THE TIMISKAMING SERIES OF THE KIRKLAND LAKE AREA

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Abstract

This paper presents a study of the stratigraphy, sedimentation and structure of the Timiskaming Series of the Kirkland Lake area, northeastern Ontario. It is suggested that this section be defined as the type section for the Timiskaming Series in Ontario. Interpretations of the geologic history of the epoch, the nature of the provenance area supplying sediments and the character and environment of deposition of the sediments are given.

The sediments south of the major Larder Lake break are tentatively correlated with the sediments in the belt to the north of the break as Timiskaming in age, on the basis of detailed structural studies in Skead and Hearst townships. Evidence in Ontario and Quebec shows conclusively that the Keewatin and Timiskaming series of the Kirkland-Larder-Noranda area are separated by a major structural unconformity.

Examination of the Timiskaming rocks discloses that the provenance area was composed of basic volcanics and intrusives, rhyolites and acid porphyries of great variety, minor amounts of chert, iron formation, jasper and slaty greywackes, and rare syenite, granite and gneiss. Disintegration of the rocks of the area was largely mechanical. The Timiskaming sedimentation represents a distinctive magna facies of eugeosynclinal environment.

Introduction

The Timiskaming rocks of the Kirkland Lake-Larder Lake area form a belt extending for 36 miles in length, from Eby township on the west, through the townships of Grenfell, Teck, Lebel, Gauthier, McVittie and McGarry, to the Quebec boundary on the east. To the west, in Eby township, the Timiskaming Series pass underneath the Cobalt Series; to the east, the sediments again pass beneath the Cobalt sediments near Cheminis Station on the Quebec boundary. The maximum width of the Timiskaming belt north of the Larder Lake fault is about 16,000 feet, in Lebel township. South of the Larder Lake fault, which is a major thrust fault extending east-west across the area, Timiskaming sediments are found in the townships of Boston, McElroy, Hearst, McFadden and Skead for a distance of 8 miles south from the fault zone.

These sedimentary rocks extend eastward into Quebec and appear from beneath the Cobalt cover in Beauchastel and Rouyn townships.

Historical Review

Geological work in the Kirkland Lake-Noranda area began with a long period of reconnaissance. The volcanics and sediments of the area were grouped together by the early workers, Miller (1902), Parks (1904), Brock (1907), Wilson (1907) and Bowen (1908), and correlated with the Keewatin series described in 1885 by Lawson in the Lake of the Woods area. Thus the name "Keewatin" came into use very early in this part of Ontario and has persisted to this day.

On M. E. Wilson's map of the "Larder Lake and Opasatika Lake Area" (map 32A, 1912). The volcanics and sediments of the Larder Lake area are grouped as Keewatin in age. During this mapping, done in 1908 and 1909, Wilson established his Pontiac group, to describe a series of biotite gneisses, biotite schists and quartz schists occurring in Quebec in the Lake Opasatika Area. The volcanics of Dasserat and Boischastel townships were classed as Keewatin in age. The relations of the Pontiac group to the Keewatin series were unknown at this time. Both the Keewatin and Pontiac were regarded as pre-Laurentian, since the granites to the south intruded both. This granite was later termed "Algoman."

During his work in the adjacent Kewagama area in 1910 and 1911, Wilson (1913) introduced the term Abitibi group (Memoir 39), to replace the term "Keewatin" on the very good grounds that correlation of these volcanics with those of the Lake of the Woods area was uncertain. In this memoir he places his "Pontiac series" as part of the "Abitibi group." The terms "Pontiac" and "Abitibi" have not been used in Ontario.

In 1911 Willet G. Miller, provincial geologist of Ontario, recognized an older pre-Cobalt series of sediments containing pebbles and boulders of Keewatin rocks at Kirk and Cross Lake in the Cobalt area. These he named the "Timiskaming Series." Very rapidly then correlations were made throughout northeastern Ontario, and in an appendix to his report of 1914 on southeastern Ontario, Miller correlated the sediments of the Kirkland Lake and Larder Lake areas with the Timiskaming series. At the same time he also grouped the sediments at Porcupine, the Doré series, the Sudbury series and the sediments of northwestern Quebec as Timiskaming in age. By this time he had already recognized two ages of granite in the Archean, and he adopted Lawson's term "Algoman" to apply to the younger post-Timiskaming, pre-Cobalt granite, retaining the term Laurentian for the pre-Timiskaming granite which supplied its pebbles to the Timiskaming conglomerates.

Miller's simple twofold classification of the Archean into a predominantly volcanic series, the Keewatin, overlain by a predominantly sedimentary series, the Timiskaming, has persisted to this day as the standard nomenclature used by the Ontario Department of Mines in northeastern Ontario.

In Memoir 103, Wilson (1918) accepts the term Timiskaming for the sediments of the Kirkland Lake-Larder Lake area. In 1919 and 1920

H. C. Cooke, working for the Geological Survey of Canada in the Kirkland Lake-Larder Lake area, correlated all the sediments as Timiskaming in age, and extended his correlation eastward into Quebec, correlating the Pontiac series of Quebec with the Timiskaming series of the Larder Lake area. In 1922 he carried his field work into Quebec and in his report on the Opasatika map area he confirms his correlation of the sediments, previously mapped as Pontiac by Wilson, as Timiskaming in age. Cooke's later work in the area led to the publication of Memoir 166 in 1931, and the term "Timiskaming" was applied to a broad belt of sediments stretching from Lake Opasatika to the Dubuisson and Bourlamaque area 80 miles east. He also used the term "Keewatin" for the lavas rather than "Abitibi."

About 1930 a period of geological work began in which structural studies became of increasing importance in unravelling the stratigraphy of the Archean.

From 1934 to 1939 Gunning and Ambrose were mapping the Joannes-Bousquet-Cadillac-Malartic area along the sedimentary belt to the east of Rouyn. Their work resulted in a four-fold classification for the sediments and volcanics: Cadillac sediments, Blake River volcanics, Kewagama sediments, and Malartic volcanics. The old two-fold Keewatin-Timiskaming classification was discarded and a controversy began over the status of the Keewatin and Timiskaming. Gunning & Ambrose (1939) state that "instead of there being just one great period of volcanism followed by a period of sedimentation, there are two great periods of volcanism separated by a period sufficiently long to permit the deposition of a two-mile thickness of sediments. A younger sedimentary group also occurs." They also note that there is structural conformity and apparent gradational passage from volcanism to sedimentation to volcanism and back to sedimentation.

Shortly after this J. E. Thomson (1941, p. 20) completed detailed mapping of McVittie and McGarry townships in the Larder Lake area and he states that "no evidence of a structural unconformity was found at any place along the Timiskaming-Keewatin boundary." The Keewatin lavas and Timiskaming sediments both face south in these townships.

About this time at the east end of the belt, in Dubuisson, Bourlamaque and Louvicourt townships, G. W. H. Norman had been mapping the continuation of Gunning's area to the east. In 1942 Norman published a paper citing field evidence that the Malartic volcanics may be equivalent to the Blake River group, and the Kewagama sediments equivalent to the Cadillac group, repeated by faulting. He suggests that the old two fold division may hold true.

However, in other areas of the Archean further detailed field work was being done on the structure of the Archean, and geologists were able to build up the stratigraphic section on structural evidence. It was found that the old two fold division into Timiskaming sediments and Keewatin volcanics (based on lithology alone) would not hold. Thick sedimentary groups were found interbedded in the Keewatin volcanic series, and it became apparent that the Keewatin was much more complex than heretofore believed. In the Timmins area for example, M. E. Hurst (1936) showed that there was a thick series of greywackes in the Keewatin series. The Timiskaming sediments of this area overlie the Keewatin volcanics and sediments with angular unconformity and Evans (1944, p. 1123) points out that a thickness of 8,000 feet of Keewatin rocks was eroded before the deposition of the Timiskaming conglomerate.

In 1943 M. E. Wilson published the results of his detailed mapping in Rouyn and Beauchastel townships south of Noranda. On the north side of the Bouzan Lake fault zone a conglomerate which he correlates with Timiskaming rests with unconformity on the Abitibi volcanics. An anticlinal axis occurs in the lavas indicating that a thickness of 3,000 feet of lavas was eroded beneath the Granada (Timiskaming) conglomerate. Wilson traces the Cadillac greywackes into Rouyn township and on the basis of his field work he concludes that the Cadillac group may have three possible relationships (1943, p. 129):

(1) the Cadillac group rests unconformably on the volcanics and belongs wholly to the Timiskaming series; (2) the Cadillac group is composed of two parts—(*a*) greywacke conformable with the volcanics and therefore belonging to the Abitibi series and (*b*) conglomerate and greywacke separated from the greywacke by an unconformity and hence a part of the Timiskaming series; and (3) the Cadillac group, as Gunning and Ambrose concluded, is wholly conformable with the volcanics and belongs entirely to the Abitibi series. Of these three possibilities, the first or second is more probable, for the conglomerate of the groups is very similar to the Granada conglomerate.

