

THESIS

PERIDOTITE XENOLITHS IN COLORADO-WYOMING
KIMBERLITES

Submitted by
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In partial fulfillment of the requirements
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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPER-
VISION BY MELISSA BRADFORD KIRKLEY ENTITLED PERIDOTITE XENOLITHS
IN COLORADO-WYOMING KIMBERLITES BE ACCEPTED AS FULFILLING IN PART
REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE .

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ABSTRACT OF THESIS

PERIDOTITE XENOLITHS IN COLORADO-WYOMING KIMBERLITES

Mantle peridotite xenoliths in Colorado-Wyoming kimberlites include abundant dunites, garnet and/or spinel harzburgites, lherzolites, clinopyroxenites and websterites. Garnet and/or spinel wehrlites, olivine websterites and orthopyroxenites are less common. Coarse equant and tabular, transitional-porphyroclastic, porphyroclastic, mosaic-porphyroclastic and granuloblastic textural types are recognized in both altered and unaltered xenoliths. The term porphyroblastic is introduced to describe textures observed in some olivine-free pyroxenite xenoliths. Special textural features such as exsolution phenomena and garnet rims around spinel are also present.

Six lithologic groups are defined on the basis of mineral and whole rock chemistry. Minerals of Group I garnet peridotites are rich in Cr_2O_3 , relatively high in MgO , and generally poor in Al_2O_3 and FeO , although clinopyroxenes of porphyroclastic xenoliths are slightly enriched in FeO . Minerals of Group II and III xenoliths, spinel peridotites of Sloan-Nix-Moen and Iron Mountain kimberlites respectively, have relatively high levels of Cr_2O_3 and MgO and low FeO , TiO_2 , Al_2O_3 and Na_2O . Olivine-free, garnet and/or spinel pyroxenites comprise Group IV and their minerals are poor in Cr_2O_3 and generally high in FeO , TiO_2 and Al_2O_3 . Group V, the "Websterite Group," consists of a variety of rock types. Mineral compositions of Group V xenoliths are generally

intermediate between those of Groups I and IV. Dunites, which comprise Group VI, have a bimodal distribution exhibited by forsterite compositions. Whole rock chemistry calculations determined on fresh nodules of Groups I, II, IV and V indicate that Group I and II xenoliths are most depleted in FeO , TiO_2 , CaO and Na_2O whereas nodules of Group IV are richest in these oxides. Group V xenolith compositions are intermediate between and overlap with those of Group I and IV.

Estimates of temperatures and pressures of equilibration made on fresh xenoliths suggest that Group I nodules formed above 1100°C at depths in excess of 150 km (50 kb). Group I xenoliths with porphyroclastic textures exhibit slightly higher temperatures and pressures than other nodules. Most xenoliths of Groups II, IV and V equilibrated at temperatures below 900°C and at depths of less than 100 km (30 kb). Spinel coexisting with garnet persists to depths of approximately 80 km (25 kb).

Texture and chemistry correlations reported from some garnet peridotite suites from African kimberlites are not observed in Colorado-Wyoming kimberlites. Chemistry of Group II and III spinel peridotites indicates these nodules may have undergone partial melting. Group IV garnet $\pm$ spinel pyroxenites may represent crystallized partial melts or cumulates from partial melts. Spinel in some peridotites of Group V appears to have reacted with orthopyroxene to form garnet rims. The two varieties of dunites, Group VI, may represent cumulates relatively rich in FeO , and residual dunites depleted in FeO .

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CHAPTER I

INTRODUCTION

Purpose of Study

Kimberlites are important not only as potential sources of diamond but also for the wealth of information they bring to the surface in the form of xenoliths from the lower crust and upper mantle. These xenoliths, rounded by attrition during ascent in the fluidized kimberlite magma, provide a rare opportunity for study of otherwise inaccessible materials.

This study was undertaken in order to expand upon existing knowledge of upper mantle peridotite and pyroxenite xenoliths recovered from kimberlite of northern Colorado and southern Wyoming. Mineralogy, textures, mineral and whole rock chemistry, and pressure and temperature conditions of formation of the xenoliths were evaluated and correlations were made between xenoliths within individual kimberlite diatremes, between xenoliths of different kimberlite diatremes and districts, and with similar xenoliths from kimberlites in other parts of the world.

Eclogite and granulite xenoliths also found in the Colorado-Wyoming kimberlites are not included in this study. Therefore, general use of the term "xenolith" or "nodule" in this report refers only to those rocks dealt with in this study.

Kimberlite Distribution

Kimberlite diatremes near the Colorado-Wyoming border were first recognized by M.E. McCallum in 1964. Since that time more than 30 diatremes have been located within the area now known as the State Line District (Fig. 1). These diatremes commonly occur in groups and have been named after the ranches on which they are found: Sloan group (pipes 1-4), Nix group (pipes 1-4), Moen group (pipes 1 and 2), Schaffer group (pipes 1-20), Ferris group (pipes 1 and 2), and Aultman group (pipes 1 and 2). Kimberlite was discovered near Iron Mountain, Wyoming by W.A. Braddock and D. Nordstrom in 1971. The 57 occurrences of kimberlite pipes and dikes of this area define the Iron Mountain District (Fig. 1).

Methods of Investigation

Standard petrographic thin sections of approximately 400 nodules from Colorado-Wyoming kimberlites were examined. Modal analyses were performed on all thin sections containing appreciable quantities of fresh constituents (Appendix I). Approximately 500 points at intervals of 0.5 mm were counted on each of the nodules sufficiently large to permit such a count density. Duplicate analyses performed on several thin sections indicate that analytical accuracy is within about ± 5 relative percent.

Microprobe analyses for eleven major oxides were performed on mineral separates and minerals in polished thin sections by D.H. Eggler, C.B. Smith, and by the author under the auspices of Dr. Eggler (Appendix II). Analyses by C.B. Smith and many of those by D.H. Eggler were performed with the MAC 400 microprobe at the Geophysical

Figure 1. Location Map.

State Line District kimberlite pipes:

SD = Sloan group

NX = Nix group

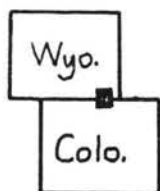
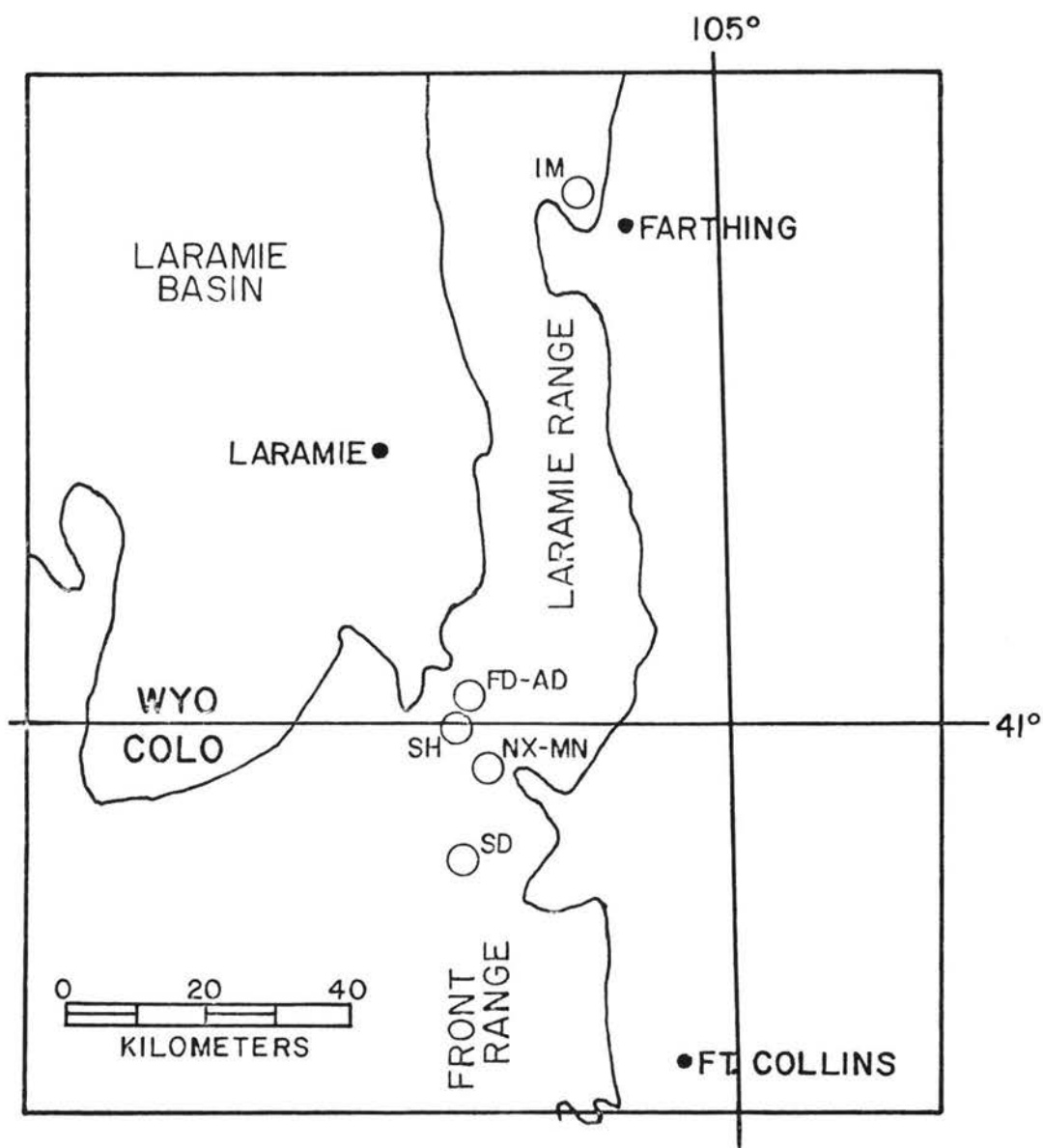
MN = Moen group

SH = Schaffer group

FD = Ferris group

AD = Aultman group

Iron Mountain District: IM



Laboratory Carnegie Institute of Washington, D.C. Other analyses by D.H. Eggler and those by the author were obtained at Pennsylvania State University on the ETEC automated electron probe microanalyser using an acceleration potential of 15 kilovolts and specimen current of approximately 0.03 microamps. All analyses were corrected on-line for matrix effects utilizing the coefficient matrix of Albee and Ray (1970). A variety of natural and synthetic glass standards were used. Major element analyses by such methods are accurate to $\pm 2-3$ relative per-cent (Nixon, 1973).

Whole rock chemical analyses were calculated from modal data and mineral chemistry (Appendix III). Volume percentages of mineral phases were converted to weight percentages utilizing specific mineral formulae obtained through the chemical analyses for each mineral. For accessory minerals rutile and phlogopite, average gram formula weights of 79.42 and 768.84 respectively were used. Calculations were carried out on the CYBER 172 mainframe computer at Colorado State University.

Estimates of equilibration pressures and temperatures from mineral compositions have been generated by the program TEMPEST (A.A. Finnerty and F.R. Boyd, unpublished) kindly supplied by A.A. Finnerty. This program computes temperatures of equilibrium utilizing several experimentally determined geothermometers and geobarometers. The methods that provided the most consistent results within groups of xenoliths of similar compositions were chosen from these available results.

Previous Work

Preliminary investigations of kimberlite occurrences near the Colorado-Wyoming border were conducted during the mid to late 1960's and results are presented in reports by Chronic et al. (1965, 1969), and McCallum and Eggler (1968, 1971). Mineralogy, chemistry, and temperature and pressure conditions of formation of xenoliths in these kimberlites have been discussed in several papers including those by Eggler and McCallum (1973, 1974, 1976), McCallum et al. (1975, 1979), McCallum and Eggler (1976), and McCallum and Mabarak (1976). Iron Mountain District kimberlites and their included nodules were studied and compared to kimberlites and nodule suites of the Colorado-Wyoming State Line District by Smith (1977).

Subdivision of Colorado-Wyoming kimberlite diatremes into three distinct clusters (Sloan-Nix-Moen groups and Schaffer-Ferris-Aultman groups of the State Line District and a third group in the Iron Mountain District--Fig. 1) was made by Eggler et al. (1979) on the basis of differences in chemistry of included megacryst assemblages. This distinction is used as a basis for definition and comparison of nodule suites in this report.

CHAPTER II

PETROGRAPHY

Introduction

Fresh xenoliths are most abundant at the Sloan 2 and Nix 2 and 4 diatremes where greater than 90 percent of the nodular material collected is fresh. Nodules considered "fresh" may be replaced by as much as 40 volume percent alteration materials whereas "altered" nodules commonly contain 100 percent alteration products. The majority of fresh xenoliths are spinel and/or garnet peridotites low in clinopyroxene (Figs. 2, 3). Dunite nodules containing essentially 100 percent olivine are relatively abundant. Less abundant are "harzburgitic-" and "hercynitic-dunites" (names here applied to xenoliths with greater than 90 volume percent olivine and minor amounts of one or both pyroxenes and/or garnet or spinel). Olivine-free, garnet and/or spinel clinopyroxenites and websterites are moderately abundant, whereas olivine websterites, wehrlites, and garnet orthopyroxenites are relatively rare (see IUGS classification for general nomenclature, Streckeisen, 1973, and Fig. 2).

Nodules from the Nix 3, Moen, Schaffer-Ferris-Aultman group and the Iron Mountain District diatremes are generally severely altered. However, approximately half of the nodules collected from these diatremes contain relict, recoverable grains of garnet, clinopyroxene, spinel, phlogopite and/or ilmenite in a serpentized, silicified, or

Figure 2a. Legend for subsequent color coded figures.

	coarse equant		dunite
	coarse tabular		herzolite
	transitional-porphyroclastic		harzburgite
	porphyroclastic		wehrlite
	mosaic-porphyroclastic		olivine-websterite
	prophyroblastic coarse		websterite
	prophyroblastic-granuloblastic		clinopyroxenite
	granuloblastic		orthopyroxenite
	exsolved garnet		

solid symbol = garnet-bearing

open symbol = spinel-bearing

right half solid = garnet + brown spinel

left half solid = garnet + green spinel

X within symbol = no garnet or spinel observed

Letter to upper right of symbol designates the nodule's kimberlite pipe group origin:

N = Nix group

F = Ferris group

M = Moen group

A = Aultman group

S = Schaffer group

I = Iron Mountain group

No letter designation = Sloan group

Abbreviations:

OLV = olivine

CPX = clinopyroxene

OPX = orthopyroxene

GAR = garnet

Figure 2b. Results of modal analyses performed on fresh xenoliths.

Nomenclature from IUGS classification, Streckeisen (chairman),
1973.

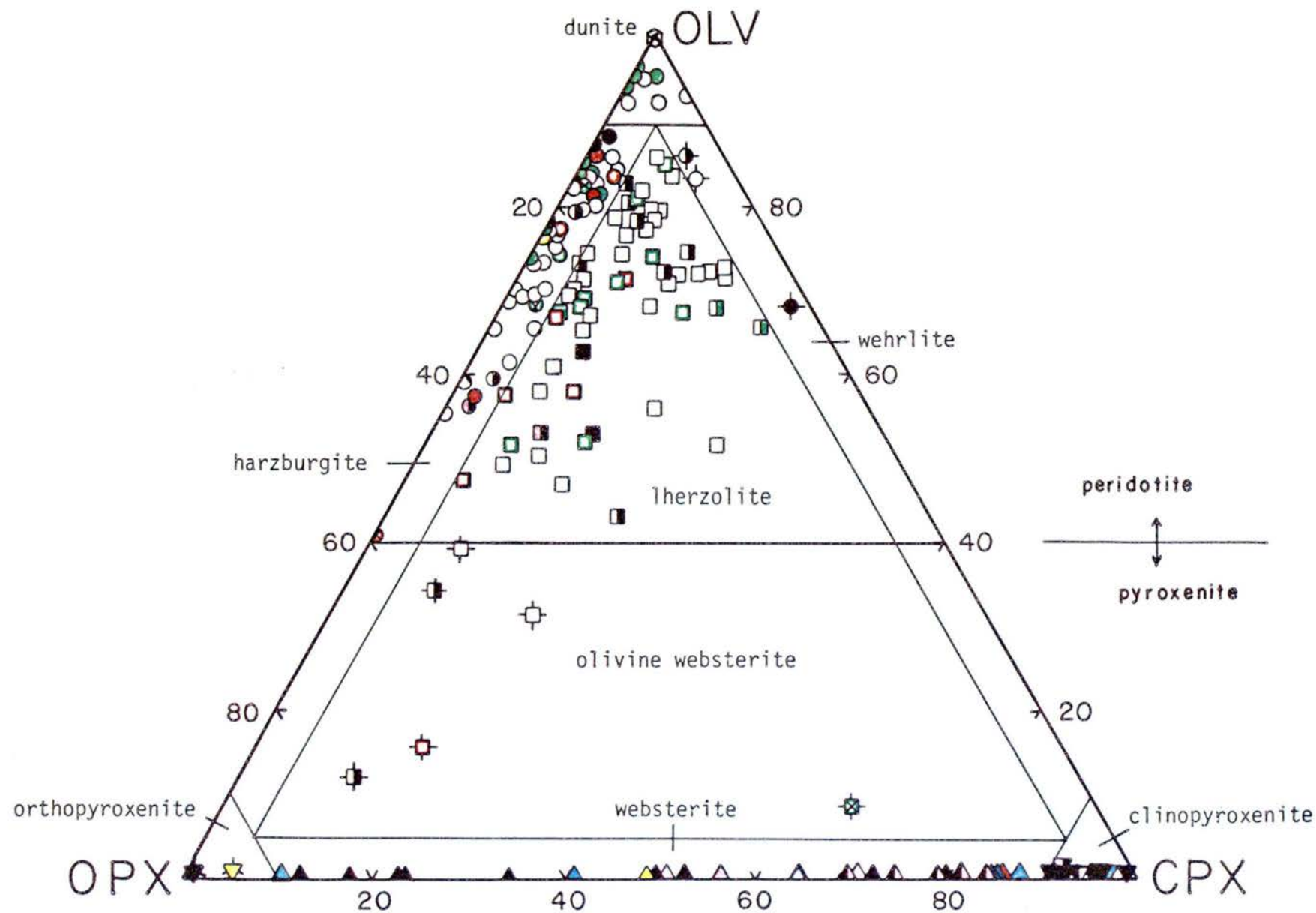
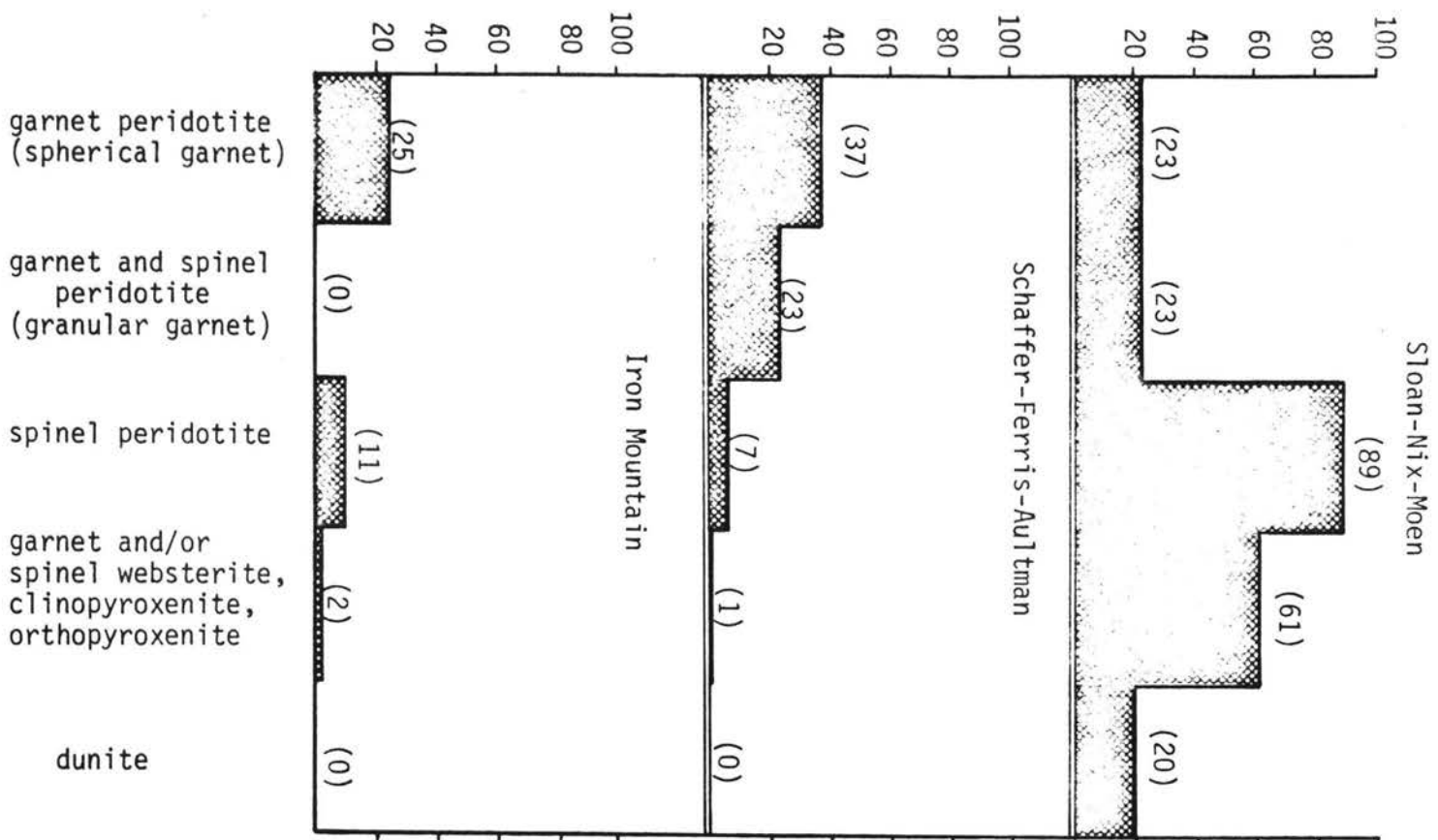


Figure 2. Generalized linear model results for Colorado-Wyoming
+ Population

Figure 3. General xenolith types recognized in Colorado-Wyoming kimberlites.



carbonatized matrix. In many nodules no primary mineral phases have survived alteration processes. Fresh orthopyroxene was recognized in only two Iron Mountain xenoliths. No olivine has been found in xenoliths from these pipes.

Hand Sample Descriptions

Sloan, Nix and Moen Nodules

Nodules from the Sloan, Nix and Moen pipes range in size from about 0.5 cm to 10 cm in their longest dimensions. Whole nodules are subspherical to ovoid; more angular xenoliths represent fragments of broken nodules. Olivine and orthopyroxene which may compose the bulk of these rocks, are usually partially serpentinized, and appear brown or greenish brown in hand specimen. Dark burgandy to purple or black spherical garnets and bright green chrome-diopside typify garnet lherzolites. Pale pink or rose garnet commonly occurs with pale grey-green diopside in garnet pyroxenites and with chrome diopside in garnet and garnet + spinel peridotites.

Altered nodules from this group of pipes range from white to mottled pale yellow, tan, brown, pale green, or slightly pink. Dark spherical garnets, black spinels or bright green Cr-diopsides, which are the last mineral phases to be altered, may be observed on surfaces of even severely altered nodules.

Schaffer, Ferris and Aultman Nodules

Xenoliths collected from the Schaffer 3 diatreme are the largest in the Colorado-Wyoming kimberlites, and they range from 3 to 15 cm (average 6-7 cm) in their longest dimension. Flattened spherical

to ovoid shapes predominate. Most of the Schaffer 3 xenoliths are replaced by hematite stained quartz and calcite and are very dense. They are rusty red and commonly exhibit a cellular boxwork-like structure on their weathered surfaces. Nodules from other pipes in the Schaffer-Ferris-Aultman group generally contain more serpentine thus are softer, and display typical powdery, white to pastel colored surfaces. Coarse (1-5 mm) spherical, deep purple garnets may be abundant, and when present they impart a spotted appearance to nodule surfaces. Clinopyroxene is less commonly visible.

Iron Mountain District Nodules

Peridotite nodules from the Iron Mountain kimberlite pipes (Smith, 1977) range from 5 to 15 cm (average about 5 cm) in their maximum dimension. Most are fragments of larger nodules characterized by flattened ovoid or spheroidal shapes. These nodules range from yellowish-white to tan or various shades of red or green. Their surfaces commonly display a reticulated texture. Relict bright green chrome diopside, deep red pyrope garnets and chromite may be visible amid the alteration products.

Mineralogy

Olivine

Olivine (generally Fo_{88-94}) in the fresh Sloan 2 and Nix 2 and 4 xenoliths ranges from 12 to 100 volume percent (Appendix I). Although olivine appears green or brown when embedded in a nodule, separated grains are very pale green to colorless and resemble fragments of broken glass. In thin-section olivine is colorless and commonly exhibits

distinct (010) parting. When this parting is present, extinction to it is parallel. This property is useful in distinguishing olivine from clinopyroxenes with poorly developed cleavage. In nodules from all other kimberlites olivine has been completely replaced by various secondary phases.

Orthopyroxene

Orthopyroxene (En_{91-94}), like olivine, is found in greatest abundance in the fresh xenoliths from Sloan and Nix kimberlites. In these nodules orthopyroxene averages about 20 volume percent; however, it may be minor or absent in some clinopyroxenites and reaches 60 percent in several olivine-websterites (Appendix 1). Orthopyroxene has been observed in only three samples from other kimberlite pipes; a relatively fresh garnet orthopyroxenite (IM26-P64), and a fresh spinel clinopyroxenite (M20-W5), both from the Iron Mountain District and a spinel peridotite from the Schaffer 3 kimberlite (SH3-L1). Individual grains of orthopyroxene are pale apple green and, due to their perfect cleavage, may appear blade-like or spintery. In thin section orthopyroxene is colorless and is generally easily recognized by its distinct cleavage and low birefringence.

Clinopyroxene

Clinopyroxene (generally Cr-diopside) content in xenoliths ranges from 67 volume percent in some garnet clinopyroxenites from the Sloan 2 diatreme to absent in some garnet or spinel harzburgites (Appendix 1). Although it is impossible to prove the complete absence of a phase in nodules whose thin sections exhibit no clinopyroxene, it

must be assumed that at best such xenoliths contain only very minor amounts of clinopyroxene.

Approximately one third of the altered xenoliths from the Schaffer-Ferris-Aultman diatreme group and approximately one fourth of those from the Iron Mountain group pipes contain unaltered clinopyroxene. When clinopyroxene is lacking in altered nodules, characteristic alteration features such as unique grain shape or different alteration coloration can sometimes be of value in estimating its original abundance. If no such features are present it cannot be determined whether all signs of its presence have been obliterated or if it was never present; therefore, such nodules cannot be accurately classified.

