PHYSIOGRAPHY AND DRAINAGE

The Coppermine map area lies in north-central District of Mackenzie. The regional terrain slopes gently northward towards Coronation Gulf. In the southern region, elevations range between 600 and 450 m, and decrease from 450 m to 200 m in the central region of the map area. Approximately 12 to 23 km inland from the coast, an east-west trending escarpment rises up to 80 m above the terrain to the south, reaching up to 340 m a.s.l. Its surface slopes northward towards the coast, where it forms a coastal plain 1 to 12 km wide. Local relief varies between less than 10 and 30 m in the southern half of the map area where elongated ridges of Proterozoic sedimentary bedrock are found between subdued drumlinoid till plains and zones of till veneer and bedrock. In the northern regions cuestas rise above the surrounding terrain 10-80 m, forming steep cliffs with talus slopes. These are best developed north of the main escarpment on the mainland as well as on the islands in Coronation Gulf. The map area encompasses three basic watershed systems. In the south-central region, lakes and streams drain westward into Melville Creek, a tributary to Coppermine River. In the southernmost part of the map area, lakes and streams drain to the southeast into Ataniriik Lake which forms part of the headwaters of Asiak River. The largest drainage area consists of the remaining lakes and streams, including the Asiak and Napaaktoktok rivers which drain to the northwest south of the prominent escarpment, and then northeastward to northward into Coronation Gulf north of this escarpment. Throughout the map area, numerous small lakes occupy glacially scoured bedrock basins, as well as isolated deander through the coastal plain. Here, the rivers have incised 20 m or more locally into marine deposits.

pressions in till plains. Most streams are shallow, but several small rivers occupying major meltwater channels closer to the coast have cut into bedrock creating steep gorges. Asiak and Napaaktoktok rivers in particular begin to me-The map area lies north of treeline. Marine sediments typically support thick mats of vegetation consisting of low willow and birch shrubs and tundra heath vegetation. Shrubs may attain 2-3 m of height in sheltered areas of the Asiak and Napaaktoktok river basins. Till deposits are generally sparsely vegetated. Permafrost was encountered at depths of 25 cm below the surface in peat in late July. Visible ice is present in fine-grained marine deposits in a reticulate pattern and as lenses up to 1 m thick. In stratigraphic sections, ice wedges were encountered measuring 40 cm wide by 3 m high (Kerr et al., 1996c). The active layer in till and glaciofluvial sediments was at least 90 cm thick in August. Ice-wedge polygons are common in organic, glaciofluvial, and raised marine deposits, and rare in till. Thermokarst ponds occur locally in raised, poorly drained marine littoral sediments near sea level.

BEDROCK GEOLOGY

The study area falls within the Bear Province near its eastern boundary with the Slave Province. The Proterozoic bedrock in the southern portion of the map area (Figure 1) consists of Aphebian phyllite, greywacke, shale, stromatolitic dolomite, sandstone, siltstone and minor pillowed metabasalts which are highly folded, steeply dipping, faulted and metamorphosed (Baragar and Donaldson, 1973). Helikian basalt flows, locally containing native copper, are interstratified with minor sandstone, dipping gently towards the north (unit 1, Fig. 1). They form a wedge of bedrock between the southern sedimentary (units 2 and 4) cover and the northern assemblage of gabbro (Coronation Sills, unit 5) and Hadrynian sandstone, siltstone, and dolomite (unit 4) which also dip gently towards the north-forming cuestas that extend as islands into Coronation Gulf. The region is transected by a variety of diabase dykes including the prominent north-northwest-trending Mackenzie swarm. Rare gossans occur within the basalts. Most rock outcrops show signs of glacial abrasion, faceting, and streamlining, and surfaces are commonly weathered. All rock types have been subjected to postglacial frost shattering and heaving, but differences were noted among rock types. Siltstone and shale are typically extensively frost shattered and heaved, especially near the base of slopes. Dolomite is somewhat less frost shattered, breaking into large blocks along joints. Solution weathering is ubiquitous in the dolomite where more resistant, intercalated chert layers and lenses have relief up to 5 cm. Gabbro and basalt are not commonly shattered or heaved but may exhibit large talus slopes of toppled angular blocks along the edges of escarpments and palisades. Locally, postglacial grussification of gabbro once submerged in the postglacial sea is

