Davidson
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CLIMAX MOLYBDENUM COMPANY
A DIVISION OF AMAX INC.

INTER-OFFICE MEMORANDUM

CONFIDENTIAL

SUBJECT: DESCRIPTION OF THE GRANODIORITE SILL AND REVISED CLASSIFICATION

DATE: 7/13/79

TO: R. C. Steininger

FROM: Dorothy Atkinson

At Yorke-Hardy a granodiorite sill is host to higher grade mineralization, to be tested in the 1979 drill program. This compilation, of existing files, drill logs, and information obtained by relogging some of the core in storage during June, 1979, was made to gain familiarity with the divisions of the granodiorite sheet used in logging and mapping to date. The present classification is useful; however, the descriptions need clarifying.

The age of the sheet is tentatively Upper Jurassic. Jonson (1967) notes the sheet exhibits both concordant and discordant relationships with the Jurassic Hazelton volcanic rocks it intrudes. The granodiorite does not crop out. It has been partially defined by drilling and exposures underground (Sections 14000E, 15000E, 16000E, 17200N, 18000N, and 18600N and plan of the 3500 Level) to occur on our grid from 13000E (DDH 102) to 17550E (DDH 65) and from 19800N (DDH 102) to 16400N (DDH 16). The granodiorite thickens from approximately 250 feet at its northwest known limit to 1,800 feet at 16000E 18000N. The domed top accounts for this increase while the base remains relatively planar dipping at approximately 30° SE to produce a wedge or lens shaped sheet. The sheet thins again to approximately 1,000 feet east and southward and the dip steepens to 70° SE.

Within the sheet three main textural zones are recognised, interpreted as products of igneous differentiation (Jonson, et al., 1968). These are Phase 1, Phase 5, and Phase 6. All are irregular, discontinuous, and repetitious. Cross sections (14000E, 15000E, 16000E, 17200N, 18000N, and 18600N) and plan view (3500 Level) show their general dis-

tribution over the grid area to be drilled summer 1979. The more complicated geological section, 15000E, is probably due to an abundance of data as compared to other sections. Another phase, Phase 7, occurs locally as blocks within other phases. The present numbering system results from rewriting an earlier classification, prior to DDH 42, 1966 (to date, June 1979, there are 146 drill holes), in which phases 2, 3, and 4 were removed. Obviously, this is confusing. The present phases should be renumbered, presumably 1, 2, 3, and 4 (rather than 1, 5, 6, and 7). However, as less than 8000 feet of core is to be drilled during 1979 spaced between previously logged drill fans, I plan to retain the present system for ease of correlation.

Division of the sheet into phases and their subphases is based on the following megascopic criteria:

1. Colour
2. Grain size
3. Texture (includes porphyritic, granophyric, aplitic, and granitic)

Not surprisingly in this type of deposit rock textures and contacts between phases and subphases are masked by alteration, particularly the dark chlorite-magnetite type. Contacts between phases are both gradational and sharp. Description of each phase follows including rewriting, chiefly simplifying, the existing classification. It should be noted that phases and subphases are often mixed within the sheet.

THE NORMAL GRANODIORITE, PHASE 6

The majority of the sheet defined to date consists of Phase 6 rocks. At the southern known limit of the sheet, Phase 6 may occupy the entire width of the sheet (Section 17200N). As the sheet thickens northwards toward 18000N, Phase 6 forms the lower portion of the sheet, attaining thicknesses of 1,400 feet. Continuing north and east, Phase 6 thins and pinches out (Sections 18600N, 14000E, 15000E, and 16000E).

Phase 6 rocks are generally mottled medium to dark green, gray, and occasionally pink or brown. It is thought the original mafic content may have been 5 to 10 percent and some chlorite ± magnetite ± pyrite ± epidote aggregates probably represent orthomagmatic mafic mineral sites. The mafic content is variable, numerous secondary mafic minerals occur as wisps, shreds, and clots, and in fractures and as replacements. Grain size ranges from fine to medium, 0.5 to 2 mm, most commonly close to 1 mm. Texture is granitic, interlocking, subhedral and anhedral feldspar and quartz grains. This often appears diffuse due to alteration clouding both texture and individual grains. Many quartz feldspar crystals show granophyric and micrographic intergrowth. Jonson et al (1968) noted some of the intergrowths are obviously post-fabric. To date I have not observed this. Phenocrysts are locally present up to 5 mm in size.