In describing the relations of the Pontiac group and the Timiskaming series Wilson (1943, p. 127) has postulated that there is an unconformity at the base of the Granada (Timiskaming) conglomerate. Wilson (1943, p. 127) states that

from one-third to one-half of the pebbles and boulders (in the Granada conglomerate) are greywacke, identical in every respect with the greywacke of the Pontiac group which it overlies. This seems to prove conclusively that an unconformity separates the Timiskaming series from the Pontiac group. The contact of the Granada conglomerate and the greywacke of the Pontiac group, so far as can be determined, is structurally conformable, however.

The presence of greywacke pebbles indicates channeling of a lower greywacke member, but does not necessarily constitute conclusive proof of an unconformity of great magnitude such as the one between the Keewatin and Timiskaming series throughout other parts of the area.

In the meantime J. E. Thomson had been working along the north contact of the Timiskaming sediments with the Keewatin lavas in Teck and Lebel townships, and in 1943 good field evidence of a major structural unconformity between the Keewatin and Timiskaming series was obtained. In 1946 Thomson published the results of this study in a paper entitled "the Keewatin-Timiskaming Unconformity in the Kirkland Lake District." The field evidence of a major structural unconformity is incontrovertible. The structure in the Timiskaming sediments truncates older folding in the Keewatin rocks. The pre-Timiskaming folding was intense enough to overturn Keewatin lavas so that the Timiskaming sediments now rest on the lavas and they face in opposite directions in a back-to-back relationship. Thomson (1946) concludes that

> there is evidence of a very great angular and erosional unconformity between the Keewatin volcanics and the Timiskaming sedimentary-volcanic complex in the Kirkland Lake district. The time interval that elapsed was sufficient for the Keewatin volcanics to be closely folded and greatly denuded before the Timiskaming sedimentation began. The Keewatin-Timiskaming unconformity may be equal in magnitude to that between the Cobalt and pre-Cobalt series.

From 1946 to 1948 mapping was carried out by the Ontario Department of Mines in Hearst, McElroy and Skead townships south of Larder Lake. Here field evidence indicated a major unconformity between the Keewatin and Timiskaming rocks, Hewitt (1949*a*), Thomson (1947), equal in importance and magnitude to that in Teck township.

General Geology

The general geology of the area is shown on the map, Fig. 1. To the north lies a broad belt of Keewatin volcanics whose structure trends east–west. To the south is another area of Keewatin volcanics intruded by the Round Lake batholith and associated stocks of Algoman syenite, granite and porphyry. From west to east the structure of the southern volcanics swings from N.70°W. to north–south paralleling the borders of the Round Lake batholith.

Between these two areas of volcanics is the east–west belt of Timiskaming rocks, chiefly sediments, but with some interbedded trachytes and associated pyroclastics. Many small dikes and stocks of Algoman porphyry cut the Timiskaming.

In Algoman times the area was greatly folded and faulted in a period of mountain building, during which the Algoman granites and syenites were emplaced. Subsequent erosion truncated the folded Archean rocks and the Cobalt series of sediments was laid down with great unconformity on the Archean basement. The Cobalt series was intruded by sills and dikes of Nipissing diabase, but no post-Cobalt granite is recognized in the area. Since Cobalt times the area has been a stable one, affected little by later orogenic activity. The Cobalt series is relatively flat-lying with dips rarely exceeding 20 to 30 degrees.

Keewatin Series

The pre-Timiskaming rocks of the area are largely assigned to the Keewatin, which is predominantly a volcanic series. Basalt and andesite predominate. These lava flows are sometimes massive and structureless. In many cases flows exceed 100 feet in thickness and the central portions of the flows are medium grained diabase or gabbro. Where only isolated outcrops are available it is difficult to distinguish between coarse-grained flows and sills. The basic volcanics may be pillowed, amygdaloidal, or variolitic. Flow top breccias and ropy tops may be present.

Massive and fragmental porphyritic dacite is common in Skead township. Trachyte flows are uncommon in the Keewatin series of this area. Rhyolites and acid fragmental lavas and pyroclastics are common. Porphyritic facies of the rhyolite frequently occur. Tuff and chert are often found in the volcanic series.

In Skead township the writer has described an acid volcanic centre which includes a large group of acid intrusive porphyries of Keewatin age, Hewitt (1949*a*). These are mainly quartz and feldspar porphyries which range from white to pink or greenish in colour. These porphyries were confused in the early days of prospecting with the Algoman porphyries of Teck township. However, field relationships in Skead townships indicate that they are overlain unconformably by the Timiskaming sediments, Hewitt (1949*a*).

Some sediments are present in the Keewatin series. Tuff, tuffaceous sediments, cherty quartzite and iron formation in bands up to 2,000 feet thick are found in the Keewatin series in Boston township, Lawton (1957, p. 8–9). A conglomerate band 300 to 800 feet wide is also described by Lawton.

In Skead township, two thin horizons of pebble conglomerate and greywacke constitute the only non-tuffaceous sedimentary horizons in the Keewatin series. One outcrop of conglomerate has well-rounded pebbles up to 4 inches in diameter. The pebbles include diorite, greenstone, porphyry and tuff or greywacke. A second outcrop shows all these pebble types plus banded black and white chert pebbles.