associated with small 'hoodoos' up to 40 cm high. SURFICIAL SEDIMENTS

Till is the dominant surficial sediment in the map area. It consists of a matrix-supported diamicton, with silt to fine sand matrix (Fig. 2), and exhibits low to moderate compaction. Matrix grain size varies according to bedrock source; till derived from sedimentary rocks is silty whereas basalt and gabbro produced a more sandy till. Clasts range in size from small pebbles to large boulders, although medium to large pebbles predominate. Subangular to subrounded clasts are most common but some exposures, notably those close to bedrock, may be dominated by angular blocks; rounded clasts are rare. Till is composed of up to 40% clasts, but most exposures have between 10 and 30%. Striated clasts are commonly found in till. Till is divided into veneer, generally less than 2 m thick, and blanket, greater

Till veneers cover large areas containing small bedrock outcrops and conform to underlying bedrock morphology. Till veneer is generally loosely compact with variable concentrations of cobbles and boulders at the surface; where veneer is thin and discontinuous, structural bedrock features are visible. In the central and southern regions, much of the fine-grained matrix in till adjacent to eskers and meltwater channels was removed by meltwater. This commonly resulted in northwest-trending linear isolated lag deposits consisting of pebble to boulder-sized clasts less than 2 m in diameter. Till blankets drape over the underlying bedrock, forming low undulating till plains of drumlinoid fields and crag-and-tail features. These tills are relatively compact. In areas of Proterozoic clastic and carbonate bedrock, till blankets are more abundant and are commonly associated with crag-and-tail and drumlinoid features. In the central map area, there are extensive areas of large, parallel crag-and-tail and drumlinoid features, 1 to 5 km long. Just beyond the eastern margin of the Coppermine map area, near the western margin of the Kikerk map area, flutings may attain 35 km in length. Till blankets and veneers are the main surficial sediment south of the limit of marine submergence. To the north of marine limit, till is rare, only occurring at the surface of rocky uplands as isolated remnants commonly having been reworked by marine processes or covered with marine sediments. However, a few subdued drumlinoid features are evident under a cover of fine-grained marine sediments along the eastern margin of

Associated predominantly with till blankets are small morainic ridges. These occur in isolated groups in the westcentral map area and in two locations along the eastern map margin. They are a few metres high and up to tens of metres long, forming ridges aligned approximately perpendicular to ice flow. These features may represent crevasse fillings or minor recessional moraines. Frost action within the active layer has resulted in the widespread occurrence of mudboils in all till units. Mudboils are best developed on till blankets, locally occurring as stripes on gently inclined surfaces. Solifluction lobes are also common and are most pronounced near the base of drumlinoid landforms. Icewedge polygons are rarely visible on tills, probably due to a thick active layer (>1.0 m), and solifluction activity on slopes. Ice wedges rooted in till may occur, however, in depressions where peat cover is on the order of 0.25 m thick or greater. Natural water contents range from 7 to 12% of the dry weight, with an average of 10% (Fig. 3).

Glaciofluvial deposits consist of eskers, kames, and proglacial outwash (Fig. 4). Texture ranges from well to poorly sorted fine sand to cobbles and may change rapidly over short distances. Kettle lakes and ice-contact slump structures are found in many areas. Clasts are generally subrounded to rounded, and pebble to cobble lags are common on the surface of the deposits. Esker ridges have a sinuous to linear form and generally trend northwest to north, often parallel to the dominant glacial flow direction; however, below the marine limit, a large esker over 15 km long is approximately perpendicular to ice flow direction. Some eskers occur within structurally controlled bedrock gorges which formed meltwater drainage channels flowing in a variety of directions during deglaciation, such as along Melville Creek. In the southern half of the map area, eskers are scarce, occurring as small discontinuous segments, ranging from a few tens of metres long to 3-4 km. In the north-central map area south of the marine limit, larger eskers up to 10 km in length and up to 1 km wide are more common. In many cases, esker segments are linked together by outwash terraces, creating glaciofluvial complexes up to 30 km long. Some of these may be found along the present and ancestral tributaries of Asiak and Napaaktoktok rivers. Glaciofluvial sediments are rare north of the marine limit and have been modified by wave action.