Jonson et al (1968) and Bright and Jonson (1966) report Phase 6 as consisting of 30 percent quartz, 18 percent orthoclase, 42 percent plagioclase (An_{32}), and 10 percent ferromagnesium minerals (Table 1). In company files only one Phase 6 thin section is reported point counted:

TS	Points	Quartz	Orthoclase	Plagioclase
26 2255	544	30%	22%	48% (An_{30})

No mafic minerals are reported. I have looked at some of the thin sections and stained one core sample for K. Some of the K-feldspar is secondary, occurring in veins and halos. Bright and Jonson (1976) published an analysis (Table 1) of an average of nine Phase 6 rocks, reporting 2 percent K_2O.

Phase 6, subphase 3 (6-3) has a reduced mafic content and is transitional to Phase 1 rocks. Phase 6, subphase 5 (6-5) is porphyritic. Subhedral quartz phenocrysts range in size to 2 mm and form 1 to 3 percent of the rock. Subhedral feldspars, dominantly plagioclase, up to 4 mm in size, make up 4 to 7 percent of the rock. Phase 6, subphase 6 is the characteristic normal granodiorite, the most common subphase.

THE APLITIC PHASE, PHASE 1

Jonson compiled the original classification and he used the term aplite for rocks with a fine grained granitic texture.

Phase 1 rocks form the northeastern edge of the sheet (Section 14000E, 15000E, and 16000E and plan of 3500 Level), are up to 800 feet thick and dip steeply north. This is discordant with the sheet. Contacts with Phase 1 rocks are often vague, grading imperceptibly into other phases. Due to an absence of ferromagnesium minerals, Phase 1 rocks are very light coloured, ranging from white, light grey to greenish grey, tan, and buff. Grain size varies from very fine to medium, it is typically even, fine grained (0.5 mm), and saccharoidal. Subphase divisions are based on texture and alteration.

Phase 1 rocks have been described in company and published reports (Bright and Jonson, 1976) as having 33 percent quartz, 27 percent orthoclase, and 40 percent plagioclase (An_{32}) (Table 1). This data stems from point counting one thin section, 15-1425, a Phase 1 rock characterized by granophyric intergrowth. There is variability in reported orthomagmatic plagioclase compositions from An_{33} to An_{10}. Having stained porphyritic, granophyric, and aplitic Phase 1 varieties for K (DDH 124, 440 feet and 450 feet, DDH 98, 475 feet, DDH 55, 148 feet, underground 17100E 18750N) and looked at some of the existing thin sections including 15-1425, I doubt the orthoclase content approaches 27 percent. Many Phase 1 rocks contain very little to no K-feldspar. Alteration in thin section varies from weak to intense. Plagioclase twinning is often obscured. Primary K-feldspar sites may have been lost during Na and/or Ca metasomatism; however, this seems unlikely as K is abundant and K-feldspar is present within fractures and alteration halos. Bright and Jonson (1976) published an analysis (Table 1) of an average of four Phase 1 rocks, reporting 1.8 percent K_2O. This is low for a granodiorite, especially if it included rock affected by K metasomatism. It is suggested Phase 1 rocks consist of 30 to 35 percent quartz, 60 to 65 percent plagioclase (An_{32-34}), and up to 10 percent orthoclase, and are therefore light colored quartz diorites or tonalites. Obviously this must be backed up by point counts.

Phase 1, subphase 1 (1-1) is characterized by granophyric intergrowth of quartz and feldspar. In core and especially in thin section, these can be spectacular. Grain size is fine to medium grained, reaching 1.5 mm. According to Jonson et al (1968) some of the granophyric intergrowths are

post-fabric, the result of recrystallization. Phase 1, subphase 2 (1-2) has a fine grained (0.5 mm) aplitic to granitic texture (that is granular, sugary anhedral to subhedral and rarely euhedral quartz and feldspar grains). Phase 1, subphase 3 (1-3) contains ferromagnesium minerals and is gradational with Phase 6 rocks. This is a compositional division based on colour. Texture may be aplitic, granitic, porphyritic, or granophyric. Phase 1, subphase 5 (1-5) is characterized by quartz and feldspar phenocrysts in a fine grained groundmass that may be granitic to aplitic and sometimes granophyric. Subhedral feldspar laths of 1 to 2 mm form 5 to 15 percent of the rock and quartz eyes of 1 to 1.5 mm form 2 to 10 percent. Phase 1, subphase 8 (1-8) contains alteration spots or ovoid clots, termed Appaloosa texture. Clots range in size from 0.5 cm to 10 cm, and consist of any or all of the following minerals: garnet, epidote, sericite, carbonate, chlorite, quartz, and magnetite. The Appaloosa texture was defined by Jonson, Davidson, and Daughty (1968) to occur at the south edge of Phase 1 rocks at or near the contact with Phase 6. The garnet composition is unknown. In thin section it is fine grained and is probably replacing feldspar. It is thought garnet formation is the result of contact metamorphism possibly due to intrusion of the quartz monzonite stock. Subphase 1-8 is especially impressive observed on mine walls where it may form up to 30 percent of the rock with pink garnet-quartz centres rimmed by bright green epidote.

