were near their present position (exclusive of Laramide uplift and faulting) by the time of development of this latest foliation.

This author disagrees with Vail's (1955) interpretation of the amphibolites and greenschists as completely texturally altered Stillwater Complex lithologies, because texturally unaltered cumulus calcic plagioclase was abundant in xenoliths found in the Lodgepole Intrusion (3 km to the ENE of these amphibolites). Even though those xenoliths were entrained in the Lodgepole (diorite) magma, only the mafic minerals were significantly altered.

(4) Mafic amphibolites and amphibole-plagioclase schist xenoliths with textures and mineralogies similar to those described for the amphibolites north of the East Boulder Fault by Vail (1955) and Garbarini (1957) are listed in Appendix 5, pp. 5-45 to 5-50. The presence of these lithologies among the xenoliths in the Lodgepole Intrusion suggests that the amphibolites and greenschists exposed 3 km to the WSW of the Clover Basin (Lodgepole Intrusion) area continue beneath the area at depth, stratigraphically above the Stillwater Complex, because mafic amphibolites and greenschists are not prevalent in the known gneissic footwall rocks beneath the Stillwater Complex to the south.

The presence of foliated and isoclinally folded quartz feldspathic-gneiss and biotite-quartz gneiss lithologies among the Lodgepole xenoliths suggests that gneissic lithologies similar to those described by Page (1977, see p. 36 this text) continue at depth beneath the Lodgepole Intrusion.

(5) The basic whole rock compositions, with tholeiitic affinities, of the cumulate textured xenoliths from the Lodgepole Intrusion, as well as the diversity of cumulate rock types (from nearly monomineralic anorthosites to mafic rich lithologies with subordinate cumulus plagioclase to xenoliths containing cumulus chromite), some showing igneous lamination, provide evidence for a xenolith source from a tholeiitic pluton in which crystal segregation and accumulation type processes were operative, compatible with the criteria of Carmichael et al. (1974, p. 461) for lithologies from rhythmically layered basic intrusions.

(6) The span of plagioclase compositions (where: An= An mole % average for a sample, expressed as a whole number, generally < 1 to ≈ 5 mole % variability within a given sample) measured by electron microprobe, for cumulus plagioclase in the xenolith suite from the Lodgepole Intrusion is An62 to An86. This span agreed with the total span of cumulus plagioclase compositions

measured by Hess (1960), An62 to An86, and Raedeke (1982), An62 to An86, for cumulus plagioclase bearing lithologies from the Banded Series of the Stillwater Complex outcrop, which is exposed from 8 to 13 km south of the Clover Basin area of the Lodgepole Intrusion.

The agreement in the total span of plagioclase compositions between the xenoliths and the Stillwater Complex outcrop, as well as the structural and whole rock evidence from (1) and (4) above, support the conclusion that the xenoliths are derived from the underlying Stillwater Complex.

The existence of a more differentiated Hidden Zone (Hess, 1960, p. 101) under the Lodgepole Intrusion is not supported by any trend to more albitic plagioclase compositions in the Lodgepole xenoliths. From density considerations (p.186) and efficiency in xenolith sampling by the Lodgepole magma , there is nothing to preclude Hidden Zone xenoliths from having been raised by the Lodgepole magma, suggesting either the absence of a Hidden Zone, or a Hidden Zone of similar composition to the exposed Stillwater Complex lithologies.

(7) Although no detailed chemistry or petrography was performed on xenoliths from Enos Mountain and Susie Peak intrusions (centered respectively approximately 9 and 12 km north of the nearest Stillwater Complex outcrop, the textural and mineralogical similarities of xenolith hand specimens from these localities with the xenoliths studied in detail from the Lodgepole Intrusion support the conclusion that the Stillwater Complex extends northward to intersect the magmatic plumbing systems of the Enos Mountain and Susie Peak intrusions.

Furthermore, the smaller sizes (both largest single xenoliths and mean sizes for lithologic classes) of cumulate textured lithologies from the Enos Mountain-Susie Peak area compared to the Lodgepole area xenoliths suggest that the Complex is deeper under the former area. A slower rate of intrusion (allowing more time for xenolith digestion and/or settling in the magma) is not supported by the angular volcanic breccias and large volcanic clasts found in the Enos Mountain and Susie Peak intrusions.

(8) The absence of any uniform imposed directional fabric in the mafic metamorphic mineral assemblages in the cumulate textured Lodgepole xenoliths suggests that

these metamorphic minerals did not form during a dynamic regional metamorphic event. (The 1,600 - 1,800 m. y. foliation (p. 38) was not detected in any of the cumulate textured xenoliths interpreted as Stillwater Complex lithologies, but this was not unexpected because this foliation is subtle and difficult to spot on a meso-or micro-scopic scale even in Stillwater Complex outcrop samples).
The presence of rounded to blocky mafic mineral domains (on a mm to cm scale), with metamorphic mineral orientation differing between domains in the same thin section (random or crystallographically controlled) suggests that metamorphic mineral growth occurred under isotropic (hydrostatic) conditions , probably caused by heating and hydration of the xenoliths in the Lodgepole magma.

The presence of these mm to cm size, blocky to rounded mafic mineral domains in basic plutonic rocks with preserved magmatic fabrics (i.e., cumulus plagioclase), suggests that the above type of mafic domains are pseudomorphic after primary high temperature ferromagnesian minerals. The tremolite/actinolite (±hornblende) + chlorite mafic mineral assemblages suggests retrograde metamorphism of these basic igneous rocks under greenschist facies conditions.

(9) The localization of the largest and most abundant crystalline basement (*i.e.*, cumulus textured and diabasic) xenoliths in the fine-grained diorite north and northeast (areas "N" and "NE", Figure 21) of the Clover Basin area in the Lodgepole Intrusion suggest that these areas overlie the magma conduits.

The presence of some angular xenoliths with few effects of assimilation (other than the hydration of mafic minerals to amphibole and chlorite), suggests rapid xenolith transport. The fine grain size ($\approx$ 1 mm) and the large proportion of groundmass (near 50%) in the fine-grained diorite suggest rapid cooling of the magma at shallow depths (calculated as $\approx$ 2000 m, based on stratigraphic thickness from the base of the Bighorn Dolomite to the top of the Eagle Formation, and on a late Cretaceous timing of intrusion, pp.80 - 83).

Although the features above suggest rapid emplacement and cooling, calculations (p.198) involving settling rates for one of the largest and densest (31 cm maximum dimension, density = 3.05 gm/cm^3) cumulate textured xenoliths require a magma ascent rate of only $\approx$ 1.7 m/sec to counter-balance xenolith settling, assuming an andesitic magma above its liquidus. At 50% magma crystallinity (*i.e.*, the observed phenocryst percentage in the fine-grained diorite), xenolith settling rates would be negligible ($\approx 2.2 \times 10^{-8}$ cm/sec).

(10) Exploratory drilling suggested both at a site in the Cambrian sediments (p. 195), and in the area of greenschists and amphibolites north of the East Boulder Fault (p. 197) could provide needed information on depths to the Stillwater Complex north of its outcrop belt. Economic considerations of mineral reserves would depend on the depth to the Complex and the type of mineralization, if any, encountered.

BIBLIOGRAPHY

Albee, A. L., and Ray L., 1970, Correction factors for electron probe microanalysis of silicates, oxides, carbonates, phosphates, and sulphates: Anal. Chem., v. 42, pp. 1408-1414.

Ando, C. J., Irwin, W. P., Jones, D. L., and Saleeby, J. B., 1983, The ophiolitic North Fork terrane in the Salmon River region, central Klamath Mountains, California: Bull. Geol. Soc. Am., v. 94, pp. 236-252.

Barker, R. W., 1975, Metamorphic mass transfer and sulfide genesis, Stillwater Intrusion, Montana: Econ. Geol., v. 70, pp. 275-298.

Bence, A. E., and Albee, A. L., 1968, Empirical correction factors for the electron microanalysis of silicates and oxides: J. Geol., v. 76, pp. 382-403.

Best, M. G., 1982, Igneous and metamorphic petrology: W. H. Freeman and Co., San Francisco, 630 pp.

Bonini, W. E., 1969, Gravity studies on Montana, Wyoming, and Washington: Trans. Am. Geophysical Union, v. 30, no. 50, pp. 531-33.

______1981, The size of the Stillwater Complex: an estimate from gravity data: Technical report 82-01, NASA Lunar and Planetary Institute, eds: D. Walker and I. S. McCallum, pp. 53-55.

Booker, W., 1957, The geology of the Enos Mountain area, Sweetgrass County, Montana (Senior Thesis): Princeton, N. J., Princeton Univ., 33 pp.

Bucher, W. H., Chamberlain, R. T., and Thom, W. T. Jr., 1933, Results of structural research work in Beartooth-Bighorn region, Montana and Wyoming: Bull. AAPG, v. 17, no. 6.

Butler, J. R., 1962, Geology of the Cathedral Peaks area, Beartooth Mountains, Montana (Ph.D. thesis): New York, N. Y., Columbia Univ., 108 pp.

______1966, Geologic evolution of the Beartooth Mountains, Montana and Wyoming: Part 6. Cathedral Peak area, Montana: Bull. Geol. Soc. Am., v. 77, pp. 45-64.

Carmichael, I. S.E., Turner, F.J., and Verhoogen, J., 1974, Igneous petrology: McGraw-Hill, Inc., N. Y., pp. 32-39.

Casella, C. J., 1969, Review of the Precambrian geology of the Eastern Beartooth Mountains, Montana and Wyoming: in Larsen, ed: Igneous and metamorphic petrology: Geol. Soc. Am. Memoir 119, pp. 53-71.

Catanzaro, E. J., and Kulp, J. L., 1964, Discordant zircons from the Little Belt (Montana), Beartooth (Montana), and Santa Catalina (Arizona) Mountains: Geochim. Cosmochim. Acta, v. 31, no. 11, pp. 2135-2150.

Clark, S. P., Jr., ed., 1966, Handbook of physical constants, Geol. Soc. Am. Memoir 97.

Collins H. B., Eggler, D. H., Eminhizer, L., 1975, Manual of operating procedures for the ETEC AUTOPROBE: Mineral Constitution Laboratory, Pennsylvania State Univ., Univ. Park, Pa., 29 pp.

Compton, R. R., 1962, Manual of field geology: John Wiley and Sons, Inc., N. Y., p. 275.

Cooley, E. F., Curry, K. J. and Carlson, R. R., 1976, Analysis for the platinum group metals and gold by fire-assay emission spectrography: App. Spectroscopy, v. 30, no. 1, pp. 53-56.

Cox, K. G., Bell, J. D., and Parkhurst, R. J., 1979, The interpretation of igneous rocks: Allen and Unwin, Ltd., London, 450 pp.

Cross, W., Iddings, J. P., Pirrson, L. V., and Washington, H. S., 1903, Quantitative classification of igneous rocks: University of Chicago Press.

Deer, W. A., Howie, R. A., and Zussman, J., 1977, An introduction to the rock forming minerals: Longman Group Ltd., London, 528 pp.

DePaolo, D. J., and Wasserburg, G. J., 1979, Sm-Nd age of the Stillwater Complex and the mantle evolution curve for neodymium: Geochim. Cosmochim. Acta, v. 43, pp. 999-1008.

Duke, J. M., 1983, Ore deposit models 7. magmatic segregation deposits of chromite: Geoscience Canada, v. 10, no. 1.

Foose, R. M., Wise, D. U. and Garbarini, G. S., 1961, Structural geology of the Beartooth Mtns., Montana and Wyoming: Geol. Soc. Am. Bull., v. 72, pp. 1143-1172.

Garbarini, G. S., 1957, Geology of the McLeod area, Beartooth Range, Montana (Ph.D. Thesis): Princeton, N. J., Princeton Univ., 359 pp.

Gast, P. W., Kulp, J. L., and Long, L. E., 1958, Absolute age of early Precambrian rocks in the Bighorn basin of Wyoming and Montana and Southeastern Manitoba: Am. Geophys. Union Trans., v. 39, pp. 322-334.

Gold, D. P., Carlson, R. R., Mann, E. L., Page, N. J., Todd, S., and Segerstrom, K., 1979, Field guide to the Stillwater layered intrusive complex, Montana, in: Guide to the Precambrian rocks of the Beartooth Mountains, The U. S. National Committee on Archean Geochemistry, Univ. of Fla., pp. 62-87.

Harris, R. L., Jr., 1959, Geologic evolution of the Beartooth Mountains, Montana and Wyoming: Part 3, Gardener Lake area, Wyoming: Geol. Soc. Am. Bull., v. 70, pp. 1185-1216.

Hess, H. H., 1960, Stillwater igneous complex, Montana - a quantitative mineralogical study: Geol. Soc. Am. Mem., 80, 230 pp.

Howland, A. L., Garrels, E. M., and Jones, W. R., 1949, Chromite deposits of Boulder River area, Sweetgrass County, Montana: U. S. Geol. Surv. Bull., 948-C pp. 63-82.

Howland, A. L., Peoples, J. W. and Sampson, E., 1936, The Stillwater igneous complex and associated occurrences of nickel and platinum group metals. Montana Bureau Mines and Geology: Misc. Contrib. 7, 15 pp.

Hutchinson, C. S., 1974, Laboratory handbook of petrographic techniques: John Wiley and Sons, Inc., N.Y., 527 pp.

Jackson, E. D., 1961, Primary textures and mineral associations in the ultramafic zone of the Stillwater Complex, Montana: U. S. Geol. Surv. Prof. Paper 358, 106 pp.

______1963, Primary features of stratiform chromite deposits, reprinted from: Methods of prospecting for chromite, proceedings of an OECD seminar on modern scientific methods of chromite prospection, Athens, 16-30 April, 1963.

______1967, Ultramafic cumulates in the Stillwater, Great Dyke, and Bushveld intrusions, in: Wyllie, P. J., ed., Ultramafic and related rocks: John Wiley and Sons, New York, pp. 20-38.

Jaeger, J.C., 1961, The cooling of irregularly shaped igneous bodies. Am. Jour. Sci., v. 259, pp. 721-34.

Jones, W. R., Peoples, J. W., and Howland, A. L., 1960, Igneous and tectonic structures of the Stillwater Complex, Montana: U. S. Geol. Surv. Bull. 1071-H, pp. 281-340.

Kushiro, I., 1978, Density and viscosity of hydrous calc-alkalic andesite magma at high pressures: Carnegie Inst. Yr. Bk. 77, pp. 675-677.

LeMaitre, R. W., 1976, The chemical variability of some common igneous rocks: J. Petrol. v. 17, pp. 589-637.

MacDonald, G. A. and Katsura, T., 1964, Chemical composition of Hawaiian lavas: J. Petrol. v. 5, pp. 82-133.

Maze, W. B. and Carlson, R. R., 1981, Fe-Ti oxides of the Stillwater Complex, Montana: mineralogy, chemistry, and implications: Lunar and Planetary Institute (NASA) Technical Report 82-01, pp. 95-98.

McCallum, I. S., 1969, Equilibrium relationships among the coexisting minerals in the Stillwater Complex, Montana (Ph.D. Thesis):Chicago, Ill., Univ. of Chicago, 175 pp.

Morton, P. S., 1979, Geology of Limestone Butte, Nye, Montana. (B. A. with Honors paper): Amherst, Mass., Amherst College, 45 pp.

Mueller, P. A., 1971, Geochemistry and geochronology of the mafic rocks of the southern Beartooth Mountains, Mt. and Wy. (Ph. D., Thesis): Texas, Rice Univ., 58 p.

Nunes P.D. and Tilton, G. R., 1971, Uranium-lead ages of minerals from the Stillwater Igneous Complex and associated rocks, Montana: Geol. Soc. Am. Bull, v. 82, no. 18, pp. 2231-2250.

Page, N. J., Simons, F. S., and Dohrenwend, J. C., 1973, Reconnaissance geologic map of the Mount Douglas Quadrangle, Montana: U. S. Geol. Surv. Misc. Field Studies Map MF-488.

______1973, Reconnaissance geologic map of the Mount Wood Quadrangle, Montana: U. S. Geol. Surv. Misc. Field Studies map MF-491.