Flat-topped kame terraces and outwash plains scarred by braided channels occur as isolated deposits and in close association with eskers. Outwash complexes generally parallel the dominant glacial flow direction northwestward to northward. Some outwash complexes were observed to cut across drumlinoid and craq-and-tail features, whereas others terminated at the marine limit in the form of ice-contact deltas such as along Asiak and Kugaryuak rivers. Throughout much of the southern map area, outwash deposits occur as relatively small isolated features whereas in the central regions they are fewer in number but larger in size. Some of these outwash plains are over 2 km wide and 10 km in length. They lead up to, and terminate above, the marine limit but feed into glaciomarine deltas by way of meltwater channels. As with eskers, their grain size is variable from medium to coarse sand and granules to rounded cobbles. Glaciofluvial deposits are potential resources for large volumes of granular materials. Throughout the map area, cobble and boulder lags, as well as scoured bedrock surfaces, may be associated with the perimeter of eskers and outwash deposits, and between discontinuous esker segments. Meltwater channels commonly accompany these deposits, either linking them together, feeding into or emanating from them.

The presence of permafrost typically results in the formation of ice-wedge polygons in glaciofluvial sediments; mudboils are rarely present in these relatively coarse-grained materials. Ice-wedge polygons are exceptionally well developed on most flat-topped outwash deposits. Polygons are on the order of 10 to 100 m in diameter with troughs of 0.3 to 2 m deep. Raised rims up to 1 m high are common, and some troughs are over 6 m wide. Ice-wedge polygons are seldomly visible on eskers in the map areas, perhaps due to the narrow and steep-sided nature of these Glaciomarine/marine deposits Raised glaciomarine and fossiliferous marine deposits are extensive along the coastal lowlands of Coronation Gulf

and extend up to 13 km inland, and approximately 170 m elevation. These deposits occur below the marine limit and consist primarily of four types: marine blanket, marine veneer, littoral sediments, and glaciomarine and marine deltas. Marine blanket consists of undifferentiated, massive to well stratified silt and clay which may be overlain by a thin sand layer, forming a coarsening-upward sequence, from 2 to 30 m or more in thickness. These are the most widespread deposits, may be extensively gullied, and are susceptible to retrogressive thaw flowslides due to the presence of ground ice. Surfaces are generally flat to gently undulating sloping towards the coast, may be heavily vegetated, and possess isolated cobble lags. Marine veneer consists of undifferentiated sand, silt, and clay, with variable amounts of granules to cobbles, less than 2 m in thickness. These deposits typically occur at lower elevations in close proximity to bedrock outcrops, infilling depressions, as a lag on washed till and bedrock, and may act as transitional zones giving way to marine

Littoral sediments are formed of medium to coarse sand and granules, through subrounded to rounded pebbles and cobbles to subangular and angular shingles, 1 to 3 m thick. They represent flights of raised beaches and spits, developed over fine-grained marine sediment, reworked glaciofluvial deposits, and wave-washed bedrock and till. Although they occur as high as 150 m or more, they are most commonly found below 20-40 m, such as along the lower

blankets. Marine blankets and veneers are generally massive, with textures varying from clayey silt to sandy silt (Fig.

Glaciomarine and marine deltas are variable in texture, ranging from silty clay to sand with pebbles to rounded cobbles. These perched landforms occur predominantly at or below the marine limit. A series of glaciomarine deltas define the marine limit at 170 m along the Asiak River and eastward along what are now creeks. Marine deltas also occur between 160 to 120 m along the Asiak River, as well as at lower elevations along other rivers. Thickness ranges from 5 to 20 m or more. Some deltas have well defined bottomset, foreset, and topset beds forming a typical coarsening-upward sequence which accounts for the variability in grain size. Their surfaces can be deeply scarred by abandoned fluvial channels and more rarely, kettle lake depressions where they occur at the marine limit.

Asiak River, forming extensive wetlands.