The classification used for DDH 42-141 (attached) is often too limited. For example, 1-1 and 1-2 are described as non-porphyritic and 1-2 as being characterized by an absence of well developed granophyric intergrowth. This is too strict as both 1-1 and 1-2 often contain feldspar and quartz phenocrysts and locally 1-2 may be granophyric. Textures are commonly mixed, the dominant type being used for subdividing. It should be emphasized again that the original description of the Aplitic Phase is a fine grained rock with granitic texture. I have used the term aplitic for fine grained, granular (equidimensional), or sugary, allotriomorphic (consisting mainly of anhedral grains) texture, and granitic for granular hypidiomorphic (a mixture of anhedral and subhedral and/or euhedral grains) texture in describing the subphases.

THE PORPHYRITIC PHASE, PHASE 5

Phase 5 generally overlies Phase 6 and in places underlies Phase 1 (Sections 14000E, 15000E, and 16000E). Drilling has located it from 17600N to 18600N with maximum development at 18000N. At its western limit, approximately 14000E, it may be 50 to 100 feet wide thickening eastward to 800 feet, forming the upper and central portion of the sheet (Sections 15000E and 18000N). Thinning again east and northward, it pinches out at approximately 16000E 18200N. East of 16500E between 17800N and 18000N, Phase 5 is again found in drill core to its presently defined eastern limit, 17500E (DDH 65, 17800N), where it is 300 feet thick, sandwiched between Phase 1 and Phase 6.

Although contacts may be masked by alteration and are therefore vague, Phase 5 is found in sharp intrusive contact with Phases 1 and 6. This is often observed where narrow Phase 5 dikes cross cut other phases close to major zones of Phase 5.

Phase 5 rocks are light colored, usually gray to greenish gray. Mafic minerals are present, making Phase 5 darker than Phase 1. It is not known whether any of the mafic minerals, clots and shreds of chlorite, pyrite, and magnetite, represent original mafic mineral sites. The groundmass is characteristically aphanitic to fine-grained, rarely reaching 0.5 mm, and has granitic texture. Phenocrysts are feldspar and quartz. Feldspars vary in color from buff to greenish gray, are occasionally euhedral, usually subhedral, and large phenocrysts (+4 mm) may be ragged. They range in size from 1.0 to 2.5 mm and rarely to 5 mm, and form 10 to 30 percent of the rock. Quartz phenocrysts are typically rounded glassy eyes, but euhedral, six sided, and square quartz crystals are locally common. They range in size from 0.75 to 1.25 mm, may reach 2.5 mm, and form 1 to 5 percent, rarely up to 10 percent, of the rock. In some Phase 5 rocks it appears there are two phenocryst generations, one of small 0.3 to 0.5 mm quartz and feldspars, and a second of 1 mm and greater. Phase 5 is similar to 1-5 but contrasts in having a finer grained groundmass and larger, more numerous feldspar phenocrysts.

Jonson et al. (1968) and Bright and Jonson (1976) state that Phase 5 consists of 30 percent quartz, 30 percent K-feldspar, 37 percent plagioclase (An_{30}), and 3 percent mafics (Table 1) and they noted the ratio of plagioclase to K-feldspar is very variable. In company reports two thin sections are reported point counted:

TS	points	quartz	K-feldspar	plagioclase	mafics
16-1176 (missing)	1000	34.9	35.2	34.7(An_{30})	2.6
80-1067	1000	30	19.7	43.7(An_{34})	1.8

Bright and Jonson (1976) published one analysis of Phase 5 showing it contains 3.4 percent K_2O (Table 1). In thin section, all feldspar phenocrysts are plagioclase. K-feldspar may form some of the groundmass. Staining for potassium shows some examples have K-rich groundmasses; however, this may be due to alteration rather than primary orthoclase content. I have stained two samples (DDH 98-700 ft., DDH 126-500 ft.); these contain respectively approximately 5 percent and 60 percent potassium stain. Point counts are required to determine the mineralogy of Phase 5 but again, like Phase 1, it seems likely that the primary orthoclase content is much less than 30 percent.