Some progress has been made in working out the stratigraphic suc-

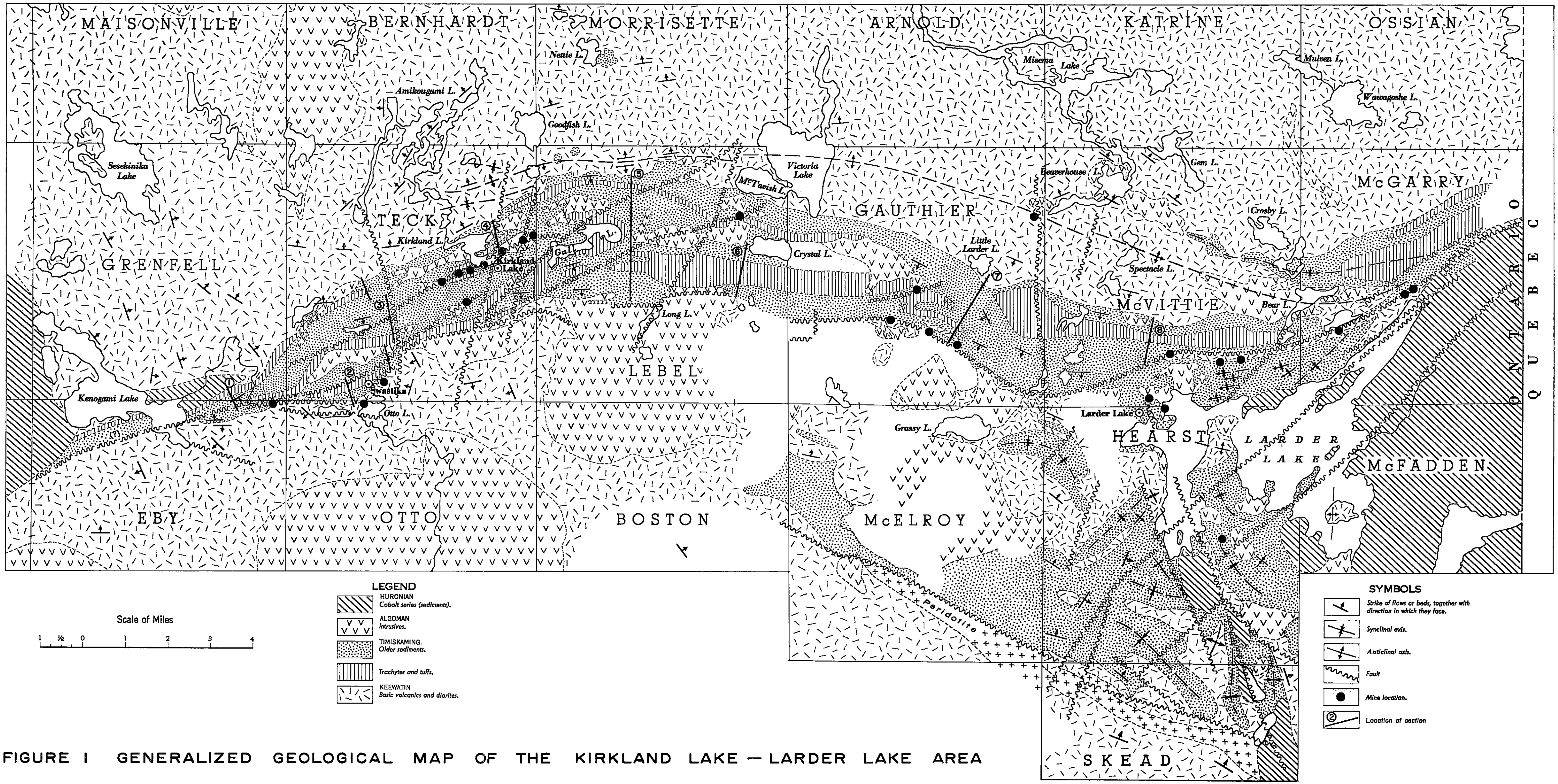

FIGURE I GENERALIZED GEOLOGICAL MAP OF THE KIRKLAND LAKE — LARDER LAKE AREA cession in the Keewatin series. In Skead township the Keewatin section is over 20,000 feet thick and is divided into four formations, Hewitt (1949*a*). These subdivisions can be recognized in McElroy townships, Abraham (1950), and in the Bryce-Robillard area to the south, Moorhouse (1941).

Timiskaming Series Stratigraphy

The Timiskaming series of the Kirkland Lake area is exposed almost continuously for a length of thirty-five miles along strike from north central Eby township just south of Kenogami Lake, where the sediments appear from beneath the Cobalt series, eastward through Teck, Lebel, Gauthier and McVittie townships, to the eastern part of McGarry township, near Cheminis Station, where they are obscured by drift before passing under the Cobalt sediments at the Quebec boundary.

The structure is relatively simple: the Timiskaming series dips vertically and faces south, representing the north limb of a major syncline. At the eastern end of the belt in McVittie and McGarry townships Timiskaming rocks are exposed in the Beaver Lake syncline, separated from the major syncline by an eastward plunging nose of Keewatin rocks, the Kerr Addison anticline. These structures pitch eastward.

The Timiskaming section has its maximum apparent thickness in Lebel township where 16,000 feet are exposed. This is probably not the true thickness. The base of the section throughout the belt is an unconformity, with the Timiskaming resting upon folded Keewatin lavas. There is pronounced non-conformity at the western end, passing into disconformity at the eastern end. The section is cut off on the south by the Larder Lake fault and by later Algoman intrusives.

Throughout the belt the Timiskaming rocks are folded and cut by plugs of Algoman intrusives making the measurement of sections and the tracing of individual members rather difficult.

Sections

A number of typical sections across the Timiskaming series are illustrated in Figure 2 and described in the following:

To correlate these sections with one another the reader is referred to the following 1,000-foot to the inch map sheets published by the Ontario Department of Mines: map 1946–1, Kenogami Lake area; map 1945–1, Teck township; map 53a, Lebel township; map 50c, Gauthier township; map 50b, McVittie township; map 50a, McGarry township.

(1) Kenogami Lake Section. At Kenogami Lake station a section of Timiskaming rocks 3,000 feet thick is poorly exposed. The Keewatin-Timiskaming contact is not exposed west of the Blanche River, but an exposure on the east side of the river shows no faulting at the contact.

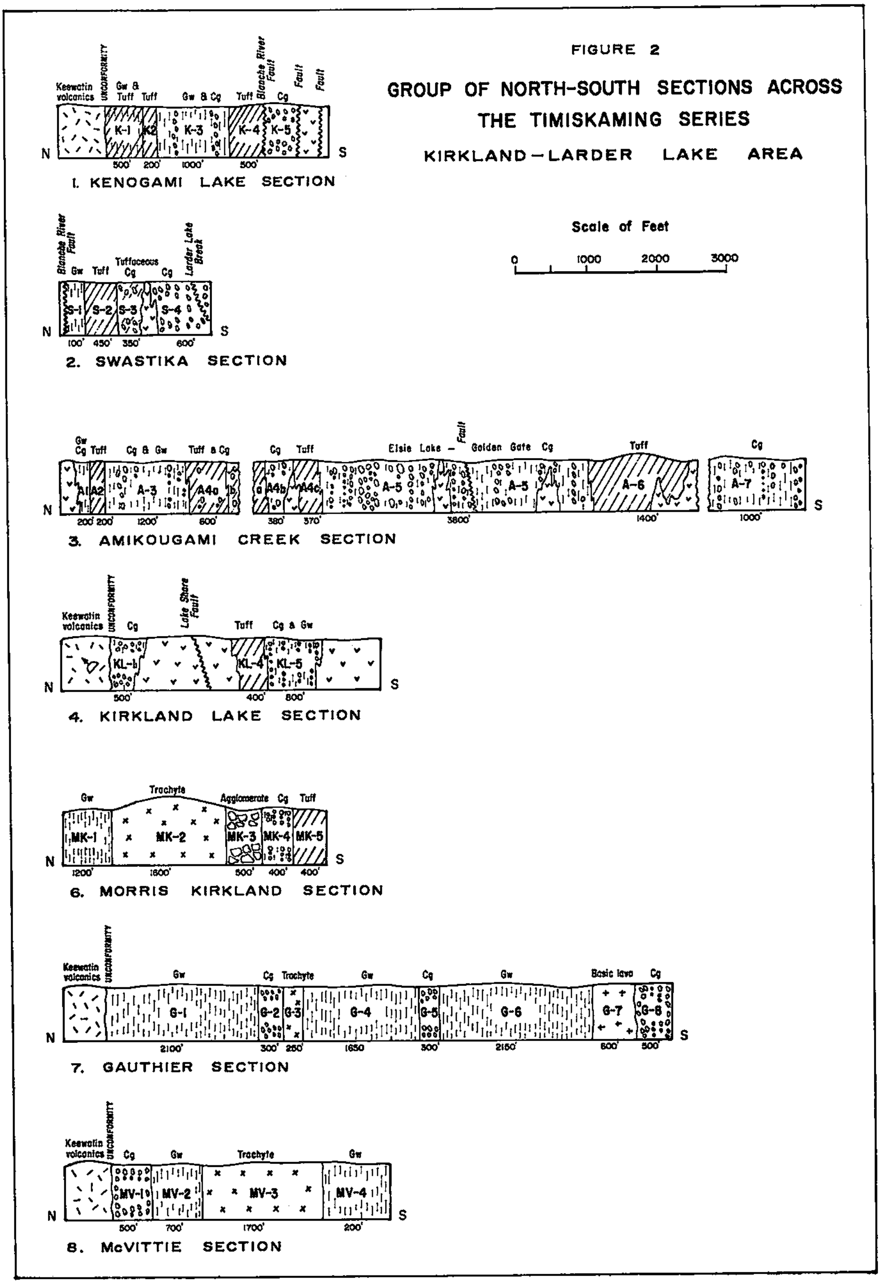
FIGURE 2
GROUP OF NORTH-SOUTH SECTIONS ACROSS THE TIMISKAMING SERIES
KIRKLAND-LARDER LAKE AREA
Scale of Feet
0 1000 2000 3000
1. KENOGAMI LAKE SECTION
2. SWASTIKA SECTION
3. AMIKOUGAMI CREEK SECTION
4. KIRKLAND LAKE SECTION
6. MORRIS KIRKLAND SECTION
7. GAUTHIER SECTION
8. McVITTIE SECTION

FIGURE 2

The basal member, K–1, is an interbedded greywacke and tuff 500 feet thick. K–2 is a dark purple crystal tuff of trachytic composition. K–3 overlying this tuff consists of 1,000 feet of interbedded greywacke and conglomerate. The conglomerate is well sorted; has imbricate structure; the pebbles are well-rounded, of medium to low sphericity, and range in size from 2 to 4 inches in diameter. Pebble types identified are jasper, chert, greenstone, greywacke, trachyte, tuff and white and grey cherty felsite. Granite and porphyry pebbles are absent. The interbedded greywacke is a medium-grained, grey-green well bedded rock. Crossbedding indicates tops south. K–4 consists of 500 feet of bedded tuff cut off to the south by the Blanche River fault, a carbonatized shear zone. The conglomerate member, K–5, exposed on the south side of the shear zone, is poorly sorted. Pebbles range from ½ to 10 inches in diameter and constitute 80 per cent of the rock. Pebble types include syenite porphyry, pink granite, red jasper, basic lava, trachyte, quartz, hornblende porphyry, greywacke and chert. The section is cut off to the south by Algoman intrusives and faulting.

