MAFIC DIKES OF THE VIRGINIA HORN REGION

by

Michael Don Schlagel

A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Arts (Geology)
at
GUSTAVUS ADOLPHUS COLLEGE

1995

Mafic Dikes of the Virginia Horn Region

by
Michael Don Schlagel
under the supervision of Dr. James Welsh

ABSTRACT

A number of mafic dikes have been identified by Welsh (pers. comm.) during geologic mapping in the Virginia Horn region of northeastern Minnesota. Petrographic study of these dikes reveals three distinct dike suites. The most abundant of these are of gabbroic composition, and are characterized by interstitial quartz, some of which is granophyrically intergrown with plagioclase. They appear to belong to the early Proterozoic Kenora-Kabetogama swarm of northern Minnesota and southern Canada. A second set of dikes is characterized by the presence of biotite and amphibole. These are interpreted as lamprophyres, and are most likely Archean in age. A third dike set is composed of plagioclase-rich metabasalts which are characterized by plagioclase and augite microphenocrysts. Mafic minerals in these rocks have been partially converted to chlorite and possibly actinolite. The age of these dikes is uncertain. They appear to have undergone greenschist facies metamorphism typical of Archean rocks, however they have not been affected by the deformation associated with that event.

ACKNOWLEDGMENTS

I would like to thank Jim for all of his input, time, and patience throughout the years and on this project especially. I would also like to acknowledge Dr. Robert L. Hybertson for the use of MSU's photographing microscope and last but not least, Julie Fitzke, with the help of my field work this past summer. Thanks to everyone who has given me help on this project.

TABLE OF CONTENTS

FIGURES

INTRODUCTION

A number of small mafic dikes have been identified by Welsh (pers. comm.) during geologic mapping of the Virginia Horn region of northeastern Minnesota (Figure 1). Field relations would indicate that some, if not all of the dikes belong to the Early Proterozoic Kenora-Kabetogama dike swarm of northern Minnesota and southern Canada (Southwick and Day, 1982). However, dikes with Archean and Keweenawan ages are known in Northeastern Minnesota, therefore dikes belonging to these systems must be considered. Some of these dikes may also be lamprophyres. Lamprophyres have been described in northeastern Minnesota, and have been identified in drill cores in the region (DNR drill core summaries).

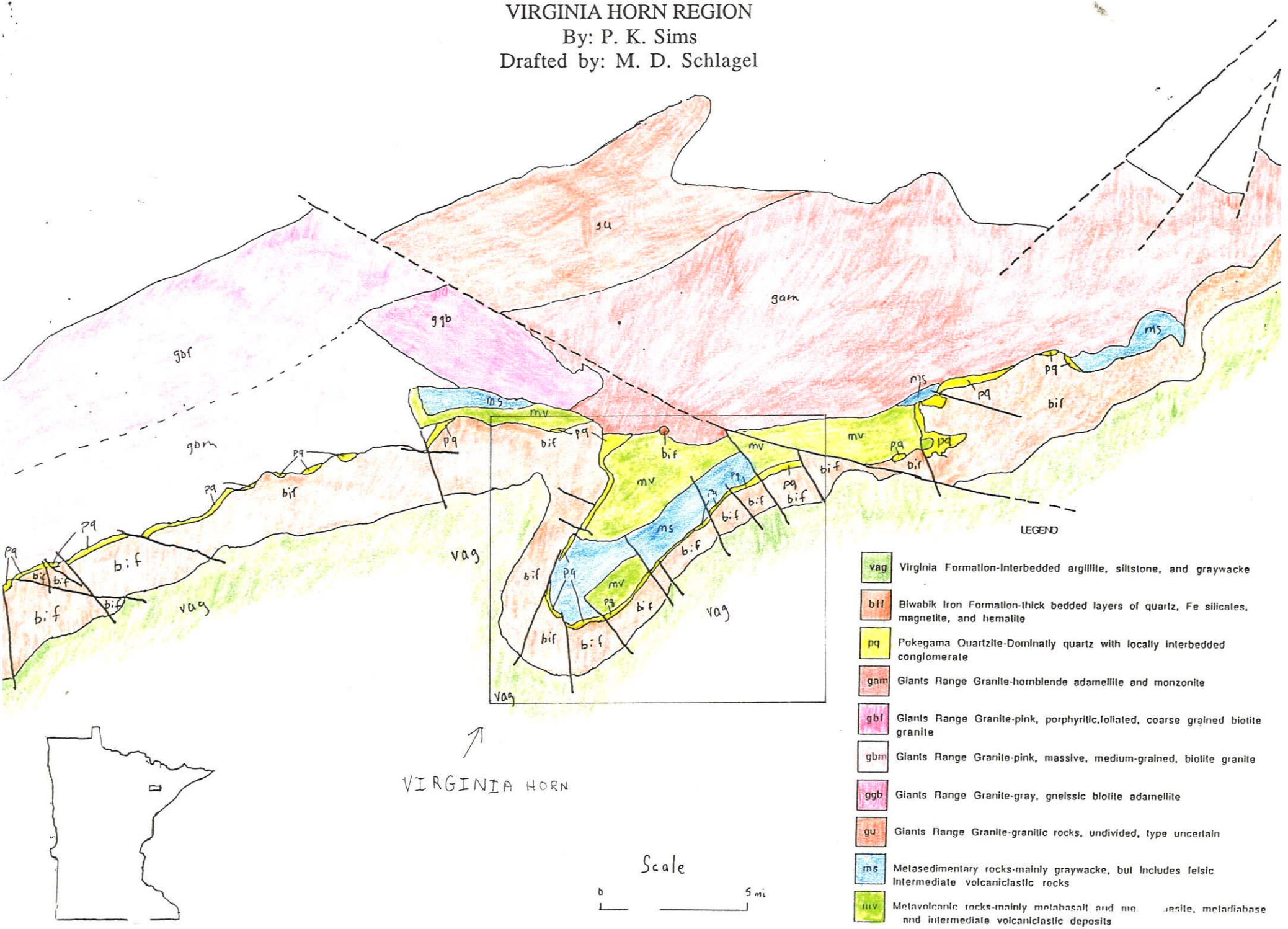
The purpose of this study is to examine these dikes petrographically. Careful description of the mineralogy and textures of the dikes may help determine whether more than one suite of dikes is present in the area, and whether these dikes may be correlated with known dike swarms.

