distribution of the syenite porphyry along the hanging-wall side of the main plane of displacement of the Kirkland Lake fault at different horizons is shown in Fig. 3 (page 70). The syenite porphyry

is the host rock for a larger percentage of the ore mined to date from the Kirkland Lake camp than all other rock types combined.

Syenite porphyry is the latest intrusive in the complex. Fresh, unaltered rock has a distinctly porphyritic texture and ranges from red to grey in colour. The phenocrysts are orthoclase and oligoclase; primary quartz is rare or absent; the ferromagnesian minerals are hornblende, chlorite, and biotite; magnetite, apatite, and carbonates are also present. Adjacent to strong breaks the porphyry is altered to mylonite; this type of wall-rock alteration is described in a later part of this report.¹

Microscopic Features of Syenite Porphyry and Altered Syenite Porphyry²

The dominant phenocrysts in all the thin sections of syenite porphyry are plagioclase; most of these show well-defined albite twinning and zonal growth. They seldom exceed one-tenth of an inch in size. In composition the phenocrysts range from oligoclase to albite ($\text{Ab}_{80}\text{An}_{20}$ to $\text{Ab}_{90}\text{An}_{10}$) and in the more altered samples are even richer in albite (Ab_{97}). Variation in composition over this range does not appear to be related to depth. All the plagioclase seems to have some potash in solid solution, particularly in the outer rims of the crystals. This is shown by staining with sodium cobalti-nitrite³ solution after fuming with hydrofluoric acid, the richer potash minerals turning deep yellow. The continuation of twinning to the outer borders of many such crystals confirms the fact that, in some at least, the potash is present in solid solution in the outer part of the plagioclase. In others, however, albite twinning does not carry through to the outer edge. In these, such rims are usually distinctly less altered than the interior and have both indices and bi-refringence lower than the plagioclase, and, though they were not checked further by optical tests, may well be orthoclase.

Phenocrysts of orthoclase occur rarely and were noted in only three sections. These stain deep yellow with cobalti-nitrite solution, confirming a high potash content; they conform to orthoclase in extinction angles, but under crossed nicols are seldom completely homogeneous and give suggestions of inclusions or fine, lenticular twinning and are hence either perthitic or possibly akin to anorthoclase. They enclose grains and laths of oligoclase-albite.

Biotite is by far the most common of the ferromagnesian minerals. It occurs in laths, which are usually slightly smaller than the feldspar phenocrysts, and is variably altered to a bleached white mica, or chlorite, or an aggregate of chlorite, carbonate, magnetite, and either leucoxene or fine rutile needles. In some porphyries remnants of original square-shaped crystals of hornblende or augite show that one or other of these minerals was originally present. These ferromagnesian minerals indicate the close relationship of the syenite porphyry to the augite syenite.

The matrix of the syenite porphyries is a very fine aggregate of feldspar, chiefly plagioclase, and quartz. Staining with cobalti-nitrite solution indicates a higher potash content of the matrix compared with the phenocrysts. This may be due to the greater development of sericite rather than to primary orthoclase.

Accessory constituents are chiefly apatite and magnetite-ilmenite. Both of these are associated more with the altered ferromagnesian minerals than with the other phenocrysts, or else occur alone. As seen in polished sections, the black iron

¹Pages 98-101.

²This section was written by J. E. Hawley and is based on the study of thin sections from all the Kirkland Lake mines submitted to him by the writer.

³See A. Gabriel and E. P. Cox, "A Staining Method for the Quantitative Determination of Certain Rock Minerals," *Amer. Min.*, Vol. 14, 1929, pp. 290-292.

oxides consist of fine lamellar and bladed intergrowths of magnetite and ilmenite, alteration of which tends to leave the magnetite in a residue of amorphous leucoxene. Replacement by pyrite in many cases shows the same fine criss-crossing blades of dark-grey minerals. Titanite is rarely found, and in no case was zircon seen.

Alteration of Syenite Porphyry.—The common alteration products in the sections consist chiefly of iron-bearing dolomite and calcite; usually these are accompanied by smaller amounts of fine-grained secondary quartz, albite or acid plagioclase, sericite, chlorite, leucoxene with or without secondary rutile or titanite, fine secondary biotite, and rarely epidote and actinolite. The reddish coloration of the porphyries is due, in most cases, to very fine disseminated red and brown specks of iron oxides. As these are confined largely to the matrix, their origin is obscure. In some cases, oxidation of the iron-bearing dolomite yields a thin coating of brown iron oxides around the grain boundaries, but in the so-called "red porphyries" this is clearly not the main cause of the colour.

Most of the feldspars show a muddy grey coloration when viewed with one nicol under the microscope. They also exhibit varying degrees of alteration to fine sericite. More rarely, disseminated flakes of chlorite or biotite replace the feldspar as well as other minerals; carbonates, with or without quartz, invade them either along fractures or irregularly. Much of the development of sericite, chlorite, carbonate, and other secondary minerals along slip planes and in fractured or crushed parts of the porphyry is distinctly later and related to the introduction of the ore.

More interesting is the effect of minute quartz-carbonate stringers; in places these occur as gash veins, which cut the feldspars. Where these pass into and through the phenocrysts the fracture-filling is largely but not entirely composed of fresh clear plagioclase feldspar, which merges insensibly with the host feldspar on either side. In many cases, the freshly deposited feldspar clearly fills the fracture and shows twinning *lamellae* coincident with that of the host; it also appears to have the same composition ($Ab_{95}An_5$). This is a case of mutual orientation, referred to by Donnay.¹ In others, the twinning of the fresh feldspar is not exactly conformable to that of the host and is composed of wider *lamellae*, suggesting a more albitic composition. In still other sections, where twinning is not visible in the plagioclase host, no twinning appears in the filling. From these occurrences it is clear that the solutions depositing carbonates and quartz in the fractures carried in the necessary plagioclase for the formation of the new feldspar filling. In places these constituents were slightly more albitic than the hosts, as is seen also in larger quartz-carbonate veins where albite has been confirmed optically as white crystals extending from the walls into quartz.

The alteration of the ferromagnesian minerals (biotite, with lesser hornblende and possibly even augite) is, in nearly all sections, even the freshest, always well advanced to an aggregate of secondary chlorite, ferruginous carbonate, quartz, and leucoxene, or other titaniferous products. Biotite alters first to green biotite, then pseudomorphously to chlorite or to white mica, in which titanium products and black iron oxides are dispersed along the cleavages. Blocky grains of hornblende (primary?), or hornblende after augite, have their outlines preserved by the aggregates mentioned above, but usually with abundant fine black iron oxides in addition. More rarely both actinolite and epidote have been developed from hornblende, the former extending beyond the borders into the matrix.

¹J. D. H. Donnay, "Plagioclase Twinning," *Bull. Geol. Soc. Amer.*, Vol. 54, No. 11, p. 1649.

Alteration of the matrix is chiefly to dolomite and calcite, and more rarely to secondary quartz and fresh albite. Disseminated chlorite flakes in the matrix may have arisen from original fine femic constituents, but in a few cases a deep-green chlorite has also been introduced. In addition fine sericite, often weakly pleochroic, and chlorite, or chlorite alone, follow slips throughout the rock, and discontinuous fine seams or veinlets of iron-bearing dolomite, calcite, chlorite, and quartz, with or without feldspar, as noted above, are also present.

Where pyrite has formed it commonly replaces primary intergrowths of magnetite-ilmenite, preserving in part their graphic structure (as seen in polished sections). It also replaces biotite and hornblende or their altered equivalents, but elsewhere appears chiefly in the matrix and without any preferred association of other alteration products.

The various alterations of the syenite porphyry may then be summarized as follows:—

Period	Type	Alteration product
Early.....	Deuteric(?).....	Slight general sericitization of feldspars; chloritization of micas and hornblende; red iron oxide staining of matrix(?).
Later.....	Hydrothermal...	More extensive sericitization of feldspars; more complete destruction of ferromagnesian minerals: biotite, hornblende to carbonate-chlorite aggregates. Introduction of ferruginous dolomite, possibly some quartz and pyrite, irregularly replacing the matrix or phenocrysts.
Latest.....	Hydrothermal...	Formation of gash veins; introduction of carbonates (dolomite and calcite), quartz, deep-green chlorite, albite with development of plagioclase where they cut phenocrysts.
	On slip planes...	Development of either slightly greenish sericite or chlorite, or both (may be earlier or later than gash veins).

QUARTZ-FELDSPAR PORPHYRY AND QUARTZ SYENITE

In addition to the common type of syenite porphyry mentioned above, there are varieties that may be regarded as slightly different phases from the normal rock. Quartz-feldspar porphyry comes in this category and is characterized by the presence of phenocrysts of primary quartz in addition to the feldspar. A band of this rock lies north of, and roughly parallel to, the main ore zone of the camp. On the surface it extends from the Kirkland Basin claims to the east end of Federal Kirkland ground. The long crosscuts to the north in the Teck-Hughes, Lake Shore, and Toburn mines provide sections across this band of porphyry. Quartz-feldspar porphyry has not been differentiated from the normal syenite porphyry on map No. 1945-1, but the geological maps of some of the mining companies show them as two distinct types of porphyry. Quartz-feldspar porphyry also forms part of the porphyry core underlying the anticlinal structure in the lower part of the Kirkland Lake Gold mine. Small patches of it are found in the underground workings of the Lake Shore mine. The exact relationship of the quartz-feldspar porphyry to the normal syenite porphyry is not definitely established. Although well-defined contacts between the two types may be seen, the age relationships are contradictory at different points. It would thus appear that the quartz-bearing variety is a more acid phase of the normal syenite

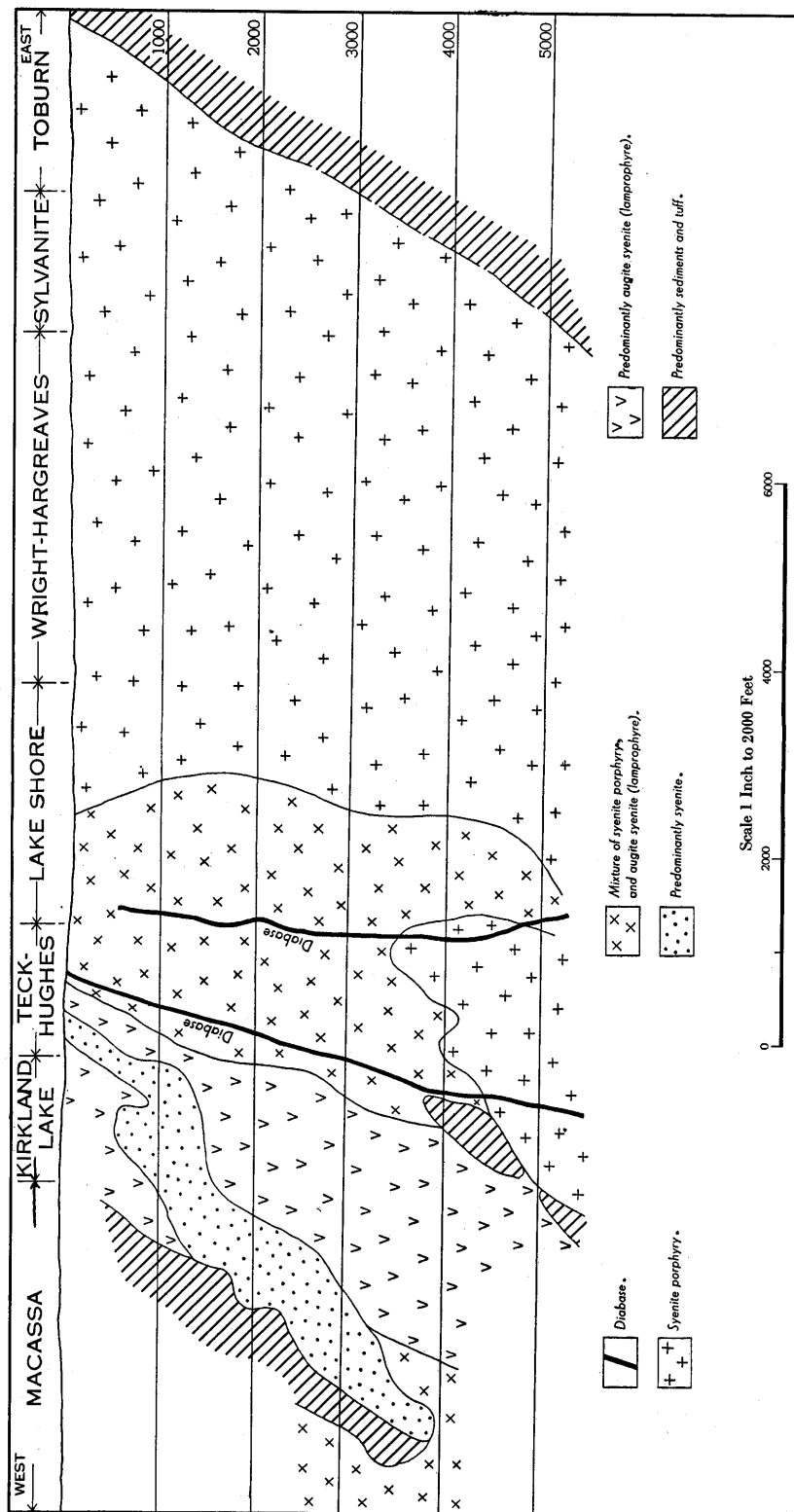


FIG. 3—DIAGRAMMATIC LONGITUDINAL SECTION ALONG THE HANGING WALL OF THE MAIN ZONE OF DISPLACEMENT OF THE KIRKLAND LAKE FAULT, SHOWING THE PRINCIPAL ROCK TYPES.

TABLE 5—CHEMICAL ANALYSES OF ROCKS AND ORES ALONG THE MAIN ORE ZONE IN THE KIRKLAND LAKE CAMP

Insert to face page 70.

	Tuff		Greywacke			Augite syenite	Syenite	Syenite porphyry	Vein wall rock and mylonite									Ore			
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13	No. 14	No. 15	No. 16	No. 17	No. 18	No. 19	No. 20	No. 21
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Silica (SiO ₂)	45.62	47.72	59.75	61.26	63.55	50.24	57.02	62.19	63.61	59.59	49.92	46.00	58.83	67.84	69.91	67.24	49.24	48.67	58.76	50.55	66.23
Alumina (Al ₂ O ₃)	10.58	11.92	13.13	13.57	13.57	16.43	18.30	14.85	14.96	12.46	15.44	12.48	14.46	12.73	10.77	12.27	12.64	11.64	12.51	13.65	13.31
Ferric oxide (Fe ₂ O ₃)	4.73	6.36	1.29	2.58	1.31	2.77	.98	1.38	1.08	.94	.97	3.00	1.37	1.37	1.51	.12	.41	1.49	.91	(Fe) 4.25	(Fe) 2.58
Ferrous oxide (FeO)	3.84	4.71	5.32	4.03	4.01	4.48	2.67	2.03	1.16	2.41	4.78	7.10	2.23	1.73	.74	1.49	4.96	6.07	3.00		
Magnesia (MgO)	6.06	3.35	4.06	3.60	2.50	3.80	1.04	2.33	1.85	2.80	3.79	6.45	3.69	1.71	.75	1.80	3.14	5.88	3.04	2.90	1.68
Lime (CaO)	10.26	6.07	3.65	3.26	3.78	5.84	1.99	3.88	3.36	5.51	5.82	6.90	4.77	3.13	4.58	3.90	10.36	6.69	4.76	4.60	3.64
Soda (Na ₂ O)	2.06	2.14	2.71	3.49	5.00	3.54	4.25	4.92	4.30	3.82	4.49	2.85	5.44	5.34	4.00	4.60	4.82	1.86	2.78		
Potash (K ₂ O)	3.53	5.84	2.02	1.99	2.51	5.84	7.41	3.76	4.12	2.80	4.52	2.89	2.12	1.58	1.37	1.69	.80	4.36	4.63	10.10	7.06
Combined water (H ₂ O+100)	1.78	1.01	2.59	2.62	1.67	1.90	.95	1.05	.88	.87	1.38	2.28	.58	.68	.78	.64	.68	1.84	1.31		
Uncombined water (H ₂ O-100)									.03	.01	.02	.04	.13	.06	.11	.04	.09				
Carbon dioxide (CO ₂)	10.02	8.28	4.36	2.58	2.17	3.35	3.06	2.79	4.08	7.68	7.22	8.20	5.96	3.10	3.64	5.06	11.84	8.86	5.91		3.10
Titania (TiO ₂)	1.02	1.68	.92	.46	.48	.93	1.90	.44	.42	.39	.98	.81	.45	.28	.25	.28	.65	.86	.55		
Phosphorus pentoxide (P ₂ O ₅)	.52	.99	.17	trace	trace	.51	.23	.37	.26	.35	.42	.55	.06	.10	none	.12	.15	.13	.22		
Sulphur (S)	trace	trace											.45	.12	1.10	.19	.29			1.00	.70
Chrome (Cr ₂ O ₃)													none	.08	none	trace	trace				
Manganese oxide (MnO)	.17	.16				.16	.17	.13	.10	.06	.09	.21	.09	.02	.12	.11	.14	.13	.09		
Pyrite (FeS ₂)										.28	.30							1.81	1.59		
Molybdenite (MoS ₂)																		none	.005	.08	trace
Lead (Pb)																		trace	.016	.02	.014
Tellurium (Te)																		.006	.012	.02	trace
Copper (Cu)																		.020	.030	.01	.008
Carbon (C)																				.09	
Loss on ignition																				6.50	
Gold (Au)																		.0013	.0023		
Silver (Ag)																		.0001	trace		
Total	100.19	100.23	99.97	99.44	100.55	99.79	99.97	100.12	100.21	99.97	100.14	99.76	100.63	99.87	99.63	99.55	100.21	100.31	100.12		
Gold ounces per ton																		0.38	0.65	0.59	0.66
Silver ounces per ton																		0.03			0.10
Specific gravity	2.763	2.816	2.768			2.819	2.681	2.730	2.699	2.689	2.750	2.805									

No. 1—Bedded tuff from drill core 560 feet below the surface, Macassa property, Ont. Dept. Mines, Vol. XXXVII, 1928, pt. 2, p. 18.
No. 2—Bedded tuff from same location as sample No. 1 but 2 inches below the surface, *ibid*, p. 18.
No. 3—Greywacke, 1,000-foot level, Sylvanite mine, *ibid*, p. 20.
No. 4—Greywacke from surface south of Government road, Lake Shore mine, *ibid*, p. 20.
No. 5—Greywacke, composite sample from Lake Shore, Tough-Oakes, and Continental properties, *ibid*, p. 20.
No. 6—Average of rock type based on 5 analyses of least altered material, *ibid*, p. 37.
No. 7—Average of rock type based on 2 analyses of least altered material, *ibid*, p. 37.
No. 8—Average of rock type based on 4 analyses of least altered material, *ibid*, p. 37.
No. 9—Altered porphyry from the north wall of the South vein, 1,500-foot level, Wright-Hargreaves mine, *ibid*, p. 88.
No. 10—Altered porphyry from the wall of an ore shoot on the main (North) vein, 600-foot level, Lake Shore mine, *ibid*, p. 89.
No. 11—Altered syenite from the wall of a vein on the 2,350-foot level, Kirkland Lake Gold mine, *ibid*, p. 89.
No. 12—Altered augite syenite (lamprophyre) from the south wall of the main vein, 2,475-foot level, Kirkland Lake Gold mine, *ibid*, p. 90.
No. 13—Mylonite from No. 4,002 drift, South vein, 4,000-foot level, Wright-Hargreaves mine. Analysis by Provincial Assay Office, 1948.
No. 14—Mylonite from No. 6,102 drift, South vein, 6,150-foot level, Wright-Hargreaves mine. Analysis by Provincial Assay Office, 1948.
No. 15—Cherty phase of mylonite, No. 4,801 west drift, 4,825-foot level, Lake Shore mine. Analysis by Provincial Assay Office, 1948.
No. 16—Buff-coloured mylonite, main south break, southeastern section, 1,000-foot level, Sylvanite mine. Analysis by Provincial Assay Office, 1948.
No. 17—Mylonite on No. 5 strike fault, shaft station, 5,400-foot level, Sylvanite mine. Analysis by Provincial Assay Office, 1948.
No. 18—Sample representing the mill run for one month from Kirkland Lake Gold mine, Ont. Dept. Mines, Vol. XXXVII, 1928, pt. 2, p. 69. Gold, 0.38 ounces per ton; silver, 0.03 ounces per ton.
No. 19—Sample representing 10,849 tons of ore milled at the Lake Shore mine, *ibid*, p. 69.
No. 20—Sample of 70,000 tons of ore run through the Lake Shore mill in November, 1935; 80 per cent. of this came from the North vein, Lake Shore Mill Staff, Trans. Can. Inst. Min. Met., Vol. 39, 1936, p. 303. Analysis by Dept. of Mines, Ottawa.
No. 21—Analysis of representative mill feed, Wright-Hargreaves mine, Eng. and Min. Jour., May, 1939, p. 45.

porphyry and is closely related to it in age. The microscopic study of the porphyries in the camp by J. E. Hawley¹ confirms this viewpoint and shows that the quartz-feldspar porphyry is only a quartz-bearing phase of the syenite porphyry.

Near the bottom of the Kirkland Lake Gold, Teck-Hughes, and Lake Shore mines, microscopic examination shows that there is a variety of intrusive that approaches quartz syenite in composition. It is almost impossible, however, to differentiate this rock from the normal syenite porphyry in hand specimens. Examination of thin sections of this rock from holes drilled below the 50th level at the Teck-Hughes mine showed that the rock is intermediate between syenite porphyry and syenite in texture, but the quartz is entirely secondary and the result of silicification. Contacts between different porphyry types may be seen in the station of No. 2 winze on the 5,450-foot level at the Kirkland Lake Gold mine. Microscopic examination shows that certain phases of this rock are closer to quartz syenite than syenite porphyry in composition, but much confusion would arise if any attempt were made to separate the two varieties macroscopically.

DISTRIBUTION OF ALGOMAN INTRUSIVES

The accompanying plans and sections show the relative distribution of the intrusives throughout the seven mines of the camp. Fig. 3 illustrates in a general way how the various types of intrusives are distributed along the hanging wall of the Kirkland Lake fault. A longitudinal section along the footwall of the structure would show the same relative distribution. It may be seen that the relative proportion of syenite porphyry to other rocks increases in the workings at depth. It is only natural that the latest phase of the intrusive should replace the older marginal phases and attain greater lateral dimensions as the workings penetrate more deeply into the core of the intrusive stock.

CHEMICAL ANALYSES

Chemical analyses of the augite syenite (lamprophyre), syenite, and syenite porphyry are given in Todd's report on the camp.² Average analyses of these rocks are shown in Table 5 of this report (facing page 70).

Post-Algoman

A few diabase and minette dikes cut the Algoman intrusives and hence are post-Algoman in age. The minette dikes are micaceous lamprophyres but are so insignificant that they are not indicated on the mine plans and do not seem worth describing. Their exact relationship with respect to the ore is not known.

The masses of diabase that have been followed from the surface to the bottom of the mine workings range from tiny dikelets to dikes with a maximum width of 80 feet. The larger dikes show typical diabasic texture with chilled edges and coarse-grained central portions. Primary quartz occurs in some thin sections of the rock. As the dikes strike about normal to the main ore zone, a longitudinal section through the camp shows their approximate dip (see Fig. 3).

There are only four dikes in the camp of sufficient size to merit description; their location is shown on the accompanying level plans. The widest dike lies near the Central shaft of the Teck-Hughes mine on the surface, but a westerly dip of 75 degrees carries it into the Kirkland Lake Gold mine below the 2,500-foot horizon. A slightly narrower dike occurs at the west end of the Lake Shore mine; on certain levels it extends over the boundary into Teck-Hughes ground on the footwall side of the Kirkland Lake fault. The over-all dip of this dike is

¹Pages 67-69.

²E. W. Todd, *op. cit.*, pp. 28, 29, 32, 36, 37.

almost vertical, although there are local rolls along it. A narrow but persistent diabase dike extends through the workings of the Toburn mine. It averages about 8 feet in width and dips about 83° W. A post-ore fault follows the plane of this dike and has produced considerable gouge along the planes of movement and altered much of the dike material to chlorite. A diabase dike about 10 feet in width cuts across the ore zone on the lower levels of the Macassa mine towards the west end of the workings; the dip of this dike is approximately vertical.

Probably the most interesting feature of the diabase dikes is their relationship to the ore. In the early days of the camp the diabase was believed to be pre-ore in age.¹ There is now, however, general agreement among the geologists of the camp that the diabase was intruded after ore deposition and that post-diabase movement along the plane of the veins produced the offset of the dikes as now observed at certain points underground. There are a number of places, especially along the subsidiary veins, where diabase dikes may be seen to cut across the ore, and there is no doubt of the relationship. Where the diabase is displaced along the Main break, it actually cuts through the veins but is offset by mud seams within the vein material so that ore may occur off the end of a dike but on the opposite side of a mud slip. At one point where a diabase dike cuts across the F vein on the 10th level in the Teck-Hughes mine, a thin film of gold was carried laterally along the margin of the dike for a few feet from the vein.

STRUCTURAL GEOLOGY

The structure in the general vicinity of the main ore zone at Kirkland Lake has been described in the first report in this volume.² Only details of structures found within the mine workings will be discussed here.

The main sequence of geological events in the vicinity of the mines has been (1) folding of the Timiskaming series, (2) intrusion of the augite syenite-syenite-syenite porphyry stock, (3) faulting and fracturing, (4) ore deposition along the breaks so formed, (5) intrusion of the diabase dikes, (6) post-ore faulting. The structures of main interest in mining operations then naturally fall into two groups, these being the pre-ore breaks, along which the gold-bearing veins were formed, and the post-ore faults, which offset the productive veins. While it is thus important to distinguish between the pre- and post-ore faults, it is not always easy to do so. In some cases pre-ore and post-ore movement have taken place along the same vein. In other instances, the age relationship of faults or fractures to ore may be in doubt. But most of the gold-bearing pre-ore breaks and barren post-ore faults along the main ore zone are well known.

The pre-ore fracture pattern of the camp has been partially controlled by the regional folding and faulting and by the shape and physical nature of the main intrusive stock. For this reason the structural features of the camp will be discussed in chronological order, as listed above.

Folding

At Kirkland Lake the belt of Timiskaming series is about 2 miles in width and strikes approximately N. 65° E. Intrusives have cut out a considerable part of the sediments and tuffs across the belt, as shown by the sections in sheet A. Structural studies, as described in the earlier report, show that the Timiskaming rocks form the north limb of a syncline. They lie unconformably on the older Keewatin volcanics along the north margin of the belt and are separated from similar volcanics to the south by the Larder Lake fault. The south limb of the

¹E. W. Todd, *op. cit.*, pp. 47, 106-107.

²Pages 22-32.

syncline has presumably been removed by upthrust along the Larder Lake fault followed by erosion. In the mine workings the beds generally have a southerly dip, which would average about 60 degrees where the strata are not locally disturbed. In places the dip of the bedding flattens to about 45 degrees, and becomes as low as 20 degrees on the surface south of the mill at the Kirkland Lake Gold mine.

Although the major structure across the Timiskaming series is homoclinal, different types of minor folds occur locally. Below the 3,750-foot level in the Kirkland Lake Gold mine, there is a well-developed anticlinal fold in the tuffs and sediments (see sheet H). These form a large inclusion in the intrusive body and occur around the margin of a porphyry plug. This anticline pitches to the west with the porphyry body. A small local syncline in the tuffs south of the No. 1 winze on the 4,125- and 4,250-foot levels at the Macassa mine may be the result of a drag in the vicinity of the intrusives and the Main break (see sheet F). Similarly, a northerly dip of the conglomerate beds near the carbonated sheared zone in the long north crosscut on the 3,075-foot level at the Lake Shore mine may be due to movements along the zone of shearing.

Shape and Structure of the Composite Intrusive Stock

Examination of the accompanying maps, plans, and sections will show that the contacts of the composite intrusive stock are rather irregular. There is generally a transition zone at the periphery of the complex in which intrusive and intruded rock are intermingled. Much of the detail regarding the outer extremities of the stock is unknown. Exclusive of the marginal irregularities, however, the stock has a definite elongation, dip, and pitch. The long axis is roughly parallel to the strike of the sediments, and satellitic dikes show the same relationship. In plan the composite stock is somewhat wedge-shaped in outline, broadening to the east (see Fig. 8 on page 88). The dip is steeply to the south, the north contact being steeper than the south contact. This results in a general widening of the intrusive complex with depth. A section through the Macassa mine (No. 2, sheet A) shows that the dip of the intrusive body is steeper than the dip of the adjoining sedimentary beds. This means that the intrusives were injected after the folding of the Timiskaming series and truncate the older strata. All these relationships are best exhibited at the west end of the camp where the intrusive body is narrower and its boundaries are more accurately known. In longitudinal section the main intrusive complex plunges downward to the west at a fairly steep angle, as shown in Fig. 3 (page 70).

The three main rock types that comprise the bulk of the intrusive complex have the same general trends as the main mass. The syenite occurs in an irregular, pipe-like form and plunges westward at an angle of about 40 degrees through the Teck-Hughes, Kirkland Lake Gold, and Macassa mines. Along the main ore zone the east extremity of the augite syenite is near the main crosscuts of the Lake Shore mine, and at depth this extremity moves westward. The main syenite porphyry body also shows a steep westerly plunge, and, being the latest phase of the intrusives, it attains greater dimensions at depth. All these features are illustrated in Fig. 3.

Pre-Ore Faulting and Fracturing

The gold-bearing veins at Kirkland Lake fill faults and fractures in the country rock. Throughout this report where displacement can be proved, these structures are defined as faults or vein-faults, and where displacement is lacking or unknown they are referred to as fractures or vein-fractures. Since displacement

can be proved at only a small number of places, many of the vein structures of the camp will come in the latter category.

Compressive stresses along the sedimentary belt following the main period of Algoman intrusion produced a number of strike faults and fault systems throughout Teck and adjoining townships. The principal gold-bearing veins of Kirkland Lake occur along one of these fault systems, and it is, therefore, called the Main break or Kirkland Lake fault. North and south of the Kirkland Lake fault there are other more or less parallel breaks, which have been explored to a limited extent. Among the parallel structures the Narrows break to the north and the Amalgamated Kirkland break to the south are the most prominent and have received the most attention.

KIRKLAND LAKE FAULT SYSTEM

Definition

Before presenting details on the Kirkland Lake fault system it should be pointed out that there are two slightly different schools of thought regarding it. The paper of the Kirkland Lake geologists¹ follows the concept that there is a continuous main fault plane across the entire camp and that all other structures are subsidiary to it. According to this idea the Kirkland Lake fault would be the most northerly continuous break through the Macassa and Kirkland Lake Gold and would continue eastward along the No. 3 vein of the Teck-Hughes and the No. 2 vein of the Lake Shore to a point near the main crosscuts. It would then diverge from the No. 2 vein and follow the diagonal veins to the South vein in the Lake Shore and Wright-Hargreaves and continue along what was formerly called the South vein through the latter property and thence along the South veins of the Sylvanite and Toburn. This interpretation of what constitutes the Kirkland Lake fault is shown on map No. 1945-1, where both it and subsidiary structures are projected to the surface.

The main difficulty with the above interpretation is that in the Lake Shore mine, between the 1,200- and 2,450-foot levels, the structure defined above as the main fault breaks up into several weak fractures, and from that point to the 4,000-foot horizon it consists of two weak slips near the junction with No. 2 vein. Instead of a single strong fault plane crossing from the No. 2 (North) to the No. 1 (South) vein, there is in reality a series of cross-over breaks angling between these veins (see Fig. 7 facing page 82 and sheet M). The over all structure thus shows main planes of faulting at the west and east ends of the camp. These are slightly offset, the east one being a little to the south. They are connected by a series of cross-over breaks in the ground lying between the 1,200- and 4,000-foot horizons in the Lake Shore and the east end of the Teck-Hughes mine. Above the 1,200-foot horizon and below the 4,000-foot horizon, there is one continuous, well-defined main plane of faulting through the entire camp.

The alternative concept is that of a Kirkland Lake fault and fracture system that comes into the west end of the camp as a single plane with local braided and parallel slip zones; going eastward it splits into more and more branches, on each of which the displacement decreases; there is, however, one branch that is stronger than the others and shows some displacement at the east extremity of the camp. This concept is more applicable in areas where there are a multiplicity of breaks on which it is not possible to prove the presence or absence of displacement. In the early days of the camp it was essential to define and follow the main fault plane because of the great amount of rich ore found along it. In recent

¹"The Gold Mines of Kirkland Lake," *Structural Geology of Canadian Ore Deposits*, Can. Inst. Min. Met., Symposium volume, 1948, pp. 644-653.

years the emphasis is more on underground exploration on the whole system of breaks throughout the camp.

The accompanying plans and sections are drawn to conform with the idea of a fault and fracture system throughout the camp, and all pre-ore breaks are indicated in one colour (red). Where the main plane of movement is definitely known, the words "Kirkland Lake fault" are printed adjacent to the red line. Even without the printed words the reader could judge which is the strongest break by its continuity on plans and sections.



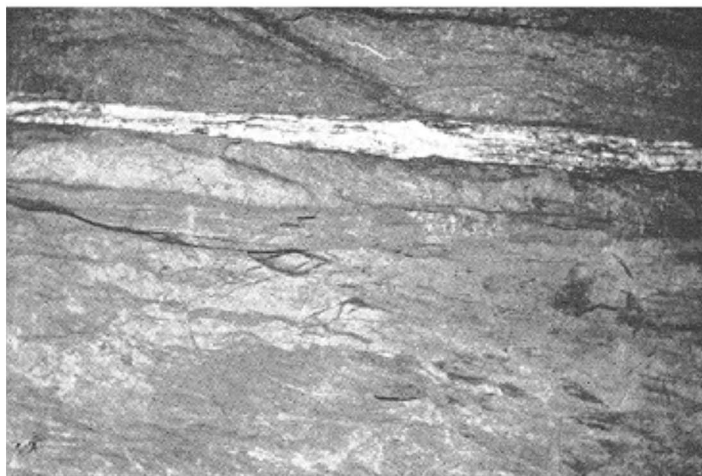
Main zone of displacement of the Kirkland Lake fault as exposed on the drift face at the east end of the 3,350-foot level, Macassa mine. Mylonite is developed adjacent to the main mud seam. The fault is not in ore at this point.

Description

The Kirkland Lake fault system is a thrust fault, which has been traced across Teck township and a short distance into Lebel township. Its overall strike through the seven producing mines is about N. 67° E. This is approximately parallel to the long axis of the main intrusive body and the trend of the beds in the Timiskaming Series; it is, therefore, a strike fault. The accompanying cross-sections show that the fault generally has a steep dip to the south; an average dip would be 75 to 80 degrees, but there are local variations from vertical to 60° S. The main plane of movement has been followed in development to the bottom of all the mine workings; in the deepest mines, it has been traced to a depth of more than 7,000 feet.

The writer has noticed that when observers first see the Kirkland Lake fault on the surface they invariably remark on the insignificance of the structure. At

present, the only exposed outcrops of the main fault in the vicinity of the producing mines are at the rear of the Macassa mine office and at the original gold discovery of W. H. Wright on Wright-Hargreaves ground. The latter location is on claim L. 1,830 about 400 feet north of the junction of the Goodfish road and Government Road East, and on the east side of the road. At the Macassa exposure there is a drift-filled depression at the augite syenite-conglomerate contact about a foot in width with two narrow parallel slips in the conglomerate. The shearing and brecciation of the syenite porphyry at the Wright-Hargreaves showing extends only a couple of feet outward from the vein. In general, unless the fault was known and being diligently searched for, it could very easily be overlooked in routine geological mapping of the surface along its entire course in Teck township.



The Main break on the 4,200-foot level, Wright-Hargreaves mine, showing the development of mylonite along the South vein structure. The main slip is filled with late calcite and quartz (white). The photograph shows the back of the drift.

Underground, the main plane of the Kirkland Lake fault is generally a single, clean-cut slip, which can be followed throughout the mine workings in the greater part of the camp. It is marked by a zone of soft gouge and schist ranging from a few inches to a few feet in width but generally confined to less than a foot. Fault grooves and striae are occasionally seen along a well-exposed surface. In places the main shear zone will break up into a number of parallel or branching slips, many of which will eventually reunite. A fault breccia containing angular and rounded fragments of the wall rock is often found with and adjoining the fault gouge.

Although the fault cuts indiscriminately across different rock types, they all show a reddish or buff-coloured discoloration adjacent to it. A feature of the fault is the development of mylonite along the walls. This is a process that shows various stages of shearing, fracturing, brecciation, granulation, and rock alteration produced by the movement of one wall over the other. In some places in the central part of the camp the mylonite may be developed over widths of several feet, whereas the mud seam may be less than an inch in width or missing. The mylonite may show distinct banding in places or it may have a well-defined

contact with the country rock and resemble a dike in appearance. Quartz veins and stringers, mylonite, and schist may be intricately intermingled. Occasionally a late generation of post-ore barren quartz and calcite occupies the main slip.

There are areas where the Kirkland Lake fault widens from a well-defined slip or closely spaced slips into a broad zone of movement. Widths of from 70 to 80 feet of heavy fracturing were found at the Kirkland Lake Gold and Teck-Hughes mines. The sections facing page 152 illustrate a zone of fracturing that attains a width of 200 feet on the North vein zone in the western part of the Lake Shore mine. In many places, under such conditions, there is a heavy mud seam along the footwall of the complex fracture system. The main zone of movement is, therefore, not always a plane but rather a network of faults and fractures. Individual faults in the network may vary greatly in strength along strike and dip as movement is transferred throughout the various slip planes in the system. There is a tendency for the faulting and fracturing to cover wider zones in the area of mixed augite syenite and syenite porphyry and to be narrower where the fault passes through a single rock type.

Pre-Ore Displacement on the Main Plane of Movement

Pre-ore displacement is calculated by the relative position of marker bodies of rock that are older than the ore on either side of the fault plane; the pre-ore rock types include all varieties of country rock except the diabase dikes.

Estimates of the amount of vertical displacement on the Kirkland Lake fault were made by Tyrrell and Hore¹ in 1926, Todd² in 1928, and the geologists of the Kirkland Lake mines³ in 1948. All have agreed that it is a thrust fault in which the south or hanging-wall side has moved upward with respect to the north or footwall side. The different estimates of the amount of vertical displacement range between 1,400 and 2,000 feet at the west end of the camp. By matching the lamprophyre-greywacke contact on either side of the fault at the Kirkland Lake Gold mine, Tyrrell and Hore calculated a vertical displacement of from 1,850 to 1,875 feet. Similarly, by matching the tuff-conglomerate contact, Todd estimated a vertical component of 2,015 feet at the Kirkland Lake Gold mine. Both of these calculations involve a considerable projection of contacts above the surface and also assume a uniform dip for these contacts.

With the deep development of the mines, it is now possible to match similar bodies of rock that lie entirely within the underground workings, thus eliminating long projections above the surface. By plotting the footwall and hanging-wall geology along the plane of the Kirkland Lake fault on separate sheets, key horizons can be matched to give a fairly accurate estimate of displacement. The splitting of the fault into a number of planes in certain areas produces a number of rock slices and makes it impossible to match the rock bodies exactly on a single plane. In addition, the mixture of rock types adjacent to the fault is so intricate over large areas that accurate matching would be impossible, even if the fault followed a single plane. But the outline of the pitching pipe-like body of syenite in the Teck-Hughes, Kirkland Lake Gold, and Macassa mines affords an estimate of displacement that would be accurate within a couple of hundred feet. Using this method the Kirkland Lake geologists⁴ calculated a vertical displacement of 1,400 feet at the west end of the camp. The writer's calculation, using the same

¹J. B. Tyrrell and R. E. Hore, *Trans. Roy. Soc. Can.*, 3rd series, Vol. 20, pt. 1, sect. 4, 1926, pp. 51-63.

²E. W. Todd, *Ont. Dept. Mines*, Vol. XXXVII, 1928, pt. 2, pp. 43-46.

³"The Gold Mines of Kirkland Lake," *Structural Geology of Canadian Ore Deposits*, Can. Inst. Min. Met., Symposium volume, 1948, p. 646.

⁴*Ibid.*

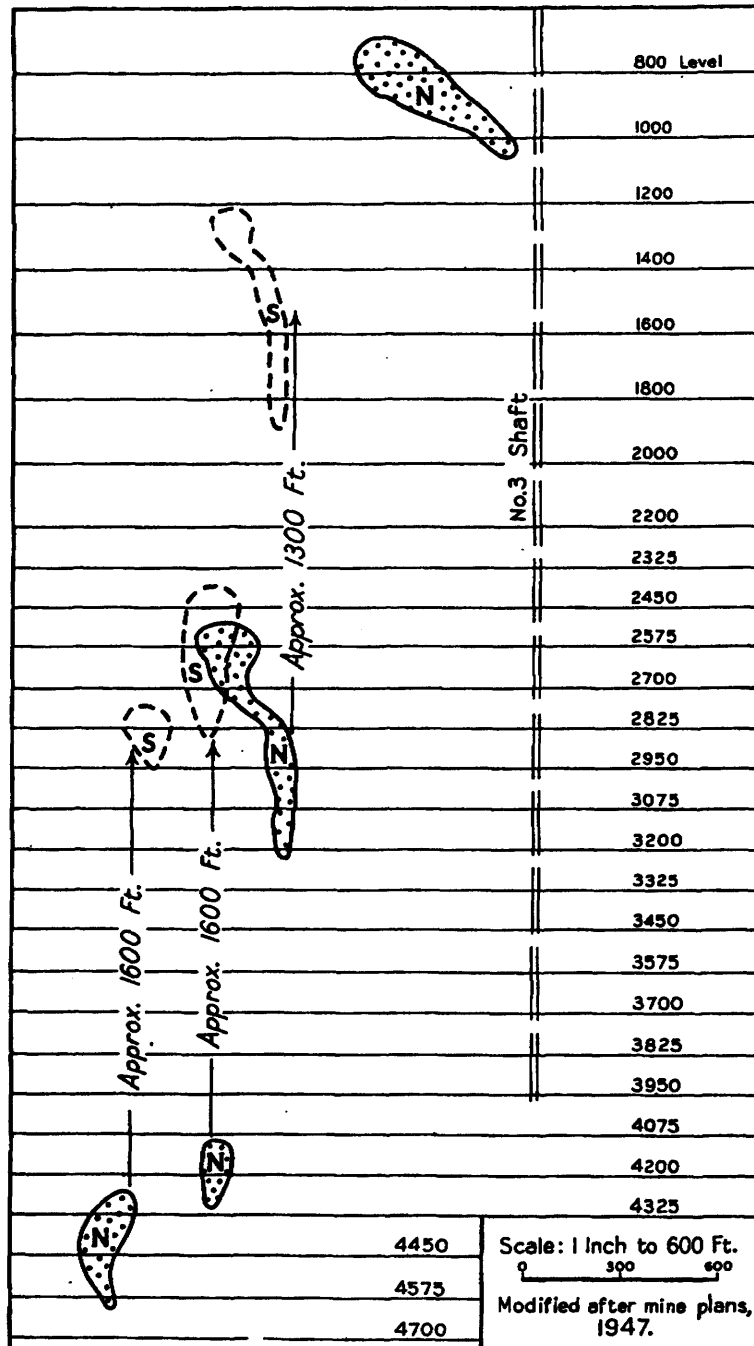


Fig. 4--Longitudinal section of part of the Lake Shore mine, showing how the offset of quartz-feldspar porphyry bodies on the North (No. 2) vein indicates a pre-ore vertical displacement on the Kirkland Lake fault. (N= quartz-feldspar porphyry bodies on the north or footwall side of the fault; S=displaced portions of the quartz-feldspar porphyry bodies on the south or hanging-wall side of the fault.)

method, shows that the south side has moved upwards approximately 1,500 feet, with practically no horizontal component.

