GEOLOGICAL SURVEY OF CANADA
DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PRELIMINARY SERIES

SHEET 74 N/7 (PART OF)

GEOLOGY
MILLIKEN LAKE
SHEET 2
SASKATCHEWAN

Scale: One Inch to 800 Feet = 1/9,600

Feet: 800 0 800 1600 2400

MAP 33-1961

SASKATCHEWAN

Geology by C.K. Bell, 1955

Cartography by the Geological Survey of Canada, 1961

Approximate magnetic declination, 25° 52' East

Air photographs covering this area may be obtained through the National Air Photographic Library, Topographical Survey, Ottawa

PUBLISHED, 1962
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LEGEND

PROTEROZOIC OR LATER

13 ATHABASCA FORMATION (12 and 13)
Sandstone

12 Basal breccia and conglomerate

9 Quartz veins, in part younger than 10; 9a, quartz stockwork

8 Pegmatite dykes; minor aplite dykes

7 Quartz and quartz-feldspar porphyry; 7a, granite porphyry, a coarse-grained phase

ARCHAEAN (?)

TAZIN GROUP (1–6)

5 Leucogranite; quartz, orthoclase-microcline, plagioclase granite

4 'Gunnar granite', granitoid paragneiss; 4a, gneissosity absent, massive granite; 4b, syenitic phase, quartz replaced by feldspar and carbonate; 4c, hydrothermally altered kaolin, sericite, carbonate, and hematite developed

2 3 2. Layered acid paragneiss, less than 15% mafic minerals; quartz-feldspar granoblastic gneiss; 2a, massive phase; in part giant layered gneiss, in part granitoid; 2b, augen structure developed, in part schistose; 2c, quartz-orthoclase-mica, lenticular (augen) gneiss; 2d, feldspar porphyroblasts developed; 2e, syenitic phase, quartz replaced by feldspar and carbonate; 2f, agmatite; 'Gunnar granite' surrounding fragments of 2, 2a, 2b; 2g, hydrothermally altered kaolin, sericite, carbonate, and hematite developed
3. Layered intermediate paragneiss, 15% to 50% mafic minerals; quartz-feldspar-biotite-hornblende-chlorite gneiss; in part migmatite

1 Quartzite; 1a, grit and sandy quartzite; 1b, pebble conglomerate; 1c, chert, cherty quartzite; 1d, ferruginous quartzite, siltstone, and mudstone; in part schistose; 1e, sericitic, schistose quartzite and grit

PROTEROZOIC OR EARLIER

11 Basalt dykes

MARTIN FORMATION (10)

10 Arkose

6 6a, basic gneiss, metamorphosed diabase, diorite, and gabbro; now amphibolite, hornblendite, etc., with retrograde chlorite; 6b, chlorite schist; 6c, tremolite schist, pyroxenite, serpentinite; in part derived from impure carbonate rocks; 6d, feldspathized phase, leucocratic, porphyroblasts developed, in part as augen; 6e, 'Gunnar granite' (4) replacing or forming veined injections in 6a, 6c; 6f, leucogranite (5) replacing or forming veined injections in 6a, 6c; 6g, diorite, monzonite, gabbro; metamorphosed basic lavas; 6h, layered, basic paragneiss, more than 50% mafic minerals; hornblende-feldspar-quartz gneiss; ubiquitous retrograde chlorite

Drift-covered area

Area of sand and gravel

Area of rock outcrop

Geological contact, in part based on diamond-drill information (defined, with dip where known; approximate, gradational)

Bedding, tops known (horizontal, inclined)

Bedding, tops unknown (inclined, vertical)

Schistosity (inclined, vertical)

Stratiform gneissosity; parallel alternating layers of different composition (horizontal, inclined, vertical)

Gneissosity; parallel fabric caused by planar disposition of rock forming minerals; to be distinguished from schistosity and stratiform gneissosity above (horizontal, inclined, vertical)

Lineation, plunge known; may be combined with other symbols

Drag-fold (arrow indicates plunge, relative movement known) may be combined with other symbols

Drag-fold (arrow indicates plunge)

Fault (defined, approximate, assumed, dip unknown)

Fault (inclined, vertical, arrow indicates relative movement)

Joint (inclined, vertical)