REGIONAL GEOLOGY

The Virginia Horn region of northern Minnesota refers to an anticline-syncline structure in the Bikwabik Iron Formation (Welsh et. al., 1991) occurring in northeastern Minnesota in the vicinity of the towns of Virginia, Eveleth, and Gilbert (Figure 1). Archean metasedimentary and metavolcanic supracrustal rocks and

GEOLOGIC MAP OF MINNESOTA
VIRGINIA HORN REGION

By: P. K. Sims
Drafted by: M. D. Schlagel



associated minor felsic intrusives are exposed in the core of the anticline (Welsh et. al., 1991). To the North, these rocks are intruded by the Giants Range Batholith. The Giants Range Batholith is a large granitic complex of Archean age (Sims and Viswanathan, 1972), and is composed mostly of quartz-bearing granitoid rocks ranging in composition from tonalites to granites (Sims and Viswanathan, 1972).

Proterozoic units in the Virginia Horn area unconformably overlie the Archean rocks and include from oldest to youngest: the Pokegama Quartzite, the Biwabik Iron Formation, and the Virginia Slate.

Both Archean and Proterozoic units have been intruded by mafic intrusive rocks of the Keweenawan system of rocks which are associated with the mid-continent rift further to the east. Three major sets of dikes have been described throughout much of northeastern Minnesota. Dike swarms recognized in the region include the Early Proterozoic Kenora-Kabetogama swarm, lamprophyres of both Archean and Proterozoic ages, and Keweenawan dikes relating to the mid-continent rift event.

The Early Proterozoic Kenora-Kabetogama dike swarm forms a major north-northwest oriented swarm extending 300 km from the Mesabi Iron Range in Minnesota to the vicinity of Kenora, Ontario (Southwick and Day, 1982).

Lamprophyres have also been described throughout much of northeastern Minnesota (Sims and Mudrey, 1972). The lamprophyres are mostly hornblendic having either granular or porphyritic

textures, with augite and biotite bearing lamprophyres being less common (Sims and Mudrey, Jr., 1972).

Numerous basaltic dikes are associated with the Keweenawan rift events (LaBerge, 1994). These dikes have been described mostly to the east of the study area

PREVIOUS WORK

Welsh has done detailed geologic mapping in the Virginia Horn region (Welsh et. al., 1991). As a result of his work, he has identified a number of dikes in the area. Field relations suggest two dike sets, Archean and Proterozoic in age.