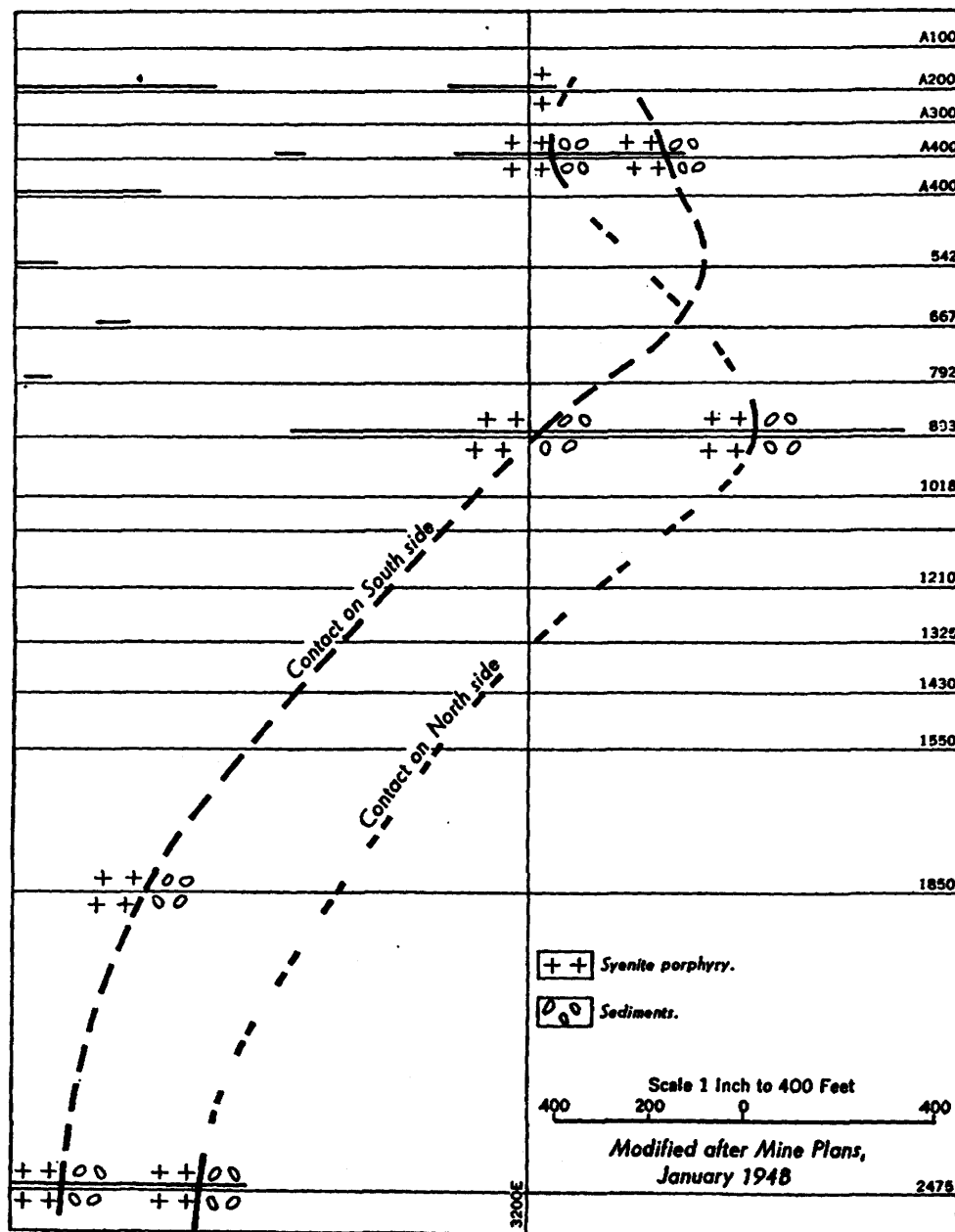


Fig. 5--Longitudinal section on the plane of the South vein (Kirkland Lake fault) at the Toburn mine, showing the displacement of the syenite porphyry-sediments contact by the fault.

In the central part of the camp there are no sizeable key horizons adjacent to the fault plane, and complications are provided by the splitting of the structure into different branches. In the Teck-Hughes and Lake Shore mines the sediments

extend downward to a depth of 800 feet on the footwall of the fault and are missing on the hanging wall, indicating a minimum displacement of 800 feet. Similarly, patches of sediments on the footwall of the Wright-Hargreaves mine show a minimum displacement of 550 feet. Todd¹ points out that these could not be ordinary intrusive contacts because on the Teck-Hughes property the faulted contact cuts off porphyry dikes. Additional data on the displacement along No. 2 vein of the Lake Shore mine is provided by the offset of three small patches of quartz-feldspar porphyry, as illustrated in Fig. 4. The information here suggests that the hanging wall moved vertically a distance of between 1,300 and 1,600 feet.

At the east end of the camp the offset of the syenite porphyry-greywacke contact along the South vein of the Toburn mine shows the displacement on the main plane of the Kirkland Lake fault. As illustrated in Fig. 5, the south or hanging-wall side of the fault has moved upward approximately 350 feet; the horizontal component is negligible in amount.

In summary, the pre-ore displacement on the main branch of the Kirkland Lake fault is rotational, amounting to about 1,500 feet at the west end of the camp and approximately 350 feet at the east end.

Pre-Ore Displacement on Branches

The main branches on the south side of the structure described above are No. 6 break in the Kirkland Lake Gold and Teck-Hughes mines, the South vein zone at the Lake Shore and Wright-Hargreaves mines, and certain unnamed veins in the South vein zone of the Sylvanite and Wright-Hargreaves mines.

No. 6 break is a strong structure that branches off the Main break in the lower workings of the Kirkland Lake Gold and Teck-Hughes mines. The line of intersection of the two structures pitches to the west at an angle of about 20 degrees (see Fig. 10 facing page 134). No. 6 break is a well-defined mud seam, similar in many respects to the Main break, but it has a flatter dip. It can be traced eastward across the Teck-Hughes mine. The amount of displacement on No. 6 break is unknown, but it appears to offset the crest of the anticlinal structure in the Kirkland Lake Gold mine (see sheet H).

The South vein at the Wright-Hargreaves and Lake Shore mines and No. 4 break at the Teck-Hughes constitute another important branch of the Kirkland Lake fault System; this merges with the main plane of displacement at depth in the Lake Shore mine, as it probably does in the Teck-Hughes mine, although the actual junction has not been found in the latter case. Much of the South vein zone in the Lake Shore mine consists of a series of diagonal fractures that branch off the North vein, which makes it a discontinuous and irregular structure, which may have varying displacements on different component parts. Todd² suggested the possibility of an 800-foot vertical displacement on this vein zone, and the Kirkland Lake geologists³ estimate it to be 500 feet.

The writer does not know of any measurable pre-ore displacements along the South vein zone, although some must exist because the diagonal breaks carry the main plane of movement from the North vein to the South vein.

There are no branches on the north side of the Kirkland Lake fault at the west end of the camp. No. 1 vein of the Teck-Hughes mine follows a subsidiary fracture on this side of the Main break down to the 9th level, where the structures merge. In the Lake Shore mine the North or No. 2 vein continues eastward as a

¹E. W. Todd, *op. cit.*, p. 43.

²*Ibid.*, p. 48.

³*Structural Geology of Canadian Ore Deposits, Can. Inst. Min. Met., Symposium volume, 1948, p. 646.*

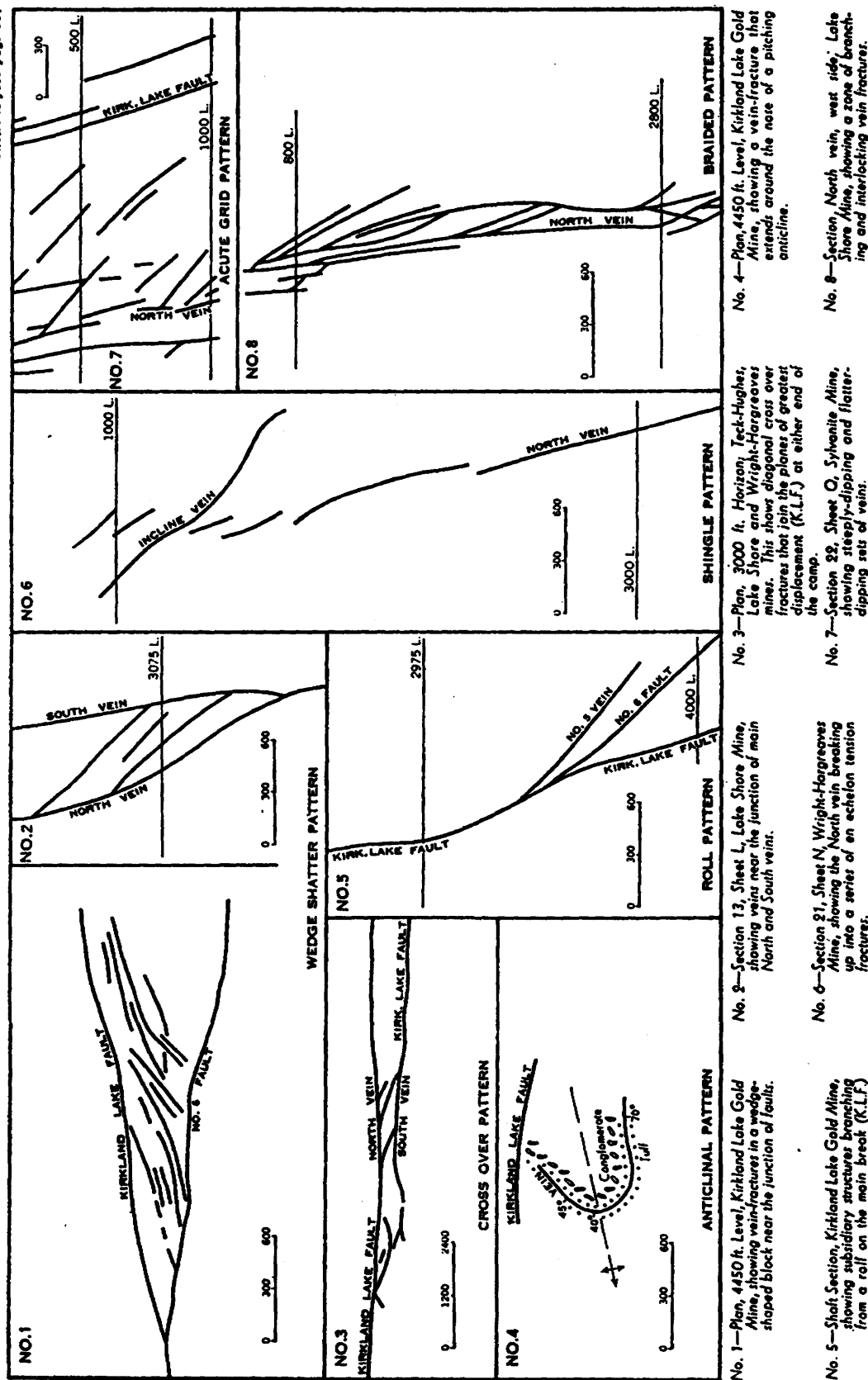


FIG. 6—DIAGRAMMATIC ILLUSTRATION OF SOME TYPES OF VEIN-FRACTURING ALONG THE MAIN ORE ZONE AT KIRKLAND LAKE.

strong structure from the junction of the various diagonal cross-overs that carry the main fault displacement to the South vein. The North vein is an important ore-producing structure through the Wright-Hargreaves, Sylvanite, and Toburn mines. Hopkins¹ has pointed out that where this structure crosses the syenite porphyry-greywacke contact at the east boundary of the Wright-Hargreaves mine on the 3,300-foot level the offset is only a couple of feet. The displacement on the North vein fault must thus decrease rapidly to the east. It dies out as a series of flatly dipping *en échelon* fractures on the upper levels of the Wright-Hargreaves, Sylvanite, and Toburn mines. These tensional fractures in places form a "shingle" pattern (see Fig. 6, No. 6, facing page 80).

Other breaks that angle off the north side of the main plane of displacement of the Kirkland Lake fault are No. 20 break at the Wright-Hargreaves mine and the North Branch vein of Sylvanite and Toburn mines. A few feet of pre-ore displacement is found along the North Branch vein in the Toburn mine.

Summary of Pre-Ore Displacement

The data on the pre-ore displacement of the Kirkland Lake fault system may be summarized as follows: At the west end of the camp there is a vertical thrust of about 1,500 feet on the main Kirkland Lake fault. Approximately the same amount of displacement occurs in the structure on the western part of No. 2 vein at the Lake Shore mine. To the east of this area the displacement is rapidly dissipated on a number of branches. The strongest branch in the fault system, however, is continuous along the South vein zones of the Wright-Hargreaves, Sylvanite, and Toburn mines and shows a vertical displacement of 350 feet in the western part of the Toburn mine. It is thus a rotational fault system, being pivoted near the termination of the various branches at the east end of the camp. It is also noticeable that the displacement decreases rapidly when the structure enters the main syenite porphyry body.

NARROWS BREAK

The Narrows break is roughly parallel to the Kirkland Lake fault on the north side of the main ore zone. In the Lake Shore mine it is called No. 3 vein zone and lies from 1,200 to 1,600 feet north of No. 2 (North) vein (see sheet D and section No. 3, sheet A). To the west it is exposed on the surface on Teck-Hughes ground and has been explored on the 30th level in the mine, where it lies 2,000 feet north of the Main break (see sheet E). Almost a mile farther west there is a vertical break in the long north crosscut from the Macassa mine that could represent a possible extension of the structure. Eastward from the Lake Shore, the Narrows break has been explored by drifting and diamond-drilling at many horizons in the Wright-Hargreaves mine to the bottom of the workings. It is represented at depth in this mine by No. 9 vein (see section No. 20, sheet N). At the Sylvanite mine the Narrows break might possibly be represented by the North A vein, although it is out of alignment. Similarly one of the steep breaks in the northern part of the Toburn mine might be part of the structure.

The Narrows break appears to be a zone of discontinuous fractures arranged *en échelon*, especially on the dip. For this reason it is lacking in continuity. It has a very steep over-all dip, which is approximately parallel to the main Kirkland Lake fault. Where exposed in underground workings, the Narrows break is generally a narrow, irregular slip. Nothing is known regarding possible displacement along it.

¹Harold Hopkins, *Trans. Can. Inst. Min. Met.*, Vol. 43, 1940, p. 689.

FRACTURING

Several types of pre-ore fracturing along the main ore zone at Kirkland Lake are illustrated in Fig. 6 (facing page 80). These types may be grouped in various ways, as shown by the detailed plans and sections of the various mines, to form the vein-fracture pattern of a mine and of the entire camp. Some idea of the over-all fracture pattern of the main ore zone is given in Fig. 7 (facing this page), where a generalized picture of the outstanding features of the camp is shown on a group of small drawings. It has been pointed out that the general vein-fracture system of the Lake Shore mine is roughly the same in plan as in section.¹ This statement would apply equally well to the other mines. It might even be stated that the same general pattern of fracturing can be found on all scales from that sometimes seen in hand specimens of vein material up to the regional system of rock dislocation along the mineral belt.

In addition to the strong, steeply dipping breaks, which have been described previously, the main ore zone contains innumerable fractures, many of which are subsidiary to the steeper structures. Most of the subsidiaries are tension fractures that accompany and are complementary to the faulting movements (see Fig. 7). These fractures have a flatter dip than the upright structures and generally branch from them on the south side. They may lie parallel to a major fault or angle between two major structures. The subsidiary fractures were produced as the south side of the Kirkland Lake fault system was thrust upward over the north side. In some places there is a tendency for the fractures to branch off the crest of a roll on the plane of the stronger break. This set of inclined subsidiary fractures is well illustrated on the accompanying cross-sections, especially throughout the Macassa mine and by No. 5 vein at the Kirkland Lake Gold mine and various veins in the Teck-Hughes mine.

Another favourable location for a set of tension fractures is in the wedge-shaped block of ground between branching major breaks (see Fig. 6, Nos. 1 and 2). These conditions are found in the area between the North and South vein faults at the Lake Shore mine and between No. 6 break and the Main break at the Kirkland Lake Gold mine and on a larger scale in the Incline vein of Wright-Hargreaves and Sylvanite mines. Another illustration of this pattern is seen on section No. 18, sheet N, between the 200- and 700-foot levels of the Wright-Hargreaves mine. The tension fractures angle across the ground between the stronger containing breaks but in some cases may not connect directly with the bounding faults. Thus, drifting along the main fault may not reveal the presence of the subsidiary vein fracture.

The Incline vein at the Wright-Hargreaves and Sylvanite mines is one of the largest subsidiary structures in the camp and illustrates large-scale fracturing between the North and South vein faults. It extends from the 1,000- to the 2,250-foot horizons and has a maximum over-all length of three-quarters of a mile (see the 1,600-foot horizon, sheet C, and section No. 21, sheet N). The Incline vein has an average dip of 45° S. but locally consists of *en échelon* fractures with variable dips. It follows an arcuate course, diverging from the North vein zone in the Wright-Hargreaves mine and returning close to it in the Sylvanite mine. Down the dip it connects with No. 20 break, which in turn branches from the main Kirkland Lake fault.

It has been pointed out in a previous section² that the displacement on the North vein fault of the camp dies out in the Wright-Hargreaves mine. As the faulting weakens along this structure there is a transition to a zone of *en échelon*

¹W. T. Robson, "Lake Shore Geology," *Trans. Can. Inst. Min. Met.*, Vol. 39, 1936, p. 108.

²Page 81.

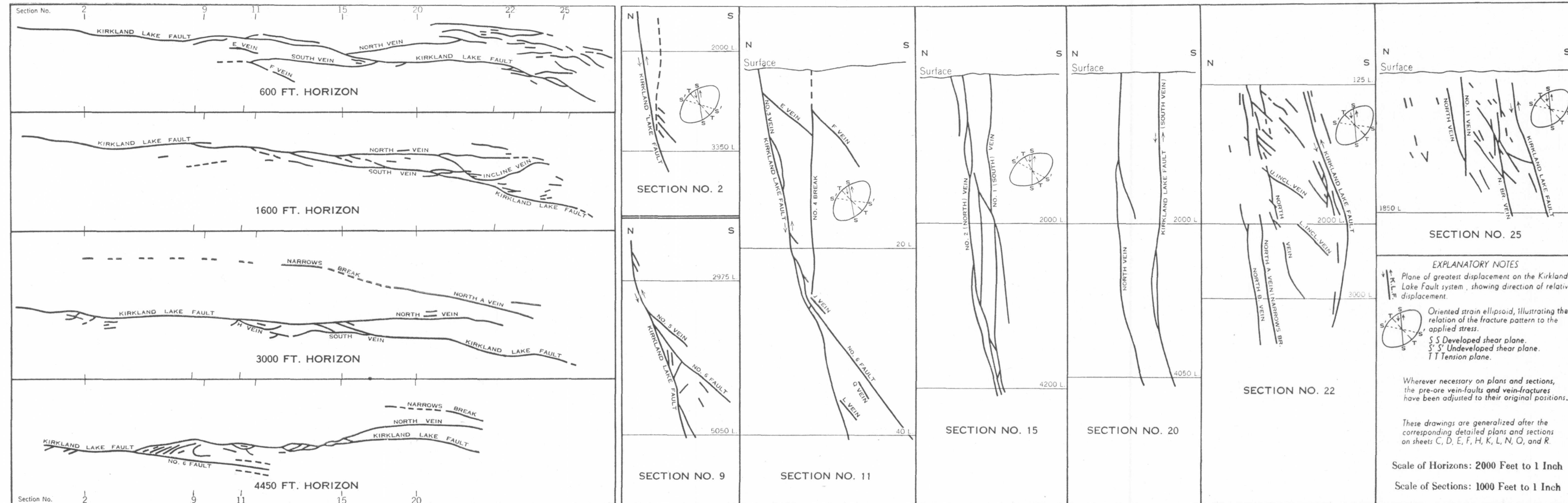


FIG. 7 — VEIN-FRACTURE AND VEIN-FAULT PATTERNS ALONG THE MAIN ORE ZONE AT KIRKLAND LAKE.

vein-fractures. These are rather flat-dipping, overlapping veins, arranged like shingles on a roof (see Fig. 6, No. 6). This shingle pattern is found along the North vein in the Wright-Hargreaves mine and pitches to the west at depth along with the general weakening of the North vein fault. The shingle pattern is a product of tensional strain in a block of ground affected by upward stresses on the south side but lacking any appreciable movement. An analysis of the mechanics of fracturing is shown in Fig. 7.

A unique set of fractures is developed in the anticlinal structure at the Kirkland Lake Gold mine (see 4,450-foot horizon, sheet E). Here the fractures are curved or horseshoe-shaped in plan and conform with the folded strata in strike and dip (see Fig. 6, No. 4).

A feature of the pattern of the subsidiary vein fractures throughout the camp is their occurrence on the south side of the Main break at the west end of the camp and on the opposite side of the main plane of displacement of the Kirkland Lake fault at the east end. The location of subsidiary vein fractures with respect to the main zone of displacement is transferred from the south side in the area west of the Lake Shore mine to the north side east of that property. In the Sylvanite and Toburn mines the vein-fracture zone attains a maximum width of 1,500 feet, most of which lies on the footwall side of the main fault. In the central part of the camp the vein-fracture system averages about 400 feet in width, with abnormal widths up to 1,000 feet in the vicinity of flat-branching structures; this is exclusive of the Narrows break. Towards the west end of the camp, No. 6 break widens to more than 800 feet, but this is exceptional; elsewhere, the maximum width of vein-fracturing is around 300 feet and would average much less. Thus, the zone of vein-fracturing widens to the east along the upper horizons in the camp. There is not enough information on lower horizons to permit a general statement.

SHEARED ZONES

In some respects the Kirkland Lake fault might be considered as a narrow sheared zone. This section, however, deals with fairly wide zones of schist and attendant rock alteration. The largest sheared zone in the country is the Larder Lake fault; this structure lies outside the mine workings and is described in an earlier part of this volume.¹ The only broad zone of shearing found in the area covered by underground exploration lies within a few hundred feet of the Keewatin-Timiskaming contact on the north side of the sedimentary belt. It is exposed in the long north crosscut into Kirkland Basin ground on the 3,075-foot level at the Lake Shore mine and consists of a zone of carbonate schist and barren quartz veins and stringers over a width of 170 feet in the conglomerate (see sheet D). A sheared zone more than 100 feet in width was cut in a hole drilled north from the end of the crosscut into Casakirk ground at the 2,950-foot level of the Macassa mine (see sheet D). Although these two intersections are more than a mile apart, they are in alignment and may represent the same zone of shearing. If projected upward this sheared zone would underlie the west bay of Kirkland lake on claims L. 2,823 and 6,446. It has not been recognized on the surface, although a little shearing may be seen on claim L. 1,429 at an old shaft and on claim L. 1,432 (see map No. 1945-1).

Post-Ore Faulting

Faults that offset the gold-bearing veins are commonly found in the eastern part of the camp but are rare in the western part. The complex faulting at the

¹Pages 27-29.

east end of the ore zone may be attributed to the fact that it lies in a great fault wedge bounded by the Lake Shore fault and the northward-dipping Murdock Creek fault system. In this area, and especially in the Wright-Hargreaves mine, there have been developed four sets of post-ore faults, most of which are of slightly different age. These have been described in detail by Hopkins.¹

The post-ore faults along the main ore zone of the camp are indicated on the accompanying plans and sections by the blue lines. Details of the post-ore faulting in each of the mines is given in the reports covering individual properties.

POST-ORE DISPLACEMENT OF THE KIRKLAND LAKE FAULT SYSTEM

The first faulting to take place after ore deposition consisted of horizontal movements along the plane of the veins. The total amount of post-ore displacement along the Kirkland Lake fault system cannot be calculated, but the portion that followed the introduction of the diabase dikes is readily measured. By plotting the location of the diabase dikes on longitudinal sections on either side of the main Kirkland Lake fault, it is found that the post-ore movement is almost entirely horizontal, the south or hanging-wall side having moved an average distance of about 80 feet to the east in the central part of the camp. This figure is obtained from the average offset of the Teck-Hughes and Lake Shore dikes, although locally there are displacements of more than 100 feet. Grooves and striae on the fault plane show that the direction of the latest movement was horizontal. In contrast to the 80-foot movement in the central part of the camp, a diabase dike at the Macassa mine is offset about 2 feet along the Main break, and two dikes at the Toburn mine are displaced about 8 feet horizontally.

Displacement of the diabase by No. 4 break at the Teck-Hughes is about the same in amount as along the Main break.

PRINCIPAL SETS OF POST-ORE FAULTS

There are two principal sets of post-ore faults in the Kirkland Lake camp. As one set of faults trends more or less parallel to the productive veins, they are strike faults. These are offset by the transverse or cross faults. The strike faults generally have a flatter dip than the veins or vein-faults. They exhibit shearing, wall-rock alteration, and even traces of mineralization. The wall-rock alteration along certain strike faults is similar in appearance to that along the ore zones and suggests that some pre-ore movement preceded the post-ore movement. The strike faults may contain late barren quartz and calcite and occasionally barite and gypsum. In contrast, the cross faults are generally clean-cut, gouge-filled single or multiple slips; they frequently contain fault breccia and occasionally show stringers of late quartz and calcite. The strike faults are thrusts formed under compression, whereas the transverse set are normal faults of tensional origin and show rotational displacement.

The order in which the different sets of post-ore faults were formed is given by the Kirkland Lake geologists² as follows:—

FIRST.—South-dipping strike fault at Lake Shore and Wright-Hargreaves—overthrust from south to north.

SECOND.—Early transverse fault, Lake Shore fault—rotatory.

THIRD.—Major north-dipping strike faults, Nos. 1, 2, 5, 6, at Wright-Hargreaves, Sylvanite, and, in part, Toburn—underthrust from south to north.

FOURTH.—Later transverse normal faults, Dike fault, Major (K), Sylvanite, F, L, and numerous smaller ones—formed under tension. Majority rotatory.

¹Harold Hopkins, *op. cit.*, pp. 689-698; and pp. 171-176 of this volume.

²Structural Geology of Canadian Ore Deposits, *Can. Inst. Min. Met., Symposium volume*, 1948, p. 651.

Southward-Dipping Strike Faults

There are a few southward-dipping strike faults in the upper horizons of the Lake Shore mine; these have displaced the veins a short distance, the hanging wall being thrust upward over the footwall. One of these has been traced along the 1,600-foot level across the Lake Shore property, where it offsets both the North and South veins a slight amount (see sheet L and 1,600-foot horizon, sheet C). It lines up with a fault in the pump station at the South shaft of the Teck-Hughes on the 17th level (see section 11, sheet K). This fault may even continue through the south drift on the 1,600-foot level in the Kirkland Lake Gold mine, as shown on the composite level plan of that horizon (sheet C). Officials of the Kirkland Lake Gold Mining Company, however, believe that this structure, called the Chaput-Hughes break on their property, is pre-ore.¹ Either the southward-dipping post-ore fault should not have been extended westward beyond the Teck-Hughes property on sheet C, or else pre-ore and post-ore movement took place along the same structure in certain places. Eastward from the Lake Shore mine, it might correspond with No. 4 strike fault in the Wright-Hargreaves mine, after allowing for the displacement on the Lake Shore fault. In the Wright-Hargreaves mine, No. 4 strike fault cuts the North vein around the 1,625-foot level² and the South vein (Kirkland Lake fault) below the 2,550-foot level (see section 18, sheet N). The dip of the fault is uniformly to the south at angles ranging from less than 45 degrees to more than 70 degrees. The displacement is generally between 50 and 100 feet west of the Lake Shore fault; in the Wright-Hargreaves mine it displaces the North vein 55 feet.³

Lake Shore Fault

The Lake Shore fault is the strongest and most important of the transverse faults in the camp. It has been traced to the bottom of the workings in the Lake Shore and Wright-Hargreaves mines. The F and L faults branch off the Lake Shore fault on the east side and slightly diverge from it in strike. The F fault splits off near the 1,250-foot level of the Wright-Hargreaves mine and cuts the veins up to its junction with the westward-dipping Sylvanite fault. The L fault branches from the Lake Shore fault around the 2,850- and 3,000-foot horizons and likewise cuts the veins.

The Lake Shore fault dips steeply east above the junction with the L fault, but below this point it reverses its dip so that at depth it is almost vertically below its surface position. Above the junction with the L fault the horizontal displacement on the Lake Shore fault ranges between 600 and 750 feet, and the vertical component is about 325 feet; the east side of the fault moved down and north with respect to the west side. Hopkins⁴ states that the movement on the Lake Shore fault is rotational, the angle of rotation being 19 degrees.

The Lake Shore fault is readily identified as a well-defined plane or series of planes containing chloritic gouge and fault breccia over widths of a few inches. Barren quartz and calcite are found sparsely distributed along the fault plane, which cuts the veins without much drag or disturbance in its immediate vicinity.

Major Northward-Dipping Strike Faults

There are four northward-dipping strike faults in the Wright-Hargreaves mine, numbered 1, 2, 6, and 5 (see sheet N); some of these extend through the

¹See page 136.

²Harold Hopkins, *op. cit.*, p. 689.

³*Ibid.*, p. 691.

⁴*Ibid.*

Sylvanite mine (see sheet Q). Nos. 1, 2, and 6 faults are found only east of the Lake Shore fault and thus do not occur in the Lake Shore mine; the junction of No. 5 fault and the Lake Shore fault would be below the present workings in the Lake Shore mine. The veins have been thrust up the hanging wall of these faults causing gaps in their vertical continuity. Sections Nos. 20a and 20, sheet N, show the position of the veins before and after post-ore faulting took place. In places there is a noticeable drag of the veins near this set of faults.

Faults numbered 1, 2, 5, and 6 are described in detail in the accompanying report on the Wright-Hargreaves mine by Harold Hopkins.¹ No. 5 is the strongest fault of the group and shows the greatest displacement. The upward projection of this fault would coincide with the Murdock Creek fault, which is a very pronounced structure on the surface (see map No. 1945-1). Underground it is a curving structure both in strike and dip. To the east it is a strike fault, but to the west it swings around to the south and appears to merge with the Lake Shore fault. In the Wright-Hargreaves mine it has a maximum displacement of 700 feet, the vertical component being 500 feet and the horizontal component being 425 feet. In the Sylvanite mine the evidence of displacement is not so definite, and there is even a suggestion that the veins could branch off this structure. The Toburn mine is not deep enough to enter No. 5 fault zone, but the Murdock Creek fault, which is presumably the same structure, has been cut in drilling to the south (see sheet S).

A feature of No. 5 strike fault is the shearing and rock alteration along it, especially on the footwall side. Mylonite is developed in the same manner as along the pre-ore structures. If alteration is any criterion of age, it would appear that there had been some pre-ore movement in addition to the post-ore displacement along this fault.

Later Transverse Faults

The transverse faults offset the strike faults as well as the veins in the part of the ore zone lying east of the Lake Shore fault. Sheets P-1 and P-2, prepared by Hopkins, show the way in which the displacement on these faults is calculated at different horizons and illustrates the rotational movement that has taken place. The Sylvanite and K (or Major) faults of the Wright-Hargreaves and Sylvanite mines and the Dike fault of the Toburn are the three main dislocations in the set, although there are many minor cross-slips in all the mines, and especially at the east end of the camp.

The set of transverse faults in the Wright-Hargreaves mine dips to the west at angles ranging from 60 to 80 degrees, and in each case the west side of the fault has moved downward, that is, they are normal faults. The Dike fault in the Toburn mine dips steeply to the west, and the displacement is entirely vertical, the west side having dropped down about 350 feet. Collectively, the set of transverse faults shows a progressive sinking of fault blocks from the east end of the camp westward to the Lake Shore fault, beyond which the ground is comparatively stable in so far as late faulting is concerned.

The Cause of Faulting and Fracturing

Up to this point the description of the structure along the main ore zone at Kirkland Lake has been largely factual. The following discussion is a theoretical analysis of the way in which the fault and fracture systems were formed and is, therefore, more speculative than the rest of this report. The only reason for considering this matter is that if the mechanics or form of the vein pattern could

¹Chapter VIII, pp. 172-174.

be correctly interpreted, it would be of some assistance in the search for undiscovered or overlooked portions of the vein system. The complexity of the fracturing, however, superimposed as it is on a variety of host rocks, provides a combination of factors that cannot be solved mathematically, nor does it conform to any ideal fracture pattern; consequently personal opinion may weigh more heavily than scientific truth in drawing conclusions.

McKinstry¹ has pointed out that fracture patterns in intrusive rocks bear a closer resemblance to the theoretical pattern than fracture systems in layered rocks, which are less homogeneous; hence, in this regard, the ore zone at Kirkland Lake offers better possibilities of analysis than such zones in many other mining camps. He also shows that if the host rocks were homogeneous and the stresses uniform, the theoretical fracture pattern would consist of two sets of complementary shear planes plus a set of tension fractures in the plane that bisects the angle between the shears. Although, in theory, there are two sets of shears, one set may actually develop before the other and relieve the stress, so that the second set may not develop at all or be quite weak.

Pre-Ore Faulting and Fracturing

The forces that produced the Kirkland Lake fault and fracture system have generally been attributed to thrust stresses applied from a southerly direction.² These forces would presumably be set up by the crustal shortening during the mountain-building processes that followed Timiskaming sedimentation and accompanied Algoman plutonic intrusion. In other words, the fracture pattern is related to regional forces. If this is the correct explanation—and it seems logical—then, the region was still under compression even after the solidification of the composite intrusive stock at Kirkland Lake. It might be noted here that this stock is not sheared throughout its entire mass. Instead, the greater part of the intrusive complex along the main ore zone is extremely massive and the sheared zones are quite narrow. The main fault system cuts directly through the central part of the elongated stock and maintains this position to great depth, where it is in an igneous body of considerable lateral dimensions. The dip of the fault system, which is very steep when compared with most thrust-fault systems throughout the world, is also maintained to great depth, although it shows a slight flattening in the Macassa mine at depth.

There is another force of purely local nature that should at least be considered as a possible source of faulting and fracturing. This is the force exercised by the solidification and cooling of the composite intrusive stock. It is a well-known fact that in this process an igneous body decreases in volume, thereby creating internal strains that result in faulting and fracturing. Leith³ states that in areas of igneous rocks there is so much intricate faulting as the result of internal strains that known faults should not be projected much beyond the point of actual exposure. After studying many mining districts, Spurr⁴ concluded that post-intrusive faulting and ore deposition are the result of the contraction of intrusive bodies on consolidation. Hulin⁵ says that the change of state from fluid magma to crystalline granitic rock may cause volume decrease approximating

¹H. E. McKinstry, "Mining Geology," Prentice-Hall, Inc., New York, 1948, p. 300.

²E. W. Todd, *op. cit.*, p. 41.

W. T. Robson, *Trans. Can. Inst. Min. Met.*, Vol. 39, 1936, p. 108.

Harold Hopkins, *op. cit.*, p. 699.

³I. C. K. Leith, "Structural Geology," Henry Holt and Co., New York, 1923, p. 90.

⁴J. E. Spurr, "The Relation of Ore-Deposition to Faulting," *Econ. Geol.*, Vol. 11, 1916, p. 619.

⁵C. D. Hulin, "Factors in the Localization of Mineralized Districts," *Mining Technology*, Jan., 1945, *Amer. Inst. Min. Eng.*, p. 7.

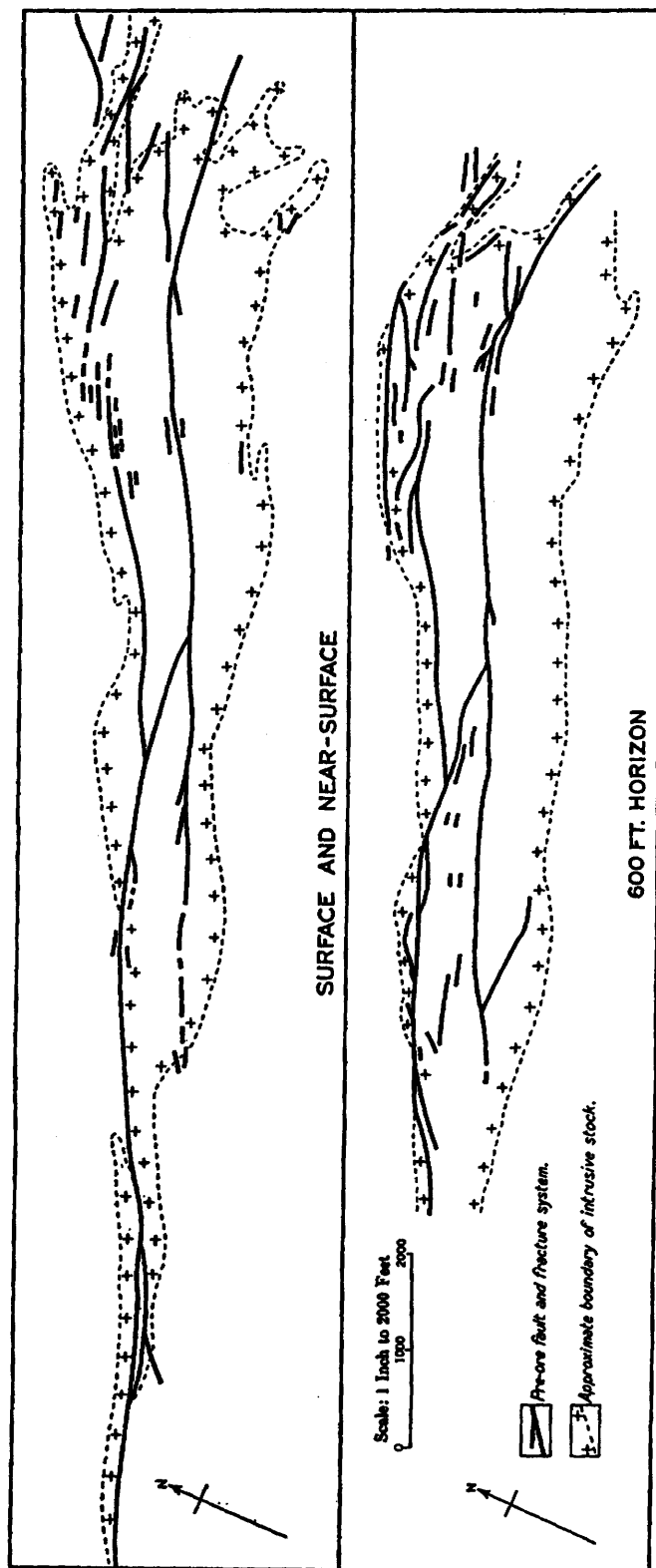


FIG. 8—PLANS SHOWING THE RELATION OF THE PRE-ORE FAULT AND FRACTURE SYSTEM TO THE COMPOSITE INTRUSIVE STOCK, MAIN ORE ZONE, KIRKLAND LAKE.

10 per cent., and that following solidification, thermal contraction, due to cooling of the rock body, causes a further volume reduction of 6 per cent. This contraction is thought to produce a succession of minor faults, which maintain the permeability of the rock body for the mineralizing solutions.

The close spatial relationship between the vein-fracture system and the augite syenite—syenite—syenite porphyry stock at Kirkland Lake is shown by the accompanying maps, plans, and sections. The relationship in plan for the upper part of the ore zone is shown diagrammatically in Fig. 8. Unfortunately, the outline of the composite intrusive body is not sufficiently established at depth to allow any accurate comparison at lower horizons. In section, the spatial relationship between the vein-fault and the intrusive complex is shown on section No. 2, sheet A. Sheets Q and R and section No. 20a, sheet N, show the vein-fracture pattern in relation to the north boundary of the syenite porphyry.

The shrinkage pattern produced within and adjacent to the composite intrusive stock by cooling could possibly be the primary control for a minor part of the vein-fracture pattern at Kirkland Lake. According to Hulin,¹ the cooling of the intrusive would tend to form a series of concentric shells parallel to the periphery of the body; this would be due to thermal contraction along radial lines. But lack of homogeneity in the rock and continuous external pressures would prevent any such regular fracturing. Instead, there would be developed only lines of weakness or potential fractures in the rock; these would guide and control the location of later movements. At Kirkland Lake, the stronger lines of weakness would strike parallel to the long axis of the stock and have the same relationship on the dip. They would bear a definite relationship to local contacts with the enclosing formations. For example, they would bend around folds such as the anticline in the Kirkland Lake Gold mine. The whole system would pitch with the different phases of the intrusive body.

The gold-bearing veins at Kirkland Lake, however, actually lie along openings that were formed after thrust-faulting (Kirkland Lake fault system) had been superimposed on whatever potential fracture pattern had been formed by the cooling of the intrusive complex. As pointed out previously,² the thrust-fault system is rotational in type with the maximum displacement at the west end of the camp. The movement becomes dissipated on a number of branches going eastward, and this is especially marked after the fault system passes into the syenite porphyry. Therefore, at the west end of the camp the influence of the Main break predominated over the earlier potential fracture pattern, but the structure followed such earlier shrinkage controls as strike, dip, and pitch. At the east end of the camp the fault system caused only a gentle reorientation of the lines of weakness in the earlier shrinkage pattern. Here, the main vein-fractures tend to parallel the adjacent (north) sediments-porphyry contact in strike, dip, and pitch, regardless of whether they lie in the intrusive or intruded rock.

At different points along the main ore zone, the combined influence of the shrinkage pattern and the later fault pattern is to be seen. For example, as previously mentioned, at one locality in the Kirkland Lake Gold mine, the influence of concentric shrinkage around the anticline of sediments predominated over the shearing influence of the Main break, so that the veins follow around the beds rather than cut across them. In the Teck-Hughes mine and the western part of the Lake Shore mine, the cooling of intermingled rock types with differing coefficients of expansion produced a widespread zone of potential fractures. Re-

¹C. D. Hulin, *op. cit.*, p. 15.

²Page 81.

current movements in the later Kirkland Lake fault would open and reopen the part of this system adjacent to it. To the east, where the host rock is a large uniform body of syenite porphyry, the shrinkage was more regular and confined to definite narrow breaks, which lie more or less parallel to the sediments contact. The shrinkage pattern in each phase of the intrusive complex would be roughly related to the shape and size of that body, thus, for example, accounting for the well-developed vein-fracturing within the pitching pipe-like body of syenite at the west end of the camp. In this way the earlier shrinkage pattern could have exerted an unobtrusive, but nevertheless firm control on the over-all strike, dip, pitch, and extent of the main Kirkland Lake ore zone. Regardless of how adequate this explanation may be, proof that some sort of control was exercised by the composite intrusive body is shown by the fact that the entire precious metal production of the camp to date has come from ore shoots in it or in the sediments of the contact zone.

The vein-fracture pattern of the Kirkland Lake camp and its association with the Kirkland Lake fault system is shown diagrammatically in Fig. 7 (facing page 82). By reference to the strain ellipsoid, it is shown in the diagrams how the upward movement on the south side of the main plane of displacement in the Kirkland Lake fault system could have produced the steep breaks along planes of shearing and flatter vein fissures along the accompanying tensional openings. Although the steeper veins may follow the fault planes, much of the actual vein material lies in the shatter zones produced by tension as movement took place along the planes of shearing. This is revealed by the vein breccias, vugs, comb structure, different generations of quartz, and vein-fracturing.

In Fig. 7 the stresses would lie approximately normal to the long axes of the oriented strain ellipsoids and be the resultant of horizontal compression from the south plus a vertical thrust on the hanging-wall side of the Kirkland Lake fault. In the Macassa, Teck-Hughes, and Lake Shore mines there are steep hanging-wall breaks, which tend to merge with the main plane of movement on the Kirkland Lake fault at depth. In the Teck-Hughes this structure is called No. 4 break, and it would correspond with the South vein at the Lake Shore mine. This set of structures is weaker than the Main break, but it forms a distinct part of the fracture pattern. Although their deviation in dip from the Main break is generally small, some observers might regard them as the complementary shear plane in the fracture system. If such were the case, however, the strain ellipsoid would have to be oriented with its long axis in a vertical position and the tensional veins would be almost flat. It seems, therefore, more likely that these steep hanging-wall shears are only a branch or part of the main shear direction.

It should be pointed out that there are really all gradations from shears to tension fractures. For example, the main North vein of the Kirkland Lake camp follows a strong shear from the Macassa mine to the Lake Shore mine but eventually breaks up at the east end of the camp into a series of tension fractures arranged in a shingle pattern.

It has been stated in a previous section¹ of this report that the vein fractures occur on the south side of the Kirkland Lake fault at the west end of the camp and on the north side of the main plane of displacement in the fault system at the opposite end of the ore zone. The Kirkland Lake geologists² suggest that torsional strains may be the cause of this transfer of vein-fractures from the hanging wall to the foot-wall of the main plane of movement, from east to west across to the camp. Torsion is a special type of non-uniform stress comparable with a rod

¹Page 83.

²*Structural Geology of Canadian Ore Deposits, Can. Inst. Min. Met., Symposium volume, 1948, p. 649.*

being held at one end and twisted at the other. McKinstry¹ has pointed out that even if the over-all stresses are torsional, the effect at any point along a structure can be analysed into ordinary shear and tensional relationships.

Fig. 7 shows that there is no appreciable change in the dip of the main shear plane at either end of the Kirkland Lake camp, as would be expected if there had been torsional movements, nor is there any evidence of an axis of torsion across the camp. Furthermore, if the vein-fracture pattern at the east end of the camp is considered to be related to a branching fault system rather than to a single fault plane, the entire picture is changed and any transfer of subsidiary veins to a footwall is not noticeable. The fracturing along the North vein-fault zone in the Wright-Hargreaves, Sylvanite, and Toburn mines is associated with the weakening and gradual disappearance of the North vein-fault, and this could have just as much influence as the movements along the main plane of displacement of the Kirkland Lake fault in the formation of the broad fracture pattern at the east end of the camp. In this connection it is noticeable that, in section, the vein-fracture pattern of the North vein and its flatter southern subsidiaries in the east end of the camp is generally similar to that of the Main break and southern subsidiaries at the west end of the camp. It is also a fact that ore shoots are more concentrated along the North vein zone than the main line of displacement in the Wright-Hargreaves, Sylvanite, and Toburn mines. There is also the added influence of the Narrows break converging with the Kirkland Lake fault system at the east end of the camp. All this evidence nullifies or tends to disprove the theory that the main plane of displacement of the Kirkland Lake fault is the only structural control of vein-fracturing and ore deposition from the Wright-Hargreaves mine eastward. It also casts considerable doubt on the theory that the over-all vein pattern of the camp is the result of torsional movements.