The presence of significant amounts of chromium in diopsides imparts a bright green color which is prominent in both hand sample and thin section. As the chrome content decreases, the intensity of green diminishes and in thin section confusion may arise between low birefringent clinopyroxenes with an optic axis nearly perpendicular to the plane of the section and orthopyroxenes. In such cases, 2V is the most useful distinguishing property.

Garnet

Two major types of garnets are found in xenoliths in Colorado-Wyoming kimberlites: (1) deeply colored (purple or burgandy to black), spherical to subspherical, 0.05 - 5 mm garnets, and (2) pale pink to rose colored, generally finer grained, 0.5 - 2.0 mm equant to granular garnets. Both types of garnet are pyrope in composition and both types have been observed in nodules from each of

the three kimberlite groups. Garnets of the first type occur in peridotite xenoliths where they may compose up to 24 volume percent of the nodule. Garnets of the second type are found in pyroxenites as well as peridotites and may constitute from 2 to 62 percent of a xenolith's volume (Appendix I). Spherical garnets appear pale pink or green in thin-section and are invariably mantled by black kelyphite. Granular garnets are colorless in thin section.

Spinel

Three types of spinel that differ in chemistry, color, habit and occurrence have been noted in mantle xenoliths from Colorado-Wyoming kimberlites. Reddish-brown spinel is found in peridotite and olivine websterite nodules from each of the three groups of diatremes but spinel peridotites are most abundant from Sloan-Nix-Moen kimberlites (Fig. 3). It has also been observed in three garnet- and olivine-free websterite xenoliths (SD2-L164, SD2-W8, and NX4-C10) from Sloan-Nix-Moen group kimberlites. Red-brown spinel content averages about 2 percent by volume (Appendix 1) and grains are seldom greater than 2 mm in size. It may be rimmed by garnet but generally is not. It is commonly vermicular and forms thin, intergranular fillings. It may also form symplectic intergrowths with orthopyroxene. This type of spinel is considered spinel *sensu stricto* because Mg and Al are the dominant cations in the 2+ and 3+ sites respectively (Deer et al., 1966).

Green spinel is dark grey to greenish black in hand sample and pale green in thin section. It is commonly quite coarse (up to 8 mm), and has been observed in xenoliths from the Sloan 2 and Nix 4 diatremes

and in two nodules from the Iron Mountain District. It may be present in trace amounts up to 40 percent by volume. This type of spinel is mantled in garnet in all but one Iron Mountain spinel clinopyroxenite (IM20-W5) and has been observed only in pyroxenite xenoliths that contain no olivine. It is chemically spinel, *sensu stricto* (Deer et al., 1966).

Black spinel, referred to throughout this work as "chromite" is more accurately designated as magnesiochromite or picotite depending on whether Mg or Fe is the dominant 2+ cation (Deer et al., 1966). Cr is the dominant 3+ cation. Chromite generally occurs as discrete accessory grains less than 1 mm in diameter and is found in peridotite nodules from all three diatreme groups. It is generally present in amounts less than 1 percent by volume. Chromite may coexist with garnet and in one instance has been observed as inclusions in garnet grains.

Accessory Minerals

Rutile is a minor accessory (generally less than 1 percent by volume) in fresh nodules of Sloan 2 and Nix 2 and 4 kimberlites. It occurs as small (up to 0.5 mm) subspherical, deep brown grains interstitial to coarser mineral phases. Rutile may also occur as aligned pink blades (less than 0.1 mm) in pyroxenes. Presence of these blades can be of assistance when fine grain size makes differentiation between olivine and pyroxenes difficult.

Phlogopite is present in several (8 out of 47) garnet websterites and clinopyroxenites and may constitute as much as 3 volume percent of some nodules. It appears to be primary in that it is

similar in size to the average grain size (about 2 mm) of the other phases in these nodules and shows no reaction relation with surrounding grains; however, grains may be strained or bent. Fine grains of phlogopite may be associated with the kelyphite rims around the spherical, deep purple variety of garnet but this occurrence of phlogopite is undoubtedly secondary.

Ilmenite has been identified in two Sloan 2 (SD2-L40, SD2-L150) and several Schaffer (SH3-L12, -L17, -L22, -L160) xenoliths. It occurs as subspherical to weblike, interstitial grains and ranges in size from about 0.2 to 1 mm. Ilmenite appears to be associated with xenoliths containing the spherical type of garnets rather than the granular variety; however, severe alteration prevents a definite determination of such a relationship.

Iron, nickel, and iron-nickel sulfides and ulvospinel (?) are present as opaque grains in some garnet pyroxenites. They occur as subspherical grains (less than 1 mm) that are commonly found at triple point junctions between pyroxenes and garnets. Total opaque content ranges to as much as two volume percent in these nodules.

Native Cu occurs as 0.1 to 2.0 mm anhedral grains that commonly are visible in hand specimens of severely altered nodules. It is believed to be a very late phase, possibly introduced during eruption of the kimberlite by fluids responsible for the intense serpentinization, silicification, and fenitization of the nodules (McCallum and Eggler, 1976, p. 264).

Mineralogy of Altered Nodules

In some samples it is possible to make estimates of original mineralogy even though the nodules are severely altered. Clinopyroxene, garnet and spinel are the most common unaltered phases thus volume percentages of these minerals can be fairly accurately determined. Olivine is the first mineral to be replaced, and alteration generally begins with the development of serpentine along irregular curved fractures in the olivine. Before olivine is completely replaced, orthopyroxene also may begin to alter to serpentine. Even when both olivine and orthopyroxene are completely replaced it may be possible to distinguish their respective products. Serpentine after orthopyroxene commonly is arranged in an orderly, parallel network that imitates the original pyroxene cleavage. Serpentine after olivine generally is randomly oriented. Furthermore, the first formed serpentine veinlets in olivine may remain distinct and are recognized by their irregular curved patterns. Continued alteration of the nodule may result in pervasive serpentinization. Equant quartz and carbonate grains may replace primary mineral phases or secondary serpentine. Determination of original mineral phases becomes progressively more difficult as these secondary constituents increase in quantity.

In general, altered samples with relict and pseudomorphous mineral phases on which accurate modal analyses can be performed are rare. Therefore such xenoliths are commonly referred to as (garnet and/or spinel) peridotites rather than, more specifically, harzburgites, lherzolites or wehrlites.

Textures

Introduction

Nodule textures were classified following Harte's (1977) nomenclature for olivine-bearing xenoliths. Some modification and improvisation of this classification was necessary in order to deal with textures of garnet websterites and garnet clinopyroxenites which contain no olivine. Abundances of textural types present in Colorado-Wyoming nodules are shown in Figure 4 and a summary of the characteristics of the textural types is given in Table 1.

Textures of the freshest nodules were studied in detail and special features and unusual mineral habits observed are described below. Textures of severely altered nodules can often be deciphered by the presence of partially pseudomorphous secondary minerals that mimic primary grain size, shape and orientation. Original grain outlines may be preserved by thread-like, red-brown hematite or serpentine, and many samples contain a few primary grains that retain their original size and habit.

Textures of Sloan-Nix-Moen Group Nodules

Fresh Samples

Coarse equant, coarse tabular, porphyroclastic, mosaic-porphyroclastic and granuloblastic textural types (defined by Harte, 1977) are recognized in the fresh xenoliths from this group of pipes. In addition, two new textural classes, porphyroblastic-coarse and porphyroblastic-granuloblastic, were introduced to describe textures

Figure 4. An example of a simple, textual type.

Figure 4. Abundance of xenolith textural types.

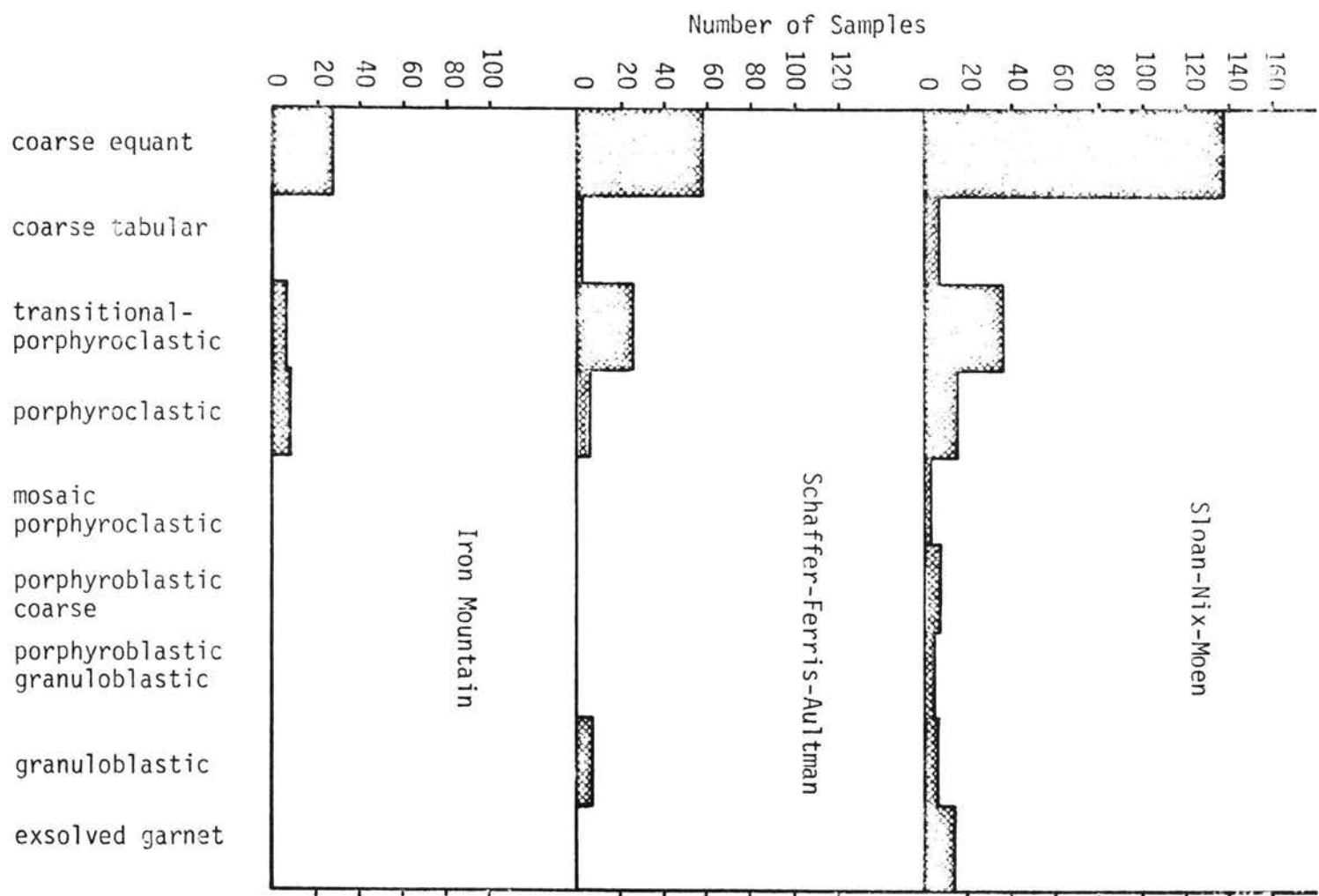


Table 1. Summary of textural types--Colorado-Wyoming kimberlite xenoliths.

Texture	Matrix/Porphyroclasts (blasts)	Grain Shape/Size	Grain Boundaries	Deformation in Crystals	Dominant Petrographic Types
COARSE EQUANT	Absent	Equant and polygonal to irregular. Generally 0.5-2 mm.	Straight, smoothly curving, less regular. 120° triple points common.	Rare kinkbands, subgrains. Undulose extinction common.	Common in dunites and other peridotites
COARSE TABULAR	Absent	Generally tabular, weak foliation implied. Generally 0.5-2mm.	Straight, smoothly curving. 120° triple points common.	Local kinkbands, subgrains, undulose extinction.	
TRANSITIONAL-PORPHYROCLASTIC	Neoblasts (chiefly olivine) developed at boundaries of coarse grains (chiefly olivine).	Equant and polygonal to tabular. Local euhedral olivine tablets in some rock types. Generally 0.1-2 mm.	Generally straight, smoothly curving.	Subgrains, undulose extinction common, local kinkbands.	
PORPHYROCLASTIC	Porphyroclasts chiefly olivine, surrounded by Neoblasts of olivine and fine-grained pyroxene	Porphyroclasts equant, irregular, or elongate, >0.5 mm. Matrix equant or elongate, <0.1-0.5mm. Euhedral olivine tablets common in some rock types.	Irregular, invaded by neoblasts.	Kinkbands common in orthopyroxene. Common undulose extinction, subgrains, and local kinkbands in olivine.	
MOSAIC-PORPHYROCLASTIC	Porphyroclasts chiefly orthopyroxene. Matrix chiefly olivine.	Porphyroclasts elongated, 1-2 mm. Matrix grains equant, elongate, irregular, 0.5-1 mm.	Irregular porphyroclasts invaded by neoblasts or straight along shear planes.	Common kinkbands in orthopyroxene. Common undulose extinction in olivine.	Observed in three (Sloan 2) spinel hercynites.

Table 1. (cont').

Texture	Matrix/Porphyro- clasts (blasts)	Grain Shape/Size	Grain Boundaries	Deformation in Crystals	Dominant Petro- graphic Types
PORPHYROBLASTIC- COARSE	Garnet porphyro- blasts. Garnet/ pyroxene matrix.	Porphyroblasts sub- spherical, ~1 cm. Matrix equant to slightly ovoid and tabular, ~2 mm.	Porphyroblasts irregular. Matrix straight to slightly curving.	Local undulose extinction and kinkbands.	Olivine-free pyroxenite and websterites.
PORPHYROBLASTIC- GRANULOBLASTIC	Porphyroblasts of garnet, exsolved or poikiloblastic pyroxenes. Gran- uloblastic, garnet/pyroxene matrix.	Porphyroblasts equant, tabular or irregular, ~5 mm. Matrix equant and polygonal to tabu- lar, <0.5 mm.	Generally smoothly curving to less regular.	Local undulose extinction and kinkbands.	
GRANULOBLASTIC	Absent	Equant, polygonal, to slightly tabular, <0.5 mm. Euhedral olivine tablets in some rock types.	Straight to smoothly curving.	Local undulose extinction.	Not common but noted in some dunites, perido- tites enites and web- sterites.

of garnet websterites and garnet pyroxenites that exhibit textures not accounted for in Harte's classification (Table 1).

Olivine-Bearing Xenoliths

Fresh olivine-bearing nodules, including harzburgites, lherzolites, wehrlites, and olivine websterites, fall fairly readily into Harte's (1977) textural categories. However, grain size distinctions made by Harte (1977) between coarse and granuloblastic textures (average grain size of coarse xenoliths being greater than 2 mm, and that of granuloblastic textures being less than 2 mm) do require modification when applied to these nodules. Most of the fresh olivine-bearing nodules from this group of pipes with textures labeled coarse have average grain sizes less than 2 mm, but their other characteristics best fit Harte's definition of coarse texture (Figs. 5, 6, and Table 1). Granuloblastic nodules (Fig. 7) are therefore rather arbitrarily denoted as such if their average grain size is notably smaller than that in coarse xenoliths, i.e., less than 0.5 mm. There appears to be a relatively smooth gradation in these nodules from those classed as coarse equant to those classed as granuloblastic. Both textures are generally characterized by grain shapes that tend to reduce surface energy to a minimum, that is, equant and polygonal (Spry, 1969, p. 41) but many coarse equant nodules also have very irregular, oddly shaped, vermicular constituents.

Porphyroclastic xenoliths (Fig. 8) with 1-2 mm porphyroclasts chiefly of olivine in very fine grained (<0.1 mm) matrices are present in this suite but severely sheared nodules (e.g., with fluidal mosaic textures such as those described by Boullier and Nicolas, 1975, or the

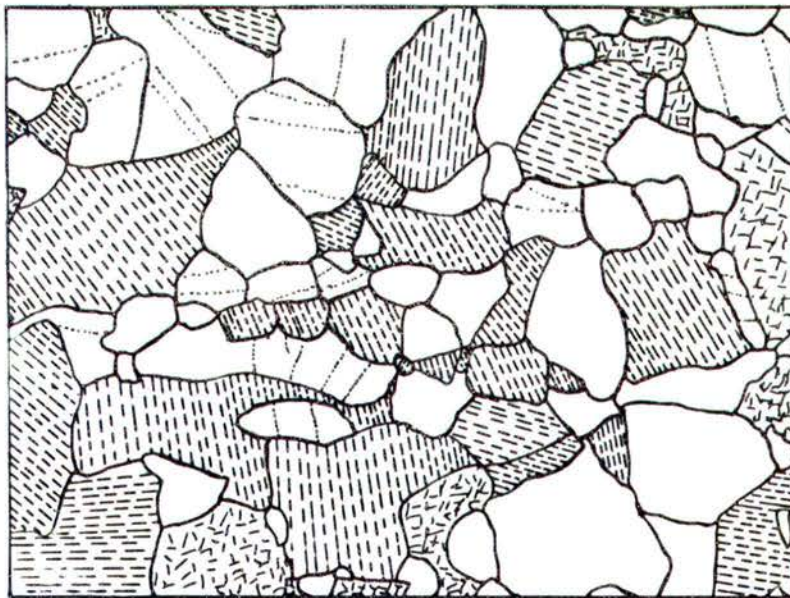
Figure 5. Coarse equant texture.

- 5a. Sketch of coarse equant texture taken from Boullier and Nicolas (1975, Fig 1A).
- 5b. Coarse equant texture exhibited by spinel lherzolite SD2-L18 (crossed nicols; nodule is approximately 2 cm across longest dimension).
- 5c. Coarse equant texture remains visible in an altered xenolith (SH3-L5) from the Schaffer kimberlite. Ghost outlines of primary grains are preserved by secondary minerals (chiefly serpentine). Only spherical garnets remain unaltered (plane light, 4 cm = 1 cm).

Figure 2. Coarse equant texture.

- a. Text. 1: coarse equant texture (taken from Douillet and Nicolas, 1978, p. 11).
- b. Coarse equant texture (textured by rapid interdiffusion). 205-118 (crossed mineral) is approximately 2 cm across (largest dimension).
- c. Coarse equant texture (textured by rapid interdiffusion). 205-118 (crossed mineral) is approximately 2 cm across (largest dimension). Text. 1: coarse equant texture (taken from Douillet and Nicolas, 1978, p. 11).

a.

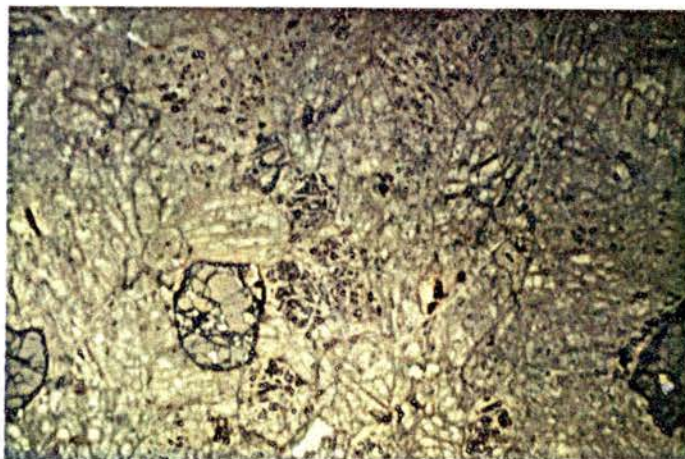


COARSE EQUANT

b.



c.



1. The first part of the paper is devoted to a study of the properties of the function $f(x)$ defined by the equation $f(x) = \int_0^x f(t) dt$. It is shown that $f(x)$ is a continuous function and that $f(0) = 0$.

2. In the second part of the paper, we consider the function $g(x)$ defined by the equation $g(x) = \int_0^x g(t) dt$. It is shown that $g(x)$ is a continuous function and that $g(0) = 0$.

3. In the third part of the paper, we consider the function $h(x)$ defined by the equation $h(x) = \int_0^x h(t) dt$. It is shown that $h(x)$ is a continuous function and that $h(0) = 0$.

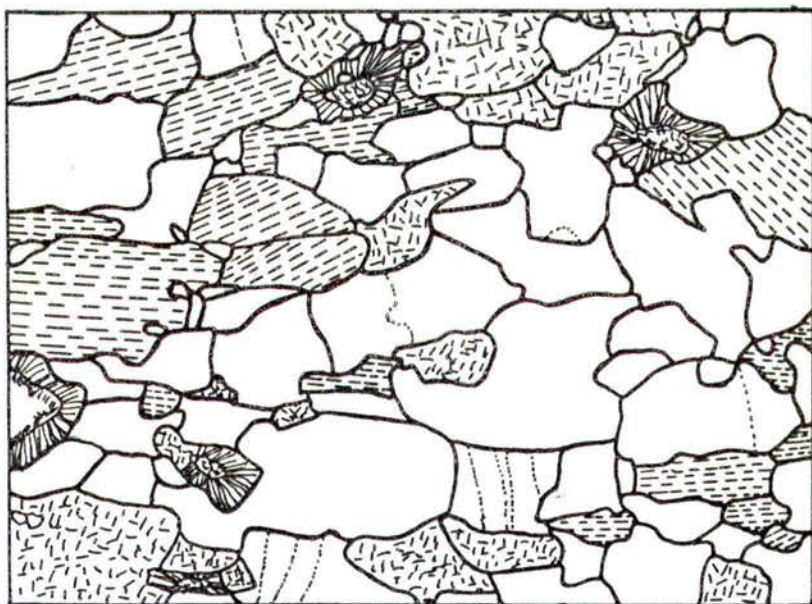
4. In the fourth part of the paper, we consider the function $k(x)$ defined by the equation $k(x) = \int_0^x k(t) dt$. It is shown that $k(x)$ is a continuous function and that $k(0) = 0$.

5. In the fifth part of the paper, we consider the function $l(x)$ defined by the equation $l(x) = \int_0^x l(t) dt$. It is shown that $l(x)$ is a continuous function and that $l(0) = 0$.

Figure 6. Coarse tabular texture.

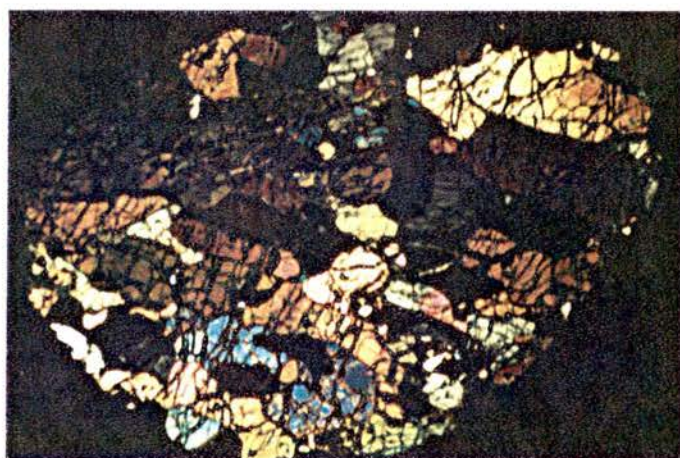
- 6a. Sketch of coarse tabular textures taken from Boullier and Nicolas (1975, Fig. 1B).
- 6b. Coarse tabular texture exhibited by spinel harzburgite SD2-L5 (crossed nicols; horizontal field of view is approximately 2 cm).

a.



COARSE TABULAR

b.



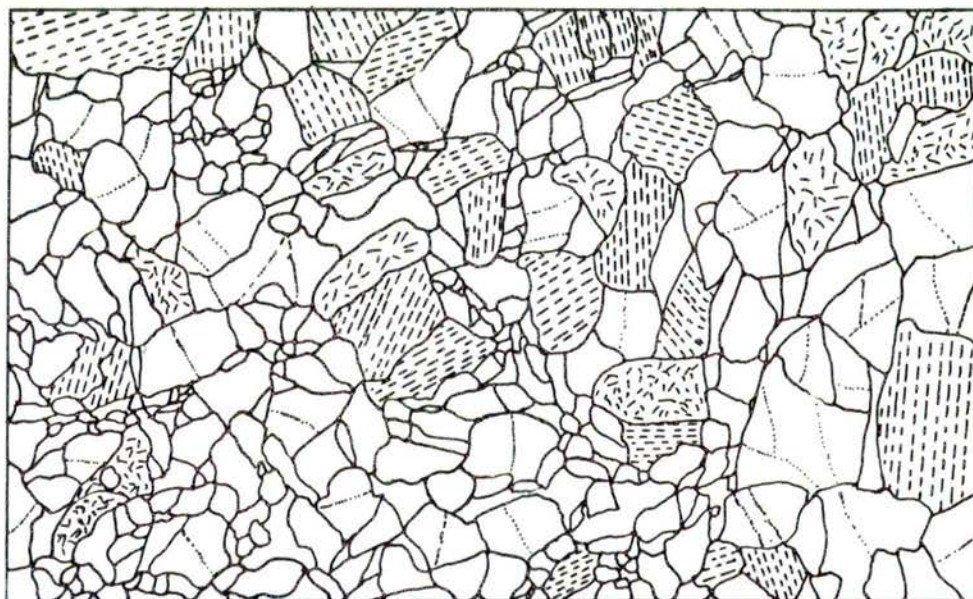
The following features

1. The degree of the subject's knowledge of the object is a function of the degree of the object's knowledge of the subject.
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Figure 7. Granuloblastic texture.

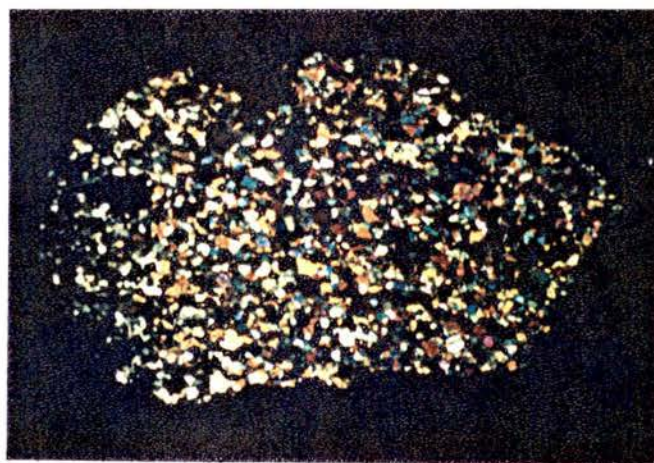
- 7a. Sketch of granuloblastic texture taken from Harte et al. (1975, Fig. 8).
- 7b. Granuloblastic texture exhibited by spinel harzburgite (SD2-L14) from the Sloan 2 kimberlite (crossed nicols; nodule is approximately 2 cm across longest dimension).
- 7c. Granuloblastic texture exhibited by spinel peridotite (SH3-L29) from the Schaffer 3 kimberlite. Colored grains are fresh clinopyroxene that remain in the nearly completely altered nodule (crossed nicols; horizontal field of view is approximately 2 cm).
- 7d. Same as 7c but under plane light where tiny brown to black fresh spinel grains are visible. Clinopyroxene and spinel are the only fresh constituents in this xenolith.

a.