The Kenora-Kabetogama dike swarm has been described on the basis of the geology, petrology, and compositional characteristics by Southwick and Day (1982) and Southwick and Halls (1986). These dikes are geologically associated with the deformational, metamorphic, and plutonic events of the late Archean (2550-2700 Ma). These dikes have been dated at 2715-2120 Ma (Southwick and Day, 1982).

Texturally and compositionally, the interiors of the larger dikes in the Kenora-Kabetogama swarm are characterized by diorite, but smaller dikes range from gabbroic to dioritic in composition and are dominantly hypidiomorphic granular except for chilled margins (Southwick and Day, 1983). Quartz and plagioclase form a striking graphic intergrowth in the interior portions of some dikes. Southwick and Day (1982) identified two distinct compositional

trends in the dikes. Both dike trends are Fe-rich tholeiites, but one of the groups is richer in Ti, Fe, and Na and the other is somewhat lower in Mg and Si.

Keweenawan dikes are mainly olivine diabases and gabbros and plagioclase-porphyritic and aphanitic basalts (Green, 1972). They are typical of continental quartz and olivine tholeiites (Green, 1972).

Lamprophyres in northeastern Minnesotahave been described by Sims and Mudrey (1972) in northeastern Minnesota as mainly hornblendic having either granular or porphyritic textures with augite and biotite-rich lamprophyres being less common. The lamprophyres in the region occur in the Archean and Proterozoic (Sims and Mudrey, 1972).

METHODS

Samples were collected from the study area and thin sections were prepared for analysis. The petrographic microscope was used to study the thin sections, and after identification of the original mineralogy, point counts were taken on most of the samples. An appendix is located at the end of the paper describing the samples.

DATA RESULTS

Three different dike types were identified: gabbroic, biotite and amphibole bearing (lamprophyre?), and metabasalt.

The most abundant of the samples are gabbroic to microgabbroic, containing principally plagioclase ranging from 40-75 % and augite ranging from 30-40 %. and are characterized by small amounts of interstitial quartz, some micrographically intergrown with plagioclase. Plagioclase forms euhedral to subhedral laths, and are intergrown with blocky, subophitic augites (Figure 3). Opaques minerals are prominent ranging to 9-2 % and generally interstitial. In more altered samples, they are altered to leucoxene and show rhombohedral "striations," indicating that they were most likely ilmenites. The rocks are moderately to strongly altered, with augites being altered to actinolite and chlorite. Secondary biotite may be intergrown with chlorite and plagioclase is saussuritized.

The second dike type recognized is a biotite-rich porphyritic rock probably a lamprophyre. Phenocrysts in the rocks are pale green amphibole (possibly actinolitic hornblende), partially to totally replaced by biotite (Figure 2). The matrix consists of smaller biotite crystals, amphibole, and untwinned feldspar (possibly alkali feldspar). Near the margins of the dikes, biotite becomes more abundant, coarser grained, and amphiboles decrease or maybe all amphibole has been replaced by biotite, and muscovite and apatite are introduced in the dike. Biotite ranges from 30-40 % and amphiboles range from 25-30%. The dike appears to have undergone greenschist facies metamorphism.

Figure 2 shows the biotite (brown) and the transparent m erals are K-feldspar. This photomicrograph is correlated to the lamprophyres in the region. (Taken under plane light)