The fact that the ore zone at Kirkland Lake does not always lie along the plane or zone of maximum displacement (Main break) has been amply demonstrated in the history of the camp, especially at the east end, and at depth in such mines as the Kirkland Lake Gold. This should encourage a greater concentration on exploration across and along the entire intrusive stock and adjacent sediments and tuffs. The distant future of the camp will depend to a considerable extent on the success of this lateral exploration.

Post-Ore Faulting

The post-ore faulting might be considered as an end product of the deformation described above. At this stage the influence of the relaxation of regional pressures was predominant, although the final cooling of the intrusive stock could possibly have played a minor role. Gravitational settling and readjustment following mountain-building produced a set of transverse and cross faults along the entire Kirkland Lake-Larder Lake gold belt. The east end of the Kirkland Lake camp happens to be in a fault wedge formed at this time by two strong lines of dislocation. This block of disturbed ground is bounded on the west by the steep Lake Shore fault and on the southeast by the northward-dipping Murdock Creek fault system. This combination of adjustments could account for the first three stages of post-ore faulting.

The final post-ore adjustment is along a set of cross faults that cut all earlier sets. As pointed out by Hopkins in the report on the Wright-Hargreaves mine,² these are pivoted north of the ore zone at Kirkland Lake, which means that the source of the disturbance lay somewhere to the south. Possibly late adjustments

¹H. E. McKinstry, *op. cit.*, p. 294.

²Pages 174, 176.

along the Larder Lake fault zone could have had some influence here. It is also noticeable that this set of faults produced a progressive foundering of the ore zone from the east end of the camp to the Lake Shore fault. It raises a question as to whether shrinkage at depth as the central part of the syenite porphyry body finally cooled could have played a part in this settling.

VEINS AND ORE DEPOSITS

The gold-bearing veins in the Kirkland Lake camp are associated with the pre-ore faults and fractures described in the section covering the structure.¹ The structures are more continuous than the veins. A structure that contains



Vein breccia and quartz stockwork in tuffs, exposed on the back of No. 4601 east drift, Sylvanite mine.

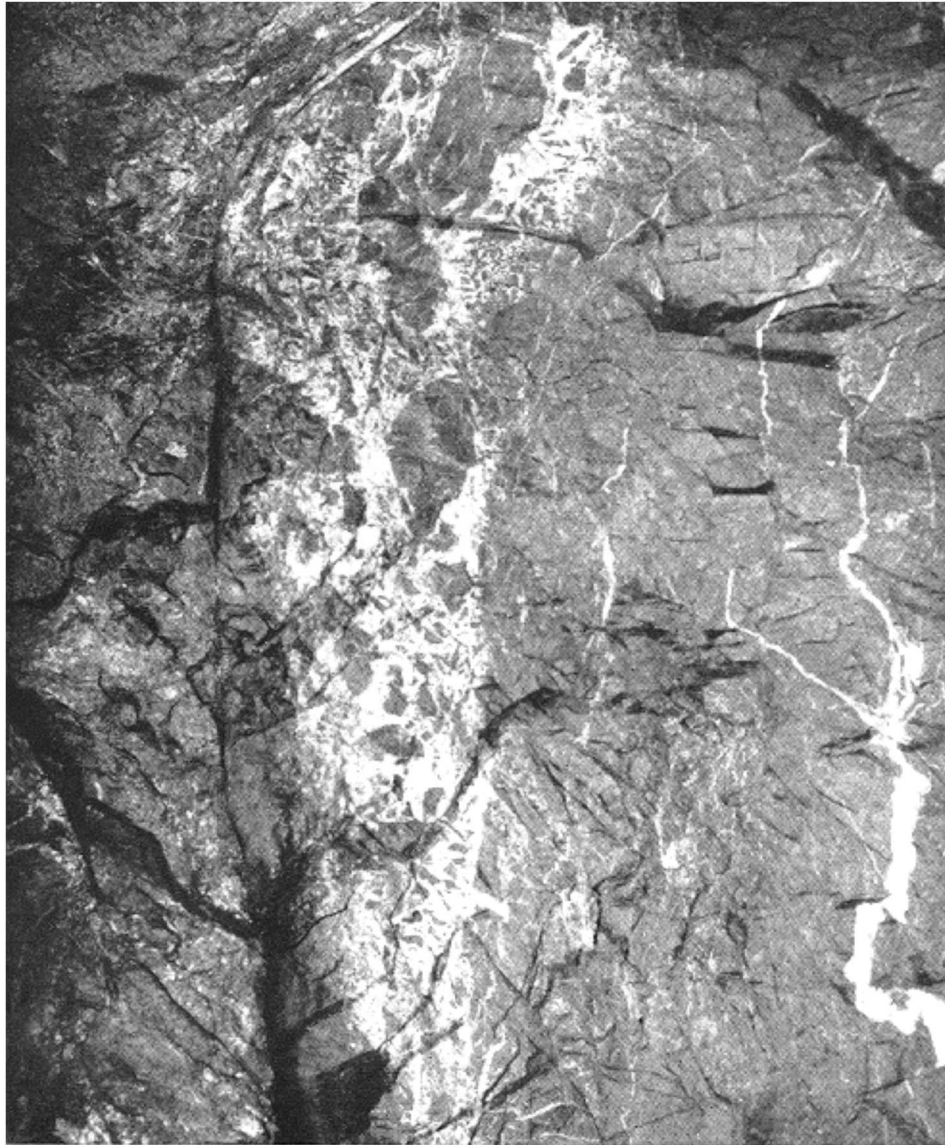
gold-bearing veins at various places along it is called a vein-fault, if pre-ore displacement can be proved; if there is no measurable displacement, it is referred to as a vein-fracture. Vein-faults and vein-fractures are commonly called breaks.

The host rock of the veins may be any of the rock types along the main ore zone except the late diabase dikes. The veins conform closely in strike and dip to the controlling slip or fracture and are generally bounded by altered wall rock. Where there is a single fault or fracture plane, it may form a clean-cut vein wall, whereas the opposite side may be more irregular with a gradually diminishing number of quartz stringers. In some places, the vein material may lie on either

¹Pages 73-83.

side of the selvage seam or seams. At other points, the selvage may occur on either side of a vein. In the central part of the camp the veins along the stronger faults may occur in a band of mylonite without any very pronounced slip plane. Along the main fault in the western part of the camp the gouge seam is continu-

Photograph by Lake Shore Mines, Limited



Vein breccia in syenite porphyry in No. 2801 west drift on No. 2 vein, Lake Shore mine.

ous, but the quartz may be discontinuous. The drifts follow the main mud seam, which leads to the various quartz veins along it. Veins in subsidiary fractures may be frozen to both walls.

The veins may be classified into a number of types according to their shape. Of these the single fissure vein is the most commonly found. There are all varia-

tions from this to intricately connected composite veins or lodes, sheeted zones, stockworks, and vein breccias. The vein-filling consists of quartz, inclusions of wall rock, some carbonates, a small amount of sulphides, and a variety of other minerals in minor amounts, including tellurides and native gold. The mineralogy of the veins is described in detail by J. E. Hawley in Chapter III of this report.

Different generations of quartz in a vein may range from a dark cherty variety to white. In many places, the vein material has a reddish colour owing to

Photograph by Lake Shore Mines, Limited.



Sheeted zone of quartz stringers in syenite porphyry, 2,700-foot level, Lake Shore mine.

the inclusions of altered wall rock, especially in the case of altered syenite porphyry. Where the vein occupies a tight fracture with little alteration, the quartz is white in colour. Quartz of ore grade is well fractured; tellurides and native gold are concentrated along these openings. In general, there is a similarity in the veins and vein mineralogy throughout the camp and at different depth horizons, although certain veins may have some special local characteristics.

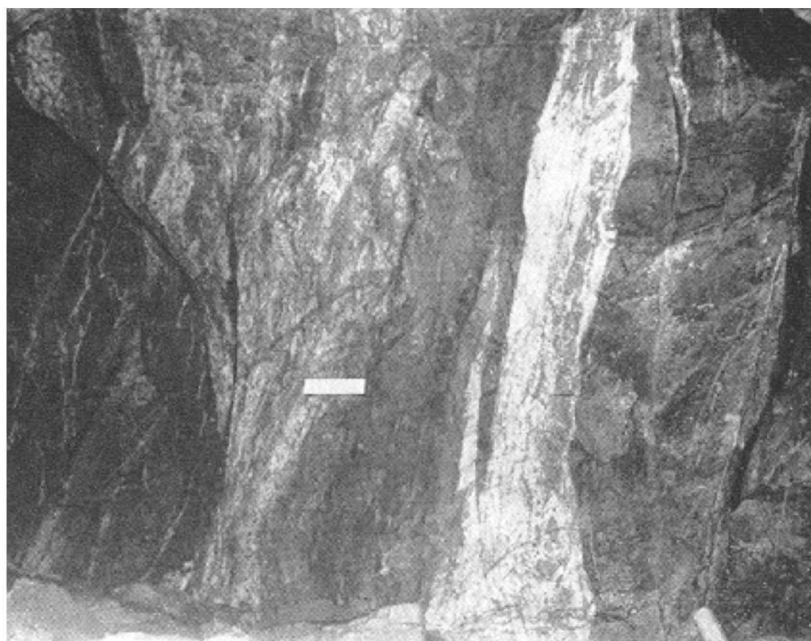
A feature of the veins along the Kirkland Lake ore zone is the relatively small amount of quartz in the ore shoots as compared with the tonnage and grade of ore obtained from them. The veins range in dimension from high-grade stringers to quartz stockworks and vein breccias as much as 70 feet in stopping width. Where the vein zone is abnormally wide, parallel veins may be stoped separately; or if the veins are more closely spaced, the whole mass may be mined together.

Following the period of gold deposition a late vein-filling was introduced throughout the ore zone. This is found in the post-ore slips along the main Kirk-

land Lake fault, along post-ore faults, and in fractures throughout the gold-bearing quartz. The late variety of quartz is barren and is readily distinguished by its glassy appearance. Associated with this quartz is a considerable amount of pink or white calcite and occasionally small amounts of barite and gypsum. Traces of specularite, galena, and chalcopyrite are found in this late vein-filling.

Throughout the mines, quartz constitutes only a small amount of the broken ore, yet it carries the bulk of the gold content. All quartz, however, does not contain sufficient gold to be classified as ore. Sheet G shows in some detail the actual distribution of quartz throughout part of two levels of the Macassa mine in relation to the sections that were stoped. It shows that the mappable quartz

Photograph by Kirkland Lake Gold Mining Company, Limited.



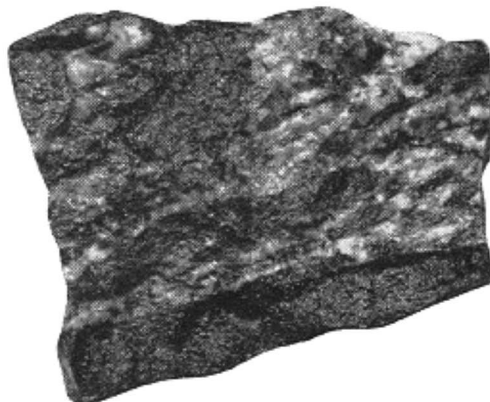
Exposure of ore in augite syenite on the 5,340-foot level,
Kirkland Lake Gold mine.

areas generally coincide with the location of stopes, but this is not universally true. A similar picture would be furnished by any of the other mines in the camp.

Other minerals associated with the quartz in the ore and wall rock are sericite, chlorite, graphite, carbonates, and sulphides; small amounts of feldspar and traces of tourmaline and actinolite are found. The sulphide content of the veins is generally small, constituting on the average less than 2 per cent. of the ore. Pyrite is the principal sulphide and is present both in the quartz and in the wall rock. Molybdenite is largely confined to slips in the fractured quartz.

Gold was deposited very late in the sequence of mineralization and is invariably seen along fractures in the quartz, although it also occurs in the secondary minerals, in pyrite, and in tellurides. A great proportion of the gold is extremely fine grained, and this feature has made fine-grinding of the ore a necessity for an adequate gold extraction in milling. When native gold is seen in the ore, it is generally in association with the tellurides. Neither native gold nor tellurides are commonly seen in the veins throughout the underground workings, but when found they are generally in very rich seams or pockets. Altaite is the

most widespread of the tellurides, but calaverite is the one that contains most of the gold that is bound up in these minerals. Petzite also carries gold but is not so commonly found; other rare tellurides are coloradoite and melonite. Silver



Specimen (one-third natural size) of ore from No. 5 vein, Kirkland Lake Gold mine. The wall rock is augite syenite. Note the sharply defined vein wall on the lower side.

occurs in the veins and in the petzite; some silver is also amalgamated with the native gold.

The average gold to silver ratio for the bullion produced at each of the seven mines is shown in Table 4 (facing page 60). The average gold to silver ratio for



Specimen (one-quarter natural size) of high-grade ore in syenite porphyry from No. 1065 stope, 1,000-foot level, Sylvanite mine.

the bullion from the entire camp to the end of 1947 is 5.7 to 1. The average fineness of the bullion from each mine is also shown in Table 4; the average fineness of the bullion from the seven mines is calculated from Table 4 to be 858. The

average fineness of the native gold is given by the Kirkland Lake geologists as 941.¹ Additional notes on the fineness of gold and gold-silver ratios are given by Hopkins in the report on the Wright-Hargreaves mine.²



Specimen (one-quarter natural size) of gold ore in tuff from 4.D stope, 4,300-foot level, Kirkland Lake Gold mine.

Analyses of Ores

Most of the available analyses of Kirkland Lake ores are given in Table 5 (facing page 70). The composition of the ore varies with the type of wall rock. This feature is illustrated in the following set of analyses of ore from the Lake Shore mine.³

	North Vein zone		South Vein zone	
	A East side	B West side	C East side	D West side
	per cent.	per cent.	per cent.	per cent.
SiO ₂	60.52	53.88	60.80	56.00
Al ₂ O ₃	15.60	17.23	14.60	14.95
Fe.....	2.86	4.04	2.15	3.56
CaO.....	2.50	4.30	2.73	3.35
MgO.....	1.09	2.61	1.47	1.18
Na ₂ O.K ₂ O.....	9.69	7.18	12.10	12.90
MoS ₂	.08	.14	.02	trace
S.....	.72	.98	1.00	1.42
Pb.....	.009	.011	.05	.03
Cu.....	.0116	.013	trace	trace
Te.....	.02	.02	.01	trace
Ignition loss.....	3.94	5.37	4.70	5.20
C.....	.04	.02	.02	.03
Au, oz. per ton.....	0.615	0.815	0.705	0.510

¹Structural Geology of Canadian Ore Deposits, Can. Inst. Min. Met., Symposium volume, 1948, p. 644

²Pages 167-168.

³Lake Shore Mill Staff, "Milling Investigations into the Ore as Occurring at the Lake Shore Mine," Trans. Can. Inst. Min. Met., Vol. 39, 1936, p. 303. (Analyses by Department of Mines, Ottawa.)

These analyses were made from four 300-pound samples, each representative of the ore from a section of the mine. Samples A and C came from veins in altered syenite porphyry and show a composition fairly close to that of the altered syenite porphyries of Table 5 (facing page 70). Samples B and D came from an area of mixed syenite porphyry and augite syenite. Here the silica content is lower, and the other constituents are more variable.

In general, the analyses of the ore are approximately the same as those of the adjacent wall rock. In other words, the amount of vein quartz in the ore is insufficient to change the percentage of the various constituents by any appreciable amount. The low metallic content of the ore is also indicated by the analyses.

Ore Shoots

The stoped areas, which are indicated in solid black on the accompanying plans and sections, give the reader some idea of the vertical and horizontal continuity of the ore shoots. When studying the distribution of stoped areas on these mine plans, the reader should remember that near working-places, such as shafts, winzes, haulageways, etc., ore has been left as supporting pillars.

The longest ore shoot in the camp occurred at the 3,000-foot horizon, where there was a combined length of about 1 1/4 miles of stoped ore with only short intervening sections that were below ore grade. This ore shoot lay along No. 3 vein of the Teck-Hughes and the North veins of the Lake Shore and Wright-Hargreaves mines. At the other extreme, there are 3-foot stopes along rich veins that may be only a few inches in width. The average stoping width of the camp is from 5 to 6 feet. Abnormal widths up to 70 feet have been stoped at the Lake Shore mine, and a 100-foot width was removed at one place in the Teck-Hughes mine. These were in areas of branching or parallel veins so closely spaced that the whole zone was stoped.

The ore shoots of the Kirkland Lake camp have been found in every rock type along the main ore zone except the diabase. Approximately 95 per cent. of the ore mined to date has come from veins located within or along the contact of the intrusives. Of this amount, the syenite porphyry accounts for almost two-thirds of the ore. The zone of complex intermingling of augite syenite, syenite, and syenite porphyry ranks second and contained about one-quarter of the ore removed. The stopes on veins in the sediments are generally narrower than those in the intrusives.

Most of the larger ore shoots do not show any particular pitch, the long axis being about vertical. Others are roughly equidimensional. Some of the shorter ore shoots show a definite pitch, and this is generally to the west, being controlled by the westerly pitch of the composite intrusive body or its component rock types (see Fig. 3 on page 70). In the Kirkland Lake Gold and Macassa mines, the ore shoots associated with the syenitic pipe pitch westward with this mass. The ore shoots controlled by the anticlinal structure and No. 6 break in the Kirkland Lake Gold mine likewise pitch westward. Several of the hanging-wall subsidiary veins at the Teck-Hughes mine have a westerly pitch. At the east end of the camp, there is again a westerly pitch controlled by the inclination of the contact of the porphyry body. There are a few minor ore shoots that show an easterly pitch over a limited vertical extent.

Wall-Rock Alteration

The alteration of the country rock adjacent to veins and breaks is a prominent feature of the Kirkland Lake camp. The drifts, raises, and stopes are driven along these structures, and as a result, there is much more altered rock exposed

throughout the mine workings than fresh rock; the latter is found mainly in the crosscuts. The effects of wall-rock alteration are much more noticeable in the intrusives than in the sediments, and as most of the workings are in the intrusive complex, the study of alteration has been concentrated on these rocks. The zone of alteration, unless accompanied by vein quartz, never carries sufficient gold to be classified as ore. A practical use can be made of rock alteration, however, because it serves as a guide in drifting along structures where the actual break is weak, missing, or dissipated over wide areas. In other words, it marks possible ore channelways. It should be pointed out, however, that there are some veins that show practically no alteration along their walls; these are in structures that are subsidiary to the main shears and appear to have been opened by tension.

Wall-rock alteration has had a two-fold effect in that the original mineral constituents have been largely obliterated and at the same time a colour change



Specimen (one-half natural size) of mylonite from the main zone of displacement of the Kirkland Lake fault, 4,000-foot level, Wright-Hargreaves mine.

has taken place in the rock. The disappearance of the granitoid texture in the intrusives is the result of rock movement, whereas the colour change is produced by hydrothermal alteration.

The rock adjacent to a vein-fault in the intrusives is changed from a massive holocrystalline rock to a banded, brecciated, or streaky variety. This may be reddened, bleached, or silicified, or there may be a mixture of all phases. The cherty-looking, silicified material has undergone the most complete granulation. Greenish-coloured alteration is prominent along some of the branch veins in the Teck-Hughes mine and certain veins in the sediments in the Sylvanite and Toburn mines. Much of the very pale green alteration is due to sericitization, but in a few places deep-green chrome mica (fuchsite) is developed over areas seldom more than an inch in diameter.

Microscopic study shows that the crystals are first cracked or sheared along parallel lines, then progressively broken, granulated, and pulverized, depending upon the amount of alteration involved. Chlorite, sericite, and leucoxene have developed along narrow seams in the rock, and carbonate minerals and secondary quartz and pyrite have been introduced. The fine-grained bleached rock thus produced has often been further shattered to form a breccia, with one type of

alteration embedded in a slightly different phase. Even this late breccia shows later fracturing. The resulting product is called mylonite in the camp. It is most commonly found along the stronger vein faults. Sometimes the mylonite bands have sharply defined contacts and resemble dikes or dikelets in appearance. The widths of the mylonite zone vary greatly and may be only a few inches or many feet.

Microscopic examination of the mylonite shows that it is a microbreccia with a cataclastic structure. Where it has been formed by the alteration of syenite porphyry, the original feldspar phenocrysts may be seen in all stages of fracturing, slicing, and granulation. Sericite and chlorite have been developed along the fracture planes. In many thin sections secondary carbonates (chiefly iron-bearing dolomite) make up about half of the mineral constituents; there is also much secondary quartz and some pyrite crystals. The colour is due to the carbonates, ferric oxide, and leucoxene.

Carbonatization may affect large areas of rock and is not necessarily associated with the ore. It may be observed in the vicinity of any slip, whether pre-ore or post-ore, and the extent of the alteration seems to be dependent upon the amount of fracturing in the rock. For example, in the Toburn mine the syenite porphyry shows reddish alteration for a distance of about 600 feet north of the South vein. At the other end of the camp, irregular areas of alteration occur throughout the system of hanging-wall veins in the Macassa mine which attain a width of 325 feet. It would appear that the period of intense carbonatization preceded the period of ore deposition and that zones of carbonatization and gold-bearing veins do not necessarily coincide, although in most cases they have followed the same channelways. The same conclusions would apply to the Larder Lake fault zone lying to the south of the Kirkland Lake camp, where there is a much greater development of carbonates. It implies widespread carbonatization throughout the country along lines of weakness as a forerunner of the gold mineralization.

Silicification and sericitization are generally limited to areas immediately adjacent to the veins and may show a rather sharp contact with the country rock. The H vein in the Teck-Hughes mine and certain veins in the Sylvanite show varying degrees of silicification along the vein walls. Silicification is seen in breccia fragments of syenite or syenite porphyry within the quartz veins where very fine quartz partly replaces the fragments. Microscopic examination of the vein material along the K vein in the Teck-Hughes mine shows a very high degree of sericitization.

The alteration of the different types of wall rock may show a slight difference in appearance, but in many places it only makes the identification of the original country rock more difficult. The syenite generally becomes a more pronounced red or pink; the dark-coloured augite syenite becomes more mottled in appearance, the ferromagnesian minerals being bleached and the feldspars reddened. In many places the syenite porphyry changes to a buff-coloured crush breccia or a mixture of buff-coloured, reddish, and cherty phases. The sediments and tuffs do not show the same degree of alteration but tend to become red, brown, or green adjacent to innumerable tiny fractures. The various colours are due to disseminated dusty particles of red hematite, brown limonite, or goethite, and to varying quantities of ferriferous carbonate and sericite.

Todd¹ gives chemical analyses of fresh and altered wall rock in some of the Kirkland Lake mines. Additional analyses of mylonite are given in Table 5 (facing page 70).

¹E. W. Todd, *op. cit.*, pp. 88-90.

In general, the hydrothermal alteration of porphyry, syenite, and augite syenite has involved a marked increase in lime, magnesia, and carbon dioxide, and in some cases of ferrous oxide and combined water. These are related to the development of both carbonates and chlorite. Apparent decreases in other constituents are due largely to this dominant alteration. Where sericitization is pronounced, as along some of the veins and adjacent to high concentrations of gold and tellurides, indicated by a yellowish-green alteration, potash appears to have increased relative to soda; but, as noted by Bruce,¹ since the potash and soda content of the fresh rocks vary considerably it is not possible to prove the extent of actual changes in these constituents. Only locally, as in some of the mylonites and wall-rock fragments in veins, has silicification occurred to any marked extent, and the introduction of silica has been confined largely to the quartz veins themselves.

Alterations ascribed chiefly to shearing and slipping of the rocks and ores include the pre-ore mechanical granulation of various rocks to mylonite and the development, at various times, of either chlorite or sericite.

Though much iron-bearing carbonate, along with barite and specularite, was introduced into post-ore (and post-diabase) fractures, no extensive alteration of the wall rocks adjacent to these appears to have taken place. It is doubtful, however, if the pre-ore and post-ore iron-rich carbonates could be distinguished from one another.

Further notes on wall-rock alteration are given in the descriptions of the mines along the main ore zone.

Structural Control along the Main Ore Zone

Various features covering structural control of ore localization along the main ore zone have been described in different places throughout this report and in the descriptions of the mines. The main factors may be summarized as follows:—

1. The master control of the main ore zone was undoubtedly the Kirkland Lake fault system.
2. Second only in importance to (1) was the influence of the intrusive stock and its component rock types, augite syenite, syenite, and syenite porphyry. The composite intrusive body in combination with the fault system controlled the extent, strike, dip, and pitch of the main ore zone.
3. Fracturing that is subsidiary to the main shears has played an important rôle. At the west end of the camp, the subsidiary fractures are mostly tensional in type and are very largely concentrated on the south side of the main zone of dislocation. They were probably formed as the south block moved upwards over the footwall. At the east end of the camp, the subsidiary fracturing is spread over a wider zone produced by the splitting up of the Kirkland Lake fault system and, to a much lesser extent, by the addition of the Narrows break.
4. Wide zones of vein-fracturing were formed off the west nose of the main syenite porphyry body, where there was a complex mixture of intrusive rocks.
5. Favourable locations for the concentration of tensional veins are in the wedge-shaped blocks of ground between the stronger breaks.
6. Areas of change in the strike and dip of the fault planes are favourable locations for fracturing. In certain localities there is a tendency for subsidiary veins to angle off rolls on the Main break.

¹E. L. Bruce, "Rock Alterations by Hydrothermal Solutions in Certain Canadian Localities," *Trans. Roy. Soc. Can., 3rd series, Vol. 35, sect. 4, pt. 1, 1941, p. 33.*

7. Special local conditions, such as the anticlinal fold in sediments at the Kirkland Lake Gold mine, provide special types of vein fracturing.

SUMMARY OF THE PRINCIPAL GEOLOGICAL EVENTS

The following is a summary of the principal geological events in the vicinity of the main ore zone at Kirkland Lake:—

1. Outpouring of Keewatin volcanics followed by folding and erosion.
2. Deposition of Timiskaming sediments and volcanics followed by close folding and regional strike-faulting. This was the period of tectonic mountain-building.
3. Associated with or closely following (2) came the intrusion of the elongated composite stock at Kirkland Lake. This was one of several bodies satellitic to the syenite batholith to the south. The Kirkland Lake stock was injected along the strike of the enclosing sedimentary formations but at a slightly steeper angle, thus truncating the sedimentary beds on the dip. The three main differentiates of the stock—augite syenite, syenite, and syenite porphyry—were intruded in the order named.
4. Cooling and solidification of the three main phases of the intrusive complex. Internal stresses set up by the contraction of the cooling mass may have produced sets of joints, fractures, and probably faults. These would be formed under tension and so oriented that the prominent set of fractures was approximately parallel to the contact of the intrusive with the adjacent sediments or tuff. This stage is more or less theoretical but explains the close association of the later gold deposition with the composite intrusive stock.
5. Renewal of stress within and adjacent to the intrusive stock, due to regional compression. The accumulated stresses were relieved by thrust displacement along the Kirkland Lake fault system and simultaneous shattering of the adjacent ground. Both fault and fracture zones tend to follow the lines of weakness mentioned in stage (4). Where displacement on the main thrust fault was greatest, i.e. at the west end of the camp, the vein-fracture pattern is closely related to the Main break; where displacement is least, i.e. at the east end of the camp, the vein-fracture system shows the influence of the earlier pattern produced by the cooling of the intrusive body. These two influences are displayed in varying degree along the ore zone.

This was a period of local recurrent movements on all faults and fractures. It produced mylonite, schist, and possibly some fault gouge along the main planes of displacement; the shattering of the wall rock and the opening of subsidiary fissures were both attendant tensional phenomena.
6. Vein formation, mineralization, and gold deposition from a deep-seated source were closely allied in space and time with the formation of openings in (5) above. The process began by hydrothermal alteration of the wall rock adjacent to slips, shatter zones, and other openings. Later came the introduction of different generations of vein quartz into the fissures. Recurrent movements continued to reopen the channelways and veins and so provided the necessary permeability for large-scale ore deposition. Last in the sequence came the precipitation of tellurides, gold, and silver along fractures in the veins.
7. Intrusion of a few quartz-diorite dikes across the ore zone.
8. After stages (6) and (7), there was continued readjustment, especially at the east end of the camp. This time most of the failure took place in sets of strike and transverse faults. There was progressive foundering in the late stages of readjustment from the east end of the ore zone to the Lake Shore fault. A

limited amount of barren quartz-calcite veining was introduced along the post-ore faults. The post-ore faulting was probably caused by the relaxation of regional stresses following mountain-building, and the final cooling of the syenite porphyry at depth may have played a minor part in the settling.

9. The mountains were gradually worn down until the upper marginal portion of the composite intrusive stock and associated ore zone became exposed at the present erosion surface.

CHAPTER III

Mineralogy of the Kirkland Lake Ores

By J. E. Hawley¹

INTRODUCTION

The following study of the mineralogy of the Kirkland Lake ores is based on the examination of a suite of rocks and ores submitted to the writer by Jas. E. Thomson. It consisted of specimens collected from the seven producing mines of Kirkland Lake in 1944 and 1947 and a few rich gold-telluride samples from collections made by A. G. Burrows and E. W. Todd during their earlier studies of the camp.

A detailed restudy of the ores of the Kirkland Lake mines attests to the thoroughness of previous investigations and has shown the occurrence of only a few minerals not previously noted. All of the rarer species, however, have been confirmed by X-ray analysis, and an attempt has been made to determine the paragenesis of both metallic and non-metallic minerals, their relations one to another, and their possible significance. A study of the non-metallic minerals has been made both by the use of staining techniques on smoothly ground surfaces and by thin sections. In addition, semi-quantitative spectrographic studies have been made of as many of the metallic minerals as could be suitably concentrated and separated from others.²

As shown by analyses by Todd³ and investigations by the staff of Lake Shore Mines,⁴ the ores consist chiefly of quartz veins, carbonated, silicified, and pyritized syenite porphyry, syenite, and augite syenite, which are enclosed in quartz stockworks and veins and usually carry not more than 2 per cent. metallic minerals. More rarely sedimentary wall rocks or brecciated fragments of these occur in the ore. Depending on the nature and amount of wall rocks mined along with quartz veins of different types, the silica content ranges from nearly 50 per cent. to 60 per cent., some of which is present in various silicates as well as quartz. Carbonates of calcium, magnesium, and iron account for from 15 to 20 per cent., and the remainder is chiefly aluminium silicates, including feldspars, micas, hornblende, and chlorite.

On the whole the ores are notably uniform in mineral content throughout the camp, the main differences in bulk composition being due to variations in the character of the wall rocks with which they are associated. The ores are also rather remarkably uniform vertically and are all characterized by exceptionally fine grained metallics, which seldom exceed 1 mm. in diameter, though minor exceptions to this have been noted.

MINERALS IN KIRKLAND LAKE ORES

All told, some 21 metallic and 13 non-metallic minerals have been identified. In both metallic and non-metallic minerals, paragenetic studies indicate that

¹In this study Considerable assistance has been given by W. J. Wark, who completed a Bachelor's thesis on some of the Kirkland Lake ore samples and supplied several of the illustrations of polished sections.

²Spectrographic research on these ores was made possible by a grant supplied by the Research Council of Ontario.

³E. W. Todd, *Ont. Dept. Mines*, Vol. XXXVII, 1928, pt. 2, pp. 67-87.

⁴Lake Shore Mill Staff, "Milling Investigations into the Ore as Occurring at the Lake Shore Mine," *Trans. Can. Inst. Min. Met.*, Vol. 39, 1936, pp. 279-434.

repeated depositions of some of these occurred. A list of these is given in the following two tables and succeeding descriptions are arranged in the approximate order of deposition.

METALLICS

Type	Mode of occurrence	Mineral	Remarks
MAGMATIC.....	.....	Magnetite-ilmenite..	In graphic intergrowths; primary constituents of syenites and porphyry.
HYDROTHERMAL.....	Elements...	Gold..... Graphite.....	Alloyed with minor silver. Minor.
	Oxides.....	Specular hematite. Red dusty hematite. Magnetite.....	Rare.
	Tellurides..	Altaite, PbTe. Calaverite, AuTe ₂ . Coloradoite, HgTe. Melonite, NiTe ₂ Pezite, (Ag, Au) ₂ Te. Tetradymite, Bi ₂ Te ₃ S. Joseite, Bi ₂ TeS.....	Rare. Ag: Au = 3:1. Locality unknown. Locality unknown.
	Sulphides...	Pyrite.	
		Arsenopyrite.....	Very rare.
		Chalcopyrite.	
		Pyrrhotite.....	Very rare.
		Molybdenite. Sphalerite..... Galena.....	Very rare. Very rare.

NON-METALLICS

Occurrence	Mineral	Remarks
IN VEINS.....	Quartz.	
	Albite.....	Very rare.
	Ferruginous dolomites.....	Of variable iron content.
	Calcite.	
	Barite.	
	Celestite.....	Rare.
	Gypsum.....	Rare.
	Sericite. Chlorite.	
IN ALTERED WALL ROCKS.....	Tourmaline.....	Rare.
	Biotite.	
	Sericite.	
	Carbonates.	
	Chlorite.	

Metallic Minerals

MAGNETITE-ILMENITE

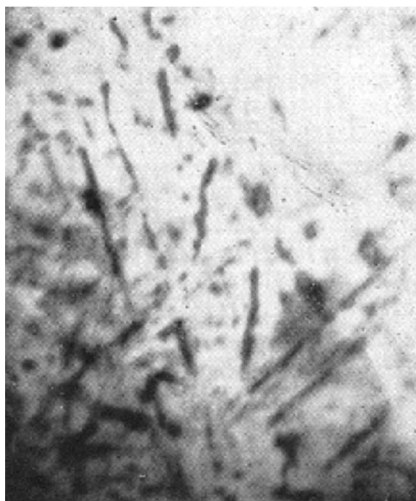
Magnetite and ilmenite are of common occurrence as primary constituents in syenite, augite syenite, and syenite porphyry. They are always graphically intergrown, thin blades of ilmenite occurring along octahedral directions in the magnetite and the latter forming in rounded to irregular-shaped grains disseminated throughout the host rocks. Where the magnetite and ilmenite have

been highly altered by ore-forming fluids, they have been replaced by pyrite to various degrees, magnetite altering more completely than the more resistant ilmenite. In a few cases native gold has been found deposited directly on the borders of still unreplaced intergrowths of these minerals. Spectrographic analyses show that the intergrown minerals contain relatively less cobalt and nickel than the average pyrite.

SULPHIDES

Pyrite

Pyrite, by far the most abundant sulphide in the Kirkland Lake ores, is usually present in amounts of less than 2 per cent. of the ore, but locally may be present in greater concentrations along fractures and in altered rocks in seams,



Photomicrograph of high-grade ore from No. 32-A.W. stope, 3,225-foot level, Macassa mine, showing pyrite (white) replacing graphic intergrowth of triangularly arranged blades of ilmenite (grey) in magnetite, the latter having been almost completely replaced. (X900.)

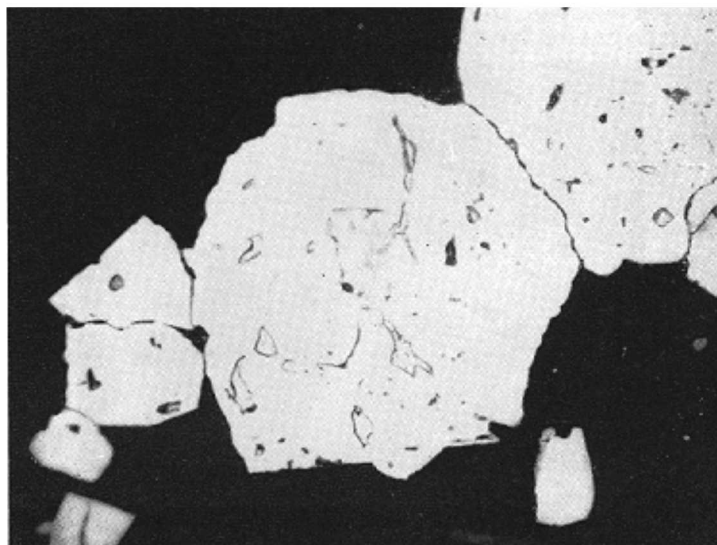
which seldom attain half an inch in width. Practically all the pyrite is in exceptionally fine grains, usually less than 0.5 mm. and grading down to a micron or less in diameter. Only rarely, as in the walls of No. 5 strike fault on the 5,400-foot level of the Sylvanite mine, are coarse cubes of pyrite seen, there attaining a diameter of nearly 10 mm.

In habit the pyrite is chiefly cubic, but much of it is in anhedral grains and aggregates. Most of the pyrite occurs either in the wall rocks adjacent to veins or in the many angular to rounded fragments of wall rock in the breccia type of ore. More rarely it is present in the quartz veins themselves, and in these it occurs in fractures, along intergranular boundaries, and within either individual quartz or carbonate grains.

In the wall rocks it is found replacing all primary minerals and even secondary carbonates, but shows a distinct preference for the intergrowths of magnetite-ilmenite, augite, and hornblende or their carbonated equivalents. In some cases pyrite can be found replacing magnetite-ilmenite in the central

portion of the grains, which are bordered by purer pyrite, indicating more complete replacement of surrounding silicates.

Most of the pyrite studied in polished sections contains abundant inclusions of exceptionally fine particles of gangue, carbonates, gold, chalcopyrite, and altaite. Lake Shore officials¹ have described minute gold inclusions, ranging from 1/2 micron to 10 microns in size, in irregular to rectangular shapes in the centre of pyrite, which is relatively free of other inclusions; an occurrence suggesting contemporaneous deposition of some gold in pyrite that either completely replaced wall rocks or was deposited in the quartz veins. In addition to this, however, coarser inclusions of gold with altaite and, in many places, chalcopyrite appear as likely replacements along concealed ducts, since all three may be found elsewhere replacing pyrite around grain boundaries and along fractures in it.



Photomicrograph of high-grade ore from No. 32 A.W. stope, 3,225-foot level, Macassa mine, showing coarse gold and altaite enclosed in pyrite in which there is no evidence of fracturing. Elsewhere both minerals replace pyrite. (X160.)

Spectrographic analyses of some 80 samples² of carefully picked pyrite from ores of all of the mines in the area have shown the presence of sodium, calcium, barium, strontium, aluminium, silicon, magnesium, copper, nickel, cobalt, chromium, manganese, vanadium, molybdenum, titanium, zinc, tellurium, gold, silver, and lead. Only the faintest lines of zinc and rarely those of tin were observed in some samples, and these elements as well as tungsten are generally absent. Sodium, calcium, magnesium, and aluminium are undoubtedly due to gangue inclusions, and titanium to remnants of unreplaced ilmenite. Gold, silver, and lead correspond generally in relative amounts to the amount of tellurium present. Only 9 of the 80 analyses show no gold or tellurium in detectable amounts, and only one shows gold without tellurium, indicating that in most the gold is present as native gold with tellurides or as gold-bearing tellurides alone. The somewhat erratic amounts of these further suggest that their occurrence is

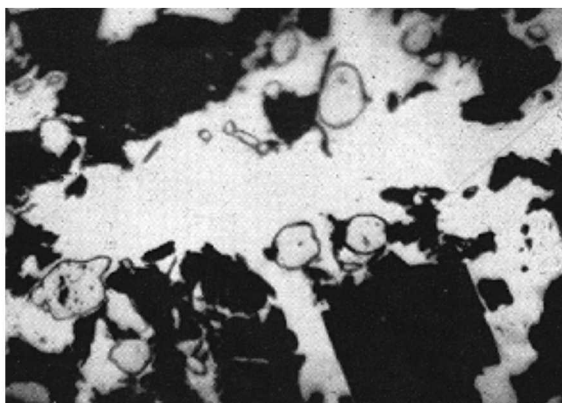
¹Lake Shore Mill Staff, *op. cit.*, p. 291.

²These consist largely of pyrite from wall rocks and breccia fragments of ore samples but may include some from the quartz portions of ores, in which it is very sparingly present.

due to inclusions or adhesions of discrete particles of these minerals rather than to solid solution. Of the 80 samples analysed, 14 containing traces of gold show no titanium, whereas 8 containing titanium show no detectable gold; but the remainder (58) contain both of these elements; all of which suggest that the gold is not limited to any particular generation or type of pyrite.

Though the samples may not be entirely representative, the averages for tellurium in pyrite increase from below the 1,000-foot level, are fairly constant between the 2,000- and 4,000-foot levels, but show a slight falling off below this level, which is in keeping with statements that visible tellurides are more common on the upper levels.¹

Lead and silver are invariably present. Cobalt and nickel with chromium and manganese are almost always indicated but in very minor amounts. Vanadium is seen less constantly owing perhaps to its lower sensitivity. There is a suggestion that the cobalt and nickel (probably in solid solution) in the pyrite



Photomicrograph of ore from J vein, 26th level, Teck-Hughes mine, showing pyrite grains (in high relief) rounded and corroded by altaite (white). Gangue is black. (X160.)

of some of the deposits increase slightly at depth; but it should be noted that the amounts are only very small fractions of 1 per cent.

Todd² has indicated that the pyrite in quartz veins is more apt to be indicative of ore than that in the wall rocks. Whether such pyrite was originally deposited with gold or acquired it by later infiltrations and replacements is not clear. Likewise, the Lake Shore investigations of mill products³ have suggested that some pyrite was deposited with what may be termed "early" gold in exceedingly small particles. Rigorous proof, however, that such inclusions within pyrite were deposited contemporaneously with it and not introduced by diffusion processes⁴ along minor irregularities in the crystal structure of the pyrite, as were some coarser particles of gold and other minerals, is at present lacking.

Arsenopyrite

Traces of arsenopyrite have been reported by G. H. Charlewood⁵ at the Lake Shore mine, but it is exceptionally rare in the Kirkland Lake camp proper,

¹E. W. Todd, *op. cit.*, pp. 82, 83.

²*Ibid.*, pp. 83-84.

³Lake Shore Mill Staff, *op. cit.*, pp. 291-293.

⁴W. T. Holser, "Metasomatic Processes," *Econ. Geol.*, Vol. 42, 1947, pp. 384-395.

⁵Page 155.

even the pyrite of which is practically devoid of arsenic. Arsenopyrite does occur in greater quantity in the Upper Canada deposit, 8 miles to the east of the Toburn, where it is found replacing pyrite in disseminated wedge-shaped crystals from an eighth to a quarter of an inch in diameter. The affiliation of these ores with those of Kirkland Lake is shown by spectrographic traces of gold, silver, mercury, lead, and tellurium. The pyrite here shows traces of arsenic, as might be expected.

Pyrrhotite

Pyrrhotite is also decidedly rare but has been reported by Todd¹ from the 13th level of the Teck-Hughes mine as grains a quarter of an inch across associated with coarse chalcopyrite and calcite as a late filling along a fault plane. It has also been noted in the present study in ore from the 4,200-foot level of the Wright-Hargreaves mine in fine grains but not in contact with any other metallic. In a high-grade specimen (from a Burrows-Todd collection of tellurides), it appears in contact with calaverite and is probably pre-gold in age.

Chalcopyrite

Though not abundant, chalcopyrite is to be found in most ore samples in minute particles comparable in size with pyrite. Todd² has noted its association with visible gold.

There are, according to Todd, at least two generations of chalcopyrite present: one either contemporaneous with or slightly earlier than the gold minerals and the other, which is not auriferous, occurring in late post-ore faults, in which it is associated with calcite, barite, and galena.

The earlier chalcopyrite invariably occurs in small blebs and wisps replacing various gangue minerals as well as pyrite and in many places is found along very fine fractures in both quartz and calcite, into which gold and the various tellurides have also been introduced. It may be found clearly replaced to some extent by altaite and rimmed by calaverite, coloradoite, or gold. Its associations indicate that it was in part deposited before the tellurides and gold, but almost contemporaneously with them in the same fractures.

Spectrographic analyses of five concentrates of chalcopyrite show in all traces of gold, silver, lead, tellurium, manganese, bismuth, titanium, nickel, mercury, and zinc. Three show cobalt and one traces of antimony. None contain chromium or vanadium. These concentrates were made from samples taken from the 500-foot level of the Sylvanite mine down to the 3,225-foot level of the Macassa mine. With the exception perhaps of nickel, cobalt, manganese, and zinc, the presence of these elements is likely due to intimately associated tellurides and gold.