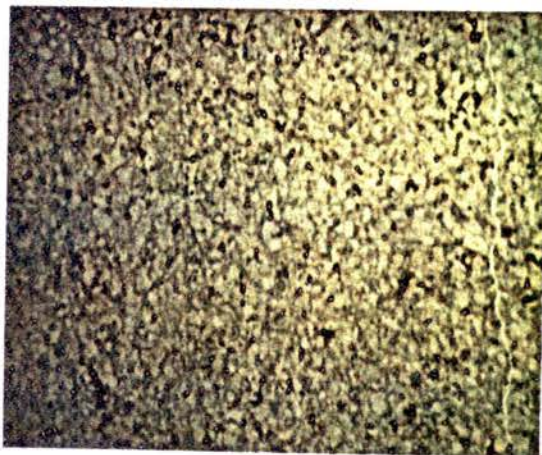


GRANULOBLASTIC

b.



c.

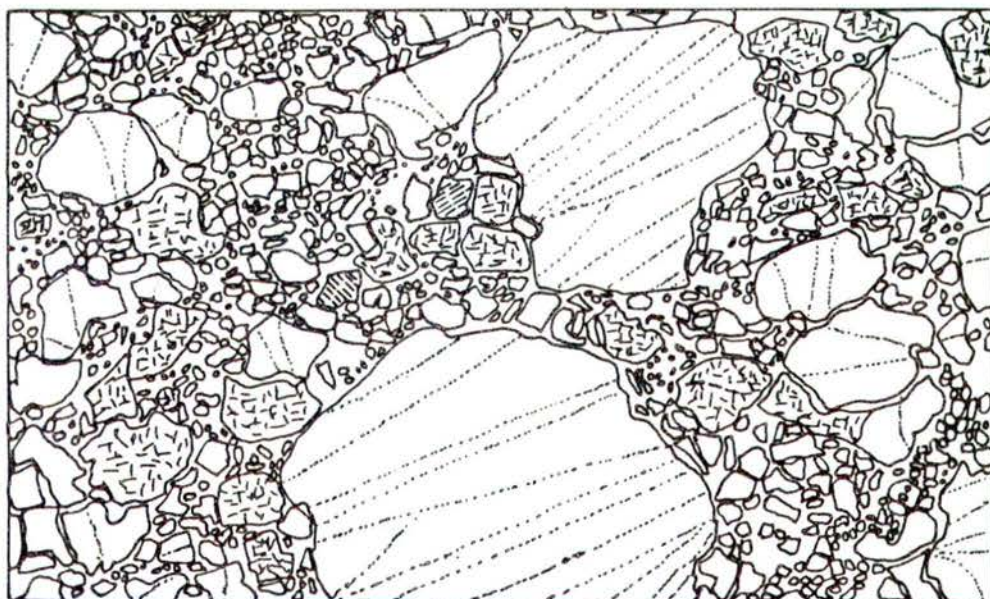


d.

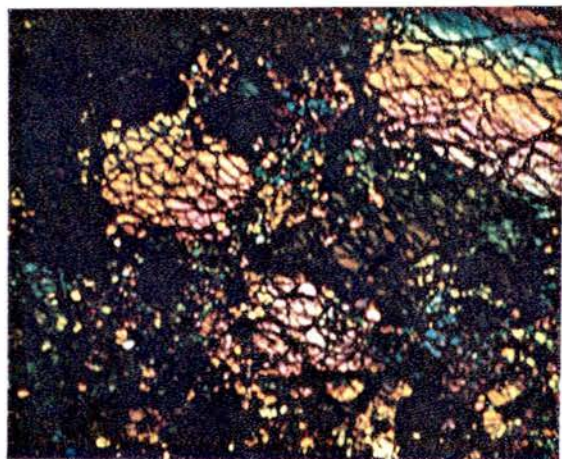
Figure 8. Porphyroclastic texture.

- 8a. Sketch of porphyroclastic texture taken from Harte et al. (1975, Fig. 6).
- 8b. Porphyroclastic texture exhibited by garnet harzburgite (SD2-L69) from the Sloan 2 kimberlite (crossed nicols; horizontal field of view is approximately 2 cm).
- 8c. Altered porphyroclastic nodule (IM42-L21) from Iron Mountain kimberlite. Fresh, subspherical garnets remain in a matrix of secondary minerals (chiefly serpentine) (plane light, horizontal field of view is approximately 2 cm).
- 8d. Porphyroclastic texture with disrupted spinel in peridotite nodule (SD2-L2) from the Sloan 2 kimberlite (crossed nicols, horizontal field of view approximately 2 cm).
- 8e. Porphyroclastic texture with disrupted spinel in peridotite nodule (SD2-L2) from the Sloan 2 kimberlite (plane light, horizontal field of view approximately 2 cm).

a.



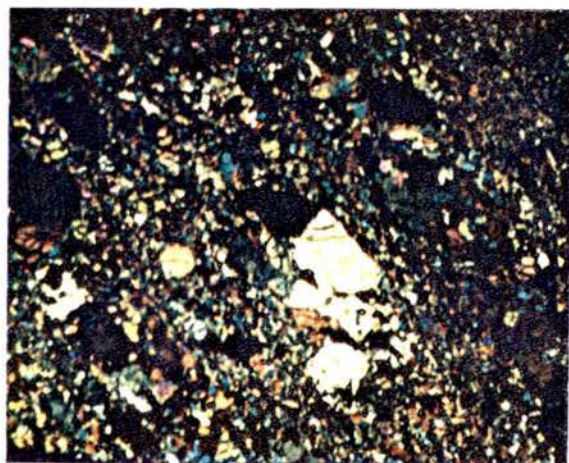
PORPHYROCLASTIC



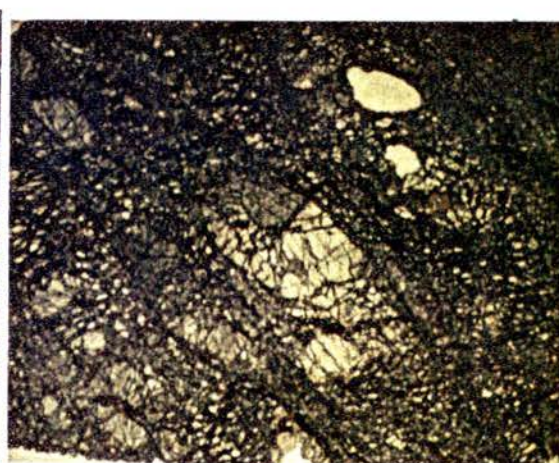
b.



c.



d.



e.

laminated-disrupted porphyroclastite of Harte, 1977) have not been recognized. Disrupted spinel occurs in sample SD2-L2 (Fig. 8d, e) which is the most deformed nodule found to date from this group of pipes.

Several nodules have been classed as transitional--porphyroclastic to indicate a texture showing some signs of cataclastic deformation and recrystallization but one in which no coarse grain has been completely surrounded by recrystallized finer grains, thus no grain can be strictly termed a porphyroclast. Evidence of deformation in rocks with transitional-porphyroclastic textures includes undulatory extinction, zones of subgrains of finer than average grain size, and neoblast development along boundaries of coarse deformation and grade in this way to porphyroclastic textures (Harte et al., 1975).

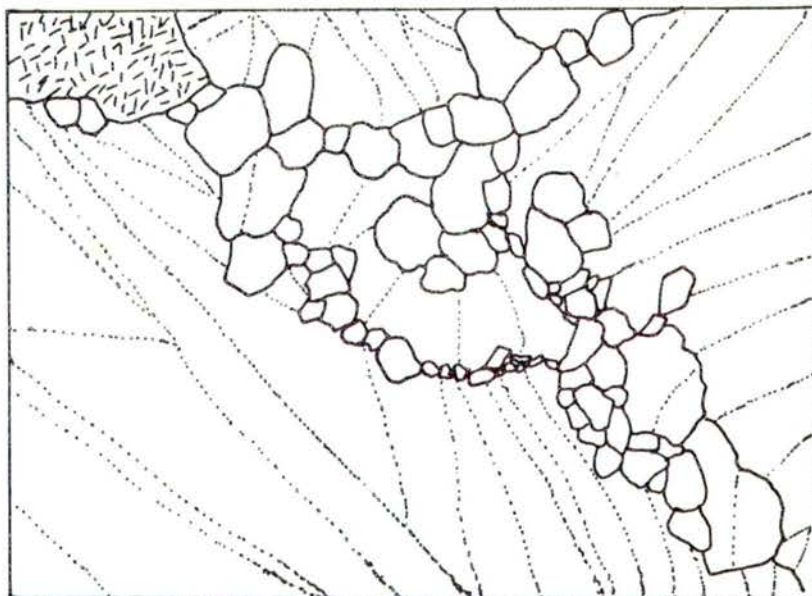
Subgrain zones consist of roughly equant grains, 0.5 mm and smaller, with nearly equal birefringence, slightly different extinction positions, and vague, unclear grain boundaries as if formed from a single coarse grain through progressive polygonization. These subgrains are in the process of becoming independent grains as more and more free dislocations are generated and move to subgrain boundaries (Mercier, 1979). Strain lamellae were observed in one peridotite sample (SD2-L60, Fig. 9d). These are straight to braided zones within a single grain of varying birefringence and extinction direction.

Neoblasts, tiny (0.1 mm), equant, recrystallized grains particularly of olivine (Figs. 9a, 9b, 9c) preferentially replace coarse, strained grains through grain boundary migration. Another type of olivine neoblast occurs as euhedral, doubly terminated tablets from 0.2 to 1 mm in size (Fig. 9d, 9e). These may cross-cut the grain

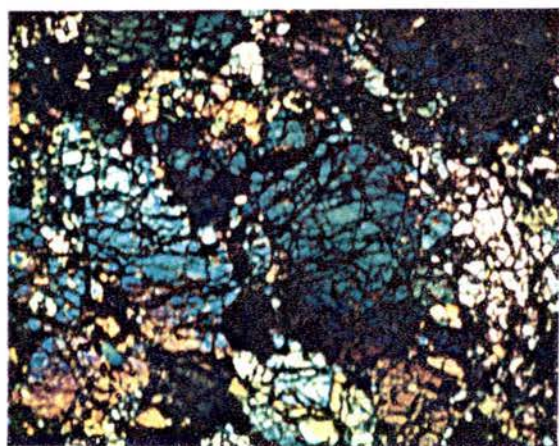
Figure 9. Transitional-porphyroclastic texture.

- 9a. Sketch of transition-porphyroclastic texture taken from Harte et al. (1975, Fig. 3A).
- 9b. Neoblast development along grain boundaries in garnet-bearing harzburgitic dunite (SD2-L123) from the Sloan 2 kimberlite (crossed nicols; horizontal field of view is approximately 2 cm).
- 9c. Neoblast development along grain boundaries in garnet-bearing harzburgitic dunite (SD2-L123) from the Sloan 2 kimberlite (plane light).
- 9d. Shear lamellae in olivine porphyroclast of harzburgite (SD2-L160) from Sloan 2 kimberlite. Note euhedral olivine neoblast tablets adjacent to the porphyroclast grain boundary (crossed nicols, horizontal field of view is approximately 2 cm).
- 9e. Euhedral olivine neoblast tablets pseudomorphed by quartz in altered peridotite nodule (SH3-L4) from the Schaffer 3 kimberlite (crossed nicols, horizontal field of view is approximately 2 mm).

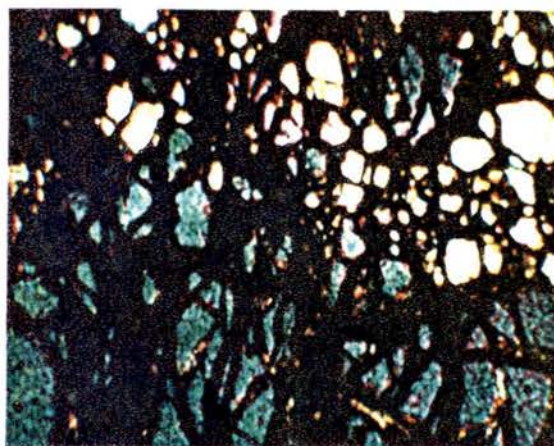
a.



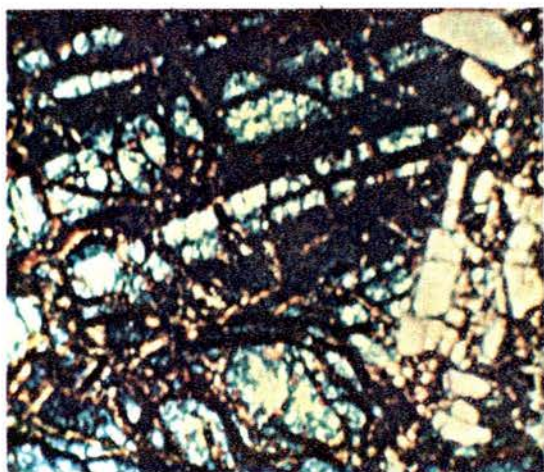
TRANSITIONAL TO PORPHYROCLASTIC



b.



c.



d.



e.

boundaries of coarse grains and are usually found within or along side zones of the more equant type of neoblasts. These euhedral olivine tablets have been noted only in dunites and in samples from the group of lherzolites characterized by subspherical to spherical garnets. They are relatively common in such xenoliths with transitional-porphyroclastic, porphyroclastic, and granuloblastic textures.

Mercier (1979) interprets the equant neoblasts and euhedral tablets as two different neoblast generations, respectively produced by primary annealing recrystallization (static grain growth) and syntectonic recrystallization. The latter is a much faster recovery process for high strain energies and high temperatures.

According to Spry's (1969) review of recrystallization in alloys, recrystallization following small deformations shows subgrain growth in little deformed regions whereas recrystallization following large deformations exhibits nucleation at many points (neoblasts) with nuclei forming continuously with time. These two types of recrystallization products, subgrains and neoblasts, may therefore represent different prevailing magnitudes of deformation in localized zones of the mantle.

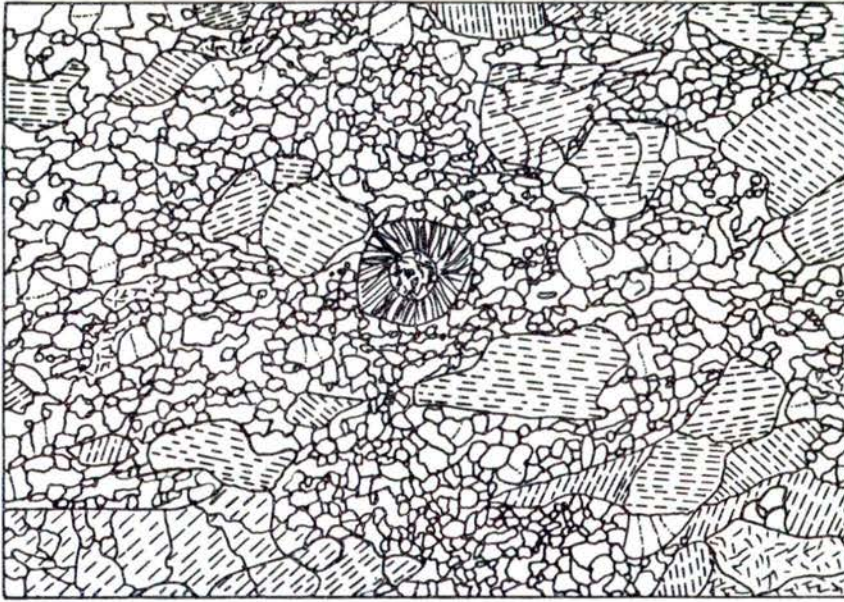
Three Sloan 2 spinel lherzolites (SD2-L91, SD2-L92, SD2-L93) have mosaic-porphyroclastic textures (Fig. 10). Porphyroclasts in these nodules consist almost entirely of strongly kinked orthopyroxene in a coarse-grained (greater than 0.5 mm) matrix of olivine, minor clinopyroxene and spinel. This texture appears to be the result of extensive olivine recrystallization and grain growth. Orthopyroxene which recrystallizes less readily is still in a state of partial recrystallization (Harte et al., 1975).

Figure 10. Mosaic porphyroblastic texture.

- 10a. Sketch of mosaic porphyroblastic texture taken from Bonnier and Nicolas (1975, Fig. 2A). Clear grains are olivine which form the matrix in orthopyroxene (dark) and garnet (center, with radial kelyphite structure rim).
- 10b. Mosaic porphyroblastic texture exhibited by spinel hercynite nodules (507-151) from the 21 km-hercynite. Pale grey elongated porphyroblasts are orthopyroxene. Matrix grains are chiefly olivine (crossed circles; 4 cm = 1 cm).

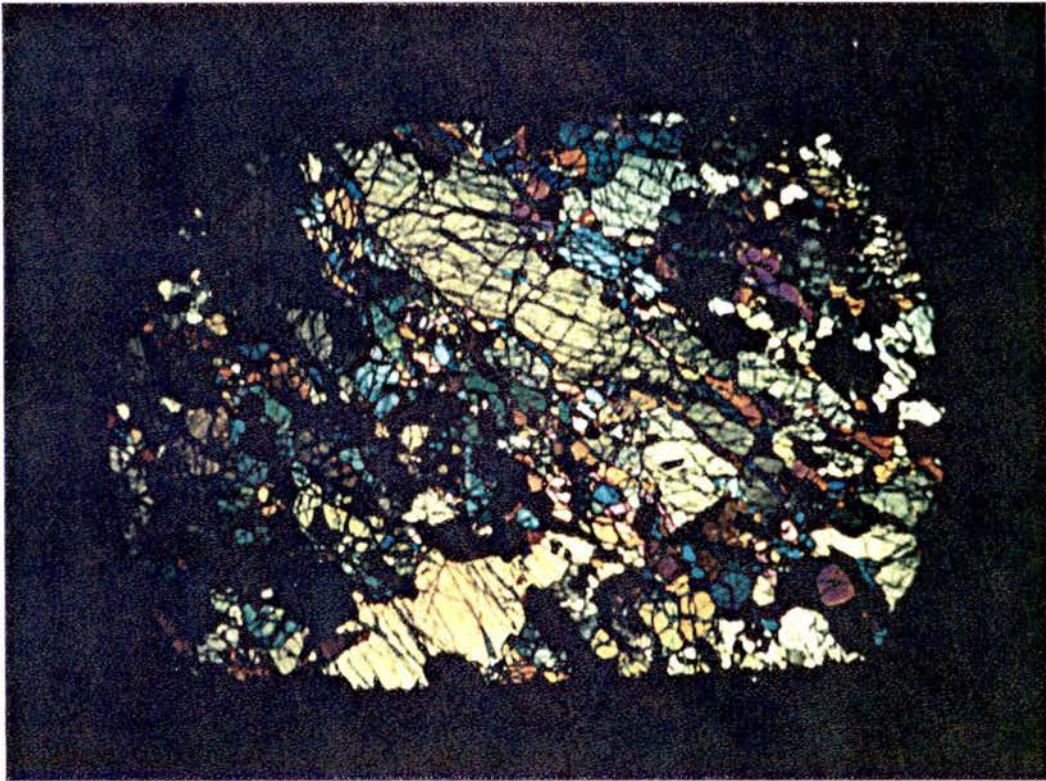
Figure 10. Mosaic porphyroclastic texture.

- 10a. Sketch of mosaic porphyroclastic texture taken from Boullier and Nicolas (1975, Fig. 2A). Clear grains are olivine which form the matrix to orthopyroxene (hatched) and garnet (center, with radial kelyphite alteration rim).
- 10b. Mosaic porphyroclastic texture exhibited by spinel ilherzolite nodule (SD2-L91) from the Sloan 2 kimberlite. Pale grey elongated phrophyroclasts are orthopyroxene. Matrix grains are chiefly olivine (crossed nicols; 4 cm = 1 cm).



MOSAIC-PORPHYROCLASTIC

a.



b.

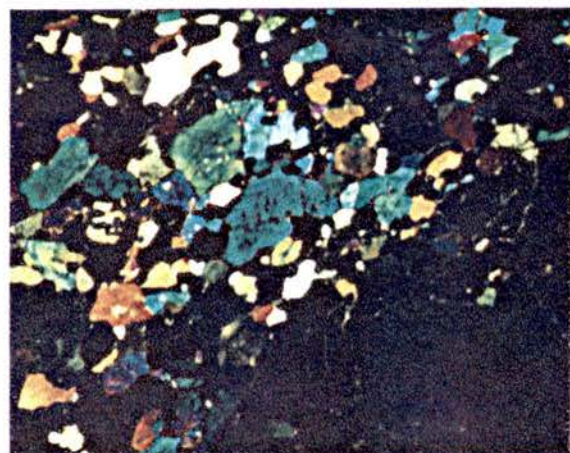
Olivine-Free Xenoliths

Most olivine-free nodules from this suite (garnet and/or spinel websterites, clino- and orthopyroxenites), although containing no olivine, exhibit characteristics that allow them to be placed in Harte's (1977) coarse equant, coarse tabular or granuloblastic categories. In general, these xenoliths are more even grained and have more regular, polygonal and subspherical grain shapes than olivine-bearing peridotite nodules. In coarse equant and granuloblastic textural types which differ mainly in average grain size (as in olivine-bearing nodules), garnets are usually subspherical and pyroxenes accommodated garnet by developing straight to slightly concave boundaries. Granuloblastic and coarse textures are commonly observed within the same nodule. Strained grains exhibiting deformation lamellae, kinkbands and subgrains are less common in olivine-free than in olivine-bearing nodules.

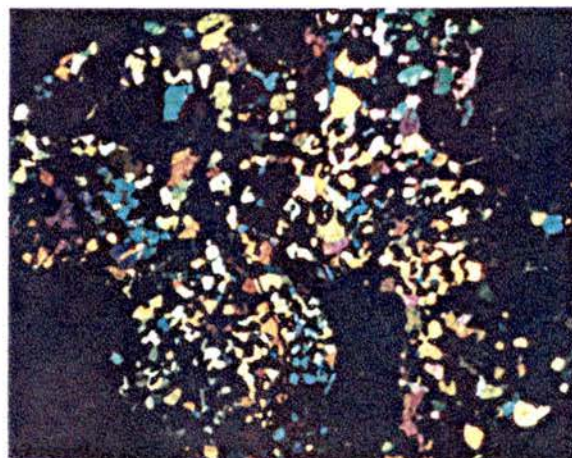
Xenoliths from this suite with textures not conforming readily to Harte's (1977) definitions were assigned two new textural terms: porphyroblastic-coarse and porphyroblastic-granuloblastic. Porphyroblastic-coarse xenoliths contain garnet porphyroblasts averaging 1 cm in diameter in a coarse equant or tabular matrix of garnet and pyroxene (Fig. 11a). Pyroxene porphyroblasts in a coarse matrix could conceivably exist but such nodules have not yet been observed in the Colorado-Wyoming suites. Garnet porphyroblasts are spherical to lobate and cracks filled with serpentine now separate once large grains into smaller subgrains. Boundaries may be embayed where porphyroblasts envelop grains from the matrix. Such inclusions may be very irregular and vermicular in shape.

Figure 11. Porphyroblastic textures.

- 11a. Garnet porphyroblast (black, lower right) in coarse equant matrix of garnet and pyroxenes (Group V nodule SD2-L48; crossed nicols; horizontal field of view is approximately 2 cm).
- 11b. Garnet porphyroblasts (black) in granuloblastic matrix of garnet and pyroxenes (garnet pyroxenite SD2-L49; crossed nicols, horizontal field of view is approximately 2 cm).
- 11c. Garnet (black) exsolved from orthopyroxene porphyroblasts in garnet pyroxenite (SD2-L132) (crossed nicols; 4 cm = 1 cm).
- 11d. Poikiloblastic pyroxenes contain subspherical garnet (black) inclusions. Nodule (SD2-L43) is approximately 2 cm in longest dimension. Arrow indicates the site of photo 11e.
- 11e. Poikiloblastic clinopyroxene containing garnet (black) inclusions (garnet pyroxenite SD2-L43, horizontal field of view is approximately 2 cm).



a.



b.



c.



d.



e.

Xenoliths with a porphyroblastic-granuloblastic texture (Fig. 11b, 11c) contain 5 mm porphyroblasts of garnet, orthopyroxene, or clinopyroxene in a granuloblastic equant or tabular matrix. Garnet porphyroblasts are similar to those in porphyroblastic-coarse textures. Pyroxene porphyroblasts may contain many garnet inclusions and could (possibly more accurately) be called poikiloblasts (Fig. 11d). The garnet inclusions are subspherical to ellipsoidal and are the same size as the matrix garnets. The pyroxene host may also be quite elongated, ellipsoidal or tabular in shape. Pyroxene porphyroblasts in porphyroblastic-granuloblastic textured rocks may instead contain coarse (0.1-0.25 mm thick) exsolution lamellae and blebs (garnet lamellae in orthopyroxene or clinopyroxene porphyroblasts, or orthopyroxene and/or garnet lamellae in clinopyroxene porphyroblasts) (Fig. 11c). When exsolution features are present textures become quite complex and deviate greatly from Harte's (1977) descriptions. They are therefore described in detail in a following section of special features.

Altered Samples

Sloan 1, Nix 3 and Moen xenoliths are severely altered but most appear to have coarse equant textures. In such nodules it is rarely possible to distinguish olivine-bearing from olivine-free types. However, in a sample (MN2-L3) from the Moen 2 kimberlite about 10-15 percent fresh to partially altered clinopyroxene has survived and it is evident from the primary grains and the subspherical to polygonal shapes of alteration material between them that the rock was a coarse equant olivine-free nodule. Another altered nodule (NX3-L1) from the Nix 3 pipe has an unusual texture in which small (0.5 mm), fresh,

rather irregular and angular clinopyroxene and spinel grains are strung out in layers approximately the thickness of a single crystal. Between these layers, which are spaced from 0.5 to 1.5 cm apart, the secondary minerals seem to retain a coarse equant texture.

Textures of Schaffer-Ferris-Aultman Nodules

Upper mantle xenoliths from the Schaffer, Ferris and Aultman kimberlite pipes are severely altered but relict textures can be recognized in the majority of these nodules. Textures of nodules from the schaffer 3 pipe are especially well preserved. Outlines of original grains, pseudomorphs of primary minerals, and relict primary grains are present in many nodules from this group of pipes, and coarse equant, coarse tabular, porphyroclastic and transitional-porphyroclastic, and granuloblastic textures have been recognized.

Most coarse xenoliths from these pipes fit Harte's (1977) definition and resemble textures of "common peridotite" as defined by Cox et al. (1973, p. 78) more closely than do Sloan, Nix and Moen peridotites. Average grain size, determined from ghost outlines of altered primary grains (Fig. 5c), is usually greater than 2 mm whereas granuloblastic textures (Fig. 7c, 7d) are significantly finer grained (average 0.5-1.0 mm). A coarse tabular texture is nicely preserved in a diamond-bearing peridotite nodule from this suite, described by McCallum and Egger (1976).