Anticline (defined, approximate, inferred axial trace, arrow indicates plunge)

Syncline (defined, approximate, inferred axial trace, arrow indicates plunge)

Glacial striae (direction of ice-movement known)

Locality where age has been determined

Gravel pit

Rock waste dump

Open pit

Mine shaft

Rock trench and stripped area

Mineral occurrence

Mylonite, breccia (alone or as subscript to legend symbols)

Highly contorted beds, bands or gneissosity (alone or as subscript to legend symbols)

MINERAL SYMBOLS

Carbonate	carb	Hematite	hem
Chalcopyrite	cp	Magnetite	mag
Garnet	gt	Pitchblende	U
Graphite	gf	Pyrite	py

Radioactive mineral stain ra

Road

Buildings

Oil, water and sulphuric acid tanks

Intermittent stream

Marsh

Reef

Height in feet above mean sea-level

INDEX MAP

DESCRIPTIVE NOTES

Gunnar lies 450 air miles north-northeast of Edmonton and 18 miles southwest of Uranium City. Wheel- or float-equipped aircraft bring personnel and light freight from both points. During the summer heavy freight is brought 250 miles by tug and barge from the railway at Waterways, Alberta. Maximum relief is 200 feet. Topography is stratigraphically controlled and most faults are in prominent valleys.

Units of the Tazin Group are arranged in order of increasing metamorphism. Units 2 to 5, which lie within or intrude the original sediments, are produced by granitization, selective melting and local intrusion of the sediments. Top determinations suggest that the oldest beds are on the mainland and the youngest on Stewart Island, but field evidence suggests that the sequence is in part repeated by folding and faulting.

Quartzite (1) and grit (1a) are white and grey, or buff to purple coloured due to hematite veinlets and iron-oxide dust. The beds are massive and generally tens of feet thick. Individual bedding planes were traced for more than a mile; but groups of beds commonly lens out or show gradational facies changes along strike. Complex joints and recent weathering have resulted in a rubble surface. Pebble-conglomerate (1b) is composed of imbricately arranged, oval, 2-inch or smaller, quartz and chert pebbles in a grey, cherty quartzite matrix. The above three members contain rare, isolated, ice-rafted cobbles. Caramel-coloured chert beds (1c) form structural markers. Some are sericitic and have a slaty cleavage. The ferruginous siltstones (1d) are variegated, thinly bedded, and weather to a hematite-red-coloured mud. Where metamorphosed, they have altered to a schistose mixture of saussuritized feldspar, biotite, quartz, garnet, and magnetite. Sericite schist (1e) indicates a zone of movement and/or a preliminary stage of regional granitization.

The layered appearance of the acid paragneiss (2) is the result of variations in both the texture and relative amounts of minerals. The acid layers are white to red and consist of quartz, microcline-orthoclase, albite-oligoclase, and minor muscovite, biotite, and retrograde chlorite. These are in knife-sharp contact with grey to dark green layers rich in biotite, hornblende, retrograde chlorite, and plagioclase. The regional red coloration of these rocks results from a mixture of iron-oxide dust, sericite, and epidote that clouds the feldspars. The acid layers weather white, grey, through pink, red, and green-brown. Many layers probably represent the position of original beds, as 'ghost' primary-depositional features and rare pebble-conglomerate beds are found in them. In places, plastic deformation has resulted in swirled layering and boudinage structures; elsewhere, differential recrystallization has partly obliterated the layering. Where the parent sediments were thickly bedded, the resulting paragneiss (2a) is more massive looking, although a megascopic foliation tends to parallel original bedding directions. These paragneisses (2, 2a) are distinguishable from granite by their medium-grained granoblastic texture. Further metamorphism has altered the layered gneisses to a massive, medium-grained, grey to pink, augen gneiss (2b) which represents a near-terminal phase in the local granitization process. The eastern remnants of a belt that continues southwest down Nunim Channel to Sampson Island are preserved as two small patches of very coarse grained, red phacoidal gneiss (2c) that contains 2-inch orthoclase augens. Albitization and carbonitization result in a fine-grained, hematite-rich, 'syenite-like' rock (2e) which is closely associated with faulting.