Galena

Todd³ reports only two occurrences of galena from ores of the Wright-Hargreaves mine and the Sylvanite mine, in which it is associated with altaite and native gold in grey calcite. It is also reported in coarse form from the Lake Shore mine, assaying \$6 in gold and 8 ounces of silver.⁴ A late generation of galena is also noted in the gouge of post-ore fault zones with chalcopyrite, calcite, or barite. None was seen in the present study.

Sphalerite

Sphalerite is reported as even rarer than galena, but Todd⁵ noted its oc-

¹E. W. Todd, *op. cit.*, p. 85.

²*Ibid.*, p. 84.

³*Ibid.*

⁴*Ibid.*, p. 85.

⁵*Ibid.*

currence in pink calcite from the Sylvanite mine and as a minute constituent of high-grade ore from the Wright-Hargreaves. Thomson¹ has reported sphalerite enclosed as small fragments in chalcopyrite, which is borne out by spectrographic traces of zinc in the chalcopyrite of various mines.

Molybdenite

Minor amounts of molybdenite, though making up only a fraction of 1 per cent. of the average ore, is widespread throughout the camp. It occurs chiefly as bluish-black coatings along slip planes in quartz or wall rocks or as thin films often showing slickensided surfaces. It is also present with other ore minerals in the black rims that surround many of the brecciated wall rock fragments now isolated in a quartz matrix.

Todd notes that this mineral is less conspicuous in the deeper workings of some of the mines² and has demonstrated by analyses that it is associated with minor traces only of graphite.³ Spectrographic analyses of four samples from the Sylvanite, Teck-Hughes, Kirkland Lake Gold, and Macassa mines are consistent in showing traces of gold, silver, mercury, lead, tellurium, bismuth, manganese, cobalt, nickel, copper, titanium, vanadium, and chromium. The Macassa specimen gives a trace of antimony. The presence of many of these elements is undoubtedly due to admixed tellurides and gold. Lead is particularly prominent, suggesting altaite.

Thin sections of black-rimmed fragments of porphyry in quartz (breccia ore) show fine black metallics in very fine, crenulated, vein-like form following the borders of the fragments and in places confined and largely interstitial to the fine mosaic quartz bordering them. In others, the veinlets penetrate short distances into the porphyry fragments, which show varying degrees of silicification. The molybdenite and associated minerals would thus appear to be either contemporaneous with or slightly later than the silicification and introduction of fine-grained quartz and later than any replacement of the porphyry fragments because they are now isolated from one another and separated by vein quartz. While much of the molybdenite is closely associated with gold and tellurides, polished sections do not show its exact age relation to them.

TELLURIDES

The Kirkland Lake camp has long been noted for the various tellurides associated with the gold deposits. Of these only two contain gold as an integral part of their composition, namely calaverite and petzite. Fine inclusions, veinlets, and rims of gold, however, are found intimately associated with the base-metal tellurides, coloradoite and altaite. In addition, melonite (NiTe_2) has been reported from these ores,⁴ and among the Kirkland Lake samples collected by Burrows and Todd, one sample has shown the presence of the bismuth tellurides, tetradymite and joseite.

As shown by milling investigations at the Lake Shore mine,⁵ gold-bearing tellurides account for from 11 to 19 per cent. of gold in the ore. Todd⁶ has indicated that locally, as on the 12th level of the Teck-Hughes mine, gold tellurides account for as much as 61.6 per cent. of the total gold present.

¹Ellis Thomson, "The Occurrence of Tellurides in Ontario," *Contributions to Can. Min.*, 1922 (reprinted from *Univ. of Toronto Studies, geol. ser. No. 14*), Univ. of Toronto Press, p. 94.

²E. W. Todd, *op. cit.*, p. 85.

³*Ibid.*, pp. 68, 86.

⁴*Ibid.*, p. 87.

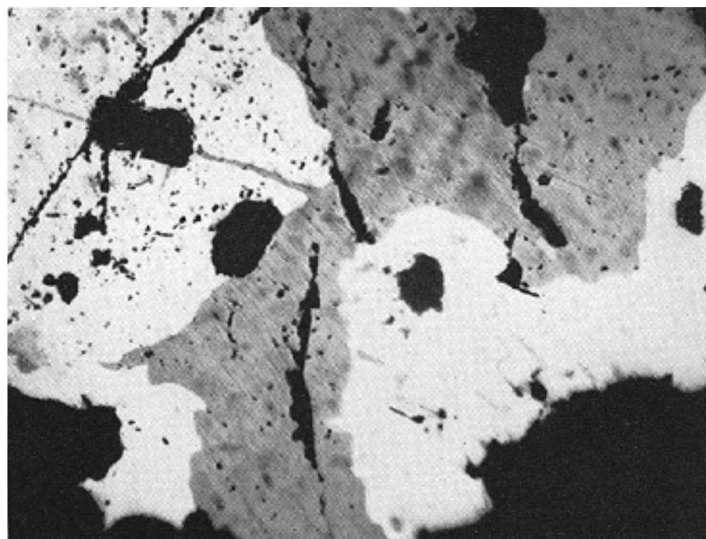
⁵Lake Shore Mill Staff, *op. cit.*, p. 296.

⁶E. W. Todd, *op. cit.*, p. 71.

Petzite

Petzite, $(\text{AgAu})_2\text{Te}$, has been reported by Todd¹ in ores from the Wright-Hargreaves, Sylvanite, and Toburn mines and is described as jet black, with a brilliant lustre, associated with other tellurides, sulphides, and gold. Differential etching (with HgCl_2) brings out the presence of small masses of coloradoite, which have sharp boundaries, and analyses indicate minor amounts of intergrown altaite. Its silver-gold ratio is almost exactly 3 to 1.

A study of specimens at present available has shown only one in more than 60 sections containing petzite. In this, the petzite is associated with coloradoite and altaite. Its boundary against coloradoite is almost imperceptible unless



Photomicrograph of a sample from the Burrows-Todd collection showing calaverite (white) on the left veined and replaced by coloradoite (grey), which in turn is replaced by altaite (white) on the right. Note late gangue (black) interrupting veinlet of coloradoite. (X160.)

stained with mercuric chloride. Where it is isolated from coloradoite, the slightly greyer colour of the petzite may be distinguished from the purple-grey of the coloradoite. Furthermore, certain grains of petzite show distinct anisotropism when examined with polarized light, and under crossed nicols a fine grid of twin lamellae at about right angles may be discerned. Both coloradoite with intergrown gold and altaite appear to embay and replace the petzite, the altaite much more clearly than the coloradoite. Only rarely is visible gold found enclosed in petzite. In contrast to these observations, however, Todd² has illustrated two specimens, one of which is described as having veinlets of calaverite penetrating an intergrowth of petzite and coloradoite, and the other as having calaverite seemingly replacing the petzite.

Calaverite

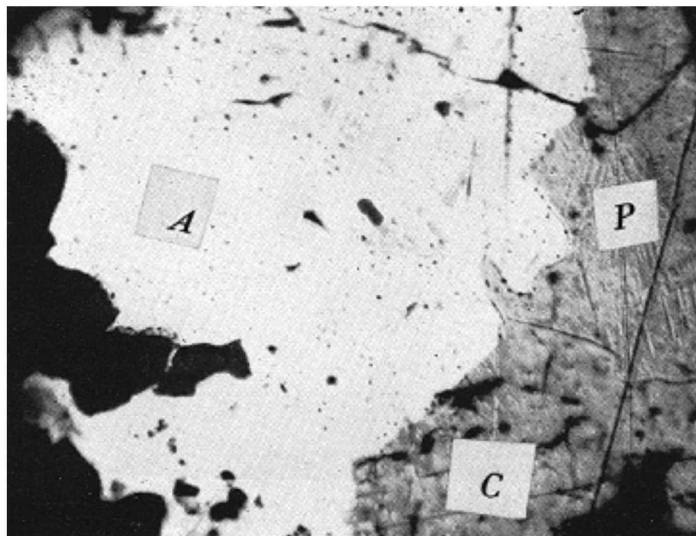
Calaverite (AuTe_2), which in hand specimens approaches pyrite in colour and in polished sections has a very pale, pinkish to creamy tone, has been shown by Todd to occur in an exceptionally pure form in the Kirkland Lake ores with

¹E. W. Todd, *op. cit.*, pp. 80-83.

²*Ibid*, pp. 74, 82.

only a minor amount of silver in solid solution with it.¹ After altaite it is the second most abundant telluride in the camp. Occurrences large enough to supply material for Todd's analyses came from the Lake Shore and Wright-Hargreaves mines, where the calaverite occurs in fractures in quartz and in porphyry. In most specimens where calaverite is present, it is intergrown with altaite and coloradoite or coloradoite alone, but it seldom appears in those in which petzite occurs.

Its relation to other ore minerals is not readily determined because in many cases it presents smooth boundaries against them. Todd² notes that calaverite is found occasionally as minute particles or veinlets in the more common altaite, and also in petzite and coloradoite, but no such occurrences have been found in the recent study. In most sections examined from all mines of the area, calaverite



Photomicrograph showing altaite (A) replacing coloradoite (C) and petzite (P), which are barely distinguishable from one another. Rims of fine gold and coloradoite border altaite (on the right). (X160.)

is found clearly replacing and embaying pyrite and chalcopyrite. Rarely it contains small rounded inclusions of gold and coloradoite, but more commonly coloradoite and altaite or altaite alone are found as rims around it, and in one case coloradoite also veins it. It thus appears as one of the earliest tellurides to crystallize, though any age difference with respect to the other tellurides may be very slight.

Coloradoite

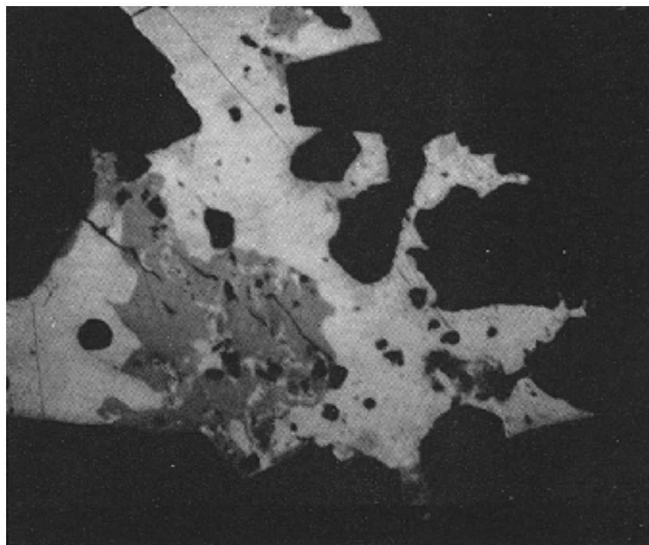
Coloradoite, though present in minute grains in specimens carrying other tellurides, is of fairly common occurrence, but appears rarely in Macassa ores. It has a purplish-black cast in hand specimens and a deep-purple tint in polished sections. Todd³ has recorded the occurrence of spectacular coloradoite in veinlets or seams about half an inch in diameter from the Lake Shore mine and notes that where it is free from gold it is fairly free from altaite.

¹E. W. Todd, *op. cit.*, p. 77.

²*Ibid.*, p. 73.

³*Ibid.*, p. 79.

In the present study, it was found that where various tellurides are present fine, rounded particles or rims and peculiar dendritic growths of gold appear more intimately associated with the coloradoite than with any of the others, as if much of the gold was either deposited contemporaneously with it or selectively precipitated by it. It is also found as rounded inclusions in native gold, in calaverite, as a fine stringer almost cutting through calaverite, and as a fine mixture with gold replacing petzite. Its relation to altaite is not so clear. In many cases it is found as thin seams or lenses between calaverite and altaite, as small fringes around gold particles in altaite, and as an irregular outer rim on many altaite grains, suggesting either that it is a deposition on altaite or, more probably, that it is a remnant left after considerable replacement by altaite, since in other sections altaite rims and appears to cut it.



Photomicrograph of a specimen from the Burrows-Todd collection showing altaite (white) enclosing and replacing coloradoite (grey), in which are many fine particles of gold (white). Gangue is black. (X160.)

Altaite

Altaite is the most abundant telluride found in the Kirkland Lake mines. In fairly fresh specimens it has a creamy-yellow colour. Locally, as in the No. 1,065 stope of the Sylvanite mine, it takes on a brilliant blue to bluish-green tarnish.¹ In polished sections it is tin-white in colour and lacks the pale-pink tone of calaverite, which it most resembles.

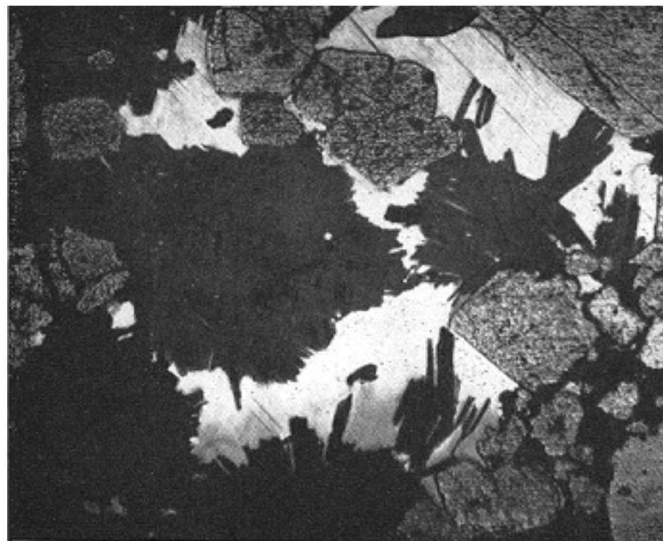
It is found everywhere in irregular masses ranging in size from minute blebs along fractures to seams with a maximum width of half an inch, which impregnate and replace highly sericitized wall rocks or vein minerals.

Altaite is found both in close association with all the other metallic minerals and, probably more than any of the other tellurides, alone in quartz or other

¹In sections where altaite is enclosed as blebs in calaverite a drop of 1:1 HCl produces a pale-blue tarnish on altaite resembling the natural one noted. It is possible that acidic natural solutions acting on such altaite may have been the cause of this peculiar behaviour. The resemblance of the above tarnish to that developed on chalcocite suggests that a minor content of copper may be necessary for this effect.

gangue minerals. In many sections it clearly replaces and fills fractures in pyrite and chalcopyrite and replaces petzite, calaverite, and coloradoite, though as noted under the last-named, outer fringes of coloradoite with gold might be interpreted as due to its later age.

Fine, rounded particles of gold are found embedded in altaite, with or without intervening rims of coloradoite, and in other cases stringer-like bands of gold follow the cubic cleavages of this mineral, definitely replacing it along these cleavages. In single fine fractures in quartz and carbonates, it occurs also as fine, isolated particles intermittently distributed along them, as are many specks of gold. In still other cases, narrow rims of gold appear around the borders of altaite grains. Rarely do peculiar fan-like aggregates of carbonate (calcite) appear to replace altaite.



Photomicrograph of high-grade ore from the J vein, 26th level, Teck-Hughes mine, showing fan-like crystals of late calcite (black) intergrown with and apparently replacing altaite (white). Crystals of pyrite (grey) are replaced by altaite and calcite. (X150.)

Melonite

The nickel telluride melonite has been reported from the former Tough-Oakes (Toburn) mine by Ellis Thomson¹ as occurring in ore with coloradoite, altaite, and gold. Todd² and Hopkins³ have also noted its occurrence in very minor quantities in the Wright-Hargreaves mine. Its relation to other tellurides is not known. None has been found in ores examined in the present study.

Tetradymite and Joseite

In one specimen obtained from a collection made by Burrows and Todd, the two bismuth tellurides tetradymite ($\text{Bi}_2\text{Te}_2\text{S}$) and joseite (Bi_3TeS) have been identified in a quartz gangue. Unfortunately, as this specimen does not contain any fragments of typically red Kirkland Lake porphyry and as none of the other common tellurides are present, there may be some doubt as to its source. The

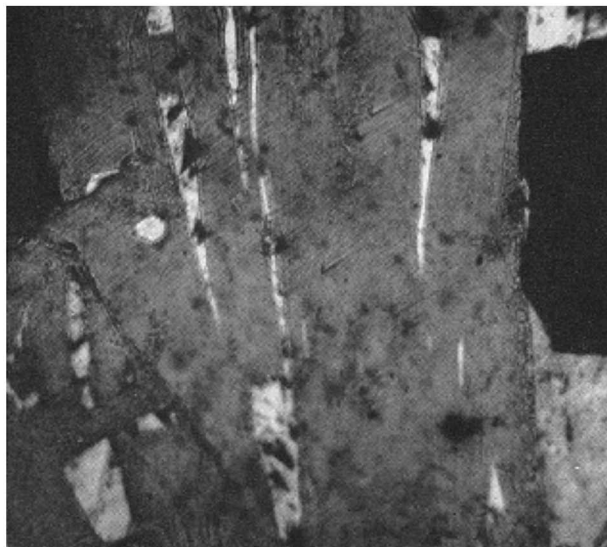
¹Ellis Thomson, *op. cit.*, p. 97.

²E. W. Todd, *op. cit.*, p. 87.

³Harold Hopkins, p. 166 of this report.

two tellurides in polished sections resemble respectively altaite and coloradoite, the tetradymite being white and the joseite slightly purple. Both staining tests and X-ray analysis have established their identity. Their resemblance to the other commoner tellurides suggests, however, that extreme care would be needed in distinguishing them.

The joseite occurs in angular grains enclosed in tetradymite, suggesting either contemporaneous deposition or unmixing from a solid solution. A test for selenium on these minerals indicates that it is present in minor amounts, and this association suggests that even if this is not a Kirkland Lake occurrence, the selenium traces reported in the ores may be associated with bismuth, which has been detected by spectrographic means as a very definite if minor constituent of altaite.



Photomicrograph of a sample from the Burrows-Todd collection showing a coarse-bladed crystal of tetradymite (grey), slightly stained with ferric chloride, and finer triangular grains and blades of joseite (white). (X150.)

ELEMENTS

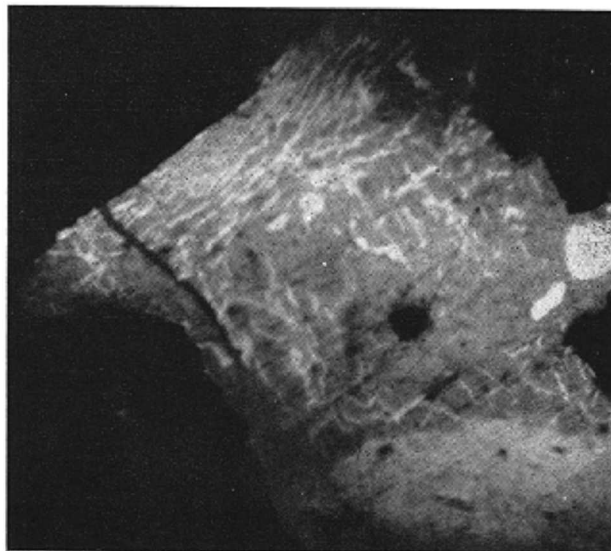
Gold

Native gold accounts for most of the precious metal of the Kirkland Lake camp, the remainder of the gold being accounted for chiefly by the tellurides calaverite and petzite.

Milling investigation on concentrates by the Lake Shore staff have indicated the occurrence of two varieties, one a paler type, enclosed in pyrite relatively free from other inclusions, and the other a deeper-yellow and relatively coarser type. They are reported to differ in their reaction to KCN.

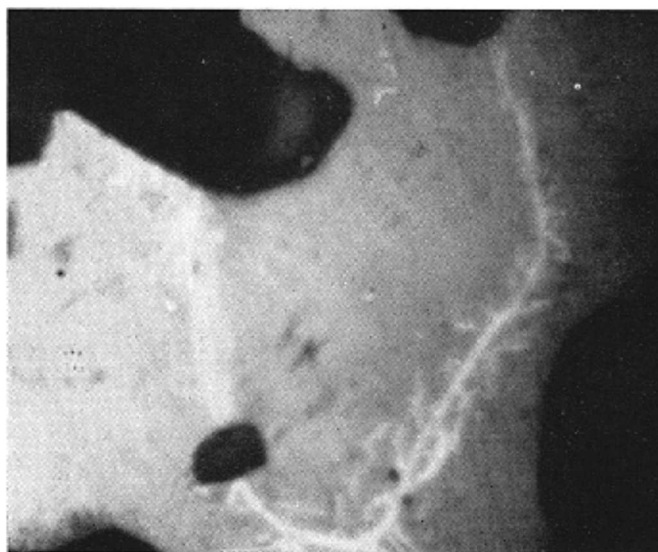
In all cases Todd¹ emphasizes the extremely small size of grain of the gold, particularly with reference to the deeper levels in the Teck-Hughes and Kirkland Lake Gold mines where coarser gold is encountered less frequently than in the upper levels; massive gold occurrences, as in the Lake Shore mine at the 800-foot level, are rare. In the specimens more recently examined, gold particles range from about a quarter of an inch to 1 micron or less in diameter.

¹E. W. Todd, *op. cit.*, p. 72.



Photomicrograph of a sample from the Burrows-Todd collection showing graphic intergrowth of gold (white) in coloradoite (grey). (X800.)

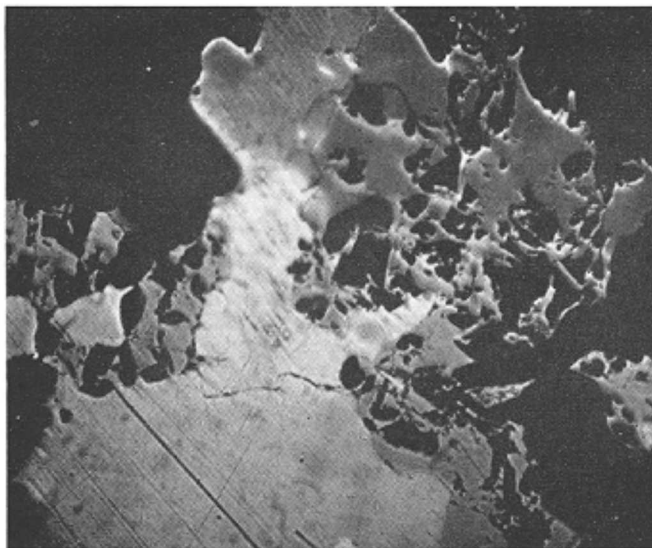
Hopkins,¹ in discussing the Wright-Hargreaves ores, has summarized data relating to the fineness of native gold in the various mines and shows that for the



Photomicrograph of a sample from the Burrows-Todd collection, showing a dendritic veinlet of gold (white) in coloradoite (grey). Ganque is black. (X800.)

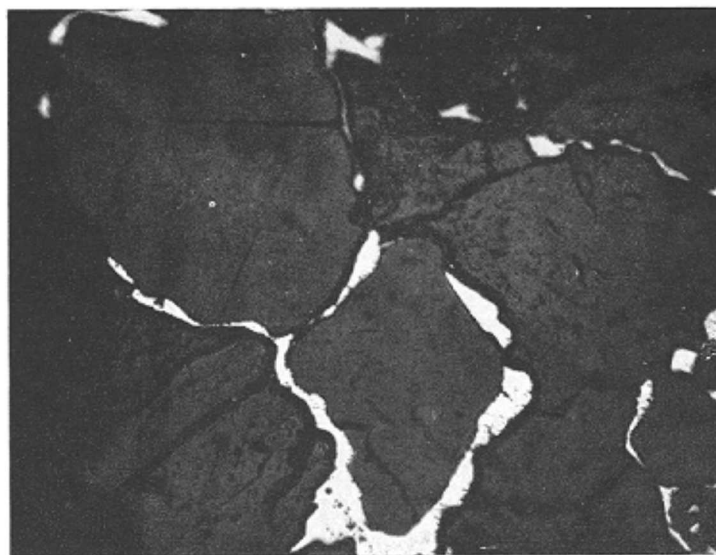
most part it is higher than 900 parts per 1,000, whereas bullion produced may be lower, owing to silver from other minerals.

¹Page 167.



Photomicrograph of ore from No. 2201 east drift, North (No. 2) vein, Lake Shore mine, showing gold (greyish-white) replacing chalcopyrite (dark-grey). (X160.)

Spectrographic analyses of 26 samples of gold from the various mines indicate that all contain minor quantities of tellurium, mercury, lead, copper,



Photomicrograph of ore from No. 2201 east drift, North (No. 2) vein, Lake Shore mine, showing gold and altaite (white) following the grain boundaries of quartz. (X160.)

silver, and iron. All but 6 show manganese, 17 contain molybdenum, and 9 bismuth. Only 6 show traces of nickel and titanium, but none carry detectable cobalt.

In the ores, gold occurs in a great variety of ways. In addition to the exceedingly fine inclusions noted in pyrite, it is present in coarser particles, visible at moderate magnifications, with or without associated altaite. It both veins (fills fractures in) and rims pyrite. It has been found within chalcopyrite and contiguous to chalcopyrite and primary magnetite-ilmenite intergrowths. Similarly, it is present as rounded inclusions in all of the tellurides but more abundantly in coloradoite than in others. A peculiar dendritic or branching-veinlet form of gold in coloradoite is shown in the photomicrograph on page 116. It has also been noted replacing, veining, following cleavages in (as in altaite and Calcite), and



Photomicrograph of a sample from the Burrows-Todd collection showing gold stringers (white) in altaite (stained grey with nitric acid). One veinlet follows cleavage and actually transects the grain boundaries of altaite. (X160.)

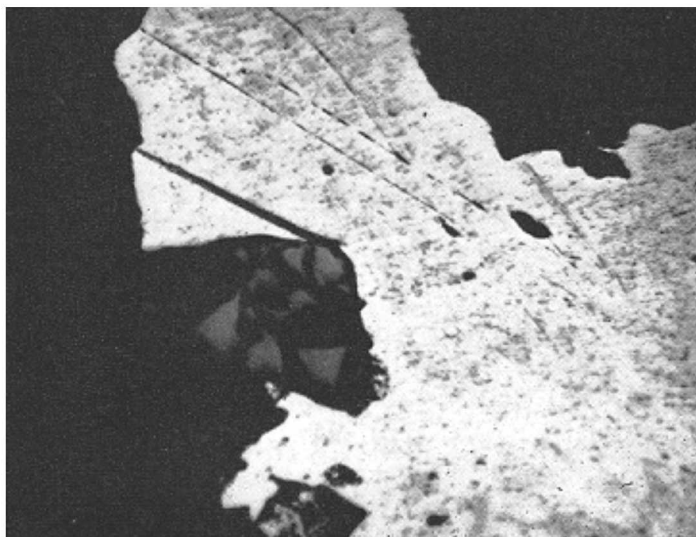
rimming many of the previously described minerals, including quartz, and in fractures in various types of wall rocks. These relations suggest that though gold may have been precipitated contemporaneously with pyrite, chalcopyrite, and the tellurides, much if not most of it formed at a later stage, in and around these earlier minerals, replacing many of them to some extent or filling fractures in them.

Graphite

Graphite has been reported by Todd¹ as a very minor constituent of the black molybdenite-bearing films found coating slip planes in or adjacent to the

¹E. W. Todd, *op. cit.*, p. 86.

ore. At the most it makes up only a fraction of a per cent. of this material and in places is completely absent. As spectrographic analyses of the black coatings containing molybdenite were made with graphite electrodes, the presence of graphite could not be confirmed.



Photomicrograph of ore from J vein, 26th level, Teck-Hughes mine, showing coarse gold (white, speckled) apparently replaced on the left by calcite (black), in which are angular fragments of magnetite (dark-grey). (X160.)

OXIDES

Magnetite

Magnetite occurs rarely in some high-grade specimens, as in one from the J vein on the 26th level of the Teck-Hughes mine, in which abundant gold and altaite are present with minor amounts of coloradoite and calaverite. The associated magnetite occurs in late calcite filling, which appears to replace the altaite. The magnetite is in ragged particles, entirely devoid of any intergrown ilmenite and free from any other metallic. It is obviously late in age and, though always separated from gold by carbonate, is likely post-gold, as is calcite in this instance.

Specular Hematite

Specular hematite has been described as filling fractures in altered and mineralized wall rocks and in fault zones in both syenites and sediments, in some of which gouge is still present. It has been noted specifically in the Wright-Hargreaves, Teck-Hughes, and Macassa mines and, according to G. H. Charlewood,¹ is post-ore in age at the Lake Shore.

A specimen from the Q vein, 34th level of the Teck-Hughes mine, taken at the contact between tuffs and porphyry, contains a solid seam of specularite from a quarter of an inch to half an inch in width with a selvage on either side of ferruginous dolomite. The porphyry adjacent to it is highly sericitized and carbonated and well mineralized with pyrite, and on the walls it is coated with thin seams of chlorite partly replaced by dolomite. The specularite invades both.

¹Page 156.

In age the specularite is in many cases post-ore and does not appear to contain any gold. Spectrographic traces of tellurium, mercury, lead, silver, manganese, molybdenum, copper, titanium, nickel, cobalt, zinc, strontium, and bismuth, though possibly due to contamination of the mineral or of solutions carrying in the specularite working over other ore minerals, probably signify a rather close genetic relation to the ores. In a specimen from the Macassa mine, fine stringers of specularite are clearly truncated by later quartz.

Red Dusty Hematite

The relation of the specularite to fine dusty-red hematite, which is a prominent colouring agent in many of the wall rocks near ores, is not known. This was in part likely introduced early in the mineralizing period and is distributed throughout feldspars and some quartz, but is missing from much of the fine quartz and carbonates, which are more closely associated with the ore minerals. Where silicification of feldspars has occurred, the red iron oxides in some cases remain in the quartz. Whether or not a further introduction of these fine oxides occurred at the same time as the late specularite is difficult to ascertain.

Non-Metallic Vein Minerals

QUARTZ

Quartz is by far the most abundant vein mineral. It ranges from colourless to white to grey to almost black and is for the most part massive, though cross-sections of single crystals do appear in a few polished sections of ore, and Hopkins¹ describes the occurrence of these in what were likely original vugs now filled with nests of tellurides. Most of the quartz is fine- to medium-grained, averaging about 1 mm. but ranging up to 4 mm. in diameter. Meen² indicates that etching tests show that it is of the low-temperature type (deposited below a temperature of 573° C).

A study of many thin sections of vein fillings shows that quartz has been deposited at various times throughout the period of mineralization. Hopkins³ describes the early vein filling as milky white, followed by a later darker type, though in thin sections both contain fine dusty inclusions. Where the light quartz cements porphyry fragments in the breccia type of ore, a narrow rim is of very fine grain, gradually coarsening away from the contact, indicating a cooling effect of the rock fragments. Much of the coarser quartz has been strained and shows undulatory extinction and a parallel lamellar structure, as well as granulation both along grain boundaries and on incipient fractures that have been healed by recrystallization of a perfectly clear, inclusion-free mosaic of very fine grains.

Some quartz is usually associated with fine carbonates and chlorite, which fill narrow tensional fractures in both earlier quartz and wall rocks. Quartz is noted in many descriptions of individual mines as a constituent of veins in post-ore faults.

CARBONATES

Ferruginous Dolomites and Calcite

Iron-bearing dolomite and calcite are the principal carbonates present. They occur chiefly in the wall rocks and to a lesser extent in the quartz veins. Todd's

¹Pages 164-165.

²V. B. Meen, "Contributions to Canadian Mineralogy, 1935" (reprinted from Univ. of Toronto Studies, No. 38), p. 67.

³Page 164.

bulk analyses of ore¹ indicate enough CO₂ to account for nearly 20 per cent. carbonates.

The ferruginous dolomite is white where it is fresh but shows oxide stains where it is at all weathered. Indices of refraction and potassium ferrocyanide staining solutions indicate slight variations in composition from 20 to 25 per cent. CaFe (CO₃)₂, and because of this the term dolomite is preferred to ankerite. It is most abundantly developed in basic syenite and porphyry and their mylonitized equivalents as an early alteration product of such ferromagnesian minerals as augite or hornblende and as disseminated grains in feldspars and quartzose matrixes. In the veins it may appear as highly twinned crystals forming a selvage between quartz and wall rocks, or as fine veinlets which merge with or are indistinguishable from the disseminated dolomite. In most cases it is clearly older than the main quartz introduction, but some appears to have formed in finer quartz stringers within both the veins and the wall rocks.

Calcite,² white to pink, is found in many places cutting dolomitized wall rocks, dolomite veinlets, and quartz. It has developed as peculiar radiating prismatic crystals, which are fan-shaped, in altaite and may possibly replace it, but is earlier than some gold that occurs in fractures within it.

A later generation of both dolomite and calcite is reported in post-ore faults, as at the Lake Shore mine.

Though in many cases, pyrite is developed in dolomitic areas in the wall rocks, there is no clear relationship between the amount of pyrite or gold values and the extent of dolomitization.

FELDSPARS

Albite and Orthoclase

As vein-forming constituents, feldspars are decidedly rare. Hopkins³ reports both orthoclase and albite. In the present study only two examples of albite in veins have been noted in specimens from the Sylvanite and Upper Canada mines. In both cases albite has been deposited after ferruginous dolomite and is followed by quartz. In addition, examination of many wall-rock samples has shown that in the intrusive porphyry and syenite, fine gash veins of quartz, carbonate, and, in places, chlorite carry either albite or oligoclase, which has been deposited where these transect feldspars. As seen under the microscope, these are clearly fracture-fillings, indicating that the solutions must have carried in the feldspar constituents. The amount so deposited, however, is very small.

OTHER SILICATES

Silicate minerals developed within the veins are in every case found also as alteration products within the wall rocks.

Tourmaline

Tourmaline, which shows pleochroism varying from brownish-black to light-brown, suggesting a distinct magnesium content, occurs sparingly in ore specimens from the Kirkland Lake Gold and Upper Canada mines. In ore from the 4,600-foot level of the Kirkland Lake Gold mine, the tourmaline is in fine rods and irregular grains in carbonated and pyritized porphyry. It appears to replace feldspar and early carbonates but is slightly replaced by pyrite and was formed

¹E. W. Todd, *op. cit.*, p. 69.

²Staining of calcite with Lemberg solution has proved useful in distinguishing it from dolomite.

³Page 165.

before the introduction of the quartz-carbonate veinlets. In other samples it is intimately intergrown with pyrite and appears to have formed at the same time.

Biotite

Biotite in a mat of very fine plates is found as a secondary mineral, developing in part from chlorite, in the vicinity of pyrite in wall rocks of ores from both the Kirkland Lake Gold and the Macassa mines.

Sericite and Chlorite

Both pale yellowish-green sericite (secondary white mica) and chlorite are minor constituents of the veins but are more prominent as alteration products within the wall rocks and breccia fragments, but their distribution is not nearly so widespread as that of the dolomitic carbonates. A minor amount of very fine sericite within feldspars bears no relation to the ores and is doubtless deuteric. Extensive sericitization, though seldom extending beyond a few inches from some of the veins, is indicated by the olive-green colour of the wall rocks referred to in individual descriptions of properties.¹ This alteration does appear to be related to values. Wall rock from a high-grade seam of tellurides and gold, with relatively little quartz, from the 26th level of the Teck-Hughes mine shows intense alteration to sericite immediately adjacent to the vein, decreasing outward within 1 1/2 inches into the more typical alteration to carbonates, chlorite, and quartz. The association of massive tellurides and intense sericitization here clearly indicates its superposition on the earlier carbonate type of alteration.

In addition, very minor sericite is found along fractures and slips within the quartz veins, whereas chlorite more commonly accompanies the much finer quartz and carbonate veinlets, coats fractures and walls of syenite or porphyry, and is also present in faults and slips of post-ore age.

SULPHATES

Barite, Gypsum, and Celestite

Barite has been reported in veins occupying post-ore faults at the Lake Shore mine² and barite and gypsum at the Wright-Hargreaves.³ In addition celestite has been identified in this study as clusters of fine radiating needles in a small vug of an ore-bearing quartz vein from the Lake Shore mine. All are of minor importance. Their genetic relation to the main ore-forming period of mineralization, however, is suggested by the occurrence of traces of barium in all and strontium in many of the pyrite samples from these deposits that have been examined spectrographically.

PARAGENESIS OF THE KIRKLAND LAKE ORES

Both field and microscopic studies indicate that the introduction of the ores of Kirkland Lake occurred during a period of rather complex fracturing and faulting, which did not end until some time after the actual ore minerals had been emplaced, as evidenced by barren veins filling post-ore faults. It is altogether probable that the fractures of tensional and shear origin were opened or formed progressively and were progressively mineralized and that minerals deposited early in the sequence were, in places, fractured and in part replaced by later ones. The actual succession of events that obtained in one part of the ore deposits may not then be exactly representative of what happened in another,

¹Chapters IV to X.

²Page 157.

³Page 168.

but the following may be regarded as a generalized history of the formation of the ores.

Pre-Ore Alteration

The pre-ore alteration (deuteric or hydrothermal) of the Kirkland Lake ores occurred as follows: alteration of augite to hornblende, of hornblende and biotite to chlorite, ferruginous carbonates, and secondary quartz; slight general sericitization of feldspars. Possibly some of the red iron oxide staining of feldspars and matrix of porphyry and syenites occurred either at this stage or at the beginning of the next.

Hydrothermal Mineralization

The hydrothermal mineralization of the Kirkland Lake ores may be summarized as follows:—

1. More extensive alteration of wall rocks to ferruginous dolomite and more complete destruction of augite, hornblende, and biotite to carbonates, quartz, chlorite, and leucoxene; wide dissemination of carbonates and introduction of dolomite veinlets with varying amounts of quartz and chlorite in wall rocks and particularly in mylonitized fracture zones.

2. Pyritization of wall rocks, at first chiefly by the addition of sulphur, replacing iron minerals such as magnetite-ilmenite intergrowths, but later by introduction of pyrite itself and replacement of other minerals. Only locally were tourmaline and biotite developed at this stage.

3. Main introduction of quartz either contemporaneously with the development of pyrite or closely following it, relatively minor pyrite being deposited with the quartz. In some places ferruginous dolomite and albite formed selvages on quartz veins, but in most they are missing. Relatively minor silicification occurred in walls and breccia fragments, but replacement of either fine gouge around fragments or the fragments themselves is indicated. The fine grain of quartz deposited on many fragments of syenite or porphyry suggests a chilling effect. Progressive fracturing and introduction of white and darker varieties of quartz.

4. Minor and local introduction of calcite both in quartz veins and in wall rocks, rarely accompanied by albite.

5. Main deposition of sulphides, later tellurides, and native gold. The general order of deposition appears to have been: minor arsenopyrite and pyrrhotite; chalcopyrite with rare sphalerite and galena; molybdenite(?); calaverite or petzite, coloradoite, altaite, and gold. Locally, reversals of this order may occur. The Lake Shore descriptions¹ of most minute gold inclusions in some pyrite and its almost constant presence in spectrographically analysed pyrite from all of the mines strongly suggest that some gold was deposited directly with the pyrite. On the other hand, the relations of gold to chalcopyrite and the various tellurides are such as to imply that it was present in the same fluids from which these were being precipitated, some of the gold crystallizing contemporaneously with them, but much of it remaining in the residual solutions until after the others had formed, as shown by the manner in which it rims them and fills fractures or locally replaces them. At the same time, at least locally, still more intensive sericitization of wall rocks occurred, particularly where marked concentrations of tellurides and gold were formed. Where these last gold-rich liquids invaded only fine fractures, little evidence of such hydrothermal alteration is present.

¹Page 107.

Post-Ore Faulting, Veins, and Alteration

The continuation of faulting and fracturing and the introduction of post-ore veins carrying pink calcite, dolomite, quartz, barite, gypsum, celestite, some chalcopyrite, sphalerite, possibly galena, and, locally, specularite or magnetite represents the closing and final period of mineralization in the area.

CLASSIFICATION OF THE KIRKLAND LAKE ORES

As noted by Todd,¹ the ores of the Kirkland Lake camp indicate, by their mineral composition, texture, structure, fineness of grain, and associated wall-rock alterations, that they were formed under intermediate temperatures and pressures, which only very locally approached those of the deeper-seated type. They are accordingly classified as mesothermal. Both the character of the minerals and the wall-rock alterations as detailed above clearly point to the infiltration of the ores in hydrothermal solutions, the effect of which, even at the stage where tellurides and gold were being deposited, is marked by intense local sericitization.

The extreme fineness of grain of both the associated pyrite and the other metallics, their uniformity in this respect over great lateral and vertical distances, the very fine grained, chilled borders of quartz against wall-rock fragments in veins, the evidence of open-space fillings, and the usual absence of typical high-temperature silicates suggest that the ore-bearing solutions ascended into fractured rocks which were probably slightly cooler than the solutions themselves.

The uniformity of the mineralization to depths of more than 6,000 feet, with the possible exception of the quantitative distribution of tellurides (reported to be richer in the upper levels²), is rather strikingly borne out by spectrographic analyses of pyrites from various horizons and indicates that rather similar chemical and physical conditions prevailed over this interval during the deposition of the ores and that any further variations that may be found at still greater depths may be due more to structural controls than to other factors.

¹E. W. Todd, *op. cit.*, p. 91.

²*Ibid*, pp. 82, 83.
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CHAPTER IV

Geology of the Macassa Mine

By Wm. Ward¹ and Jas. E. Thomson

History and Development

The Macassa is the most westerly of the seven producing mines along the Kirkland Lake break. Macassa Mines, Limited, was organized in 1926, and in 1933 acquired the assets of United Kirkland Gold Mines, Limited. The company now owns a block of eleven claims covering a length of about 4,300 feet along the Kirkland Lake fault at the surface. First work on the property was done by Elliott Kirkland Gold Mines, Limited, who sank a shaft on the Main break on claim L. 1,617 to a depth of 23 feet and did some lateral work on the 300-, 400-, and 500-foot levels before operations were discontinued in 1917. Macassa Mines did further work on the 500-foot level in 1926 and 1927.

Successful development of the Macassa mine began in the year 1931. It was known that the pipe-like body of syenite in which important ore shoots were found at the Kirkland Lake Gold mine pitched westward on the hanging-wall side of the Main break and entered Macassa ground. Accordingly, Macassa Mines arranged to drive westward along the break from the 2,475-foot level of the Kirkland Lake Gold. This work located the first Macassa ore bodies. In the mean time No. 1 shaft was sunk and connected with the workings at this horizon.

A 200-ton mill was constructed and commenced production in October, 1933; later the capacity was increased to 400-425 tons daily. During the Second World War, production was curtailed. In 1947 the average daily tonnage milled was about 267 tons.

No. 1 shaft extends to the 3,000-foot level and No. 1 winze from the 3,000-foot level to a depth of 4,826 feet (1947). No. 2 shaft is located about 1,000 feet southwest of No. 1 and extends to the 4,000-foot level. The Elliott shaft is connected to the main workings by a raise from the 1,500-foot level to the 500-foot level (see sheet B). The ore bodies are developed and mined from levels and sub-levels extending from the 1,300- to the 4,625-foot horizon. Up to the beginning of 1947 ore had been stoped from all these levels to a depth of 4,250 feet and development had been extended to the 4,625-foot level. Long exploration crosscuts have been driven north and south across the property on the 3,000-foot level.

General Geology

The rock formations on the Macassa property consist of tuffs, sediments, and a variety of intrusive types; most of the mine workings are in the intrusives. The sedimentary formations and the long axis of the main intrusive bodies strike N. 60°-80° E. and dip to the south, generally at a steep angle.

The main sedimentary rock type both on surface and in the mine workings is boulder and pebble conglomerate. Pebbly grit, arkose, and greywacke also occur and are interbanded with tuff in the Amalgamated Kirkland and Casakirk crosscuts on the 3,000-foot level. The tuff is a hard, cherty variety, generally bedded. Interbedded with the tuffs at a few points in the underground workings

¹Geologist, Macassa Mines, Limited.

are bands of trachyte and porphyritic trachyte. The latter type contains larger feldspar crystals and is similar to the so-called "spotted trachyte" found on the surface at several localities in Lebel township.

The intrusives in the mine workings are classified as augite syenite (formerly called basic syenite or "lamprophyre"), syenite, syenite porphyry, and diabase. As indicated on the accompanying plans and sections (in map case), the augite syenite is the oldest and most widespread of the intrusive types. It is an elongated, tabular mass of irregular outline. The body dips 75° to 80° S. to about the 2,000-foot horizon and then appears to bulge on the south side and generally flatten slightly in dip. The augite syenite is normally a medium- to coarse-grained black rock. It alters to a reddish colour in the vicinity of veins and the Main break. The augite syenite is intruded by a westward-pitching, pipe-like mass of syenite. At some points the contact between syenite and augite syenite is sharply defined; at others there is a transition zone between the two types. This behaviour is noticeable in drill cores. The syenite has been sliced into two parts by the main fault, and the southern part has been thrust upwards about 1,500 feet. The syenite porphyry occurs as dikes with sharply defined intrusive contacts and cuts the syenite and augite syenite. These dikes conform fairly closely in strike and dip to the regional trend of the formations. Only one diabase dike has been found in the mine workings. It is about 10 feet in width and strikes slightly west of north. It cuts all other rock formations.