Page, N. J. and Nockleberg, W. J., 1974, Geologic Map of the Stillwater igneous complex: U. S. Geol. Surv. Misc. Invest. Series Map I-797.

Page, N. J., 1977, Stillwater Complex, Montana; rock succession, metamorphism, and structure of the complex and adjacent rocks: U. S. Geol. Surv. Prof. Paper 999, 79 pp.

______1979, Stillwater Complex, Montana - structure, mineralogy, and petrology of the Basal Zone with emphasis on the occurrences of sulfides: U. S. Geol. Surv. Prof. Paper 1038, 69 pp.

Parsons, W. H., 1942, Origin and structure of the Livingston Igneous Rocks, Montana: Bull. Geol. Soc. Am., v. 53, pp. 1175-1186.

Pierce, W. G. and Nelson, W. H., 1971, Geologic map of the Beartooth Butte quadrangle, Park County, WY: U. S. Geol. Surv. map GQ-935.

Poldervaart, A., and Bentley, R. D., 1958, Precambrian and later evolution of the Beartooth Mountains, Wyoming and Montana: Billings Geo. Soc. Ninth Annual Field Conf. Guidebook, pp. 7-15.

Raedeke, L. D., 1979, Stratigraphy and petrology of the Stillwater Complex, Montana (M.S. Thesis): Seattle, Washington, Univ. of Washington, 89 pp.

______1982, Petrogenesis of the Stillwater Complex. (Ph.D. Thesis): Seattle, Washington, Univ. of Washington, 280 pp.

Richards, P. W., 1957 Geology of the area east and southeast of Livingston, Park County, Montana: U. S. Geol. Survey Bull. 1021-L, pp. 385-438.

Robie, R. A., Hemingway, B. S., and Fisher, J. R., 1979, Thermodynamic properties of minerals and related substances at 298.15 K and at higher temperatures: U. S. Geol. Surv. Bull. 1452, 456 pp.

Rocky Mountain Mapping Center, Natl. Cartigraphic Information Center, U. S. Geol. Surv. Box 25046 Stop 504, Federal Center, Denver, CO 80225. (Orthophotoquads: Squaw Peak $7\frac{1}{2}$', Sliderock Mtn. $7\frac{1}{2}$', Mt. Douglas NE $7\frac{1}{2}$', and Mt. Wood NW $7\frac{1}{2}$'; all in Montana Index.)

Rouse, J. T., Hess, H. H., Foote, F., Vhay, J.S., and Wilson, K. P., 1937, Petrology structure and relation to tectonics of porphyry intrusions in the Beartooth Mountains, Montana: J. Geol., v. 45, no. 7, pp. 717-740.

Segerstrom, K. and Carlson, R. R., 1977, Preliminary geologic map of the upper zones of the western end of the Stillwater Complex, Park and Sweetgrass Counties, Montana: U. S. Geol. Surv. Open File Rept., 77-370.

_____ 1979, Preliminary geologic map of the Picket Pin to Mountain View sector of the Stillwater Complex, Stillwater County, Montana: U. S. Geol. Survey Open File Rept., 79-656.

_____ 1980, Preliminary geologic map of the eastern part of the Upper Zones of the Stillwater Complex, Stillwater County, Montana: U. S. Geol. Surv. Open File Rept., 80-364,

_____ 1982, Geologic map of the Banded Upper Zone of the Stillwater Complex and adjacent rocks; Stillwater, Sweetgrass, and Park Counties, Montana: Misc. Invest. Series Map I-1383 .

Shaw, H. R., 1969, Rheology of basalt in the melting range: J. Petrology, v. 10, pp. 510-535.

Spencer, E. W., 1958, Structural trends in the Beartooth Mountains, Montana and Wyoming: Billings Geol. Soc. Ninth Annual Field Conference Guidebook, pp. 16-23.

Streckeisen, A. L., 1973, Classification and nomenclature recommended by the IUGS subcommission on the systematics of igneous rock: Geotimes, v. 18, pp. 26-30.

Sylvester, S., 1980, Trace element measurement by x-ray fluorescence: Lab. no. 7, Geol. 51 course, Franklin and Marshall College, Lancaster, PA.

Terry R. D. and Chilinger, G. V., 1955, Charts for estimating percentage composition of rocks and sediments: Sed. Pet., v. 25, pp. 229-234.

Ulmer, G. C. and Smothers, W. J., 1969, The system MgO - Cr_2O_3 - Fe_2O_3 at 1300° C in air: J. Amer. Ceram. Soc., v. 51, no. 6, pp. 315-319.

U. S. Dept. of Agriculture, Aerial Photo Laboratory, 222 West 2300 South Streets, P. O. Box 30010, Salt Lake City, Utah, 84125. Aerial Photo Indices: GS-VEUM, 1980 Hurd; GS-F2, 1948 Aero SVC Corp.; GS-MH, 1951 Aero Svc. Corp.

U. S. Dept of Agriculture, Forest Service, 1976, Forest visitors map, Custer National Forest (Beartooth Division) Montana and Wyoming: principal meridian Montana and sixth principal meridian, scale: ½" = 1 mile.

Vail, P. R., 1955, The igneous and metamorphic complex of the East Boulder River area, Montana (M. S. Thesis): Northwestern Univ., 68 pp.

Vhay, J. S., 1934, The geology of a part of the Beartooth Mountain front near Nye, Montana (Ph. D., dissertation): Princeton Univ., 122 pp.

Wager, L. R., and Brown, G.M., 1967, Layered igneous rocks: W. H. Freeman and Company, San Francisco, 588 pp.

Wilson, C. W., Jr., 1936, Geology of the Nye-Bowler lineament, Stillwater and Carbon Counties, Montana: Bull. Am. Assoc. Petroleum Geologists, v. 20, pp. 1161-1188.

Wooden, J. W., Mueller, P., and Bowes, D., 1981, An informal guidebook for the Precambrian rocks of the Beartooth Mountains, Montana-Wyoming, in: NASA Lunar and Planetary Science Technical Report Number 82-01, pp. 195-234.

APPENDIX 1

WHOLE ROCK MAJOR ELEMENT ANALYSIS BY XRF

1-A Intrusive Phases

1-B Xenoliths *

1-B(1) CIPW Silica Undersaturated

1-B(2) CIPW Silica Saturated (with cumulus plagioclase) **

1-B(3) CIPW Silica Saturated Mafic (no cumulus plagioclase)

1-B(4) CIPW Silica Oversaturated

1-C Comparison of Interior and Exterior of Selected Xenoliths

1-D Fe_2O_3/FeO Adjusted to 0.15 Weight Ratio (used in normative calculations because the primary mafic minerals in the xenoliths are pervasively altered.

* Xenoliths classified on the basis of Cross, Iddings, Pirsson and Washington (1903)(CIPW) normative mineralogy as:

Silica Undersaturated - nepheline normative

Silica Saturated - hypersthene and olivine normative

Silica Oversaturated - quartz normative

(see text, p. 134)

** for 1-B(2): An (mole %) determined by Electron Microprobe Analysis, except as indicated.

WHOLE ROCK XRF ANALYSIS-INTRUSIVE PHASES

	Wt. % Oxide												
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total
Fine grained diorite(AD-8380)	55.77	0.49	18.14	4.07	3.13	0.14	2.89	6.81	3.64	2.37	0.36	3.17	100.97
Fine grained diorite(13-81-241)	55.88	0.69	17.58	4.71	2.90	0.13	3.18	6.23	3.74	2.79	0.33	4.46	101.63
Coarse porphyritic dacite(13-81-240)	60.89	0.54	16.42	3.59	2.57	0.09	3.20	5.12	3.56	2.80	0.26	3.51	102.56
Coarse porphyritic dacite(AD-8530)	60.60	0.54	16.37	3.24	2.88	0.10	3.15	5.48	3.77	2.68	0.26	2.82	101.88
Medium porphyritic dacite(N-81-140)	65.43	0.45	15.98	1.81	2.23	0.06	2.55	3.17	4.36	3.19	0.18	2.54	101.95
Medium porphyritic dacite(10-81-135)	64.50	0.40	14.75	2.19	1.93	0.06	2.53	3.73	3.22	3.58	0.15	4.60	101.64
Rhyodacite (N-81-153)	73.68	0.08	15.05	0.61	1.01	0.02	0.12	0.92	4.75	4.27	0.01	1.46	101.97
Rhyodacite (CB-8550-B-6)	72.39	0.09	14.87	1.05	2.17	0.02	0.11	0.94	4.34	4.36	0.01	1.22	101.55

APPENDIX 1-A

WHOLE ROCK XRF ANALYSIS - XENOLITHS

CIPW Silica Undersaturated

	Wt.% Oxide												
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	TOTAL
13-81-227	41.38	0.05	19.13	3.55	4.76	0.13	15.19	10.19	1.14	0.35	0.01	3.75	99.63
N-81-166	46.82	0.05	29.51	0.68	1.08	0.03	2.85	15.86	2.00	0.16	0.01	1.29	100.34
NE-81-500	46.47	0.13	29.77	0.68	1.38	0.02	1.60	14.49	2.43	0.15	0.02	1.93	99.07
N-7(1)-18	49.50	0.39	27.26	1.78	1.74	0.04	1.44	13.00	3.20	0.43	0.04	1.79	100.60

APPENDIX 1 B(1)

WHOLE ROCK XRF ANALYSIS - XENOLITHS

CIPW Silica Saturated
(with cumulus plagioclase)

	An Mole %+	Wt. % Oxide												
		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	TOTAL
NE-81-502	85.16	49.88	0.08	16.22	1.43	2.65	0.11	11.76	15.38	1.11	0.19	0.01	1.88	100.72
N-81-110	83.19	47.20	0.09	29.07	0.84	1.22	0.04	2.57	15.17	2.02	0.12	0.02	1.73	100.09
replicate N-81-110	83.19	47.28	0.10	29.10	0.90	1.22	0.04	2.65	15.36	1.96	0.12	0.01	1.73	100.46
N-81-160	82.39	47.51	0.07	31.47	0.41	0.91	0.01	1.63	15.64	1.98	0.14	0.02	1.17	100.97
13-81-229	81.75	47.57	0.07	30.75	0.41	0.92	0.02	1.76	15.69	2.09	0.12	0.01	1.20	100.61
NE-81-245-IN	81.71	47.46	0.11	22.24	1.29	3.15	0.06	7.92	13.92	1.84	0.24	0.01	1.26	99.49
replicate NE81-245 IN	81.71	47.76	0.10	22.25	1.27	3.15	0.06	8.18	14.05	1.69	0.24	0.01	1.21	99.98
TU-1-80	81.57	47.59	0.05	28.27	0.89	1.31	0.04	3.85	15.34	1.82	0.20	0.01	1.22	100.60
N-81-113	81.53	46.15	0.08	24.01	1.52	2.30	0.07	5.81	14.93	1.68	0.09	0.02	2.34	99.01
N-81-162	80.72	48.99	0.11	15.88	2.40	3.80	0.13	12.01	12.90	1.30	0.30	0.01	3.85	101.67
N-7(1)-2	80.37	46.49	0.08	24.43	1.61	1.89	0.07	5.73	15.37	1.64	0.10	0.02	2.54	99.97
E-4	79.72	47.78	0.14	22.48	1.46	3.10	0.08	7.41	13.56	1.82	0.17	0.02	1.91	99.93
N-7(1)-16	79.10	45.93	0.09	24.34	1.83	2.27	0.07	6.59	14.62	1.50	0.14	0.01	2.12	99.50

\+ An mole % determined by electron microprobe analysis

APPENDIX 1 B(2)

WHOLE ROCK XRF ANALYSIS - XENOLITHS

CIPW Silica Saturated Cont'd

	An Mole %+	Wt. % Oxide											LOI	TOTAL
		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5		
NE-81-501	78.64	48.82	0.07	13.86	1.75	3.62	0.13	14.91	10.10	1.48	0.48	0.01	3.61	98.83
NE 81-507	78.50	48.75	0.10	23.62	1.34	2.11	0.07	6.48	13.84	1.84	0.28	0.01	1.71	100.15
E-1-B-8	78.12	48.45	1.15	20.13	5.84	3.93	0.11	3.56	9.23	2.84	1.15	0.13	3.81	100.33
N-81-246	76.45	47.35	0.13	26.28	1.34	2.27	0.06	3.92	14.00	2.15	0.25	0.03	1.73	99.51
N-80-TU-5	76.25	48.14	0.44	28.16	2.47	1.74	0.05	1.74	13.49	2.51	0.43	0.04	1.83	101.03
NE-81-244IN	73.98*	48.01	0.14	14.90	2.67	4.99	0.12	13.50	13.08	1.22	0.20	0.00	1.53	100.37
NE-81-201	73.96*	48.00	0.07	31.89	0.43	0.62	0.01	1.23	13.98	2.41	0.46	0.01	1.48	100.60
N-81-130	71.19*	47.88	0.18	25.87	1.67	1.80	0.06	3.40	13.73	2.50	0.22	0.02	2.00	99.33
N-80-TU-3	69.22	50.68	0.18	27.03	1.61	1.93	0.04	2.10	12.37	3.27	0.38	0.02	1.98	101.60
N-81-8720A3	62.71	51.13	0.27	22.24	2.40	3.40	0.10	4.54	11.22	3.16	0.30	0.02	2.62	101.39
N-81-102	62.33	50.87	0.15	18.28	2.93	3.75	0.14	7.86	11.23	2.45	0.52	0.02	2.73	100.93
N-81-203	61.05*	52.10	0.10	13.28	1.63	3.71	0.12	12.81	11.69	1.76	0.29	0.01	1.76	99.26
13-81-237	47.28	49.87	0.97	17.94	6.11	5.94	0.14	4.86	8.50	3.35	0.59	0.11	2.65	101.03

*An not determined from microprobe analysis, normative An used instead.

+ An mole % determined by electron microprobe analysis.

WHOLE ROCK XRF ANALYSIS - XENOLITHS

CIPW Silica Saturated (no cumulus plagioclase)

	Wt. % Oxide											LOI	TOTAL
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5		
N-8400-A1	52.70	0.17	6.32	3.03	6.68	0.29	17.05	11.17	0.76	0.58	0.01	1.92	100.68
NE-81-508	49.07	0.12	11.65	2.32	4.84	0.15	16.93	10.86	1.47	0.30	0.01	2.54	100.27
N-81-161	51.58	0.22	7.07	3.30	6.29	0.30	16.04	12.55	1.00	0.74	0.01	1.78	100.85
8300 S. Spine	49.34	0.24	8.63	3.89	7.30	0.29	15.96	10.33	0.97	0.85	0.01	3.01	100.83
TR-1(0) 1 (replicate)	48.86	0.33	9.96	4.87	7.15	0.24	11.16	10.09	1.10	1.11	0.03	5.75	100.65
TR-1(0)-1	48.83	0.32	9.85	4.98	7.15	0.23	11.00	10.03	1.06	1.13	0.02	5.75	100.36
WCB-1 *	49.03	0.75	14.43	1.49	9.92	0.21	8.24	12.42	2.40	0.45	0.05	2.38	101.76

* FeO not measured for WCB-1.
Set at Fe_2O_3/FeO = 0.15 by weight.