Phase 5, subphase 3 (5-3) is gradational with 6-5, being mafic rich. Like 1-3, this is a compositional division based on color. Phase 5 subphase 4 (5-4) is similar to 1-5. 5-4 is deficient in mafic minerals compared to other Phase 5 rocks, but is found in close association with Phase 5. Phase 5, subphase 5 (5-5) is the most common subphase, and as described earlier it is distinctly porphyritic. The Appaloosa texture, described in conjunction with Phase 1 is also found in Phase 5 rocks.

The classification used for logging DDH 42-146 describes Phase 5 rocks as having aplitic and sugarey groundmass. This may lead to confusion with the Aplitic Phase 1; therefore, I suggest removing the terms and using fine-grained to aphanitic as used in the classification to 1966.

THE DIORITIC PHASE, PHASE 7

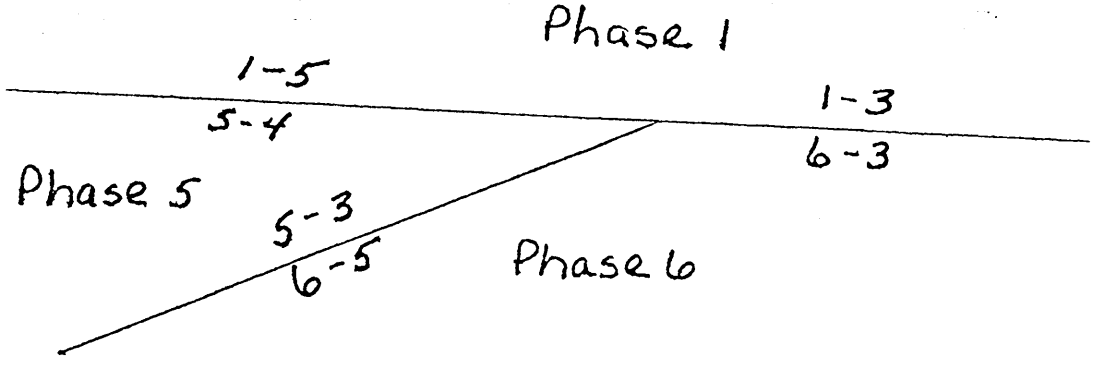
Phase 7 is a dark green to black diorite occurring as blocks within other phases. Block zones are described as generally trending east and dipping steeply. Blocks vary in size, and Jonson (1966) reports blocks to 10 feet in length. They are usually equidimensional, but Jonson describes some that are several feet long yet only inches wide. Contacts with other phases are both sharp and gradational; grain size is fine- to medium-grained with a granitic texture. Some of the blocks probably represent zones of chlorite-magnetite; however, in thin section, Phase 7 typically contains less than 5 percent quartz and are, therefore, not thought to be alteration products of other phases. Phase 7 consists of approximately 60 percent plagioclase (An_{30-38}) and 35 to 40 percent mafic minerals, chiefly chlorite with hornblende, minor magnetite, and pyrite. Two point counts are recorded:

TS	points	quartz	K-feldspar	plagioclase	mafic minerals
26 2112	1000	1	---	59.3(An_{28})	39.8
27 2674	500	3.8	15	45.4(An_{38})	35.8

K-feldspar in TS 27 2674 is associated with a vein and alteration halo. Blocks are usually at least weakly magnetic and are often crosscut by magnetite-chlorite veins occasionally rimmed by bleached halos. Volcanic xenoliths occur within the sheet, especially at the margins. These are easily confused with Phase 7, but are characteristically finer grained and may show a weak foliation.

CONTACTS BETWEEN PHASES

Phases often grade into each other by color change, either by increasing or decreasing their mafic mineral content. The gradational phases are depicted idealistically in the following cross section:



It should be noted this rarely occurs and alteration, both bleaching and mafic types, as previously mentioned, confuse distinction between phases.

SUMMARY OF GRANODIORITE DIVISIONS

Phase 6, the Normal Granodiorite, is mottled medium- to dark-green and gray, contains 5 to 10 percent mafic minerals, is fine- to medium-grained with granitic texture, and may be granophyric and/or weakly (less than 5 percent) porphyritic. Subphases are:

- 6-6 Normal Granodiorite, most common type, as above.
- 6-5 Porphyritic Normal Granodiorite, phenocryst content greater than 5 percent.
- 6-3 Lighter colored Normal Granodiorite, containing few mafic minerals, transitional to Phase 1.