Intermediate layered paragneiss (3) is contemporaneous with the acid and basic paragneisses and occurs as belts and lenses within units 2 and 2a. The acid layers contain albite-oligoclase, microcline, and quartz, with minor biotite and hornblende. In some places, the basic layers form 80% of the rock across a few tens of feet and consist of hornblende and biotite, much of which is partly altered to retrograde chlorite, albite-oligoclase, and rare quartz. Individual layers range down to a few millimetres wide, the chloritized amphibolite being separated by lit-par-lit ribbons of quartz or granitic material. Some of these striped gneisses are highly crenulated. The fresh rock has a medium-grained granoblastic texture, is pale green to black, and weathers dark green. It was probably derived from mafic sediments.

'Gunnar granite' (4), the host rock at Gunnar Mines, is formed by a further granitization of layered paragneiss. The mutual contact may be knife-sharp, faulted, or rarely gradational, and may parallel or cross the local gneissic structure. Unaltered, in situ, remnants of unit 2 are found within the 'Gunnar granite'. The average rock is a coarse- to medium-grained hypidiomorphic granular mixture of equal amounts of quartz, altered untwinned orthoclase and microcline-perthite, and albite. The mafic mineral is biotite rimmed by retrograde chlorite; and muscovite is a minor constituent. The fresh rock is generally pink, due to hematitic dust in the feldspars. Weathered surfaces are orange-red. The rock is gneissic; foliation is formed by the platy mafic minerals and by flat ovoids of quartz which are up to 2 inches long. Where cleavage is developed the quartz forms lineations within the cleavage plane. Where the rock is not gneissic it is a red to grey, massive granite (4a) that contains biotite, or more commonly, retrograde chlorite. In a few places, unit 4a veins and forms lit-par-lit injections in the paragneiss, suggesting local melting and mobilization. 'Gunnar granite' is altered to a 'syenite-like' rock (4b) by the metasomatic replacement of quartz and K-feldspar by Na-feldspar. The end product of this syenitization is a rock composed almost entirely of fine-grained, unaltered, equant albite grains. Between the two extremes are gradations in which the original feldspars are intensely altered; dusty, undulatory quartz recrystallizes as late, clean, quartz that is occasionally euhedral; and the micas are completely altered to chlorite. During one phase of the Na-metasomatism, accompanying carbonate replaced either quartz or K-feldspar to form a carbonitized syenite (locally termed 'sponge rock') that is the host rock at the Gunnar orebody. Ore is post-albitization and probably accompanied the late stages of carbonitization. Large areas of units 4 and 4b are mylonitized, and irregular, sharp-boundaried, chlorite-rich, breccia zones are common. Small chlorite-filled shear zones crisscross these rocks everywhere.

Leucogranite (5) is massive, medium grained, and pink, and may possibly be a phase of the 'Gunnar granite'. In places it has sharp, crosscutting contacts with units 2 to 4; elsewhere it is gradational with unit 4.

Basic gneiss (6a) occurs as sill and dyke swarms which range in composition from fine-grained aphanitic diabase, through coarse-grained diorite-gabbro, to oligoclase-andesine amphibolite and hornblendite. They are dark grey-green to black on a fresh surface and weather brown, green or black. The contained plagioclase weathers orange and flecks exposed surfaces. Most of the dykes and sills are massive to slightly gneissic and some have chilled edges. They contain segregations and injections of quartz, pegmatite, and granite, but no inclusions of country rock. Many of these basic gneisses show internal evidence of plastic deformation. Some have become remobilized after consolidation and intrude the surrounding rock as apophyses, stock-works, and isolated pods. Retrograde chlorite replaces up to 100% of the mafic minerals in these rocks, ultimately resulting in chlorite schist (6b). Hematite is common as veinlets, joint coatings, and dust, and rare magnetite is seen in unit 6a only. The large masses of mafic rock outcropping at the mouth of Heinen Bay, Johnston Island are recrystallized volcanic rocks (6g). Ghost pillow-structures and intercalated tuffaceous material confirm a volcanic origin. Coarse-grained, hexagonally jointed hornblende-gabbro comprises much of the rock, but there are various mixtures of hornblende, albite-oligoclase, quartz, epidote, hematite and minor magnetite. Chlorite is conspicuously rare. The acid beds are composed of combinations of quartz, feldspar, biotite, carbonate, and opaque material. The basic, layered members of unit 6h are amphibolite, hornblendite, or mixtures of hornblende, biotite, and plagioclase; most of the mafic minerals in these rocks are in part chloritized. The dark layers are separated by ribbons of plagioclase-rich, granitic rock and rarely by lit-par-lit quartz lenses. The overall rock is dark green and generally schistose. The presence of carbonate and tremolite in some areas suggests original limy sediments, and where these are in large enough bodies they are mapped as unit 6c. In places, the assignment of rocks to either unit 6a or 6h is uncertain because some basic sediments may have been so amphibolitized that they are indistinguishable from metamorphosed basic rocks of igneous origin. It is also possible that some of the rock mapped as unit 6a was originally of volcanic origin.