The west drift on the 4,500-foot level shows a series of small, narrow, irregular dike-like bodies. They appear to cut the syenite with well-defined contacts and contain inclusions of that rock. The dike-like bodies are light-coloured and show pale-green altered phenocrysts. Their relationship to other rock types has not been ascertained. Microscopic examination shows that they consist of fine-grained carbonate, quartz, chlorite, and sericite. This suggests that they may be alteration products rather than intrusives. On the 4,500- and 4,625-foot levels these dike-like bodies are frequently slightly faulted. Gold-bearing quartz veins occur within and along the contacts of these bodies; they are thus pre-ore in age.

Structure and Ore Deposits

The main structural feature of the Macassa mine is the Kirkland Lake fault, or Main break, which traverses the entire length of the property. It is a definite and clean-cut fault, which can be easily followed throughout the mine workings. The fault is marked by a zone of chloritic schist and gouge ranging from a few inches to a few feet in width but generally limited to a foot or less. In places the main shear zone has split into two or more slips and formed a braided structure. A fault breccia is frequently found along the structure, especially where the mud zone is not so strongly developed. The fault breccia contains angular and rounded fragments of the wall rock; in places even white quartz fragments are found in the breccia. The fault is frequently bounded on either side by different rock types, all of which tend to show a reddish or buff-coloured alteration adjacent to it. Gold-bearing quartz veins frequently adjoin the main fault. They may be on either hanging wall or footwall or on both sides of the main plane of movement, but the bulk of the ore is on the hanging-wall side.

The attitude of the Main break is shown on the accompanying plans and sections (in map case). It tends to bend and roll slightly at certain points both on strike and dip. The general dip is about 80° S. to a depth of around 3,500 feet; below that depth it flattens to about 60 degrees. No other faults or strong breaks in any way comparable to the Main break are known in the mine workings. The

long crosscuts to the north and south on the 3,000-foot level have revealed mostly minor fractures. At the Casakirk boundary, however, two stronger structures occur; these correspond roughly in location to the Narrows break found in the mines to the east (see sheet D in map case).

The amount of displacement on the Main break is indicated approximately by the offset of the two most prominent marker horizons. These are the westward-plunging syenite pipe and the narrow north-south trending diabase dike. The syenite displacement is pre-ore, whereas the offset of the diabase is post-ore movement. As the boundaries of the syenite mass are irregular, different cross-sections may show a considerable variation in the amount of vertical movement. If the outline of the syenite, however, is plotted on longitudinal sections along the hanging wall and footwall of the Main break and these are adjusted to fit, the best approximation of the displacement shows that the hanging wall (south side) has moved vertically about 1,500 feet without any lateral movement. The displacement of the diabase is negligible in amount. A dike on the 4,250-foot level has been offset laterally about 2 1/2 feet by the Main break. The best estimate of the displacement on the Main break is thus a pre-ore vertical thrust of about 1,500 feet on the hanging wall and practically no post-diabase movement.

The nature of the pre-ore vein fracturing adjacent to the Main break is shown by the accompanying plans and sections. Some of the subsidiary fractures branch off the Main break both vertically and laterally; others have not been traced into the Main break in mining operations to date. The dip of these subsidiaries varies considerably but is generally flatter than the main shear zone. Practically all of the important subsidiary vein fractures found to date are on the hanging-wall side of the Main break. The maximum known lateral extent of these quartz-filled fractures to the south of the Main break is about 325 feet.

Although the hanging-wall subsidiary veins almost always have a flatter dip than the Main break, there are a few exceptions to this general rule. For example, a steeply dipping hanging-wall vein of some importance has been traced from the 1,500-foot level to the 3,100-foot level (see Fig. 9 on page 128) and may branch from the main fault somewhere below this horizon. As shown by the generalized section in Fig. 9, on the 1,500-foot level the break lies 300 feet south of the main fault, whereas on the 3,100-foot level it is found only 60 feet to the south. The ore bodies along this structure occur almost entirely within the hanging-wall syenite; they pitch west, as shown on the longitudinal section in Fig. 9. About 800 feet of almost continuous ore has been developed along this break on the 2,800-foot level.

Other steep hanging-wall veins of this type occur on a smaller scale between the 3,225- and 3,600-foot levels near the east boundary of the property. These veins lie parallel to the Main break at distances up to 80 feet to the south, pitch west at an angle of about 45 degrees, and have a steeper dip than the main fault. Here the country rock is augite syenite. Ore lengths of from 200 to 400 feet have been developed along this vein zone.

Recent exploration (October, 1948, to April, 1949) on the 4,625-foot level has located what appears to be a new ore occurrence in the mine. It lies a short distance west of any ore yet found on levels above this horizon. A break containing both massive vein quartz and stringers over widths of as much as 3 feet has been drifted on for 330 feet, 240 feet of which was of ore grade over a 3-foot width. This break strikes exactly east-west and is dissimilar to any other ore-bearing structures in this part of the mine in that it dips to the north at an average of 60 degrees. It lies in augite syenite. Gold values have been found in three holes drilled into the north wall of this break at depths of from 25 to 100 feet.

In April, 1949, the exact location of the Main break in this part of the mine had not been determined, and the significance of the northward-dipping vein was not known.

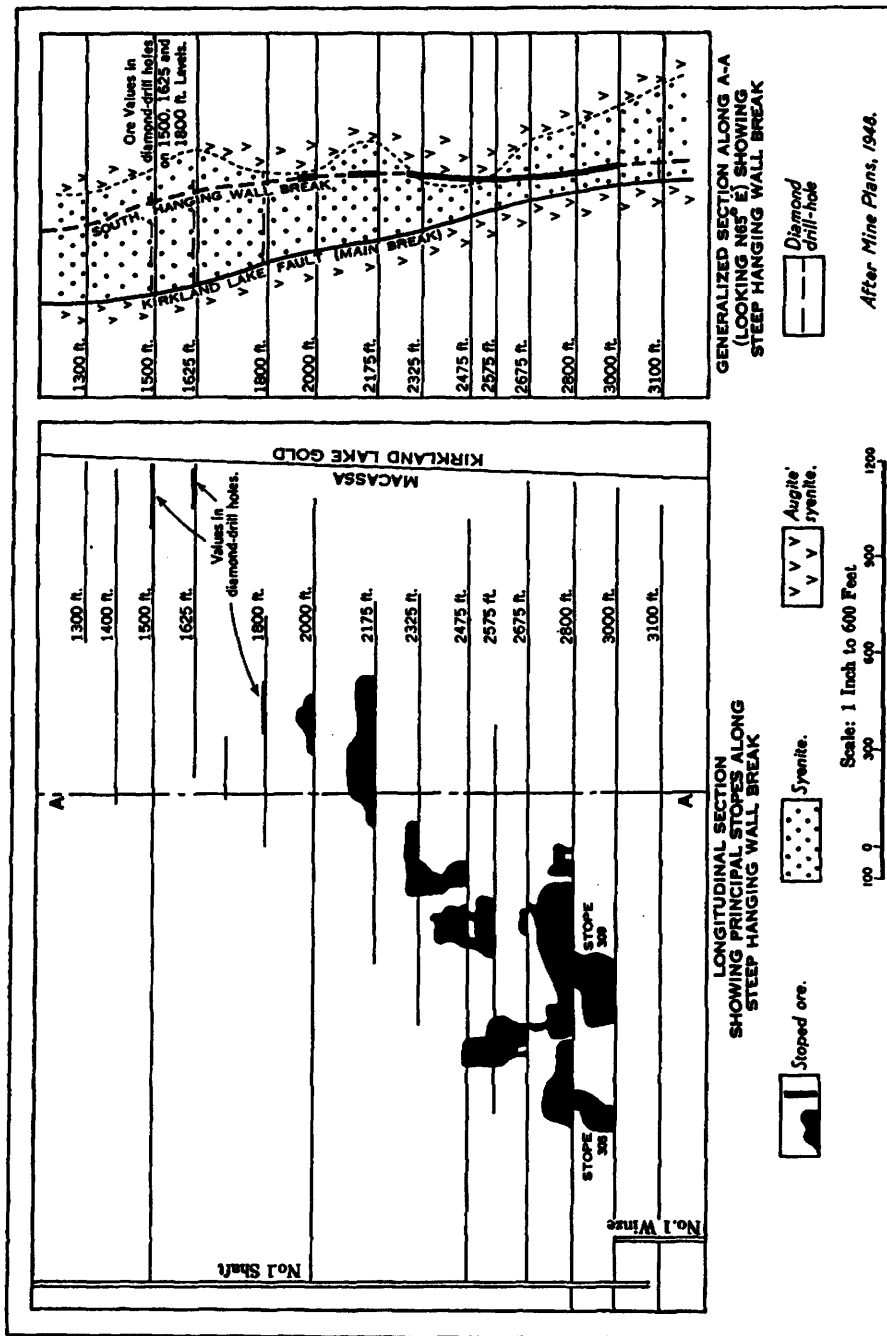


Fig. 9—Longitudinal section and generalized section showing ore along the steep hanging-wall break, Macassa mine.

The quartz veins that follow the main fault are generally found on the hanging-wall side of the break to a depth of from 3,300 to 3,400 feet and thus have

syenite as the host rock. Below this horizon the veins are generally on the foot-wall side of the main mud seam and lie in the augite syenite. In exploration along the Main break, the drifts are kept on the hanging-wall side of the fault on the upper levels and on the opposite side at deeper horizons.

Veins

The productive veins at the Macassa mine are always quartz-filled fractures, though all of the quartz does not necessarily make ore. The veins may range in size from a mass of quartz several feet in width to a zone of parallel stringers, each of which may be only a fraction of an inch in width. Along the Main break, the chloritic gouge may form a clean-cut wall, whereas the opposite side may be irregular with a gradually diminishing number of quartz stringers. Where the latter condition occurs the ore is mined to an assay wall.

The veins occur in every type of country rock in the vicinity of the Main break and hanging-wall area with the exception of the diabase. This feature is well illustrated on the accompanying mine plans. Many of the veins occur in or adjacent to the hanging-wall part of the westward-pitching syenite pipe. Below this body the veins are found mostly either in augite syenite or along the faulted contact between it and the footwall part of the syenite pipe. As syenite porphyry dikes occur irregularly throughout the mine workings, the veins occasionally occur within or along the faulted contact of these bodies. As indicated on the accompanying sections, many of the stopes on the Main break are bounded by different rock types on the hanging-wall and footwall sides.

Sheet G shows in detail the shape and distribution of quartz veins throughout a small part of the 3,000- and 3,100-foot levels. This is more or less typical of the general condition throughout the mine. It shows the discontinuous and irregular nature of the quartz and its location with respect to both pre- and post-ore fractures. The distribution of quartz with respect to the location of ore is also indicated by the position of the stoped areas. It will be seen that not all the quartz areas are of ore grade and that some portions of the ore shoots contain very little quartz along the drifts.

The distribution of quartz along the Main break is spotty and irregular; the actual percentage of quartz in the ore is relatively low. In contrast, the subsidiary veins are well-defined quartz-filled fissures. They are thus much more regular and continuous quartz bodies than the veins along the Main break.

The vein filling consists of quartz, inclusions of wall rock, small amounts of sulphides, tellurides, and gold. Tellurides and visible gold are seen only in extremely rich portions of the veins and are rarely found. The quartz consists mainly of a dark greasy variety and a white vitreous type, both of which are frequently intermingled in the same vein. Different generations of quartz are seen in crosscutting relationships throughout the veins. Inclusions of the wall rock may be in the form of angular fragments of breccia or slabs elongated parallel to the vein walls. The inclusions have a reddish colour similar to the altered wall rock. The chief sulphide is pyrite, and it is always in a very fine grained and disseminated state. It is sparsely distributed and generally in the wall rock or the inclusions. Molybdenite occurs along the fracture planes in the vein, and it is in such places that tellurides and native gold frequently occur. The gold-bearing quartz is always well fractured. Gold values are erratically distributed throughout the quartz, and the ore boundaries are only indicated by assay.

Wall-Rock Alteration

The most noticeable feature of wall-rock alteration is the very reddish discoloration of all types of country rock adjacent to the veins or Main break. In

addition, patches of a buff-coloured and cherty alteration product, which may be either massive or brecciated, are developed locally adjacent to the fault. This is the so-called mylonite that is found throughout all the mines in the camp. The width of the zone of alteration varies greatly depending upon the distribution of the veins and slips. Where there are several subsidiary veins on the hanging wall of the Main break, the area of alteration is extremely irregular. In areas where veins are lacking, the alteration generally does not extend beyond from 10 to 15 feet from the fault plane. The zones of alteration, unless accompanied by quartz veins or stringers, never carry sufficient gold to be classified as ore.

Ore Shoots

The distribution and size of the ore shoots is indicated in part on the accompanying plans and sections. They do not present a true picture of the ore continuity, however, because many ore shoots are only partially stopped or tied up in supporting pillars. In places high-grade veins only a few inches in width can be profitably mined; at other points the ore is stopped over widths of as much as 30 feet. The average stoping width for the mine would be approximately from 8 to 10 feet. On the average, the ore bodies along the Main break are considerably wider than those in the hanging-wall subsidiaries. The Main break ore bodies also have the greater continuity. For example, total ore lengths of about 2,000 feet have been found along the break on the 3,100-foot level within a total length of 2,400 feet. The vertical range of these ore shoots is from 1,200 to 1,300 feet. In comparison, the hanging-wall ore bodies are much smaller and generally have a flatter dip.

In longitudinal section, the upper extremity of the ore bodies in the mine rakes to the west at an angle of roughly from 35 to 40 degrees, to a depth of 3,000 feet. Below this horizon the west extremity of the ore is roughly vertical.

Post-Ore Faulting

The displacement of veins, ore shoots, and structures by post-ore faulting is small. The offset is generally on narrow slips or fractures, along which calcite or barren quartz is sometimes found. They strike and dip at many different angles. At certain points on the lower levels, a system of faults cuts the veins at a very acute angle. The maximum known displacement of ore in the mine is about 30 feet, but generally it is only a few feet. Most of the post-ore faulting affects the subsidiary veins only and occurs as a series of minor slips, on each of which there is a small amount of displacement.

Structural Control of Ore Bodies

The most important structural control in the mine is the Main break. Practically all the known ore occurs either along it or within a distance of not more than 325 feet normal to it on the hanging-wall side. Even the ore shoots along the Main break are concentrated on the hanging-wall side of the main mud seam throughout most of the mine. The weaker system of steeply dipping veins, which tend to converge at depth with the Main break, would occupy branching and parallel planes of shearing in the structural pattern.

The flatter hanging-wall veins appear to have occupied fissures and would be formed in those localities where tensional forces were acting (see section No. 2, Fig. 7, facing page 82). The thrusting of the hanging wall over the footwall would produce tension fractures on the moving side, and these would be concentrated adjacent to the main plane of movement. Lesser movements on the fault plane after the vein formation would accentuate the development of the mud seam or fault gouge.

TABLE 6—MACASSA MINE STATISTICS, 1937-1946

	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946
Tons milled.....	90,617	110,718	148,085	150,674	142,332	120,400	103,259	83,392	71,988	87,383
Tons milled daily.....	275	275-400	406	411	390	329	283	229	197	239
Recovery per ton.....	\$16.16	\$15.98	\$15.65	\$17.79	\$17.71	\$17.81	\$16.05	\$16.81	\$15.14	\$15.19
Value of bullion recovered.....	\$1,464,560	\$1,769,951	\$2,317,985	\$2,680,187	\$2,521,388	\$2,144,500	\$1,657,950	\$1,402,042	\$1,089,839	\$1,327,323
Operating costs per ton milled.....	\$6.62	\$6.78	\$6.13	\$6.87	\$6.81	\$6.93	\$7.29	\$8.54	\$9.70	\$9.78
Yearly operating profit (before write-offs, depreciation, and taxes).....	\$902,845	\$1,019,685	\$1,411,600	\$1,645,318	\$1,551,654	\$1,309,955	\$904,870	\$675,392	\$390,705	\$472,217
Net yearly profit.....	\$608,193	\$683,660	\$1,005,676	\$1,054,077	\$981,321	\$872,378	\$578,554	\$424,398	\$236,417	\$301,002
Estimated ore reserves (tons).....	290,000	344,200	378,580	453,900	507,350	506,710	492,306	462,800	412,600	413,650
Estimated grade of ore reserves (ounces per ton).....	0.45	0.451	0.469	0.45	0.451	0.46	0.451	0.452	0.444	0.439
Dividends paid.....	\$535,613	\$669,517	\$870,372	\$937,323	\$937,323	\$803,420	\$642,736	\$482,052	\$321,368	\$321,368

¹Plus 20,700 tons of an indicated average grade of 0.26 ounces per ton.

The various intrusive rock types do not appear to have exerted much selective influence on the localization of the ore, and it occurs freely throughout syenite, augite syenite, and syenite porphyry. The upper extremity of the ore shoots to a depth of 3,000 feet corresponds roughly to the pitch of the upper margin of the pipe-like body of hanging-wall syenite. For this reason it might be argued that the pitch of the syenite controls the rake of the ore. On the other hand, the ore shoots continue below the lower boundaries of this syenite body without any apparent relationship to it and without any suggestion that it controls the rake of the ore shoots. It also happens that below the 1,500-foot horizon in longitudinal section the upper boundary of the syenite corresponds roughly to the tuff-conglomerate contact. In other words, in longitudinal section, the upper termination of ore is near the margin of the main intrusive body, and this might be the structural feature that controls the rake. The boundary of the main intrusive body is, of course, extremely irregular, but from the information available it appears to plunge about 45° W. in the vicinity of the Main break, and this is fairly close to the rake of the ore bodies to a depth of 3,000 feet.

Statistics

The annual and total value of bullion produced and tonnage milled by the Macassa mine from the commencement of production in 1933 to the end of 1947 is given in Table 3. (facing page 60). The yearly and total output of gold and silver in ounces, the average gold-silver ratio, and the average fineness of the bullion are shown in Table 4 (facing page 60). The yearly and total dividends paid are given in Table 1 (page 59).

A detailed yearly analysis of production, recovery, costs, profits, ore developments, and ore reserves over the 10-year period ending December 31, 1947, covering conditions of peace and war, is given in Table 6 (page 131). This information is taken from the annual report of the company.

CHAPTER V

Geology of the Kirkland Lake Gold Mine

By O. S. Perry¹ and Jas. E. Thomson

History and Development

The Kirkland Lake Gold mine is located near the west end of the Kirkland Lake camp. It lies between the Macassa mine on the west and the Teck-Hughes mine on the east. The property covers a length of about 1,450 feet along the Kirkland Lake break on surface, but at depth the strike length along this structure is nearly doubled owing to the southerly dip of the break and the increased length of the southern part of the property.

The Kirkland Lake Gold Mining Company, Limited, was organized in 1915 and at that time owned only one claim (L. 1,236) along what later proved to be the main vein-fault of the camp. In 1929 the company bought the adjoining Chaput-Hughes property on the south and in 1936 further extended their holdings in that direction by purchasing the ground of Grozelle Kirkland Gold Mines, Limited. At present the main property consists of six mining claims, totalling 172 acres; four claims located north of the property of Macassa Mines, Limited, are also owned by the company. A 44.3 per cent. interest is held in Kirkland Basin Gold Mines, Limited.

According to Todd² the main vein-fault was drift-covered on the surface but native gold was found in deep trenches. The original discovery was made on the main vein near the Teck-Hughes boundary by projecting its strike from workings on that property. Two shafts were sunk, the first to a depth of 900 feet and the second to a depth of 1,000 feet. From these, levels were driven at 100-foot intervals.

The mine is now serviced from surface by a 3-compartment shaft extending to a depth of 2,666 feet. Owing to the southerly dip of the ore bodies, two winzes have been put down south of the main shaft (see sheet B). No. 1 winze is collared on the 2,475-foot level about 375 feet south of the main shaft and reaches a depth of 4,914 feet. No. 2 winze lies about 1,000 feet south of No. 1 and services the levels from 4,900 feet to 5,850 feet. The ore developed after these winzes were sunk showed a rake to the west, and two additional winzes were sunk. No. 3 winze was put down from the 3,600-foot level to the 4,450-foot level in the western section of the mine to work the downward extension of the ore from the upper levels, which crossed the corner of the property in this vicinity. No. 4 winze, which is also located in the western section of the mine, was collared on the 4,750-foot level, and at the time of writing (1949) has been taken to the 5,450-foot level. This winze will be deepened to the 5,850-foot level in the near future.

Gold production began in the year 1919 and has continued to date except for the year 1925. Table 7 (page 139) shows how the average daily milling rate has fluctuated in recent years as the result of labour shortages during the war and post-war period.

The policy of the company during the earlier years in the life of the mine was to concentrate on development at depth, where it was considered that ore conditions would improve. By 1935 the mine workings had been carried down to the 5,850-foot level. The ore came chiefly from the Main break zone until the

¹Geologist, Kirkland Lake Gold Mining Company, Limited.

²E. W. Todd, *Ont. Dept. Mines, Vol. XXXVII, 1928, pt. 2, p. 94.*

year 1937, when an important subsidiary vein was found on the south side of the Main break structure at and below the 3,475-foot level. Subsequently, other important hanging-wall veins were found below this horizon. In recent years the development of deeper veins has revealed much high-grade ore.

General Geology

The rock formations on the surface of the property are shown on map No. 1945-1, and their downward extension is indicated on the accompanying level plans and cross-sections (in map case). The two main groups of rocks on the property are the older sediments and the later intrusive rocks. The older sediments consist of conglomerate, greywacke, and tuffs of the Timiskaming series. These are intruded by augite syenite (lamprophyre), syenite, syenite porphyry, and quartz-feldspar porphyry and diabase. Ore is found in all the formations except the diabase. The bulk of the stopes are in syenite and syenite porphyry above the 3,500-foot horizon and in augite syenite below that horizon.

On the surface the main vein-fault follows the north contact of a sill-like mass of augite syenite about 250 feet in width. Another narrow parallel band of augite syenite lies 60 feet to the north. Conglomerate occupies the area between these intrusives and forms the footwall of the vein in certain localities to depths as great as 1,500 feet before being cut out entirely by them. On and near the surface the main intrusive body is flanked on the north by boulder conglomerate followed by tuff. The same succession is found on the south side of the fault and is believed to be the faulted repetition of the northern sequence. Conglomerate, greywacke, and tuff also occur in a pitching anticlinal structure in the lower part of the mine and have been followed to the bottom of the present workings on the 5,850-foot level.

The body of augite syenite widens somewhat with depth. In the upper part of the mine the augite syenite has been intruded by a westward-pitching irregular, pipe-like body of red syenite. The syenite outcrops on the Teck-Hughes property, crosses the Kirkland Lake Gold claims, and continues into the Macassa mine. This pitching body has been sliced into two parts through its long dimension by the Kirkland Lake fault, and the southern or hanging-wall part has been thrust upwards roughly 1,500 feet. The hanging-wall part of the syenite outcrops south of the fault on Teck-Hughes ground, crosses the Kirkland Lake Gold property between the 300- and the 1,600-foot levels and continues through the Macassa workings. The footwall part of the same body extends through the mine workings between the 1,600- and the 3,100-foot levels. This body continues through the southeast corner of the Macassa mine and then re-enters the Kirkland Lake Gold mine on the 3,375-foot level. It extends downward to a point below the 4,450-foot level before passing completely into the Macassa mine.

Syenite porphyry intrudes both the syenite and the augite syenite. The amount of syenite porphyry in the mine increases with depth. At the surface only a few dikes of porphyry appear. The larger porphyry bodies enter the mine on its east side and at the 5,450-foot level extend about half way across it. Quartz-feldspar porphyry occurs on the south side of the porphyry core within the anticlinal structure below the 4,450-foot level. It generally presents a sharply defined contact with the syenite porphyry, but the exact relationships of one type of porphyry to the other are not well established. A diabase dike, which trends more or less normal to the veins, dips into the property from the Teck-Hughes mine at a depth of about 2,500 feet and has been followed to the bottom of the mine workings. This dike dips about 75° W. It cuts all rock types, veins, and most of the ore, but is displaced a small amount by late movements along

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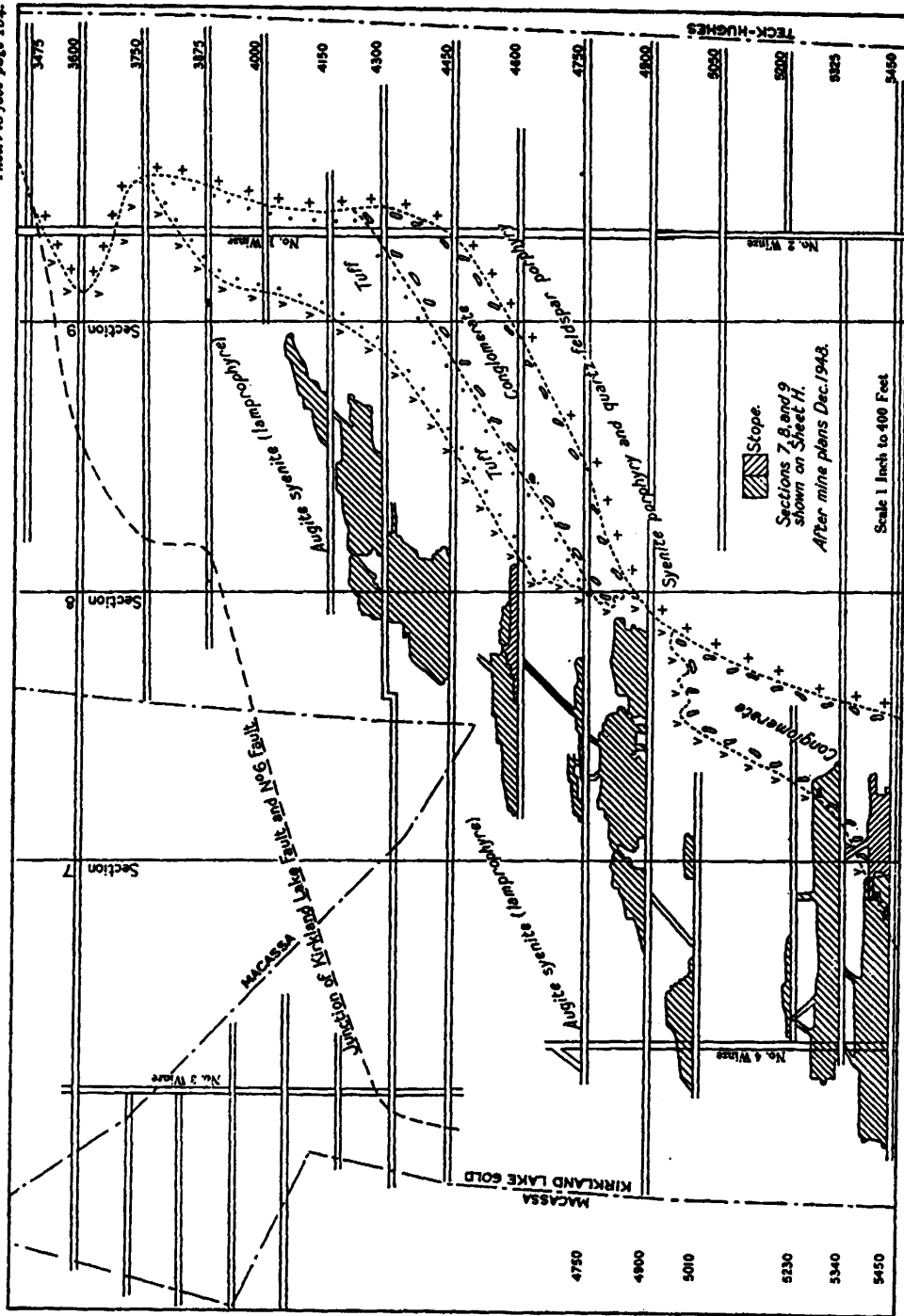


Fig. 10—Longitudinal section through part of the Kirkland Lake Gold mine, showing the relationship of the ore zone to the junction of the Kirkland Lake fault and No. 6 fault and also to the anticlinal structure. (Note that there are from 3 to 6 parallel stopes on each level, but for the sake of clarity only 2 are shown. See sheets E and J for the location of all stopes.)

and near the main Kirkland Lake fault. J. B. Tyrrell¹ states that some bodies of rich ore lying against the diabase on upper and intermediate levels appeared to be post-diabase.

Pre-Ore Structure

The Kirkland Lake fault crosses the entire property and has been traced to a depth of 5,850 feet in the eastern section of the mine. The over-all dip of the fault from the surface to the bottom of the workings would be about 75° S. As shown on the accompanying sections (sheet H), however, there are rolls on the fault plane at certain points, which produce considerable deviations from the average dip.

Todd² describes the fault zone on the upper levels as follows:—

Above the upper mass of syenite the fracturing is limited to narrow gouge-filled cracks confined to a width of ten feet or less, while in and around this rock the footwall and hanging wall are as much as 70 feet apart in places.

J. B. Tyrrell³ states that from here downward in the syenite both hanging walls and footwalls were well-defined. There was a moderate amount of gouge, and in places quartz veins containing rich lenses of gold were found in the vicinity of one or both walls.

No. 6 break branches from the main fault at the Teck-Hughes boundary below the 3,375-foot level, thus forming a split structure that straddles the lower anticlinal structure. Lying above No. 6 break, and more or less parallel to it, is the fracture occupied by No. 5 vein. The line of intersection of No. 5 vein with the Main break pitches to the west at an angle of about 20 degrees. No. 6 break is a well-defined mud seam similar in many respects to the Main break. The actual displacement on this structure is unknown, but it appears to cut off the crest of the anticlinal structure at certain points (see section No. 9 on sheet H). It does not displace a diabase dike, however, at least not horizontally, on the 3,750-foot level.

Only a small amount of ore has been found along the plane of No. 6 break, but between it and the Main break there are a number of productive veins. The line of intersection of No. 6 break with the Main break pitches to the west at an angle of approximately 20 degrees, but it pitches quite steeply in some places (see Fig. 10 facing page 134). The pitch of the line of intersection is roughly parallel to the pitch of the porphyry core that lies beneath, and the local variations in pitch are approximately parallel to the periphery of the porphyry body.

The top of the anticlinal structure begins on the 3,750-foot level towards the east end of the mine and pitches downward to the west as far as the 4,900-foot level and then steepens, as shown in Fig. 10. The anticlinal structure consists of a central core of syenite porphyry and quartz-feldspar porphyry surrounded in outward succession by horizons of conglomerate, greywacke, and tuff, followed in places by a second horizon of conglomerate (see 4,450-foot horizon, sheet E). The anticline is surrounded on all sides except the east by augite syenite, which intruded the tuff and conglomerate in a very irregular fashion. As the conglomerate and tuff bands of the anticlinal structure are mostly isolated from the similar formations lying to the north and south by the intrusives, their stratigraphical relationships have so far not been determined. The north limb of the anticline dips steeply and in places terminates at the Main break; the south limb dips with the porphyry and continues to the bottom of the mine workings (see sheet H).

¹President, Kirkland Lake Gold Mining Company, personal communication.

²E. W. Todd, *op. cit.*, p. 96.

³Personal communication.

The main Kirkland Lake fault has been followed to the bottom of the present workings in the east end of the mine, but at the west end there has been insufficient work on the bottom levels to correlate the structures with accuracy. Here, on the 5,340- and 5,450-foot levels, there are a number of more or less parallel vein fractures in the vicinity of the downward projection of the Main break from the 4,900-foot level. Lack of development information in the intervening ground, however, plus the complications arising from north-dipping post-ore faults (see section No. 7, sheet H), makes it difficult to trace the structures through from the 4,900- to the 5,450-foot horizon at the time of writing this report (1949).

In the interval between the preparation of sheet J and the writing of this report it has been found that the break shown on the main drift on the 5,450-foot level from section No. 8 to section No. 7 on sheet J is probably a post-ore fault.

By matching the hanging-wall and footwall parts of the syenite pipe it has been calculated that the south side of the Kirkland Lake fault was thrust vertically about 1,500 feet.

The so-called Chaput-Hughes break lies from 650 to 800 feet south of the main Kirkland Lake fault on the 1,600-foot level. This is a strong southward-dipping structure and is shown as a post-ore fault on sheet C and section No. 9, sheet H, for reasons given on page 85 of this report. After the lithographing of these maps had been completed, however, officials of the Kirkland Lake Gold Mining Company stated to the writer that they were definitely of the opinion that this is a pre-ore structure because it contains gold-bearing vein material. Probably the southward-dipping post-ore fault should not have been extended westward beyond the Teck-Hughes property on sheet C. There is also the possibility that both pre-ore and post-ore movement took place along this structure in a manner similar to that in which the adjustment of different periods took place on the Main break. The structure lying from 250 to 300 feet north of the Chaput-Hughes break on the 1,600-foot level is weak and indefinite.

Wall-Rock Alteration

Along the Main break the typical alteration of the Kirkland Lake camp is found. Where the structure passes through the intrusives the rock adjacent to mud seams shows reddish and buff-coloured discoloration, brecciation, and fracturing. The width of the zone of alteration varies considerably from place to place. Away from the main Kirkland Lake fault there is very little alteration along the walls of the quartz veins in the augite syenite, tuffs, and other sediments.

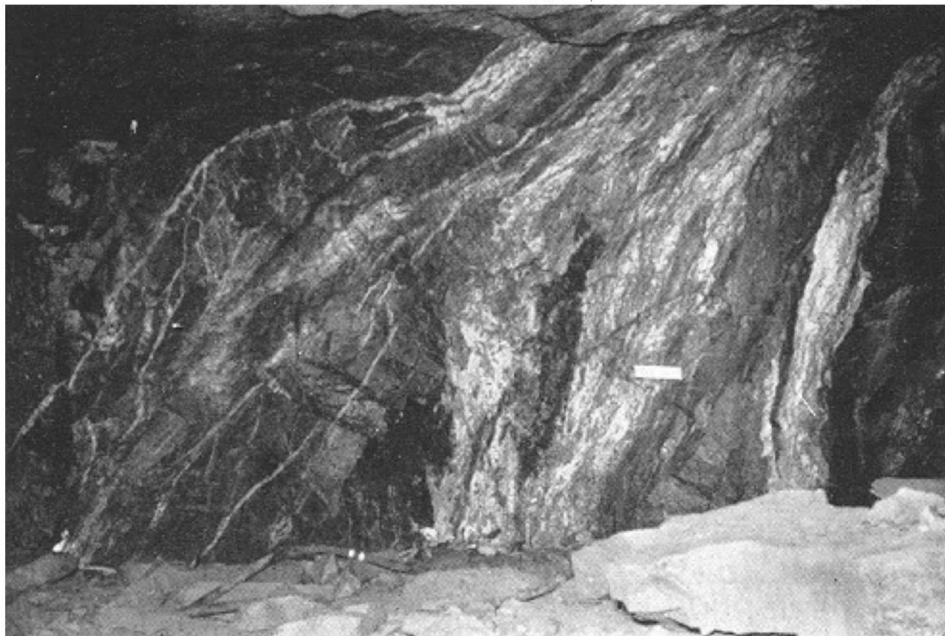
Veins and Mineralization

The accompanying plans and sections show that above the 3,400-foot horizon the productive veins occur in the zone of fracturing along the Kirkland Lake fault. They are found chiefly in those parts of the fault zone where syenite occurs on one side of the structure. There were thus two main productive horizons in this part of the mine. The upper horizon covered the extent of the hanging-wall syenite and lay approximately between the 300- and 1,850-foot levels. The lower zone embraced the foot-wall portion of the syenite between the 1,600- and 3,100-foot horizons. The westerly pitch of the syenite bodies has controlled the localization of the ore in this part of the mine. The sections on sheet H show that the veins are concentrated on the plane of the fault zone or on the hanging-wall side in both sections of the syenite body. Where the vein material lies in the Main break and is bounded by augite syenite on one side and syenite on the other, the vein-breccia fragments are always syenite and a well-defined slip separates

the vein material from the augite syenite. Veins in the augite syenite on the hanging-wall side of the slip (2,600- to 2,850-foot levels, section No. 9, sheet H) are of a different type and similar in nature to the deeper hanging-wall branch veins.

Below the 3,375-foot level the veins occur in a different environment. No. 5 vein branches from the hanging wall of the Main break and lies entirely in the augite syenite between the 3,375- and 3,875-foot levels. It begins in the vicinity of a roll on the Main break and dips from 30° to 40° S. The vein follows a well-defined fracture with varying widths of quartz. In some places it is a single quartz-filled fracture, in others a zone of parallel or branching quartz stringers or a vein breccia with inclusions of augite syenite. There is no very marked wall-rock alteration, and the host rock and vein inclusions are black augite syenite.

Photograph by the Kirkland Lake Mining Company, Limited.



Exposure of ore at the junction of Nos. 53-1.K and 53-4.L veins, 5,340-foot level, Kirkland Lake Gold mine.

The veins of the anticlinal structure lie in a zone of fracturing in tuffs and conglomerate, which folds around a central plug of intrusive porphyry. Some veins lie wholly within the tuffs, and others follow the tuff-conglomerate contacts. The anticlinal vein system has been developed from the 3,750-foot level as far as the 4,900-foot level. Some veins are found on the north and south limbs of the anticline and dip approximately parallel to the formations; one vein has been followed around the nose of the anticline. This means that the veins near the top of the anticline have a relatively flat dip, whereas those around the sides have steeper dips. None of the veins actually join the Main break.

The veins in the wedge-shaped block bounded by the main fault and No. 6 break are best shown on the composite geological plan of the 4,450-foot level (sheet E) and on sections Nos. 8 and 9 of sheet H. In both plan and section the veins between the 4,000- and 4,900-foot levels form a more or less parallel series that angle across the ground between the two faults. Below the 4,900-foot level

the dip of No. 6 break takes it so far to the south that the relationship of veins to this fault wedge is unknown. The veins in this part of the mine strike parallel to the trend of the Main break at higher levels and have an almost vertical-dip. The host rock of this vein system is largely augite syenite, but some of the veins lie along or near small syenite porphyry dikes in the augite syenite. As the pitch of the intersection of the No. 6 and main faults is to the west, the vein system also conforms in pitch with the controlling structure. The veins lie along fractures in the host rock and consist of quartz with very little attendant wall-rock alteration.

Quartz is the main vein-filling in the productive veins of the Kirkland Lake Gold mine. It frequently constitutes only a small percentage of the broken rock but contains the bulk of the gold content. Quartz veins may occupy a single fissure or be distributed in a sheeted zone across several feet. Vein breccia with inclusions of altered wall rock were commonly found on the upper levels. The quartz may be white or dark in colour or be a mixture of different generations, but in the high-grade veins it is always well fractured. Small to moderate amounts of sulphides are associated with the vein material. Pyrite is the common metallic mineral; traces of chalcopyrite, molybdenite, and graphite are also found. Carbonates are sometimes associated with the quartz. Tourmaline has been found in some veins in the lower part of the mine, and in some instances is associated with tellurides and native gold. In the lower part of the mine the mineralization is generally fine-grained, and visible gold and tellurides are rarely seen, even in the very high grade ore. According to J. B. Tyrrell,¹ native gold and tellurides were seen more frequently on the upper levels.

Post-Ore Faulting

There is little post-ore faulting in the upper part of the mine, but below the 4,600-foot level some of the veins in the west end of the mine have been displaced a small amount. The offset of veins and ore bodies is along narrow slips, which may contain some calcite or glassy quartz.

All the post-ore movement, except for very minor cross-slips, has taken place along faults that strike about parallel to the veins and pre-ore structures. A small amount of movement, apparently horizontal, along the plane of the main Kirkland Lake fault has offset the post-ore diabase dike. On the south side of the fault the dike has been moved to the east an average distance of about 80 feet.

The largest amount of post-ore faulting in the mine is shown on section No. 7 of sheet H between the 4,600- and the 5,340-foot levels. Here, there are three north-dipping strike faults that displace the veins and porphyry dikes for short distances.

Structural Control of Ore Bodies

The main structural features in the mine that have exerted a controlling influence on the localization of ore can be listed as follows: (1) the Kirkland Lake fault, (2) the pitching syenite bodies in the upper part of the mine, (3) a roll on the Main break, which may have had some influence on the branching of No. 5 vein and No. 6 break, (4) the lower anticlinal structure, (5) the wedge-shaped zone of fracturing between No. 6 fault and the Main break, and (6) the Main break in the vicinity of the 5,450-foot level (sheet J and section No. 7 on sheet H), which, going westward, may have locally split into a broad zone of fracturing on the north flank of the anticline.

¹Personal communication.

TABLE 7—KIRKLAND LAKE GOLD MINE STATISTICS, 1938-1947

	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
Tons milled.....	92,665	99,401	137,986	136,613	100,854	83,987	77,457	85,359	91,444	91,172
Tons milled daily.....	254	272	377	374	276	230	212	234	250	250
Recovery per ton.....	\$16.01	\$17.42	\$14.87	\$13.76	\$14.46	\$14.16	\$13.60	\$12.72	\$11.97	\$17.70
Value of bullion re-covered.....	\$1,483,769	\$1,731,243	\$2,051,789	\$1,879,726	\$1,458,823	\$1,189,478	\$1,053,155	\$1,086,211	\$1,094,836	\$1,613,856
Operating costs per ton milled.....	\$6.70	\$7.60	\$7.29	\$7.56	\$9.10	\$9.67	\$10.09	\$9.17	\$9.58	\$11.36
Yearly operating profit.....	\$890,874	\$990,271	\$1,056,165	\$854,739	\$547,748	\$384,049	\$282,954	\$313,257	\$209,192	\$558,368
Net yearly profit.....	\$711,278	\$780,240	\$702,472	\$549,659	\$324,481	\$207,099	\$154,610	\$177,691	\$94,388	\$364,416
New ore developed:										
Length (feet).....	.....	.....	.....	.....	1,507	1,965	499	1,126	2,057	2,435
Average width (inches).....	.....	.....	.....	.....	2.9	3.0	3.1	3.2	3.0	3.5
Average cut grade ¹.....	.....	.....	.....	.....	\$23.50	\$20.80	\$14.85	\$15.50	\$23.50	\$36.75
Estimated ore reserves (tons).....	161,133	229,315	266,878	293,636	288,623	356,538	352,968	364,384	318,892	331,540
Estimated gross value of ore reserves.....	\$3,906,843	\$4,263,914	\$4,310,298	\$4,135,722	\$4,037,200	\$4,856,680	\$4,879,910	\$4,891,145	\$4,538,808	\$5,412,327
Dividends paid.....	\$532,670	\$532,670	\$639,204	\$585,936	\$319,602	\$213,068	\$213,068	\$213,068	\$159,801	\$213,067

¹Dollars per ton, gold valued at \$35.00 per ounce.

The master control has been the movements along the Kirkland Lake fault, and all other influences are subsidiary to it. The position of the lower porphyry body has controlled the location and pitch of the veins associated with the anticlinal structure and of the veins in the wedge-shaped block between the No. 6 and main faults. Movements along the No. 6 and main faults appear to have exerted a shattering effect on the intervening ground, producing the set of vein fractures in the area towards the apex of the wedge. At greater depth the fault wedge widens, and the influence of No. 6 fault diminishes. Here, another set of fractures is formed on the north side of the anticlinal structure.

Statistics

The annual and total value of bullion produced and tonnage milled by the Kirkland Lake Gold mine from the commencement of production in 1919 to the end of 1947 is shown in Table 3 (facing page 60). The yearly and total output of gold and silver in ounces, the average gold-silver ratio, and the average fineness of the bullion are given in Table 4 (facing page 60). The yearly and total dividends paid are shown in Table 1 (page 59).

A detailed yearly analysis of production, recovery, costs, profits, ore developments, and ore reserves over the 10-year period ending December 31, 1947, covering conditions of peace and war, is given in Table 7 (page 139). This information is taken from the annual reports of the company.

CHAPTER VI

Geology of the Teck-Hughes Mine

By K. Griffin¹ and Jas. E. Thomson

History and Development

The Teck-Hughes mine is located in the central section of the Kirkland Lake camp and is bounded by the Lake Shore mine on the east and the Kirkland Lake Gold mine on the west. The main property consists of a group of nine claims covering a length of about 1,450 feet along the strike of the main vein system on surface. The mine has been developed by 50 levels to a depth of 6,105 feet. It is serviced by 2 main shafts, the Central and South, and 5 internal winzes.

The story of the development of the Teck-Hughes mine over a period of thirty years has been fully described by J. G. McMillan, general superintendent, in the annual report of the company for 1942, as follows:—

The Teck-Hughes Gold Mines, Limited, formed in 1913 to acquire the Hughes claims located by Sandy McIntyre at the west end of Kirkland lake, has had more than its share of the turns of fortune which fall to mining companies. After eight years as a prospect and small struggling producer accumulating little but debts and another three years consolidating its position for development at depth, it became in the next six years the outstanding development of a gold mine on one-quarter mile on the strike of a vein or more properly a vein system. This was only made possible by the courage of the president, Charles L. Denison, and his associates on the board, of Buffalo and New York, who advanced over half a million dollars for development, and to the ability and perseverance of David L. H. Forbes, general superintendent 1918-27, later general manager and from 1932, president, succeeding Albert W. Johnston, who became chairman of the board. In that year, Roy J. Henry was promoted general superintendent.

