

706.2', 938'-948', 973'-975' (scattered), 1246'-1270' (scattered). Stratiform veins at 421.7'-421.8', 630'-669' (scattered), 973'-975' (scattered), 975'-1303' (few, scattered). Local, scattered 1-2 mm calcite concretions. 3 x 1/2 cm pyrite concretion at 952'.

## Acid Test Results

Footage	Angle of Hole from Horizontal	Bedding Angle with Core Axis
120	49°	60°
420	56°	67°
720	63°	75°
1000	65°	79°

**Notes:** Eight thin section heels have been cut. Six composite samples have been sent in for analysis. Analytical results follow in Table ZM-1. Can tuffs be correlated with volcanism in other parts of the basin? Detailed log is available for study.

## CONDENSED GEOLOGIC LOG FOR DDH TS-1

Hole drilled at 90° angle (vertical).

0'-3'	Ice.
3'-10'	Water.
10'-32'	Gyttja.
32'-99'	Overburden.

**99'-241' T.D. Interlaminated-bedded black-dark brownish grey-grey hornfelsed siliceous-sideritic siltstone.** Minor color variations due to graphite, pyrite, and/or siderite content. Bedding angles to core axis are 35° near top to 5° at base. Schistosity is poorly developed near the top (37° to core axis), but becomes more recognizable with depth (50° to core axis). Schistosity cuts across bedding, and locally offsets it. Core is locally very broken. Pyrite varies from 2-10%, with higher disseminated amounts in darker bands. Pyrite also found along cleavage and in quartz-calcite veinlets (often subparallel to core axis). 155'-156.7' is a disturbed (folded-brecciated), recrystallized, somewhat calcareous zone with local coarse-grained calcite; very fine-grained brown sideritic mudstone; green-black serpentine-chlorite; and medium-grained altered plagioclase(?) (calcite) and pyroxene-olivine (serpentine-chlorite). Believed to be edge of dike from Duluth Complex.

**Notes:** Ten thin section heels have been cut. Rock may show

slightly increased recrystallization with depth. One composite and seven individual samples have been sent in for analysis. Analytical results follow in Table TS-1. Detailed log is available for study.

## CONDENSED GEOLOGIC LOG FOR DDH BM-2

Hole drilled at a 51° angle and an azimuth of 182°.

**0'-85' Overburden.**

**85'-97' No core.**

**97'-554.3' Medium-dark grey phyllitic siltstone.** Slightly graphitic. Very minor, thin, white siliceous-clayey altered tuff(?) laminae. Phyllite may contain up to 5% fine disseminated pyrite. Core fairly broken to 323' and sporadically to 554.3' (decreasing in general with depth). Foliation is typically 45-60° to core axis. Bedding is folded and is often at a low angle to core axis. Graphite decreases(?) with depth. Local hairline fractures-veinlets with pyrite. Local thicker, irregular quartz-pyrite veins-masses. They typically appear deformed to broken and are subsequently healed. Veins at: 212.8'-213'; 529'-540' (with few scattered irregular masses to .2'); 545-545.2' (irregular with minor vugs and chlorite); 546.4'-546.8'; 552'-555.7' (interval with irregular veining with vugs and chlorite).

**554.3'-1025' Interbedded phyllite, para- and orthoconglomerate, and siliceous-tuffaceous greywacke.** Ratio phyllite:conglomerate:greywacke = 4.0:4.7:1. Phyllite similar to above unit, except black to dark grey to dark grey-brown. Typically with good cleavage, local tuffaceous laminae and slightly calcareous. Greywacke poorly to moderately sorted, typically very siliceous with grey silty-graphitic to green chloritic matrix. Orthoconglomerate composed of coarse to fine pebbles and is generally polymictic, largely quartz pebbles, with lesser pink felsic pebbles, K-spar and plagioclase phenocrysts, phyllite pebbles, chloritic pebbles, and tuffaceous greywacke intraclasts and/or volcaniclasts. Quartz is typically sub-moderately rounded, with other pebbles less rounded. Some quartz pebbles appear to be embayed (phenocrysts?). Matrix is usually fine-grained, chloritic, and may be tuffaceous. Minor sand also in matrix. Monomictic-oligomictic "greywacke" intraclast orthoconglomerate, may be volcanoclastic (in either case, matrix is similar to clasts). Grain shapes tend to be subangular, subprismoidal. As conglomerate pebbles become finer grained, grain size distribution becomes less bimodal, and sediment grades into paraconglomerate and coarser greywackes. There is also some tendency for finer greywackes to grade into tuffaceous phyllites. In general, lithologic contacts are fairly sharp. Some contacts show slickensides and may, in part, be tectonic. Little grading within beds. Quartz pebbles-grains