Phase 1, the Aplitic Phase, is very light colored, lacks mafic minerals, and its fine-grained granular texture may be granophyric and/or weakly porphyritic. Subphases are:

- 1-1 Characterized by well developed granophyric intergrowths of quartz and feldspar.
- 1-2 Texture is aplitic to granitic.
- 1-3 Darker colored, mafic minerals present, transitional to Phase 6.
- 1-5 Porphyritic, containing more than 5 percent phenocrysts.
- 1-8 Characterized by Appaloosa texture, prominent ovoid clots of garnet, epidote, chlorite, and sericite.

Phase 5, the Porphyritic Phase, is light colored, containing some mafic minerals, distinctly porphyritic containing up to 30 percent subhedral 1 to 2.5 mm plagioclase phenocrysts and up to 5 percent 1 mm quartz eyes in a very fine grained to aphanitic groundmass. Texture of the groundmass is granitic. Subphases are:

5-5 The most common type, as above.
5-3 Darker colored with moderate (approximately 5 percent) mafic mineral content, similar to 6-5.
5-4 Lighter colored, mafic minerals are rare, similar to 1-5.

Phase 7, the Dioritic Phase, occurs as blocks with other phases. It is dark green to black, contains 30 to 40 percent mafic minerals, and is fine- to medium-grained with granitic texture.

Dorothy Atkinson

DA/dr
Attachments (as indicated)
CC: R. C. Steininger
W. H. White

Table 1 - Partial chemical analysis, norms, and modes of the Granodiorite Sheet (from Bright and Jonson, 1976).

MAJOR OXIDES

	Phase 6	Phase 1	Phase 5
SiO_2	72.6	76.5	78.3
Al_2O_3	12.0	10.6	10.3
Fe_2O_3	2.6	1.5	3.0
MgO	0.8	0.2	0.4
CaO	2.2	1.5	1.0
Na_2O	4.5	3.9	3.9
K_2O	2.0	1.8	3.4
Total	96.7	96.0	100.3
	Avg. of 9 anals.	Avg. of 4 anals.	

CIPW NORMS

Q	33.8	43.7	40.8
Or	11.8	10.6	20.1
Ab	38.1	33.0	33.0
An	6.7	6.1	0.6
	(An_{15})	(An_{16})	(An_2)
Mt*	2.5	1.4	2.9
Di	3.3	1.0	2.1
Wo	---	---	0.7
Hy	0.5	---	---
NS	---	---	---

Table 1 (cont'd.)

MODES

	Phase 6	Phase 1	Phase 5
Quartz	30	33	30
Orthoclase	18	27	30
Plagioclase	42 (An_{32})	40 (An_{32})	37 (An_{32})
Amphibole-Biotite	--	--	--
Altered ferromags.	10	--	3

CLASSIFICATION TABLE

Rock classification of Granodiorite Sheet used in 3500 Level mapping and in logging DDH 42-146.