The acquisition of the property of Orr Gold Mines early in 1923 gave the company a full quarter mile along the Main break and assured protection on the dip to the south. All debts were paid in 1924, and the company began an intensive programme of development at depth. The Central 4-compartment shaft was completed to a depth of 1,500 feet in 1925 and the mill capacity increased to 250 tons daily. As an instance of this development, within a year 830 feet of ore was developed on the South vein and 658 feet on the North vein of the Main break on the 13th or 1,480-foot level, and roughly 500 feet in each vein averaged 2 ounces over widths of 7 and 7.5 feet.

With such encouragement it was decided to continue the shaft to 3,000 feet and build a 300-ton unit of a new mill to treat deep-level ore. The expenditure in 1927 of \$600,000 on the plant greatly increased its efficiency and brought capacity to 550 tons and, with the addition of a second unit to the new mill, early in 1928 to 900 tons daily. Six new levels, which averaged 900 feet each of new ore, brought development to the 19th level at 2,230 feet.

As the Central shaft had passed through the ore zone between 1,900 and 2,000 feet and another six levels would carry development to the limit of the surface hoisting-equipment at a depth of 3,000 feet, it was decided to sink a new South shaft with one 3,700-foot lift for deep development below the 30th level at 3,605 feet, and a vertical winze in the footwall of the ore zone for the development of the intervening levels. A site for the new shaft was selected 670 feet south of Central shaft, and work began in the summer of 1928. Bullion recovery was more than doubled in that year and exceeded four and a half million dollars in value, a far cry from the struggling prospect of six years earlier.

The mine continued to expand at a lesser rate for the next three years to reach an annual production of close to 300,000 ounces and a value of \$6,000,000. A third unit was added to the mill early in 1931, bringing capacity to 1,300 tons.

Plans were also made for the development of ten new levels from the 30th to the 40th by sinking an incline winze in the footwall of the ore zone and a 4-compartment extension of South shaft, which was continued to 5,500 feet, with haulage levels at 625-foot intervals on the 35th, 40th, and 45th level horizons.

The depression years 1931 and 1932 marked the peak of production as the grade of the ore fell off slightly below 3,000 feet. However, due to the abandonment of the gold standard by Britain in September, 1931, the revaluation of gold by the United States in April, 1933, and the

¹Geologist, Teck-Hughes Gold Mines, Limited.

consequent rise in the price of gold, the annual revenue of the company was maintained until the incidence of the bullion tax in 1935, though bullion production declined nearly 50 per cent. in the four years.

This marked decline in production began with a moderate falling off in the quantity of gold produced in the blocks of five levels below 3,000 feet and continued with a more serious decline in both grade and tonnage on the 41st level at a depth of 4,980 feet. Large ore bodies of good grade and in places up to 100 feet in width were found on the five levels centred about the 45th level, but these were subject to heavy dilution in mining.

Development of the three bottom levels to 6,105 feet showed only some short lengths of ore insufficient to pay the cost of development. The break persisted, but the association had changed. Diamond-drilling to a vertical depth of 6,650 feet did not improve the prospects, and deep development was suspended in 1936....

The finding of subsidiary veins is not entirely a development of recent years in this camp. Diagonal fractures were noted in the Lake Shore mine twenty years ago but not followed to any extent. Somewhat later, ore was mined from veins as flat as between 20 and 30 degrees at the Burnside shaft of Toburn Mines. At Teck-Hughes some very rich ore was mined from the apex of one of these veins on the 19th level in 1928. In general, however, the search for ore was confined to the main ore zones, and diamond-drilling at close intervals was limited to holes too short to reach the hanging-wall veins, which dip at about 45° S. and may branch off from the Main break at any angle up to 45 degrees. As a result they may be found at any distance up to 300 feet or more from the Main break. The lessened cost and wider use of diamond-drilling has been of great assistance in locating these veins.

In 1937, reports were current of the finding of veins in the hanging wall in the adjoining Kirkland Lake Gold mine. One of these veins on the 3,600-foot level was close to the Teck line. The first drift on the Teck 30th level failed to find the vein, but two diamond-drill holes gave rich intersections nearer the Main break. The drift on this line found 83 feet of 11 dwt. ore in the No. 6 shear, and a short distance west the K vein with a hundred feet of ore at the west boundary. This vein has produced 23,000 tons of 12 dwt. ore to where it apexed at the 29th level and downwards to the 31st level, where a portion remains to be stoped.

The fact that the draw on the 8th level in the west end of the mine continued for a year or two after the tonnage carried in reserve had been removed led to the inference that ore in the hanging wall must have been caving into the stopes somewhere above that horizon. Diamond-drilling from the main drift on the 5th level, which was still accessible in part, gave some intersections of value; and after a lot of drifting between the diabase dike and the west boundary, three separate lengths of 50 to 60 feet of ore were found. Stopping above the 5th level showed this ore to be continuous and to extend to and above the 400-foot level, where this E vein joined the Main break and gave access to a considerable block of ore in No. 3 vein extending to the 200-foot level. Drifting on E vein on the 6th level found a hundred feet of ore west of the dike and two short lengths near the west boundary. The former shoot bottoms about the 7th level horizon.

Mention by Ken Griffin of a small vein, which assayed 8 dwt. over 1 foot, having been cut at the 8th level horizon in the sinking of South shaft led to the discovery of F vein from an old drift along the South break from the south crosscut on the 6th level of Central shaft. The ore, which had a length of about 150 feet, only extended about 50 feet above the 6th level and did not extend to the break.... Development on the 8th level was delayed until a crosscut was driven 700 feet from Central to South shaft as there were not stations in South shaft above the 25th level. An equal length of ore was developed and stoping began on what proved to be an ore body extending 500 feet along the pitch, which was at about 45 degrees above the 8th level. Stopping was only recently completed after over three years.

Exploratory work during 1938 in the central and eastern part of the mine on the 24th and 25th levels led to the discovery of the hanging-wall veins G and H. Drifting on the H vein on the 25th level showed a length of 200 feet of ore up to the Lake Shore line. Drifting on the 26th level gave nearly 600 feet of ore, averaging from 6 to 16 dwt. over 6 feet, more than half of which ran half to three-fourths of an ounce. In plan on this level the vein takes a diagonal course from the Main break in the centre of the mine to a point 240 feet south of the break near the boundary, then continues northeasterly along a fault across the line. The search for G vein on and above the 24th level was much more difficult, but later it was found to continue above the 23rd level.

At this stage the programme of hanging-wall development was away to a good start except that ten levels above the 24th were not accessible due to two levels in the Central shaft having been collapsed by rock bursts in 1936 and 1937.

Hanging-wall exploration in the western end of the mine at this horizon began in 1939 on the 26th and 27th levels because a short length of the 25th level west was caved. On the 26th level a 50-foot length of ore was found in the central part of the mine, and later, after considerable drifting about, a 55-foot length in the west section with a parallel length of 100 feet 40 feet south. Separate lengths of 70 feet and 95 feet were found in basic syenite on the 27th level. In stoping, these merged and made a stope 260 feet long up to a fault, along which it gradually lessened to the 55-foot length on the 26th level. However, the true trace of this J vein only became evident a year later with its development on the 25th level, where it took a southwest direction from the Main break for 200 feet in the porphyry before turning west in the syenite. On the 26th level we had missed the diagonal, which was spotty, and found only the east-west portion. Stopping here has not progressed sufficiently to show the relation of J south to J vein. From the 25th level stope we would look for the apex of J vein at or above the 23rd level.

During the same summer L vein was found on the 37th level. Drifting on the vein proved it to be in the form of a bow leaving the Main break and returning to it 400 feet farther west. Four separate lengths of from 30 to 60 feet of ore, totalling 130 feet, were found, and grading from 6 to 13 dwt. over 6 feet. Before stoping began, 40 feet of the footwall caved into the No. 3 south stope, interfering with ore extraction. The two easterly lengths, a hundred feet apart, made stopes fifty feet or so in length, which are about half mined out; the two westerly ones remain to be stoped. The vein L south is a split to the southeast from L vein and having a flatter dip, so that it rolls into the other. Lengths of 15 and 30 feet of ore 50 feet apart were found in L south. Stoping proved these to be continuous. So far some 14,000 tons have been taken from these workings, which are a combination of shrinkage and open stopes.

Drifting on L vein on the 38th level showed only a length of 30 feet, which graded 6 dwt., but the stope opened up above this has a length of about 200 feet. Further west and nearer the Main break a vein, L north, gave from west to east, a length of 85 feet, of 6 to 7 dwt. ore, a blank of 20 feet and a further 55 feet grading 9.5 to 3.2 dwt. Stoping on this vein had only begun at the time of the strike.

Most of the branch veins so far discovered are connected with the Main break or No. 3 vein system: the F vein, which is in the hanging wall of No. 4 break, is an exception.... H vein may be filling the apex of the No. 6 shear, but this has not been proven. K vein is so close to the top of this shear that they appear as one in No. 32 west section (section No. 10, sheet K, in map case). The association of the latter vein differs from the others, being over most of its length little more than parallel fractures in a brittle siliceous tuff, brick-red in colour. The filling, however, is very high grade on even the tightest fracture. Another peculiarity is the presence of specular iron.

During 1940 and 1941 a considerable programme of diamond-drilling and crosscutting in the west end of the mine resulted in tracing the No. 6 shear below the 31st level to the 40th level horizon at 4,855 feet and in finding a number of ore intersections near the plane of this break, which is inclined 50° to 55° S. as compared with an average dip of about 75 degrees in the Main break.

The 35th and 40th levels having stations in the South Shaft extension were selected for the first of these drives to the south. Crosscuts were later driven on the 34th and 36th levels and some lateral development done on all four levels. This work led to the finding of M vein on the 40th level west and of R vein on the 35th level in a more central position astride the crosscut. Both veins were found 50 to 60 feet north of the shear. On the 34th level, Q vein was found in the same relative position and what is thought to be the top of R vein close to the shear.

Development of M vein gave a length of 85 feet of 16 dwt. ore and spots of ore for 40 feet to the west and 120 feet to the east. The association here is quite unique, as the ore is in the tuff-breccia south of the porphyry. A minimum of stoping has not been very satisfactory as the ore tends to cut out at the porphyry contact.

Development of R vein on the 35th level gave a length of 85 feet of 13 dwt. ore with 35 feet of 4.5 grade to the west, a blank of 18 feet to the east, and then 30 feet of 7.7 dwt. grade. A stope 190 feet in length has been carried up for 30 feet with some tendency for the ore to shorten....

The No. 4 break, which is almost vertical and should join No. 3 somewhere between the 25th and 30th levels, has not been drifted on west of the diabase dike in the Teck-Hughes. As it did not yield any ore in the upper ten levels, little has been learned of this fault in recent years. A fault located 40 feet south of the east end of H vein on the 26th level has the same attitude and may be the downward continuation, but if so the junction would be with No. 6 shear.

The total production from branch veins in the last five fiscal years has amounted to 244,832 tons, averaging 7.9 dwt., equal to 1,934,000 dwt. or 96,700 ounces... to which has been added an estimated 5,000 ounces obtained in level development. This represents 15.77 per cent. of the tonnage and 22.35 per cent. of the total production since this development began. The production from branch veins increased during the four years of active development to 32.3 per cent. of tonnage and 41.6 per cent. of gold production in the fiscal period of 1940-41, but has fallen to 17.3 and 14.4 per cent., respectively, during 1942 as only the two veins E and F are being worked in the clean-up of the upper ten levels.

The estimate of "positive ore" in known branch veins is 59,466 tons, containing 23,800 ounces, but these are expected to yield at least four times that amount when stoping is completed.

The yield to date of less than 100,000 ounces from branch veins may not appear large compared with the total of 432,684 ounces in the past five years or with the mine's total production of 3,039,000 ounces to date, from which \$78,141,157 was realized; but in extending the life of the mine they are an important factor.

General Geology

The rock formations covering the surface of the main property of the Teck-Hughes are indicated on map No. 1945-1, and the accompanying plans and sections (in map case) show the general distribution of rock types in the underground workings. The intermingled sediments, tuffs, and elongated intrusive bodies strike approximately N. 65° E. north of the Main break on surface and

roughly N. 80° E. south of the fault system. The dips are steeply to the south. Most of the mine workings are in the intrusives.

The main intrusive body in the Teck-Hughes mine is an irregular-shaped mass, sill-like in general outline and consisting of intermingled augite syenite ("lamprophyre"), syenite, and syenite porphyry; these were intruded in the order named. The syenite is confined to the upper levels and is part of the faulted westward-pitching pipe-like body that crosses Kirkland Lake Gold and Macassa mines. The hanging-wall part of the syenite body is exposed at the surface and pitches westward into the Kirkland Lake Gold around the 5th level. Other irregular-shaped bodies of the syenite, however, are found on the hanging-wall side of the fault down to the 10th level in the vicinity of F vein. The footwall syenite occurs on the west side of the workings from the 14th to 17th levels but is cut out by the syenite porphyry in the eastern part of the mine. Augite syenite and syenite porphyry are intricately interfingered throughout the entire mine. The augite syenite, being the older rock type, predominates near the margin of the intrusive body and, therefore, is the main country rock in the southern part of the mine workings. As the proportion of syenite porphyry to augite syenite in the vicinity of the Main break increases with depth, most of the workings in the lower half of the mine are in syenite porphyry.

A diabase dike, averaging 80 feet in width, strikes in a general north-south direction across the property. It dips about 75° W. and so passes into the Kirkland Lake Gold mine at depth. Another diabase dike, which occurs largely on the Lake Shore property, enters the east side of the Teck-Hughes mine on the footwall side of the main mud seam from the 19th to the 34th levels. The diabase cuts all the rock types, veins, and ore bodies but has been offset by later faulting movements along the Main break and No. 4 break.

Structure

The most important structure in the Teck-Hughes mine is the Kirkland Lake fault, and the bulk of the gold production has come from veins associated with it. South of the main fault are a series of hanging-wall subsidiary structures. These are indicated on the accompanying plans and sections.

The Kirkland Lake fault or Main break has an over-all dip of from 75° to 80° S.; local rolls on the structure produce a variation of a few degrees from the general dip. The fracturing is dispersed over widths up to 80 feet, and throughout this area there may be one or more seams of gouge. This broad quartz-filled fracture system is known as No. 3 vein. A probable subsidiary structure, called No. 1 vein, outcrops about 100 feet to the north of the main fault and joins it at the 9th level. Todd¹ has estimated that the total vertical displacement along the main fault on the Teck-Hughes amounted to a thrust of about 2,000 feet on the hanging-wall side. This was based on the displacement of the tuff-conglomerate contact and requires considerable upward projection of the contacts and fault above the present erosion surface. As both the contact and fault vary considerably in strike and dip at different points, this figure is only an approximation. A more accurate, but still rough estimate of the pre-ore displacement by the offset of the irregular-shaped syenite pipe gives a vertical component of 1,500 feet with no appreciable lateral movement.

Displacement of the diabase dike by the main fault on the west side of the property shows a horizontal dislocation of 110 to 140 feet at different horizons. At the Lake Shore boundary another diabase dike shows a lateral displacement of

¹E. W. Todd, *Ont. Dept.: Mines, Vol. XXXVII, 1928, pt. 2, pp. 44, 50.*

30 to 150 feet along the fault plane. Both dikes may be best matched in longitudinal section along the plane of the fault by moving the hanging wall 80 feet west. Horizontal striae on the walls of the mud seam indicate that the latest movement on the fault was entirely lateral. Thus, the best estimate of the post-diabase displacement would be that the south side moved about 80 feet east. There would still be an unaccounted-for post-ore displacement between the time of ore deposition and the introduction of the diabase.

About 600 feet south of the main fault lies another structure called No. 4 break in the Teck-Hughes mine. It is in alignment with the South (No. 1) vein at the Lake Shore mine and is generally considered to be the westerly extension of that structure, but it has produced no ore in the Teck-Hughes mine. It has been traced to the 10th level in the eastern and central part of the property but has never been definitely recognized in the western half. It may continue downward to a fault on the 26th level as indicated on sheet K, in which case it may merge with No. 6 break. There is another strong southward-dipping break in No. 17 level pump station at the South shaft; this would be more or less in alignment with a southward-dipping structure on the 1,600-foot level at the Kirkland Lake Gold mine (see sheet C, 1,600-foot horizon). These structures, however, have a much flatter dip than the South (No. 1) vein in the Lake Shore mine and No. 4 break on the upper levels at the Teck-Hughes. On the 1,600-foot level at the Lake Shore mine the fault that dips 60° S. displaces the South (No. 1) vein ore bodies about 100 feet (see section No. 13, sheet L), which proves that there has been post-ore movement on it. It is probably a continuation of this post-ore strike fault that is represented in the 17th level pump station (South shaft) at the Teck-Hughes mine.

The nature of No. 4 break is best observed on the 6th level, where it has been followed in drifting for 500 feet. It is a well-defined, clean-cut mud slip with a 3- to 6-inch width of gouge. As the fault has displaced the diabase dike about 100 feet horizontally on this level, there has been some post-ore movement. The fact that some low gold values have been obtained along it shows that there may also have been some pre-ore movement.

The relative positions and attitudes of E and F veins with respect to No. 4 break might suggest that F vein is a faulted southward continuation of E vein (see section No. 11, sheet K). F vein, however, was never traced up to No. 4 break, nor was E vein followed to the structure, so the exact relationship is unknown.

Another prominent structure in the west end of the mine is No. 6 break. This is a continuation of the structure from the Kirkland Lake Gold mine and has been traced from the 30th to the 40th level in the western part of the mine (see sheet K). No. 6 break branches off the Main break to the south. It dips at an angle of from 50 to 55 degrees, as compared with the 75-degree dip of the Main break. The junction of the two structures pitches flatly to the west. As shown in section No. 10, sheet K, the K ore body follows No. 6 break, so that the structure is well exposed in the stopes on this ore shoot. It is a narrow, clean-cut slip, which runs through and along the side of the alteration zone that comprises the K ore body. As the narrow diabase dikes that cut the K ore body are offset a few inches by No. 6 break, there has been a little post-ore movement on it. It is possible that H vein may be the upward extension of No. 6 break, because they are more or less in alignment (see section No. 12, sheet K), but there is a gap of six levels through which the structure has not yet been traced. The Q, R, and M veins lie near the footwall of No. 6 break and have a slightly steeper dip.

The Narrows break is a structure lying to the north of the Main break. The zone has been partially explored on the 30th level, where it lies about 2,000 feet

north of the main fault (see plan of 3,600-foot horizon, sheet E). The break is also exposed on the surface, where it cuts through augite syenite and sediments. It has been intersected in diamond-drill holes from surface. In the drift on the 30th level it is a narrow slip with associated gold-bearing quartz veins and stringers at intervals. It has been indicated by drifting and drilling for a length of 1,100 feet west of the Lake Shore boundary. The dip is very steep and varies from north to vertical to south. The break lines up with what is believed to be the same structure on the Lake Shore property (see sheet D).

Veins

The vein system in the Teck-Hughes mine is shown on the accompanying plans and sections. Structurally, the vein fractures fall into two groups: one being the No. 3 or Main break veins, and the other being the hanging-wall subsidiaries. The Main break system extends over widths up to 80 feet, in which branching, interlocking, or parallel quartz veins and stringers have been found in the vicinity of the main fault zone. Probably most of the veins were found on the hanging-wall side of the main mud seam, but some veins were on the footwall. The subsidiary veins branch off the hanging wall of the main fault and have a flatter dip than the main structure. Some tend to flatten near the junction with the main fault and steepen away from it. They are generally tight quartz veins or zones of alteration, and only in a few places, as in the K ore body, are the veins adjacent to a mud slip. Most of the Teck-Hughes veins contain quartz, although the amount may vary greatly. Fairly well defined quartz veins could be followed for considerable distances along the Main break, but a fair proportion of the Main break ore consisted of intermingled quartz and mineralized country rock. A vein breccia containing angular fragments of wall rock is a common vein structure. At some points the subsidiary veins contain a large proportion of olive-green alteration products with a smaller amount of fractured white quartz veinlets and fairly heavy, fine-grained sulphide mineralization. Pyrite is the usual sulphide in the veins; molybdenite and graphite occur along slips in the quartz; specularite is found locally. The vein quartz may be a dark-coloured, greasy or smoky variety or a white, vitreous or porcellaneous type. At some points these are intermingled; the white variety appears to predominate in the subsidiary veins. The quartz and inclusions are generally fractured. Visible gold and tellurides are erratically distributed in the veins.

The accompanying plans and sections show that the host rock of the veins is largely augite syenite and syenite porphyry; a small proportion of the ore on the upper levels is lodged in the remnants of the westward-plunging syenite pipe. The area of interfingering augite syenite and syenite porphyry on the Teck-Hughes and the western part of the Lake Shore has been a particularly favourable zone of vein localization. The most southerly vein yet investigated is the M zone, which occurs in the contact area between the tuff and syenite porphyry.

Wall-Rock Alteration

A common type of alteration, especially in the Main break ore bodies, is the typical reddish to pinkish discoloration adjacent to veins and mud slips. This extends over the width of the No. 3 vein series and hence shows widths up to about 80 feet. This alteration occurs in all host rocks but is probably most noticeable in the augite syenite. The altered rock generally contains only low gold values. In the subsidiary veins, a pale olive-green alteration is widespread. This has a tendency to become reddish near the border of the zone and to terminate with a sharp boundary. The altered rock may contain a few inclusions

of the typical reddish fragments and wisps of bright-green material. Fine-grained pyrite occurs plentifully throughout the rock either in disseminated form or in veinlets. The sharp boundary of the zone of alteration is most noticeable when the country rock is syenite porphyry, probably on account of the pronounced contrast in colour. In some places the olive-green discoloration produces a fine-grained, massive rock; at other points the altered rock contains quartz stringers and may be of ore grade. The greenish type of alteration never attains any great width and is generally limited to a few feet on either side of the vein.

Ore Shoots

By far the greatest proportion of ore mined has come from the No. 3 or Main break vein system. J. G. McMillan, in the report previously quoted,¹ shows that up to the end of 1942 the branch veins had yielded about 3.3 per cent. of the mine's gold production. The sections on sheet K show that almost continuous stoping was done over a considerable vertical range in certain parts of the mine along the No. 3 vein system. Exceptional widths of ore, ranging up to 100 feet, were mined on the five levels centred about the 45th level. The No. 3 vein ore shoots conformed in a general way with the strike and dip of the Main break. Longitudinal stoping plans make it evident that the ore bodies plunged very steeply and showed no definite tendency to rake along the structure.

The known hanging-wall ore shoots extend anywhere up to 750 feet south of the No. 3 vein system, but the bulk of the ore lies less than 300 feet from the main structure. The stopes on the branch veins are considerably flatter, narrower, and less continuous than those mined earlier on the Main break. Detailed information on the hanging-wall ore shoots has been given previously in the abstract of Mr. McMillan's report.² Some of these rake to the west.

Post-Ore Faulting

The post-ore movement along the Main break and No. 4 and No. 6 breaks has already been discussed.³ In general, the veins and ore bodies are not greatly disturbed by faulting, and where displacement occurs the offset is never more than 45 feet. H vein has been offset a short distance by several northeastward-striking faults.

Structural Control of Ore Bodies

The Kirkland Lake fault has been the chief structural control in the mine. Movements along it produced a widespread fracturing and brecciation in the adjacent wall rocks and thus provided channels for the vein-forming solutions. These faulting movements were continued intermittently until long after the quartz was introduced and so produced different periods of fracturing and re-opening in it for the introduction of the precious metal mineralization in the final stages of the vein-forming process.

The branch veins are similarly related to the main fault and probably represent tensional structures produced in the hanging wall during its upward movement over the footwall (see section No. 11, Fig. 7, facing page 82). Such openings would tend to be flatter and stronger near the point of rupture than at some distance from it. No. 4 break represents a shear zone that branches from the Main break. The structure in the mine thus conforms to a conventional fracture pattern in which the main fault and No. 4 break were formed under compres-

¹Annual report of the company for 1942.

²Page 142.

³Page 145.

TABLE 8—TECK-HUGHES MINE STATISTICS, 1937-1946

	Sept. 1, 1936, to Aug. 31, 1937	Sept. 1, 1937, to Aug. 31, 1938	Sept. 1, 1938, to Aug. 31, 1939	Sept. 1, 1939, to Aug. 31, 1940	Sept. 1, 1940, to Dec. 31, 1941	1942	1943	1944	1945	1946
Tons milled.....	369,652	376,465	388,770	337,430	356,820	93,335	100,705	102,920	108,006	91,302
Value of bullion re- covered.....	\$4,570,855	\$3,930,534	\$3,401,059	\$3,605,276	\$3,645,581	\$1,365,513	\$1,251,047	\$989,004	\$1,098,532	\$1,093,701
Recovery per ton.....			\$8.75	\$10.68	\$10.22	\$14.63	\$12.42	\$9.61	\$10.36	\$11.98
Operating costs per ton treated.....	\$5.12	\$5.43	\$5.26	\$5.62	\$5.93	\$6.85	\$6.29	\$6.50	\$7.11	\$9.32
Operating profit.....	\$2,580,648	\$1,873,006	\$1,354,864	\$1,709,302	\$1,529,218	\$725,782	\$617,467	\$319,652	\$344,907	\$243,101
Operating profit per ton treated.....			\$3.49	\$5.06	\$4.29	\$7.78	\$6.13	\$3.11	\$3.25	\$2.66
Estimated ore reserves (tons).....	640,443	610,895	537,549	515,197	345,969	318,966	304,010	285,478	281,472	263,939
Estimated grade of ore reserves (penny- weights per ton)...	8.02	6.91	6.01	5.85	6.79	6.84	6.72	6.92	6.87	7.09

¹Plus 37,780 tons of old tailings.

²Plus 15,671 tons of old tailings.

sional stresses and the flatter subsidiaries resulted from the tensional forces thus set up.

Statistics

The annual and total value of bullion produced and tonnage milled by the Teck-Hughes mine from the commencement of production in 1917 to the end of 1947 are shown in Table 3 (facing page 60). The annual and total output of gold and silver in ounces, the average gold-silver ratio, and the average fineness of the bullion are given in Table 4 (facing page 60). The yearly and total dividends paid are shown in Table 1 (page 59).

A detailed yearly analysis of production, recovery, costs, profits, ore developments, and ore reserves over the 10-year period ending December 31, 1946, covering conditions of peace and war, is given in Table 8 (page 148). This information is taken from the annual reports of the company.

CHAPTER VII

Geology of the Lake Shore Mine

By G. H. Charlewood¹ and Jas. E. Thomson

History and Development

The Lake Shore mine is centrally located amongst the seven producing mines of Kirkland Lake. It is the largest gold producer in the camp, accounting for more than 40 per cent. of the entire output. The Lake Shore ranks second only to Hollinger Consolidated amongst the gold mines of Canada in the total value of bullion produced and the amount of dividends distributed to date.

Lake Shore Mines, Limited, was incorporated in 1914 and originally owned four claims and four fractions totalling 171 acres and covering a length of slightly less than half a mile along the strike of the Kirkland Lake vein system on surface. In 1934, four claims belonging to Minaker Kirkland Gold Mines, Limited, were acquired and a controlling interest was purchased in the Kirkland-Hudson Bay Gold Mines, Limited. These properties adjoin the Lake Shore property on the south. In 1938 an agreement was made with Kirkland Basin Gold Mines, Limited, whereby Lake Shore Mines would do some underground exploration on that property under the bed of Kirkland lake.

One of the original stakers and principal owner of the Lake Shore claims was Harry Oakes. He organized the company but, like other pioneers in the camp, experienced difficulties in financing, and company shares at one time sold as low as 30 cents. The first discovery was on the South or No. 1 vein. There was no surface indication of the more important North or No. 2 vein, which lay beneath the lake. Surface work on the South vein proved encouraging, and in 1914 a 2-compartment shaft was sunk to the 400-foot level near the shore of the lake. Drifts were driven on the South vein and followed by a crosscut to the North vein on the 200-foot level. By March, 1917, 1,500 feet of drifting on the South vein and 800 feet on the North vein had disclosed ore of very good grade and width on all the levels developed. The company commenced gold production in March, 1918, at an initial mill capacity of about 60 tons per day. This was gradually increased until a capacity of 2,400 tons per day was attained. As shown in Table 9 (page 159), however, production fell off greatly during the Second World War.

Sheet B (in map case) shows that the Lake Shore mine is serviced by four surface shafts and two internal shafts. No. 1 is a 3-compartment, vertical shaft extending to a depth of 4,500 feet in two stages, the second stage of 2,450 feet now being used for ventilation only. No. 2 is an inclined service shaft, 200 feet in depth. No. 3 is a 5-compartment vertical shaft extending to 4,000 feet but is now out of operation. No. 4 internal shaft starts at the 4,325-foot level and extends to the bottom of the mine workings. No. 5 is a 5-compartment shaft on the footwall side of the vein system and extends to a depth of 4,000 feet. No. 6 is a 5-compartment internal shaft and extends from the 3,950- to the 6,075-foot level. Up to the end of 1947, levels had been developed at regular intervals to a depth of 6,075 feet and drifting was in progress on the 6,575-foot level. At the end of 1947, No. 4 internal shaft had reached a depth of 7,096 feet below the surface and preparations were in progress to deepen it to the 8,075-foot horizon. A long cross-cut has been driven north across the Kirkland Basin property on the 3,075-foot

¹Geologist, Lake Shore Mines, Limited.

level. Crosscuts have also been extended south into the adjoining Kirkland-Hudson Bay property on the 2,700- and 4,450-foot levels.

General Geology

Map No. 1945-1 shows the distribution of rock types on the Lake Shore property at the surface; the accompanying level plans and sections (in map case) indicate their downward extension through the mine. It will be seen that practically all the mine workings are in the intrusives, but long lateral drives or drill-holes cut either sediments or tuffs of the Timiskaming series. Remnants of sediments are also found on the north side of the North (No. 2) vein to a depth of about 800 feet. The long north crosscut on the 3,075-foot level passes through interbedded conglomerate, greywacke, and reddish-brown bedded tuff. Drilling south of the productive veins shows that tuffs flank the main intrusive body, followed in turn by conglomerate. The deepest sedimentary body found in the mine to date consists of conglomerate. This occurs 1,600 feet north of the main workings in a crosscut on the 3,700-foot level and in a diamond-drill hole 1,200 feet north of the 5,825-foot level. Tuffs have been encountered in a diamond-drill hole 1,100 feet south of the vein zone on the 4,800-foot level. Conglomerate has not been reached below a depth of 1,400 feet in the southern part of the mine.

The main intrusive body trends about N. 65° E., or approximately parallel to the vein system, and dips steeply to the south. As the south contact has a flatter dip than the north boundary, the intrusive body widens with depth. The intrusives consist of augite syenite, syenite, syenite porphyry, quartz-feldspar porphyry, and diabase, intruded in the order named, except that the relationship of the quartz-feldspar porphyry to the syenite porphyry is not definitely established. In the vein zone the augite syenite is confined to the area west of the shaft section and is interfingered with syenite porphyry and, to a much lesser extent, with syenite. With increasing depth the proportion of augite syenite to syenite porphyry decreases in amount, and below the 5,000-foot horizon the augite syenite becomes relatively scarce. A few small irregular bodies of syenite are found on the upper levels at the west end of the mine. The syenite porphyry is the most prevalent host rock of the veins in the mine and has replaced all other rock types in the eastern half of the mine and on the lower levels. Robson¹ has pointed out that the west margin of the main syenite porphyry body plunges almost vertically to a depth of 3,825 feet. As the area of complexly intermingled intrusives adjacent to the main porphyry stock has been very productive ground, the steep plunge of these host rocks has been an important factor in Lake Shore geology.

Quartz-feldspar porphyry occurs in small irregular bodies within the syenite porphyry; these may be remnants of a slightly earlier phase of the intrusive complex. Although contacts between the two rock types may be seen, the age relationships are conflicting. A large dike of quartz-feldspar porphyry is found in the long north crosscut on the 3,075-foot level.

Diabase occurs in a single dike near the west boundary of the property and cuts all other rock types as well as veins and ore bodies. This dike strikes about normal to the veins and has a very steep dip to the west down to 3,000 feet and to the east below that horizon.

Structure

The accompanying composite plans show the position of the Lake Shore

¹W. T. Robson, "Lake Shore Geology," *Trans. Can. Inst. Min. Met.*, Vol. 39, 1936, pp. 107-108.

vein system with respect to the entire Kirkland Lake fault and fracture pattern. In the upper part of the Lake Shore mine the fracture system consists of the well-defined North (No. 2) vein-fault zone, the less continuous South (No. 1) vein zone, and various diagonal vein fractures that lie between them. Each vein zone may locally have a number of parallel or branching fractures. The net result is a pattern of diamond-shaped blocks throughout the mine, both in plan and section. Nos. 1 and 2 vein zones have an over-all strike of about N. 65° E. near the surface, but there are local deviations from this average. The over-all dip of the No. 2 vein zone to a depth of 6,000 feet would range from 75° to 85° S. in different

Photograph by Lake Shore Mines, Limited.

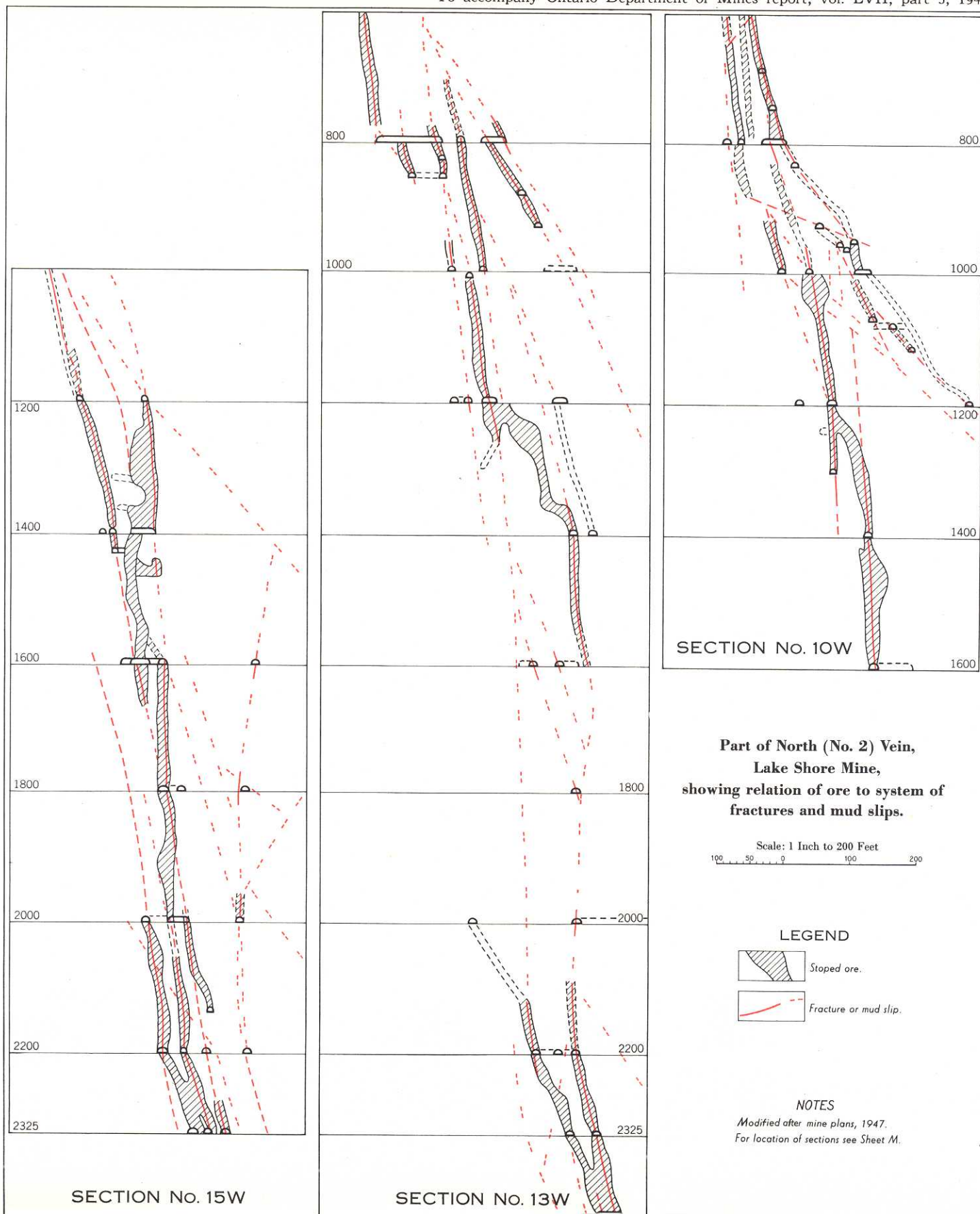


A zone (8 by 5 feet) of irregular quartz patches and stringers on the North (No. 2) vein, Lake Shore mine.

sections of the mine; rolls on the structure produce flatter and steeper dips locally. As No. 1 vein zone dips more steeply than No. 2 zone, the two structures coalesce in the lower part of the mine. The maximum width of the fracture system is about 500 feet. An exceptional width is found on the 600- and 800-foot levels where a southward-dipping branch vein lies from 500 to 700 feet south of the No. 1 vein zone. The No. 3 vein zone or Narrows break lies 1,200 feet north of No. 2 vein and should probably be regarded as a separate structure.

North (No. 2) Vein Zone

The North (No. 2) vein zone is the strongest and most productive structure in the mine and extends across the entire property for a distance of about 2,800 feet from the Teck-Hughes to the Wright-Hargreaves boundary. It is equally



persistent vertically and has been followed below the 6,000-foot horizon. The No. 2 vein zone lies along a pre-ore fault, on which the south or hanging wall has been thrust upward some 1,300 to 1,600 feet. This is a continuation of the fault or Main break that passes through the mines to the west. It is recognized by the occurrence of gouge, brecciation, and alteration of the wall rock. In places the fault is represented by a single plane of movement, but frequently it consists of two or more planes with a braided, *en échelon*, or cross-over pattern, as illustrated in the sections facing page 152. This zone of fracturing locally widens to about 200 feet on the 800-foot level west of the main crosscut (from No. 1 to No. 3 shaft). Here, the fracturing lies in the complex mixture of intrusives, previously mentioned,¹ which provide favourable conditions for widespread rock disturbance. To the east, however, the break passes through the large body of syenite porphyry where the fractured zone narrows, as do also the ore bodies. The zones of gouge, or mud seams, represent planes of shearing and movement, and the brittle rocks bordering the shear zones have been crushed, brecciated, and altered. The strongest shearing is usually on the footwall side of the ore.

South (No. 1) Vein Zone

Above the 1,000-foot level the South (No. 1) vein lies in a fractured zone that roughly parallels the North (No. 2) vein from 400 to 500 feet to the south. Below this horizon, diagonal fractures that branch off No. 2 vein form a considerable part of the No. 1 vein zone. As a consequence, No. 1 vein becomes a more discontinuous and irregular structure. For example, at the 3,200-foot level, illustrated in sheet M, a large part of the No. 1 vein zone consists of three independent diagonal fractures which branch off No. 2 vein. The most westerly of these is a continuation of the Teck-Hughes H vein, a structure branching off the Main break. At about the 4,000-foot horizon, No. 1 vein branches from No. 2 vein in the central part of the property and east of the junction becomes the stronger structure and appears to be the continuation of the main fault. These conditions continue to the lowest developed levels.

Diagonal Veins

It has been mentioned above that certain parts of the South (No. 1) vein are essentially diagonal veins branching off the North (No. 2) vein. In the upper part of the mine, however, there are certain zones of fracturing that run diagonally between No. 2 and No. 1 veins both in plan and cross-section. Between the 400- and 800-foot levels, three such vein fractures have been explored east of the crosscut between No. 1 and No. 3 shafts. One of these is a strong diagonal fracture with a heavy mud seam that leaves No. 2 vein immediately west of the crosscut and might be considered as the main fault if it were not for the fact that between the 1,200- and 2,450-foot levels it breaks up into several weak fractures. From the 2,450-foot level to the 3,700-foot level it becomes a definite structure near the junction with No. 1 vein, but towards No. 2 vein it weakens into two fractures. At about the 4,000-foot horizon, this diagonal fracture system merges with No. 1 vein, which, as mentioned above, becomes the stronger vein structure.

Narrows Break (No. 3) Vein Zone

The Narrows break, or No. 3 vein zone, lies from 1,200 to 1,600 feet north of the North (No. 2) vein zone and strikes more or less parallel to it (see plan of the 3,000-foot horizon, sheet D). It has been partly explored on the 3,075- and 3,200-foot levels and intersected in drill-holes on the 1,400-, 2,325-, and 5,450-

¹Pages 70, 151.

foot horizons and is currently (1948) being investigated at the 3,700-foot horizon. It is a fairly persistent, but somewhat irregular fracture with an almost vertical dip. The host rock is augite syenite. Quartz occurs at intervals along the structure, and some ore has been developed on it.

Estimate of Fault Displacement

The lack of reliable markers adjacent to the breaks makes any estimate of displacement open to question. Contacts between tuffs and sediments are too far away, imperfectly known, and so affected locally by intrusives that they are unreliable as markers. The apparent offset of irregular-shaped masses of intrusives is always open to doubt, especially when they are so complexly intermingled as in the Lake Shore mine. It happens, however, that a few small bodies of quartz-feldspar porphyry occur in the intrusive complex, and these are adjacent to certain parts of the North (No. 2) and South (No. 1) veins. Fig. 4 (page 78) shows three bodies of this porphyry, which lie in approximately the same relative position to each other on the hanging wall and footwall sides of the No. 2 vein fault. By matching the individual bodies, there is a suggestion that the south or hanging-wall side of the fault has moved upwards roughly from 1,300 to 1,600 feet. A fourth footwall body on the 800- and 1,000-foot levels would have been elevated above the present erosion surface. It will be noted that the porphyry bodies have not exactly the same shape on either side of the fault. But, owing to the width of the fault zone and the number of slices involved in the movement, it could hardly be expected that the two parts would look identical in longitudinal section. These offsets would suggest a possible pre-ore vertical displacement of somewhere between 1,300 and 1,600 feet. Similarly, it can be shown by matching longitudinal sections on either side of the fault plane that a post-diabase displacement of about 100 feet took place; this appears to be almost entirely a horizontal movement.

Any possible pre-ore fault displacement along the South vein zone is even more difficult to calculate, because it consists of a number of discontinuous structures, each of which may have been displaced different amounts.

The multiplicity of breaks on the Lake Shore property and the lack of any evidence on possible displacement along most of them make it impossible to trace the Kirkland Lake fault across the camp as a structure that follows a single plane of movement. To the west of the Lake Shore mine the main faulting movement has been along the continuation of the North vein, whereas in the mines to the east the South vein is the stronger structure and believed to be the main locus of movement. It appears that throughout the Lake Shore mine this movement has been transferred from the North to the South breaks by a number of diagonal fractures rather than on a single plane. Possibly this cross-over pattern helps to explain the widespread fracturing and resulting large productive capacity of the Lake Shore mine.

Veins and Mineralization

The productive veins occur along the fracture system described above and are found in all rock types within the fractured zone with the exception of the diabase. West of the crosscut between Nos. 1 and 3 shafts the host rocks are principally the intermingled bodies of augite syenite and syenite porphyry, whereas in the eastern part of the mine the veins lie entirely in the syenite porphyry. The different veins range in size from narrow high-grade quartz stringers to quartz stockworks and quartz breccia bodies having a maximum width of 70 feet. They lie in zones of alteration adjacent to the fractures and mud seams.

The vein material consists of different varieties of quartz and inclusions of altered and mineralized country rock. Where the inclusions are angular and numerous, they form a vein breccia. Along much of the North (No. 2) vein, the quartz has been introduced as irregular masses and stringers and as fillings around fragments of the host rock. The quartz may be a dark, greasy variety or a white, glassy type, or an intermingling of both kinds, and is generally well-fractured. Later quartz deposited along the fractures contains most of the mineralization and some late carbonates. Generally the quartz constitutes only a small proportion of the ore broken in the stopes.

The chief sulphide mineral in the vein zones is pyrite, which is disseminated widely throughout the ore and wall rock. It is estimated to form from 1.6 to 2.2 per cent. of the ore by weight and is in a dense, compact form, which is very difficult to grind.¹ Other sulphides occur only in minor amounts and consist of chalcopryite, galena, and molybdenite; traces of sphalerite, arsenopyrite, and pyrrhotite have been found in the ore. Sulphide mineralization is most plentiful in the South (No. 1) vein zone and occurs in lesser amounts where the veins are entirely in the porphyry than in the complex mixture of rocks west of the cross-cut between No. 1 and No. 3 shafts. Calcite, barite, chlorite, sericite, and chalcopryite fill post-ore fractures and mud seams along the veins.