Transitional-porphyroclastic and porphyroclastic textures are recognized by the presence of fine grained (about 0.1 mm), rounded secondary minerals and/or pseudomorphs after olivine neoblasts which are concentrated along the edges of coarse secondary grains or along

the ghost outlines of original coarse grains (Fig. 9). Euhedral olivine tablets, commonly present in sheared areas of fresh Sloan 2 garnet peridotites, may be perfectly pseudomorphed by quartz. These also imply a transitional- or porphyroclastic texture (Fig. 9e).

Granuloblastic textures are beautifully preserved in several nodules by a mosaic of polygonal quartz or calcite grains separated by thin serpentine selvages. These samples may contain polygonal garnet and clinopyroxene relicts scattered throughout the nodule (Fig. 7d).

Textures of Iron Mountain District Nodules

Primary textures in the severely altered xenoliths from Iron Mountain pipes are poorly preserved. It is usually possible, however, to determine if the nodule has been significantly deformed, that is, to distinguish between coarse and porphyroclastic textural types. Nodules displaying characteristics of both these relict textures are termed transitional-porphyroclastic.

In the well preserved textures of Schaffer xenoliths, coarse equant primary grains are usually replaced by coarse grained secondary minerals, therefore coarse grained alteration products in the Iron Mountain nodules also are inferred to represent originally coarse textures. This conclusion is reinforced in some nodules where a few ghost grain outlines or fresh grains are preserved. Fine (0.1-0.2 mm) secondary grains after original rounded neoblasts may form chains and web-like aggregates between coarser grains suggesting a transitional-porphyroclastic texture. Relatively coarse fresh phases or coarse grained secondary minerals completely surrounded by a fine,

equigranular matrix of secondary grains imply porphyroclastic texture. Despite the extensive alteration of the Iron Mountain xenoliths, some relict textures are still easily determined. One sheared nodule (IM42-L21) has the most extensively deformed texture found in xenoliths from Colorado-Wyoming kimberlites (Fig. 8c).

Special Textural Features

Garnet

Garnets are perhaps more diverse in habit than any other mineral in Colorado-Wyoming xenoliths. Two basic subdivisions have been made: (1) deeply colored, spherical, 0.5-5.0 mm garnets similar to the garnets in coarse "common peridotite" described by Cox et al. (1973), and, (2) pale pink, generally granular, 0.5-2.0 mm garnets. The latter type includes the typically equant garnets of olivine-free garnet websterites and pyroxenites as well as aggregates of granular garnets that exhibit a variety of special textural features such as garnet rims around spinel and garnet exsolution lamellae from pyroxenes (Table 2).

Exsolved Garnet

Garnet exsolved from orthopyroxene and/or clinopyroxene is present in 14 Sloan-Nix-Moen group xenoliths. Eleven of these 14 xenoliths are olivine-free and exsolved pyroxenes form porphyroblasts in generally granuloblastic matrices. The remaining 3 samples are peridotites in which exsolved pyroxenes occur as coarse equant constituents.

Table 2. Inventory of some special textural features.

Sample	Garnet Exsolution from Clinopyroxene	Garnet Exsolution from Orthopyroxene	Orthopyroxene Exsolution from Clinopyroxene	Garnet Rims Green Spinel	Garnet Rims Brown Spinel
*SD2-L11	X	X			X
SD2-L111	X		X	X	
SD2-L112	X		X	X	
SD2-L113	X		X		
SD2-L114	X		X	X	
*SD2-L115	X		X		
*SD2-L132		X			
*SD2-L164			X		
*SD2-L172	X	X			X
SD2-L173	X		X	X	
SD2-OP152	X				
*SD2-W8			X		
*SD2-W9	X		X		X
SD2-W10	X			X	
*NX2-W1	X				X
*NX4-C10			X		
NX4-L7	X			X	

*Websterite Group (Group V) xenolith. All others are Group IV nodules.

Garnet exsolution lamellae average 0.2 mm in width and extend nearly the full length of the host crystal, generally terminating shortly before contacting the host grain boundary. Oriented blebs (0.1 x 0.2 mm) may occur instead of or in addition to the more extensive lamellae. An interesting effect is created in a Sloan 2 websterite (SD2-L132, Fig. 11c) in which a strongly kinked orthopyroxene porphyroblast contains garnet exsolution lamellae. The lamellae parallel the bent and curving orthopyroxene cleavages but coalesce into subspherical granules at orthopyroxene kinkband boundaries.

Garnets exterior to pyroxenes hosting exsolved garnet are commonly elongate, interstitial, and nearly completely rim the exsolved pyroxene or other constituents of the nodule. Garnet exsolution lamellae locally join interstitial garnet grains (Fig. 12). According to Spry (1969), concentrations of garnet at grain boundaries might result from precipitation within the host followed by migration of the garnet to the boundaries, or by nucleation immediately at the structurally defective boundary.

Coarse and granuloblastic zones within these nodules may be related to the exsolution event, representing exsolution lamellae, blebs and host pyroxenes that recrystallized to polygonal shapes. However, these textures may be completely distinct from the exsolution event, and may represent an unaffected matrix.

Garnet Rimming Spinel

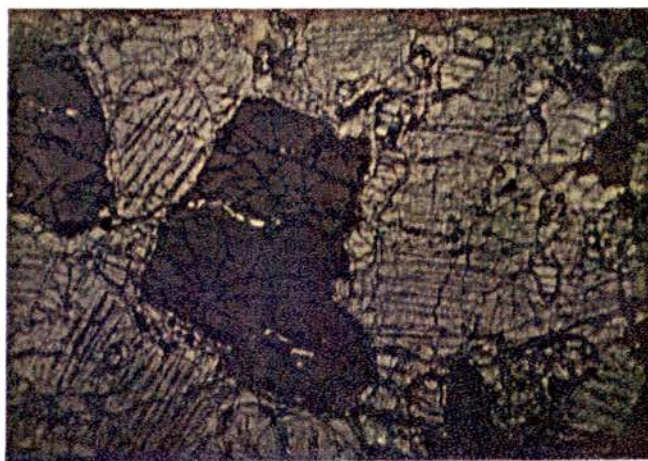
Whenever garnet and spinel (excluding chromite) coexist in a Colorado-Wyoming nodule, the garnet invariably forms relatively continuous rims around spinel (Figs. 12 and 13). This phenomenon is

12. Greenish brown, brown by dried and variegated with greenish brown from chlorophyllous to green & brown. Leaves
 taste bitter (224/11) from the 21st & 22nd day.
13. Brown light. Leaves slightly as narrow, light
 colored veins around green veins and between
 veins are green (224/11).
14. Greenish brown. Spots and veins brownish
 colored veins are visible as brown in
 and to have yellow chlorophyllous spots (224/11
 1 cm).

Figure 12. Green spinel rimmed by garnet and associated with garnet exsolved from clinopyroxenes in garnet + spinel pyroxenite nodule (SD2-L111) from the Sloan 2 kimberlite.

12a. Plane light. Garnet visible as narrow, light colored selvages around green spinel and between pyroxene grains (4 cm = 1 cm).

12b. Crossed nicols. Spinel and garnet both extinct. Exsolved garnet is visible as black stripes in gold to pale yellow clinopyroxene grains (4 cm = 1 cm).



a.



b.

present in 6 olivine-free and 23 olivine-bearing xenoliths. Included in the group of olivine-bearing xenoliths are 4 altered nodules from the Schaffer 3 pipe in which relict garnet surrounds spinel. Textures and secondary mineralogy imply that these xenoliths were olivine-bearing. In all of the olivine-free xenoliths garnet surrounding spinel is associated with garnet exsolved from pyroxene. However, not all of the olivine-free nodules with exsolved garnet contain spinel. Of the 23 olivine-bearing nodules with garnet rimming spinel, 3 (SD2-L172, SD2-L11, NX2-W1) also contain garnet exsolved from pyroxene. Spinel rimmed by garnet is always the brown variety in olivine-bearing xenoliths whereas green or brown spinel may be rimmed by garnet in olivine-free rocks.

Individual garnet grains that compose the rims around green spinel (Fig. 12) in olivine-free xenoliths are elongate and in thin section appear to be approximately twice as long in the dimension parallel to the garnet-spinel contact as they are wide. An exception is sample SD2-W10 which has a texture quite different from most garnet + green spinel xenoliths. In general the texture is coarse equant. Green spinel is quite rare in this nodule and occurs as tiny (less than 0.5 mm) subspherical inclusions in garnet grains. Subspherical garnet inclusions are common in the equant pyroxene grains and anhedral to euhedral pyroxene inclusions (Fig. 14b) are also found enclosed in coarse pyroxene grains. Vague remnants of garnet exsolution lamellae in pyroxenes are visible. It appears that the texture of this xenolith may have been more similar to other xenoliths of its type but it has recrystallized to a dominantly coarse equant texture.

The more common variety of garnet that rims brown spinel in olivine-bearing xenoliths tends to form chains of equant and polygonal granules that are generally less than 0.5 mm in diameter (Fig. 13).

Textures of garnet + spinel xenoliths with associated garnet exsolved from pyroxene are commonly dominated by the characteristics of the exsolved garnet described above. Elongate interstitial garnet grains locally nearly completely rim mineral constituents other than spinel. Elongate, interstitial garnets may also be found in olivine-bearing xenoliths with garnet rimming spinel whether or not garnet exsolved from pyroxene is observed in the nodule. This may imply that garnet exsolution was once present in now reequilibrated pyroxene grains.

In other olivine-bearing, spinel + garnet xenoliths, no evidence of exsolution can be seen. It is typical in such nodules to find the polygonal garnet granules that rim spinel extending away from the spinel grain boundary, impinging with surrounding minerals. These contacts of garnet with pyroxenes or olivine tend to be deeply concave and dentate and the garnet granules enclose small (0.1-0.5 mm) angular fragments of other minerals (Fig. 13c). These fragments commonly appear to be in optical continuity with a nearby coarser grain, but just as commonly there appears to be no optical relationship.

Zoning in Garnet

Garnets from one Iron Mountain District peridotite (IM42-L58) are zoned. Garnet grains are subhedral to anhedral, 2-4 mm in diameter. Rims are approximately 0.5 mm width and locally are clearly

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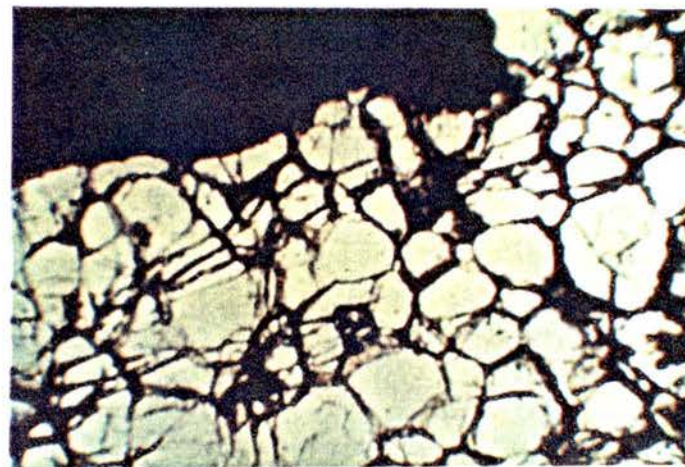
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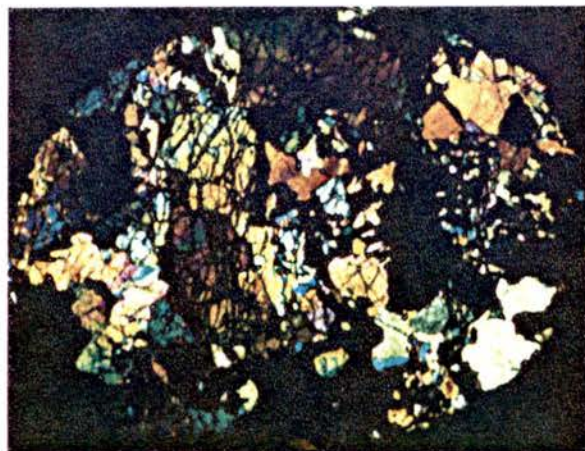
- Figure 13a. Incipient development (?) of garnet rim around red-brown spinel of garnet + spinel olivine websterite (SD2-L28) from the Sloan 2 kimberlite (plane light; horizontal field of view is 2 mm).
- 13b. Granular nature of well developed garnet rim around red-brown spinel of garnet + spinel lherzolite (SD2-L10) from the Sloan 2 kimberlite (horizontal field of view is approximately 2 mm).
- 13c. Full view of thin section of garnet + spinel lherzolite SD2-L10. Note tiny olivine grains surrounded by garnet granules (extinct, right half of photo)(crossed nicols; nodule is approximately 2 cm in diameter).
- 13d. Same as 13c; plane light. Spinel is nearly black, garnet is pinkish, olivine is riddled with black serpentine veinlets, pyroxenes are greenish.



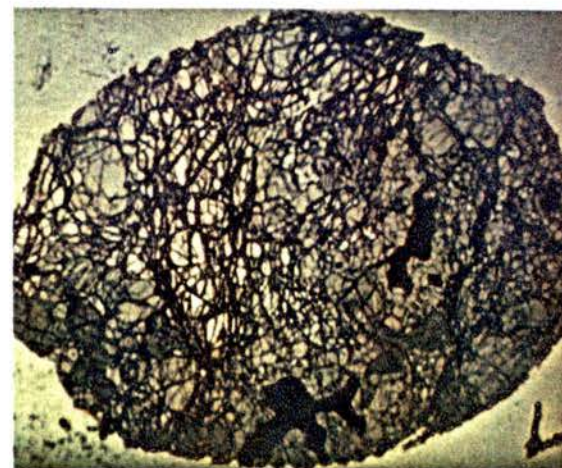
a.



b.



c.



d.

defined by concentric fractures accentuated by thin linings of red-brown alteration material. Variation in thin section color or other visible evidence of zoning from core to rim is not apparent. The garnet overgrowths most likely formed within the mantle before incorporation into kimberlite in response to some change in pressure, temperature or chemical environment (Smith, 1977).

Orthopyroxene

Kinkbands in orthopyroxene (Fig. 14a) were included as characteristic features in textural types described by Boullier and Nicolas (1973, 1975) because there seems to be a correlation between intensity of shearing in the nodule and degree and clarity of kinking in orthopyroxene grains. This correlation is generally evident in the fresh orthopyroxene-bearing xenoliths that are found primarily in the Sloan 2 and Nix 4 kimberlites. Kinkbands are more common in orthopyroxenes of olivine-bearing xenoliths than in those of olivine-free websterites and orthopyroxene-bearing clinopyroxenites.

Orthopyroxene has exsolved from clinopyroxene along the same lamellae as garnet in several garnet and garnet + spinel websterites and clinopyroxenites (Fig. 14d). Orthopyroxene exsolution lamellae, like garnet, average 0.1 mm in width and usually extend the full length of the host, terminating shortly before contacting the host grain boundary. If garnet and orthopyroxene exsolve from the same clinopyroxene host, one or the other is subordinate in amount and more limited in extent. Sample SD2-L113 (Fig. 14d) contains irregular patches of orthopyroxene that are not arranged as regular straight lamellae but are present with garnet exsolution lamellae and blebs

1. The first of these is the fact that the system is not in a state of equilibrium. This is because the system is not in a state of minimum energy. The system is in a state of maximum energy, and this is why it is not in a state of equilibrium.
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10. The tenth of these is the fact that the system is not in a state of minimum energy. This is because the system is not in a state of minimum energy. The system is in a state of maximum energy, and this is why it is not in a state of equilibrium.

Figure 14a. Kinkbands in an orthopyroxene grain from a transitional-porphyroclastic spinel lherzolite (SD2-L9) from the Sloan 2 kimberlite. Horizontal field of view is approximately 2 mm; crossed nicols.

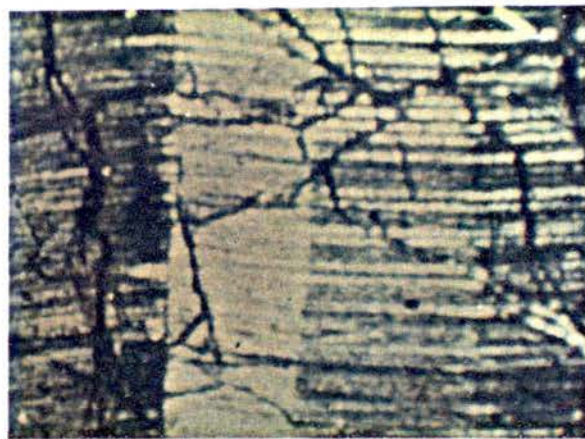
14b. Euhedral orthopyroxene inclusion within clinopyroxene of a garnet + spinel clinopyroxenite (SD2-W10) from the Sloan 2 kimberlite. Horizontal field of view is approximately 2 mm; crossed nicols.

14c. Hairline orthopyroxene (?) lamellae (white) in clinopyroxene (upper right hand corner) from spinel lherzolite SD2-L17 from the Sloan 2 kimberlite (crossed nicols; nodule is approximately 2 cm in diameter).

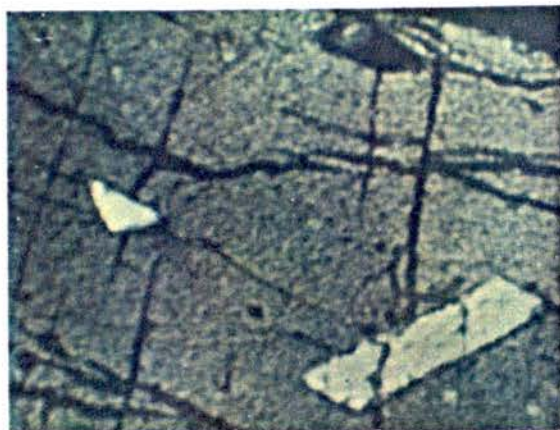
14d. Garnet (black) and orthopyroxene (white) exsolved along the same planes of clinopyroxene (grey) in a garnet websterite nodule (SD2-L113) from the Sloan 2 kimberlite (crossed nicols; horizontal field of view is approximately 2mm).

14e. Orthopyroxene (grey) and clinopyroxene (yellow) intergrown in spinel-bearing websterite (SD2-L164). Crossed nicols; nodule is approximately 2 cm in diameter.

14f. Orthopyroxene (extinct) exsolution lamellae in clinopyroxene (yellow) of spinel-bearing websterite (SD2-L164). Crossed nicols; horizontal field of view is approximately 2 mm.



a.



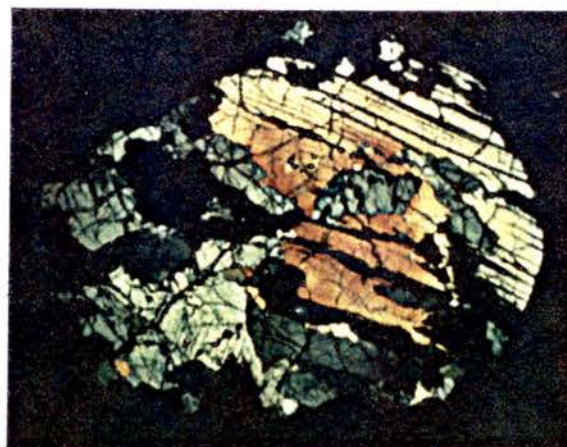
b.



c.



d.



e.



f.

in the host clinopyroxene grain. The orthopyroxene lamellae coalesce at one end of the clinopyroxene host and there more closely resemble a single orthopyroxene grain with clinopyroxene and garnet lamellae.

Orthopyroxene has exsolved from clinopyroxene (Fig. 14e, 14f) in each of the 3 brown spinel-bearing, garnet- and olivine-free websterites (SD2-W8, SD2-L164, NX4-C10). These orthopyroxene lamellae are very straight and regular and range in thickness from 0.1-0.5 mm in width. Orthopyroxene exsolution lamellae may thin near the host clinopyroxene grain boundary but generally extend all the way to the boundary.

A spinel + garnet clinopyroxenite (SD2-W10) contains clinopyroxene grains that enclose a 0.7 x 0.2 mm euhedral orthopyroxene inclusion that is quite distinctive chemically (analysis Pc, Table 6, Fig. 14b). This inclusion and euhedral olivine neoblast tablets described above are the only euhedral constituents recognized in Colorado-Wyoming xenoliths.

Clinopyroxene

Exsolution of clinopyroxene in orthopyroxene may occur as hairline (0.01 x 0.2-0.5 mm) lamellae but thicker, more prominent clinopyroxene exsolution phenomena comparable to exsolution of garnet and orthopyroxene from clinopyroxene have not been found in Colorado-Wyoming nodules. Fine twin lamellae in both pyroxenes may have a similar hairline habit and in many cases the only way to distinguish twin from an exsolution lamella is by microprobe analysis.

CHAPTER III

MINERAL CHEMISTRY

Introduction

Six chemically distinct groups of mantle xenoliths are delineated in variation and triangular diagrams (Figs. 15-30) and ranges of oxide content in minerals of each group are outlined in Table 3. Garnet peridotites (Group I) are distinctive petrographically as they usually contain spherical garnets and/or tabular euhedral olivine or pseudomorphs thereof. Chromite may be present in these xenoliths. Chemically unique spinel harzburgites from the Sloan 2 diatreme plus one from the Nix 4 kimberlite define Group II. Iron Mountain District spinel peridotites comprise Group III. The general term peridotite is used to describe the Iron Mountain spinel-bearing xenoliths of Group III because the severely altered nature of many samples does not allow distinction between lherzolites and harzburgites. Group IV xenoliths include olivine-free, garnet $\pm$ spinel websterites and clinopyroxenites. Spinel present in these xenoliths is exclusively a green Al_2O_3 -rich variety that is invariably rimmed by garnet and associated with garnet exsolved from pyroxenes. The Websterite Group (Eggler and McCallum, 1974; McCallum et al., 1979a, b) defines Group V and includes xenoliths from diatremes in all of the Colorado-Wyoming districts under study. Group V xenoliths are the most diverse mineralogically. They include brown spinel and/or garnet lherzolites,

harzburgites, wehrlites, olivine websterites, websterites, clinopyroxenites and orthopyroxenites. All nodules containing brown spinel rimmed by garnet belong to the Websterite Group. Peridotites of the Websterite Group that have no spinel generally contain garnets that are identical in composition and appearance to garnets rimming spinel, thus it is quite likely that spinel is or was present in such nodules but was not intersected in thin section. Dunites consisting of 100 percent olivine by volume comprise Group VI.

It should be noted that olivine and orthopyroxene plots are dominated by analyses of Sloan group xenoliths. Only one nodule from a Schaffer pipe (SH3-L1) and two from the Iron Mountain District (IM26-P64 and IM20-W5) contain fresh orthopyroxene and only Sloan and Nix xenoliths contain fresh olivine.

Olivine

A plot of FeO versus MgO in olivines (Fig. 15, Plate 1) shows that xenoliths of Group II spinel harzburgites contain the least FeO and are richest in MgO. However, the range of FeO and MgO contents in olivines of Group II xenoliths (Table 3) exhibits considerable overlap with that of Group I. Olivines of Group V xenoliths exhibit a relatively large field, however, the range of FeO and MgO content (Table 3) is not significantly greater than that of Groups I or VI. The dunites of Group VI exhibit a bimodal distribution with two subgroups characterized by olivine compositions of approximately Fo₈₈₋₉₀ (11.5-12.0 weight percent FeO) and Fo₉₂₋₉₃ (approximately 7.0-8.5 weight percent FeO). As previously noted, Groups III and IV contain no olivine.

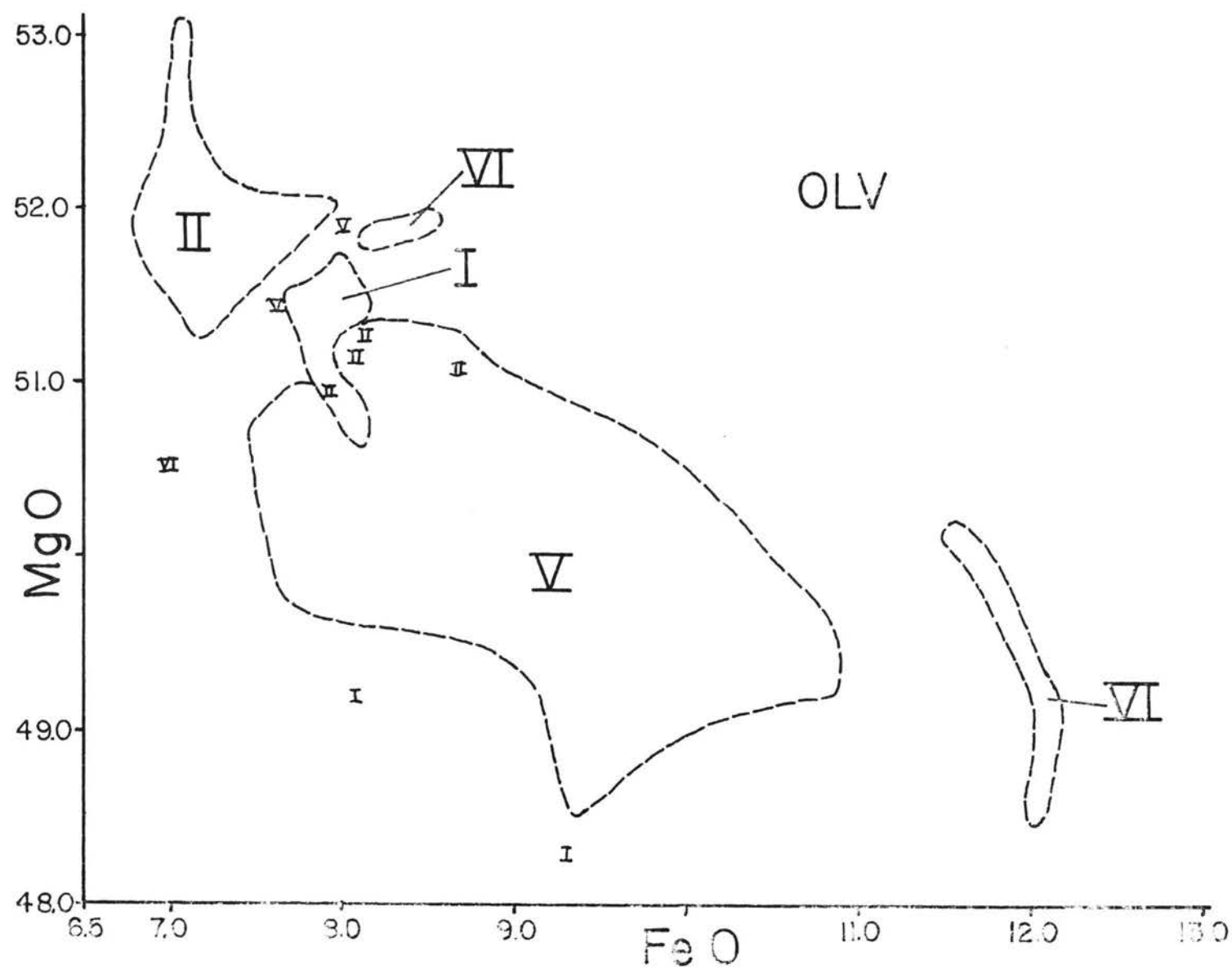
Table 3. Ranges of selected oxides in minerals of kimberlite xenoliths as shown in Figures 15-29 and Plates 1-15.