APPENDIX 1-B(3)

WHOLE ROCK XRF ANALYSIS - XENOLITHS

CIPW Silica Oversaturated

	Wt. % Oxide												
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	TOTAL
N-7(6)-17	74.56	0.13	14.81	0.77	0.25	0.01	0.29	1.93	4.57	2.67	0.02	1.05	101.07
CC-1	75.73	0.13	13.41	0.42	0.72	0.02	0.49	2.16	2.48	5.87	0.06	2.56	103.30
NE-81-V-1	77.80	0.05	14.45	0.21	0.47	0.01	0.10	1.61	5.04	2.19	0.01	0.91	102.37

WHOLE ROCK XRF ANALYSIS - XENOLITHS

Comparison of Interior vs. Exterior Composition of Xenoliths in Fine Grained Diorite Host

	Wt. % Oxide												
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	TOTAL
NE-81-245 OUTSIDE*	47.03	0.09	22.89	1.16	3.17	0.07	7.02	13.02	1.96	0.36	0.01	1.70	98.49
NE-81-245 INSIDE *	47.61	0.10	22.24	1.28	3.15	0.06	8.05	13.98	1.76	0.24	0.01	1.24	99.74
Residual (OUTSIDE - INSIDE) **	-0.58	-0.01	+0.65	-0.12	+0.02	+0.01	-1.03	- 0.96	+0.20	+0.12	0.00	+0.46	
Residual (as % of element present)¢	-1.22	-10.00	+2.92	-9.38	+0.64	+16.66	-12.80	- 6.86	+11.36	+50.00	0.00	+37.10	
NE-81-244 OUTSIDE	47.23	0.14	18.28	2.47	4.33	0.10	10.62	12.70	1.68	0.26	0.01	1.80	99.63
NE-81-244 INSIDE	48.01	0.14	14.90	2.67	4.99	0.12	13.50	13.08	1.22	0.20	0.00	1.53	100.37
Residual (OUTSIDE - INSIDE)	-0.78	0.00	+3.38	-0.02	-0.66	-0.02	-2.88	-0.38	+0.46	+0.06	+0.01	+0.27	
Residual (as % of element present)	-1.62	0.00	+22.68	-0.75	-13.22	-16.67	-21.33	-2.90	+2.53	+30.00	+100.	+17.65	

* OUTSIDE = outer ¼" of xenolith, INSIDE = interior of approx. 1 $ft.^3$ xenolith
** (+) residual = element gain going from xenolith interior to xenolith exterior, -residual = element loss
¢ residual as % of element present = (wt.% element residual/wt.% of element in interior of xenolith) x 100

APPENDIX 1-D

List of Fe_2O_3 and FeO standardized at an (Fe_2O_3/FeO) ratio of 0.15 by weight. This artificial ratio was used in the normative mineralogy calculations because the primary mafic minerals in the xenoliths are pervasively altered.

	Wt. % Oxide	
	Fe_2O_3	FeO
XENOLITHS		
CIPW Silica Undersaturated		
13-81-227	1 05	7.01
N-81-166	0.22	1.49
NE-81-500	0.26	1.75
N-7-(1)-18	0.44	2.94
CIPW Silica Saturated		
NE-81-502	0.52	3.47
N-81-110	0.26	1.74
N-81-160	0.17	1.13
13-81-229	0.17	1.13
NE-81-245 IN	0.58	3.84
NE-81-245 OUT	0.56	3.71
TU-1-80	0.28	1.86
N-81-113	0.49	3.23
N-81-162	0.79	5.25
N-7 (1)-2	0.44	2.93
E-4	0.58	3.89
N-7 (1)-16	0.52	3.45
NE-81-501	0.69	4.57
NE-81-507	0.44	2.92
E-1-B-8	1.21	8.09

	Wt. % Oxide	
	Fe_2O_3	FeO
CIPW Silica Saturated (Cont.d)		
N-81-246	0.46	3.05
N-80-TU-5	0.53	3.49
NE-81-244 IN	0.98	6.52
NE-81-244 OUT	0.87	5.77
NE-81-201	0.13	0.89
N-81-130	0.44	2.91
N-80-TU-3	0.45	2.97
N-81-8720-A3	0.74	4.90
N-81-102	0.84	5.63
N81-203	0.68	4.56
13-81-237	1.51	10.08
CIPW Silica Saturated (no cumulus plagioclase)		
N-8400-A1	1.24	8.28
NE-81-508	0.92	6.11
N-81-161	1.22	8.15
8300 S. Spine	1.43	9.52
TR-1(0)-1	1.53	10.16
WCB-1	1.49	9.92
CIPW Silica Oversaturated		
N-7(6)-17	0.12	0.83
CC-1	0.15	0.97
NE-81-V-1	0.03	0.17

APPENDIX 2

WHOLE ROCK TRACE ELEMENT ANALYSIS BY XRF
(Samples are in the same order as in major element tables Appendix I.)

	ppm by wt.			
	Rb	Sr	Ni	V
INTRUSIVE PHASES				
Fine grained diorite				
AD-8380	47	1042	12	80
13-81-241	55	878	20	107
Coarse porphyritic dacite				
13-81-240	40	928	10	88
AD-8530	55	985	30	92
Medium porphyritic dacite				
N-81-140	62	890	37	61
10-81-135	62	875	44	58
Rhyodacite				
N-81-153	80	877	-	3
CB-8550-B-6	75	896	3	4
XENOLITHS				
CIPW Silica undersaturated				
13-81-227	10	88	903	21
N-81-166	7	186	39	6
NE-81-500	1	306	23	14
N-7(1)-18	2	323	26	63
CIPW Silica Saturated(with cumulus plagioclase)				
NE-81-502	5	189	304	73
N-81-110	-	160	45	20
N-81-160	7	214	41	1
13-81-229	-	190	36	3

	ppm by wt.			
	Rb	Sr	Ni	V
CIPW Silica Saturated(with cumulus plagioclase)				
continued				
NE-81-245 IN	-	158	277	45
TU-1-80	-	259	85	11
N81-113	-	172	301	36
N-81-162	-	254	362	96
N-7(1)-2	2	179	292	36
E-4	-	209	212	53
N-7(1)-16	7	187	348	38
NE-81-501	16	256	388	61
NE-81-507	5	210	179	45
E-1-B-8	21	425	55	199
N-81-246	2	267	100	42
N-80-TU-5	18	274	15	68
NE-81-244IN	-	91	486	85
NE-81-201	11	287	16	1
N-81-130	1	416	126	42
N-80-TU-3	-	389	74	38
N-81-8720 A3	4	317	51	95
N-81-102	10	404	108	84
N-81-203	-	359	337	83
13-81-237	-	397	61	221

	ppm by wt.			
	Rb	Sr	Ni	V
CIPW Silica Saturated (no cumulus plagioclase)				
N-8400-A1	4	86	478	71
NE-81-508	11	92	468	67
N-81-161	-	76	448	83
8300 S. Spine	6	106	525	88
TR-1(0)-I	7	190	594	66
WCB-1	4	280	141	221
CIPW Silica Saturated				
N-7-(6)-17	30	230	-	-
CC-I	133	480	-	16
NE-81-V-1	33	387	-	6

APPENDIX 3

CIPW NORMATIVE MINERALOGY (wt.%)

Xenoliths classified on the basis of Cross, Iddings, Pirsson and Washington (1903) (CIPW) normative mineralogy as:

Silica Undersaturated - nepheline normative

Silica Saturated - hypersthene and olivine normative

Silica Oversaturated - quartz normative

(see text, p. 134)

Code:
Q = quartz
Or = orthoclase
Ab = albite
An = anorthite
Ne = nepheline
Hy = hypersthene
Aug = augite
Ol = olivine
Mt = magnetite
Il = ilmenite
Ap = apatite
Cc = calcite
C = corundum

All Fe_2O_3/FeO ratios adjusted to 0.15 by weight, unless otherwise noted. Artificial ratio (0.15 by weight) was used because the primary mafic minerals in the xenoliths are pervasively altered.

CIPW NORMATIVE MINERALOGY (wt.%)

INTRUSIVE PHASES	Q	Or	Ab	An	Ne	Hy	Aug	Ol	Mt	Il	Ap	Cc	C	mole fraction MgO	calculated mole % An
Fine grained diorite AD-8380	4.49	14.36	31.59	26.83	-	15.06	4.51	-	1.34	0.95	0.88	-	-	0.494	34.91
13-81-241	2.11	17.03	32.69	23.70	-	15.89	5.00	-	1.41	1.36	0.81	-	-	0.513	31.43
Coarse porphyritic dacite 13-81-240	11.63	16.75	30.50	20.81	-	14.91	2.61	-	1.13	1.04	0.64	-	-	0.566	29.77
AD-8530	10.38	16.03	32.28	20.06	-	13.73	4.76	-	1.12	1.03	0.61	-	-	0.561	28.53
Medium porphyritic dacite N-81-140	15.52	18.98	37.16	14.68	-	11.61	-	-	0.75	0.87	0.42	-	0.01	0.617	20.09
10-81-135	19.42	21.84	28.12	15.71	-	11.03	1.95	-	0.78	0.78	0.37	-	-	0.609	23.32
Rhyodacite N-81-153	26.41	25.12	40.01	4.54	-	2.54	-	-	0.29	0.14	0.01	-	0.94	0.148	6.29
CB-8550-B-6	26.14	25.69	36.62	4.61	-	4.85	-	-	0.59	0.16	0.02	-	1.31	0.072	6.67

INTRUSIVE PHASES *

CIPW NORMATIVE MINERALOGY (wt.%)

	Q	Or	Ab	An	Ne	Hy	Aug	Ol	Mt	Il	Ap	Cc	C	mole fraction MgO	calculated mole % An
Fine grained diorite															
AD-8380	8.13	14.32	31.48	26.74	-	7.19	4.28	-	6.03	0.95	0.88	-	-	0.838	35.91
13-81-241	6.48	16.96	32.56	23.60	-	6.52	4.68	-	7.03	1.35	0.81	-	-	0.951	31.43
Coarse porphyritic dacite															
13-81-240	14.81	16.70	30.41	20.75	-	7.93	2.48	-	5.25	1.03	0.63	-	-	0.910	29.77
AD-8530	13.17	15.98	32.20	20.01	-	7.68	4.57	-	4.74	1.03	0.61	-	-	0.843	28.53
Medium porphyritic dacite															
N-81-140	16.97	18.96	37.11	14.66	-	8.36	-	-	2.64	0.87	0.42	-	0.01	0.810	20.09
10-81-135	21.32	21.80	28.07	15.68	-	6.82	1.87	-	3.27	0.78	0.37	-	-	0.875	23.32
Rhyodacite															
N-81-153	26.85	25.10	39.99	4.54	-	1.55	-	-	0.88	0.14	0.01	-	0.94	0.238	6.29
CB-8550-B-6	26.84	25.67	36.60	4.61	-	3.27	-	-	1.52	0.16	0.02	-	1.31	0.105	6.67

* Fe_2O_3/FeO as measured by titration for FeO, this page only.

XENOLITHS

CIPW NORMATIVE MINERALOGY (wt.%)

	Q	Or	Ab	An	Ne	Hy	Aug	Ol	Mt	Il	Ap	Cc	C	mole fraction MgO	calculated mole % An
CIPW Silica Undersaturated															
13-81-227	-	2.18	5.45	48.15	2.51	-	3.76	36.26	1.59	0.10	0.01	-	-	0.803	85.81
N-81-166	-	0.95	14.31	71.79	1.51	-	6.11	4.88	0.32	0.10	0.02	-	-	0.787	81.65
NE-81-500	-	0.92	19.23	71.97	1.06	-	1.58	4.56	0.39	0.25	0.05	-	-	0.649	77.15
N-7(1)-18	-	2.58	27.41	59.53	0.02	-	4.66	4.32	0.65	0.75	0.09	-	-	0.513	65.28
CIPW Silica saturated (with cumulus plagioclase)															
NE-81-502	-	1.19	9.51	39.18	-	12.91	30.17	6.10	0.76	0.15	0.03	-	-	0.865	77.64
N-81-110 replicate	-	0.73	17.39	71.11	-	1.91	4.31	3.95	0.38	0.17	0.05	-	-	0.744	78.75
N-81-110	-	0.71	16.81	71.20	-	1.87	4.85	3.96	0.40	0.19	0.01	-	-	0.745	79.34
N-81-160	-	0.83	16.80	76.76	-	1.68	0.73	2.79	0.23	0.14	0.04	-	-	0.745	80.46
13-81-229	-	0.73	17.80	74.62	-	0.04	2.92	3.49	0.25	0.13	0.03	-	-	0.756	79.19
NE-81-245 IN replicate	-	1.41	15.85	52.67	-	0.93	14.09	12.96	0.86	0.21	0.02	-	-	0.799	74.29
NE-81-245 IN	-	1.44	14.49	53.10	-	4.42	13.97	11.52	0.84	0.20	0.02	-	-	0.807	75.95
TU-1-80	-	1.21	15.50	68.83	-	2.25	6.16	5.49	0.41	0.10	0.03	-	-	0.799	79.58
N-81-113	-	0.60	14.72	59.73	-	0.85	13.55	9.61	0.74	0.17	0.04	-	-	0.775	78.65
N-81-162	-	1.80	11.26	37.49	-	16.64	22.41	9.00	1.17	0.21	0.01	-	-	0.813	73.16

CIPW NORMATIVE MINERALOGY (wt.%)

Continued	Q	Or	Ab	An	Ne	Hy	Aug	Ol	Mt	Il	Ap	Cc	C	mole fraction MgO	Calculated mole % An
N-71-2	–	0.63	14.26	60.62	–	0.38	14.14	9.10	0.66	0.16	0.04	–	–	0.790	79.36
E-4	–	1.06	15.72	53.76	–	7.51	11.88	8.90	0.86	0.26	0.05	–	–	0.786	75.18
N-7(1)-16	–	0.86	13.05	60.94	–	1.93	10.92	11.34	0.78	0.17	0.01	–	–	0.786	80.55
NE-81-501	–	2.97	13.17	31.29	–	22.10	16.97	12.31	1.05	0.14	0.01	–	–	0.860	64.88
NE-81-507	–	1.68	15.83	56.30	–	10.19	10.74	4.40	0.65	0.19	0.03	–	–	0.810	75.29
E-1-B8	–	7.04	24.91	40.21	–	15.14	5.33	2.96	1.82	2.26	0.32	–	–	0.489	54.57
N-81-246	–	1.54	18.62	62.76	–	2.68	6.62	6.77	0.68	0.25	0.06	–	–	0.715	74.66
N-80-TU-5	–	2.58	21.45	64.94	–	3.21	2.01	4.11	0.76	0.84	0.09	–	–	0.516	71.93
NE-81-244N	–	1.22	10.46	35.04	–	10.00	24.61	16.96	1.44	0.27	–	–	–	0.798	73.99
N-81-201	–	2.77	20.58	69.90	–	3.80	–	0.54	0.19	0.13	0.03	–	2.06	0.736	73.96
N-81-130	–	1.35	21.76	60.40	–	1.85	7.77	5.83	0.66	0.35	0.04	–	–	0.699	71.19
N-80-TU-3	–	2.29	27.81	58.23	–	5.36	2.75	2.52	0.64	0.35	0.04	–	–	0.586	64.68
N-81-8720-A3	–	1.81	27.11	46.25	–	12.94	8.26	1.99	1.09	0.51	0.04	–	–	0.646	60.20
N-81-102	–	3.11	21.16	38.12	–	16.82	15.06	4.15	1.24	0.29	0.04	–	–	0.727	59.87
N-81-203	–	1.77	15.29	28.21	–	27.59	24.93	1.00	1.01	0.19	0.01	–	–	0.842	61.05
13-81-237	–	3.55	28.95	32.86	–	15.77	7.89	6.60	2.24	1.88	0.27	–	–	0.500	48.96

CIPW NORMATIVE MINERALOGY (wt.%)

	Q	Or	Ab	An	Ne	Hy	Aug	Ol	Mt	Il	Ap	Cc	C	mole fraction MgO	calculated mole % An
CIPW Silica saturated (no cumulus plagioclase)															
N-8400-A1	-	3.45	6.52	12.31	-	39.13	35.14	1.26	1.82	0.33	0.03	-	-	0.794	54.26
NE-81-508	-	1.82	12.74	24.90	-	15.50	24.06	19.34	1.37	0.24	0.03	-	-	0.840	61.88
N-81-161	-	4.43	8.56	12.76	-	22.52	40.25	9.25	1.79	0.42	0.02	-	-	0.788	48.57
8300 S. Spine	-	5.12	8.46	17.09	-	23.66	28.47	14.57	2.12	0.48	0.03	-	-	0.761	54.80
TR-1(0)-1 replicate	-	6.94	9.84	20.05	-	30.16	26.64	3.30	2.33	0.67	0.07	-	-	0.679	53.57
TR-1(0)-1	-	7.08	9.51	19.92	-	31.52	26.66	2.23	2.37	0.64	0.06	-	-	0.673	53.70
WCB-1	-	2.70	20.64	27.71	-	4.07	28.26	13.03	2.02	1.45	0.13	-	-	0.648	52.98
CIPW Silica over-saturated															
N-7(6)-17	32.71	15.78	38.69	9.42	-	1.96	-	-	0.17	0.26	0.08	-	0.95	0.436	14.12
CC-1	32.97	34.18	20.68	8.00	-	1.77	1.78	-	0.20	0.25	0.15	-	-	0.523	12.48
NE-81-V1	35.90	12.76	42.05	7.86	-	0.46	-	-	0.03	0.09	0.01	-	0.86	0.598	12.05