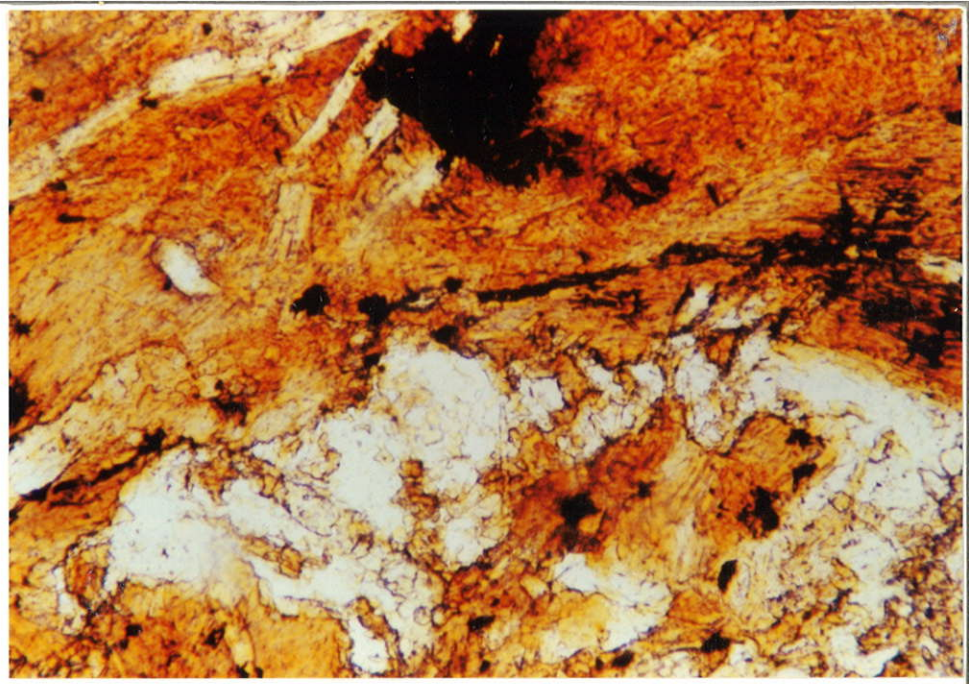


Figure 3. shows the pyroxene (transparent, high relief) in the in the upper portion of photograph and plagioclase in the center which is (transparent, low relief). The minerals look dirty which is a chlorite aleration. This photomicrograph is correlated tc ıe Kenora-Kabetogama swarm. (Taken under plane light)

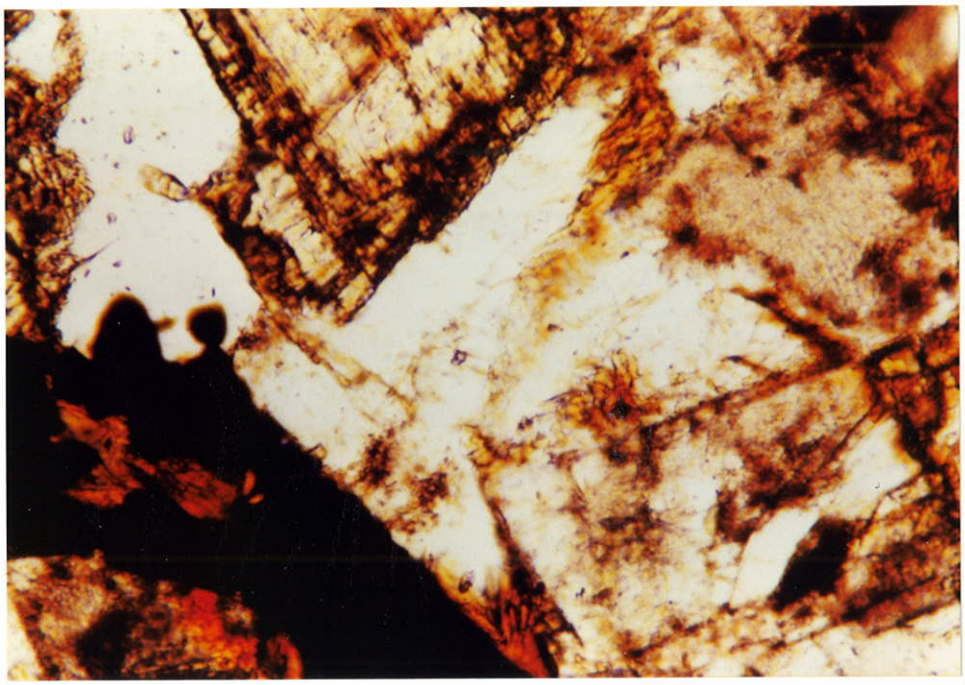
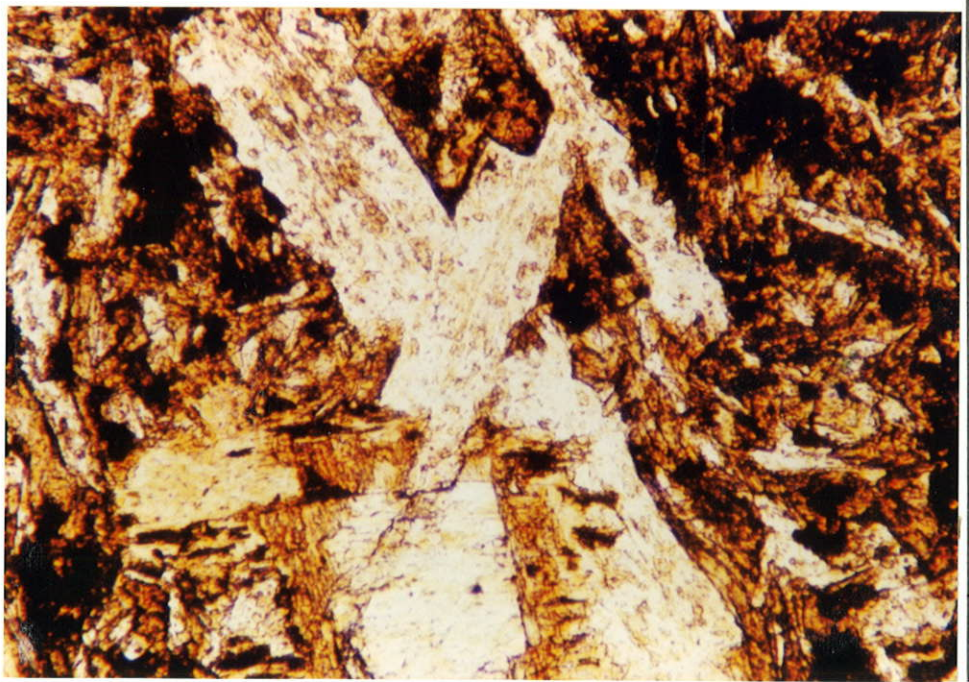