Porphyries occur as small, irregularly shaped masses and dykes that are red, brown, or grey-green and weathered orange-red. Quartz, and quartz-feldspar porphyry (7) contain less than 20% phenocrysts; up to 100% of the phenocrysts are colourless quartz crystals that are as much as 5 mm long but average 1 mm, and the rest are microcline and minor oligoclase less than 1 mm long. The matrix is a microcrystalline mixture of quartz, orthoclase-microcline, plagioclase, biotite (retrograde chlorite), sericite, and secondary pyrite, iron-oxide dust, and calcite. More than 50% of the granite porphyry (7a) consists of phenocrysts; three quarters of these are microcline with minor oligoclase, and the other quarter is quartz. The feldspars average 6 mm in length, some being 2 cm; quartz averages less than 5 mm. The matrix is a medium-grained, hypidiomorphic granular aggregate of the above minerals. Most of the porphyries are slightly mylonitized, the phenocrysts being bent, fractured, and corroded. Chlorite, where abundant in the matrix, forms a rude foliation parallel with the regional structural trend. Both porphyries contain chloritized inclusions of the country rock. Veinlets of carbonate and quartz are widespread. The porphyries have a common origin, those with a microcrystalline matrix being emplaced early.

Pegmatites (8) are simple quartz-orthoclase-muscovite dykes and sills. They are not gneissic and are therefore later than the regional metamorphism. Some have been altered to a carbonitized syenite at Gunnar Mine. A K-A age determination on muscovite from a late, unaltered pegmatite intruding 'Gunnar granite' at Gunnar Mine gave 1,815 m.y.

Quartz veins (9) are small and of many ages, including post Martin Formation. Small quartz gash-veins occur in and adjacent to the pegmatites. Late vuggy quartz veins fill the northwest-striking faults on Johnston Island. Neither pegmatites nor quartz veins are economically important.

The terms 'Martin Formation' and 'Athabasca Formation' are defined by Fahrig[1]. The relationship between these two formations in this area is unknown. Martin rocks (10) may represent upper members of the Proterozoic Athabasca Formation, that have been tilted and down-faulted between the Black Bay – Crackingstone fault systems, or they may be late Archaean. Martin sediments are separated from Tazin rocks by the Jug Bay fault (Crackingstone fault on Map 38-1959). The arkose member (10) is pink, red, orange or brown, and weathers brick-red. The grain size averages 1/2 mm with wide variations up to the size of pebbles in conglomerate lenses. Beds are thick, massive, and difficult to delineate. Primary depositional structures are vaguely defined; pebble-conglomerate and rare interformational conglomerate lenses provide the best horizon markers. Milky to grey quartz forms up to 60% of the rock, and bright orange feldspar the rest; both minerals are angular. The cement is a fine-grained, iron-stained silt with chips of quartz and feldspar.

Late basalt dykes (11) are known to intrude the lower members of the Martin Formation north of the map-area but their relationship to the Athabasca Formation is still indefinite.