	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO	MgO	CaO	Na ₂ O	Mg/Mg+Fe	Ca/Ca+Mg
OLIVINE									
Group I				7.7-10.0	48.3-51.7				
Group II				6.8-8.6	51.0-53.1				
Group III			No fresh olivine remains in nodules of Group III						
Group IV			Nodules of Group IV contain no olivine						
Group V				7.5-13.0	47.6-51.9				
Group VI				6.9-13.0	47.5-52.0				
ORTHOPYROXENE									
Group I	0.00-0.38	0.56-0.99	0.13-0.88			0.53-1.20			
Group II	0.00-0.08	2.10-2.90	0.26-0.59			0.17-0.65			
Group III			No fresh olivine remains in nodules of Group III						
Group IV	0.00-0.21	0.40-4.60	0.00-0.36			0.16-0.56			
Group V	0.00-0.36	0.70-6.90	0.00-0.52			0.17-1.40			
Group VI			Nodules of Group VI contain no orthopyroxene						
CLINOPYROXENE									
Group I	0.03-0.96	0.15-4.00	0.53-3.80	1.50-5.10			0.87-3.80	0.862-0.951	0.396-0.491
Group II	0.00-0.18	2.00-2.80	0.58-0.95	1.20-1.90			0.35-0.91	0.944-0.962	0.495-0.508
Group III	0.00-0.45	2.50-4.60	0.86-2.30	1.00-1.40			1.10-2.70	0.953-0.968	0.453-0.511
Group IV	0.14-1.00	1.60-8.20	0.00-0.48	1.20-8.30			0.28-2.40	0.784-0.949	0.380-0.539
Group V	0.00-0.73	1.40-7.80	0.52-1.62	1.20-4.23			0.47-3.50	0.902-0.963	0.456-0.544
Group VI			Nodules of Group VI contain no clinopyroxene						
GARNET									
Group I	0.01-1.50	11.00-21.8	0.60-15.3	4.00-11.2	18.0-21.9	4.7-8.6			
Group II			Nodules of Group II contain no garnet						
Group III			Nodules of Group III contain no garnet						
Group IV	0.02-0.24	21.60-24.2	0.00-1.40	7.10-18.5	13.2-22.4	3.8-7.0			
Group V	0.03-1.00	20.90-24.0	0.40-2.20	7.00-13.0	16.4-21.8	3.6-5.9			
Group VI			Nodules of Group VI contain no garnet						
SPINEL									
Group I		7.0-22.5	37.0-61.7	0.383-0.399	0.613-0.639				
Group II		31.0-46.5	24.0-47.0	0.186-0.330	0.650-0.796				
Group III		21.5-43.5	26.0-47.0	0.284-0.366	0.621-0.707				
Group IV		61.0-65.5	1.0-4.0	0.174-0.298	0.684-0.814				
Group V		21.5-61.5	7.5-43.0	0.184-0.379	0.590-0.810				
Group VI			Nodules of Group VI contain no spinel						

*All oxides are given in weight percent.

Figure 15. Weight percent MgO versus FeO in olivines. Fields designated by dashed outlines indicate the regions where the majority of olivines from each group plot. Large numerals label each group's field. Small numerals indicate olivines that plot outside their group's field as outlined.

Olivine in xenoliths of Group III has been completely replaced by secondary minerals thus no Group III field is indicated.

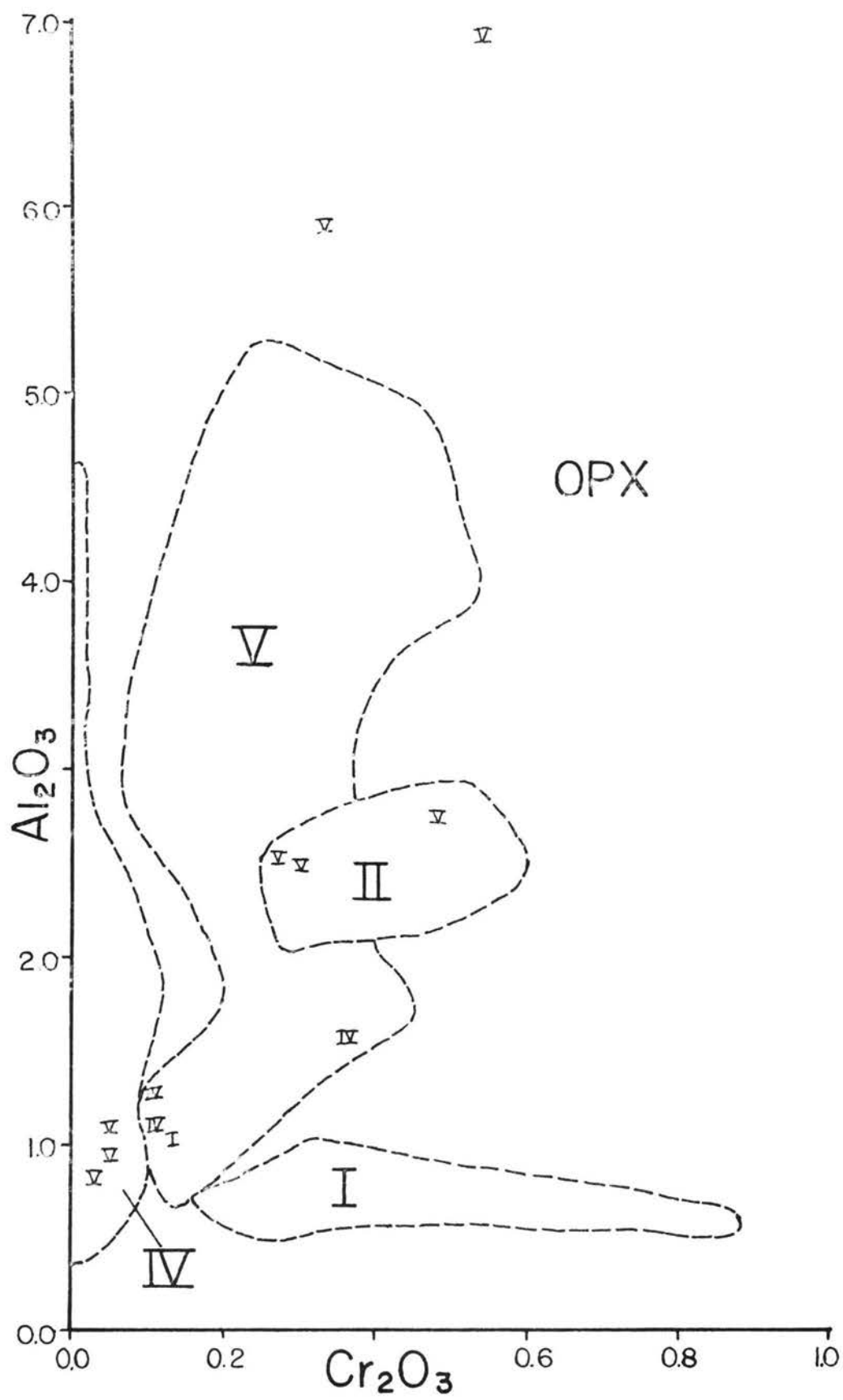


Orthopyroxene

Weight percent Al_2O_3 versus Cr_2O_3 (Plate 2, Figure 16, Table 3) provides perhaps the clearest picture of variations in orthopyroxene chemistry. On this basis, garnet $\pm$ spinel-bearing xenoliths are nearly completely separated from xenoliths containing spinel and no garnet; the latter contain greater than and the former contain less than 2.0 percent Al_2O_3 by weight. Exceptions include several very low chrome orthopyroxenes from Group IV xenoliths and orthopyroxenes from two garnet + brown spinel Websterite Group (Group V) xenoliths that contain greater than 2.0 percent Al_2O_3 . Orthopyroxenes of Group I xenoliths contain the least Al_2O_3 but exhibit the widest range and highest values of Cr_2O_3 . Group II orthopyroxenes have the most restricted chemical field. The three orthopyroxenes from Group V xenoliths that plot within the Group II field are spinel ilmenite with mosaic-porphyroclastic textures. Pyroxenes of these xenoliths are quite consistently similar chemically to those of Group II xenoliths. No fresh orthopyroxene has been recovered from Group III xenoliths. Orthopyroxenes of Groups IV and V exhibit wide ranges of Al_2O_3 contents and these group fields overlap at low Cr_2O_3 (less than 0.15 percent) and low Al_2O_3 (less than 1.5 percent) values. The Group V xenolith SD2-L40 contains orthopyroxene with the lowest Al_2O_3 content of that group. This xenolith is unusual in that it contains subspherical garnet somewhat similar in appearance to the garnets commonly found in Group I garnet peridotites. It is also one of the few ilmenite-bearing xenoliths observed from the Sloan group kimberlites. Although classified as a Group V xenolith, minerals of this sample are chemically very similar to and commonly plot very close to those of

Figure 16. Weight percent Al_2O_3 versus Cr_2O_3 in orthopyroxenes. Fields designated by dashed outlines indicate the regions where the majority of orthopyroxenes from each group plot. Large numerals label each group's field. Small numerals indicate orthopyroxenes that plot outside their group's field as outlined.

Orthopyroxenes of Group III xenoliths have been completely replaced by secondary minerals thus no Group III field is indicated.



Group I. Orthopyroxenes of the three Group V olivine-free pyroxenites (SD2-L164, SD2-W10, NX4-C10) that contain brown spinel and no garnet exhibit the highest Al_2O_3 values.

A CaO versus Cr_2O_3 diagram (Fig. 17, Plate 3) shows considerable overlap of all fields. However, orthopyroxenes of Group I exhibit the highest CaO values (Table 3). Orthopyroxenes of xenoliths from all groups also show considerable scatter in a plot of TiO_2 versus Cr_2O_3 (Fig. 18, Plate 4). The most significant feature of this diagram is the low TiO_2 content of most Group II xenolith orthopyroxenes (Fig. 18, Table 3).

Clinopyroxene

As with orthopyroxenes, plots of Al_2O_3 versus Cr_2O_3 in clinopyroxenes (Fig. 19, Plate 5, Table 3) define the major, chemically distinct xenolith groups. Clinopyroxenes of Group I xenoliths (containing spherical garnets and/or euhedral olivine tablets) exhibit the lowest Al_2O_3 values and the broadest range of Cr_2O_3 contents. Conversely, clinopyroxenes from xenoliths of Group IV (olivine-free, garnet $\pm$ green spinel websterites and clinopyroxenites) show a wide range of Al_2O_3 with Cr_2O_3 content restricted. Clinopyroxenes from two altered Schaffer xenoliths (SH3-L22, SH3-L160) that were probably olivine-bearing contain less than 0.5 weight percent Cr_2O_3 . These xenoliths are also ilmenite-bearing. The textures in these nodules are nearly completely obliterated by replacement minerals thus it is not possible to determine positively whether or not they once contained spherical garnets or euhedral olivine tablets characteristic of Group I xenoliths. Clinopyroxenes of two other altered Schaffer

Figure 17. Weight percent CaO versus Cr_2O_3 in orthopyroxenes. Fields designated by dashed outlines indicate the regions where the majority of orthopyroxenes from each group plot. Large numerals label each group's field. Small numerals indicate orthopyroxenes that plot outside their group's field as outlined.

Orthopyroxenes of Group III xenoliths have been completely replaced by secondary minerals thus no Group III field is indicated.

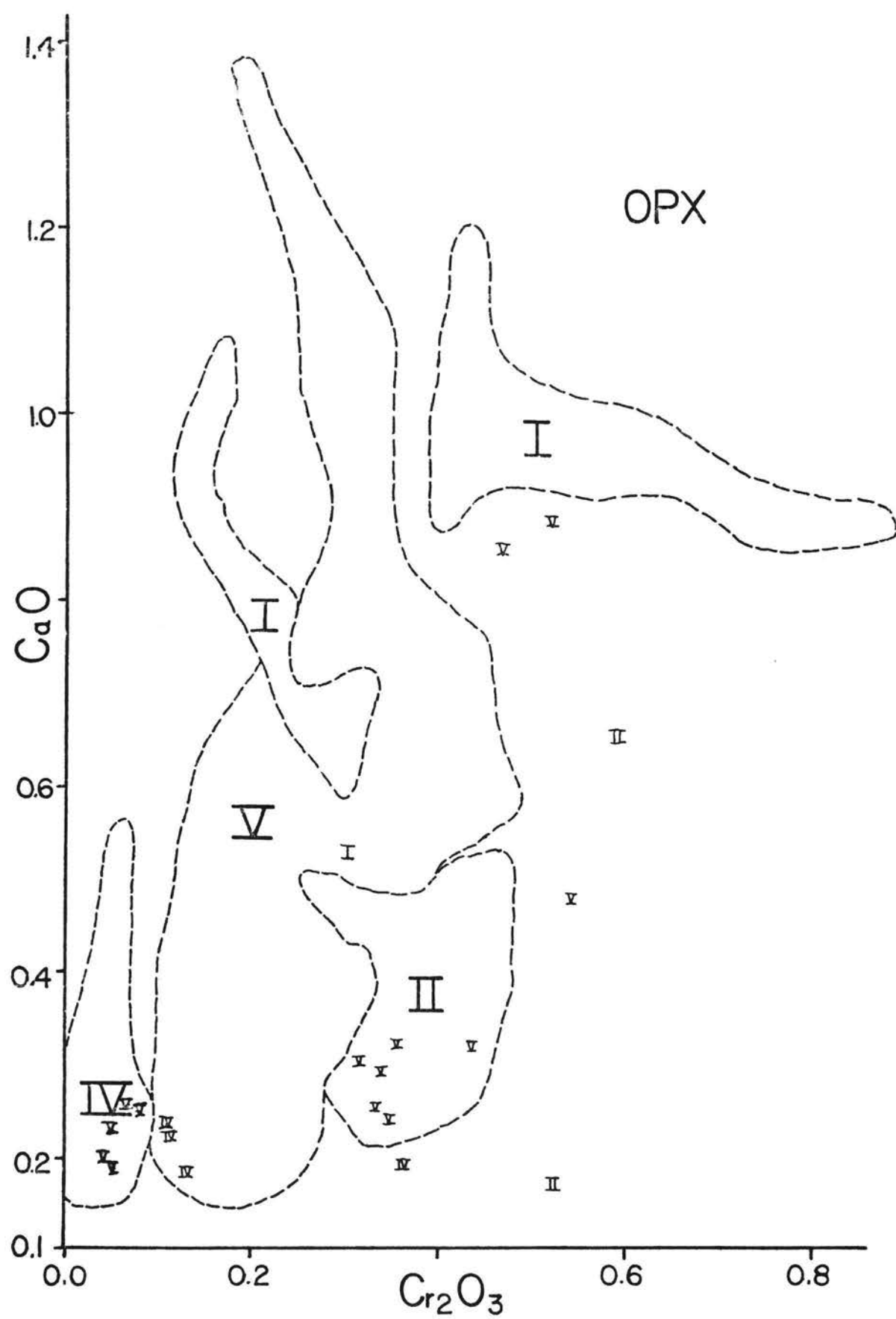


Figure 28. Weight percent TiO₂ versus TiO₂ in orthopyroxenes. Fields designated by dashed outlines indicate the regions where the majority of orthopyroxenes from each group plot. Large numbers label each group's field. Small numbers indicate orthopyroxenes that plot outside their group's field as outlined.

Orthopyroxenes of group III xenoliths have been completely replaced or secondary minerals from no group III field is indicated.

Figure 18. Weight percent TiO_2 versus Cr_2O_3 in orthopyroxenes. Fields designated by dashed outlines indicate the regions where the majority of orthopyroxenes from each group plot. Large numerals label each group's field. Small numerals indicate orthopyroxenes that plot outside their group's field as outlined.

Orthopyroxenes of Group III xenoliths have been completely replaced by secondary minerals thus no Group III field is indicated.

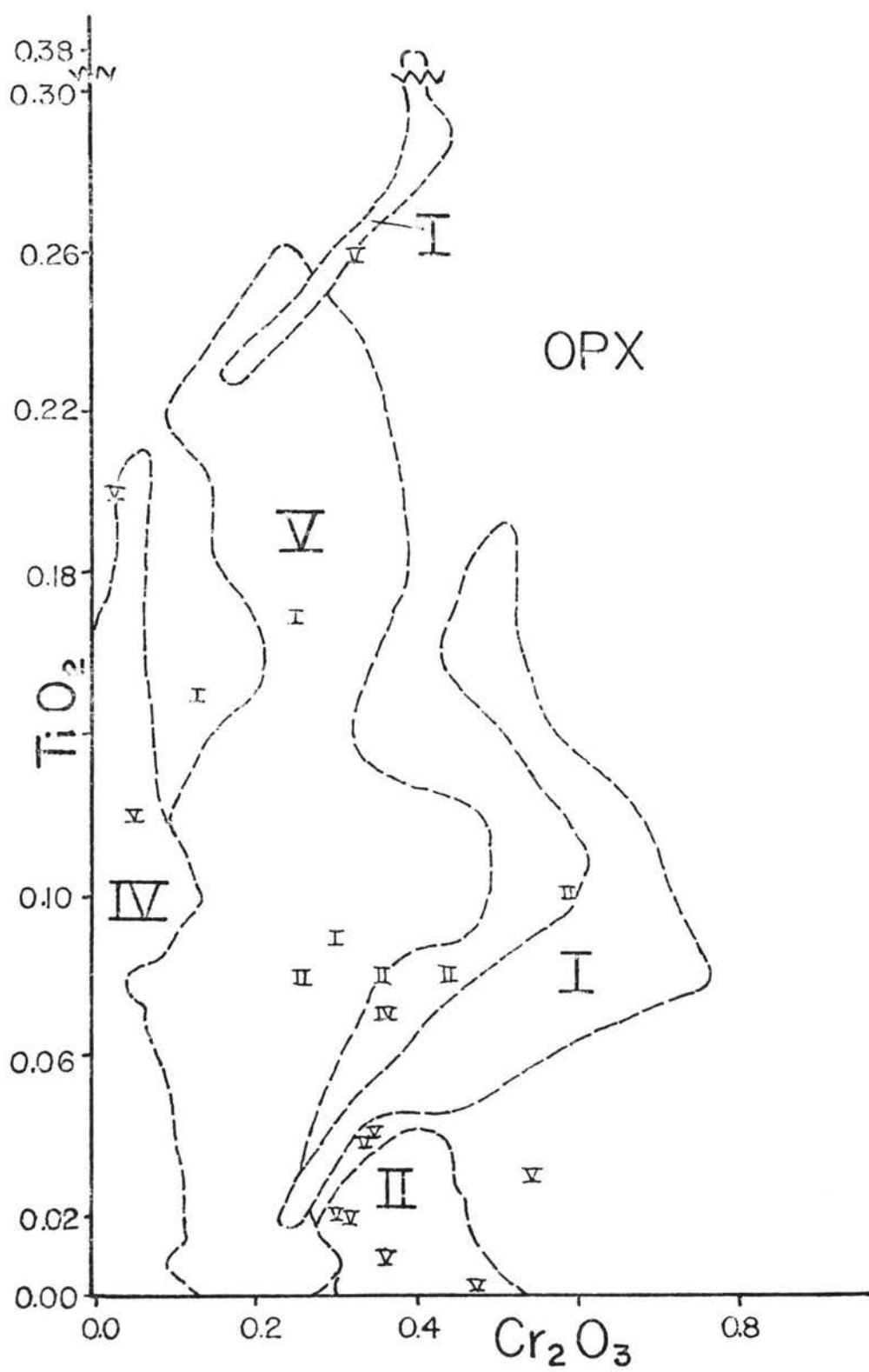
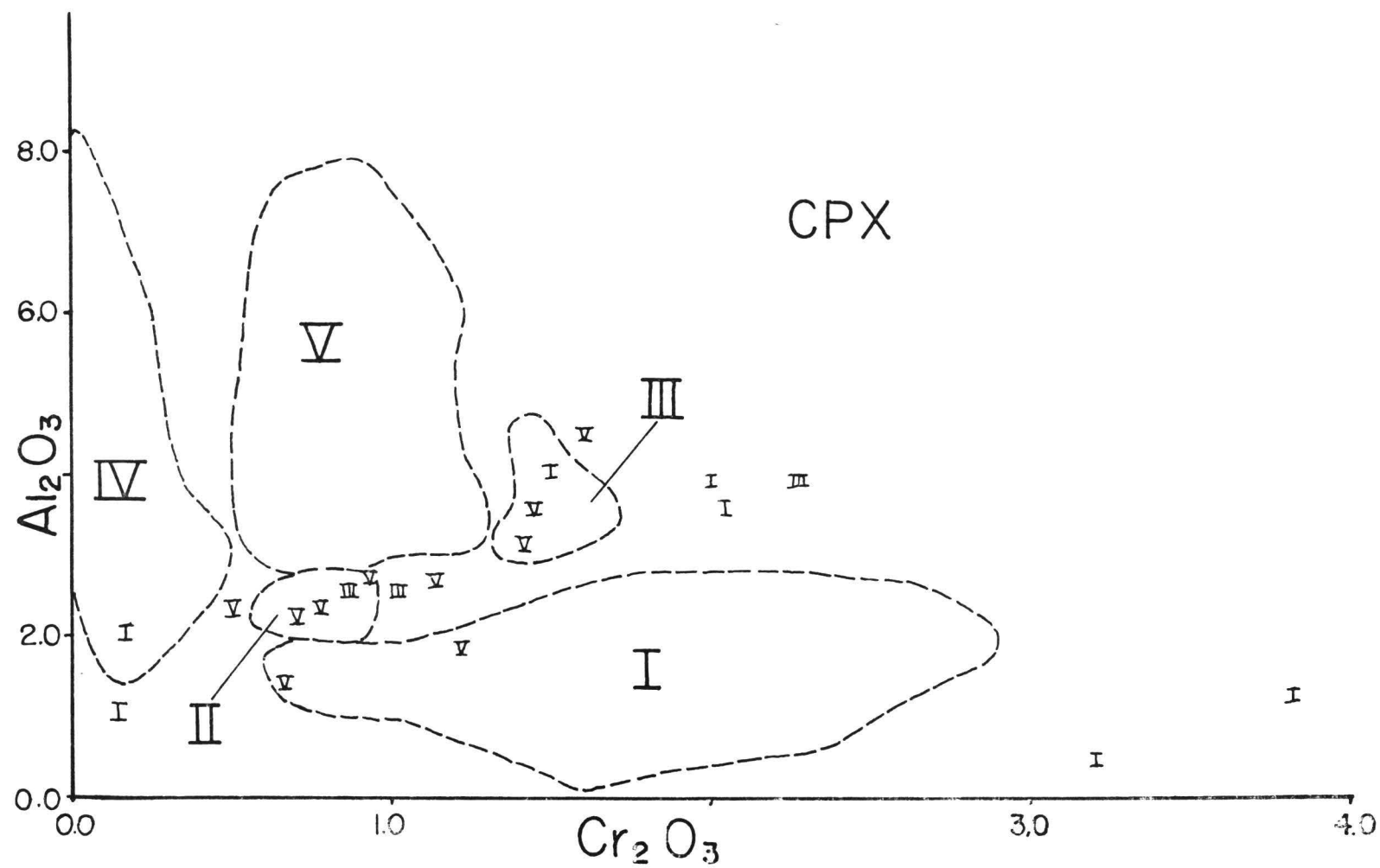


Figure 19. Weight percent Al_2O_3 versus Cr_2O_3 in clinopyroxenes. Fields designated by dashed outlines indicate the regions where the majority of clinopyroxenes from each group plot. Large numerals indicate each group's field. Small numerals indicate clinopyroxenes that plot outside their group's field as outlined.



xenoliths (SH3-L12, -L17) that contain ilmenite and obvious spherical garnets and pseudomorphs of euhedral olivine tablets plot with the Group I field of Figure 19 (Plate 5) but fall at the low Cr_2O_3 end of the Group I field. It is therefore assumed that xenoliths SH3-L22 and SH3-L160 are members of Group I and that minerals of such ilmenite-bearing xenoliths may be chemically distinct from the majority of Group I minerals. Clinopyroxenes from the coarse equant Iron Mountain peridotite IM42-L71 plot in the Group IV field whereas garnets from this nodule consistently plot with Group I garnets. Were it not for these exceptions, the Group IV field would include only olivine-free, garnet $\pm$ spinel websterites and clinopyroxenites. Clinopyroxenes of Sloan-Nix spinel harzburgites (Group II) exhibit a relatively restricted field and there is some overlap of this group with clinopyroxenes from Iron Mountain spinel peridotites (Group III) which exhibit much wider ranges of both Cr_2O_3 and Al_2O_3 (Table 3) than do those from Group II xenolith. As in orthopyroxenes, garnet $\pm$ spinel xenoliths of Group V generally contain less Al_2O_3 than orthopyroxenes of garnet-free xenoliths (Plate 5). Clinopyroxenes from the three Group V spinel-bearing, olivine- and garnet-free xenoliths (SD2-L164, SD2-W8, NX4-C10) are among the highest in Al_2O_3 content. Low Al_2O_3 content in clinopyroxenes of the three Group V spinel lherzolites with mosaic-porphyroclastic textures causes them to plot among those of Group II.