CIPW NORMATIVE MINERALOGY (wt.%)

	Q	Or	Ab	An	Ne	Hy	Aug	Ol	Mt	Il	Ap	Cc	C	mole fraction MgO	Calculated mole % An
Comparison of interior vs exterior of xenoliths															
NE-81-245 OUT	-	2.22	17.14	54.36	-	3.63	9.91	11.67	0.84	0.19	0.02	-	-	0.784	72.70
NE-81-245 IN	-	1.41	15.85	52.69	-	1.93	14.09	12.96	0.86	0.21	0.02	-	-	0.799	74.29
NE-81-244 OUT	-	1.60	14.56	42.55	-	5.17	17.59	16.96	1.28	0.28	0.03	-	-	0.779	71.40
NE-81-244 IN	-	1.22	10.46	35.04	-	10.00	24.61	16.96	1.44	0.27	-	-	-	0.798	73.99

APPENDIX 4

ELECTRON MICROPROBE ANALYSIS OF SELECTED MINERALS

4-A Plagioclase Phenocrysts in Fine Grained Diorite

4-B Hornblende Phenocrysts in Fine Grained Diorite

4-C Plagioclase in Xenoliths

4-D Mafic Minerals and Alteration Products in Xenoliths

4-E Diffusion Rims and Plagioclase Grain Interiors from Anorthositic Xenoliths in Diorite Host

4-F Sample #CB-AD-8530 (Chromite and Tremolite)

4-G Sample #E-1-B-8 (Sulfide and Magnetite)

4-H Sample #S-116 (Garnet and Pyroxene)

Notes:

(1) All Fe reported as FeO

(2) H_2O not included in totals for amphiboles and other water-bearing phases

(3) An (mole %) calculated as $An = \frac{CaO}{CaO + 2(Na_2O + K_2O)} \times 100$

(4) See Table 5 for ± wt.% precision for elements analyzed

(5) n.a. - not analyzed for

(6) — (probe readout = 0.00)

ELECTRON MICROPROBE ANALYSIS
PLAGIOCLASE PHENOCRYSTS IN FINE GRAINED DIORITE

	Wt.% Oxide									
	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	MnO	FeO	TOTAL	An(mole %)
from:										
N-81-110*										
Grain #5										
core	4.91	—	26.57	55.88	0.25	9.41	—	0.07	97.09	50.16
rim	6.28	—	25.86	57.13	0.32	7.95	0.06	—	97.60	40.37
average	5.60	—	26.22	56.50	0.28	8.68	0.03	0.04	97.34	45.26
Grain #6										
core	5.43	—	27.50	54.16	0.21	10.90	0.02	0.13	98.35	51.98
rim	4.60	—	25.88	55.37	0.19	10.43	—	0.17	96.64	54.98
average	5.02	—	26.69	54.76	0.20	10.66	0.01	0.15	97.50	53.48
Sample av.	5.31	—	26.46	55.63	0.24	9.67	0.02	0.10	97.42	49.43
from:										
NE-81-244OUT										
Grain #4										
core	5.67	0.07	27.12	55.53	0.23	10.56	—	0.04	99.22	50.04
rim	5.17	0.06	28.00	53.38	0.28	10.67	—	0.08	97.64	52.48
average	5.42	0.06	27.56	54.45	0.25	10.62	—	0.06	98.42	51.26
Grain #5										
core	6.35	0.09	25.82	57.20	0.27	9.51	—	0.04	99.28	51.98
rim	6.40	0.07	25.51	57.27	0.41	8.52	—	0.07	98.25	41.41
average	6.38	0.08	25.67	57.24	0.34	9.02	—	0.06	98.79	46.70
Sample av.	5.90	0.07	26.62	55.84	0.30	9.82	—	0.06	98.60	48.98

* phenocrysts analyzed in intrusive
phase from these specimens.

APPENDIX 4-A

ELECTRON MICROPROBE ANALYSIS
PLAGIOCLASE PHENOCRYSTS IN FINE GRAINED DIORITE (Cont'd)

	Wt.% Oxide									
	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	MnO	FeO	TOTAL	An(mole%)
from:										
N-81-106*										
Grain #4										
core	5.05	—	25.99	54.92	0.27	9.37	—	0.19	95.90	49.73
rim	5.85	—	24.06	57.33	0.31	7.48	—	0.28	95.34	40.52
average	5.45	—	25.03	56.13	0.29	8.42	—	0.24	95.63	45.13
Grain #7										
core	5.53	—	25.60	55.90	0.21	8.58	—	0.05	95.87	45.53
rim	4.58	—	27.17	54.34	0.20	10.59	—	0.07	97.06	55.54
average	5.06	—	26.38	55.12	0.21	9.59	—	0.06	96.48	50.54
Sample av.	5.26	—	25.70	55.62	0.25	9.00	—	0.30	96.06	47.83
from:										
NE-81-508										
Grain #3										
core	4.03	—	26.06	52.11	0.16	10.46	0.05	0.02	92.89	58.28
rim	5.39	—	24.24	56.66	0.33	8.48	—	0.01	95.11	45.51
average	4.71	—	25.15	54.39	0.24	9.47	0.03	0.02	94.01	51.90
Grain #4										
core	5.28	—	25.05	55.18	0.22	9.55	0.08	0.05	95.41	49.28
rim	5.15	—	23.91	55.38	0.29	8.32	—	0.02	93.07	46.26
average	5.22	—	24.48	55.28	0.26	8.93	0.04	0.04	94.25	47.77
Sample av.	4.96	—	24.82	54.84	0.25	9.20	0.04	0.03	94.13	49.80

* phenocrysts analyzed in intrusive
phase from these specimens.

ELECTRON MICROPROBE ANALYSIS

HORNBLENDE PHENOCRYSTS IN FINE GRAINED DIORITE

	Wt. % Oxide									
	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	MnO	FeO	TiO_2	TOTAL*
from: NE-81-244OUT										
Grain #6 av.	1.70	13.39	9.54	44.56	0.75	11.85	0.40	14.57	n.a.	96.75
Grain #7 av.	1.98	10.93	13.27	40.37	0.93	12.31	0.17	15.30	n.a.	95.26
Sample av.	1.84	12.16	11.40	42.46	0.84	12.08	0.28	14.94	n.a.	96.00
from: N-81-106										
Grain #5 av.	1.70	11.82	10.74	42.95	0.97	11.20	0.26	14.52	1.83	96.00
Grain #6 av.	1.84	12.60	11.91	41.05	1.01	10.83	0.14	12.52	1.72	93.62
Sample av.	1.77	12.21	11.32	42.00	0.99	11.02	0.20	13.52	1.78	94.81
from: NE-81-508										
Grain #5 av.	1.66	14.57	12.37	41.82	1.26	11.57	0.08	10.08	1.48	94.91
Grain #6 av.	1.54	13.48	9.03	44.53	0.69	11.41	0.40	13.09	1.48	95.65
Sample av.	1.60	14.02	10.70	43.18	0.98	11.49	0.24	11.58	1.48	95.68

* Totals do not include H_2O.

ELECTRON MICROPROBE ANALYSIS OF PLAGIOCLASE IN XENOLITHS

	WT%									An (mole%)				
SAMPLE #	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	MnO	FeO	TOTAL	SAMPLE AVERAGE	LOW	HIGH	RANGE	A(G)*
NE-81-244-IN	0.41	-	34.22	44.73	0.03	19.53	0.13	0.19	99.27	96.17	95.63	96.70	1.07	2(1)
NE-81-502	1.54	-	30.95	47.18	0.04	16.26	0.02	0.25	96.34	85.16	84.33	87.12	2.79	2(3)
N-81-257	1.55	0.05	32.36	47.06	0.06	16.40	0.07	0.20	97.81	85.08	83.44	86.22	2.78	2(3)
NE-81-245-OUT	1.66	0.06	33.20	46.66	0.06	17.54	-	0.10	99.26	85.08	81.30	93.02	11.72	3(2)
N-81-110	1.85	-	31.42	47.88	0.01	16.63	0.03	0.27	98.15	83.19	82.31	84.15	1.84	2(2)
N-81-166	1.90	-	32.74	47.92	0.06	16.68	-	0.30	99.60	82.62	81.34	83.89	2.55	2(2)
N-81-160	1.91	-	31.46	48.63	0.06	16.51	0.09	0.37	99.11	82.39	81.10	83.83	2.49	2(4)
13-81-229	2.03	-	32.33	47.28	0.06	16.78	0.02	0.37	98.96	81.75	80.63	83.35	2.72	2(3)
NE-81-245-IN	1.99	0.17	31.61	47.80	0.06	16.41	0.01	0.03	98.09	81.71	80.69	84.60	3.91	2(3)
TU-1-80	2.06	0.04	32.18	47.37	0.10	17.02	-	0.12	98.88	81.57	80.90	82.23	1.33	2(2)
N-81-113	1.94	-	31.15	47.38	0.06	15.81	0.05	0.20	96.59	81.53	80.85	82.35	1.50	2(2)
N-81-162	2.13	0.10	31.48	49.14	0.08	16.54	0.02	0.30	99.84	80.72	79.68	81.36	1.68	2(2)
N-7(1)-2	2.24	0.08	32.27	47.70	0.05	16.84	-	0.24	99.44	80.37	79.51	80.84	1.33	2(2)
E-4	2.24	0.01	31.89	47.82	0.06	16.21	0.02	0.08	98.33	79.72	77.80	80.80	3.00	2(2)
N-7(1)-16	2.37	--	32.04	48.17	0.07	16.55	-	0.43	99.64	79.10	78.38	80.15	1.77	3(2)

- (denotes probe readout = 0.00)

* A (G) ="A" number of analysis on each of "G" grains

APPENDIX 4-C

ELECTRON MICROPROBE ANALYSIS OF PLAGIOCLASE IN XENOLITHS (cont'd)

	WT%									An (mole%)				
SAMPLE #	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	MnO	FeO	TOTAL	SAMPLE AVERAGE	LOW	HIGH	RANGE	A(G)*
NE-81-501	2.08	0.02	31.20	49.09	0.30	15.17	-	0.14	98.08	78.64	58.26	89.16	30.90	2(2)
NE-81-507	2.36	0.02	32.04	48.59	0.07	15.90	0.03	0.36	99.36	78.50	76.52	79.92	3.40	3(3)
NE-81-500	2.42	0.01	31.53	48.28	0.08	16.33	-	0.25	98.91	78.49	76.84	80.73	3.89	2(3)
E-1-B-8	1.71	0.08	29.49	49.32	0.84	14.62	-	0.90	96.97	78.12	57.08	89.64	32.56	2(3)
N-81-106	2.40	0.03	30.76	48.32	0.05	15.07	0.02	0.32	97.49	77.39	75.50	78.68	3.18	2(3)
N81-246	2.65	-	31.06	49.13	0.07	15.81	0.11	0.38	99.21	76.45	73.78	78.94	5.16	2(3)
N-80-TU-5	2.70	0.07	30.97	49.21	0.05	15.88	-	0.22	99.10	76.25	75.66	77.97	2.31	2(3)
NE-81-244-OUT	2.74	0.13	31.71	48.63	0.07	16.03	-	0.07	99.38	76.07	75.92	76.17	0.25	2(1)
N-80-TU-3	3.44	0.08	30.17	50.48	0.13	14.35	-	0.33	98.98	69.22	66.01	73.08	7.07	2(3)
N-81-8720-A3	4.11	-	29.15	52.30	0.12	12.75	-	0.45	98.86	62.71	62.25	63.37	1.12	2(2)
N-81-102	4.18	-	28.80	54.01	0.16	12.83	0.05	0.40	100.45	62.33	60.80	63.64	2.84	2(3)
13-81-237	4.22	1.23	22.61	55.36	1.81	8.78	0.07	2.52	96.60	47.28	29.72	57.63	27.91	2(3)
N-81-159 +	6.97	-	24.93	59.51	0.64	7.32	0.01	-	99.38	36.44	34.48	38.40	3.92	2(2)
N-7(6)-17++	8.68	0.01	21.38	65.67	0.78	3.36	-	0.03	99.91	16.80	16.37	17.52	1.15	2(3)

- (denotes probe readout = 0.00)   * A (G)= "A" number of analysis on each of "G" grains

non-cumulate textured xenoliths: + plagioclase gneiss ++ granite

EMP ANALYSIS OF MAFIC MINERALS AND ALTERATION PRODUCTS IN XENOLITHS

	Wt. % Oxide										
	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	MnO	FeO	TiO_2	Cr_2O_3	TOTAL¢	A(G)*
13-81-237												
hornblende (av)	1.30	10.04	10.32	43.40	0.75	11.36	0.35	17.83	n.a+	n.a.+	95.34	2(2)
N-81-245 IN												
hornblende (av.)	1.04	16.19	9.40	48.37	0.26	11.79	0.09	8.02			95.17	2(3)
chlorite	—	24.54	17.09	30.86	0.01	0.51	0.10	11.80			85.00	2(1)
E-4												
actinolite	0.65	16.74	4.12	52.72	0.15	12.50	0.16	9.65			96.69	2(1)
hornblende	0.92	15.83	5.97	48.84	0.28	11.99	0.17	10.93			94.93	2(1)
N-81-113												
augite	0.37	15.19	2.29	51.22	0.01	22.47	0.17	6.32			98.04	2(1)
N-7(1)-2												
hornblende	1.09	17.66	7.21	48.81	0.16	12.43	0.06	8.25			95.68	2(1)
center alteration assemblage	1.19	5.47	27.60	44.15	0.09	16.70	—	2.93			98.13	2(1)
quartz (inner rim alteration assemblage)	0.02	0.09	0.12	90.98	—	1.18	—	0.23			92.62	2(1)
outer rim alteration assemblage	0.04	0.54	0.50	26.87	0.02	35.00	2.15	1.98			66.01	2(1)
augite	0.28	16.03	2.06	52.06	0.01	22.76	0.08	6.05			99.33	2(1)

* A(G) = "A" number of analysis on each of "G" grains
\+ n.a. = no analysis
— (denotes probe readout = 0.00)
¢ H_2O not included in total

APPENDIX 4-D a

EMP ANALYSIS OF MAFIC MINERALS AND ALTERATION PRODUCTS Cont'd.

	Wt. % Oxide											
	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	MnO	FeO	TiO_2	Cr_2O_3	TOTAL	A(G)*
NE-81-245 OUT actinolite	0.67	18.40	6.22	52.56	0.02	12.77	0.07	6.86	n.a.	n.a.	97.57	2(1)
hornblende (av.)	1.26	16.83	9.48	48.65	0.24	12.35	0.03	8.23			97.14	2(2)
N-80-TU-5 hornblende (av.)	1.61	10.92	9.88	43.06	0.68	11.48	0.26	18.31			96.21	2(2)
13-81-229 augite (av.)	0.34	14.40	2.22	51.44	0.04	22.24	0.11	7.90			98.68	2(2)
N-81-8720-A3 hornblende	1.07	13.13	6.55	46.44	0.43	11.08	0.10	14.16			92.96	2(1)
quartz	—	0.03	0.20	94.16	—	—	—	—			94.39	1(1)
NE-81-500 hornblende	0.99	11.46	7.13	46.75	0.39	11.59	0.38	17.02			95.71	2(1)
NE-81-507 tremolite (av.)	0.46	21.15	2.16	55.08	0.11	11.75	0.24	6.40			97.35	2(2)
N-81-246 chlorite	0.04	16.69	10.33	40.96	0.56	1.92	0.22	14.84			85.56	1(1)
N-81-159 augite (av.)	0.94	12.69	3.63	50.59	0.10	20.51	0.18	9.99			98.53	2(3)
NE-81-501 tremolite (av.)	0.63	19.79	4.79	52.62	0.32	11.60	0.07	5.19	0.13	0.45	95.37	2(3)

APPENDIX 4-Db

EMP ANALYSIS OF MAFIC MINERALS AND ALTERATION PRODUCTS Cont'd.