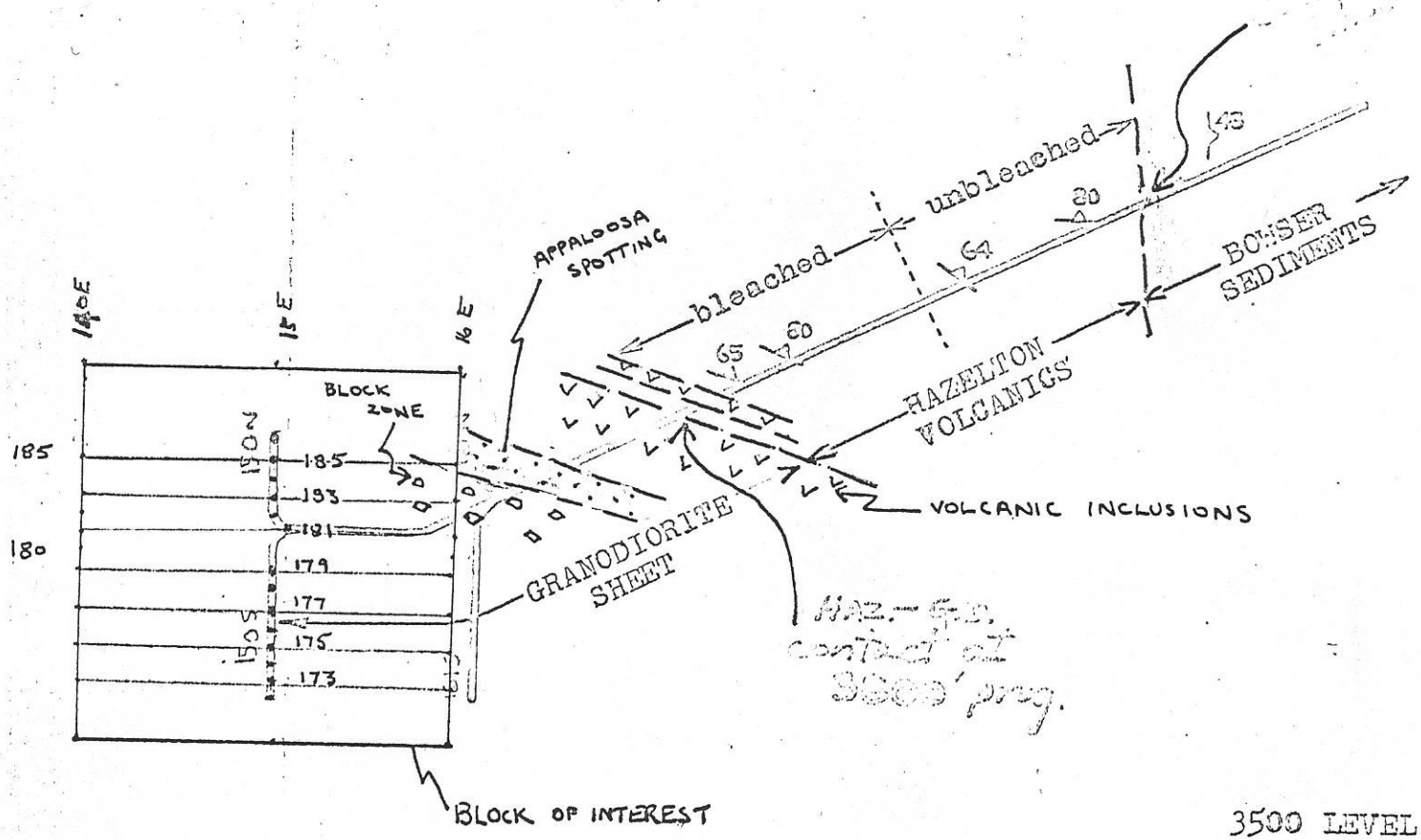
GRANODIORITE

(Flesh 757)	1-1 Aplitic Phase. No mafics, non-porphyritic, characterized by well-developed granophyric growths.
(Flesh 757)	1-2 Aplitic Phase. No mafics, non-porphyritic, characterized by absence of well developed granophyric intergrowths.
(Light Green 738-1/2)	1-3 Aplitic Phase. Mafic content increased and is transitional to Phase 6 type rocks. May be granophyric and/or weakly prophyritic.
(Flesh 757)	1-5 Porphyritic Aplitic Phase.
(Flesh 757) (Sky Blue 740-1/2)	1-8 Appaloosa Aplite. Characterized by prominent ovoid clots of any or all of garnet, epidote, chlorite, sericite
(Light Green 738)	6-3 Normal Granodiorite. Mafic content reduced and is transitional to Phase 1 rocks. May be granophyric and/or weakly porphyritic.
(Grass Green 738)	6-5 Porphyritic Normal Granodiorite.
(Grass Green 738)	6-6 Normal Granodiorite. May be weakly granophyric and/or porphyritic.
(Green 739)	7-7 Dioritic Phase. Often confused with volcanic "Block Zone" map unit.
(Green 739) (Host of 757, 738 or 738)	"Block Zone". Blocks of 7 in either Phase 1 or Phase 6 rocks.
(Yellow Ochre 736) (Hatching Grass Green 738)	5-3 Porphyritic Phase. Mafics present in moderate amounts. Groundmass aplitic. Similar to 6-5 but intimately associated with Phase 5 rocks.

CLASSIFICATION TABLE (cont'd.)

(Yellow Ochre 736)	5-4	Porphyritic Phase. As above but mafic difficient. Similar to 1-5 but intimately associated with Phase 5 rocks.
(Yellow Ochre 736)	5-5	Porphyritic Phase. Characterized by well developed porphyritic texture and very fine grained sugary groundmass.

→ proposed 1979 drill stations
• existing drill stations.



3500 LEVEL

SKETCH OF GENERALIZED GEOLOGY

SCALE 1 inch: 1000 ft