(2) Swastika Section. This section is taken across the strike of the Timiskaming rocks which lie south of the Blanche River fault just west of Swastika village. The base of the section is the Blanche River fault. At the top of the section is a sheared carbonate zone separating the Timiskaming sediments from the Keewatin lavas to the south.

The lowest member, S–1, is a poorly bedded, greenish-black, medium-grained greywacke which is intruded by Algoman porphyry and much altered. This greywacke member grades upwards into well-bedded, dark grey-green, uniform tuffs with good grain gradation. Tops face south. This 450-foot thick member, S–2, thickens rapidly to the east to over 1,400 feet. In this thicker portion of the member the tuff is reddish-green to mauve in colour. Tuffaceous or trachytic fragments up to 8 inches in size occur in this member. Crossbedding is common. This member is a lens of well-sorted, waterlaid pyroclastic material thinning rapidly westward. This tuff grades upwards into S–3, a 350-foot tuffaceous conglomerate member with a dark green sandy matrix. Scattered pebbles make up 20 per cent of the rock. They are 3 inches or less in diameter and the pebble types are as follows: chert and banded tuff, 60 per cent; red jasper; feldspar porphyry, pink felsite, and greywacke. The member is thick bedded. To the west this member grades into well-bedded, fine to medium-grained greywacke, with beds from 6 inches to 2 feet thick. The uppermost member, S–4, is a grey arkosic conglomerate with abundant black, white and banded chert pebbles averaging 2 to 3 inches in size. This conglomerate contrasts with the lower conglomerate, S–3, in that it is light grey in colour rather than dark green, and apparently derived from a source supplying abundant chert and quartz. The lower conglomerate has a more basic tuffaceous matrix.

(3) Amikougami Creek Section. A thick section of over 9,200 feet of interbedded conglomerate, greywacke and tuff is well exposed near Amikougami Creek in central Teck township. The section is much faulted and intruded by Algoman syenite and porphyry. The Keewatin-Timiskaming contact is not exposed at the base of the section on the McIvor property due to intrusion of syenite porphyry, but Thomson (1946, p. 118) has described the unconformity one mile to the west at Perron Lake.

The lowest member, A–1, intruded by syenite porphyry, is a 200-foot, thin-bedded coarse grained grit with interbeds of pebbly conglomerate with pebbles from ½ to

3 inches in diameter in some bands, and 3 to 8 inches in diameter in other bands. Member A–2 is a 200-foot dark grey-black hornblende tuff. It is well bedded with 2-inch to 12-inch beds showing cross-bedding and grain gradation. Interbedded with the tuff are narrow pebble conglomerate beds, some only 6 inches thick, with angular pebbles from ½ to 1 inch in diameter. The pebbles are predominantly trachyte, with a few chert. Member A–3 is a thick conglomerate and greywacke unit 1,200 feet thick. At one outcrop the conglomerate consists of 80 per cent pebbles which average 3 to 4 inches in size, with a 10-inch maximum size. The larger pebbles are well rounded, the smaller ones often subangular. At one locality the pebbles are granite (scarce), trachyte (abundant), jasper (scarce), and syenite porphyry (common). At a second locality the pebbles are pink chert and felsite (8 per cent), syenite porphyry (50 per cent), trachyte and tuff (42 per cent), with rare white chert: a rather restricted assemblage. At a third locality the pebbles are tuff and trachyte (50 per cent) and syenite and trachyte porphyries (50 per cent). Interbedded with the coarse conglomerate are bedded greywacke and pebble conglomerate with one-inch pebbles.

Member A–4, lying above conglomerate member A–3 and below conglomerate member A–5, is a 1,000-foot unit of tuff with interbeds of greywacke conglomerate interfingering from the west. The medium to fine-grained, even bedded, well sorted tuff is grey-black in colour dotted with red feldspar crystals. The tuff is overlain by a very thick (3,800-foot) conglomerate member. It is well sorted and shows imbricate structure. The well rounded pebbles are closely packed and one, two and three-inch pebbles predominate, but rare pebbles up to 8 inches in size can be found. The pebble assemblage is as follows: red jasper (12 per cent); white chert (4 per cent) green basic lava (22 per cent); pink porphyry (62 per cent); black chert (scarce). The conglomerate contains greywacke interbeds with sparse pebbles.

Member A–6 consists of 1,400 feet of dark green-purple bedded tuff showing good grain gradation and bedding from 3 inches to one foot in thickness. Small black hornblende crystals occur scattered through the rock. Texturally the tuff is a medium grained sand or grit. The upper portion of this member is cut off by an intrusion of augite porphyry.

The uppermost member, A–7, is conglomerate over 1,000 feet thick, with interbedded greywacke. Half a mile west of Amikougami Creek this member is well exposed along the power line. The section is cut off to the south by Algoman syenite and the Blanche River fault.

(4) Kirkland Lake Section. A section of Timiskaming rocks is exposed in the Goodfish road north of the Wright-Hargreaves property. The actual Timiskaming-Keewatin contact is not exposed but Keewatin lava outcrops a few feet away from the basal member of the Timiskaming series. The contact was cut in drill holes from a crosscut on the 3,075-foot level at Lake Shore mine and was not faulted. The Keewatin pillow lavas face north and the Timiskaming sediments face south, indicating a major unconformity.

The basal member, KL–1, is a schistose conglomerate with interbedded gritty greywacke. The pebbles are flattened parallel to bedding schistosity. The rocks are highly carbonatized and chloritized. Pebble types noted were jasper, porphyry, green schist, greywacke and chert. This member is tentatively correlated with A–1 in the Amikougami Creek section. The section is intruded by syenite porphyry.

KL–4 member is a finely bedded black tuff speckled with red feldspar crystals. It is tentatively correlated with A–4 of the Amikougami Creek section; presumably KL–2 and 3 are cut out by intrusion. Above this tuff is 800 feet of interbedded greywacke and conglomerate. Pebbles constitute 70 per cent of the conglomerate; they are well rounded to subangular, of medium sphericity and range in size from ½ to 5 inches in diameter, averaging about 1 inch. Pebble types are jasper (common), syenite porphyry (common), green and white chert (abundant), spotted trachyte (scarce), black chert (common), and tuff and greywacke (scarce). There is some imbrication. The pebble bands are well sorted. The coarse grained greywacke interbeds average 2 to 3 feet in thickness. The section is cut off to the south by syenite intrusives.

Commentary. A long crosscut running north on the 3,075-foot level at Lake Shore mine exposes a fine section of Timiskaming sediments. Here the A4–KL4 tuff member and what is probably the A3 conglomerate are seen. Pebble types include gneissic granite (very rare), syenite porphyry (common), jasper (scarce), green and white chert and felsite (common), trachyte and tuff. Pebbles average 2 inches in size.

Tracing the A–5 member of the Amikougami Creek section eastward for one and a half miles from Amikougami Creek, the pebbles become coarser. This member outcrops on Government road at the Golden Gate corner in Chaput Hughes. Here the conglomerate is poorly sorted and contains boulders up to 18 inches. Pebbles average 4 to 5 inches in diameter and make up 60 per cent of the rock. They are mostly rounded. Pebble types are syenite porphyry, granite, white and black chert, jasper, greywacke, greenstone, and green spotted trachyte.

The A–6 member of the Amikougami Creek section persists and thickens eastward. One mile east of the creek a thick section of red and green bedded tuffs is exposed in the Amalgamated Kirkland property. The tuff is well bedded with poor grain gradation, and ranges in grain size from silt to coarse sand. Hornblende crystals are common. Farther east a few conglomerate lenses appear in the member. This is the uppermost member of the Timiskaming in eastern Teck township.

(5) Gull Lake Section (Lebel township). The section in Lebel township is much disturbed by faulting and intrusion and no accurate measurement can be made. A. MacLean (1956) has set up a stratigraphic sequence in the township, numbering members from 1 to 13.

GL–1 is a 2,000-foot member consisting of conglomerate, greywacke and tuff. The basal unit of the Timiskaming, which rests on Keewatin lavas, is a conglomerate. It is well exposed near Doig Lake in the northwest corner of Lebel township. The unconformable relations are described by Thomson (1946, pp. 116–17). Near Julia Lake this member consists of interbedded conglomerate and greywacke. The conglomerate bands have well-rounded pebbles from ½ to 4 inches in diameter. The pebbles are greenstone, greywacke, porphyry, jasper and chert. Interbeds of greywacke and tuff are dark green to black in colour.