Gold occurs (1) along fractures in the quartz, (2) in the altered wall rock and inclusions, (3) associated with the pyrite, and (4) in some of the tellurides. Coarse visible gold and associated tellurides are not commonly found throughout those parts of the mine now being worked, but Todd² reports that the horizons above the 1,000-foot level contained the best showings of gold and tellurides in the camp at that time. Much of the gold is in extremely fine-grained particles. This condition makes fine-grinding a necessity for proper recovery in milling operations. Silver occurs with the gold and in the mineral petzite. The ratio of gold to silver in all the ore milled to date, as calculated from Table 4 (facing page 60), is approximately 5 to 1 by weight. Studies of the ore in connection with milling research³ has shown that the tellurides occur in the following order of abundance: altaite, calaverite, coloradoite, and petzite. Calaverite is the most abundant of the gold tellurides. In the milling investigations, it was estimated that 19 per cent. of the total gold in the ore is in the form of tellurides, and at least nine-tenths of this is present as calaverite.

Wall-Rock Alteration

The rock adjacent to the veins, mud seams, and fractures is generally altered to such an extent that it differs considerably in appearance from the country rock. The crystal constituents of the intrusives have become obliterated and replaced by a fine-grained, bleached, banded, or brecciated rock. The alteration may produce a reddish discoloration, a buff-coloured product, a dark cherty product, or an intermingling of all three types. A feature of the alteration is the sharply defined boundaries of the buff-coloured phases and to a lesser extent of the cherty phases. In places they resemble dikelets and irregular brecciated intrusive masses rather than a product of hydrothermal alteration. The buff-coloured material tends to occur in fragments and is itself cut by minute fractures. It is sometimes referred to as mylonite. At some places along the breaks the shearing, as represented by gouge or schist, practically disappears and only

¹Lake Shore Mill Staff, "Milling Investigations at the Lake Shore Mine," *Trans. Can. Inst. Min. Met.*, Vol. 39, 1936, p. 291.

²E. W. Todd, *Ont. Dept. Mines*, Vol. XXXVII, 1928, pt. 2, p. 120.

³Lake Shore Mill Staff, *op. cit.*, pp. 291, 294.

the "mylonite" marks the continuation of the structure. Study of the distribution of mylonite shows that it occurs on a number of different fracture zones throughout the mine.

The widths of rock alteration adjacent to vein fractures varies greatly, and no useful figures can be given; the alteration may extend from a foot to as much as 60 feet from a vein fracture. Reddish discoloration of the syenite porphyry has taken place over even wider ranges and is not always connected with the veins. In these cases it may be associated with post-ore fractures, especially those in which specularite occurs.

Photograph by Lake Shore Mines, Limited.



Jointing along the walls of a vein in syenite porphyry at the Lake Shore mine.
Alteration has taken place along the set of joint planes.

Robson¹ has pointed out that jointing is a feature of the rocks adjacent to the veins and breaks. In mining operations small angular blocks will break along the joints and, if unsupported, will slough off for some distance into the walls.

Ore Bodies

The accompanying plans and sections show the great lateral and vertical continuity of the ore bodies along the North (No. 2) vein zone. The stoping width varies considerably, depending upon the type and extent of the fracturing. In the western part of the mine, certain parallel ore bodies on No. 2 vein have been mined separately (see sections facing page 152), but at other places a

¹W. T. Robson, *op. cit.*, p. 124.

number of closely spaced veins are stoped together and constitute wide ore bodies. Robson¹ has stated that stoping widths on No. 2 vein have ranged from 3.5 to 70 feet. In places wide ore bodies occur at the junction of veins; rolls on the veins also tend to provide widespread fracturing and parallel ore shoots. A mud seam commonly forms one smooth, well-defined stope wall. These slips tend to lie on the footwall of the ore, but in places vein material occurs on both sides of the "false wall" or between a number of mud seams. As a general rule, the hanging wall of an ore shoot is the most irregular and may be defined only by assay boundaries.

The South (No. 1) vein zone comprises a number of structures, and consequently the ore bodies are more irregular in distribution and show less continuity than those on No. 2 vein zone. Generally, the better values on No. 2 vein zone are confined to narrower widths. As a rule the stopes are not so wide as on No. 2 vein, but a series of rich parallel veins may extend across widths of several feet. Robson² gives a maximum stoping width of 35 feet and a minimum of 3 feet for the No. 1 vein zone.

Up to the end of June, 1947, the average grade of the ore from the No. 1 vein zone was approximately 0.452 ounces per ton from 3,439,686 tons milled, as compared with 0.617 ounces per ton for the No. 2 vein zone from 8,609,597 tons milled. No separate record for the early production from subsidiary veins is available, but since 1940, 227,050 tons of ore milled from these veins has averaged 0.316 ounces per ton.

Post-Ore Faults

Post-ore faults are well-defined planes of movement, along which chlorite, graphite, and gouge have been developed; in places calcite, barite, and quartz have been introduced. They trend at various angles with respect to the veins and may be classified as strike faults, oblique faults, and cross faults, but all sets may have the same type of mineralization.

Strike Faults

Some of the mud seams along the productive veins are definitely produced by post-ore movement because they offset the post-ore diabase dikes; it is possible that most of the narrower slips along the ore zone are post-vein structures. Striae on the fault planes indicate that this late movement is mostly horizontal.

Strike faults not associated with the ore zones generally dip at a lower angle than the veins, and the displacement is small. A number of these are indicated on the sections through the Lake Shore mine shown on sheet L. Most of these faults dip at low angles, generally between 30 and 45 degrees. The hanging wall invariably moved upward over the footwall, tending to leave a narrow fault gap where the vein is pulled apart. Most of these low-angle faults have a southerly dip.

Cross and Oblique Faults

The most important cross fault occurs near the east end of the mine and is called the Lake Shore fault. This structure has been traced to the deepest workings in the mine. It dips steeply southeast in the upper part of the mine, but at a depth of about 3,000 feet it splits into two branches. The branch still referred to as the Lake Shore fault reverses its dip to an average of 85° N.W. The other

¹W. T. Robson, *op. cit.*, p. 118.

²*Ibid.*

branch, called the L fault, continues to dip east to its junction with the Sylvanite fault.

Above the junction with the L fault the amount of horizontal displacement on the Lake Shore fault ranges from 600 to 750 feet and the vertical component is about 325 feet, the east side having moved down and north relative to the west side. According to Hopkins¹ the movement on this fault is rotational, the east side having moved through an angle of 19 degrees relative to the west side.

Below the junction, the components of movements are split about evenly between the L and the Lake Shore faults. The effect of this has been that the South (No. 1) vein, which was faulted from Lake Shore ground into Wright-Hargreaves property east of the Lake Shore fault, is, below the junction with the L fault, retained on the Lake Shore property several hundred feet farther east.

The Lake Shore fault may consist of a single plane or a number of roughly regular planes, all characterized by the development of a few inches of chloritic gouge. Fracturing extends for several feet from the fault plane into the adjacent wall rock.

Northeastward-trending cross faults occur west of the shaft section. They are of minor importance, the maximum displacement being about 40 feet. Some do not extend below the 1,000-foot level. These faults dip steeply and generally displace the east side to the north.

Structural Control of Ore Bodies

The fracture pattern produced by the Kirkland Lake fault system has been the underlying structural control of ore deposition in the Lake Shore mine. The property covers the west margin of the elongated syenite porphyry body and the complex mixture of intrusive types adjacent to it. It is in the latter area that the most widespread fracturing occurred, but it continued through the porphyry body as well. The mineralizing solutions not only spread through and along the permeable ground adjacent to the main thrust-fault plane (North or 2 vein zone) but also migrated along numerous diagonal fractures extending to the South (No. 1) vein zone. As previously mentioned,² the transfer of the main faulting movement from the North vein zone in the western part of the camp to the South vein in the eastern part takes place in the form of a broad zone of fracturing, located largely on the Lake Shore property. Individual faults and fractures in the network vary in strength along strike and dip as the movement is transferred from one structure to another. Thus, a break may weaken and disappear or be joined by another and become stronger.

The amount of local shattering and brecciation resulting from successive movements along the main thrust fault was probably the controlling feature in the localization and extent of ore shoots associated with it. This movement under compression also produced tension fractures in the upthrust block on the hanging-wall side of the main shear zone (see section 15, Fig. 7, facing page 82). These strike diagonally and dip at a low angle to the main thrust plane. These openings also provided channelways for ore solutions. The net result of both tensional and compressional forces was a branching fracture system with a somewhat similar pattern in both plan and cross-section.

Certain areas were especially well fractured in this broad zone of structural disturbance and so provided favourable conditions for abnormal widths of ore. These were (1) the wedge-shaped blocks at the junction of branching veins and

¹Harold Hopkins, *Trans. Can. Inst. Min. Met.*, Vol. 43, 1940, p. 691.

²Page 154.

TABLE 9—LAKE SHORE MINE STATISTICS, 1938-1947

	July 1, 1937, to June 30, 1938	July 1, 1938, to June 30, 1939	July 1, 1939, to June 30, 1940	July 1, 1940, to June 30, 1941	July 1, 1941, to June 30, 1942	July 1, 1942, to June 30, 1943	July 1, 1943, to June 30, 1944	July 1, 1944, to June 30, 1945	July 1, 1945, to June 30, 1946	July 1, 1946, to June 30, 1947
Tons milled.....	928,036	898,894	755,661	612,906	388,738	338,810	267,698	261,583	331,048	294,665
Value of bullion re- covered.....	\$15,030,273	\$14,608,714	\$12,281,332	\$9,404,781	\$6,191,672	\$5,540,130	\$4,498,530	\$4,276,226	\$4,983,114	\$4,681,358
Average recovery per ton.....	\$16.19	\$16.25	\$16.25	\$15.34	\$15.93	\$16.35	\$16.80	\$16.35	\$15.05	\$15.88
Operating costs per ton treated.....	\$5.99	\$6.39	\$6.57	\$6.44	\$7.33	\$7.54	\$8.09	\$8.69	\$7.70	\$9.33
Total costs per ton treated.....	\$7.90	\$8.40	\$8.96	\$9.45	\$10.00	\$10.58	\$11.04	\$11.18	\$9.96	\$11.20
Total ore developed by drifting and avail- able for stoping:										
Length (feet).....	17,226	16,803	13,290	17,103	17,236	16,925	17,122	17,365	17,724	18,779
Width (inches) be- fore slashing.....	55	54	54	54	56	57	58	58	58	58
Grade (ounces per ton).....	0.600	0.601	0.585	0.624	0.606	0.575	0.575	0.556	0.551	0.523
Net profit.....	\$7,732,417	\$7,070,767	\$5,534,927	\$3,639,318	\$2,279,231	\$1,918,183	\$1,521,977	\$1,337,135	\$1,652,791	\$1,348,173
Dividends paid.....	\$10,000,000	\$8,000,000	\$5,500,000	\$3,700,000	\$2,200,000	\$1,600,000	\$1,600,000	\$1,600,000	\$1,600,000	\$1,440,000

(2) localities where sharp changes in strike and dip of the fault planes produced widespread shattering and vein formation.

Statistics

The annual and total value of bullion produced and tonnage milled by the Lake Shore mine since the commencement of production in 1918 to the end of 1947 are shown in Table 3 (facing page 60). The yearly and total output of gold and silver in ounces, the average gold-silver ratio, and the average fineness of the bullion are shown in Table 4 (facing page 60). The yearly and total dividends paid are given in Table 1 (page 59).

A detailed yearly analysis of production, recovery, costs, profits, ore developments, and ore reserves over the 10-year period ending June 30, 1947, covering conditions of peace and war, is given in Table 9 (page 159). This information is taken from the annual reports of the company. The policy of the company has always been to state the lineal footage of ore developed by drifting and available for stoping at the end of each fiscal year.

CHAPTER VIII

Geology of the Wright-Hargreaves Mine

By Harold Hopkins¹

Introduction

It was on the property of Wright-Hargreaves Mines, Limited, that gold was first found in the Kirkland Lake area by W. H. Wright in 1911. Since that time mining operations have been carried to a depth of 7,271 feet, but the surface outcrop of the original find has only recently been mined. Three tons of ore, which yielded 43 ounces of gold and 404 ounces of silver were shipped from the property in 1913, but regular production did not commence until 1921. Fig. 11 (facing page 162) shows graphically the yearly data on the total value of bullion recovered, total ounces of gold produced, total tons milled, average recovery in ounces of gold and silver, gold to silver ratio, and average price received per ounce of gold; it also shows the mean depth of ore extraction.

General Geology

The main rock types that occur in the Wright-Hargreaves mine are the Timiskaming conglomerate and greywacke and the Algoman augite syenite and syenite porphyry. The distribution of these rocks is shown on the accompanying plans and sections (in map case).

TIMISKAMING

The conglomerate has a greywacke matrix, and the pebbles represent a great variety of pre-Timiskaming rocks. On one face in the mine, 8 by 7 feet in dimension, 46 different types of pebbles were noted. There were 10 kinds of plutonic rocks, 19 varieties of hypabyssal rocks, 9 lava types, 3 kinds of tuff, red jasper; and a grey chert; mineralized quartz pebbles have also been seen. None of the rock types represented by the pebbles occur in the immediate vicinity of the Kirkland Lake mines.

The greywackes range in grain size from varieties almost fine-grained enough to be called argillite to more gritty types with grain size as much as 1.5 millimetres. The most common constituents are the feldspars, orthoclase and plagioclase, and quartz; these are present in angular to subangular grains. The feldspars are, in general, moderately fresh, but any fragments of original ferromagnesian minerals are altered to chlorite and iron ores. Apatite and sphene have been seen, but they are quite rare.

Most greywackes show some signs of carbonatization, but metamorphism of these rocks is, in general, of a low order. There are, however, some shear zones in which these rocks become sericitic; and in places, near the intrusives, there may be a development of biotite.

Cross-bedding is often seen in the finer-grained varieties of greywacke. In the thicker and coarser greywacke, the bedding is often shown by thin pebbly bands.

ALGOMAN

Augite Syenite

Augite syenite is a rock of granitoid texture and has a coarser grain than any of the other intrusives. When fresh it is a grey or black and white mottled rock,

¹Geologist, Wright-Hargreaves Mines, Limited.

in which black augite crystals, with dimensions up to 5 millimetres, and biotite are embedded in whitish feldspars. Alteration of these minerals yields rocks of varying colours; these may be reddish, pink and green mottled, grey and green mottled, or cream-coloured and black. Much of the feldspar is orthoclase; associated with it is microperthite and a feldspar with very fine twinning *lamellae*, which may be anorthoclase. The pyroxene is a pale-coloured variety, which is well developed in many places and contains poikilitic inclusions of apatite and biotite. Biotite is less abundant than augite but occurs in fairly large crystals and also as smaller ones, which in many places are scattered throughout the feldspars. Apatite is a common accessory; magnetite, a minor one.

Syenite Porphyry

Syenite porphyry, which intrudes all the rocks previously described, covers a large part of the property. This rock is generally partially altered; but where seen in the fresher phases, it is a brownish-grey in colour. Feldspar phenocrysts, which are usually white but occasionally pink in colour, are quite prominent; they have an average size of from 1 to 2 millimetres, with a maximum of 8 millimetres. The feldspar phenocrysts make up from 30 to 50 per cent. of the rock. Megascopically, biotite is often recognized, but hornblende rarely so. In mine workings, the rock usually has a reddish colour and is characterized by the presence of chloritized inclusions. These inclusions range from small fragments to those several inches in size, and one or two of them are usually seen in drift faces where the country rock is syenite porphyry. Some are inclusions of the intruded sediments; others are segregations of the ferromagnesian minerals in the porphyry. Inclusions of fresh rocks are rare, though granitic inclusions as much as 2 feet in diameter have been seen.

Structural Geology

The major structure in the Kirkland Lake area, in the writer's opinion, is a graben. This has been described in a previous paper.¹ The writer believes that the folded Timiskaming sediments have been dropped between two steeply dipping faults in the region of an anticlinal fold in the Keewatin series. These faults lie along the north and south contacts of the Timiskaming series. The throw on these faults appears to measure in thousands of feet.²

The structure of the ore zone at the mine is part of the major structure of the area and is well illustrated in the accompanying level plans and sections. A study of these will show that the Kirkland Lake fault passes through the property and has been followed by development work and diamond-drilling from surface to a depth of 6,900 feet. Other ore-bearing structures are found in faults that have branched off the Kirkland Lake fault and in parallel faults and tension fractures. In contrast to the distribution of the subsidiary structures on the south or hanging-wall side of the main fault in the western half of the camp, at the Wright-Hargreaves mine practically all ore-bearing structures are found on the north or footwall side of the main fault.

Owing to the numerous post-ore faults at the mine, the geological relationship of the Kirkland Lake fault to the syenite porphyry can best be seen on section No. 20a, sheet N, which is a reconstruction of section No. 20 (through the shaft area), showing the veins restored to the positions they occupied before post-ore faulting took place. In plan, the Kirkland Lake fault passes through

¹Harold Hopkins, "Structure at Kirkland Lake," *Bull. Geol. Soc. Amer.*, Vol. 60, No. 5, 1949, pp. 912-914.

²For discussion, see pages 13-14.

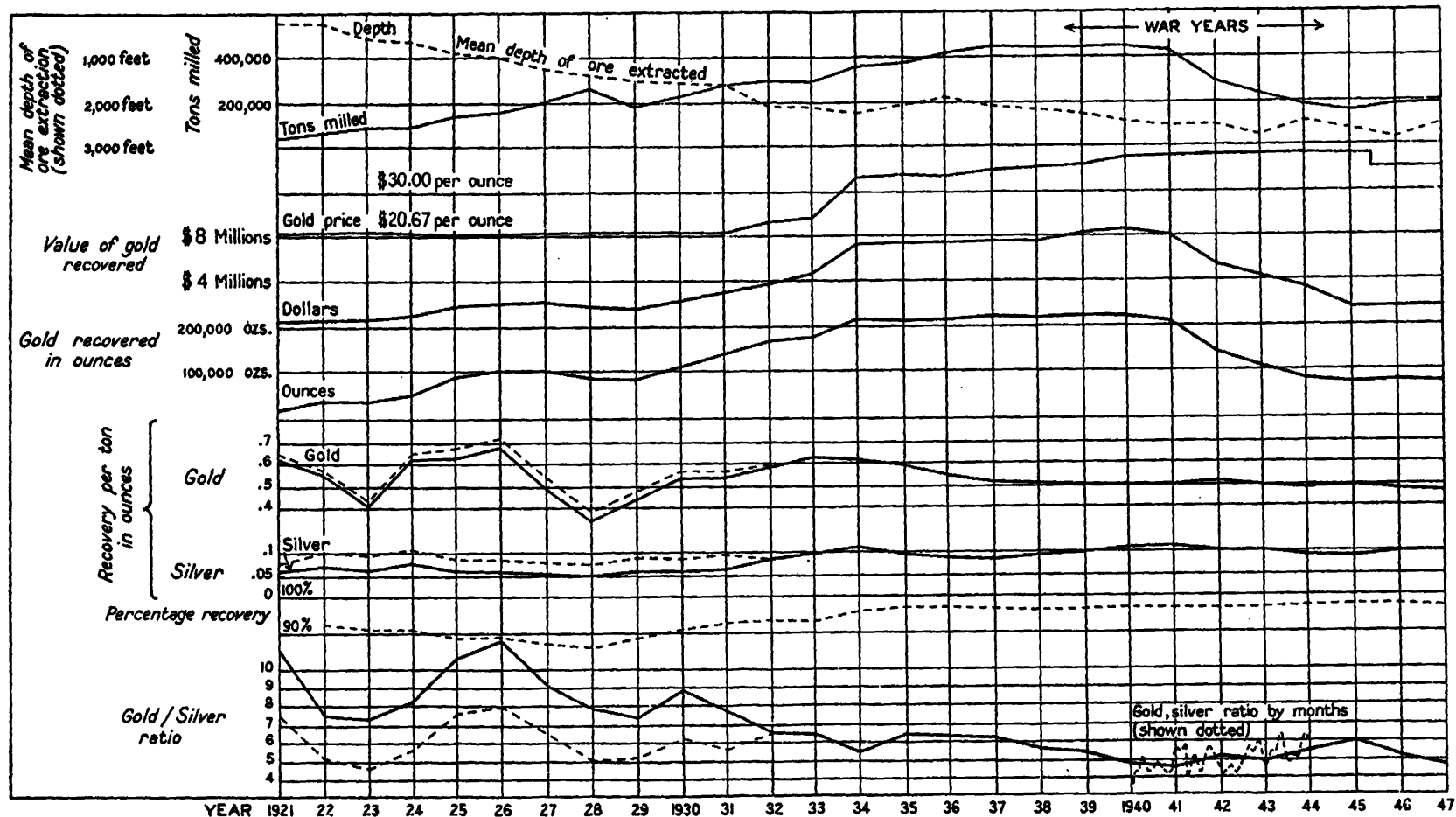


FIG. 11—GRAPH SHOWING SOME WRIGHT-HARGREAVES MINE STATISTICS.

the centre of the syenite porphyry stock with a strike of N. 67° E. In section, it parallels closely the north contact of this rock. The fault is more or less vertical to a depth of 3,500 feet; below this horizon it shows a slight southerly dip to 6,300 feet, and then resumes an almost vertical dip. In spite of the southerly dip in part of its downward course, the post-ore faults have moved this major structure towards the north, so that at a depth of about 7,200 feet the fault is almost vertically beneath its position on the surface.

Although much ore has been mined from the Kirkland Lake fault, the structure producing the greater tonnage of ore is the North vein, which branches off

Photograph by Harold Hopkins.



Exposure of the North vein on the back of the 3,000-foot level, Wright-Hargreaves mine, showing the stockwork type of vein with flat and steep minor post-ore faults. The wall rock is syenite porphyry.

on the north side of the main fault just west of the Wright-Hargreaves property. On section No. 20a, the North vein is shown lying parallel to and 200 feet south of the north syenite porphyry contact. The actual contact is noticeably lacking in vein structures. Not only has the North vein been the most productive structure to date in mining down to the 6,150-foot level, but it still shows, from diamond-drilling to depths of 7,200 feet, greater promise than the Kirkland Lake vein-fault to the south. Ore indications on the North vein in diamond-drilling between the 6,450- and 7,200-foot levels may be seen in the section facing page 164.

Other important vein structures are the South vein-fault, the Incline vein, No. 20 break, No. 60 break, and No. 8 vein. The South vein-fault branches off the south side of the Kirkland Lake fault in the western part of the mine. No. 20 break branches off the north side of the Kirkland Lake fault in the central part of the mine. No. 20 break and the Incline vein structure are both shown on the plan of the 1,600-foot horizon on sheet C and on section No. 21, sheet N. The Incline vein extends from the 1,000- to the 2,250-foot level; its maximum lateral extent is about three-quarters of a mile, although there are some *en échelon* structures on both strike and dip over this length. It has an average dip of 45° S. and follows an arcuate course. Going downward, it connects with No. 20 break; going upward, it passes through the North vein zone, as part of a shingle structure (see Fig. 6 facing page 80), and continues into the Sylvanite property. No. 8 vein, which dips 50° S., breaks off the North vein at the 5,100-foot level and has been mined upwards to the 4,350-foot level.

In addition to the main vein structures, there are some smaller veins on tension fractures. These may parallel the major faults in strike and dip, or perhaps in strike only, or angle between these structures. *En échelon* structures are common in the subsidiary veins; these structures are probably evidence of the varying stresses to which different areas and horizons were subjected. Favourable locations for tension fractures are in the wedge-shaped blocks between the main faults. An example of this is shown on section No. 18, sheet N, where a set of tension fractures lies between the Kirkland Lake fault and the South vein on the upper levels of the mine.

Veins and Their Minerals

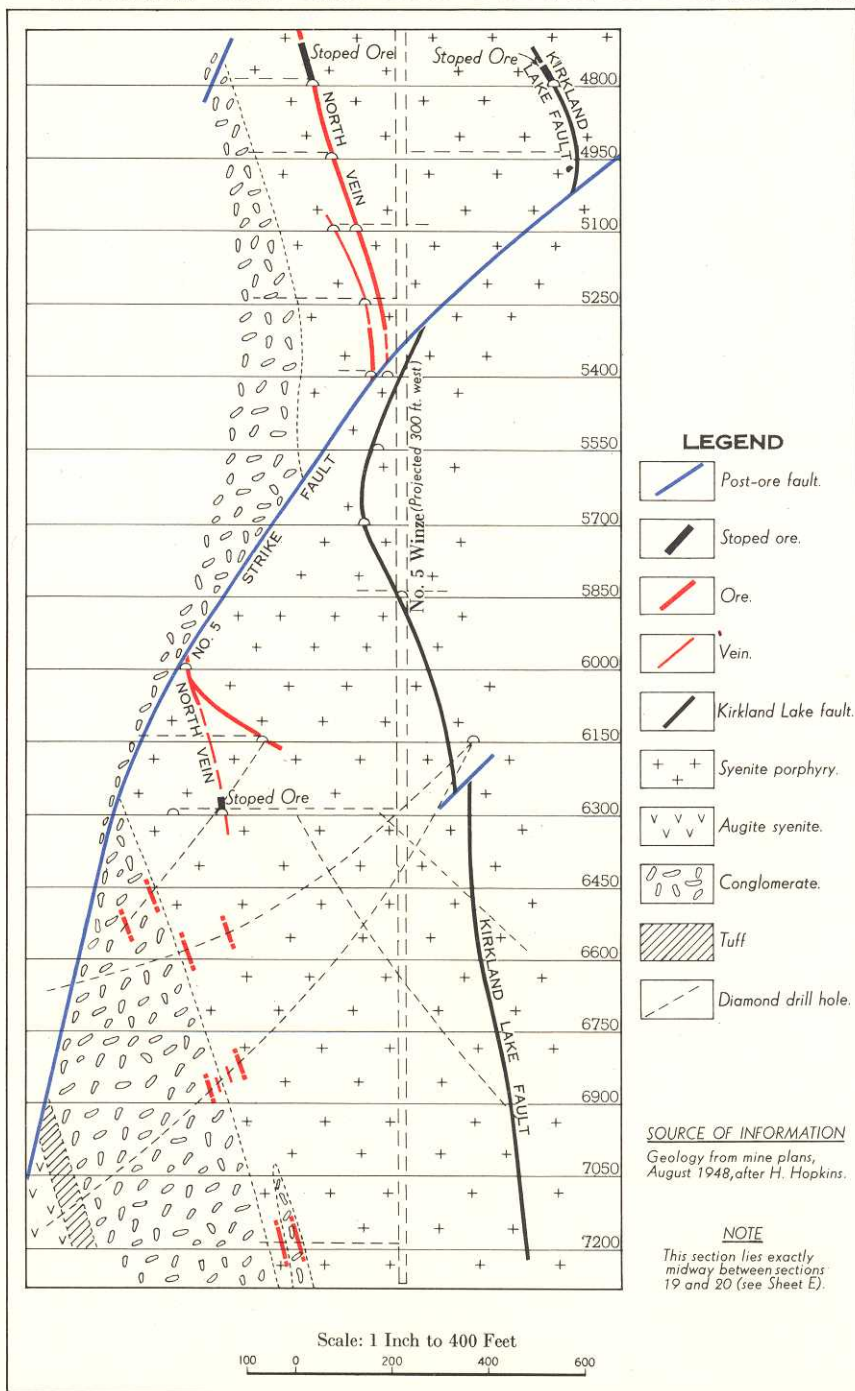
Associated with the above-mentioned structures in the mine are veins of various types. Fissure veins are the most common, and the larger ore bodies on the various faults are of this type. Lodes, stockworks, breccia, and gash veins are found on other structures. The veins are composed of the gangue minerals and varying widths of altered country rock. If sufficient precious metal is present in the veins, they constitute minable ore bodies.

The principal gangue mineral is quartz; some calcite is usually associated with it. Other minerals present in very small amounts are albite, orthoclase, ankerite, barite, and apatite. The secondary minerals are sericite, carbonates, chlorite, and pyrite.

Gold is the principal metal, and with it is associated the gold telluride, calaverite. Gold occurs in the native state and also in the pyrite of the veins. Silver is associated with both the native gold and the gold bound up in the pyrite, but probably in different proportions in each case; it also occurs in the silver telluride, petzite. Other minerals in the ores are chalcopyrite, hematite, galena, sphalerite, molybdenite, graphite, and the tellurides, altaite, coloradoite, and melonite.

Quartz

The greater part of the vein quartz has a milky-white colour, but that which crystallized late is often dark owing to the large proportions of inclusions. Even the white quartz is generally clouded in thin section. Although hypidiomorphic texture is occasionally seen, the quartz is, in general, in allotriomorphic grains of varying sizes up to 2.5 millimetres. Strain shadows are often seen; when brecciation has taken place the first sign is the granulation of the quartz at the borders of the grains. Vugs are rarely seen, but when present they contain well-formed crystals of smoky quartz. That vugs were present at the time of mineralization



SECTION THROUGH THE WRIGHT-HARGREAVES MINE, SHOWING THE NORTH VEIN ORE ABOVE AND BELOW THE NO. 5 STRIKE FAULT IN DRIFTS AND DIAMOND-DRILL HOLES.

seems apparent on inspection of nests of tellurides in the quartz, for quite often crystals of smoky quartz are found among the tellurides; these crystals are usually small and can generally be seen only by using a lens.

Carbonates

Calcite is an abundant associate of the vein quartz; ankerite is less common.

Feldspars

Out of 40 thin sections of vein gangue examined by the writer, albite was seen in 6 of them and orthoclase in 5. In 2 of the sections both feldspars were found.

Barite

Barite is not always present in the gangue but was found in appreciable amounts in the Narrows break, where it had a brick-red colour. A cream-coloured variety has been noted in the South vein.

Chlorite

Chlorite is commonly present on minor slips and in the shear planes of the major faults.

Sericite

Sericite is a common constituent of the veins, being present in both the wall rocks and the gangue, where it is seen replacing the quartz.

Graphite

Graphite is apparently present, as shown by analyses of the ores, but is difficult to find in the ores; it apparently occurs on the slickensides and in the gouge. Analyses of ores by the Mines Branch, Ottawa, gave 0.20 per cent. carbon in a sample of the former and 0.13 per cent. in one of the latter.

Molybdenite

Molybdenite is seen on slickensides and fracture planes in both the wall rocks and the quartz gangue. An analysis of a specimen of a blackish, crushed syenite porphyry from a slickensided vein slip showed 16.5 per cent. molybdenite. Analyses of 22 bulk samples of ore, taken half from the North vein and half from the South vein and representing horizons at intervals of 500 feet in depth, showed molybdenite to occur within a range of 0.018 to 0.06 per cent. The range appeared to be similar for each vein, and no vertical zoning is apparent.

Specular Hematite

Specular hematite in places fills fractures, mainly in the altered wall rocks.

Galena, Sphalerite, and Pyrrhotite

Galena, sphalerite, and pyrrhotite are rarely found; in places galena is associated with the tellurides. Pyrrhotite is apparently quite rare; Todd¹ reported its occurrence in only one specimen, and since the publication of his report it has been seen by the writer in only one other specimen.

Chalcopyrite

Chalcopyrite is often seen in the gangue and is frequently associated with nests of high-grade, particularly in the presence of tellurides. In amount, how-

¹E. W. Todd, *Ont. Dept. Mines, Vol. XXXVII, pt. 2, p. 85.*

ever, it is not of great importance. In 22 bulk samples of ore, copper was found to range from a trace to 0.18 per cent.

Pyrite

Pyrite of two types occurs in the ores, one due to the alteration of the ferromagnesian minerals in the wall rocks and the other introduced by the ore-forming solutions. The amount of pyrite in the ores ranges from 1 to 2 per cent. by weight. Cubes and pyritohedra are seen, but much of the pyrite is in irregular grains; in rare cases it attains 2 millimetres in size, but is generally much finer, often requiring the use of a lens to be seen. The coarser type is generally seen only in the wall rocks and rock inclusions in the gangue, whereas the finer variety is seen in both the gangue and the altered wall rocks. Gold is associated with both types of pyrite, as a replacement of the secondary type and as an original constituent of the vein-forming pyrite.

Tellurides

Tellurides are present in the ore and are found at all depths. Those represented are altaite (lead), calaverite (gold), coloradoite (mercury), petzite (silver-gold), and melonite (nickel). Their distribution is quite erratic, though they are often seen in high-grade portions of a vein. Being erratic it is difficult to state their relative abundance, but the writer believes it is in the order named. In places they occur alone; but frequently, if one is seen, then one or two others are likely to be associated with it or will be found near by. Melonite is apparently quite rare in these ores. Ellis Thomson¹ identified this telluride in Tough-Oakes (Toburn) ores. The only other occurrence known to the writer was found recently in a stope at the mine. The specimen was small and was determined for the writer by M. A. Peacock and R. M. Thomson, of the University of Toronto.

The tellurides are found in nests and stringers in the gangue and in the wall rocks and are usually associated with native gold. The nests in the vein quartz give the impression of having filled vugs, for they are often accompanied by minute, well-formed crystals of smoky quartz. Underground, the back of a drift that has been left untouched for some time frequently shows black streaks along the vein, resembling marks that might be made with a miner's carbide lamp. These streaks are mere films on the surface and are believed to be lead sulphide produced by the decomposition of altaite by mine waters. These black streaks are generally a good indication of ore.

Gold

Native gold occurs in the gangue, wall rock, and pyrite, and also as a constituent of the tellurides calaverite and petzite. The latter mineral is rarely seen, but calaverite is commoner and is an important source of gold. Stringers and lumps of gold are occasionally seen, but the greater part of the gold is in fine particles. The gold was the last of the vein minerals to be deposited and is seen cutting through the pyrite, chalcopyrite, and tellurides. It does not appear to have been partial to any particular gangue or wall rock; it occurs in both the quartz and the calcite of the gangue and has been deposited in all the rocks along the ore zone. A large proportion of the gold is in fractures in the wall rocks and inclusions of these in the gangue. Thin sections of rocks showing veinlets of gold do not show any particular sign of alteration that can be related to the deposition of the gold, which apparently came in after the processes that caused the alteration of the wall rocks had ceased to function.

¹Ellis Thomson, "Contributions to Canadian Mineralogy," 1922, Univ. of Toronto Press, p. 97.

The native gold is high in fineness throughout the whole length of the ore zone at Kirkland Lake. In Todd's report¹ are to be found data on the percentage of silver in native gold at several of the mines that give the following indications of fineness: Teck-Hughes, 933, 945; Lake Shore, 961, 926, 936, 946; Wright-Hargreaves, 949; Sylvanite, 928, 925; Toburn, 954, 960. Recent determinations on two specimens of gold at the Wright-Hargreaves gave fineness of 927 and 944. The average fineness of all these is 941.

In contrast to the fineness of the native gold (941) is that of the bullion, which, for the Wright-Hargreaves mine from the commencement of milling to the end of 1944, was 859.4.

Some 9 per cent. of the silver in the bullion must come from sources other than the native gold. Some of this silver comes from petzite; but as this mineral is rarely found, the amount of the silver derived from petzite is believed to be small. Todd² found that there was no gold or silver in molecular combination in either the altaite or the coloradoite, and tests made for the writer confirm this. In regard to the calaverite, Todd³ reported an almost negligible amount of silver "indicating a purer gold telluride than has been described elsewhere." Confirmation of this is seen in an analysis of calaverite made recently at the mine, which showed the following:—

	Per cent.	Molecular ratio	
Gold.....	42.8	0.218	Au 1 to Te 2.06
Tellurium.....	57.2	.448	AuTe ₂

There is no conclusive proof of the origin of much of the silver in the bullion, but possibly the gold in the vein pyrite may have a much lower fineness than the native gold.

Gold-Silver Ratios

Gold-silver ratios based on the annual production of bullion at the mine are shown in Fig. 11 (facing page 162). There are few assays for silver apart from those yielded by the bullion; and it is impossible, without assaying all samples for silver as well as gold, to make any determinations respecting the gold-silver ratio for any one level or stope. Even monthly bullion figures are found to vary over a wide range. This is seen in Fig. 11, where the monthly figures for the four years 1941-44 are plotted. Annual figures appear to be the only ones that can be used with any satisfaction in following trends in the gold-silver ratio. A variable factor is the percentage recovery in the mill (shown in Fig. 11), because it appears that with a low recovery there is a greater proportional loss of silver than of gold, resulting in a higher ratio than the ores should show. In Fig. 11 an attempt has been made to adjust for the low recovery in the mill up to the year 1932 on the curves showing recovery per ton in ounces of gold and silver and in the gold-silver ratio.

Gold-silver ratios for some mines of the Kirkland Lake camp and the Porcupine camp have been discussed by Bruce:⁴—

If the trends shown in the ore from the Lake Shore and Wright-Hargreaves mines represent control of the ratio by depth, then it should be possible to predict the depth at which the precious metal content will be below ore grade. With the present information it is possible only to con-

¹E. W. Todd, *op. cit.*, p. 72.

²*Ibid*, pp. 74, 75, 80.

³*Ibid*, p. 79.

⁴E. L. Bruce, "Gold-Silver Ratios in Certain Ontario Gold Mines," *Trans. Roy. Soc. Can.* 3rd series, Vol. 37, sect. 4, 1943, pp. 23-31.

clude that: (a) The gold-silver ratio for some deposits seems to decrease with depth; (b) the ratio is different for different kinds of wall rocks even on the same level; (c) silver shows less variation than gold.¹

Fig. 11 does appear to show a declining gold-silver ratio with depth at the Wright-Hargreaves mine, and the silver shows less variation than gold. The declining ratio, however, would appear to be influenced more by an increasing silver content in the ores than by a decreasing gold content. Although the mine is developed to a depth of more than 6,000 feet, the mean depth of ore extraction is still only 2,500 feet. Even if the gold-silver ratio declines with greater depth, this will be due to the higher silver content accompanying the gold ores of higher than average mine grade. Thus, the trend in the gold-silver ratio apparently does not help to predict the depth at which the precious metal content will be below ore grade.

Wall-Rock Alteration

Along the thrust faults in the mine the rocks have been changed to micro-breccias and mylonites. This happens regardless of whether the faults are steeply or flatly dipping and apparently takes place on the side of the fault that moved. The microbreccia and mylonite range in width from an inch to several feet. They are often streaky and range in colour through shades of buff to grey, black, flesh-coloured, and red. The varieties that have undergone extreme granulation are cherty in appearance. Although mylonitization does not imply recrystallization and alteration by carbonatization and sericitization, these rocks have actually been altered in this way. The carbonatization and sericitization probably took place at the same time that the rocks of the whole area were so affected.

The most abundant type of vein wall-rock alteration is that due to the addition of carbon dioxide, silica, and potash. Carbonatization is in evidence along the faults, even in the absence of ore. Much of the carbonatization in the ore zone may be related to the earlier regional alteration, and it may be impossible to distinguish between the earlier alteration and that due to the ore fluids. Sericitization and silicification appear to be directly associated with the veins.

Apart from chlorite, pyrite, and sericite, secondary products are scarce, though biotite is sometimes formed in the greywackes and the matrix of the conglomerates. The bleaching, reddening, and mottling of the rocks in the process of alteration have already been referred to.²

Late Vein-Filling

Post-ore movements along the vein faults are evidenced by the offsets of the post-ore diabase dikes in mines to the east and west of the Wright-Hargreaves. During these movements, the ore was faulted and brecciated, and slickensides were formed on which gold was drawn out and pyrite was ground to powder. Following this stage a later filling of quartz and calcite along with some barite and gypsum was introduced. This is usually present along the vein faults regardless of whether ore is present or not. The quartz is glassy. The calcite shows various tints; it is generally white but frequently reddish-brown in colour owing to the presence of some magnesia. It may be pink in colour where manganese is present. Some ankerite is occasionally seen. Sulphates are represented by barite, which is usually a reddish-brown colour, and gypsum. Unlike the vein gangue, this late filling, which ranges in thickness from a fraction of an inch to 2 feet, is often banded with quartz and calcite, which are separated by thin

¹E. L. Bruce, *op. cit.*, p. 30.

²Page 162.

chloritic walls or seams. The late filling has filled fractures in the earlier vein quartz and calcite. Mineralization in the late filling is rather sparse, but chalcopyrite, galena, and specular hematite are sometimes seen; no gold is associated with these. If both late filling and ore are absent, the faults are characterized by gouge and chloritic seams.

Photograph by Harold Hopkins.



Late minor faulting along the North vein, Wright-Hargreaves mine, showing calcite filling (C) along late flat fractures in the quartz.

Ore Deposits

The pre-ore structures in the mine provided the channelways for the fluids that formed the ore deposits. The Kirkland Lake fault, which is the strongest of the vein structures, probably provided the main channelway. Travelling upwards and laterally from this fault the ore fluids would reach most of the structures in which the ore bodies are now found. Many of the ore bodies on the subsidiary structures can best be explained by lateral flow of the ore fluids, for it is often possible to trace connecting channelways sideways and often apparently impossible to trace these same structures vertically. Connecting channelways, however, may sometimes be traced vertically more easily than laterally. The *en échelon* arrangement of veins occurs in both plan and section. Where the *échelon* is on the dip, a lateral connection can often be traced; and where it is on strike, vertical connections are found. For example, No. 20 break does not

connect with the Kirkland Lake fault on the dip but does so along the strike. In its turn, No. 20 break is seen as a possible feeder for the ore bodies on the Incline vein (see plan of the 1,600-foot horizon, sheet C, and section No. 21, sheet N).

Widths of ore in the mine vary according to structures. On the weaker tensional fractures the ore may be only a foot or two in width, and stopes less

Photograph by Harold Hopkins.



Exposure of the North vein on the 3,000-foot level, Wright-Hargreaves mine, showing the well-defined footwall (lower right corner). The wall rock is syenite porphyry.

than three feet have been mined. The average stoping width, however, is from 5 to 6 feet. Exceptional widths are occasionally mined. These are directly related to the junctions of subsidiary structures with the Kirkland Lake fault; stoping widths in such locations may be anywhere up to 30 feet, as, for example, on the 400- and 2,250-foot levels.

Ore Shoots

Ore shoots in the mine vary in size and shape. Many of the larger shoots are vertical, but others pitch either to the east or to the west. A pitching ore shoot can usually be related to some geological feature. For example, the general westerly pitch of the east end of the ore zone is controlled by the pitch of the main syenite porphyry mass. The ore shoot on No. 8 vein pitches to the west at

35 degrees; shoots with so flat a pitch are rare. Many of the medium-sized shoots, although irregular in outline, are more or less equidimensional and cannot be said to pitch either way; others are longer than they are high.

Zoning in the ore shoots is not apparent. High values may persist to the margins of ore shoots and then drop quite abruptly.

Post-Ore Faulting

The earliest post-ore faulting in the mine would appear to be the horizontal movements along the Kirkland Lake and South vein faults. This movement, following the deposition of ore on the Kirkland Lake fault, is shown by almost horizontal fault striae and by the offsetting of the post-ore quartz diabase dikes in mines to the west of the Wright-Hargreaves.

The west end of the Wright-Hargreaves mine marks the westerly margin of an area that has been affected by intense faulting at different periods. Some of the faults are due to compression, and others were formed under tension. The relative order of these periods of faulting in the Wright-Hargreaves mine can be recorded as follows: (1) southward-dipping strike fault (No. 4), overthrust from south to north; (2) early transverse fault (Lake Shore fault), rotatory; (3) major northward-dipping faults (Nos. 1, 2, 5, 6), underthrusts from south to north; (4) later transverse faults (Major or K, Sylvanite, F, L, and numerous smaller ones), formed under tension, majority rotatory.

The strike faults and transverse faults have different characteristics. The strike faults show shearing, variable displacements, and a filling of late quartz and calcite, which causes these structures to resemble the veins except that the quartz is the "bull" type. On the transverse faults, brecciation is seen rather than shearing and gouge is often present, but any deposition of quartz and calcite on them is apt to be thin. The displacements on the transverse faults vary in proportion to the amount of rotatory movement on them.

SOUTHWARD-DIPPING STRIKE FAULT

The main southward-dipping strike fault is known as No. 4 in the Wright-Hargreaves mine. At the west end of the mine it is on the west side of the Lake Shore fault, but elsewhere it is on the east side of this cross fault and can be traced for 1,500 feet. This strike fault has a feature common to most of the strike faults in that the dip steepens with depth. Where two branches of this fault cut the North vein on the 1,625-foot level and above the 1,850-foot level, the dips are 45 degrees or less; but where the Kirkland Lake fault is broken between the 2,550- and 2,700-foot levels, the dip is 70 degrees. No. 4 fault has been offset by the transverse faults and by the later series of northward-dipping strike faults.