	Wt. %. Oxide											
	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	MnO	FeO	TiO_2	Cr_2O_3	TOTAL	A(G)*
TR-1(0)-1 actinolite	1.13	16.54	8.04	49.83	0.50	11.52	0.37	8.38	0.18	0.56	97.04	2(2)
N-81-257 hornblende (av.)	0.97	17.68	6.60	51.26	0.26	11.44	0.40	7.59	0.10	0.38	96.67	2(2)
N-81-8400-A3 hornblende (av.)	1.46	15.00	9.17	45.53	0.68	11.06	0.13	10.13	0.86	0.18	94.21	2(2)
N-81-162 chlorite	0.01	24.35	18.88	31.17	0.05	0.36	0.10	11.49	0.09	0.04	86.54	2(1)
N-81-502 augite (av.)	0.22	16.38	2.04	52.85	0.02	22.54	0.19	4.04	0.10	0.62	99.00	2(2)
tremolite	0.38	19.55	3.50	53.53	0.11	12.07	0.13	5.68	0.16	0.55	95.66	2(1)
NE-81-244 IN uralite	1.75	15.60	13.58	45.82	0.29	11.82	0.18	9.27	0.30	—	98.61	2(1)
actinolite	1.05	17.22	7.68	50.63	0.16	11.59	0.21	9.21	0.14	0.09	97.98	2(1)
NE-81-508 hornblende	1.22	16.20	10.74	47.70	0.22	11.46	0.15	6.62	0.16	0.16	94.64	2(2)
N-8400-A1 actinolite (av)	0.38	21.41	0.91	57.29	0.12	11.79	0.27	5.76	0.01	0.41	98.34	1(3)
8300 South Spine actinolite (av.)	0.66	18.11	4.72	52.25	0.20	11.70	0.39	8.10	0.02	0.68	96.83	2(2)
chlorite	0.02	22.05	16.73	30.07	—	0.76	0.39	13.23	0.73	1.28	85.26	1(1)

ELECTRON MICROPROBE ANALYSIS
DIFFUSION RIMS AND PLAGIOCLASE GRAIN INTERIORS FROM ANORTHOSITIC
XENOLITHS IN CONTACT WITH DIORITE HOST ROCK

	Wt.% Oxide									
	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	MnO	FeO	TOTAL	An(Mole %)
N-81-110										
Grain #1										
Diffusion Rim	6.53	—	23.53	60.04	1.06	6.30	0.09	0.15	97.70	(32.52)*
Grain Interior	3.65	—	27.89	49.27	0.18	10.89	—	0.25	92.13	61.46
Grain Interior	3.98	0.04	27.86	51.51	0.22	10.51	0.02	0.36	94.50	58.45
Grain #4										
Diffusion Rim	3.36	—	15.40	70.75	4.71	1.95	—	0.24	96.41	(14.26)
Grain Interior	1.97	—	31.75	48.87	0.06	16.66	0.01	0.23	99.55	82.12
Plagioclase from xenolith interior	1.85	—	31.42	47.88	0.01	16.63	0.03	0.27	98.15	83.19
NE81-244 OUT										
Grain #2										
Diffusion Rim	6.19	0.04	26.21	56.92	0.41	9.16	—	0.10	99.03	(43.88)
Grain Interior	4.46	0.08	28.04	53.81	0.64	11.43	—	0.20	98.66	56.42
Grain #3										
Diffusion Rim	6.50	0.04	24.95	58.35	0.44	8.43	—	0.12	98.83	(40.71)
Grain Interior	2.78	0.08	31.16	49.32	0.08	15.93	—	0.05	99.40	75.60
Plagioclase from xenolith interior	2.74	0.13	31.71	48.63	0.07	16.03	—	0.07	99.38	76.07

*( ) = "equivalent" Anorthite content calculated for glassy melt rim on xenolith

APPENDIX 4-E

ELECTRON MICROPROBE ANALYSIS

(Sample # CB-AD-8530)

ANALYSIS #	Wt.% Oxide						Wt.% Element				
	MgO	Al_2O_3	TiO_2	Cr_2O_3	FeO	TOTAL	Mg	Al	Ti	Cr	Fe
CHROMITE											
Grain #3											
Center	6.41	14.03	0.43	50.58	29.14	100.59	3.87	7.42	0.26	34.60	22.65
Rim	6.16	14.18	n.a.	50.56	29.47	100.36	3.71	7.50	n.a.	34.59	22.90
Rim	6.46	14.17	0.51	49.69	29.61	100.44	3.90	7.50	0.30	34.00	23.02
Average	6.34	14.13	0.47	50.28	29.41	100.46	3.83	7.47	0.20	34.40	22.86
Grain #1											
Center	6.43	13.73	0.36	49.98	30.06	100.56	3.88	7.27	0.21	34.20	23.37
Rim	6.36	13.99	0.65	50.12	29.66	100.79	3.84	7.40	0.39	34.29	23.05
Average	6.40	13.86	0.50	50.05	29.86	100.68	3.86	7.34	0.30	34.24	23.21
Sample Avg.	6.37	14.00	0.48	50.16	29.64	100.57	3.84	7.40	0.25	34.32	23.04

APPENDIX 4-F

ELECTRON MICROPROBE ANALYSIS

(Sample # CB-AD-8530) (Cont'd)

	Wt.% Oxide							
	MgO	Al_2O_3	SiO_2	K_2O	CaO	Cr_2O_3	FeO	TOTAL
TREMOLITE								
Grain #4	22.27	2.32	56.60	0.22	12.21	1.01	2.86	97.49
Grain #5	24.08	1.87	57.59	0.09	12.22	0.32	2.32	98.48
Sample Average	23.18	2.10	57.10	0.16	12.22	0.66	2.54	97.98

ELECTRON MICROPROBE ANALYSIS

(Sample # E-1-B-8)

ANALYSIS #	Wt % S	Wt % Fe	Wt % Cu	TOTAL	Atomic % S	Atomic % Fe	Atomic % Cu
Chalcopyrite Grain #2							
Anal. 1	35.12	31.75	33.69	100.55	49.92	25.91	24.17
Anal. 2	33.10	33.69	31.21	98.00	48.54	28.37	23.10

	Wt % Oxide SiO_2	SO_3	CaO	FeO	CuO	TOTAL	Wt % Element Si	S	Ca	Fe	Cu
Oxide (?)	17.28	1.16	1.25	63.55	7.59	90.84	8.08	0.47	0.89	49.40	6.06

	Wt % Oxide SiO_2	TiO_2	Al_2O_3	FeO	Fe_2O_3*	MgO	TOTAL
Magnetite** Grain #1	0.17	4.51	1.59	34.56	57.76	0.46	99.11
Grain #2	0.10	4.42	1.72	34.54	57.75	0.47	98.99
Grain #3	1.34	0.01	0.18	31.47	63.14	0.17	96.31
Grain #4	0.31	4.02	1.87	34.33	57.01	0.33	97.87

* FeO/Fe_2O_3 partitioned on basis of normative assumption for magnetite structure
**Cr_2O_3 below detection limit by wave length dispersive spectroscopy

APPENDIX 4-G

ELECTRON MICROPROBE ANALYSIS

SAMPLE #S-116
GARNET AND PYROXENE

	Wt. % Oxide								
	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	MnO	FeO	TOTAL
Garnet									
Grain #2									
Core	0.03	8.73	21.60	40.52	—	6.58	0.53	24.02	102.01
Rim	0.01	8.64	21.58	39.21	—	6.90	0.37	23.50	100.21
Average	0.02	8.68	21.59	39.87	—	6.74	0.45	23.76	101.11
Grain #3									
Core	0.02	8.44	20.65	39.66	—	7.28	0.41	23.44	99.90
Rim (1)	—	8.99	21.79	39.77	—	6.81	0.48	23.61	101.45
Rim (2)	0.02	9.10	21.50	39.09	—	6.70	0.42	23.11	99.94
Average	0.01	8.84	21.31	39.51	—	6.93	0.44	23.39	100.43
Sample av. (Garnet)	0.02	8.76	21.45	39.69	—	6.84	0.44	23.58	100.77
Pyroxene									
Grain #1 av.	1.04	12.37	3.68	51.13	0.03	21.06	0.21	9.92	99.44

APPENDIX 4-H

ELECTRON MICROPROBE ANALYSIS

SAMPLE #N-81-159

PLAGIOCLASE AND CLINOPYROXENE
(Adjacent Lamellae in mineral grains)

	Wt. % oxide									Mole %
	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	FeO	TOTAL	An
Plagioclase										
Lamellae 4a	6.60	-	25.64	57.78	0.46	7.55	-	0.13	98.16	37.67
Lamellae 4b	7.06	-	25.71	59.84	0.51	7.37	-	0.07	100.56	35.56
Lamellae 5a	6.79	-	26.07	58.29	0.31	7.85	-	0.11	99.42	38.26
Lamellae 5b	7.20	-	26.00	58.81	0.36	7.84	-	0.04	100.25	36.80

	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	FeO	TOTAL	mole prop. Ca	Mg	Fe
Clinopyroxene												
Lamellae 1a	1.00	13.08	3.43	51.23	-	19.90	-	10.96	99.60	43	39	18
Lamellae 1b	1.00	12.48	3.61	51.02	-	20.90	-	10.57	99.58	45	37	18
Lamellae 2a	0.79	12.92	3.07	52.19	-	22.09	-	9.99	101.05	46	38	16
Lamellae 2b	0.88	13.47	3.19	50.91	-	21.39	-	9.86	99.70	45	39	16
Lamellae 3a	1.02	12.10	3.52	51.65	-	21.07	-	10.99	100.35	45	36	19
Lamellae 3b	1.09	12.35	3.73	51.49	-	20.99	-	10.03	99.68	46	37	17

APPENDIX 4-I

INDEX TO APPENDIX 5

EXPLANATION KEY FOR APPENDIX 5

SAMPLE #

the typed sample # below the photo is the one used throughout the text and appendices.

HAND SPECIMEN:

rock names assigned according to the classification in Chapter III, in part based on an interpretation of the mafic mineralogy and textures. Description refers to xenolith only. Chapter II, section 2 contains a general description of intrusive phases.

THIN SECTION:

examples for notations in ( ):

(An82 EMP) - plagioclase anorthite component rounded to nearest whole number determined by electron microprobe (listed in Appendix 4-C)

(An80 NORM)- plagioclase anorthite component rounded to nearest whole number, from normative mineralogy (listed in Appendix 3)

hornblende (4-Dc) - electron microprobe analysis listed in Appendix 4-D, page c

µm - microns

MATRIX:

Host intrusion. (location of matrix in photo is noted)

REACTION RIM:

Reaction rim between xenolith and host intrusion noted for hand specimen (and thin section, if thin section contains intrusive - xenolith contact).

SHAPE:

refers to xenolith shape

rounded:	no corners visible
subrounded:	corners visible but well rounded
subangular:	corners distinct but slightly rounded
angular:	corners sharp

SIZE:

refers to xenolith size only, maximum dimension

ANORTHOSITE

SAMPLE #
13-81-229

HAND SPECIMEN:
dark grey anorthosite. (96%) dark grey plagioclase. (4%) dark green mafic minerals as anhedral granular segregations and veinlets.

THIN SECTION:
1-5 mm tabular, euhedral to subhedral plagioclase (An82 EMP), slight saussuritization. (2%) augite (4-Da) as anhedral intercumulus space fillings to 0.5 mm. (2%) actinolite + chlorite as alteration product of augite.

MATRIX:
fine-grained diorite. (upper left 1/2 of photo, dark spot in center at contact is lichen).

REACTION RIM:
none visible.

SHAPE:
angular.

SIZE:
10 cm

SAMPLE #
N-81-160

HAND SPECIMEN:
dark grey anorthosite. (97%) dark grey plagioclase. (3%) light green mafic minerals interstitial to plagioclase grains.

THIN SECTION:
1-3 mm tabular, euhedral to subhedral plagioclase (An82 EMP). (1%) anhedral, intercumulus augite preserved where completely surrounded by plagioclase. (1%)1mm wide carbonate veinlets, (1%) very fine grained ($<$ 0.2 mm) randomly oriented, blady, lt. green actinolite + chlorite .

MATRIX:
fine-grained diorite (not visible in photo)

REACTION RIM:
none visible

SHAPE:
angular

SIZE:
15 cm

(NO PHOTO)

(Rock sample crushed for whole rock analysis. Original print did not turn out)

SAMPLE #
N-81-500

HAND SPECIMEN:
dark grey anorthosite. (97%) plagioclase with saussuritization along grain boundaries. (3%) lt. green mafic minerals as anhedral, space fillings to 1 mm.

THIN SECTION:
3-7 mm tabular, euhedral plagioclase (An 78 EMP) moderately saussuritized internally and along grain boundaries. (2%) lt. green very fine granular (20-50 μm) aggregates of pleochroic (green/lt. green) hornblende (4-D6) as intercumulus anhedral space fillings; (1%) mixture of fine grained (≈20 μm) aggregates of opaque oxides and lt. green non-pleochroic actinolite in centers of mafic areas.

MATRIX:
fine-grained diorite

REACTION RIM:
none

SHAPE:
angular

SIZE:
10 cm

SAMPLE #

N-81-201

HAND SPECIMEN:

- white anorthosite. (99%) white to lt. grey plagioclase (An 74 NORM).(1%) interstitial dark green amphibole.

THIN SECTION:
none

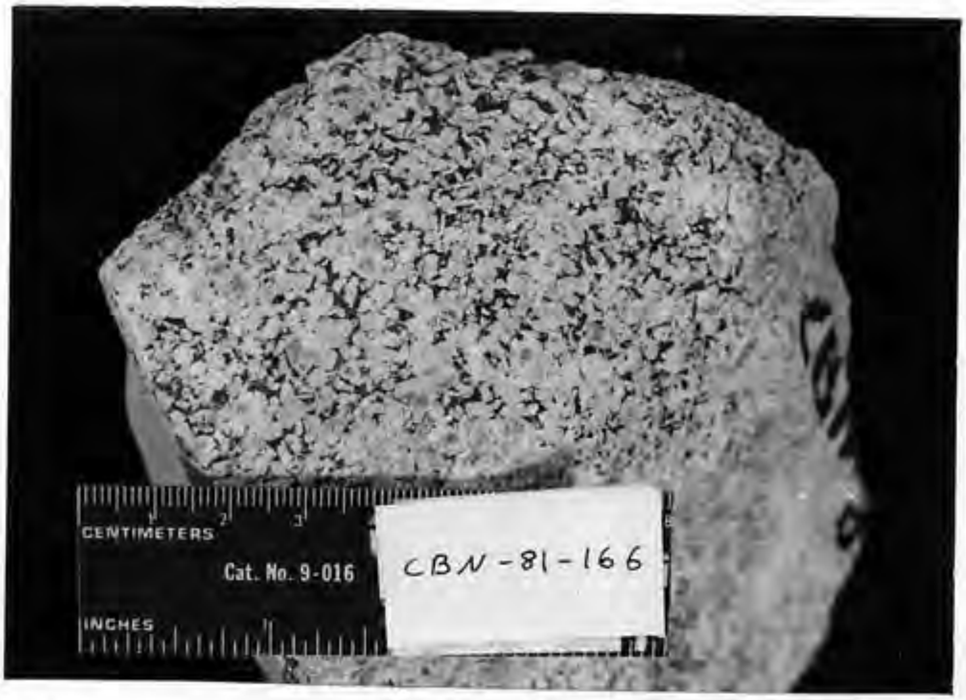
MATRIX:
fine-grained diorite (upper 2/3 of photo, far right side, and spot at far left)

REACTION RIM:
none visible

SHAPE:
subangular

SIZE:
15 cm

GABBROIC ANORTHOSITE



SAMPLE #
N-81-166

HAND SPECIMEN:
gabbroic anorthosite. (89%) equant to tabular, randomly oriented, euhedral light grey plagioclase.(11%) anhedral, intercumulus mafic minerals.