GL–2 is a 2,000-foot conglomerate and greywacke member. East of Gull Lake the conglomerate has pebbles ranging from 1 to 4 inches in size, and averaging 2 inches. They are well rounded to subangular. Pebble types are jasper, chert, quartz, trachyte, tuff, greywacke and rare syenite porphyry.

GL–3 consists of 500 feet of well bedded dark green tuff containing beds of tuffaceous conglomerate with many angular pebbles of green spotted trachyte. Bedding in the tuff is uniform and crossbedding is common. Beds range from ½-inch to 2 feet in thickness.

GL–4 is a 1,000-foot conglomerate member containing pebbles from ½ to 5 inches in diameter and averaging 2 inches. Pebbles are quartz, jasper, chert, greywacke and syenite porphyry.

GL–5 is 1,500 feet of purple feldspathic tuff and tuffaceous conglomerate. The tuffaceous matrix of the conglomerate is greenish mauve and medium to coarse-grained. Pebbles range from 1 to 10 inches in size and consist of jasper, tuff, chert, greenstone, greywacke and felsite.

GL–6 is a 700-foot thick green porphyritic trachyte flow. The flow thickens to the east. Above the trachyte flow is a 400-foot conglomerate member, GL–7, with a coarse grained matrix and rounded to angular pebbles $\frac{1}{4}$ to 5 inches in size. The matrix appears to be largely trachytic tuff. Pebbles include jasper (common), green carbonate (common), white chert, trachyte and porphyry (abundant), and rare black chert. Above this conglomerate is a lenticular trachyte body which MacLean interprets as a sill. Above this sill is a thick greywacke unit which is cut off to the south by the Lebel batholith.

The section in western Lebel measures 16,000 feet from Keewatin on the north to syenite on the south. Due to faulting and intrusion the true thickness is not known but must exceed 10,000 feet.

(6) Morris Kirkland Section. The Morris Kirkland section is chosen to give an excellent section across the trachytic flows of the Timiskaming series. The section begins in greywacke below the trachyte flows and ends in conglomerate and tuff above the flows. The basal member is cut off to the north by an Algoman porphyry boss south of the Bidgood mine. The uppermost tuff member is cut off to the south by the Lebel batholith.

MK–1 consists of 1,200 feet of green, grey or buff carbonatized greywacke with regular graded $\frac{1}{4}$ to 2-inch beds. There is good slaty cleavage. Above this member is a series of trachyte flows, designated MK–2, measuring 1,600 feet in thickness. The lower part of the section is fine-grained trachyte with hornblende phenocrysts. The central part is porphyritic with rare ropy flow structure. The upper part is more feldspathic and is typical green spotted trachyte. The rock is grey-green on weathered surfaces. Above these trachyte flows there is 500 feet of tuffaceous agglomerate, MK–3. The matrix is pink coloured, coarse grained sandy tuff which is very rough on weathered surfaces. Angular to subangular trachyte fragments range from 2 to 10 inches in size. Member MK–4, which correlates with GL–7 of the Gull Lake section, consists of 400 feet of sharpstone conglomerate with subangular pebbles ranging from $\frac{1}{8}$ to 4 inches in size. The matrix is pink or grey-green, coarse to medium-grained and very rough on weathered surfaces. Pebbles are trachyte (abundant), tuff (abundant), green carbonate, quartz, jasper (rare) and chert. The uppermost member, MK–5, is 500 feet of well-bedded tuff.

(7) Gauthier Township Section. The best section of Timiskaming rocks in Gauthier township can be seen near the Beaverhouse Lake road in eastern Gauthier, where a 6,800-foot section is exposed. The basal member of the Timiskaming is 2,100 feet of well-bedded, schistose carbonatized greywacke resting with unconformity on the Keewatin acid volcanics. The bedding is crenulated and contorted. The greywacke grades upwards into G–2, a 300-foot conglomerate member with well rounded to subangular pebbles of greenstone, porphyry and acid lava. Above this is G–3, a 250-foot thick pinkish massive trachyte flow. This is overlain by G–4, consisting of 1,650 feet of fine to medium-grained, well bedded greywacke with good grain gradation. Above this is G–5, a 300-foot member consisting of pebble conglomerate and interbedded greywacke, highly carbonatized. The uppermost member, G–6, consists of 2,150 feet of well bedded altered greywacke.

(8) McVittie Section. North of Larder Lake station in McVittie township a

section of over 3,000 feet of Timiskaming rocks is exposed south of the Keewatin contact. The basal member of the Timiskaming, MV–1, is 500 feet of interbedded conglomerate and greywacke resting with disconformity on Keewatin pillow lava. The average diameter of pebbles is 4 inches. The basal conglomerate contains pebbles of greenstone, rhyolite, felsite, granite, syenite, diorite, jasper, chert, iron formation and vein quartz, Thomson (1941, p. 11). This member grades upward into MV–2, 700 feet of sandy greywacke. It is massive and poorly bedded and contains much hornblende, quartz and feldspar. It grades from coarse sandy to fine silty greywacke. The greywacke is overlain by 1,700 feet of pink porphyritic trachyte with prominent feldspar phenocrysts. This lava is well exposed at Larder station townsite. The trachyte is overlain by MV–4, a finely bedded greywacke and tuff with good grain gradation. This member is closely folded on the Omega property and the true thickness cannot be measured. It is cut off to the south by the Larder Lake fault.

General Description

At the western end of the Timiskaming belt in Grenfell and Teck townships, the Timiskaming series consists of conglomerate, greywacke and tuff. There is little trachytic flow material, but trachytic tuff is common.

Tuffs. There are four tuff members in Teck township. The lowermost, represented by the A–2 member of the Amikougami Creek section, is discontinuous and is interbedded with greywacke. There are pebble conglomerate interbeds. Since these tuffs are waterlaid, they do not have the constancy of tuffs laid down subaerially, and the tuffaceous material blends with normal clastic rock detritus.

The second tuff, represented by member A–4 of the Amikougami Creek section, attains 1,200 feet in thickness and can be traced from a point just north of Elsie Lake for a distance of five miles to the east shore of Kirkland Lake where it is cut off by intrusives. At the west end, the tuff member thins and fingers out into greywacke and conglomerate.

The third and main tuff, the A–6 member of the Amikougami Creek section exceeds 2,000 feet in thickness. It can be traced from the Blanche River in western Teck township where it is cut off by the Blanche River fault, eastward south of Elsie and Kirkland Lakes to the Lebel boundary. Here there is intense faulting. This tuff member may continue into Lebel township and be represented by the GL–5 member of the Gull Lake section.

The fourth tuff member is only found in the Swastika section where it is represented by the S–2 member. It can only be traced for two miles along strike and is cut off by faulting.

The presence of tuff near the base of the Timiskaming series in this area indicates that there was trachytic volcanism during the opening stages of the Timiskaming epoch in this area. The tuffs thin westward indicating an easterly source. This is substantiated by the increasing amounts of trachyte flow material eastward in Lebel and Gauthier townships.

Conglomerates. Basal conglomerate does not mark the base of the Timiskaming section. The basal member is sometimes a tuff, sometimes a greywacke, and sometimes a grit or pebble conglomerate. Often these units are interbedded.

The principal conglomerate member of the Timiskaming section is the Elsie Lake conglomerate which can be traced from the Blanche River near Kenogami station eastward across Teck township, through Chaput-Hughes where the conglomerate is well exposed on the highway, into Lebel township. This conglomerate is the A–5 member of the Amikougami Creek section and probably the GL–4 member of the Gull Lake section. It cannot be recognized farther east. It has a maximum thickness of 4,000 feet near Chaput-Hughes and thins eastward and westward. The pebbles in this member are larger than those in the lower members of the series, being up to 10 to 12 inches, rarely 18 inches, and averaging 4 to 5 inches. This conglomerate is more poorly sorted than the lower conglomerate beds, which often show imbrication. Cut-and-fill structures were not observed.

Excellent grain gradation in tuff and greywacke members indicates a rather quiet environment of deposition and a cyclic type of sedimentation more characteristic of a near shore clastic facies laid down in relatively quiet water.

Trachyte. In Lebel township there are two major bands of trachyte flows. The lower trachytes are well exposed in the vicinity of Bidgood Kirkland mine. The upper trachytes occur some 3,500 to 4,000 feet above the Bidgood trachytes and are best developed on the Morris Kirkland property.

In addition to tuffaceous material supplied by this trachytic volcanism, there are many trachyte pebbles in the conglomerate members indicating that some of the trachytes were undergoing active erosion during Timiskaming times. These trachyte pebbles appear in the conglomerates very low in the section, being present in the A–3 member of the Amikougami Creek section and the GL–2 member of the Gull Lake section. In some cases trachyte pebbles appear in flood proportions and it is apparent that the centres of Timiskaming volcanism made a large contribution to the Timiskaming sediments of this area.