Permafrost has extensively affected the marine sediments, and mudboils are widespread on marine silts and clays. Ground ice occurs in the form of segregated and disseminated ice, as well as ice lenses up to 1 m thick. In a few areas along the coast, the fine grained marine blanket deposits are gullied and bare of vegetation cover. Retrogressive thaw flowslides are common along streams and gullies, with active slides up to 10-20 m in diameter, headwalls 1-2 m high, and mounds 2-3 m high at the toe of slopes. As with till, ice-wedge polygons are rarely visible on fine-grained marine deposits, probably due to mudboil and solifluction activity. Ice-wedge polygons are common on most raised beach and sandy littoral sediments whereas mudboils are rare. Where littoral sediments form laterally extensive veneers over marine silts or clays, tundra ponds, low-centre polygons and thermokarst depressions are common. As with the outwash plains, large ice-wedge polygons in excess of 30 m diameter with deeply incised troughs are found on the coarse glaciomarine/marine deltaic deposits. Natural water contents in the fine-grained marine sediments vary between 18 and 29%, with an average of 24% (Fig. 3).

Alluvial deposits comprise gravel- to silt-sized sediment deposited by modern streams and rivers. They range from massive to well stratified and vary in thickness from 1 to 5 m. Throughout the map area, alluvial sediments are associated with meandering and braided environments, as well as floodplains and alluvial fans, in places covered by icings. The coarse-grained alluvial sediments may also form stripes and sorted circles within perennially active stream beds. The most significant extent of alluvial sediments can be found along the lower Asiak and Napaaktoktok rivers in the form of point bar deposits.

Organic deposits consist of peat formed by the accumulation of fibrous, woody vegetative matter and muck up to 2 m or more in thickness, locally overlain by a dense grass or shrub cover. They occur predominantly in topographic depressions and valley bottoms with poor drainage, but are most noticeable below the marine limit where they overlie fine-grained marine sediments. Ice-wedge polygons are common in organic sediments, and are rooted in the underlying till, glaciofluvial, or marine deposits. Frozen ground is commonly encountered at depths greater than 30 cm

Large-scale ice flow indicators such as drumlinoid till forms, crag-and-tails, and roches moutonnées are common throughout much of the map area except for the most northern regions occupied by islands in Coronation Gulf and coastal terrain submerged by the postglacial sea. In the latter region, drumlinoid landforms are rare and subdued by the blanket of marine sediments overlying them. The most prominent and highest concentration of crag-and-tails and drumlinoid forms occurs in the central map area where relatively extensive till blankets occur. In the southern regions, isolated drumlinoids and crag-and-tails are generally associated with narrow, elongated pockets of till blanket between large zones of exposed bedrock and patches of till veneer. The majority of indicators have a northard orientation. The direction of flutings, however, shifts gradually to the northwest south of Napaaktoktok

Preservation of striae on outcrops is highly variable throughout the map area and is a function of bedrock type. Glacially scoured basalt and gabbro outcrops, prevalent in the north-central regions, have at some locations main tained their glacial polish, and frost-shattering and heaving is generally minimal. Roches moutonnées and glacial plucking on the lee side of outcrops are common. Proterozoic sedimentary rocks, such as argillite, are more susceptible to frost action and are commonly shattered along joints and outcrop edges. Striae and whaleback structures, however, are readily apparent in places. In the southwest region, striae on some Proterozoic dolomites are poorly preserved, as the surface of the bedrock has undergone solutional etching producing a recessive, irregular pitted surface. Striae can be present as faint traces on the more resistant chert layers, and large glacial grooves are commonly visible. The majority of striated outcrops show one distinct set of striae varying within 5-10° of each other. he dominant striae directions are generally north-northwestward along the eastern boundary of the map area but shift gradually more to the northwest along the western boundary of the map area. At a few sites, striae directions are at high angles to each other, but in most cases, the cross-cutting age relationship is ambiguous. Along the coast of Coronation Gulf and on the islands there is more variability in striae direction, as they range from northward to westnorthwestward. The dominant striae direction is regionally consistent with both large-scale ice-flow indicators and

the Late Wisconsin maximum (18 000 to 13 000 years BP) (Dyke and Prest, 1987; Dyke and Dredge, 1989), and all ice-flow indicators are thought to relate to the Late Wisconsin glaciation. Some aspects of the ice-flow history can be determined by the relative age of striations, as well as large-scale indicators. Figure 5 is a summary diagram of flow direction based on airphoto plots of streamlined landforms and more than 80 striae points, in addition to regional observations made by Craig (1960) and St-Onge (1995). Large-scale ice-flow indicators and striae reflect the main phase of glaciation (Fig. 5a) to the north-northwest in the eastern map area. In the western half of the map area, ice flow begins to gradually fan out towards the northwest . This dominant ice flow does not appear to have been affected by the large gabbro escarpments and continued across the area now occupied by Coronation Gulf. A similar flow relating to the main phase of the last glaciation is reported by Dredge et al. (1996)