often bluish (strained). Within the unit there are 20 phyllite beds between .2' and 95' with a mean thickness of 9.7' (standard deviation 21.7'), for a total thickness of 193.4'. There are 14 conglomerates and conglomeratic greywacke beds between .4' and 58.7', with a mean thickness of 16.0' (standard deviation 17.4') for a total thickness of 224.4'. There are 9 greywacke beds between .1' and 20.9' with a mean thickness of 5.3' (standard deviation 7.3') for a total thickness of 47.8'. There are 2 units, 3.3' and 1.8' thick, where the 3 rock types are more intermixed on a finer scale. Pyrite abundances vary from 1-3% in greywacke and conglomerate matrix to occasionally 5% in the phyllite as disseminations and small masses. Veins also contain minor pyrite. Veining is typically irregular to folded, and contains quartz, calcite, dolomite, chlorite, and pyrite, with local vugs and minute sphalerite crystals (628'). Very minor chalcopyrite also. Cleavage is 35-60° to core axis. Bedding occurs at all angles to bedding.

**1025'-1445.5' Mixed-interbedded, fine-coarse-grained, light to dark grey siliceous-tuffaceous greywacke, and dark grey phyllite.** Greywacke and phyllite similar to previous units. Local fine pebble conglomerate 1431'-1435' with chloritic matrix and downward coarsening. Greywacke: phyllite is equal to 3.3:1. Contacts are fairly sharp to gradational, with slip along some of them. Unit contains 26 phyllite beds from .4' to 20.5' (total thickness 96.8'), with a mean thickness of 3.7' (standard deviation 4.5'). Twenty-eight greywacke beds from .5' to 58.5' combine to give a total thickness of 322.9', with a mean thickness of 11.5' (standard deviation 13.4'). Pyrite content is from 2-5% as disseminations and within veins. Chalcopyrite occurs in trace amounts. Veining is typically quartz with lesser chlorite, pyrite and dolomite. Local muscovite, biotite, chalcopyrite, and K-feldspar alteration occur with some veins (1177'-1186', 1232'-1264', 1390'-1413', 1443.1'-1445'). Veining composes 1-20% of the core. Cleavage is typically 50° to core axis. Bedding is at all angles to core axis, but typically 10-30°.

**1445.5'-1485' Interbedded ortho- and paraconglomerate and siliceous-tuffaceous greywacke.** Rock types similar to previously described units. The lower conglomerate beds are coarser than previous units (contain small cobbles, not just pebbles), and contain chlorite-biotite pebbles, and intra-clast greywacke-volcaniclast pebbles and cobbles. Matrix is chloritic-biotitic-pyritic. Unit contains 5 greywacke beds from .8' to 9.8' (total thickness 19.5'), with a mean thickness of 3.9' (standard deviation of 4.1'). Unit contains 6 conglomeratic beds from .8' to 7.3' (total thickness 20.0'), with a mean thickness of 3.3' (standard deviation 2.7'). Pyrite amounts vary from 2-7%, with largest amounts in conglomerate matrix (and clasts?). Chalcopyrite occurs in trace amounts. Veining increases with depth from very minor, quartz-dolomite veinlets near top, to chlorite-pyrite-calcite-dolomite veinlets, to quartz-dolomite-chlorite-pyrite veins which make up 30% of the rock. Unit has more brittle deformation-tension veining than most units in hole. Bedding generally 0-30° to core axis. Separate schistosity not as obvious, but appears to subparallel bedding.