The two major trachyte bands noted in Lebel township can be traced eastward into Gauthier township, but the lower one is cut off by intrusives on the Northland property. The upper band can be traced east to the

Upper Canada property where there is a preponderance of trachyte breccia and agglomerate with 7 to 8-inch trachytic fragments.

Due to lack of exposure and lens-like character of the members of the sections, none of the units recognized in Teck and Lebel township can be definitely correlated with those in eastern Gauthier township. In eastern Gauthier township the predominant rock type is finely bedded greywacke as described in the section at Beaverhouse Lake road. The conglomerates are much less prominent in this area than farther west and there is a notable decrease in coarse boulders.

In eastern Gauthier township at the base of the section, along the Misema River, there is a thick trachyte member consisting of porphyritic trachyte, trachyte breccia, agglomerate and tuff. It can be traced east for over 7 miles through McVittie township to Bear Lake where it is cut off by the Kerr Addison anticline and the Larder Lake break. This is the MV–3 member of the McVittie section.

Summary

The best section of Timiskaming rocks exposed in this belt is in Teck township where over 11,000 feet of greywacke, conglomerate and trachytic tuff are exposed. Eastward in Lebel township trachytic flow material appears in the section and throughout the belt to the east as far as the Quebec boundary these acid volcanics and associated pyroclastics form an important part of the Timiskaming series.

The thickest conglomerate member is the Elsie Lake conglomerate of Teck township which is 4,000 feet thick. Conglomerates decrease in amount eastward.

South Belt Sediments. South of the Larder Lake fault several areas of Timiskaming sediments are found, mainly in McElroy, Hearst and Skead townships. The structure in the southern belt is extremely complex as there is much faulting and folding. Mapping in Skead and McElroy townships (Hewitt, 1949*a*; Abraham, 1950) covered the south boundary of the Timiskaming sediments with the Keewatin lavas. No volcanic rocks occur in the Timiskaming rocks of the south belt and the sedimentary series, consisting predominantly of greywacke, arkose and conglomerate, rests with major unconformity on the Keewatin volcanics. The maximum section of Timiskaming sediments exposed in Skead township is 2,000 feet in thickness.

Conglomerate members in Skead township are rarely over 100 feet in thickness and often contain interbedded greywacke. The matrix is arkose or greywacke ranging from silt to coarse sand size. Pebbles average 2 to 3 inches, but occasional boulders to 24 inches have been observed. They are angular to well rounded and consist of all the Keewatin rock types:

greenstone, dacite, diorite, rhyolite, quartz and feldspar porphyries, tuff, chert, greywacke and arkose. Generally the assemblage is a restricted one of local derivation with diorite, greenstone, rhyolite and quartz porphyry predominating. Jasper pebbles, so common in the northern belt conglomerate, are rare or absent.

In describing the conglomerates of Hearst township, Thomson (1947, p. 7–8) states:

> the normal conglomerate contains boulders and pebbles of syenite and quartz porphyry, rhyolite, diorite, gabbro, bedded sediments, quartz, iron formation, pink trachyte and jasper. Greenstone pebbles generally predominate in the conglomerate and constitute from 40 to 90 per cent of the various rock types. Trachyte and jasper are very rare. Boulders as much as two feet in diameter have been seen in the conglomerate, but they generally are less than six inches in maximum dimension.

The greywackes are medium to fine grained clastic sediments, generally well-bedded, composed of quartz, feldspar and heterogeneous rock fragments, chiefly volcanic, ranging from rhyolite to basalt in composition. These rocks are derived from a Keewatin volcanic terrane by immature weathering and largely through mechanical breakdown. For this reason although they are often well sorted as to size, their mineralogic composition reflects the heterogeneous character of the distributive province. These greywackes are distinctly first cycle sediments. They are usually grey or buff in colour, sometimes black or green. Secondary alteration often produces much carbonate, sericite, kaolin and chlorite in these rocks. The greywackes show excellent grain gradation, frequent crossbedding and occasional ripple marks. Slaty cleavage is sometimes developed.

Timiskaming-Keewatin Relations. Mapping in Skead and Hearst townships indicates that there was a period of folding at the end of Keewatin times, followed by erosion, and the Timiskaming sediments were laid down on the eroded surface of the folded Keewatin rocks. This unconformity is well exposed in several places in Skead township, Hewitt (1949*a*). In one place there is truncation of over 2,000 feet of Keewatin volcanics. In another place the Timiskaming sediments and Keewatin volcanics show back-to-back relations similar to those found in Teck township, Thomson (1947).

Pebble Assemblages in Timiskaming Conglomerates

The accompanying table gives a summary of the pebble assemblages of 27 Timiskaming conglomerates of the north belt, 10 Timiskaming conglomerates of the south belt, 2 Keewatin conglomerates and 4 Cobalt

TABLE 1. PEBBLE ASSEMBLAGES

Locality Tp.	Cg. Member	Pebble size inches Max.	Min.	Avg.	Granite, Syenite, Gneiss	Porphyry	Felsite	Diorite, Gabbro	Basic Lava	Rhyolite	Tuff, Trachyte	Jasper, I.F.	Chert	Greywacke	Quartz	Carbonate	Metamorphic rocks	Misc.
I. Timiskaming Conglomerates—North Belt																		
Eby	K-3			2					x		x	C	x	x				
Eby	Upper	10	½	3		x			x		x	C			x			
Eby	Upper	8		2	x	x			x			C	x	x	x			
Teck	S-3	3		2		C					A	C	A	R				
Teck	S-4			2									F					
Teck	A-1					A	C				A		x					
Teck	A-3			1		S					F	S	S					
Teck	A-3	10		3	R	C					A	S						
Teck	A-3	8	½	4		A			x		A							
Teck	A-5	8		2	VR	F			C			C	S					
Teck	KL-1			3		x		x	x			x	x	x				
Teck	KL-5	5	½	1		C					x	c	A	x				
Lebel	GL-2	4	½	1		R					x	x	x	R	x			
Lebel	GL-4	4		1	x	C	C					C	C	C				
Lebel	GL-4	5	½	2		x						x	x		x			
Lebel	GL-5	10	1	5		C	x		x		x	x	x	x				
Lebel	GL-7	5	½	1		A					A	C	x			C		
Lebel	MK-3	10	2	6							F							
Lebel	MK-4	4	¼	½							A	R	S			S		
McVittie				3		x	x				x	x	x		x			
II. Timiskaming Conglomerates—South Belt																		
Skead	5/VI	2	1/8	½		x				F								
Skead		6	1			x		x	x	x			x					
Skead	8/VI	10	6					x	x									
Skead	9/VI					x			x		x		x	x				
Skead	8/V			4				x	x	x			x	x				
Skead	10/V			3										F				
Skead	12/VI					x		A	C	F								
Skead	10/VI					F				A								
Hearst					x	x		x	F	x	x	VR		x	x			
Hearst						x			x	x			x	x				
III. Keewatin Conglomerates																		
Skead	10/V	4				x		x	x									
Skead	5/I	7	2						x		x							
IV. Cobalt Conglomerates																		
Kenogami		20	1/8	5	F	C			R			S	S	C	R			R
Skead	6/II	12	½	4	A	C	x	x	x		x		S	x	x			x
Skead	6/I	10	¼	3		x			x		x			x				

Pebble Frequency Table

F	flood	over 50 per cent	R	rare	2 or 3 pebbles
A	abundant	25 to 50 per cent	VR	very rare	1 pebble
C	common	5 to 25 per cent	x	present	percentage not estimated
S	scarce	5 to 10 pebbles			

conglomerates. The pebble types are divided into fourteen groups as follows:

(1) Granite, syenite and gneiss. This group includes pink and grey, medium grained, equigranular granite and syenite and granite gneiss.

(2) Acid porphyries. This group includes pink and white quartz and feldspar porphyries similar in lithology to the Keewatin porphyries which form dikes, sills and vent plugs in the Keewatin acid volcanic centre in Skead township. Many Keewatin acid agglomerates contain fragments of these Keewatin porphyries. This group is interpreted as derivatives of the Keewatin or Timiskaming acid volcanic centres and are therefore distinguished from the granite, syenite and gneiss pebbles which may possibly be of plutonic origin.

In the literature many of the descriptions do not distinguish between the porphyries and the granite-syenite-gneiss group, and this has led to erroneous interpretations regarding the prevalence and significance of so-called "granite pebbles" in Timiskaming conglomerate. Granite and syenite pebbles are actually very rare in the conglomerates of the north belt, and absent in the south belt. Porphyry pebbles, on the contrary, are abundant, and in some members, such as A–5 of the Amikougami Creek section and the Skead conglomerates, are present in flood percentages. In the south belt porphyry pebbles are seldom absent.