A small number of crosscutting striations in the east-central map area indicate a subsequent, younger flow to the west-northwest (Fig. 5b). However, large-scale flutings do not appear to have been remoulded or modified by this second flow, and it probably represents a local and short-lived event in the late stages of glaciation. Closer to the coast, a second set of crosscutting striations (Fig. 5b) also indicate a later reorientation of ice flow to a more northerly direction. This may be the result of ice being drawn down to Coronation Gulf following the main phase of the last glaciation. Rare striations of different orientation likely represent local, topographically controlled ice flow either during

Radiocarbon dates on marine shells, found approximately 15 km beyond the eastern boundary of the map area, suggest that the coastal region was ice-free prior to 10 500±120 BP (GSC-5998), and that woody vegetation had established itself in Coppermine River valley 20 km to the west by at least 9150±100 BP (LV-1452; Geurts, 1985). The orientation of esker complexes, outwash terraces, and small moraines associated with deglaciation indicate that regional ice recession was towards the southeast. Deglaciation of the coastal region was accompanied by a synchronous marine incursion of isostatically depressed terrain (Kerr, 1994, 1996) and the formation of the marine limit as defined by glaciomarine deltas at approximately 170 m a.s.l. (Fig. 5c). As deglaciation progressed, local ice flow became more topographically controlled, being diverted by many escarpments. South of the marine limit, linear zones of washed till veneer and scoured bedrock dissected by meltwater channels attest to a period of considerable erosion during and following ice retreat from the map area. Extensive glaciofluvial outwash deposits also suggest that proglacial meltwaters contributed to the formation of scattered cobble to boulder lags across the region. Successive outwash plains and terraces resulted inland as ice continued to recede southeastward. A series of raised beaches and deltas record marine regression due to isostatic uplift.

PROVENANCE INVESTIGATIONS A regional provenance study based on the lithology of pebbles in till, and field observations on boulder lithologies, was undertaken to determine the relation between till and bedrock, and to estimate glacial transport distances and directions. Figure 6 shows the percentage and distribution of volcanic, basalt, and gabbro pebbles in till over igneous (volcanic rock, gabbro, basalt) and sedimentary bedrock. The greatest concentrations of gabbro, basalt, and volcanic clasts occur in areas underlain by igneous rocks, with concentrations reaching up to 90% at one site. At most sites underlain by these rock types, however, the abundance of gabbro, basalt, and volcanic clasts is generally less than 40%, and more commonly less than 20%. Concentrations as low as 6% occur as far as 20 km or more down-ice into the terrain underlain by igneous rock. The unusually low concentration of locally derived clasts in till sampled in these areas is the result of dilution by the abundance of sedimentary (argillite and dolomite) clasts derived from the southern and east-central regions. Where sedimentary rock outcrops, sedimentary clasts generally range from 80 to 100% in till, except in proximity to dykes. This high sedimentary clast concentration extends across igneous terrain, up to 30 km down-ice from sedimentary bedrock sources. This distribution of clasts coincides well with the regional north-westward ice flow direction across the map area. Glacial transport distances for sedimentary clasts can be estimated

rare. The high number of sedimentary clasts may be a function of their greater susceptibility to glacial erosion than REFERENCES

the harder, more resistant igneous rocks.

along dominant ice-flow pathways to be 30 km or more. It is difficult to assess transport for the gabbro and basalt clasts, as they are relatively few in number and till sample sites north of the main outcrop (below the marine limit) are

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> Compilation by D.E. Kerr Digital cartography by D. Viner, Geoscience Information Division

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Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada

GEOLOGICAL SURVEY OF CANADA COMMISSION GÉOLOGIQUE DU CANADA NATMAP Natural Resources Ressources naturelles Canada CARTNAT Canada's National Geoscience Mapping Program Le Programme national de cartographie géoscientifique du Canada 115°00′ 114°00′ 68°00′-Coronation Gulf BERENS I S L A N D S 50'

ICE FLOW INDICATORS **GLACIAL HISTORY** The Coppermine map area lies west of the Laurentide Ice Sheet's M'Clintock Ice Divide which developed during ice build-up or in the deglaciation phase.