Figure 4. shows the microphenocrysts of plagioclase(transparent) and interstitial opaques. This photomicrograph is unrelated to the known swarms of the region. (Taken under plane light)



Scale

0 1mm

A third dike type is a plagioclase-rich metabasalt, characterized by microporphyritic plagioclase and partially altered pyroxene microphenocrysts (Figure 4). The matrix consists of somewhat pilotaxitic plagioclase microlites (approx. 20%) with intergranular pyroxene and opaques. Opaques consist of two varieties; 1) larger ovoidal grains and 2) abundant small intergranular grains. The larger opaques appear to be breaking down into a cluster of closely disseminated small grains. Pyroxenes are partially altered to chlorite and possibly actinolite. Smaller opaque grains have been altered to leucoxene.

INTERPRETATION

The gabbroic dike can be related to the Early Proterozoic Kenora-Kabetogama swarm. The north-northwest trends of the dikes, the gabbroic composition, and hypidiomorphic granular texture with some micrographic intergrowths indicate that they can most likely be correlated to the Kenora-Kabetogama swarm. The dikes cross-cut both greenstone and Giants Range units which indicates that they are post Archean.

As indicated, the biotite-rich dikes are most likely lamprophyres. The textures and mineralogy of these rocks suggest that they have been recrystalized and have probably undergone greenschist facies metamorphism. These features probably indicate that they were intruded during the Archean.

The relationship of the third dike set to regional geology is unclear. The metabasalt dike suite is characterized by microphenocrysts of plagioclase. Although the texture of the rocksis relatively "fresh," the mafic minerals are partially converted to chlorite and actinolite, suggesting greenschist facies metamorphism. However, the dike appears to have cross-cut the Archean deformational pattern. It is unclear as to whether these dike should be assigned to the Archean or Proterozoic. It is unlikely, however, that thse dikes are Keweenawan

CONCLUSION

In summary, three distinctly different dike suites occur in the Virginia Horn region of northeastern Minnesota. The oldest known suite is associated with the lamprophyres, and these were most likely intruded during the Archean. The most abundant dikes are gabbroic to microgabbroic in composition and can be correlated to the Kenora-Kabetogama swarm. A third dike type consists of a relatively "fresh" metabasalt. Primary minerals, however are partially altered to greenschist facies minerals. Because these dikes cut across the Archean metamorphic fabric, their probable age of intrusion is late Archean or Proterozoic.

APPENDIX 1:

DESCRIPTION OF SAMPLES

Correlated samples to the Kenora-Kabetogama dike swarm.