On the east side of the Lake Shore fault, the maximum displacement shown by No. 4 fault is 230 feet on the Kirkland Lake fault. This is between the 2,550- and 2,700-foot levels. No. 4 strike fault is in the correct position for movement by the Lake Shore fault; that is, down on the east side. This fact suggests that the later set of strike faults may be underthrusts. The latter do not appear on the west side of the Lake Shore fault. If the later set of strike faults were overthrusts, their displacement is so great that the earlier strike faults would have now been found at a horizon 800 feet above their present location.

LAKE SHORE TRANSVERSE FAULT

The Lake Shore transverse fault appears to be a master fault and can be followed from surface to the deepest workings of the mine. Plans and sections of the Kirkland Lake camp show few faults on the west side of the Lake Shore

fault, but numerous strong faults on the east side in the Wright-Hargreaves, Sylvanite, and Toburn mines. Strong faults, such as the F and L, branch off the Lake Shore fault on the east side. The Lake Shore fault strikes N. 12°-25° E. and dips steeply east on the upper horizons; it is almost vertical in the middle horizons, and then reverses its dip so that at a depth of about 5,000 feet the fault is vertically under its surface location. Gouge from half an inch to 2 inches thick is usually present, but quartz and calcite filling are generally absent. Above the branching F fault, the horizontal component of movement on the Lake Shore fault is the more important, being on the order of 650 feet; the vertical component is around 325 feet. The east side has moved north; north-dipping striae have been seen on the fault plane.

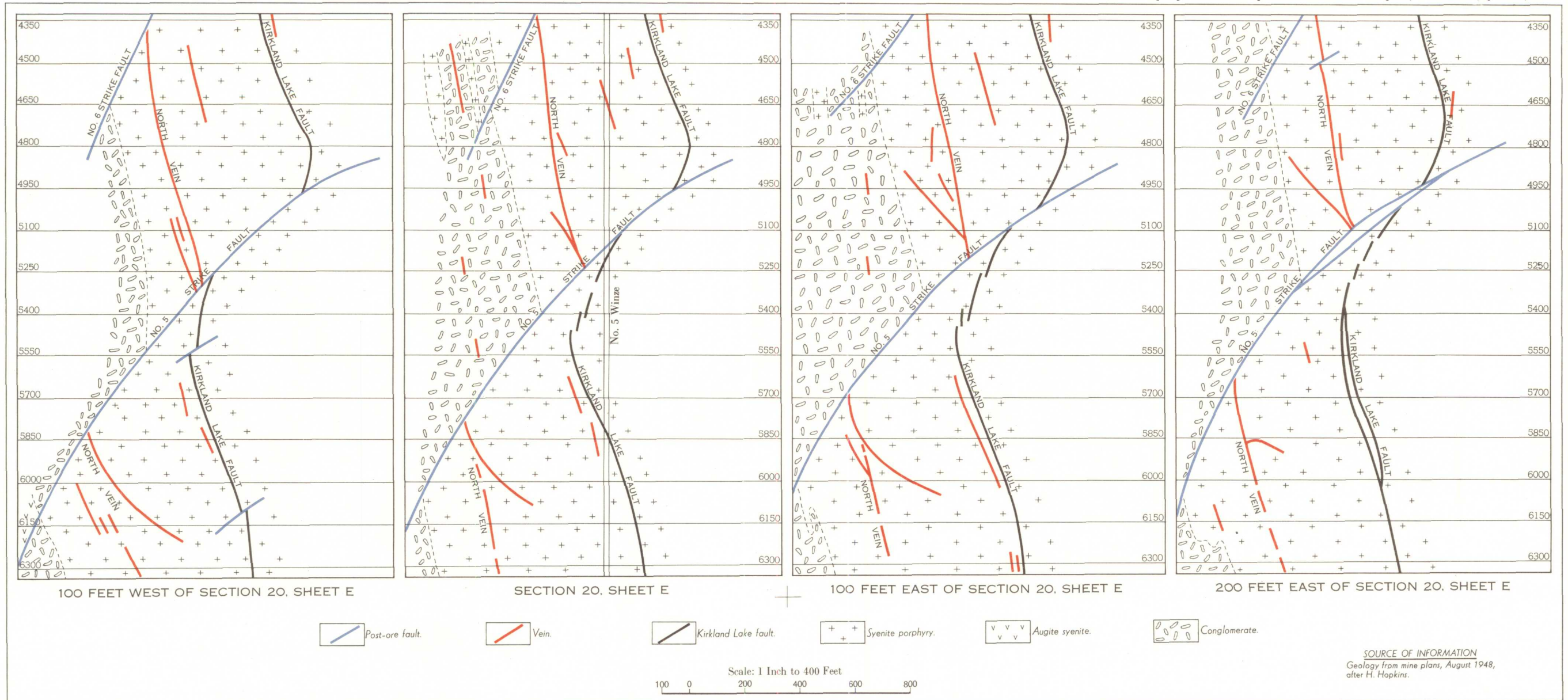
The L fault, which is shown on sheets D and E, branches off the Lake Shore fault at the 3,300-foot level. It has a dip to the east for a depth of 300 feet from the junction and then becomes vertical; this is in the region where the Lake Shore fault has reversed its dip to west and a wedge-shaped block has been formed between the two faults. Above the junction of the L fault with the Lake Shore fault, both the Kirkland Lake fault and the North vein are on Wright-Hargreaves property on the east side of the Lake Shore fault. Below the junction the horizontal component of the movement of the wedge-shaped block is only 350 feet, and in this fault block part of the Kirkland Lake fault or Main break is on Lake Shore property and part on Wright-Hargreaves.

MAJOR NORTHWARD-DIPPING STRIKE FAULTS

East of the Lake Shore fault there are four major northward-dipping strike faults, all of which can be seen on sections Nos. 19, 20, and 21, sheet N. They are numbered 1, 2, 6, and 5. As in the case of No. 4 strike fault, displacements are found to vary, particularly in relation to the movement of the Kirkland Lake fault. In some places the strike fault will be found to cut the Main break, whereas in others the Kirkland Lake fault appears to have been folded. Displacements of the subsidiary veins by these faults are more uniform, and the veins in many places are cut rather abruptly, though drag is not entirely absent.

No. 1 strike fault has been traced across the Wright-Hargreaves property to the region of the Sylvanite boundary, where the fault apparently dies out. The maximum displacement by this fault is on the North vein in the western half of the Wright-Hargreaves mine, where a displacement of 150 feet occurs. No. 2 strike fault causes a larger displacement and can be followed a little farther to the east than No. 1. In the Central part of the mine, this fault shows a displacement of 300 feet on the North vein and has a throw (vertical component) of 180 feet and a heave (horizontal component) of 240 feet. With this throw of 180 feet, which is greater than the level intervals of 150 feet, the absence of the North vein in several fault blocks is due to the fault. Both No. 1 and No. 2 strike faults usually dip at 45 degrees or less to the north in the ore zone; and they are true strike faults throughout their course.

No. 6 strike fault is the least important of the northward-dipping set, though in places it does have a fairly large displacement. A maximum displacement of 120 feet is found, though generally the displacement is closer to 80 feet. The average dip on this fault is 65 degrees. It has been traced east from the Lake Shore fault to the eastern part of the Wright-Hargreaves mine and passes through the Sylvanite internal No. 5 shaft. In the western half of its known extent it is in the nature of an oblique fault, striking N. 30° E.; but as it is followed eastward, its strike changes to N. 60°-65° E. and it parallels the veins. At its east extremities, this fault merges with No. 2 strike fault.



SECTIONS THROUGH PART OF THE WRIGHT-HARGREAVES MINE, SHOWING VARIABLE DISPLACEMENTS ON THE NO. 5 STRIKE FAULT.

The most important of the northward-dipping strike faults is No. 5, which is known on the surface as the Murdock Creek fault. It is a curving structure both on strike and dip, as can be seen on the plans of the 4,450- and 5,200-foot horizons, sheet E, and on sections Nos. 19, 20, and 21, sheet N; it has been traced from the Toburn mine through the Sylvanite mine to the western part of the Wright-Hargreaves mine. Like No. 6 fault, it is an oblique type in its western half but a true strike fault towards the east. Its steepening dip with depth is seen on section No. 21, which also shows a split in the fault. In the Wright-Hargreaves workings, the dip is about 45° N., but where the fault is encountered farther north in the Sylvanite No. 5 shaft, at deeper levels, the dip has increased to 75° - 80° N. In the Wright-Hargreaves mine workings, No. 5 fault strikes N. 25° E. at the west end, changes to northeast going east, and finally, where known farthest east, is striking parallel to the veins. This change in strike is most noticeable on longitudinal sections of the veins, which show the fault gap to be horizontal in the eastern part of the mine, whereas in the western part the gap is plunging westward. The curving strike of this structure is seen on map No. 1945-1, where it is named the Murdock Creek fault. From the Teck-Lebel township line, the fault can be followed for almost 2 miles in a southwesterly direction; then it is seen to bend to the south and for the next 1 1/2 miles it strikes S. 10° W. and coincides with the valley of Murdock creek. Here, a branch of the Lake Shore fault is seen to merge with it. In this region, where the fault would be regarded as a transverse type, the rocks on the east side have been offset 1,000 feet to the north. This east side of the fault represents the footwall side of No. 5 strike fault in the ore zone and is the underthrust referred to previously. At the Wright-Hargreaves mine, the fault is found to have a maximum displacement of 700 feet, a throw of 500 feet, and a heave of 425 feet. Ore intersections in the diamond-drilling of the North vein below this strike fault to a depth of 7,200 feet are shown on the section facing page 164.

A characteristic of the strike faults that has been referred to earlier, i.e. varying displacements, is noticeable in No. 5 strike fault. On the insert facing page 172 are shown four sections at 100-foot intervals through the Wright-Hargreaves mine. They show the attitude of No. 5 strike fault with respect to the Kirkland Lake fault (South vein), the North vein, and the syenite porphyry-greywacke contact. The North vein and the contact are, apparently, cut fairly clean and are displaced regularly. The Kirkland Lake fault, on the other hand, appears to behave in a different fashion. On the most westerly section shown, it is apparently faulted in a manner similar to that of the other structures, but on the remaining sections irregularities appear. Consideration has been given to the possibility that the bends in the Kirkland Lake fault near the strike faults may be original rolls in the earlier structure and that later strike faults pass through those particular areas. Whatever the dip on the Kirkland Lake fault, however, that structure should be moved a distance equivalent to the displacement of the North vein or the intrusive contact. In all cases it is noticed that if the dips of the Kirkland Lake fault near the strike fault are disregarded and, instead, the dips of the structure farther away from the strike fault are projected to it, then the apparent displacement of the Kirkland Lake fault by the strike fault is equivalent to the displacement of the North vein and the formational contact. Therefore, the writer regards the bending of the Kirkland Lake fault as due to the drag of that structure by the strike fault.

Mineralization accompanying the quartz-calcite filling on strike faults is rather sparse, but occasionally nests of coarse-grained galena and chalcopyrite, with smaller amounts of pyrite, are seen. These minerals are not gold-bearing;

for example, when a typical sample of galena and chalcopyrite from No. 6 strike fault at the Wright-Hargreaves mine was assayed, it was found to contain no gold and 0.03 ounces of silver per ton.

TRANSVERSE FAULTS

There are several transverse faults that were formed after the strike faults described above. The most important of these are the Sylvanite and Major (K) faults. The planes of these faults are marked by gouge, from 1 inch to 2 feet in thickness, and in many places by a thin band of quartz and calcite. There may be some slight brecciation of the rocks, and the direction of horizontal movement on the fault may be indicated by slight drag on the vein. The drag may show for only an inch or so, because these cross faults cut through the older structures, even the Kirkland Lake fault, in a more definite manner than do the strike faults. The cross faults are not parallel to each other in strike. Some are joined to form wedge-shaped blocks, which have moved towards the point of the wedge.

Most of the cross faults are found to be normal faults and are rotatory. This has resulted in the movements showing variable horizontal components, on account of varying dips on the different structures. The slight drag of a vein is a good indication of the horizontal direction of the movement, but faulted ore shoots would be more difficult to find if the actual displacement on these faults were unknown. Graphical methods are used to solve the post-ore transverse fault problems. Sections of the hanging wall and footwall of a fault, showing intersections of veins, strike faults, and rock contacts, can be moved on one another to bring the structures together. Then the ore on one side of a fault can be definitely related to ore on the other side, even though the faulted ore may be one or two levels above or below the ore first found. The method of solving displacements on the Sylvanite fault is illustrated on sheets P-1 and P-2.

Sylvanite Fault

The Sylvanite fault has an average strike of N. 10° W. at the surface. It dips westward at 60 degrees towards the Lake Shore fault as far as the 4,050-foot level and then steepens to more than 80 degrees down to the 6,300-foot level. No strong cross fault branches off the footwall side of the Sylvanite fault, but the hanging-wall block of ground between it and the Lake Shore fault is broken into several segments by the B, C, D, E, F, G, and L faults. But from the surface to a little below the 3,750-foot level where it joins the F fault, the immediate hanging wall of the Sylvanite fault is disturbed only by minor cross faults. Sections on the plane of the fault down to the 3,750-foot level show that the movement has been rotatory with a theoretical pivotal point 1,600 feet above the surface and some 5,000 feet north of the ore zone. Actually, the fault has not been traced so far north at the surface, and it is possible that the fault dies out in this direction. The throw on the fault is 150 feet, the west side having dropped that amount; the heave, of course, is variable and increases with depth on account of the above-surface pivoting. On the 3,750-foot level the horizontal displacement is 150 feet, the west side having moved north.

Major or K Fault

The Major or K fault strikes N. 5° E. through the Sylvanite property at the surface and is shown on map No. 1945-1 to follow this trend for 2 miles to the south. It dips west like the Sylvanite fault but at a steeper angle; the dip is 80 degrees down to the 1,200-foot level, below which it flattens to 68 degrees. This dip carries the fault into the Wright-Hargreaves east claim around the

TABLE 10—WRIGHT-HARGREAVES MINE STATISTICS, 1938-1947

	Sept. 1, 1937, to Aug. 31, 1938	Sept. 1, 1938, to Aug. 31, 1939	Sept. 1, 1939, to Aug. 31, 1940	Sept. 1, 1940, to Aug. 31, 1941	Sept. 1, 1941, to Aug. 31, 1942	Sept. 1, 1942, to Aug. 31, 1943	Sept. 1, 1943, to Aug. 31, 1944	Sept. 1, 1944, to Aug. 31, 1945	Sept. 1, 1945, to Aug. 31, 1946	Sept. 1, 1946, to Aug. 31, 1947
Tons milled.....	437,130	436,250	443,930	438,210	316,210	245,130	196,600	159,710	169,830	181,114
Tons milled daily.....	1,197	1,195	1,213	1,200	866	672	537	437	465	496
Recovery per ton.....	\$18.15	\$17.95	\$19.66	\$19.57	\$19.80	\$19.93	\$18.88	\$19.74	\$18.73	\$16.60
Value of bullion re- covered.....	\$7,933,104	\$7,828,494	\$8,729,477	\$8,576,063	\$6,259,433	\$4,886,358	\$3,710,866	\$3,152,857	\$3,180,892	\$3,006,772
Operating costs per ton milled.....	\$6.80	\$6.70	\$6.76	\$6.70	\$7.33	\$7.68	\$8.19	\$9.53	\$9.78	\$9.70
Net costs per ton milled	\$8.90	\$8.90	\$10.23	\$10.97	\$11.44	\$11.83	\$11.71	\$13.02	\$12.76	\$11.94
Estimated ore reserves (tons).....	1,470,772	1,516,961	1,431,464	1,316,618	1,185,445	1,150,521	1,060,835	990,739	920,000	.....
Estimated grade of ore reserves (ounces per ton).....	0.53	0.53	0.52	0.52	0.50	0.50	0.49	0.47	.....	.....
Net yearly profit.....	\$4,088,445	\$4,044,338	\$4,234,919	\$3,817,810	\$2,691,176	\$2,039,891	\$1,468,636	\$1,130,238	\$1,083,477	\$908,278
Dividends paid.....	\$3,850,000	\$3,850,000	\$3,850,000	\$4,001,250	\$2,475,000	\$1,925,000	\$1,375,000	\$1,100,000	\$1,100,000	\$880,000

2,700-foot level. It has been followed in underground workings to the 4,650-foot level; below this horizon only the 6,150-foot level has been extended far enough east to pass through this fault zone, but here the fault is not in evidence. Like the Sylvanite fault, the Major fault is a rotatory normal fault. The theoretical pivotal point is 8,000 feet to the north at a depth of around 8,600 feet below the surface. This gives the fault a throw of about 275 feet and a displacement of 350 feet. The variable heaves caused by rotatory faulting of structures of varying dips are again well illustrated by this fault.

The pivotal points of all the transverse faults are found to the north of the ore zone, some being below the surface and some above. In addition to the main faults described, there are numerous strike and transverse faults of smaller magnitude. One effect of the total movement by the various faults can be seen on sections Nos. 20 and 20a, sheet N, where the present 7,200-foot level is at a horizon 750 feet below its position before faulting. Also the last period of faulting, in which the area was under tension in an east-west direction, produced a stretching of the length of the ore zone, east from the Lake Shore fault, of about 20 per cent.

Statistics

The annual and total value of bullion produced and tonnage milled by the Wright-Hargreaves mine from the commencement of production to the end of 1947 are given in Table 3 (facing page 60). The yearly and total output of gold and silver in ounces, the average gold-silver ratio, and the average fineness of the bullion are shown in Table 4 (facing page 60). The yearly and total dividends paid are given in Table 1 (page 59).

A detailed yearly analysis of production, recovery, costs, profits, ore developments, and ore reserves over the 10-year period ending August 31, 1947, covering conditions of peace and war, is given in Table 10 (page 175). This information is taken from the annual reports of the company.

CHAPTER IX

Geology of the Sylvanite Mine

By C. G. MacIntosh¹ and Jas. E. Thomson

History and Development

The property of Sylvanite Gold Mines, Limited, is situated in the eastern part of the Kirkland Lake camp. It consists of five mining claims, totalling 228 acres, which lie north and east of the Wright-Hargreaves property and west of the Toburn property.

A considerable amount of surface work was done in the early days without any very encouraging results. The company was organized in 1913, and the success attained on neighbouring properties led to underground development. The shaft had attained a depth of 1,500 feet and a considerable amount of ore had been developed on various levels down to this horizon before 1927, when a 200-ton mill was built and commenced operations.²

The mill capacity was increased to 600 tons daily in 1940, but during the latter part of the Second World War the milling rate was curtailed. In 1946 and 1947, the output was increased as shown in Table 11 (page 182).

The mine workings are shown diagrammatically on sheet B (in map case). There are five shafts on the property; of these Nos. 2 and 4 are the main openings from surface. No. 2, the main production shaft, is located on claim L. 2,100. It contains three compartments, extends to a depth of 3,642 feet, and services 28 levels. No. 4 shaft is in the southeast corner of claim L. 11,398 and goes to a depth of 1,762 feet. No. 5 shaft starts at the 3,150-foot level, where it is connected with No. 2 shaft, and goes to the bottom of the present workings at a depth of 5,550 feet. It provides for the opening of 16 levels, some of which are now (1948) under development.

General Geology

The surface geology of the property is shown on map No. 1945-1, and the rock formations encountered to a depth of 4,950 feet are indicated on the composite level plans and mine sections (in map case).

On surface the southern part of the property is occupied by part of the main syenite porphyry stock, and to the north there is a complex mixture of sediments and intrusives that flank the main intrusive body. A band of tuffs lies north of the sediments. The northern intrusives consist of syenite porphyry and augite syenite (lamprophyre), both of which occur in the form of dikes that trend about parallel with the long axis of the main porphyry stock. The sediments consist of greywacke and pebble and boulder conglomerate.

In the upper part of the mine, the workings are largely in syenite porphyry. As depth is attained, however, the southerly dip of the porphyry stock brings more of the flanking sediments into the workings. The band of tuffs lying north of the sediments has been traced by drilling from the 2,500-foot level to the bottom of the present workings. The sediments and tuff dip to the south at an angle of about 60 degrees. The sediments to the south of the main syenite porphyry body have been encountered in drilling beneath No. 5 strike fault on the 3,600-foot level.

¹Geologist, Sylvanite Gold Mines, Limited.

²E. W. Todd, *Ont. Dept. Mines, Vol. XXXVII, 1928, pt. 2, p. 134.*

Pre-Ore Structure

The pre-ore fault and fracture pattern extends over widths up to 1,500 feet on the Sylvanite property. As indicated by the cross-sections (sheet Q), there are a large number of fractures. Some of these dip steeply to the south; others are inclined at flatter angles.

The strongest and most continuous break in the mine is the zone of maximum displacement of the Kirkland Lake fault, which extends across the southern part of the mine. It lies south of No. 2 shaft below the 500-foot level and dips south down to the 3,000-foot level. Below the 3,000-foot level, the dip swings to the north and the Kirkland Lake fault joins No. 5 strike fault. The actual relationship of these two faults is as yet obscure, but it is possible that some of the post-ore movement on No. 5 strike fault may have continued upward along the pre-ore structure. The Kirkland Lake fault ranges in width from a thin mud seam with a few inches of alteration to a 15-foot width of mylonite, in which several mud seams occur. On the Sylvanite property the pre-ore displacement on the Kirkland Lake fault cannot be measured because the break lies entirely within the syenite porphyry body.

Closely associated with the main zone of displacement of the Kirkland Lake fault are steeply dipping subsidiary structures, which either branch from or lie parallel to the Main break. These structures generally appear weaker than the Main break and contain an inch or less of chloritic gouge and calcite; some also contain a few inches of mylonite. There is some evidence of post-ore faulting along these structures as well as along the Main break.

North of the South vein zone, the three most important steeply dipping fractures or fracture systems are called the North vein, the North A vein, and the North B vein. On the upper horizons each of these systems is composed of roughly parallel, discontinuous, and sometimes overlapping structures, as illustrated on sheet Q. As depth is attained, however, there is some evidence that the fractures tend to be more continuous; this is most apparent in the workings below No. 2 strike fault.

The North vein structure is the easterly continuation of the Wright-Hargreaves North vein and has been followed from surface to the 3,150-foot level. It dips to the south and east and rakes irregularly to the west from the Toburn boundary on the 800-foot level to No. 2 shaft on the 3,000-foot level.

The North A vein structure has been followed intermittently from a point near surface to the 3,600-foot level, and on the 1,000-foot level it has been developed over approximately 3,000 feet on strike.

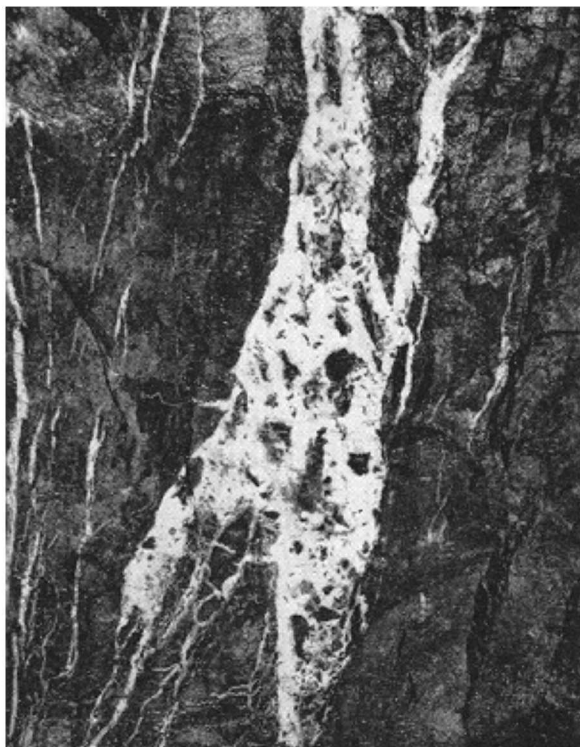
The North B vein has been followed from the 2,250-foot level to the 3,150-foot level. Below No. 2 strike fault, where it apparently merges with the North A vein to the west, it has been followed from the 4,350-foot level to the 5,400-foot level. There has been very little work on this structure above the 2,250-foot level.

In addition to the steep breaks, there are a series of flatter or inclined fractures. They lie between the upright structures and sometimes branch from them.

Wall-Rock Alteration

Where the veins or breaks occur in the porphyry they are bounded by a zone of altered rock, which may show a reddish or greenish discoloration. The reddish alteration is caused by the development of a finely divided reddish "dust," probably ferric oxide. This is adjacent to innumerable fractures of microscopic size that cut both the phenocrysts and the groundmass of the porphyry. The tiny fractures are generally filled with quartz and crystalline carbonate.

Mylonite is developed along the Kirkland Lake fault and some of the associated parallel breaks. It occasionally occurs on some of the inclined structures and on the North A vein in the upper part of the mine. At some points the mylonite forms a narrow band adjacent to a slip and has a well-defined boundary, resembling a dike in appearance. Microscopic examination, however, shows that this is only a much altered syenite porphyry in which the feldspars have been sliced and granulated. Carbonate, sericite, chlorite, and leucoxene have been developed along tiny fractures, thus giving the rock a bleached or buff-coloured



High-grade vein exposed on the back of No. 4508 drift, Sylvanite mine, showing conglomerate on the left and syenite porphyry on the right.

appearance. Chlorite seams up to 3 inches in width occur within the zone of alteration and may represent the zones of post-ore movement.

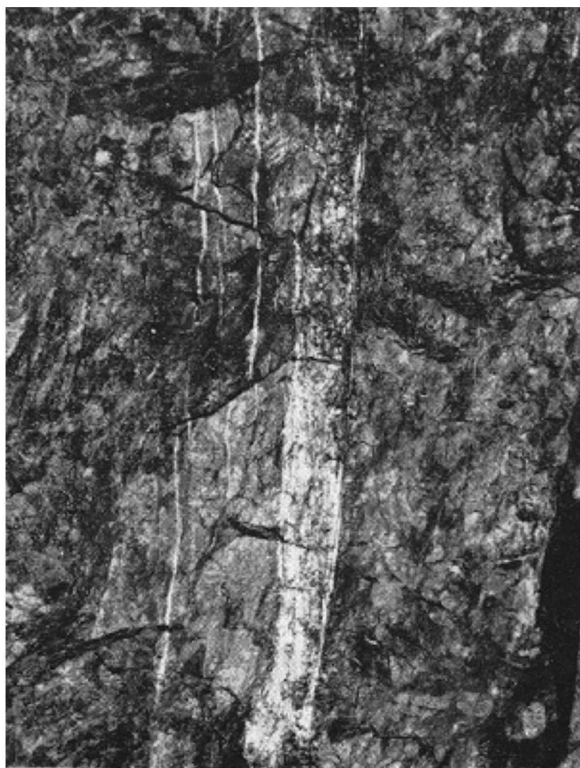
Where the veins or breaks occur in greywacke or conglomerate, alteration is shown by a brownish, reddish-brown, or greenish discoloration of the sediment for several inches on either side of the vein or fracture. Microscopic examination shows that granulation and carbonatization are generally weak or absent in this host rock. The vein fracture is filled with chlorite, sericite, quartz, and carbonate. In all veins, varying degrees of silicification show in the wall rock or rock fragments adjacent to the quartz.

Veins and Mineralization

The veins in the Sylvanite mine follow the fault and fracture patterns that have been described. They vary in type and may be classified as follows:

- (1) quartz-filled fissures or breaks, usually containing some brecciated wall rock;
- (2) quartz-filled fissures accompanied by subsidiary veinlets or stringers; and
- (3) brecciated zones with irregular masses and stringers of quartz, and angular inclusions of wall rock.

The fissure veins are the commonest type and are the source of most of the ore. The breccia zones are found along the Kirkland Lake fault and adjacent structures and occur near the junctions of breaks or between closely spaced parallel breaks.



High-grade vein in pebble conglomerate, exposed on the back of No. 4308 west drift, Sylvanite mine. The main quartz vein is about 6 inches in width and greatly fractured.

The vein matter consists of quartz with associated altered and mineralized wall rock. Different generations of quartz ranging from dark, glassy to white varieties may be intermingled in the same vein. The quartz constitutes a relatively small percentage of the broken ore but carries most of the gold content.

The chief metallic constituent of the vein is pyrite. It is disseminated throughout the quartz and wall rock. Most of the productive veins have one or more thin, smooth slips containing molybdenite. Other sulphides are scarce. Visible gold and tellurides are distributed along slips and fractures in the quartz and can usually be observed in stope or development faces that assay above average mine grade.

Narrow bands of calcite, glassy quartz, and chlorite are frequently present along the planes of post-ore movement.

Ore Bodies

The accompanying plans and sections show the distribution of some of the ore bodies in the mine. They indicate that the ore shoots are not continuous over great distances, but are a series of bodies having irregular outlines. Some ore shoots up to 900 feet in maximum dimension have been mined, but most of them are smaller. The average stoping width for the mine is about 5 feet, although abnormal widths of from 20 to 25 feet have been mined along the Kirkland Lake fault.

Post-Ore Faults

There are several post-ore strike faults in the Sylvanite mine, the most important of which are No. 2 and No. 5. The apparent displacement along No. 2 strike fault in the vicinity of the North vein is about 350 feet, but at the Kirkland Lake fault the apparent displacement is reduced to about 50 feet. This discrepancy may be explained by assuming that some of the post-ore movement was taken up along the plane of the Kirkland Lake fault and other parallel structures. Little information is available to date about the movement on No. 5 strike fault. Where observed in the Sylvanite mine, No. 5 strike fault exhibits the same type and amount of alteration as the Kirkland Lake fault, whereas No. 2 fault shows lesser amounts at certain places. If wall-rock alteration can be accepted as a criterion for the age determination of faults, it follows that these fault planes must have existed as pre-ore structures. Other post-ore strike faults displace the veins anywhere up to 50 feet. The general direction of movement along this set of faults is north side up.

Cross faults, the most important of which are known as the K and Sylvanite, displace the strike faults. The fault planes contain a few inches of gouge. These structures extend through the Wright-Hargreaves property and are described by Hopkins elsewhere in this volume.¹

Structural Control of Ore Bodies

In the Sylvanite mine, veins are found in all of the rock formations within the fractured zone. On the upper horizons the veins occur in syenite porphyry and greywacke. In the northern part of the mine, where these rocks are intermingled, the veins pass from one rock type into another without any apparent change in strength, though there may be some offsetting or deviation near the contact. On the lower levels, most of the development is in conglomerate, but on some levels fractures have been followed to the east into tuff. The above observations indicate that, although the different rock types may have had a modifying influence on the location, attitude, or detailed character of the veins, they are not a primary factor in the formation of the structural pattern.

The Kirkland Lake fault and subsidiary structures characterized by the presence of mylonite are regarded as the strongest structures. A series of recurrent movements along these have produced the main ore channelways.

On the upper levels, the strike of the Kirkland Lake fault deviates to the south going east, for a distance of approximately 700 feet, about midway across the property. It seems probable that the vein-fractures in the South vein zone are the result of stresses induced in the vicinity of this warp by movement along the plane of the main fault.

Below the 3,000-foot level the Kirkland Lake fault deviates to the north and joins No. 5 strike fault; to date, there is not much information on the pre-ore

¹Page 174.

TABLE 11—SYLVANITE MINE STATISTICS, 1938-1947¹

	April 1, 1937, to March 31, 1938	April 1, 1938, to March 31, 1939	April 1, 1939, to March 31, 1940	1941	1942	1943	1944	1945	1946	1947
Tons milled.....	178,462	193,044	204,119	197,293	175,745	148,190	137,822	114,227	154,582	151,140
Tons milled daily.....	.....	.....	.....	540	481	406	377	313	423	414
Recovery (ounces per ton).....	0.36	0.35	0.33	0.34	0.30	0.35	0.32	0.33	0.30	0.27
Value of bullion re- covered.....	\$2,255,381	\$2,409,670	\$2,561,331	\$2,589,635	\$2,021,506	\$2,025,005	\$1,722,241	\$1,452,360	\$1,693,581	\$1,450,334
Operating costs per ton milled.....	\$6.06	\$5.87	\$5.81	\$6.38	\$6.38	\$6.74	\$7.16	\$7.55	\$7.27	\$7.90
Yearly operating profit.....	\$1,207,627	\$1,299,783	\$1,375,291	\$1,230,139	\$900,669	\$1,026,460	\$735,325	\$589,382	\$570,255	\$280,204
Net yearly profit.....	\$1,021,416	\$1,061,229	\$1,090,223	\$883,803	\$596,923	\$550,187	\$385,550	\$359,275	\$373,650	\$209,850
Dividends paid.....	\$824,875	\$824,875	\$824,875	\$923,860	\$593,910	\$395,940	\$395,940	\$395,940	\$395,940	\$263,960

¹The fiscal period, April 1 to December 31, 1940, has been omitted because, owing to the change in the fiscal year, it constituted only 9 months.²After deducting depreciation.

structure below this junction. Although the extent of the deviation of the Kirkland Lake fault may be uncertain, an upward thrust of the rock mass to the south of the Kirkland Lake fault would tend to produce the steep structures to the north and flatter tensional fractures between the steeper breaks (see section No. 22, Fig. 7, facing page 82).

Statistics

The annual and total value of bullion produced and tonnage milled by the Sylvanite mine since the commencement of production in 1927 to the end of 1947 are given in Table 3 (facing page 60). The annual and total output of gold and silver in ounces, the average gold-silver ratio, and the average fineness of the bullion are shown in Table 4 (facing page 60). The yearly and total dividends paid are given in Table 1 (page 59).

A detailed yearly analysis of production, recovery, costs, profits, ore developments, and ore reserves over the 10-year period ending December 31, 1947, covering conditions of peace and war, is given in Table 11 (page 182). This information is taken from the annual reports of the company.

CHAPTER X

Geology of the Toburn Mine

By S. P. Ogrizlo¹ and Jas. E. Thomson

History and Development

Toburn Gold Mines, Limited, was incorporated in 1931 as a subsidiary of the Premier Gold Mining Company, Limited. It acquired the Tough-Oakes Burnside property, which was located at the east end of the Kirkland Lake camp, adjoining the property of Sylvanite Gold Mines, Limited. The property consists of 10 claims covering 343 acres in Teck and Lebel townships. The American Smelting and Refining Company manages the mine.

The Tough-Oakes Burnside was the first producing mine in the Kirkland Lake camp. Rich surface discoveries of gold were made on the Tough-Oakes claims in 1912. These claims were later amalgamated with the Burnside property to the south. An account of the early development of the mine is given by Burrows and Hopkins² and Todd.³ Production by the Tough-Oakes Burnside mine prior to the incorporation of Toburn Gold Mines, Limited, amounted to \$2,909,597 from 290,477 tons milled. The Toburn mine commenced production in 1932 with a 100-ton mill and later increased the capacity to 165-170 tons daily.

The company holds an interest in Continental Kirkland Mines, Limited, Federal Kirkland Mining Company, Limited, and Kirkland Combined Mines, Limited, all of which adjoin the Toburn property on the east and north.

There are 4 shafts on the property, the main opening being No. 3, which extends to a depth of 1,090 feet; a subshaft extends from the 1,090-foot level to the 2,475-foot level. As shown diagrammatically on sheet B (in map case), these service 21 levels. Long crosscuts have been driven north into the Federal Kirkland claims on the 1,090- and 2,475-foot levels. On the A 400-foot level a long drive extends to within 300 feet of the Continental Kirkland boundary and passes near the southwest corner of claim L. 2,378 in Lebel township.

General Geology

The surface geology of the Toburn property is indicated on the maps of Teck (No. 1945-1) and Lebel townships.⁴ The level plans on sheet C and S and sections Nos. 25 and 26 on sheet R show the rock types in the underground workings. The property covers the east end of the main syenite porphyry stock of the Kirkland Lake camp. This body extends eastward from the Sylvanite boundary through the upper part of the mine workings for about 900 feet. It then fingers out into a number of narrower dike-like masses in the sediments. Narrow dikes of syenite porphyry also occur to the north and south of the main porphyry mass. As shown on Fig. 5 (page 79), the main porphyry body plunges steeply westward.

¹Geologist, Toburn Gold Mines, Limited.

²A. G. Burrows and P. E. Hopkins, *Ont. Dept. Mines, Vol. XXXII, 1923, pt. 4, pp. 2-4, 26-28, 42-46, 68.*

³E. W. Todd, *Ont. Dept. Mines, Vol. XXXVII, 1928, pt. 2, pp. 141-147.*

⁴*Ont. Dept. Mines, map No. 53a.*

Adjacent to the porphyry the rocks are sediments and tuffs, the latter predominating at the east end. The sediments consist of interbedded greywacke and conglomerate; greywacke is found in the southern part and changes over into coarse boulder conglomerate to the north. A narrow band of tuffs, which is in contact with conglomerate on the south and intruded by augite syenite on the north, occurs in the northern part of the mine workings and has been intersected in the long crosscuts to the north and in drill-holes. This band dips about 60° S. Another tuff horizon, 900 feet south of the above, is found in the northeastern part of the mine workings on the 2,475-foot level. This is probably the downward extension of the tuffs found on the surface in the eastern part of the property. If this is so, these tuffs are pitching steeply westward beneath the porphyry body. Throughout the property the tuffs are fine-grained, thinly bedded rocks, conformable with the sediments.

An augite syenite (basic syenite) body occurs as a long, narrow dike striking about N. 55° E. across the central part of the mine workings. Other bodies outcrop on claim L. 2,376; their probable downward extension is found on the 1,090- and 2,475-foot levels in the long north crosscuts into Federal Kirkland ground. On the 2,475-foot level a third body has been intersected in the northeastern part of the mine workings.

Quartz-feldspar porphyry outcrops in the extreme northwestern corner of claim L. 2,376 and is found underground in the 1,090- and 2,475-foot level crosscuts into the Federal Kirkland claims. This variety of porphyry is an easterly continuation of a body that extends across the northern part of the camp from the Kirkland Basin property. Another dike-like body of quartz-feldspar porphyry, approximately 150 feet wide, occurs on the 400-foot level on claim L. 2,378, Lebel township, and trends about N. 50° E. It is also found on the 2,475-foot level in the northeastern part of the mine workings.

A few minette dikes, with a maximum width of 30 feet, occur in the northwest corner of the property. A diabase dike about 8 feet wide strikes in a north-south direction through the mine workings and dips about 83° W.

Structure

A fracture system, about 1,500 feet in maximum width, extends slightly north of east across the western part of the property. As shown by the mine sections (sheet R), this fracture system has a general southerly dip, but individual breaks may range from a vertical to an almost horizontal position.

The most persistent break lies near the south side of the fracture system and is the easterly continuation of the main branch of the Kirkland Lake fault from the Wright-Hargreaves and Sylvanite mines. It is locally called the South vein. The displacement on the fault is approximately 350 feet near the Sylvanite boundary. This is measured by the offset of the porphyry-greywacke contact in longitudinal section as shown in Fig. 5 (page 79). The south or hanging-wall side of the fault has been thrust upward, and the movement appears to be largely vertical. The post-diabase movement on the fault is very small and amounts to only 8 feet where it can be measured on two narrow dikes on the A 400- and 893-foot levels. This appears to be mostly horizontal movement.

The North Branch vein lies 200 feet north of the South vein in the western part of the mine and shows a divergence of about 20° E. A few feet of pre-ore displacement is found on the North Branch vein where it displaces a porphyry-sediments contact. There is no measurable pre-ore movement along any other veins in the mine. The vein-fractures in the sediments are generally narrower and better-defined than those in the porphyry.

Veins and Mineralization

The veins lie along the planes of the fault and fracture system described above. They may occupy a single fracture or occur as a series of parallel, branching, or interlocking veinlets; sometimes a vein breccia with inclusions of altered wall rock in the quartz is formed. The main vein filling is quartz. It is accompanied by a small percentage of carbonate and some disseminated sulphides. The chief metallic mineral is pyrite; chalcopyrite, sphalerite, and molybdenite occur in lesser amounts. Native gold and tellurides occur together along fractures in the quartz and are of common occurrence in the veins. The veins occur in syenite porphyry, conglomerate and greywacke, tuff, and augite syenite, although no ore has been found to date in the last-named rock. About half the ore milled has come from veins in the porphyry, and the other half from veins in the sediments.

Wall-Rock Alteration

The pre-ore faults and fractures show the typical wall-rock alteration of the Kirkland Lake camp. Mylonite, brecciation, and mud seams are found along the South vein, the North Branch vein, and the Murdock Creek fault. The mud seams range in width from a mere crack to more than a foot in width, depending upon the strength of the structure. Other vein fractures show a smaller amount of brecciation and alteration, although the entire porphyry body for a distance of about 600 feet north of the South vein generally shows a reddish discoloration.

The zones of alteration along veins in the sediments are usually narrow and generally extend less than one foot from the vein fracture. They are always pale-green in colour in contrast to the reddish- and buff-coloured alteration in the porphyry.

Ore Bodies

The general distribution of ore bodies in the Toburn mine is indicated on the plans and sections. The ore shoots are numerous but generally small, although some show a continuous length up to a maximum of 600 feet. Mining widths range from a minimum of 3 feet to a maximum of 30 feet where several closely spaced veins are mined together. The actual widths of the veins in which nearly all the gold values are concentrated are generally less than 8 inches. The dip of the ore shoots ranges from vertical to almost horizontal. The ore bodies in the porphyry are generally wider than those in the sediments.

Post-Ore Faulting

The relative displacement on the larger post-ore strike faults is best shown by the cross-sections (sheet R). These strike about parallel to the veins and generally dip to the north at angles that range from 30 degrees to vertical. They displace the ore bodies anywhere from a few feet to a maximum of 90 feet, the movement being mostly vertical.

The two main cross faults are known as the Dike fault and the O'Connell Lake fault. The Dike fault follows the diabase dike and is marked by one or more planes of movement accompanied by much gouge. It dips 83° W. and has a general north-south strike. The average displacement on the Dike fault is about 350 feet; the east side has moved vertically upward. The O'Connell Lake fault is exposed on three levels in the eastern part of the mine but is too far eastward to displace any known ore bodies. Little is known about No. 2 strike fault. The Murdock Creek fault has been cut only in drilling.

TABLE 12—TOBURN MINE STATISTICS, 1938-1947

	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
Tons milled.....	52,434	55,272	59,524	60,715	43,635	40,905	39,940	41,655	40,753	41,849
Value of bullion re- covered.....	\$1,098,563	\$1,210,824	\$1,281,837	\$1,083,456	\$722,088	\$602,397	\$487,544	\$482,988	\$478,633	\$508,147
Recovery per ton.....	\$20.95	\$21.91	\$21.54	\$17.84	\$16.55	\$14.72	\$12.21	\$11.59	\$11.74	\$12.14
Operating costs per ton treated.....	\$10.25	\$10.42	\$10.48	\$9.60	\$11.03	\$11.11	\$10.44	\$10.76	\$10.81	\$11.36
Operating profit.....	\$548,996	\$640,769	\$658,564	\$512,361	\$247,746	\$168,581	\$69,661	\$62,929	\$37,446	\$30,429
Net profit.....	\$429,673	\$361,352	\$414,576	\$309,064	\$149,645	\$89,838	\$29,607	\$22,998	\$14,156	\$14,109
Estimated ore reserves (tons).....	149,050	149,100	145,900	114,325	93,400	83,200	77,600	72,600	62,925	68,000
Estimated grade of ore reserves (ounces per ton).....	0.58	0.56	0.56	0.53	0.53	0.55	0.51	0.525	0.52	0.50
Dividends paid.....	\$259,000	\$296,000	\$370,000	\$333,000	\$240,500	\$92,500	\$55,500	\$55,500	\$37,000	.....

Structural Control of Ore Bodies

The Toburn mine lies at the east end of the Kirkland Lake vein-fault and vein fracture system. In passing eastward through the main syenite porphyry stock the displacement on the various branches of the Kirkland Lake fault either decreases or dies out completely. In the case of the North vein of the camp, the fault displacement dies out on Wright-Hargreaves ground, but the general zone of fracturing continues eastward across the Sylvanite and into the Toburn property. The North vein and No. 11 vein of the Toburn mine together with the flatter hanging-wall veins form a pattern similar to the vein system in the west end of the camp.

The main south branch of the Kirkland Lake fault system is the strongest and most persistent structure in the Toburn mine. It does not contain much ore, however, although to the west on Sylvanite and Wright-Hargreaves ground, it has been a more productive structure. It is probable that the movements on this fault plus the fracturing off the end of the main North vein fault have produced the fracture pattern of the Toburn mine. The upward movement of the south side with respect to the north would produce a series of tensional fractures with a somewhat flatter dip than the main breaks (see section No. 25, Fig. 7, facing page 82).

Statistics

The annual and total value of bullion produced and tonnage milled by the Toburn mine from the commencement of production in 1913 to the end of 1947 are given in Table 3 (facing page 60). The annual and total output of gold and silver in ounces, the average gold-silver ratio, and the average fineness of the bullion are shown in Table 4 (facing page 60). The yearly and total dividends paid are given in Table 1 (page 59).

A detailed yearly analysis of production, recovery, costs, profits, ore developments, and ore reserves over the 10-year period ending December 31, 1947, covering conditions of war and peace, is given in Table 12 (page 187). This information is taken from the annual reports of the company.

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