In the Timiskaming conglomerates along strike to the east in Quebec, porphyry pebbles are abundant. Descriptions from Wilson (1943) and Cooke (1931) group all the acid intrusive pebbles together as "granite" and report "granite" in abundant or flood percentages. Examination of the Granada conglomerate near Rouyn by the writer disclosed that most of the acid intrusive pebbles are porphyry. Gunning & Ambrose (1941) have distinguished between granite and porphyry pebbles and report granite as "very rare" and porphyry as "abundant" in 2 pebble assemblages given in their report.

In his article on Archean sediments, Pettijohn (1943) does not distinguish between the two types of acid intrusive pebbles, and quotes a large percentage of granite in Timiskaming conglomerate.

In contrast to the Archean conglomerates, abundant granite and porphyry pebbles are both present in Cobalt conglomerates.

(3) Felsite. These are light-coloured, fine grained intrusive or extrusive rocks.

(4) Diabase, diorite, gabbro; (5) Basic and intermediate lavas. These two groups include all the Keewatin basic intrusive and extrusive rocks which are commonly found as pebbles throughout the whole of the Timiskaming belt.

(6) Rhyolite. Rhyolite pebbles are rare or absent at the western end of the north belt, but present at the eastern end. In the south belt rhyolite and associated white quartz porphyry are common pebble types.

(7) Trachyte and tuff. Timiskaming volcanism made an important contribution to the conglomerates of the north belt: trachyte and tuff pebbles derived from these volcanics are almost invariably present in the north belt conglomerates, and in places these Timiskaming volcanics apparently supplied nearly all the detrital material, including the tuffaceous matrix, for the conglomerate members.

Trachyte pebbles and tuffaceous material is present in the lowermost members of the Timiskaming series, indicating that trachyte volcanism was a very early contributor to these rocks. Trachyte pebbles are almost exclusively confined to the conglomerates of the north belt in Ontario, however a few trachyte pebbles are present in the south belt conglomerates.

(8) Jasper, iron formation; (9) Chert. Bedded iron formation, jasper and chert are commonly present as pebbles in the Timiskaming conglomerates. Red jasper pebbles constitute a small but constant percentage of most conglomerate members of the north belt. Jasper may be absent in members of local derivation, such as those in which trachyte approaches flood proportions.

Iron formation is often present; pebbles of iron formation constitute over 50 per cent of pebbles present in one south belt conglomerate in McVittie township near Larder Lake village.

Black, white, grey and green chert pebbles from the Keewatin volcanic series are found as pebbles in the Timiskaming conglomerates. In Skead township a distinctive type of pink chert forms common pebbles in several conglomerate members and is thought to be derived from erosion of pink chert beds of Timiskaming age in the basal part of the Timiskaming section in this area.

(10) Greywacke. Greywacke pebbles occur in 9 of 27 conglomerates examined in the north belt, and 5 of 10 conglomerates in the south belt. The greywacke is thought to be mainly derived by erosion of earlier Timiskaming greywacke beds.

(11) Quartz. Pebbles of white vein quartz occur in several conglomerate members.

(12) Carbonate; (13) Metamorphic rocks; (14) Miscellaneous. Pebbles of green carbonate rock occur in the GL–7 conglomerate in Lebel township and are thought to be derived from an intensely carbonatized zone associated with lower trachyte volcanics.

No pebbles of metamorphic rocks containing such metamorphic minerals as garnet, kyanite, staurolite or the like, were observed. Although these minerals are present in the Pontiac schists in adjacent areas of Quebec, no such pebbles are found in the Timiskaming conglomerates.

Miscellaneous pebbles include arkose, feldspar and conglomerate (present in Cobalt conglomerates).

Geologic History of the Timiskaming Epoch

The geologic history of the Timiskaming epoch is by no means clear; however, on the basis of facts gathered in this study, some interpretations of the nature and environment of Timiskaming sedimentation can be made.

Nature of the Provenance Area.

By examination of the rocks of pre-Timiskaming age exposed in the area, and by study of the nature of the Timiskaming sediments, the pebbles of the conglomerates and the heavy accessory minerals of all the rocks, we can reconstruct a picture of the provenance area which supplied the detrital material for the Timiskaming sediments.

Examination of pebble types present in Timiskaming conglomerates indicates that contributions came from two sources: (i) the pre-Timiskaming basement; (ii) the Timiskaming rocks themselves. In many areas, such as northern Skead township, the bulk of detrital material was derived from Keewatin terrane. In other areas, as in Teck and Lebel townships, important contributions were made by the Timiskaming rocks, in this case trachytes and tuffs.

The distributive province supplying sediments to the Timiskaming trough was composed of basic volcanics and intrusives, rhyolites and acid porphyries of great variety, minor amounts of chert, iron formation, jasper, and slaty greywacke, and rare syenite, granite and granite gneiss. It was essentially an igneous volcanic terrane. Metamorphic rocks were apparently lacking. Large areas of unroofed batholithic intrusives: granite, syenite and injection gneisses, were not present in the distributive province. However abundant acid porphyry pebbles were supplied by porphyritic flow rocks, and by erosion of dikes, sills and cone sheets forming an integral part of acid volcanic centres which stood up in relief in the volcanic terrane.

Integrating the detailed descriptions of Keewatin rocks in the area with the studies of pebble types in the Timiskaming conglomerates, it is noteworthy that nearly all of the pre-Timiskaming pebbles are represented by Keewatin bedrock formations present in the neighbouring fifty townships. The exceptions are granite, syenite and granite gneiss pebbles. The pebble assemblages are restricted in the sense that pebbles are largely of Keewatin volcanic origin: however there is great variety in lithology.

At the present time, in an area of 1,800 square miles comprising the fifty townships of northeastern Ontario centred around the Kirkland-Larder Lake area, the writer estimates that the rock types exposed are as follows: Keewatin series, 60 per cent; Timiskaming series, 6 per cent; Algoman granite and syenite batholiths and stocks, 20 per cent; Cobalt sediments, 10 per cent; Nipissing diabase, 2 per cent; Paleozoic limestone, 2 per cent. The writer believes that the Keewatin rock types exposed in 60 per cent of the area today, represent lithologically the nature of the rocks in the Timiskaming provenance area. In point of metamorphism and alteration there is undoubtedly considerable change between Archean times and today, especially along zones of major shearing in the Keewatin complex, near the Algoman intrusives, and in the vicinity of some mineral deposits where hydrothermal metamorphism has been intense. However, there is good evidence that many of the Keewatin rocks were highly chloritized, sericitized, saussuritized and carbonatized in pre-Timiskaming times, since rock fragments in the Timiskaming sediments show these alterations. That the alterations are in many cases pre-Timiskaming is indicated by the fact that adjacent clastic fragments have diverse types and degrees of alteration, and sometimes the matrix will be unaltered.

In Skead township acid volcanics make up about 10 per cent of exposed Keewatin volcanics, the remainder being intermediate and basic extrusives, and dacite, diorite and andesite porphyries. Rhyolite and quartz porphyry pebbles constitute a notable percentage in the Timiskaming conglomerates of the area, and are more prominent in the conglomerate than their percentage in the Keewatin series now exposed would tend to suggest. It is difficult to estimate what percentages of acid volcanics were exposed to erosion in Timiskaming times, but it is likely that the prevalence of acid porphyry pebbles in the conglomerate is due to two factors: (i) the stability of this pebble type under erosion and transportation, (ii) the fact that the centres of acid volcanism with their associated dike complexes were areas of high relief.

The Granite Pebble Problem. As pointed out earlier, much emphasis has been placed on the presence of "granite" pebbles in the Timiskaming conglomerates. The presence of plutonic granite pebbles implies the unroofing of granitic batholiths in the provenance area, and was cited as evidence of a major unconformity at the base of the Timiskaming. The paradox is that no other evidence of a pre-Timiskaming granite can be found.

Pettijohn (1943) observes that "the composition of conglomerates in which granite is the most conspicuous and in some cases the most abundant constituent, lead us to conclude that granite was fully as widely exposed as was the Keewatin greenstone complex in Archean times. If so it would be singular indeed if these early granites had not survived orogeny and erosion as well as have the associated Keewatin rocks."