**1485'-1514.8' Interbedded dark grey phyllite and medium-dark grey siliceous-tuffaceous greywacke.** Rock types similar to those previously described. Unit contains 8 phyllite intervals from .2' to 1.8' (total thickness 8.0') with a mean thickness of 1.0' (standard deviation .6'). Unit contains 8 greywacke beds from 1.0' to 4.4' (total thickness 21.8') with a mean thickness of 2.7' (standard deviation 1.4'). Grain size variations somewhat gradational and show coarsening in different directions (*possible* tectonic reversals in slices?). Pyrite ranges from 2-5%, with a trace of chalcopyrite. Veining increases downward from minor thin quartz-dolomite veinlets grading into quartz veins with minor chlorite-dolomite-pyrite. Vuggy vein at 1500.5'-1500.6' also with calcite. Veins in basal 11' make up 20% of the rock and contain scattered biotite. 1496'-1509' contains local pink K-feldspar(?) in quartz veins adjacent to phyllite fragments, and in gouge 1511'-1511.5'. Brittle deformation and fabric similar to previous unit. Phyllite occasionally disrupted-brecciated.

**1514.8'-1585' Interbedded medium-dark grey greywacke, light-medium grey conglomerate-conglomeratic greywacke, and dark grey phyllite.** Lithologies similar to above units. Unit contains 8 beds of greywacke from .3'-24.0' (46.6' total thickness), with a mean thickness of 5.8' (standard deviation 8.2'). Unit contains 5 beds of conglomeratic rocks from .4'-9.6' (15.8' total thickness), with a mean thickness of 3.2' (standard deviation 3.9'). Phyllite occurs as 4 beds, .1', 3.7', 3.8', and .2' thick (2.0' mean, 2.1' standard deviation). Pyrite amounts vary from 2-7% with a trace of chalcopyrite. Veining consists of minor quartz-dolomite-chlorite veins, with basal 15' being composed of 5% veins, with pyrite and a few pink K-feldspar veinlets. Brittle deformation and fabric similar to above unit.

**1585'-1666' Interbedded medium grey greywacke and dark grey phyllite.** Bedding contacts tend to be fairly gradational, with one sharp contact at 1657.8'. Greywacke is fine-medium-grained, silty, siliceous, tuffaceous, poorly sorted, and consists of 5 beds from 4.5'-26.0' in thickness, with a mean thickness of 11.2' (standard deviation 8.6'). The phyllite consists of 5 beds from .5 to 13.0' thick, for a total thickness of 25' (5.0' mean, 6.0' standard deviation). Local graded beds appear to coarsen uphole. Locally intervals are brecciated(?)-intraclastic(?), especially in phyllite zones. Pyrite varies from 1-5%. Trace chalcopyrite(?). Veining is minor with quartz (often drusy) and lesser chlorite, dolomite, and pyrite. Superimposed bedding-schistosity is 45-60°, but closer to 20° near slip surfaces.

**1666'-1723' T.D. Medium grey, fine-medium grained, silty, siliceous, tuffaceous greywacke.** Minor fairly gradual clast size changes, with local graded beds coarsening uphole. Contains 1-5% pyrite and a trace of chalcopyrite(?) Minor quartz (drusy) veins with lesser chlorite, dolomite and pyrite. Superimposed bedding-schistosity 45-60°, but closer to 20° near slip surfaces.

## Acid Test Results

Footage	Drill Angle from Horizontal	Bedding Angle with Core Axis	Schistosity Angle with Core Axis
100	51°	0-5°	51°
400	52°	47°	53° (across bedding)
703	46°	-	78° (conglomerate)
1003	36°	17°	51° (subparallel with bedding)
1303	30°	7°	43° (?)
1603	30°	5°?	56°

**Notes:** Graded beds *may* indicate a major reversal in the stratigraphic section, as in drilling across a fold hinge (1485'-1514.8'?). Limb stratigraphy may not match *because* of tectonism, and/or facies changes. Sixteen thin section heels have been cut. Thirty-one composite and two individual samples, along with area rock samples, have been sent in for analysis. Analytical results follow in Table BM-2. A detailed log is available for study.

## CONDENSED GEOLOGIC LOG FOR DDH SE-3

Hole drilled at a 60° angle and an azimuth of 263°.

**0'-158' Overburden.**

**158'-163' No core.**

**163'-191' Dark grey basalt with slight red tinge near top.** Minor hairline fractures-veinlets with local hematite staining, calcite, epidote, and zeolites. Core broken at base.