Minerals	Percentage	Description of grains
GR 32		
Plagioclase;	41.8%	euhedral to subhedral, lath shape
Augite;	37.2%	subhedral, prismatic to blocky
Opaques;	9.8%	anhedral, interstitial
Quartz;	6.8%	anhedral, interstitial
Hornblende;	4.4%	subhedral to anhedral, prismatic

Textures; micrographic intergrowth of plagioclase and quartz, hypidiomorphic intergranular

Alterations; chlorite and actinolite is associated with pyroxenes and biotite intergrown with chlorite; plagioclase being saussuritized; opaques altered to leucoxene

GR 46		
Plagioclase;	77.4%	subhedral, lath shape
Augite;	8.8%	subhedral to anhedral, blocky
Opaques;	6.8%	anhedral, interstitial
Quartz;	5.0%	anhedral, interstitial
Hornblende;	2.0%	subhedral to anhedral, prismatic

Texture; micrographic intergrowth of plagioclase and quartz, hypidiomorphic intergranular

Alterations; chlorite and actinolite associated with pyroxenes;

plagioclase is being saussuritized; opaques are altering to leucoxene

GR 339

Plagioclase;	40%	subhedral, lath shaped
Augite;	37%	subhedral, blocky
Hornblende;	13.8%	subhedral to anhedral, prismatic
Opaques;	5.4%	anhedral, interstitial
Quartz;	3.8%	anhedral, interstitial

Texture; micrographic intergrowth of plagioclase and quartz, hypidiomorphic intergranular

Alterations; chlorite and actinolite are associated with hornblende and pyroxenes; plagioclase is being saussuritized; opaques are altering to leucoxene

GR 816

Plagioclase;	46%	subhedral, lath shaped
Augite;	41%	subhedral to anhedral, prismatic to blocky
Hornblende;	9%	subhedral, prismatic
Opaques;	2%	anhedral, interstitial
Quartz;	2%	anhedral, interstitial

Texture; hypidiomorphic intergranular

Alterations; chlorite and actinolite alterations are associated with hornblende and pyroxenes; plagioclase is being saussuritized; opaques are altering to leucoxene

GR 915

Plagioclase;	53%	subhedral, lath shaped
Augite;	34%	euhedral to subhedral, blocky
Opaques;	7%	anhedral, interstitial
Hornblende;	3%	euhedral to subhedral, prismatic
Quartz;	3%	anhedral, interstitial

Texture; hypidiomorphic intergranular

Alterations; chlorite and actinolite alterations are associated with hornblende and pyroxenes; plagioclase is being saussuritized; opaques are altering to leucoxene

GR 920

Plagioclase;	45.5%	subhedral, lath shaped
Augite;	39%	euhedral to subhedral, blocky
Opaques;	7.5%	anhedral, interstitial
Hornblende;	4%	euhedral to subhedral, prismatic
Quartz;	4%	anhedral, interstitial

Texture; small amount of micrographic intergrowth of plagioclase and quartz, hypidiomorphic intergranular

Alterations; chlorite and actinolite alterations are associated with hornblende and pyroxenes; plagioclase is being saussuritized; opaques are altering to leucoxene

Uncorrelated dike sample, age is uncertain.

GR 873

Microphenocrysts

Plagioclase;	21.6%	subhedral, lath shaped

Opaques;	3.8%	anhedral (ovoidal), some interstitial
Augite;	2.2%	anhedral to subhedral, blocky
Groundmass		
K-feldspar		(most abundant)
Opaques		
Pyroxenes;		
Total	72.4%	

Texture; inequigranular

Alteration; chlorite and clay mineral alteration are associated with hornblende, plagioclase, and pyroxenes.

Correlated samples to the lamprophyres in the region

GR 901B

Phenocrysts

Amphibole pseudomorphs	32%	subhedral, blocky and prismatic
Biotite	20%	anhedral to subhedral, tabular
Muscovite	9%	anhedral to subhedral, tabular
Apatite	3.5%	subhedral, prismatic
Carbonates	1%	subhedral, prismatic
Quartz	1%	anhedral, interstitial
Opaques	0.5%	anhedral, interstitial
Groundmass		
K-feldspar	(29%)	anhedral to subhedral, tabular

Amphibole	(1%)	anhedral to subhedral, prismatic
Pyroxene	(3%)	anhedral to subhedral, blocky and prismatic
Total	33%	

Texture; inequigranular

Alterations; chlorite and clay mineral alterations are associated with amphibole pseudomorphs, and K-feldspar and amphibole and pyroxenes in the groundmass

GR 901C

Phenocrysts

Biotite;	31.4%	anhedral to subhedral, tabular
Amphibole pseudomorphs	29.4%	subhedral, prismatic

Groundmass

K-feldspar		(most abundant)
Amphibole		
Pyroxene;		
Total	39.2%	

Texture; inequigranular

Alterations; chlorite alteration is associated with amphibole pseudomorphs and clay mineral alterations is associated with everything.