The writer believes that this paradox can be solved by the following facts: (i) the term "granite" as usually applied in describing pebbles of the Timiskaming conglomerates includes the following lithologic types: granite, syenite, granite gneiss, syenite porphyry, feldspar porphyry, quartz porphyry, rhyolite porphyry, dacite porphyry, granodiorite and syenodiorite porphyry and in some cases porphyritic quartz diorite. (ii) The percentage of true plutonic granite and granite gneiss pebbles which may have been derived from the unroofing of a granite batholith is small or almost non-existent. The writer searched diligently for granite and gneiss pebbles, and found that they were present, but quantitatively rare. Other geologists in the area who have distinguished "granite" from "porphyry" have come to a similar conclusion (Gunning & Ambrose, 1941). (iii) Most of the so-called "granite" pebbles in the Timiskaming are derived from acid intrusives forming part of acid volcanic centres in the Keewatin complex. In Skead township a Timiskaming conglomerate containing abundant pink and white quartz-feldspar porphyry pebbles is found resting on the older Keewatin porphyry from which these pebbles were derived, Hewitt (1949*a*).

The presence of rare pebbles of undoubted granite, syenite and granite gneiss indicates that somewhere within the provenance area, there were intrusives of this type present. In considering this problem Wilson (1939) states:

> it could be possible that pebbles and boulders of granite in the conglomerates of the Timiskaming type are derived from a pre-Keewatin granite. The chief objection to this hypothesis is that it would almost certainly necessitate the transportation of the boulders long distances, and their large size in some conglomerate belts notably preclude this.

Bass (1961, p. 668) recently suggests that "the 'granite' pebbles, gneissoid and massive, are plausibly derived from flows and shallow intrusives emplaced contemporaneously with and genetically related to associated Keewatin type lavas." While the writer was able to trace the source of the major percentage of porphyry pebbles to acid Keewatin volcanic centres where such rocks were exposed, a careful search did not disclose any potential source rocks for certain rare pebbles of undoubted granite and syenite observed in the Timiskaming conglomerates.

Relief and Erosion of the Provenance Area. The nature of the Timiskaming sediments (the size and heterogeneity of pebbles, presence of unstable pebble types, unweathered character of the detritus, etc.) indicates that the provenance area was one of considerable relief, an area of physiographic youth and immature drainage.

The disintegration of the rocks of the provenance area was largely mechanical. Large volumes of detrital material, very little altered by chemical decomposition, were supplied to the Timiskaming trough. The rock fragments making up the greywacke and the matrix of the conglomerates are relatively fresh. These rocks are the products of immature weathering: there was probably little or no development of soil cover and vegetation was apparently lacking as no traces of carbonaceous material are found. Due to lack of chemical weathering, clays, lateritic iron and aluminium oxides, salines and carbonate rocks are not present in the section. Both stable and unstable mineral and rock fragments are present as allogenic constituents of the Timiskaming sediments, indicating that agents of weathering and transportation exercised little modification of the rocks of the distributive province.

The Timiskaming sediments give little or no indication of climate. Pettijohn (1949, p. 253) has pointed out that greywackes can very probably form under diverse climatic conditions and Krynine has given examples of formation of greywacke under varied climates. Both Eskola and Pettijohn (1949, p. 253) have suggested that the absence of iron oxide concretions in Archean greywackes suggest non-tropical climate.

The clastic sedimentary facies making up the Timiskaming series reflect the history and environment of deposition. Noteworthy features are the lack of quartzite and limestone in the sedimentary section, the presence of tuff and volcanics in the north belt, the presence of pink chert and arkose in Skead township, the absence of metamorphic rocks in the distributive province, and the first cycle character of the sediments.

Transportation and Deposition. The clastic detrital material was transported by water and deposited in a sea. Indications are that erosion was rapid, transportation in many cases short, and that deposits were built up rapidly. The fact that pebbles of soft carbonate, tuff and greywacke are present in the conglomerates along with pebbles of porphyry and greenstone indicates that the agents of transportation did not greatly modify the suite supplied from the source area. Similarly the presence of rather unstable heavy accessory minerals such as chlorite, epidote and hornblende as detrital accessory minerals implies short transportation and little modification. The detrital heavy mineral assemblages of the Timiskaming rocks is essentially the same as that of the source area

(Hewitt, 1949*b*); there has been little restriction of the suite due to transportation.

Some of the sediments, such as the grits and granule sharpstone conglomerate on lot 11, concession V and VI, Skead township, are of local derivation. Other conglomerates, such as the A–3 member at Amikougami Creek, have a rather restricted pebble assemblage of 2 to 4-inch, well rounded pebbles of medium sphericity indicating lengthy transportation.

The general poorer sorting in the higher conglomerate members may be a response to increased relief in the source area which included Timiskaming volcanic centres.

Crossbedding, ripple marks, excellent graded bedding, continuity of bedding and cyclic sedimentation in the greywacke units indicate that the sediments were laid down in a large body of shallow water. Absence of cut-and-fill structures indicates a lack of channeling by stream action. The great thickness of clastic sediments with the evidence of shallow water environment indicates that the area receiving sediments was subsiding during sedimentation.

It is postulated that these sediments were laid down in a geosynclinal trough flanking the Keewatin highland area, and represent marginal deposits laid down in a shallow sea.

Other Interpretations of Archean Sedimentation

It is not surprising to find some controversy over interpretations of Archean sedimentation and geologic history of the Timiskaming epoch. A terrestrial subaerial environment is postulated for the Archaen sediments of the Lake Superior region by Van Hise & Leith (1911, p. 603) and for the Archean conglomerates of the Seine series by Lawson (1913, p. 62) who described them as "fanglomerates of subaerial origin."

Coleman (1926, p. 234) postulated a glacial origin for the Doré series and MacLean (1956, p. 18–22) has favoured a glacial origin for the Timiskaming conglomerates of the Kirkland Lake area.

Cooke, James & Mawdsley (1931), Thomson (1941) and Wilson (1943) have been in general agreement that the Timiskaming rocks of the Kirkland Lake-Noranda belt are products of the transitional environment of piedmont and shallow continental or epicontinental seas. Thomson (1941, p. 19) states that "the sediments of the Timiskaming series were probably deposited in a large shallow continental sea, bordered by mountainous country, from which large amounts of detritus were rapidly accumulated through action of torrential streams during flood seasons. The climate was probably rigorous and favoured gravel production and incomplete weathering." Wilson (1943) states that "the great thickness of conglomerate, and the poorly sorted clastic character of the sediments suggests deposition in shallow water, and hence in the sea near shore or in lakes." Wilson further states that "the large size and subangular form of the boulders and presence within the conglomerate of beds of laminated greywacke suggest deposition from floating ice possibly in glacial lakes." Wilson (1956, p. 1425), reaffirms this latter view in a later paper.

Pettijohn (1943) has postulated a geosynclinal environment of deposition for the Archean sediments of the Timiskaming type and likens them to the thick accumulations of sediments in the Caledonian geosynclines of Great Britain and the Franciscan geosyncline of California. Bass (1961, p. 697) has interpreted the Timiskaming sediments of the Canadian shield as deposits associated with island arcs and deposited adjacent to series of volcanic islands.

Status of the Timiskaming Series of the Kirkland Lake Area

Detailed mapping has indicated that stratigraphic and structural methods can be applied to the Archean rocks, and a purely lithologic subdivision into a Keewatin volcanic series and a Timiskaming sedimentary series no longer applies. Important sections of sedimentary rock several thousands of feet thick are now being found in the Keewatin series and these Archean sediments appear to be of diverse ages.

In the Kirkland Lake area field evidence shows conclusively that the Timiskaming rocks rest with great structural unconformity on the Keewatin rocks. Older folded structures in the Keewatin are truncated by the Timiskaming rocks. The Timiskaming rocks can best be defined as that series of sedimentary and volcanic rocks which lies stratigraphically above the Keewatin series, and separated from them by an unconformity. No basic volcanics younger than the Timiskaming series are present in the Kirkland Lake area. The Timiskaming series includes all those conformable formations above the pre-Timiskaming unconformity.

This redefinition of the Timiskaming with acceptance of the Timiskaming of the Kirkland Lake-Noranda area as the type section has been suggested by Wilson (1943). He states that "it is reasonably certain that the belt of sediments above the unconformity in the Rouyn area and that the unconformities in the two localities are the same. For this reason the writer proposes to use the name Timiskaming, but in the redefined way, for all the formations in the Noranda-Rouyn-Beauchastel district from the unconformity upward that are conformable with one another."

The term "Timiskaming" should be restricted to those rocks whose stratigraphic position and relations can be reasonably well proven to be equivalent to those of the north belt of the Kirkland Lake area. It is suggested that this should be the type area for the Timiskaming series.

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