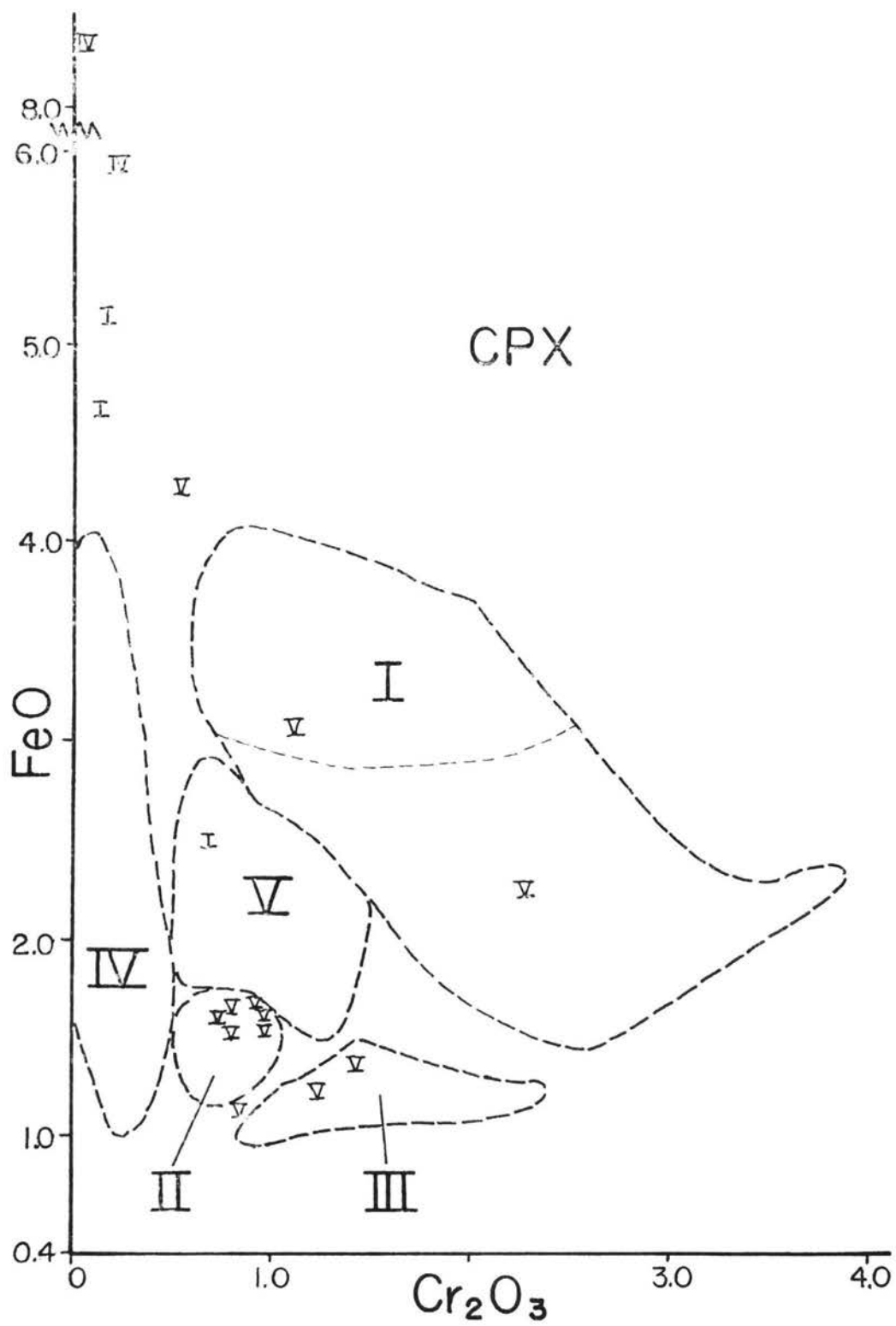
A plot of FeO versus Cr_2O_3 in clinopyroxenes (Fig. 20, Plate 6, Table 3) shows that Group I clinopyroxenes exhibit a wide range of FeO contents but most contain higher FeO than do the majority of clinopyroxenes from other groups. Clinopyroxenes from Group I xenoliths

Figure 20. The various types of chlorophylls. The dashed line indicates the region where the majority of chlorophylls from each group occur. The horizontal line indicates the region where the majority of chlorophylls from each group occur. The horizontal line indicates the region where the majority of chlorophylls from each group occur.

The chlorophylls of the Group 1 field below 2.0 and 4.0 percent are included in chlorophylls from xanthophylls with porphyrin-like structure.

Figure 20. FeO versus Cr₂O₃ in clinopyroxenes. Fields designated by dashed outlines indicate the regions where the majority of clinopyroxenes from each group plot. Large numerals indicate each group's field. Small numerals indicate clinopyroxenes that plot outside their group's field as outlined.

The subfield of the Group I field between 3.0 and 4.0 percent FeO includes clinopyroxenes from xenoliths with porphyroclastic textures.

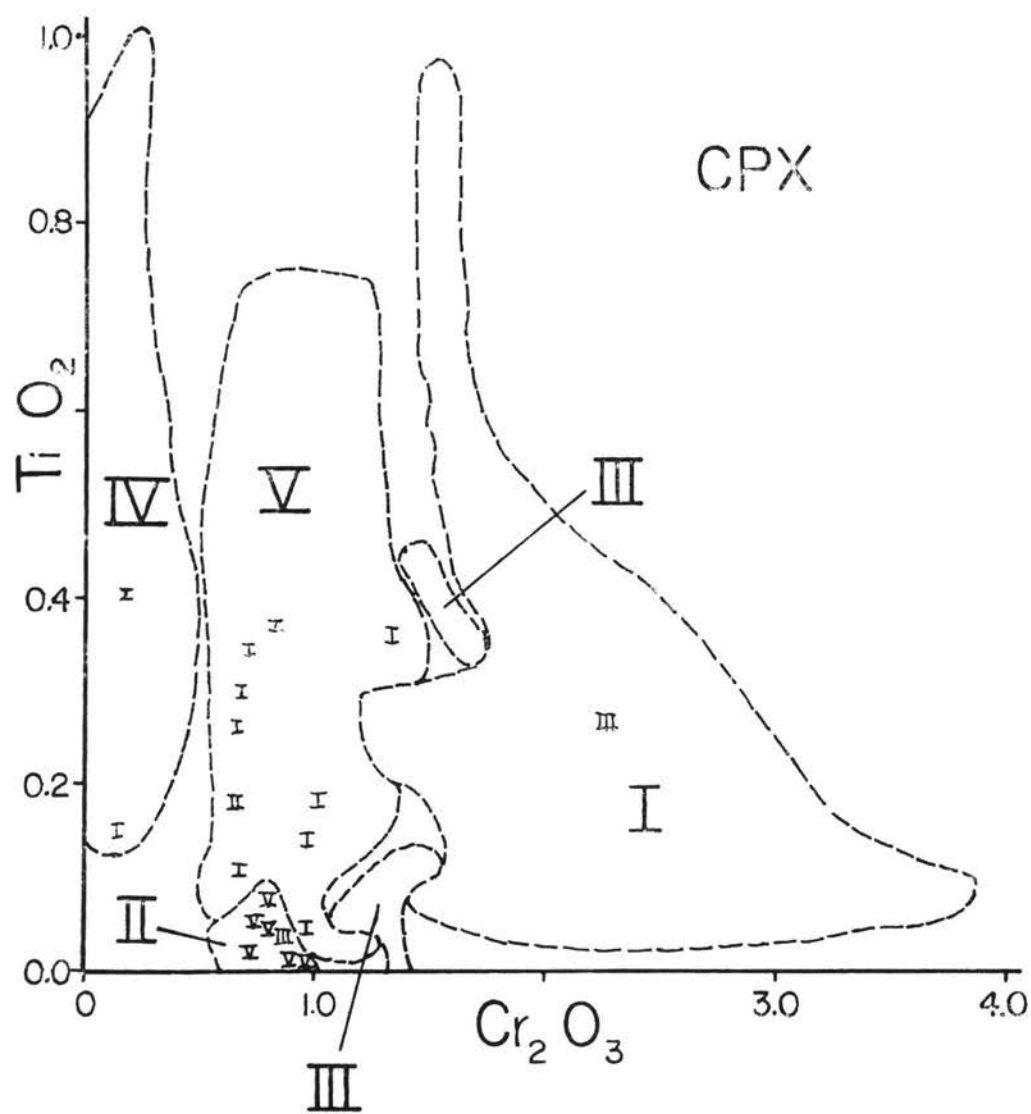


with porphyroclastic textures are typically high in FeO (Fig. 20). Group I ilmenite-bearing xenoliths SH3-L22 and SH3-L160 are also high in FeO (5.14 and 4.68 weight percent FeO, respectively). Sloan-Nix spinel harzburgites and Iron Mountain spinel peridotites (Groups II and III, respectively) contain clinopyroxenes with the lowest FeO contents. Considerable overlap exists between the Group II and Group V fields at approximately 1.5 and 1.9 weight percent FeO. Clinopyroxenes of mosaic-porphyroclastic spinel lherzolites of Group V are among those falling in the Group II field. Group IV xenoliths contain clinopyroxenes with the widest range in FeO content due to two very iron-rich clinopyroxenes, SD2-P1 and SD2-W10, with FeO values of 5.91 and 8.34, respectively. With few exceptions, clinopyroxenes of the Websterite Group (Group V) xenoliths are relatively tightly clustered between approximately 1.5 and 2.9 weight percent FeO.

TiO₂ content in clinopyroxenes (Fig. 21, Plate 7, Table 3) follows a pattern similar to that in orthopyroxenes (Fig. 18, Plate 4). The small range and low TiO₂ contents of Group II spinel harzburgites is again notable. Clinopyroxenes of Group I xenoliths with porphyroclastic textures tend to have TiO₂ contents slightly higher than the average for the group as a whole. TiO₂ in clinopyroxenes of Iron Mountain spinel peridotites (Group III) is considerably more widespread than that of Group II spinel harzburgites. The bulk of clinopyroxenes from Groups IV and V have similar TiO₂ contents. Clinopyroxenes of Group I ilmenite-bearing xenoliths SH3-L22 and SH3-L160 plot with Group IV clinopyroxenes, whereas those from Group I ilmenite-bearing xenoliths SH3-L12 and SH3-L17 plot with Group V as do several other Group I clinopyroxenes. Clinopyroxenes of Group IV xenoliths with

During the past few years, the work of the
 various departments of the Government has been
 largely directed towards the improvement of
 the condition of the people, and the
 establishment of a more efficient system of
 government.

Figure 21. Weight percent TiO_2 versus Cr_2O_3 in clinopyroxenes. Fields designated by dashed outlines indicate the regions where the majority of clinopyroxenes from each group plot. Large numerals indicate each group's field. Small numerals indicate clinopyroxenes that plot outside their group's field as outlined.



green spinel rimmed by garnet and/or garnet exsolution from pyroxenes are among the clinopyroxenes highest in TiO_2 (greater than 0.55 percent TiO_2 by weight).

An Na_2O versus FeO diagram (Figure 22, Plate 8, Table 3) exhibits distinct separation of clinopyroxenes of Groups II and III spinel peridotites. Clinopyroxenes of Group II spinel harzburgites are low in Na_2O as well as FeO . Group III spinel peridotites from Iron Mountain are low in FeO but exhibit a relatively wide range of Na_2O . A few clinopyroxenes of the Websterite Group (Group V) xenoliths plot outside the Group V field and within Group II and III fields. These exceptions include the clinopyroxenes of Group V spinel lherzolites with mosaic-porphyroclastic textures. Groups IV and V are inseparable on this diagram and considerable overlap exists between the composite IV and V field and that of Group I.

Lower CaO and higher FeO contents in clinopyroxenes of the porphyroclastic xenoliths of Group I garnet peridotites are notable in a plot of $\text{Ca}/\text{Ca} + \text{Mg}$ versus $\text{Mg}/\text{Mg} + \text{Fe}$ (Fig. 23, Plate 9, Table 3). The low FeO and high CaO contents of clinopyroxenes of the Iron Mountain spinel peridotites (Group III) are also emphasized. Clinopyroxenes of Group II spinel harzburgites have $\text{Mg}/\text{Mg} + \text{Fe}$ values similar to those of Group III but $\text{Ca}/\text{Ca} + \text{Mg}$ values of Group II are generally slightly lower. Considerable overlap exists between fields of Groups IV and V in this diagram.

Garnet

It is evident from Al_2O_3 versus Cr_2O_3 plots (Fig. 24, Plate 10, Table 3) that as Cr_2O_3 content increases, Al_2O_3 decreases in garnets

1. The first thing I noticed when I stepped out of the plane was the cold. It was a sharp contrast to the warm, humid air of the tropics. I shivered as I walked down the stairs, my hands tucked into my pockets. The ground beneath my feet was hard and cold, a stark difference from the soft, yielding earth of the islands. I took a deep breath, the crisp air filling my lungs. It felt like a new beginning.

2. The second thing I noticed was the silence. It was a profound silence, a void that seemed to swallow all sound. I looked around, but saw nothing but the vast, open landscape. The only sounds were the rustle of my clothes and the distant hum of the plane's engines. It was a strange, almost eerie feeling.

Figure 22. Weight percent of Na_2O versus FeO in clinopyroxenes. Fields designated by dashed outlines indicate the regions where the majority of clinopyroxenes from each group plot. Large numerals indicate each group's field. Small numerals indicate clinopyroxenes that plot outside their group's field as outlined.

Clinopyroxenes from Groups IV and V are inseparable in this diagram thus a composite field is outlined.

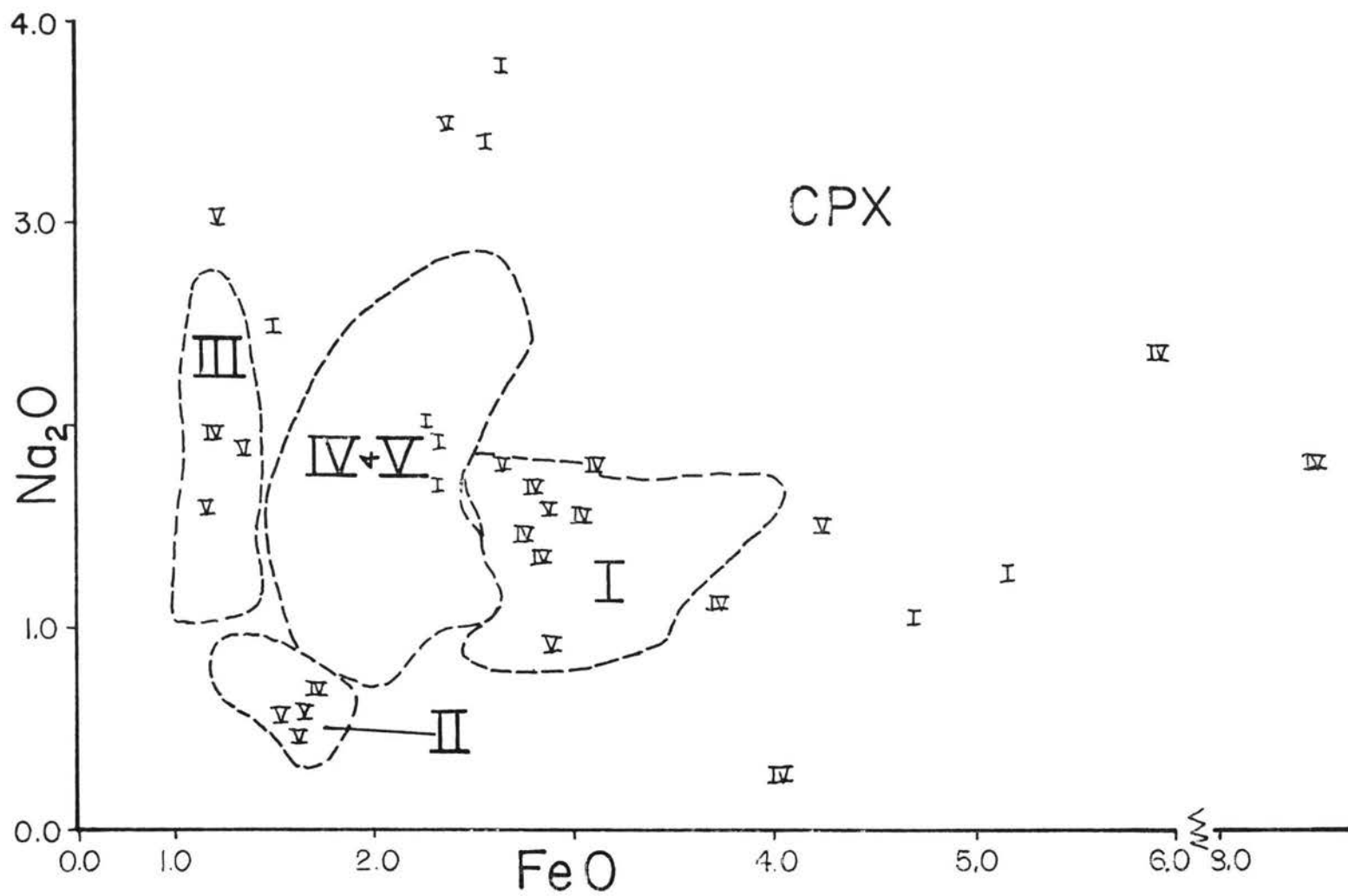
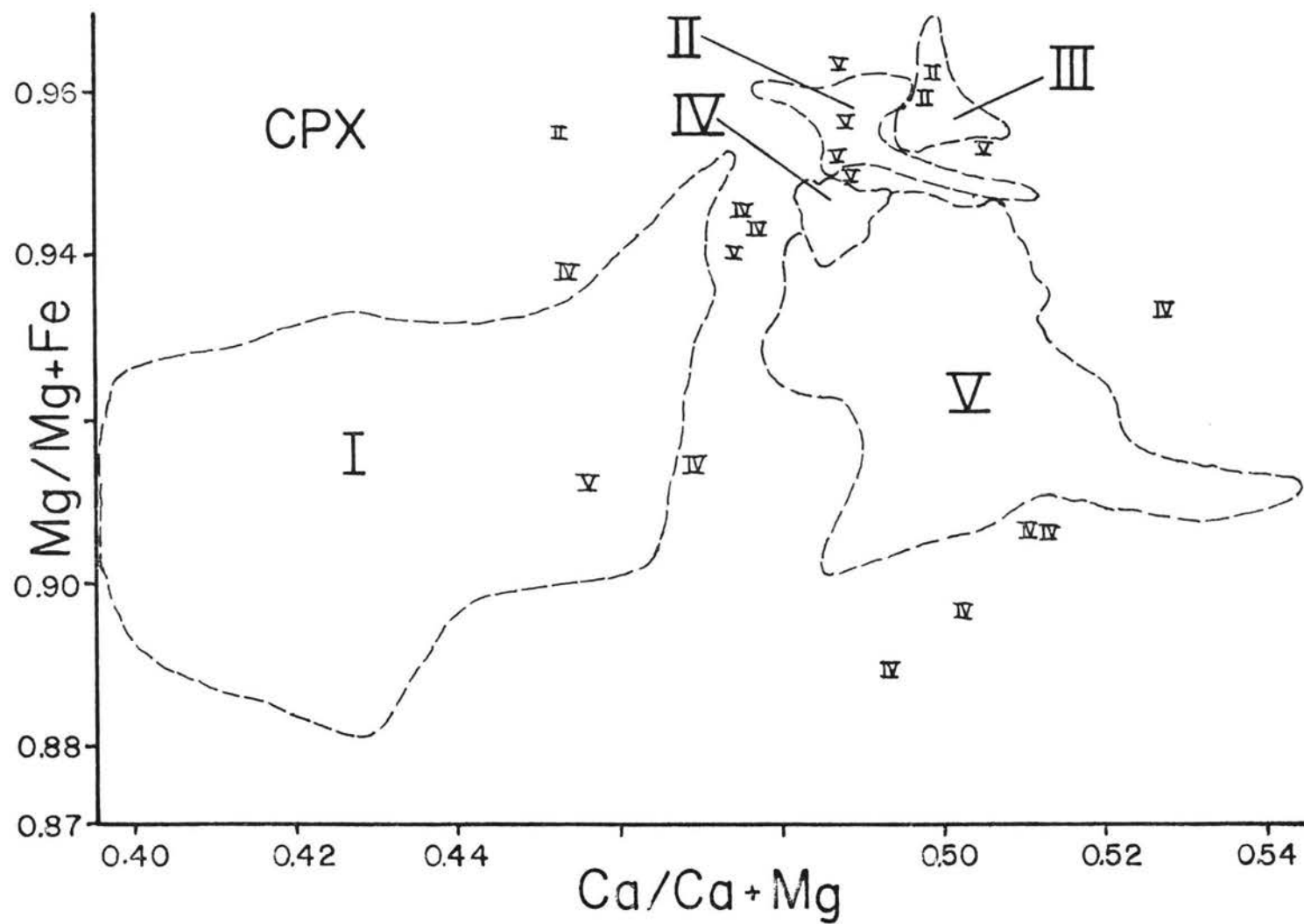


Figure 23. $\text{Mg}/(\text{Mg} + \text{Fe})$ versus $\text{Ca}/(\text{Ca} + \text{Mg})$ in clinopyroxenes. Fields designated by dashed outlines indicate the regions where the majority of clinopyroxenes from each group plot. Large numerals indicate each group's field. Small numerals indicate clinopyroxenes that plot outside their group's field as outlined.



of Colorado-Wyoming xenoliths. Garnets of Group I garnet peridotites have the highest Cr_2O_3 content and lowest Al_2O_3 content. Within this group there is no distinct correlation of Cr_2O_3 and Al_2O_3 with xenolith texture; however, the majority of garnets of Group I Schaffer-Ferris-Aultman (Subgroup Ia, Fig. 24) xenoliths, most of which have coarse equant textures, generally have higher Al_2O_3 and lower Cr_2O_3 than do garnets of most Iron Mountain xenoliths (Subgroup Ib, Fig. 24), many of which have porphyroclastic textures. Garnets of the Sloan-Nix-Moen Group I xenoliths, most of which have transitional-porphyroclastic textures, generally are lowest in Al_2O_3 and highest in Cr_2O_3 (Subgroup Ic, Fig. 24). Considering the Group I xenoliths of each diatreme group individually, however, garnets show no correlation between texture and Cr_2O_3 and Al_2O_3 content. Garnets of ilmenite-bearing xenolith SH3-L22 plot in the composite Group IV + V field and garnets of ilmenite-bearing xenoliths SH3-L12 and SH3-L17 plot in the Group I field but near the low Cr_2O_3 , high Al_2O_3 end of the field. Ilmenite-bearing Group V xenolith SD2-L40 garnets plot outside their expected field and in the field of Group I garnets. No distinct separation can be made between the garnets of Groups IV and V, however, the majority of garnets from Group IV xenoliths contain between 23.0 and 24.0 percent Al_2O_3 and less than 1.0 percent Cr_2O_3 whereas the majority of Group V garnets contain between 22.0 and 23.0 percent Al_2O_3 and between 1.0 and 2.0 percent Cr_2O_3 by weight. Xenoliths of Groups II and III contain no garnet.

Spherical garnets from Group I garnet peridotites show a wide scatter in TiO_2 content (Fig. 25, Plate 11, Table 3) and there is no distinct correlation between TiO_2 content and texture. Group IV and V

Figure 24. Al_2O_3 versus Cr_2O_3 in garnets.

Fields designated by dashed outlines indicate the regions where the majority of garnets from each group plot. Large numerals label each group's field. Small numerals indicate garnets that plot outside their group's field as outlined.

Fields IV and V overlap so much as to be inseparable thus a composite field is outlined.

Subfield Ia indicates region within which the majority of garnets of nodules from the Schaffer-Ferris-Aultman kimberlite plot.

Subfield Ib indicates region within which the majority of garnets from nodules from the Iron Mountain District kimberlites plot.

Subfield Ic outlines the region where majority of garnets from nodules of Sloan-Nix-Moen kimberlites plot.

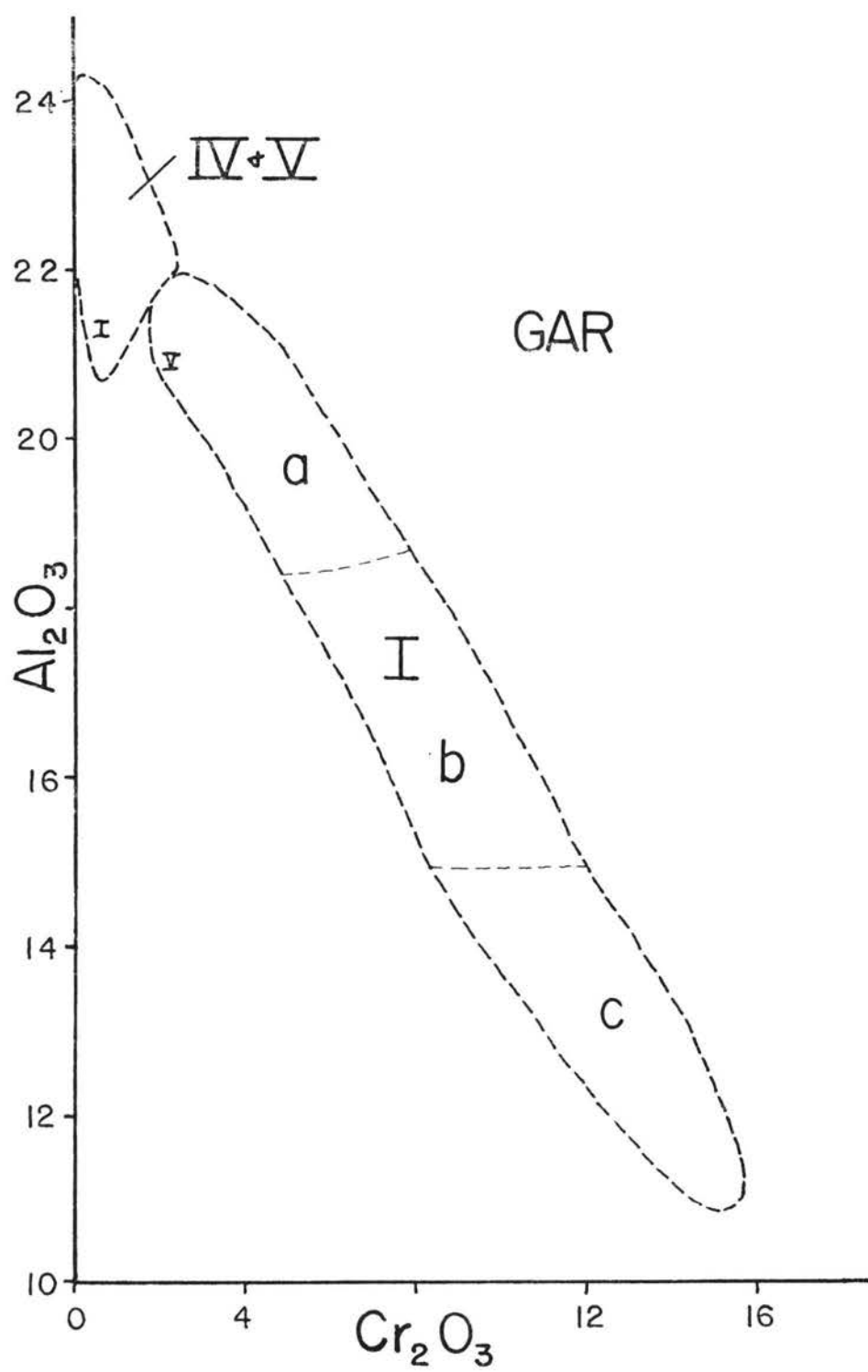


Figure 10. The vector $\mathbf{C}_2$ in Figure 10.