GR 901D

Phenocrysts

Plagioclase;	21.6%	subhedral, lath shape
Opaques;	3.8%	anhedral, interstitial

Augite;	2.2%	anhedral to subhedral, blocky

Groundmass

K-feldspar (most abundant)
Opaques

Pyroxene; 72.4%

Texture; inequigranular

Alterations; chlorite alteration is associated with amphibole pseudomorphs and clay mineral alterations is associated with plagioclase, augite, K-feldspar.

GR 901E

Plagioclase;	42.8%	anhedral to subhedral, lath shaped
Biotite;	41.8%	anhedral to subhedral, tabular
Quartz;	16%	anhedral, interstitial

Texture; inequigranular

Alterations; chlorite and clay mineral alterations are associated with plagioclase and biotite.

REFERENCES

Craddock, C. , 1972, Regional Geologic Setting, in Sims, P.K. and Morey, G.B., Geology of Minnesota: A Centennial Volume, p. 281-291

DNR drill core summaries

Green, J.C., 1972, General Geology, Northeastern Minnesota, in Sims, P.K. and Morey, G.B., Geology of Minnesota: A Centennial Volume, Minnesota Geological Survey, p.292-293

Green, J.C., Bornhorst, T.J., Chandler, V.W., Mudrey, M.G. Jr., Myers, P.E., Pesonen, L.J., and Wilband, J.T., Keweenawan Dykes of the Lake Superior Region: Evidence for Evolution of the Middle Proterozoic Midcontinent Ri ft of North America: Geological Association of Canada Special Paper 34, p. 289-302

LaBerge, G.L., 1994, Geology of the Lake Superior Region, Geosciences Press, Inc.

MacKenzie, W.S., Donaldson, C.H., and Guilford, C., 1982, Atlas of igneous rocks and their textures, Halsted Press, A Division of John Wiley & Sons, Inc

MacKenzie, W.S. and Guilford, C., 1980, Atlas of rock-forming minerals in thin section, Halsted Press, A Division of John Wiley & Sons, Inc

Morey, G.B., 1972, Mesabi Range, in Sims, P.K. and Morey, G.B., 1972, Geology of Minnesota: Centennial Volume, Minnesota Geological Survey

Sims, P.K., 1970, Geologic Map of Minnesota, Hibbing Sheet, Bedrock Geology, Minnesota Geological Survey

Sims, P.K., 1972, Northern Minnesota, General Geologic Features, in Sims, P.K. and Morey, G.B., 1972, Geology of Minnesota: A Centennial Volume, Minnesota Geological Survey, p. 41-48

Sims, P.K. and Mudrey, Jr., M.G., 1972, Syenitic Plutons and Associated Lamprophyres, in Sims, P.K. and Morey, G.B., 1972, Geology of Minnesota: A Centennial Volume, Minnesota Geological Survey, p. 140-152

Sims, P.K. and Viswanathan, S., 1972, Giants Range Batholith, in Sims, P.K. and Morey, G.B., 1972, Geology of Minnesota: A Centennial Volume, Minnesota Geological Survey, p. 120-139

Southwick, D.L., 1968-1971, Bedrock Map of Minnesota, University of Minnesota

Southwick, D.L. and Halls, H.C., 1986, Compositional characteristics of the Kenora-Kabetogama dyke swarm (Early Proterozoic), Minnesota and Ontario: Canadian Journal of Earth Sciences p.2197-2205

Southwick, D.L., and Day, W.C., 1982, Geology and Petrology of Proterozoic mafic dikes, north-central Minnesota and western Ontario: Canadian Journal of Earth Sciences, 20, p.622-638

Weiblen, P.W., 1982, Keweenawan intrusive igneous rocks, in Wold, R.J. and Hinze, W.J., 1982, Geology and Tectonics of the Lake Superior Basin, Geological Society of America, Inc, Memoir 156, p.57-82

Welsh, J. L., 1994-1995, personal communication

Welsh, J.L., Englebert, J.L., and Hauck, S.A., 1991, General Geology, Structure, and Geochemistry of Archean Rocks of the Virginia Horn Area, Northeastern Minnesota, in Englebert, J.A. and Hauck, S.A., 1991, Bedrock Geochemistry of Archean Rocks in Northern Minnesota: Natural Resources Research Institute, University of Minnesota, Duluth, p.100-137