THIN SECTION:
(89%) 2-7 mm equant to tabular, slightly saussuritized plagioclase (An83 EMP). anhedral, intercumulus aggregates up to 2 mm across composed of 100-200 µm, randomly oriented actinolite (8%) + chlorite (2%). Dark green pleochroic, equant hornblende (1%) to 0.5 mm.

MATRIX:
fine-grained diorite (not visible in photo)

REACTION RIM:
none visible

SHAPE:
rounded

SIZE:
9 cm.

SAMPLE #
N-7(1)-18

HAND SPECIMEN:
gabbroic anorthosite. (95%) lath-shaped, 5-8 mm plagioclase, (5%) intercumulus dark green mafic minerals. (Minor weathered sulfide staining and graphite, Fire assay by R. Carlson (p. 158) showed no detectable PGM values

THIN SECTION:
Large (5-8 mm) lath-shaped, euhedral plagioclase (An65 NORM), grains internally fresh but cut by numerous saussuritized fractures. (5%) mafic minerals as anhedral, intercumulus aggregates characterized by fine-grained ($<$ 50 µm) opaque oxides (0.5%) in a fine-grained ($<$ 20 µm) matrix of non-pleochroic lt. green actinolite (3%) and chlorite (1.5%).

MATRIX:
fine-grained diorite (not visible in photo)

SHAPE:
angular

REACTION RIM:
none visible

SIZE:
collected from 31 cm xenolith

SAMPLE #

N-81-106

HAND SPECIMEN:

gabbroic anorthosite. (93%) tabular, euhedral to subhedral plagioclase. (7%) anhedral (1-3 mm) aggregates of dark green mafic minerals.

THIN SECTION:

3-7 mm, tabular, euhedral to subhedral plagioclase (An 77 EMP), grains saussuritized around edges. Fracture fillings and anhedral aggregates to 3 mm of lt. green (50-100 μm) non-pleochroic actinolite (5%) + chlorite (2%)

MATRIX:

fine-grained diorite (surrounding the xenolith in center of photo)

REACTION RIM:

heavy saussuritization of plagioclase for $\approx$ 3 mm around rim of xenolith, segregation of mafic minerals (amphiboles) along boundary in thin section.

SHAPE:

subangular

SIZE:

7 cm

SAMPLE #

N-80-TU-3

HAND SPECIMEN:

gabbroic anorthosite. (88%) light grey plagioclase, with tabular xls. in sub-parallel planar alignment. (12%) dark green mafic minerals as intercumulus material and fracture fillings.

THIN SECTION:

highly fractured, 3-7 mm tabular, euhedral plagioclase (An69 EMP) moderately saussuritized. Mafic minerals in 1-2 mm aggregates of green, strongly pleochroic, randomly oriented, 100 µm hornblende (10%) and euhedral, 50-100 µm opaque oxides.

MATRIX:

fine-grained diorite (left 1/5 of photo)

REACTION RIM:

none visible

SHAPE:

Subangular

SIZE:

20 cm

SAMPLE #
N-81-102

HAND SPECIMEN:
gabbroic anorthosite. (70%) dark grey subhedral plagioclase (An62 EMP), saussuritized around grain boundaries. (30%) intercumulus, anhedral aggregates of mafic minerals up to 5 mm across, rimmed dark green with lt. green cores.

THIN SECTION:
tabular to equant plagioclase. Mafic assemblages to 5 mm rimmed by pleochroic 1-2 mm hornblende (5%) in cracks and embayments in plagioclase, + 20-50 µm equant, granular hornblende (5%) surrounding central areas (20% total) of very fine-grained 20-50 µm hornblende + blady actinolite + carbonate + rounded opaque oxides.

MATRIX:
fine-grained diorite (far right side of photo)

REACTION RIM:
none visible in hand spec., ≈ 20 um in thin section

SHAPE:
subangular

SIZE:
8 cm

SAMPLE #

N-81-8720-A3

HAND SAMPLE:

gabbroic anorthosite. (80%) med. grey 10-15 mm tabular plagioclase xls. in subplanar orientation. (20%) intercumulus dark green mafic minerals.

THIN SECTION:

tabular, euhedral 10-15 mm plagioclase (An63 EMP), mafic minerals in anhedral aggregates to 5 mm, with rims of 100 µm, equant, pleochroic hornblende (3%) (4-Db) + 50 mm opaque oxides (1%), surrounding central areas of lt. green blady actinolite (10%) + opaque oxides (1%) up to 1.5 mm. Larger hornblende to 1 mm in embayments in plagioclase around edges of mafic assemblages (5%). One 200 µm equant quartz (4-Db) grain.

MATRIX:

fine-grained diorite (not visible in photo)

REACTION RIM:

none

SHAPE:

subangular

SIZE:

10 cm

SAMPLE #
N-80 - TU-5

HAND SPECIMEN:
gabbroic anorthosite, (85%) lt. grey tabular plagioclase in random orientation. (15%) mafic minerals as dark green anhedral, intercumulus areas

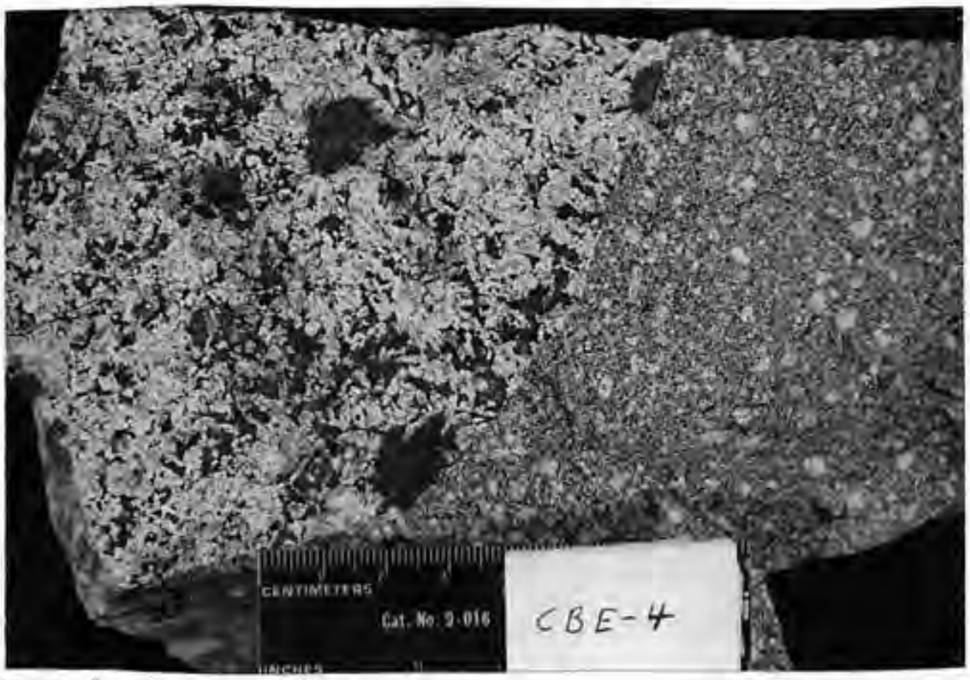
THIN SECTION:
3-6 mm plagioclase (An76 EMP) internally fresh but saussuritized along grain boundaries. mafic minerals as 0.5-3 mm aggregates containing pleochroic hornblende (4-Db) as equant, euhedral, 0.5-1 mm xls (5%) and granular aggregates of 100-200 μm hornblende (5%) + chlorite (4%) + opaque oxides (1%).

MATRIX:
fine-grained diorite (not visible in photo)

REACTION RIM:
none visible

SHAPE:
rounded

SIZE:
14 cm



SAMPLE #
E-4

HAND SPECIMEN:
gabbro. (70%) tabular white plagioclase, random orientation. (30%) mafic minerals: (10%) intercumulus dark green amphibole, (20%) mafic aggregates to 15 mm.

THIN SECTION:
2-3 mm tabular, euhedral plagioclase (An80 EMP). (10%) dark green pleochroic hornblende as thin anhedral intercumulus fillings. (20%) mafic aggregates consisting of dark green pleochroic hornblende rims and lt. green actinolite (4Da) cores, individual xls. < 50 μm.

MATRIX:
coarse porphyritic dacite (right 1/2 of photo)

REACTION RIM:
none visible

SHAPE:
subangular

SIZE:
13 cm

SAMPLE #
NE-81-245

HAND SPECIMEN:
gabbro. (75%) plagioclase: equant, euhedral xls. (25%) dark green amphibole as anhedral to subhedral mafic patches (1- 10 mm).

THIN SECTIONS:

NE-81-245 IN
2-3 mm equant, euhedral plagioclase (An82 EMP), moderate saussuritization along grain boundaries. (20%) 2-5 mm, equant, weakly pleochroic hornblende (4Da) in rounded domains to 10 mm across. also hornblende as 100 um xls. around the larger hornblende xls. and in fractures and interstitial spaces between plagioclase. One 5 mm chlorite grain (4Da) ($<$ 1%).

NE-81-245 OUT
2-3 mm strongly saussuritized plagioclase (An85 EMP). (15%) weakly pleochroic hornblende in mafic clots up to 10 mm across, xls. to 2 mm and also as 20-30 um xls in granular aggregates. (5%) lt. blue-green actinolite (4Db) to 5 mm. (5%) chlorite as alteration of mafic minerals near contact with intrusive host.

MATRIX:
fine-grained diorite (not visible in photo)

REACTION RIM:
none visible in hand specimen, thin section: chloritization of mafic minerals in xenolith near contact.

SHAPE:
subrounded (shape of original 31 cm sample)

SIZE:
collected from 31 cm sample

SAMPLE #
N-81-257

HAND SAMPLE:
gabbro (far left) in contact with diabase (center). 1 mm quartz veins crosscut both lithologies but not the host intrusion. gabbro: (40%) round mafic domains of fine granular texture in matrix of white plagioclase. diabase: fine grained 1 mm hornblende laths in feldspar matrix, trachytic texture.

THIN SECTION:
contact between gabbro and diabase shows assimilation of gabbro by diabase along irregular contact. gabbro: (60%) lath-shaped, euhedral plagioclase to 8 mm (An85 EMP). (40%) mafic minerals in rounded domain to 8 mm, consisting of strongly pleochroic hornblende (4-Dc) in aggregates of 100 - 150 µm xls. diabase: (35%) blady strongly pleochroic, 300 - 400 um, randomly oriented hornblende, (5%) biotite to 2 mm, in matrix of 1 - 2 mm plagioclase, commonly poikilitically enclosing mafics. Minor ($< 0.5\%$) euhedral opaque oxides to 100 µm.

MATRIX:
coarse porphyritic dacite (far right 1/3 of photo)

REACTION RIM:
1 mm mafic rich rim on gabbroic portion of xenolith

SHAPE:
rounded

SIZE:
9 cm gabbro portion, 13 cm overall

MAFIC GABBRO

SAMPLE #
NE-81-501

HAND SPECIMEN:
mafic gabbro. (30%) euhedral plagioclase, (10%) anhedral plagioclase. (60%) mafic minerals as rounded, lt. green domains 3-5 mm.

THIN SECTION:
(40%) 1-2 mm plagioclase (An79 EMP), strongly saussuritized. (50%) fibrous, lt. green tremolite (4Db) in parallel to subparallel arrays, individual needles 20 µm to 1 mm. (10%) blocky, euhedral uralite with individual xls. to 1 mm. (<1%) chlorite

MATRIX:
fine-grained diorite (surrounding dark xenolith)

REACTION RIM:
none visible

SHAPE:
subangular

SIZE:
9 cm

SAMPLE #

NE-81-244

HAND SAMPLE:

mafic gabbro. (30%) plagioclase in domains up to 20 mm, minor plagioclase within mafic domains. (70%) dark green mafic mineral domains up to 50 mm, granular texture.

THIN SECTIONS:

NE-81-244 IN

(30%) strongly saussuritized and fractured 3-6 mm plagioclase (An74 NORM). (40%) randomly oriented, granular to blady, lt. green actinolite (4Dc) and (25%) lt. green, blocky uralite (4Dc). (5%) chlorite as 20-50 μm xls. interstitial to the 50-200 μm actinolite and uralite.

NE-81-244-OUT

same as NE-81-244 IN except that amphibole is darker green and strongly pleochroic near contact with intrusive.

MATRIX:

fine-grained diorite (not visible in photo)

REACTION RIM:

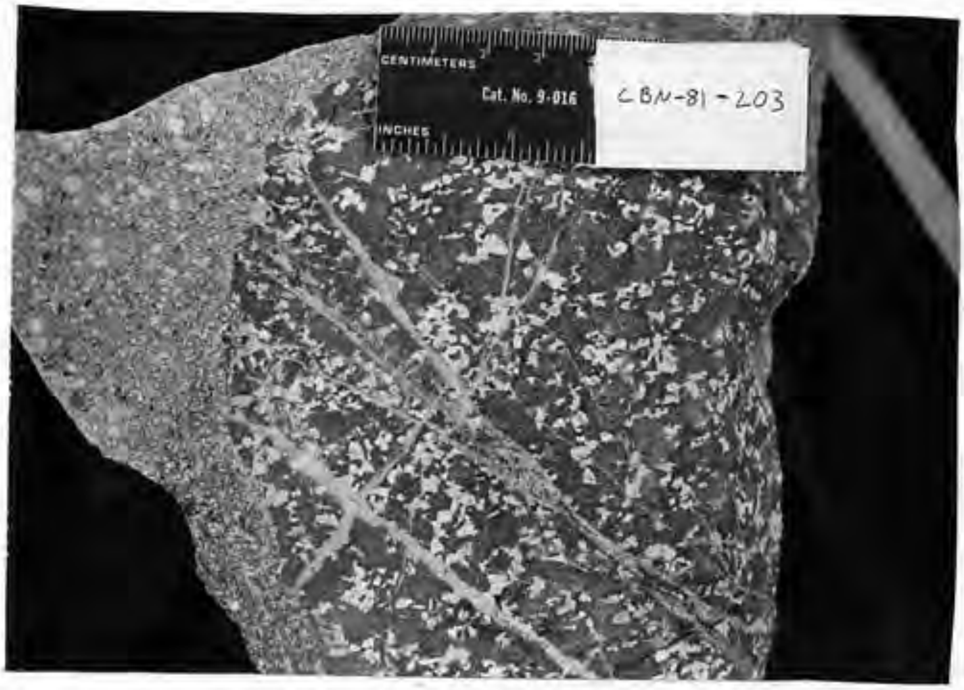
none visible in hand specimen; 100 μm diffusion rim visible on plagioclase in thin section. (See Appendix 4-E)

SHAPE:

subangular (shape of original 31 cm xenolith)

SIZE:

from 31 cm xenolith



SAMPLE #
N-81-203

HAND SPECIMEN:
mafic gabbro, crosscut by 2 directions of quartz veins. (10%) euhedral plagioclase, (10%) anhedral plagioclase in mafic matrix. (80%) fine granular mafic material.

THIN SECTION:
strongly saussuritized, fractured, 2-3 mm plagioclase (An61 NORM). granular, crosscutting quartz vein. tabular mafic domains to 10 mm in parallel orientation, comprised of 50 - 200 μm tabular to blady actinolite (75%) with minor interstitial chlorite (5%).

MATRIX:
coarse porphyritic dacite (far left of photo)

REACTION RIM:
none visible

SHAPE:
rounded

SIZE:
15 cm

SAMPLE #
TU-1-80

HAND SPECIMEN:
norite. (92%) white plagioclase. (8%) rounded 3- 5 mm domains of dark green amphibole rimmed, soft chlorite cored mafic minerals. mafics define layering ("NW" to "SE" in above photo).

THIN SECTION:
3 - 5 mm, equant, euhedral plagioclase (An82EMP), weakly saussuritized along grain boundaries. (8% of total) mafic minerals in 3- 5 mm rounded to oblate domains: blue green uralite rimmed,with chlorite cores. Granular uralite in cracks and space fillings in plagioclase.