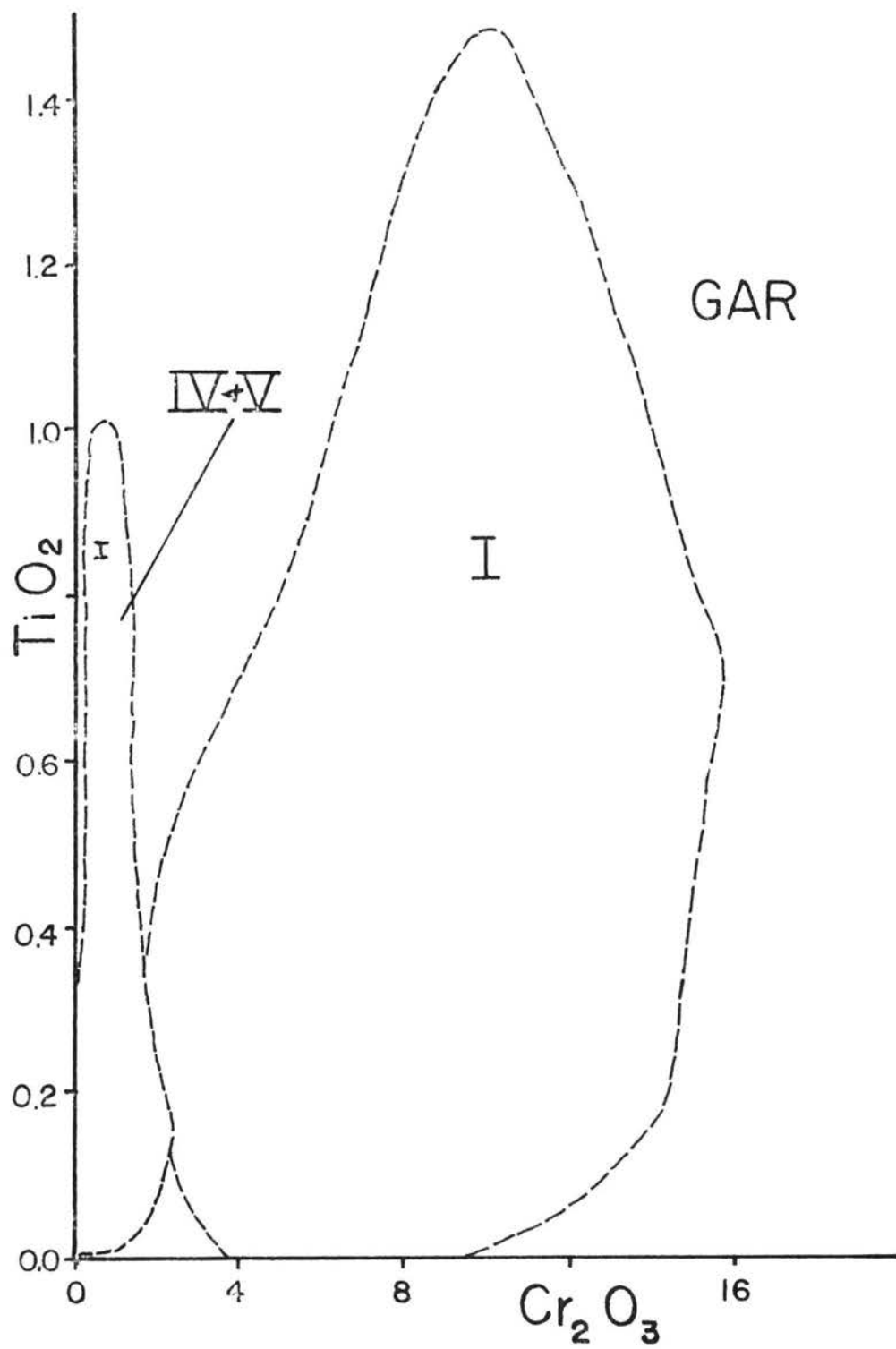
Field $\mathbf{C}_2$ is a vector field. It is defined in the region where the unit vector $\mathbf{e}_2$ is defined. Large numbers label each vector field. Small numbers indicate points that are outside the region of the field as defined.

Fields $\mathbf{C}_1$ and $\mathbf{C}_2$ are independent in this diagram from a composite field; it is defined.

Figure 25. TiO_2 versus Cr_2O_3 in garnets (GAR).

Fields designated by dashed lines indicate the regions where the majority of garnets from each group plot. Large numerals label each group's field. Small numerals indicate garnets that plot outside their group's field as outlined.

Fields IV and V are inseparable in this diagram thus a composite field is outlined.



garnets cluster tightly below approximately 0.25 weight percent TiO_2 except for a few Group V garnets from Schaffer xenoliths and one from the Moen 2 pipe that have higher TiO_2 values.

In general, CaO content of garnets increases with increasing Cr_2O_3 content thus creating the strong linear trend seen in Figure 26 and Plate 12. Garnets from two Group I xenoliths contain from 1 to 3 percent less CaO than the majority of garnets and thus fail to plot along the linear trend. One of these, a tabular peridotite (SH3-L3) is diamond-bearing. Garnets of the Schaffer-Ferris-Aultman xenoliths (Subgroup Ia, Fig. 26) generally contain less CaO than those of the Iron Mountain District (Subgroup Ib, Fig. 26) which in turn contain less CaO than garnets of the Sloan-Nix-Moen xenoliths (Subgroup Ic, Fig. 26). A vertical line at 2.35 percent Cr_2O_3 serves to nearly completely separate the spherical garnets of Group I garnet peridotites from garnets of Group IV and V nodules. Only spherical garnets from three ilmenite-bearing peridotites (SH3-L12, SH3-L17, SH3-L22) plot outside of their general group field on this basis.

Garnets of Group I xenoliths are relatively clearly separated from those of Groups IV and V in a plot of MgO versus FeO (Fig. 27, Plate 13, Table 3). Within Group I, xenoliths can be subdivided in a manner similar to that described in the discussion of Al_2O_3 , Cr_2O_3 and CaO content of garnets above. Garnets from the Schaffer-Ferris Aultman xenoliths (Subgroup Ia, Fig. 27), garnets most of which have coarse equant textures, contain more MgO than do most garnets of Group I Iron Mountain xenoliths (Subgroup Ib, Fig. 27) of both coarse equant and porphyroclastic textural types. The majority of garnets from Group I Sloan-Nix-Moen xenoliths (Subgroup Ic, Fig. 27),

The first of these is the fact that the
 system is not a simple one. It is a
 complex one, and it is not possible to
 describe it in a simple way. It is a
 system of many parts, and it is not
 possible to describe it in a simple way.
 It is a system of many parts, and it is
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 many parts, and it is not possible to
 describe it in a simple way. It is a
 system of many parts, and it is not
 possible to describe it in a simple way.

Figure 26. CaO versus Cr_2O_3 in garnets.

Fields designated by dashed lines indicate the regions where the majority of garnets from each group plot. Large numerals label each group's field. Small numerals indicate garnets that plot outside their group's field as outlined.

Subfield Ia indicates the field within which the majority of garnets of nodules from Schaffer-Ferris-Aultman kimberlites plot.

Subfield Ib indicates the field within which the majority of garnets of nodules from Iron Mountain District kimberlites plot.

Subfield Ic indicates the region within which most garnets from nodules from Sloan-Nix-Moen kimberlites plot.

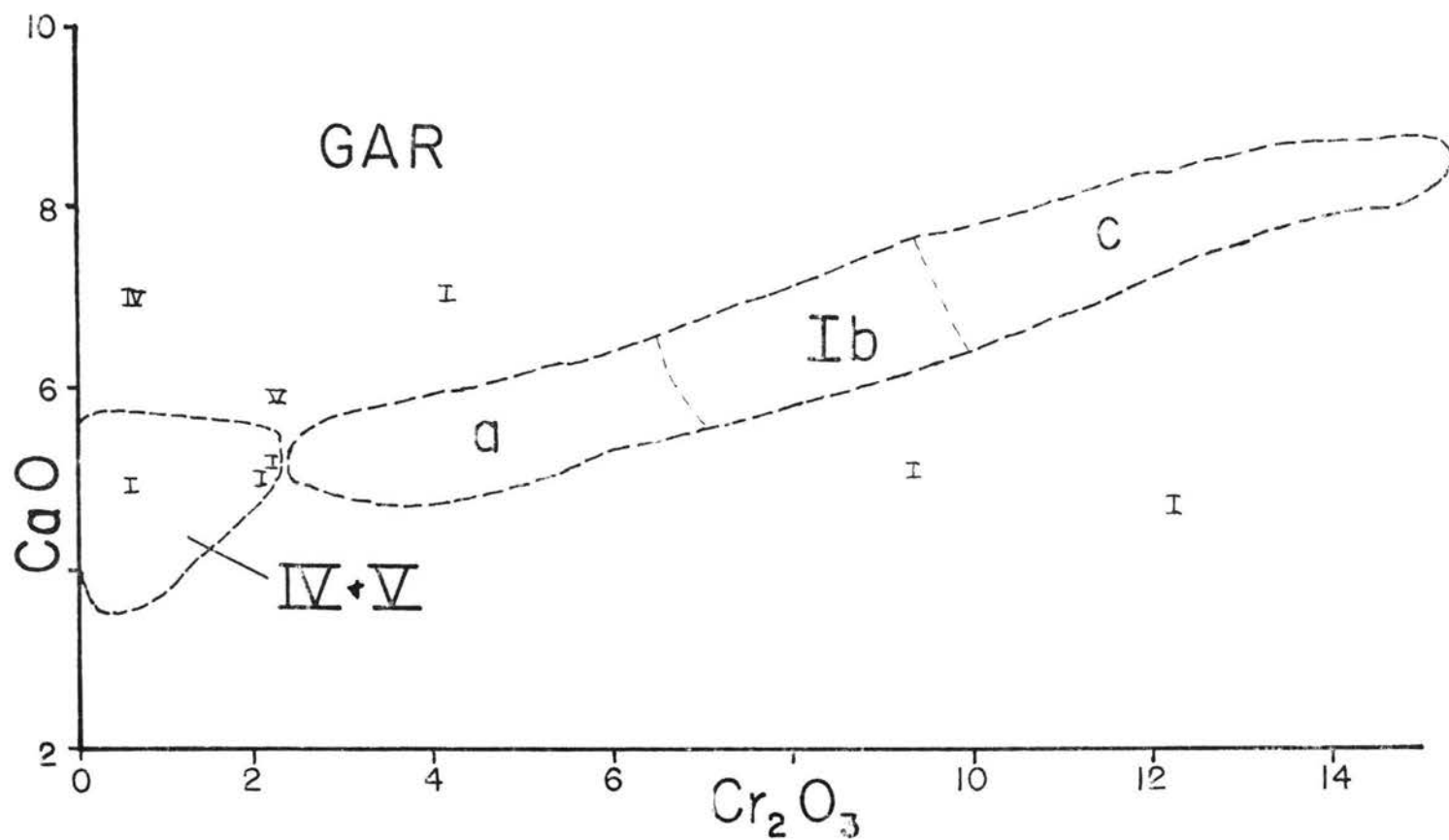


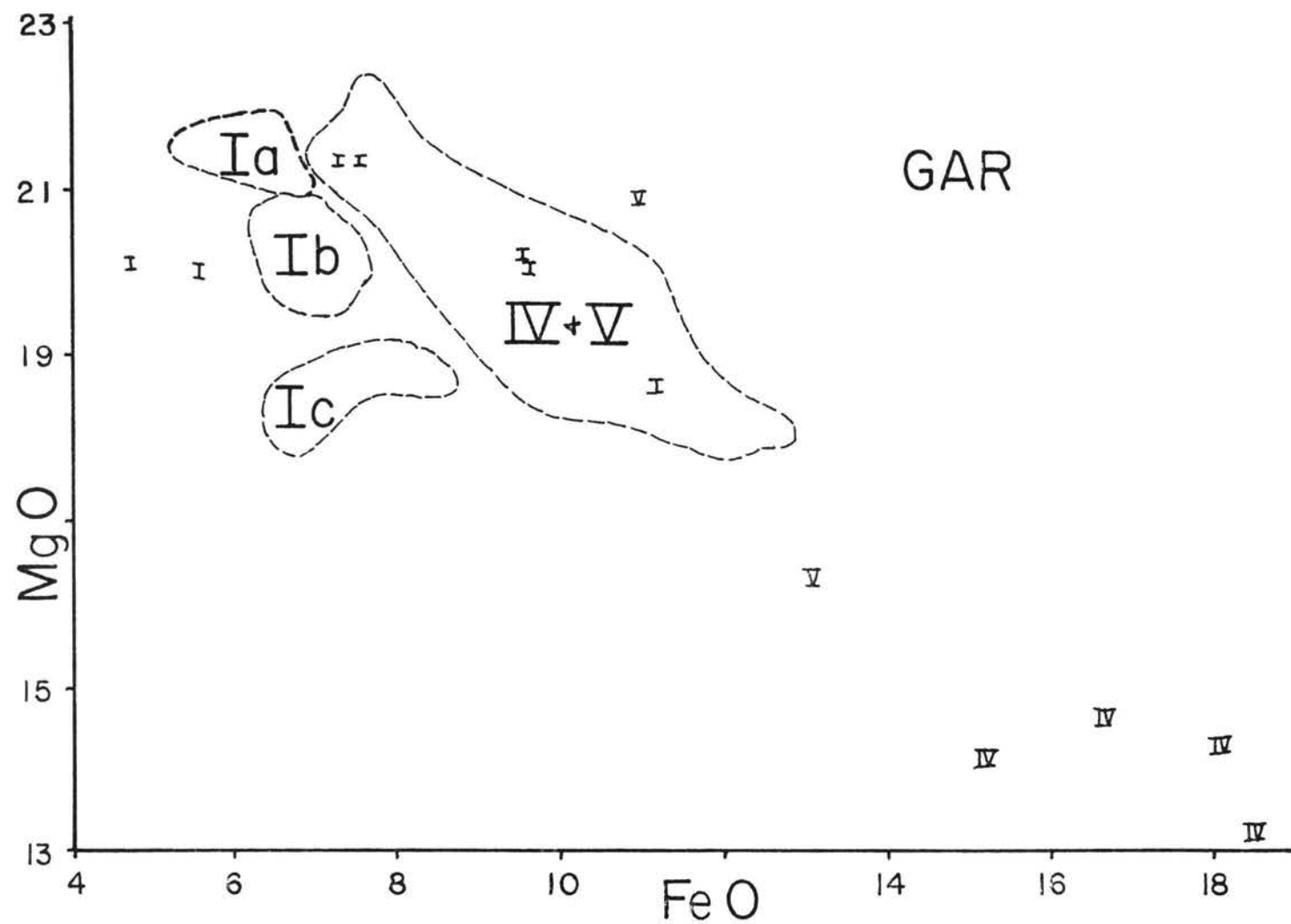
Figure 27. MgO versus FeO in garnets.

Fields designated by dashed lines indicate the regions where the majority of garnets from each group plot. Large numerals label each group's field. Small numerals indicate garnets that plot outside their group's field as outlined.

Subfield Ia indicates the field within which the majority of garnets of nodules from Schaffer-Ferris-Aultman kimberlites plot.

Subfield Ib indicates the field within which the majority of garnets of nodules from Iron Mountain District kimberlites plot.

Subfield Ic indicates the region within which most garnets from nodules from Sloan-Nix-Moen kimberlites plot.



most of which have transitional-porphyroclastic textures, generally contain the least MgO. Each of these groups of garnets has similar FeO content. There is some overlap of Group I and Group IV and V fields in the low FeO-high MgO region and garnets from Group I ilmenite-bearing xenoliths SH3-L12, SH3-L17, and SH3-L22 plot within the Group IV + V field due to their relatively high FeO content. Garnets of Groups IV and V cannot be clearly separated on the basis of MgO and FeO content although the majority of garnets from Group IV contain greater than 21.0 percent MgO and less than 8.5 percent FeO whereas the majority of garnets in Group V contain less than 20.0 percent MgO and greater than 8.5 percent FeO by weight. Garnets from several Group IV xenoliths, however, contain greater than 10 percent FeO by weight and garnets of Group V ilmenite-bearing xenolith SD2-L40 have greater FeO (13.05 percent) than other Group V garnets. In garnets of Groups IV and V, MgO content generally decrease as FeO content increases. This relationship is not exhibited by garnets of Group I.

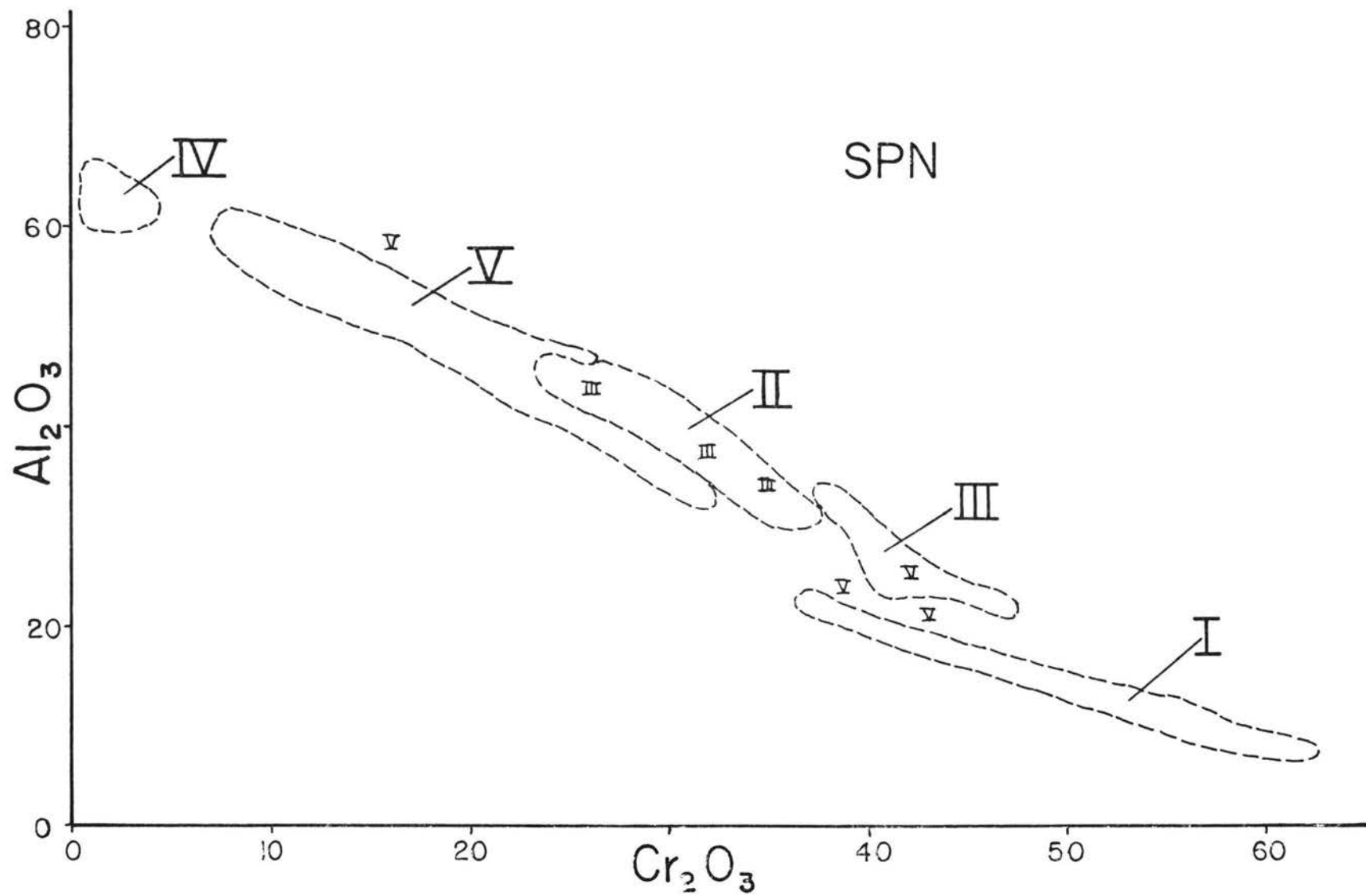
Spinel

Of all Colorado-Wyoming spinel group minerals, chromites of Group I xenoliths are generally richest in Cr_2O_3 and poorest in Al_2O_3 (Fig. 28, Plate 14, Table 3). These chromites appear to be chemically gradational with red-brown spinels of Groups II, III, and V. Spinel from Iron Mountain spinel peridotites (Group III) overlap in Cr_2O_3 and Al_2O_3 contents with those of Sloan-Nix harzburgites (Group II), but Iron Mountain spinels generally contain the lowest Al_2O_3 and the most Cr_2O_3 (Table 3) of spinels (*sensu stricto*) from the three groups of pipes. Coarse, green spinel (surrounded by garnet and associated with

Figure 28. Al_2O_3 versus Cr_2O_3 in spinel group minerals.

Fields designated by dashed outlines indicate the regions where the majority of spinels from each group plot. Large numerals label each group's field. Small numerals indicate spinels that plot outside their group's field as outlined.

The dunites of Group IV contain no spinel.



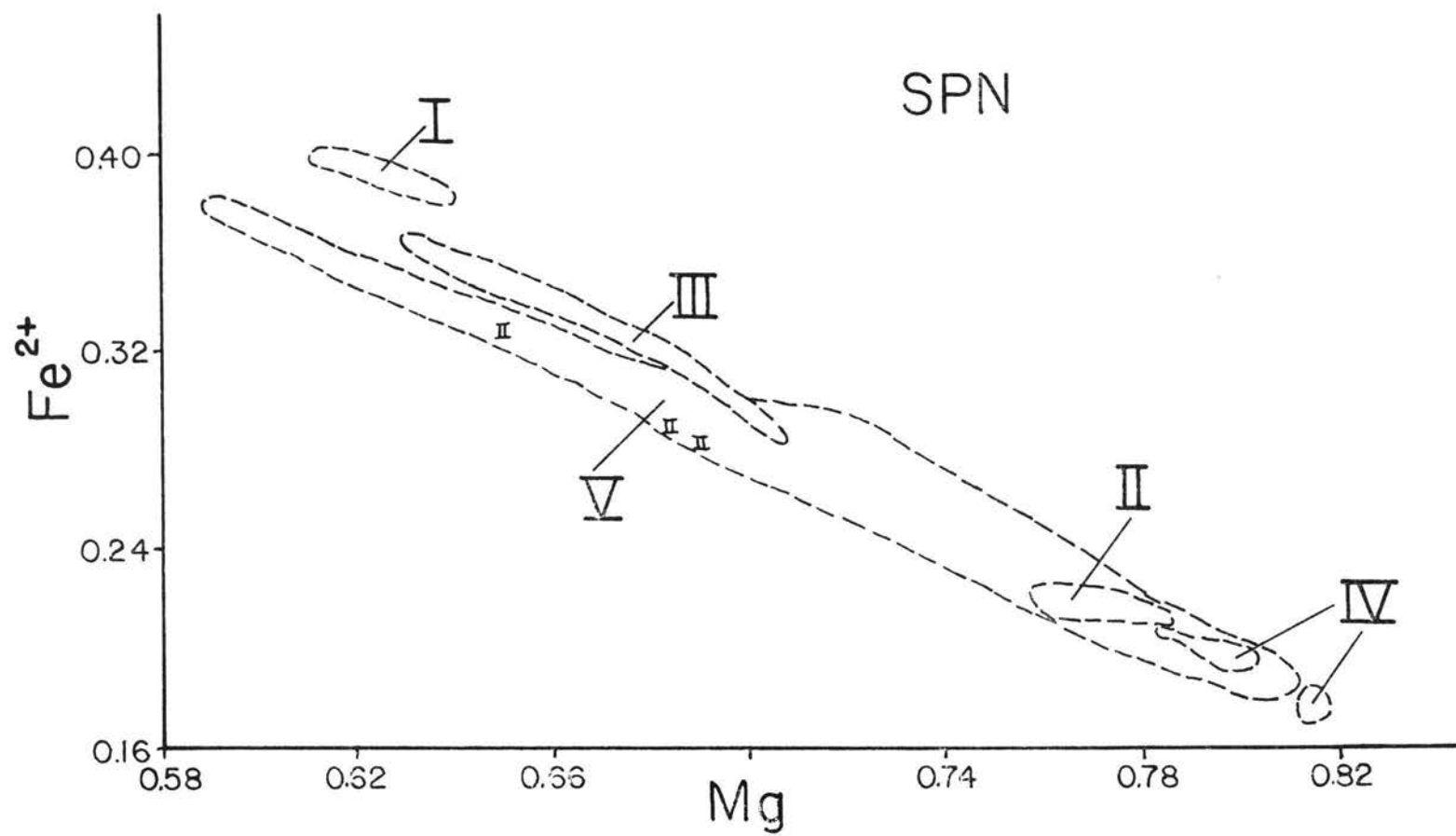
garnet exsolved from pyroxenes) of Group IV invariably contains less than 5.0 weight percent Cr_2O_3 and Al_2O_3 content is restricted to 60-70 percent. Red-brown spinel surrounded by garnet (Group V) can be found through nearly the full range of Cr_2O_3 - Al_2O_3 contents and spinel within a single xenolith of this type can be quite variable chemically as shown by analyses on two different grains from garnet + spinel xenolith SD2-L39 (Plate 14). Red-brown spinels from the three Group V olivine- and garnet-free Sloan Group xenoliths (SD2-L164, SD2-W8, NX4-C10) are quite low in Cr_2O_3 (less than 12.0 percent) and are almost as high in Al_2O_3 as are the Group IV green spinels. Spinel occurring without garnet in other xenoliths of the Websterite Group (chiefly spinel lherzolites) are intermediate in Cr_2O_3 and Al_2O_3 content with those from the spinel peridotites of Sloan-Nix and Iron Mountain (Groups II and III respectively) and the green spinels of Group IV.

A linear trend is created by a plot of Mg^{2+} versus Fe^{2+} in spinel group minerals from Colorado-Wyoming xenoliths (Fig. 29, Plate 15). Chromites of Group I xenoliths generally contain low Mg^{2+} and high Fe^{2+} , however, the Group I field is determined by only two points. Spinel of Group II xenoliths are quite distinct from those of Group III; the former contain generally less Fe^{2+} and more Mg^{2+} than the latter. However, spinels from a few Group II xenoliths fall within the Mg^{2+} - Fe^{2+} range of spinels of Group III. Green spinels from garnet + spinel xenoliths of Group IV contain the least Fe^{2+} and are the richest in Mg^{2+} with the exception of the spinel of one xenolith of this group (SD2-W10) which is considerably more Fe-rich. Spinel from garnet + brown spinel xenoliths of Group V contain the

Figure 29. Fe^{2+} versus Mg in spinel group minerals.

Fields designated by dashed outlines indicate the regions where the majority of spinels from each group plot. Large numerals label each group's field. Small numerals indicate spinels that plot outside their group's field as outlined.

The dunites of Group IV contain no spinel.



complete range of Mg^{2+} contents and variability among spinels from a single xenolith is exhibited by analyses from two different grains of Group V xenolith SD2-L39 (Plate 14). The bulk of spinels from Group V xenoliths (chiefly Sloan-Nix spinel lherzolites) are similar in Fe^{2+} content to those of Group II.