The Athabasca Formation (12, 13) unconformably overlies the quartzitic rocks (1–1e). In places a brown regolithic siltstone veneers and fills the highly jointed and cracked pre-Athabascan erosional surface, forming 'clastic dykes'[1]. These dykes have been exposed by subsequent erosion down to the surface of unconformity. The basal breccia (12) consists of angular blocks of the underlying sediments in a cement of brown mudstone, siltstone, and fine-grained quartzite. A few feet above the unconformity the boulders become subrounded. Overlying the conglomerate is maroon, red-brown or buff, medium-grained, quartzite and sandstone. Rare mudstones, siltstones, and derived intraformational conglomerates form interbeds. Crossbedding, ripple-marks and other shallow-water primary structures are abundant. The majority of the grains are rounded, well-sorted quartz, with minor quartzite and chert. Much of the interstitial material is ferruginous, with mudstone chips and rare feldspar grains. Quartz overgrowths weld the rock into orthoquartzite.

Tazin paragneiss (2) is complexly folded on the mainland. The axial traces and plunges are predominantly southwest, but north of the Chimo fault they are northwest. Axial traces are bent, suggesting at least two periods of folding. Most lineations plunge south, but anomalous north-plunging lineations may have originally plunged south and later became folded into their present position. The complex cross-faulting makes it impossible to trace individual fold axes far. In detail, some of the folding is on a scale of tens of feet; such extremely complex areas are designated on the map by a 'k'.

The fault pattern suggests that the main regional shear fractures are the transverse St. Mary's Channel and Heatherington faults. The Dome, Chimo, and Iso faults are complimentary minor fractures along which there appears to have been little movement. Eastward, the St. Mary's Channel and Heatherington faults curve into longitudinal faults that strike northeast up Crackingstone Peninsula. The Zeemel fault—a bedding fault—may predate the others. The 'Gunnar granite' contact has a right-hand strike separation of 7,000 feet on the Zeemel fault. The zone enclosed by the Zeemel, Iso, and St. Mary's Channel faults, and underlying St. Mary's Channel, is highly brecciated and hydrothermally altered but contains no radioactive minerals. Movement along these faults may have provided a structurally controlled distant zone that formed the locus for Gunnar ore deposition. The Jug Bay fault appears to be younger than the others and has been traced for 10 miles. Gouge associated with this fault is up to 15 feet thick; the gouge zones associated with the Zeemel, Iso, and St. Mary's Channel faults are only inches thick. Many minor faults and joints occur within the Tazin rocks, but most are too small to map or are hidden by drift. Many of the steeply dipping, northwest-striking tension faults on Johnston Island have right-hand strike separations with minor movement. All are filled by a fault breccia cemented by low-temperature, milky quartz. In the more metamorphosed Tazin paragneiss, silicification and red-hematite alteration has affected most fault breccias.

The Gunnar orebody[2,3] is a pipe-like mass of granular, microbrecciated carbonate-syenite which occupies the northeast corner of the 'Gunnar syenite' mass. The pipe plunges 45°S for a known length of 1,400 feet. The ore is largely pitchblende which is disseminated as microcolloform rims on the breccia fragments, and as rare veinlets. Supergene activity extends to the deepest part of the orebody and accounts for the widespread distribution of uranophane. Hematite and traces of pyrite, chalcopyrite, and galena accompany the ore minerals. The Gunnar mine has produced at capacity since production started in September 1955. The mill capacity is rated at 2,000 tons/day, and to the end of 1960, production has averaged 1,709 tons/day with 92.5% recovery. The overall grade of ore milled has been 3.7 pounds U_3O_8 per ton on a total processed tonnage of 3,304,923. The open-pit has produced much of the mill feed to date, but by late 1961 all production will be from underground. Proven ore reserves at the end of 1960 contain 10,000,000 pounds uranium oxide.

All other known radioactive occurrences in the map-area are too small to be of economic value. Most of the larger ones are shown on the map. The pitchblende and secondary uranium minerals occur as thin films and vein fillings in tension joints in amphibolite (6a) and rarely in the paragneiss (2). Minor pitchblende veinlets also occur in the syenitized paragneiss (2e).

[1] Fahrig, W.F.: The Geology of the Athabasca Formation; Geol. Surv., Canada, Bull. 68 (in press).
[2] Jolliffe, A.W.: The Gunnar "A" Orebody; Trans. Can. Inst. Min. Met., vol. 59, pp. 181–185 (1956).
[3] Jolliffe, A.W., and Evoy, E.F.: "The Gunnar Mine" in Structural Geology of Canadian Ore Deposits; Can. Inst. Min. Met., vol. 2 (1957).