MATRIX:
found in talus slope of fine-grained diorite, but no matrix on sample

REACTION RIM:
weathered out

SHAPE:
rounded

SIZE:
14 cm

SAMPLE #
NE-81-502

HAND SAMPLE:
norite. (60%) white plagioclase. (25%) lt. green intercumulus material. (15%) rounded 4 - 5 mm actinolite rimmed, dark brown chlorite cored mafic domains.

THIN SECTION:
equant, euhedral, 2-3 mm plagioclase (An85 EMP), cut by expansion cracks that radiate from mafic areas. mafic minerals: (25% of total)=remnant cores of augite 2 - 3 mm (4-Dc), rimmed by 50 - 100 μm tremolite (4-Dc). (15% of total)=4 - 5 mm rounded, tremolite rimmed, chlorite cored mafic domains.

MATRIX:
fine-grained diorite (top 1/4 of photo)

REACTION RIM:
none visible

SHAPE:
angular

SIZE:
11 cm

SAMPLE #

N-81-110

HAND SAMPLE:

norite. (90%) dark grey plagioclase. (6%) intercumulus mafic minerals.(4%) dark green amphibole rimmed, chlorite cored, 5 - 8 mm, round mafic domains.

THIN SECTION:

1-4 mm equant to tabular, euhedral plagioclase (An83 EMP), strongly saussuritized along grain boundaries. mafic minerals: (6%) weakly pleochroic, 20 µm, granular hornblende; (4%) rounded to anhedral mafic areas, rimmed by fine granular hornblende, with blady actinolite and serpentine (?) cores.

MATRIX:

fine-grained diorite (bottom and lower right hand side of photo)

REACTION RIM:

2 mm white diffusion rim (see EMP data appendix 4-E).

SHAPE:

rounded

SIZE:

10 cm

SAMPLE #
N-81-246

HAND SAMPLE:
norite. (90%) dark grey plagioclase. (5%) intercumulus dark green amphibole. (5%) 4 - 8 mm mafic domains with dark green amphibole rims and chlorite cores, commonly weathered out.

THIN SECTION:
2 - 5 mm equant, euhedral plagioclase (An76 EMP), strongly saussuritized around grain boundaries. (5%) lt. green non-pleochroic 50 - 75 µm actinolite as intercumulus fillings. (5%) rounded mafic domains with med. green pleochroic hornblende rims and dark brown chlorite cores.

MATRIX:
weathered out, but found in talus slope of fine-grained diorite

REACTION RIM:
weathered out

SHAPE:
rounded

SIZE:
12 cm

GABBRONORITE

SAMPLE #
NE-81-507

HAND SAMPLE:
gabbronorite. (80%) medium grey plagioclase, randomly oriented. (20%) mafic minerals, with (15%) as anhedral, intercumulus material and (5%) as 3-5 mm subhedral, rounded domains.

THIN SECTION:
1-2 mm equant, euhedral plagioclase (An78 EMP). (15%) lt. green, non-pleochroic actinolite(4Db) as intercumulus material and rounded, subhedral domains up to 2 mm, with dark brown chlorite (5%) cores in half of the subhedral areas,

MATRIX:
fine-grained diorite (left half of photo)

REACTION RIM:
none visible

SHAPE:
subrounded

SIZE:
12 cm

SAMPLE #
N-81-162

HAND SPECIMEN:
mafic gabbronorite. (40%) white plagioclase, in segregations up to 20 mm. (60%) mafic minerals: (15%) as anhedral med. green, inter-cumulus material, (15%) as subhedral 4 mm clots of medium green granular amphibole, (30%) as large (to 7 mm) euhedral domains of amphibole with chlorite cores.

THIN SECTION:
strongly saussuritzed 1- 3 mm plagioclase (An81 EMP) in a mafic matrix. 3-4 mm tabular, euhedral domains of granular to fibrous lt. green actinolite (15%). (15%) fine granular intercumulus actinolite (interstitial to tabular mafic domains and to plagioclase). (30% of total) very fine fibrous lt. green actinolite + chlorite surrounding chlorite (4Dc) cores

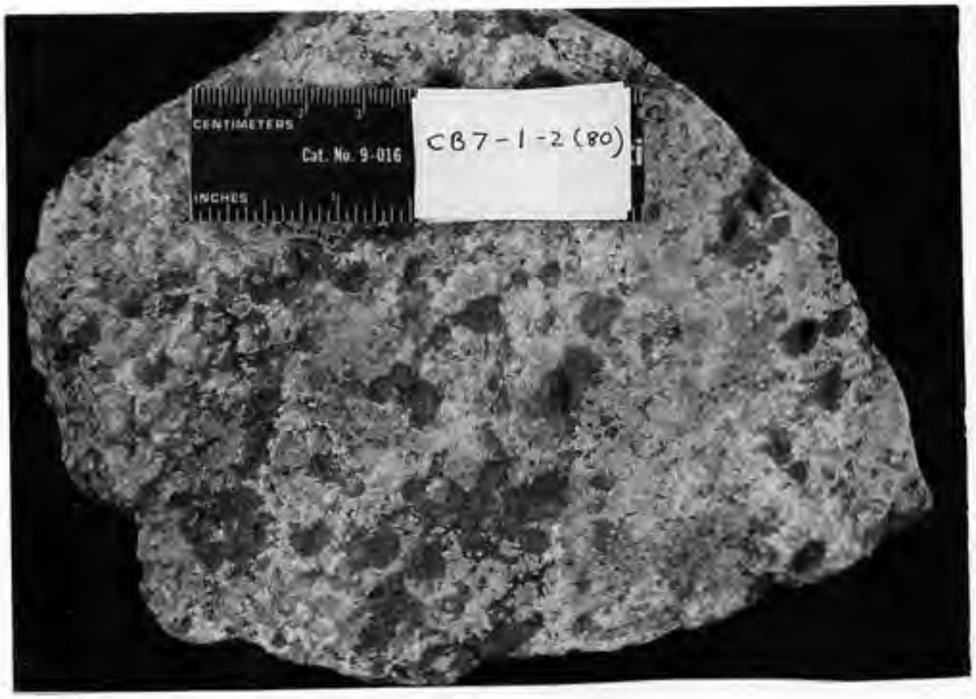
MATRIX:
fine grained diorite (small corner,extreme lower right of photo)

REACTION RIM:
none visible

SHAPE:
subrounded

SIZE:
14 cm

TROCTOLITE



SAMPLE #
N-7(1)-2

HAND SPECIMEN:
troctolite. (85%) plagioclase. (15%) mafic minerals as rounded, 3-5 mm areas with dark green amphibole rims and gold-brown chlorite + (strongly magnetic) magnetite cores, weathered out in negative relief.

THIN SECTION:
3-5 mm equant, euhedral plagioclase (An 80 EMP). (5%) blue-green hornblende + minor opaque oxides as intercumulus fillings. (10%) of total)= alteration assemblage, rounded, embayed, consisting of extremely fine mixture of chlorite + actinolite + opaque oxides at core, rimmed by quartz, outer rim of calc-silicate (?) (4-Da). Minor ($<$ 1%) augite (4-Da) interstitial to plagioclase.

MATRIX:
weathered out of matrix, found loose in talus slope of fine-grained diorite

REACTION RIM:
weathered out of matrix

SHAPE:
rounded

SIZE:
17 cm.

SAMPLE #
N-81-113

HAND SPECIMEN:
troctolite. (93%) med. grey plagioclase. (7%) mafic minerals as rounded, embayed aggregates, with dark green amphibole as 1 mm rims around soft, brown chlorite + hematite (?) cores, dark green hornblende as crack fillings and intercumulus material.

THIN SECTION:
1-2 mm rounded to subhedral plagioclase (An82 EMP) with interstitial anhedral augite (4-Da), altered to granular, 50-100 μm lt. green actinolite along contact of augite with plagioclase grains. (None of the rounded mafic areas discussed under "hand specimen" are visible in the thin section).

MATRIX:
weathered out of matrix, found loose in talus slope of fine-grained diorite.

REACTION RIM:
weathered out of matrix

SHAPE:
rounded

SIZE:
13 cm

SAMPLE #
N-81-130

HAND SPECIMEN:
troctolite. (92%) dark grey plagioclase with saussuritized grain boundaries. (8%) rounded, subhedral mafic areas, rimmed by dark green amphibole, cores of gold-brown chlorite + (strongly magnetic) magnetite, with hematitic brown alteration.

THIN SECTION:
1-5 mm rounded, subhedral plagioclase (An71 NORM). 4-6 mm rounded mafic assemblages (6% of total), with granular actinolite (20 um crystals) rims; chlorite + opaque oxide in cores. (2%) 1-2 mm anhedral augite, partially altered to actinolite at contacts with plagioclase. 3 anhedral multiphase sulfide grains as interstitial space fillings (to 1 mm) surrounded by plagioclase.

MATRIX:
weathered out of matrix, found loose in talus slope of fine-grained diorite

REACTION RIM:
weathered out of matrix

SHAPE:
rounded

SIZE:
12 cm.

SAMPLE #
N-7 (1) - 16

HAND SPECIMEN:
troctolite. (90%) lt. grey plagioclase, (10%) mafic minerals as 5-7 mm rounded, amphibole rimmed assemblages, surrounding chlorite + (strongly magnetic) magnetite cores

THIN SECTION:
2-3 mm equant plagioclase (An79 EMP). (2%) intercumulus blue-green, non-pleochroic amphibole aggregates, 20 μm individual grains. (8% of total) rounded 7-8 mm areas with chlorite rims surrounding fine (< 50 um) chlorite + actinolite + magnetite.

MATRIX:
weathered out of matrix, found loose in talus slope of fine-grained diorite

REACTION RIM:
weathered out of matrix

SHAPE:
rounded

SIZE:
20 cm.

CHROMITITE

SAMPLE #
CB-AD-8530

HAND SAMPLE:
chromitite. (30%) 0.2 - 1 mm euhedral opaque oxide, (70%) dark green silicate.

THIN SECTION:
(30%) 0.2 - 1.0 mm euhedral chromite (4-F); in a matrix of lt. green, non-pleochroic, blady tremolite (65%) (4F); with interstitial chlorite (5%).

MATRIX:
coarse porphyritic dacite (surrounding the dark xenolith in the bottom center of photo)

REACTION RIM:
1 mm dark green (hornblende?) rim visible in hand specimen.

SHAPE:
subangular

SIZE:
3 cm

ULTRAMAFIC/MAFIC ROCKS WITH "RELICT CUMULUS" TEXTURE

SAMPLE #
N-81-161

HAND SAMPLE:
(55%) dark green amphibole; in (40%) lt. green amphibole matrix, pattern on 5 mm scale. (5%) felsic minerals.

THIN SECTION:
dark green, euhedral, hornblende as 1 - 2 mm xls. surrounded poikilitically by blue-green non-pleochroic actinolite. (5%) plagioclase as 1- 2 mm anhedral space fillings.

MATRIX:
fine-grained diorite (not visible in photo)

REACTION RIM:
none

SHAPE:
rounded

SIZE:
7 cm

SAMPLE #
TR-1(0)-1

HAND SPECIMEN:
Dark green/lt. green mafics, mottled, on 5 mm scale. (20%) interstitial felsic minerals.

THIN SECTION:
(20%) fibrous, 1 mm actinolite (4-Dc) as equant-shaped domains to 10 mm; in a matrix of fine granular, lt. blue-green non-pleochroic uralite (60%) + lt. green pleochroic, 20 μm crystalline amphibole (10%). (5%) 20 - 50 μm quartz. (5%) 20 - 100 μm plagioclase

MATRIX:
coarse porphyritic dacite (not visible in photo)

REACTION RIM:
none

SHAPE:
rounded

SIZE:
10 cm

Sample #
13-81-227

HAND SAMPLE:
altered ultramafic. (99%) mafic, (1%) felsic minerals. med. green, mosaic pattern created by dk. brown straining along healed fractures.

THIN SECTION:
serpentine rimmed, chlorite filled, rounded, 3 mm domains, and 3 - 5 mm domains of tremolite, both in a fine 10 - 20 μm matrix of non-pleochroic, granular tremolite, a few grains (to 500 μm) of remnant olivine (high birefringence, high relief, clear in plane light, no pleochroism)

MATRIX:
fine-grained diorite (upper left hand corner)

REACTION RIM:
none visible in hand specimen, but xenolith breaks away freely from diorite host

SHAPE:
rounded

SIZE:
10 cm

(GREEN) SAUSSURITIZED PLAGIOCLASE
+ AMPHIBOLE

SAMPLE #
E-1-B-8

HAND SPECIMEN:
(green) saussuritized plagioclase with amphibole. (65%) lath-shaped, green, clouded plagioclase. (32%) dark green mafic minerals. (3%) 0.5 mm opaque oxides.

THIN SECTION:
2 - 5 mm lath shaped, euhedral plagioclase (An 57 — 90 range EMP), very strongly saussuritized and contains disseminated very fine (< 20 µm) opaque oxides. mafic minerals: (35% of total) anhedral, inter-plagioclase domains of very fine (20 µm) hornblende + chlorite + quartz + opaque oxides + chalcopyrite (see appendix 4-G) + minor calcite.

MATRIX:
fine-grained diorite (not visible in photo)

REACTION RIM:
none visible

SHAPE:
rounded

SIZE:
9 cm

SAMPLE #
13-81-237

HAND SAMPLE: (sample is saw cut)
(green) saussuritized plagioclase with amphibole, mottled on 10 mm scale. (60%) very strongly saussuritized plagioclase. (40%) dark green mafic minerals. minor weathered sulfide staining.

THIN SECTION:
3 - 5 lath-shaped outlines of very strongly saussuritized plagioclase (An30-58 EMP), with 20 µm opaque oxides and 20 µm dark green hornblende disseminated internally in the plagioclase. anhedral mafic domains up to 5 mm: (37%) dark green hornblende as 20 - 50 µm xls in granular aggregates and as xls up to 2 mm + (3%) opaque oxides up to 100 µm disseminated throughout hornblende + (< 0.5%) Fe-sulfide (EMP wave length dispersive determination).

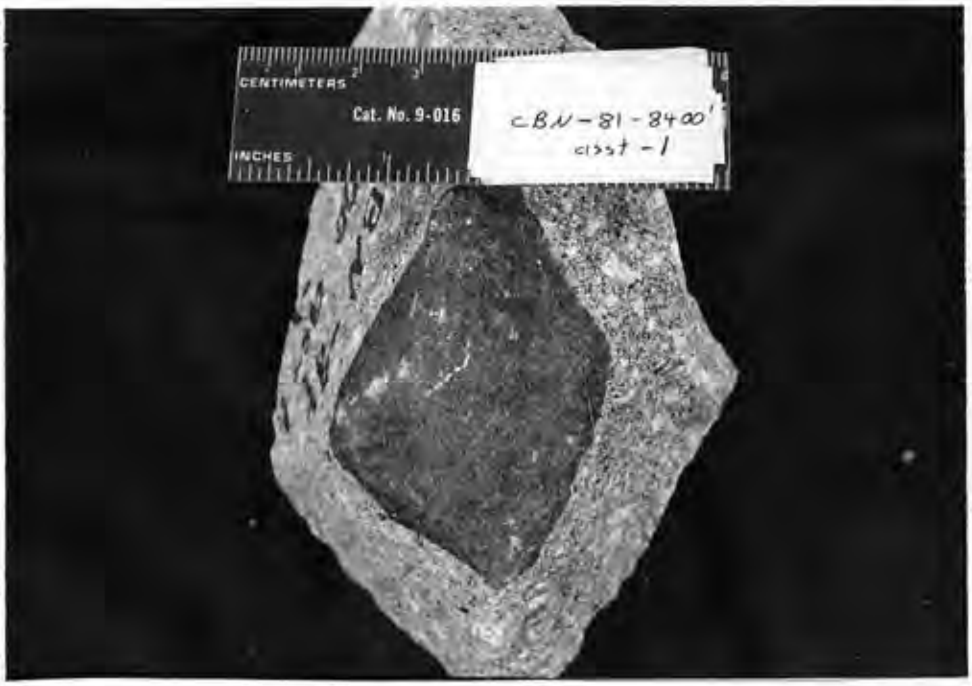
MATRIX:
coarse porphyritic dacite (not visible in photo)

REACTION RIM:
2 mm dark green amphibole rich rim

SHAPE:
subrounded

SIZE:
14 cm

GRANULAR AMPHIBOLITE



SAMPLE #
N-81-8400-A1

HAND SPECIMEN:
dark green, granular textured amphibolite.