Copies of this map may be obtained from the Geological Survey of Canada 601 Booth Street, Ottawa, Ontario K1A 0E8 3303-33rd Street, N.W., Calgary, Alberta T2L 2A7

LOCATION MAP

COPPERMINE (East Half) DISTRICT OF MACKENZIE NORTHWEST TERRITORIES

30'

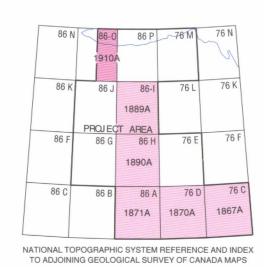
MAP 1910A

SURFICIAL GEOLOGY

Scale 1:125 000 - Échelle 1/125 000 10 Kilomètres Transverse Mercator Projection Projection transverse de Mercator CM 114°30', Scale Factor 1 MC 114°30', facteur d'échelle 1

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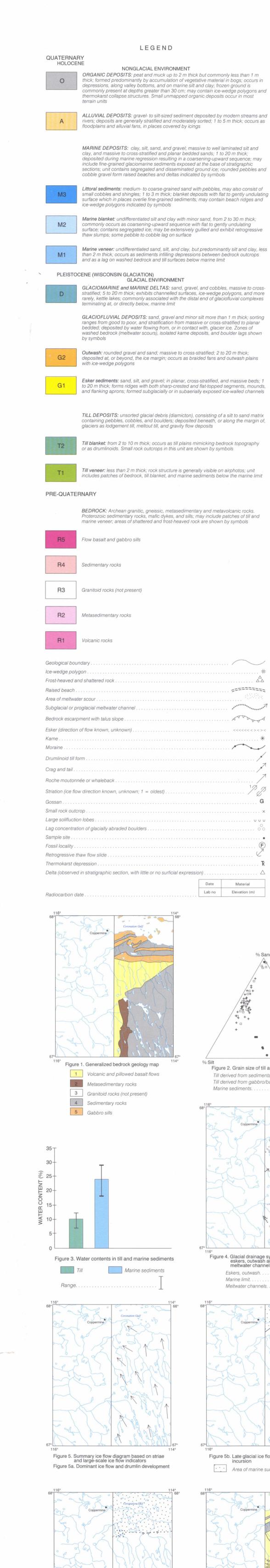
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Sector

Figure 5c. Marine limit and glaciomarine deltas

Marine limit

Glaciomarine delta △



LEGEND

NONGLACIAL ENVIRONMENT

GLACIAL ENVIRONMENT

Figure 2. Grain size of till and marine sediments Till derived from sedimentary rock. . . . Till derived from gabbro/basalt. . . Figure 4. Glacial drainage systems determined from eskers, outwash and major proglacial meltwater channels Eskers, outwash......... Meltwater channels.....

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Material

Marine sediments Figure 5. Summary ice flow diagram based on striae Figure 5b. Late glacial ice flow associated with marine and large-scale ice flow indicators Figure 5a. Dominant ice flow and drumlin development

Area of marine submergence Figure 6. Clast lithology map showing contoured percentage of gabbro and basalt clasts in till

Area of marine submergence Igneous bedrock Digital base map data compiled by Geomatics Canada, and modified by the Geoscience Information Division Copies of the topographical edition of this map area may be obtained

from the Canada Map Office, Natural Resources Canada,

Elevation in metres above mean sea level

Ottawa, Ontario, K1A 0E9 Mean magnetic declination 1997, 31°00' E, decreasing 25.1' annually. Readings vary from 30°01' E in the SE corner to 32°03' E in the NW corner of the map



Sedimentary bedrock

This map has been produced from a scanned version of the original map Reproduction par numérisation d'une carte sur papier

3076, scale 1:125 000.