**191'-198.5' Dark red-grey amygdaloidal flow top basalt with hairline fractures and brecciation.** Amygdules contain quartz, zeolites, epidote, and chlorite. Fractures contain zeolites, epidote, hematite, chlorite, quartz, talc, and Na-plagioclase(?).

**198.5'-201.3' Dark grey amygdaloidal basalt.** Slightly magnetic with 3-7% magnetite. Amygdules with quartz, zeolites, epidote and chlorite. Few fractures.

**201.3'-202.6' Dark grey basalt, nonmagnetic.**

**202.6'-222.5' Dark grey amygdaloidal basalt.** Somewhat magnetic with 7-10% magnetite. Amygdules with quartz, chlorite, and zeolites. Contains minor fractures with talc, calcite, chlorite, hematite, and zeolites. Local minor flow structure and brecciation. 1 cm, oxide layered, oxide bearing microgabbro dike with 5-60% magnetite (average 15%) at 204.5'.

**222.5'-225.6' Variegated altered basalt.** Dark grey-red-green. Inter-flow contact with hematite, epidote, zeolite, talc(?), and chlorite(?) alteration.

**225.6'-232' Dark grey, somewhat magnetic amygdaloidal hornfelsed basalt with xenoliths(?), and phenocrysts.** Contains 7-10% magnetite. Amygdules contain quartz, chlorite, calcite, zeolites. Plagioclase phenocrysts to 1 cm. Xenoliths(?) slightly coarser (microgabbro?). Could also be related to amygdules or more volatile rich areas. Minor fractures with talc, epidote, calcite, and zeolites. Basalt texture almost microgabbroic, granular.

**232'-237' Dark grey, somewhat magnetic hornfelsed basalt with xenoliths(?) and phenocrysts.** Similar to above unit except no amygdules. Fractures contain calcite with quartz, K-feldspar, and plagioclase toward base of unit.

**237'-244' Dark grey, slightly magnetic hornfelsed basalt with xenoliths(?) and phenocrysts.** Similar to above unit except only 3-7% magnetite. Contains scattered fine-medium-grained diorite-granodiorite dikes (largest one 239'-239.5'). Magnetic oxides decrease toward base. Basal footage contains trace amounts of pyrite-pyrrhotite.

**244'-245' Fine-grained, chilled, somewhat magnetic, dark grey, noritic(?) gabbro.** 7-10(?) magnetite.

**245'-288.5' Dark grey, medium-grained gabbro with oxides.** Slightly to somewhat magnetic with trace to 10% oxides (averages 7%). Plagioclase 40-50%, clinopyroxene 25-35%, altered orthopyroxene-clinopyroxene 15-25%. Subophitic(?). Green pyroxene alteration is chloritic, serpentinitic, and deuteric(?); more noticeable near hairline fractures. Hairline fractures with chlorite, serpentine, calcite, and talc. Plagioclase locally albitized (also with K-feldspar). 1 cm basaltic dike at 281' and 1 cm altered brecciated basaltic dike at 282'. Locally pegmatoidal.

**288.5'-303' Dark grey, medium-coarse-grained noritic(?) gabbro with magnetite (7-10%).** Similar to above unit except 25-35% greenish, altered pyroxene slightly coarser grained; and fewer hairline fractures cutting rock, with associated alteration (calcite, chlorite).

**303'-314' Dark grey, medium-coarse-grained gabbro with 7-10% magnetite.** Similar to 245'-288.5' but without hairline fractures and associated alteration minerals.

**314'-365' Dark grey, medium-coarse-grained noritic(?) gabbro with 7-10% magnetite.** Similar to 288.5'-303', except contains more hairline fractures; and associated calcite, talc, chlorite, Na-plagioclase, and dolomite. Some with slickensides.

**365'-403' T.D. Dark grey, medium-coarse-grained gabbro with 7-10% magnetite.** Similar to 245'-288.5'. 370.5'-381' locally brecciated with corroded plagioclase altered to Na-plagioclase and K-feldspar with a chloritic matrix and slightly less magnetite. Hairline fractures and alteration decrease with depth.