THIN SECTION:
blady to fibrous, 500 µm actinolite (4Dc), random orientation. at contact with host intrusion, the amphibole becomes dark green pleochroic hornblende and xl. size increases to 800 µm ((100%) amphibole).

MATRIX:
coarse porphyritic dacite (surrounding the dark xenolith)

REACTION RIM:
2 mm dark rim, visible in hand sample and thin section.

SHAPE:
subrounded (perspective of photo makes xenolith look more angular than when viewed in hand sample)

SIZE:
8 cm

SAMPLE #
N-81-111

HAND SPECIMEN:
dark green granular textured amphibolite with biotite.

THIN SECTION:
(68%) fine granular to blady aggregates of 200 - 300 µm, slightly pleochroic actinolite; (20%) 200 - 300 µm zoned plagioclase; and (10%) 500 - 700 µm euhedral, strongly pleochroic hornblende. (2%) biotite as 1 mm, euhedral xls.

MATRIX:
medium porphyritic dacite (surrounding the dark xenolith at bottom center of photo)

REACTION RIM:
none visible

SHAPE:
rounded

SIZE:
6 cm

SAMPLE #
8300 S. SPINE

HAND SAMPLE:
dark green, very finely granular amphibolite. (98%) mafic. (2%) feldspar (?).

THIN SECTION:
(95%) 50 - 100 µm, granular, randomly oriented actinolite (4Dc). (3%) chlorite interstitial to actinolite and as one 3 mm rounded, fibrous clot. (2%) feldspar (?). minor (<0.5%) 20 µm disseminated opaque oxides.

MATRIX:
coarse porphyritic dacite (right 2/3 of photo, dark spots toward right are lichen)

REACTION RIM:
none visible

SHAPE:
rounded

SIZE:
7 cm

AMPHIBOLE - PLAGIOCLASE SCHIST

SAMPLE #
NE-81-508

HAND SAMPLE:
amphibole - feldspar schist. (75%) green amphibole. (25%) white feldspar overall, as 2 - 10 mm stringers parallelling schistosity.

THIN SECTION:
foliation defined by elongation of 20 - 50 µm hornblende (4Dc) (65%). chlorite (10%) along foliations. no plagioclase visible in section.

MATRIX:
fine-grained diorite (top 2/3 of photo)

REACTION RIM:
none visible in hand specimen. extremely fine 10 µm "recrystallization rim" visible in thin section.

SHAPE:
rounded

SIZE:
8 cm

AMPHIBOLE IN FELDSPAR + QUARTZ
GROUNDMASS

SAMPLE #

N-81-8400-A3

HAND SPECIMEN:

(80%) dark green subhedral amphibole; in pink feldspar-rich groundmass.

THIN SECTION:

(80%) dark green pleochroic hornblende as discrete 5 mm xls. (4Dc). (2%) euhedral apatite (EMP wave length dispersive composition determination). (18%) very fine grained to aphanitic feldspar +quartz groundmass. (< 1%) 100 µm opaque oxides.

MATRIX:

coarse porphyritic dacite (far upper right of photo)

REACTION RIM:

none visible

SHAPE:

subrounded

SIZE:

4 cm

ALKALI GRANITE

SAMPLE #
CC-1

HAND SPECIMEN:
alkali granite/micropegmatite. (50%) quartz, (50%) alkali feldspar.

THIN SECTION:
hypidiomorphic granular texture, 1-2 mm strained quartz + strongly sericitized feldspar. no mafic minerals.

MATRIX:
fine-grained diorite (far upper right of photo)

REACTION RIM:
ragged edge, but no visible rim

SHAPE:
rounded

SIZE:
10 cm

Sample #
N-7(6)-17

HAND SPECIMEN:
alkali granite/micropegmatite. (30%) quartz, (70%) white feldspar, (<1%) amphibole + zircon. (Dark areas in photo are clear quartz)

THIN SECTION:
Hypidiomorphic granular texture of 1-3 mm quartz + dominant orthoclase feldspar + oligoclase (An17 EMP). Quartz is unstrained.

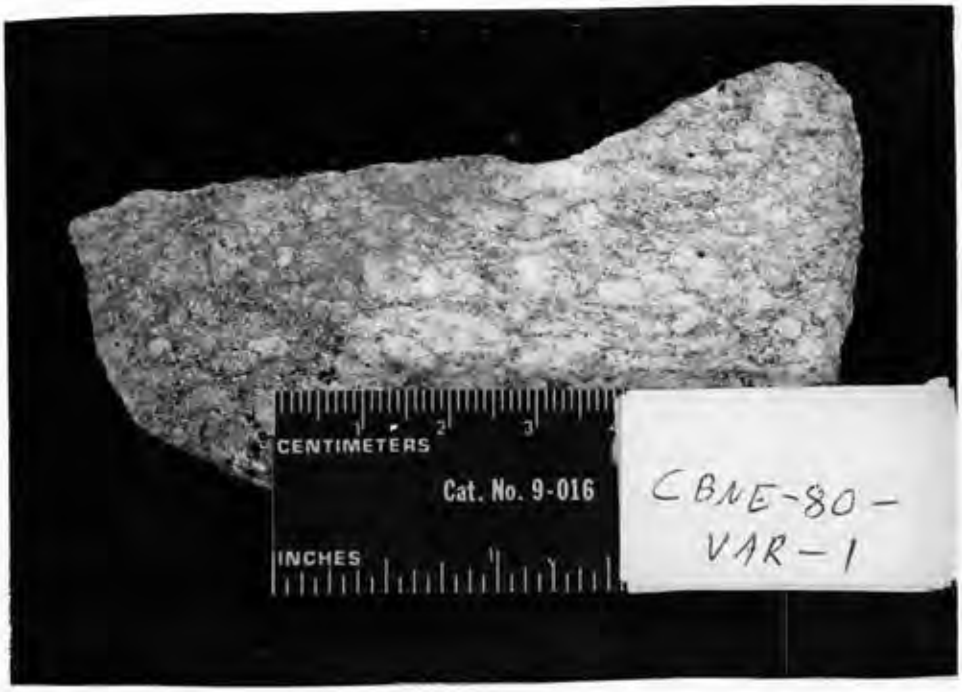
MATRIX:
fine-grained diorite (not visible in photo)

REACTION RIM:
none

SHAPE:
angular

SIZE:
8 cm

GNEISS



SAMPLE #
NE-80-VAR-1

HAND SPECIMEN:
quartz-feldspar gneiss. foliation on mm scale defined by quartz and muscovite in a white feldspar matrix.

THIN SECTION:
(40%) quartz + (55%) oligoclase in parallel bands on 1-2 mm scale, alternating coarse ($>$1 mm) and fine ($<$ 200 μm) crystalline bands define foliation.($<$ 1% biotite).(5%) muscovite.

MATRIX:
coarse porphyritic dacite (left 1/3 of photo)

REACTION RIM:
none visible

SHAPE:
subangular

SIZE:
6 cm

SAMPLE #
N-81-159

HAND SPECIMEN:
mixed xenolith:
(2/3) white plagioclase gneiss with green mafic
mineral clusters to 1.0 cm (upper right center of photo)
in contact with
(1/3) feldspar-amphibole gneiss (lower left center of photo)

(fine foliation in "microgneiss" lower 1/3 of
xenolith is parallel to coarse layering in
upper 2/3 of xenolith.)

THIN SECTION:

(from upper 2/3) hypidiomorphic granular texture
of (1-5 mm) plagioclase (An 36 EMP) (70%) + quartz
(5%), surrounding 15 mm domains of mafic minerals
composed of clinopyroxene (4-I) (20%), with minor
chlorite (3%) + dk. green granular pleochroic
hornblende (2%).

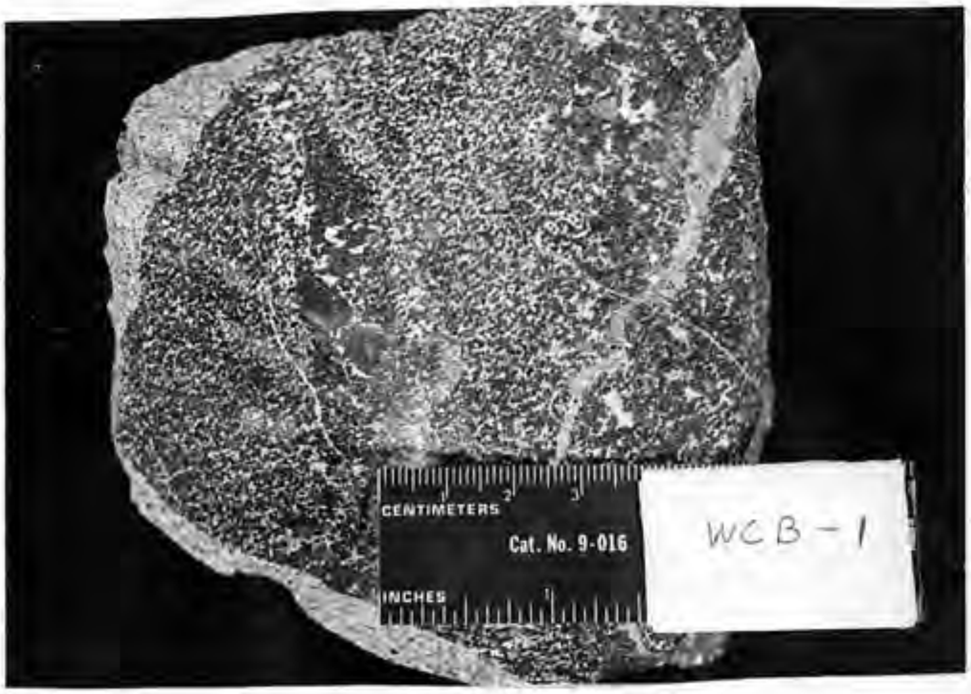
MATRIX:
coarse porphyritic dacite (surrounding xenolith in the
center of the photo)

REACTION RIM:
none visible

SHAPE:
subrounded

SIZE:
7 cm

DIABASE



SAMPLE #
WCB-1

HAND SAMPLE:
diabase. Sub-planar lamination of mafic (40%) and felsic (60%) minerals, feldspars weathering pink, crosscutting felsic veins to 0.5 mm.

THIN SECTION:
(40%) clusters of pleochroic hornblende (1mm) + opaque oxides (200 μm). (40%) granular, subhedral plagioclase (1-2 mm). (10%) cross-hatched microcline. (5%) strained quartz. (5%) chlorite

MATRIX:

fine-grained diorite (visible along extreme left and extreme bottom edges of photo)

REACTION RIM:
none visible

SHAPE:
subangular

SIZE:
9 cm

GARNET AND PYROXENE

SAMPLE #
S-116

HAND SPECIMEN:
dark red garnet (40%). dark green pyroxene (60%) with hypidiomorphic granular texture (1-2 mm grains).

THIN SECTION:
unzoned garnet, with a composition between almandine and grossular (EMP, App. 4-H), in hypidiomorphic granular texture with a calcic clinopyroxene (EMP, App. 4-H).

MATRIX:
coarse porphyritic dacite surrounds xenolith at lower right (dacite is badly weathered and lichen-covered in photo)

REACTION RIM:
none visible

SHAPE:
subrounded

SIZE:
3 cm

LOSS ON IGNITION

Franklin and Marshall College Analytical Procedures, Steven Sylvester (1980)

1. Zero the balance. (Do not tare until all weighings are completed !)
2. Weigh alumina crucible (Record all weights to four decimal places).
3. All approximately 1 gram of finely ground rock powder.
4. Record weight of crucible plus sample.
5. Place in muffle furnace for 60 minutes at 900° C.
6. Remove, cool and weigh (in desiccator).
7. Weight of sample before heating,less weight after heating is "initial" loss on ignition. (NOTE: if sample has lost weight, the loss is positive; if it has gained weight, the loss is negative).
8. Determine % loss on ignition by dividing "initial loss" by initial weight of sample and multiply by 100.
9. To obtain the true loss on ignition for the sample:
   (a) multiply 0.111342 times the weight % FeO (determined by titration).
   (b) add this value to the loss on ignition (whether + or -). This sum is the true loss on ignition.

APPENDIX 7

XENOLITH DENSITIES CALCULATED FROM NORMATIVE MINERALOGY

Sample No.	Density (gm/cm^3)
Silica Undersaturated	
13-81-227	3.01
N81-166	2.80
NE-81-500	2.78
N-7(1)-18	2.79
Silica Saturated (with cumulus plagioclase)	
NE-81-502	3.01
N-81-110	2.80/2.80 (rep.)
N-81-160	2.77
13-81-229	2.77
NE=81-245IN	2.89/2.91(rep.), average = 2.90
NE-81-245 OUT	2.88
TU-1-80	2.81
N-81-113	2.88
N-81-162	3.02
N-7(1)-2	2.88
E-4	2.90
N-7(1)-16	2.88
NE-81-507	2.87
E-1-B-8	2.92
N-81-246	2.83
N-80-TU-5	2.81

Sample No.	Density
NE-81-244 IN	3.05
NE-81-244 OUT	2.98
N-81-201	2.77
N-81-130	2.83
N-80-TU-3	2.79
N-81-8720A3	2.87
N-81-102	2.94
N-81-203	3.02
13-81-237	2.97
Silica Saturated (no cumulus plagioclase)	
N-8400-A1	3.20
NE-81-508	3.08
N-81-161	3.18
8300 S. Spine	3.17
TR-1(0)-1	3.14/3.14 (rep.)
WCB-1	3.13
Silica Oversaturated	
N-7(6)-17	2.66
CC-1	2.65
NE-81-VAR-1	2.64

Sample No.	Density
Intrusive Phases (fine grained diorite)	
AD-8380	2.79
13-81-241	2.86
(coarse porphyritic dacite)	
13-81-240	2.80
AD-8530	2.80

---

method of density calculation:

(1) assume 100 grams total sample, therefore

(X wt.% = X grams)

(2) volume of any normative mineral A given by:

$$\text{volume A } (cm^3) = (\text{grams})_A \times \frac{1 \text{ mole}}{\text{formula wt.A (grams)}} \times \frac{\text{molar volume A } (cm^3)}{1 \text{ mole}}$$

(3) sum volumes of all normative minerals = total volume (cm^3)

(4) $$\text{rock density } (gm/cm^3) = \frac{100 \text{ (grams) total sample}}{\text{total volume of normative minerals } (cm^3)}$$

molar volumes and formula weights from Robie *et al.* (1979)

APPENDIX 8

DIFFERENTIAL THERMAL ANALYSIS OF CARBONATES

CBS-81-125(c)	Carbonate at (≈ 2 mm away from intrusive) intrusive contact with coarse porphyritic dacite
sample wt = 0.105 g	
DTA: *	sharp, intense, endothermic peak at 924°C (Hutchinson, 1974, p. 453: calcite = single sharp intense endothermic peak, may vary from 860° C to 1010° C - no other peaks present.)
XRD: #	calcite (no other phases present in detectable quantity)

CBS-81-125(a)	Carbonate 3' from contact at (c) above
sample wt = 0.105 g	
DTA:*	sharp, intense, endothermic peak at 933°C (Hutchinson, 1974, p. 453: calcite = single, sharp, intense endothermic peak, may vary from 860° C to 1010° C - no other peaks present.)
XRD:#	calcite (no other phases present in detectable quantity).

---

* DTA: both samples run against 0.056 g MgO standard; air flushed furnace; 1" - 1 mV graph; differential amplification = 100 x; (Pt + 10 Rh) vs. (Pt) thermocouple; Al_2O_3 ceramic block; Pt sample holders; temperature calibration checked with NaCl melting point: (801° C) check.

#XRD: Phillips/Norelco XRD: 500 counts full scale; 2°/minute; time constant = 0.5