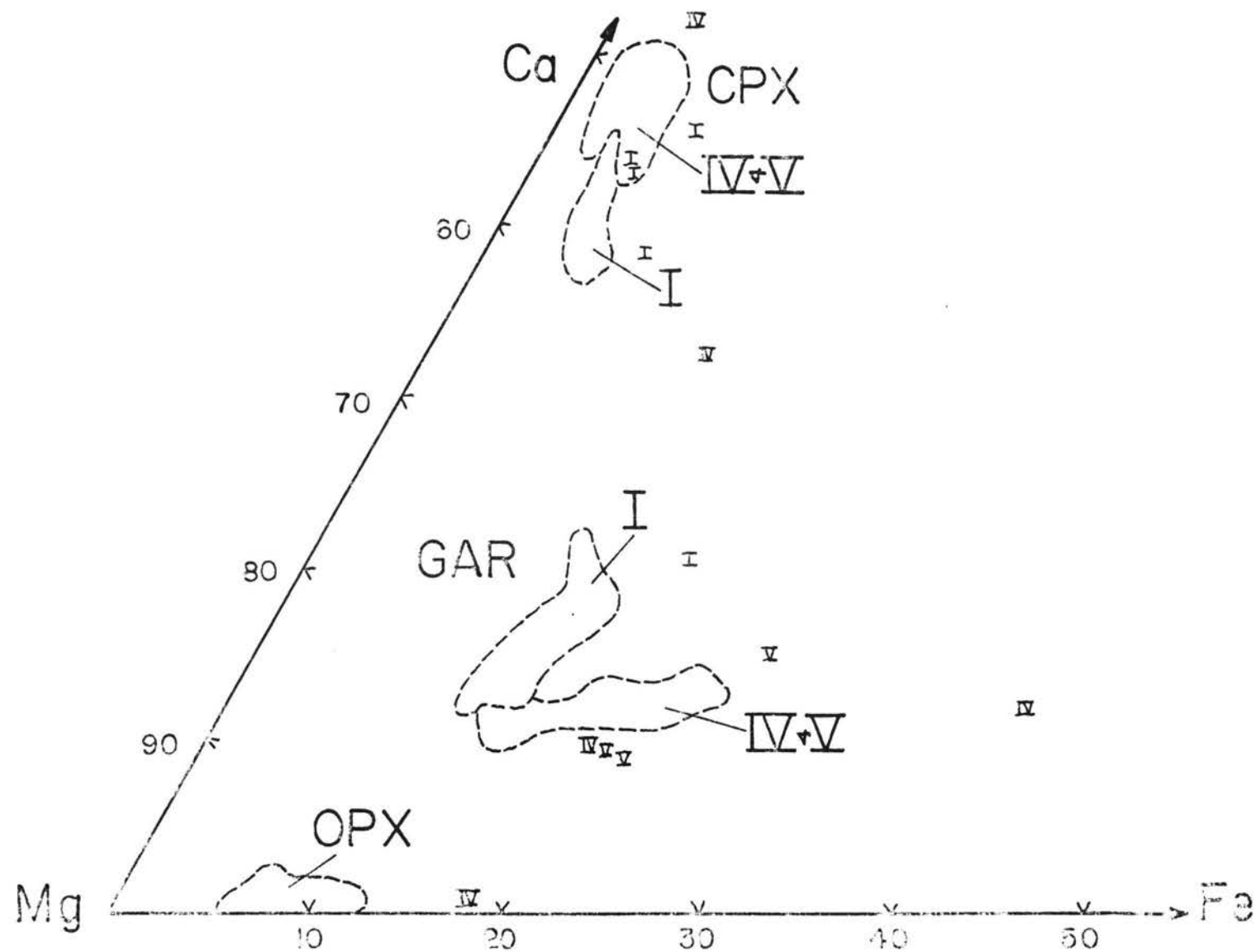
Summary

A Ca-Mg-Fe triangular diagram (Fig. 30, Plate 16) summarizes many of the chemical characteristics noted above. Clinopyroxenes maintain a relatively constant Fe content (generally between 2.5 and 5.0). Clinopyroxenes of Group I have generally higher Mg and lower Ca values than do clinopyroxenes of the other groups. The very high Fe Group IV garnet + green spinel xenolith SD2-W10 is clearly exhibited in this diagram. Garnets exhibit a horseshoe shaped field in the Ca-Mg-Fe diagram. Garnets of Group I with relatively constant Fe content and variable Mg and Ca form one limb of the garnet field whereas garnets of Groups IV and V with relatively constant Ca content and variable Mg and Fe form the lower limb. Once again the unusually high Fe content of garnets of SD2-W10 is notable. Orthopyroxenes contain very little Ca and only slightly variable Mg and Fe, hence they plot in a restricted field in Figure 30, although orthopyroxenes of Group I xenoliths tend to have slightly higher Ca values. High Fe in orthopyroxene of SD2-W10 is evident.

The first group used a simple method of
 selecting a group of 100 subjects from the
 population. The second group used a
 more sophisticated method of selecting
 subjects. The third group used a
 method of selecting subjects that was
 based on the results of a previous
 study. The fourth group used a
 method of selecting subjects that was
 based on the results of a previous
 study. The fifth group used a
 method of selecting subjects that was
 based on the results of a previous
 study.

Figure 30. Portion of a Ca-Mg-Fe diagram indicates general compositions of clinopyroxenes (CPX), garnets (GAR) and orthopyroxenes (OPX) in xenoliths from Colorado-Wyoming kimberlites.

Fields are designated by dashed lines. Large numerals label xenolith group fields, small numerals indicate minerals that plot outside their group's field as outlined.



Chemistry of Special Textural Features

Minerals exhibiting special textural features were analyzed in order to determine if chemical variations could be correlated with the textural varieties observed. Green spinel + garnet websterite SD2-L111 and brown spinel + garnet lherzolite SD2-L172 exhibit many of these special textural features such as exsolved garnet and pyroxene and garnet rims around spinel and these samples were chosen for detailed microprobe analysis. Sections of these samples with points representing microprobe spot analyses are shown in Figures 31 and 32. Corresponding analyses are presented in Tables 4 and 5. Samples exhibiting special textural features not observed in nodules SD2-L111 and SD2-L172, such as euhedral mineral constituents, were also analyzed and results are given in Tables 6 and 7.

Garnet

SD2-L111

Analyses were made of garnet exsolution lamellae, garnets rimming green spinel, and interstitial garnets not associated with spinel in SD2-L111 in order to determine if chemical variations exist between these garnets of different habits. A few tenths of a percent variation in oxide content across garnet rims around spinel is common but no distinct chemical gradients were noted in garnet rims (Analyses Ga, Gb, Gc, Gd, Table 4). Nor are garnet rims between spinel and orthopyroxene significantly different from garnet rims between spinel and clinopyroxene.

Figure 31. Sketch taken from a portion of the thin section through garnet + green spinel websterite nodule SD2-L111.

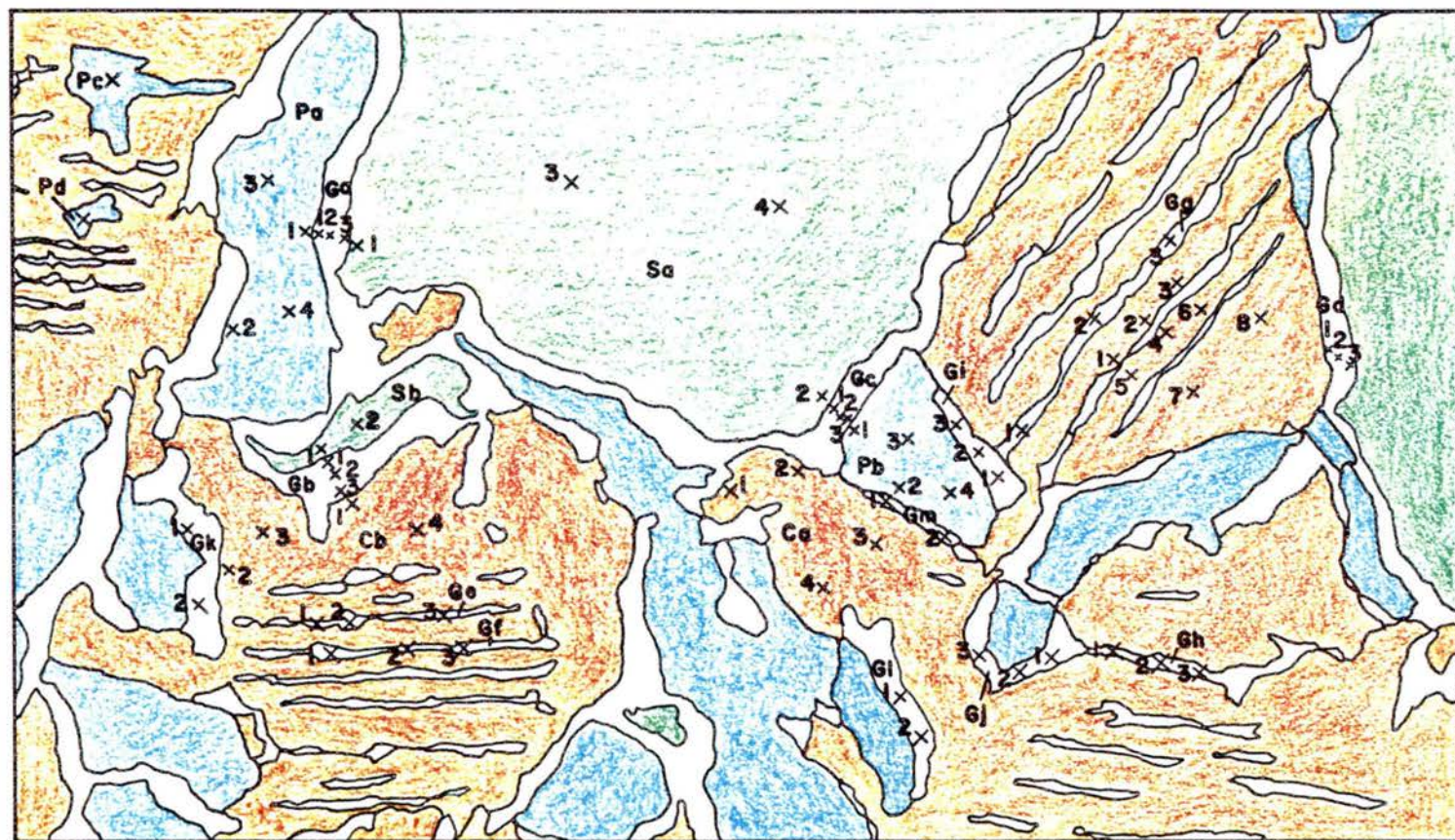
X's indicate locations of spot microprobe analyses.
Corresponding analyses are given in Table 4.

Green = Spinel (S)

White = Garnet (G)

Blue = Orthopyroxene (P)

Orange = Clinopyroxene (C)



SD2-LIII

5mm

Figure 32. Sketch of a portion of the thin section through garnet + brown spinel hercynite nodule SD2-L172.

X's indicate locations of spot microprobe analyses. Corresponding analyses are given in Table 5.

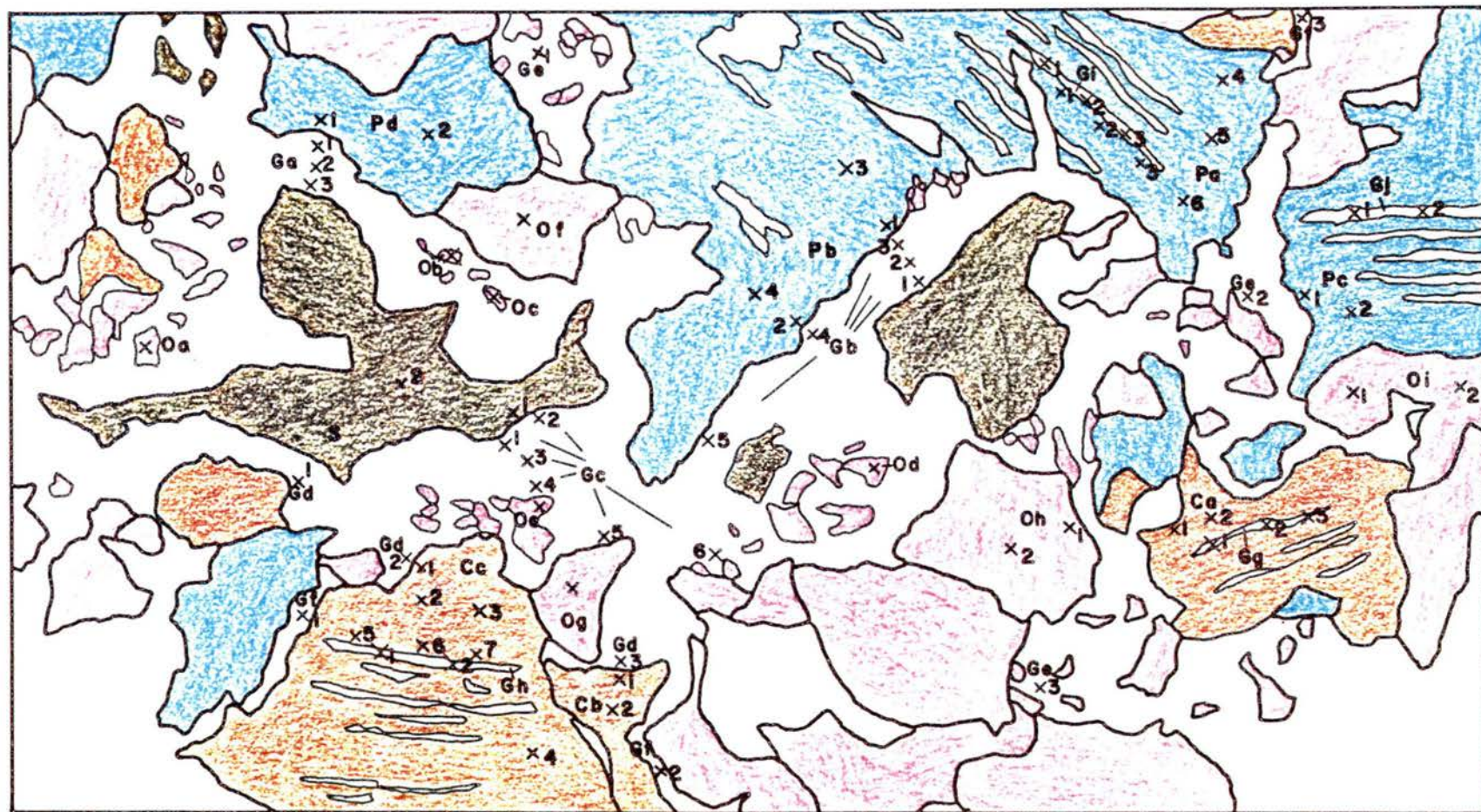
Pink = Olivine (O)

Blue = Orthopyroxene (P)

Orange = Clinopyroxene (C)

Brown = Spinel (S)

White = Garnet (G)



SD2-L172



Table 4. SD2-L111--garnet rims around spinel.

	Ga			Gb			Gc			Gd		
	1	2	3	1	2	3	1	2	3	1	2	3
SiO ₂	41.8	41.6	41.3	41.1	41.9	42.0	42.8	42.2	42.1	42.4	42.5	42.6
TiO ₂	0.08	0.1	0.13	0.15	0.15	0.06	0.07	0.05	0.04	0.11	0.0	0.08
Al ₂ O ₃	23.7	23.7	23.5	23.4	23.6	23.6	23.3	23.5	23.3	23.5	23.3	22.9
Cr ₂ O ₃	0.14	0.14	0.16	0.13	0.17	0.17	0.11	0.11	0.2	0.14	0.15	0.13
*FeO	12.3	12.1	12.01	11.9	11.8	11.5	11.8	11.6	11.9	12.0	11.7	11.6
MnO	0.5	0.55	0.44	0.54	0.43	0.42	0.53	0.49	0.56	0.66	0.52	0.52
NiO	0.0	0.0	0.0	0.5	0.0	0	0	0.0	0.0	0.0	0.0	0.0
MgO	17.6	18.1	18.1	17.8	18.1	18.4	17.9	18.2	17.8	17.8	18.2	18.0
CaO	5.7	5.4	5.4	5.6	5.6	5.4	5.5	5.4	5.6	5.4	5.5	5.4
Na ₂ O	0.0	0.0	0.0	0	0	0	0.02	0.01	0.06	0.0	0.02	0.05
K ₂ O	0.0	0.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	101.82	101.69	101.02	101.09	101.67	101.7	101.97	101.96	101.68	101.98	101.92	101.44
Si	1.485	1.478	1.478	1.482	1.487	1.489	1.51	1.497	1.496	1.501	1.503	1.513
Ti	0.002	0.003	0.003	0.004	0.004	0.001	0.002	0.001	0.001	0.003	0.0	0.002
Al	0.993	0.992	0.990	0.089	0.987	0.998	0.971	0.981	0.978	0.979	0.971	0.961
Cr	0.004	0.004	0.005	0.004	0.005	0.005	0.003	0.003	0.006	0.004	0.004	0.004
Fe ³⁺												
*Fe ²⁺	0.365	0.359	0.360	0.356	0.350	0.341	0.347	0.343	0.355	0.355	0.357	0.344
Mn	0.015	0.017	0.013	0.016	0.013	0.013	0.016	0.015	0.017	0.020	0.015	0.016
Ni	0.0	0.0	0.0	0.001	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Mg	0.933	0.962	0.964	0.950	0.956	0.972	0.944	0.964	0.943	0.939	0.962	0.955
Ca	0.216	0.208	0.209	0.215	0.211	0.206	0.208	0.206	0.213	0.203	0.207	0.206
Na	0.0	0.0	0.0	0	0	0	0.002	0.0	0.004	0.0	0.001	0.003
K	0.0	0.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygens	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
cations	4.013	4.023	4.022	4.017	4.013	4.014	4.003	4.010	4.013	4.004	4.01	4.004

*Total Fe as FeO

Table 4. (Continued). SD2-1111--garnet exsolution lamellae.

	Ge			Gf			Gg			Gh		
	1	2	3	1	2	3	1	2	3	1	2	3
SiO ₂	42.2	42.64	42.69	41.9	42.13	41.58	41.6	42.3	42.9	42.2	42.5	42.3
TiO ₂	0.11	0	0.07	0	0	0.01	0.09	0.05	0.02	0.06	0.07	0.05
Al ₂ O ₃	23.1	23.4	23.27	23.54	23.31	23.16	23.4	23.0	23.2	23.6	23.1	23.5
Cr ₂ O ₃	0.19	0.2	0.2	0.19	0.25	0.21	0.29	0.21	0.25	0.33	0.25	0.26
*FeO	11.3	11.31	11.4	11.23	11.39	11.49	11.9	11.3	11.4	11.6	11.3	11.4
MnO	0.46	0.47	0.51	0.45	0.47	0.50	0.43	0.53	0.49	0.43	0.51	0.55
NiO	0	0	0	0	0	0.00	0.04	0.0	0.0	0.0	0.0	0.0
MgO	18.1	18.45	18.08	18.42	18.51	17.94	18.0	18.0	17.9	18.1	17.8	18.1
CaO	5.5	5.34	5.5	5.43	5.24	5.49	5.5	5.3	5.3	5.3	5.7	5.8
Na ₂ O	0.06	0.04	0.02	0.08	0.02	0.02	0.0	0.02	0.06	0.0	0.0	0.0
K ₂ O	0	0	0	0.02	0	0	0.0	0.0	0.0	0.0	0.01	0.02
Total	101.02	101.85	101.74	101.26	101.32	100.4	100.98	100.77	101.45	101.6	101.17	101.92
Si	1.504	1.505	1.509	1.489	1.496	1.493	1.483	1.511	1.519	1.494	1.512	1.496
Ti	0.003	0	0.002	0	0	0	0.003	0.001	0.0	0.002	0.002	0.001
Al	0.969	0.974	0.970	0.987	0.976	0.981	0.985	0.968	0.967	0.987	0.967	0.978
Cr	0.005	0.006	0.006	0.004	0.007	0.006	0.008	0.006	0.007	0.009	0.007	0.007
Fe ³⁺												
Fe ²⁺	0.336	0.334	0.337	0.334	0.338	0.345	0.355	0.338	0.338	0.346	0.335	0.337
Mn	0.014	0.014	0.015	0.013	0.014	0.015	0.013	0.016	0.015	0.013	0.015	0.016
Ni	0	0	0	0	0	0	0.001	0.0	0.0	0.0	0.0	0.0
Mg	0.963	0.971	0.953	0.976	0.980	0.961	0.959	0.948	0.944	0.955	0.945	0.955
Ca	0.21	0.202	0.209	0.207	0.199	0.211	0.211	0.203	0.200	0.201	0.216	0.218
Na	0.004	0.002	0.001	0.005	0.001	0.001	0.0	0.002	0.004	0.0	0.0	0.0
K	0	0	0	0.001	0	0	0.0	0.0	0.0	0.0	0.0	0.001
Oxygens	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Cations	4.008	4.008	4.002	4.017	4.011	4.013	4.018	4.003	3.994	4.007	3.999	4.009

* Total Fe as FeO

Table 4. (Continued). SD2-L111--orthopyroxene.

	Pa				Pb				Pc	Pd
	1	2	3	4	1	2	3	4		
SiO ₂	56.33	55.97	55.9	55.93	56.12	55.71	57.1	55.73	55.03	55.2
TiO ₂	0.09	0.04	0.10	0.16	0.09	0.12	0.07	0.06	0	0
Al ₂ O ₃	1.39	2.13	2.47	2.52	1.53	2.12	2.09	2.11	3.12	2.78
Cr ₂ O ₃	0.04	0.03	0.08	0.08	0	0	0.02	0.01	0	0.06
*FeO	6.77	6.74	6.77	6.91	6.59	6.83	6.85	6.96	7.63	7.22
MnO	0.16	0.15	0.13	0.19	0.14	0.09	0.21	0.17	0.10	0.11
NiO	0.06	0	0.13	0.14	0.02	0.15	0.12	0.04	0.14	0.09
MgO	33.92	33.61	33.10	33.44	34.17	33.72	33.85	33.74	33.39	33.35
CaO	0.17	0.23	0.21	0.23	0.19	0.23	0.20	0.28	0.19	0.24
Na ₂ O	0.02	0	0	0	0	0.05	0.04	0	0.05	0.04
K ₂ O	0	0	0	0	0	0	0	0	0	0.01
Total	98.95	98.9	98.89	99.6	98.85	99.02	100.55	99.1	99.65	99.1
Si	1.966	1.953	1.951	1.942	1.959	1.945	1.96	1.945	1.917	1.93
Ti	0.002	0.001	0.003	0.004	0.002	0.003	0.002	0.002	0	0
Al	0.057	0.088	0.102	0.103	0.063	0.087	0.084	0.087	0.128	0.115
Cr	0.001	0.001	0.002	0.002	0	0	0.001	0	0	0.002
*Fe ²⁺	0.198	0.197	0.098	0.201	0.192	0.200	0.197	0.203	0.222	0.211
Mn	0.005	0.004	0.004	0.006	0.004	0.003	0.006	0.005	0.003	0.003
Ni	0.002	0	0.004	0.004	0	0.004	0.003	0.001	0.004	0.003
Mg	1.765	1.749	1.723	1.731	1.779	1.716	1.733	1.750	1.735	1.739
Ca	0.006	0.008	0.008	0.009	0.007	0.009	0.007	0.011	0.007	0.009
Na	0.001	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0
Oxygens	6	6	6	6	6	6	6	6	5	6
Cations	4.003	4.001	3.995	4.002	4.006	4.010	3.995	4.010	4.019	4.016

*Total Fe as FeO

Table 4. (Continued). SD2-L111--clinopyroxene.

	Ca				Cb			
	1	2	3	4	1	2	3	4
SiO ₂	52.96	53.44	50.75	50.84	52.7	52.08	50.84	50.42
TiO ₂	0.46	0.32	0.78	0.80	0.62	0.65	0.63	0.54
Al ₂ O ₃	2.85	2.96	6.76	7.30	4.42	4.23	7.11	7.15
Cr ₂ O ₃	0.15	0.15	0.22	0.25	0.21	0.13	0.19	0.24
*FeO	2.25	2.33	3.08	2.87	2.32	2.49	3.05	2.78
MnO	0.10	0.12	0.11	0.07	0.12	0.07	0.08	0.14
NiO	0	0	0	0.03	0	0.08	0	0
MgO	16.37	16.34	14.51	14.19	15.68	15.93	14.32	14.38
CaO	23.47	23.54	22.26	22.21	22.62	22.66	22.04	21.96
Na ₂ O	0.91	1.08	1.47	1.50	1.17	1.14	1.58	1.62
K ₂ O	0	0.01	0	0	0	0	0.01	0
Total	99.52	100.29	99.94	100.06	99.86	99.46	99.85	99.23
Si	1.934	1.938	1.851	1.849	1.914	1.904	1.853	1.849
Ti	0.013	0.009	0.021	0.022	0.017	0.018	0.017	0.015
Al	0.123	0.126	0.291	0.313	0.189	0.182	0.306	0.309
Cr	0.004	0.004	0.006	0.007	0.006	0.004	0.005	0.007
*Fe ²⁺	0.069	0.071	0.094	0.087	0.071	0.076	0.093	0.085
Mn	0.003	0.004	0.004	0.002	0.004	0.002	0.002	0.004
Ni	0	0	0	0.001	0	0.002	0	0
Mg	0.892	0.884	0.789	0.769	0.849	0.868	0.779	0.786
Ca	0.919	0.915	0.871	0.866	0.881	0.888	0.862	0.863
Na	0.065	0.076	0.104	0.106	0.083	0.081	0.112	0.116
K	0	0	0	0	0	0	0	0
Oxygens	6	6	6	6	6	6	6	6
Cations	4.022	4.027	4.031	4.022	4.014	4.025	4.029	4.034

*Total Fe as FeO

Table 4. (Continued). SD2-L111--clinopyroxene.

	Cc							
	1	2	3	4	5	6	7	8
SiO ₂	51.7	52.82	52.61	52.71	50.98	50.6	50.21	51.26
TiO ₂	0.34	0.64	0.62	0.46	0.73	0.65	0.69	0.75
Al ₂ O ₃	4.66	4.47	4.78	5.29	7.06	7.67	8.23	6.74
Cr ₂ O ₃	0.17	0.19	0.21	0.21	0.24	0.25	0.24	0.25
*FeO	2.80	2.37	2.47	2.70	2.85	2.92	2.76	2.62
MnO	0.09	0.12	0.08	0.11	0.08	0.02	0.08	0.08
NiO	0	0	0.02	0.06	0.05	0	0	0
MgO	15.65	15.91	15.34	15.29	14.72	14.36	13.68	14.21
CaO	22.55	23.19	23.02	22.41	22.08	21.92	21.95	22.37
Na ₂ O	1.20	1.26	1.33	1.33	1.42	1.58	1.91	1.69
K ₂ O	0.09	0	0.01	0	0	0	0.01	0
Total	99.25	100.97	100.49	100.57	100.21	99.97	99.76	99.97
Si	1.897	1.902	1.903	1.902	1.85	1.841	1.832	1.865
Ti	0.009	0.017	0.017	0.013	0.020	0.018	0.109	0.021
Al	0.202	0.190	0.204	0.225	0.302	0.329	0.354	0.289
Cr	0.005	0.006	0.005	0.006	0.007	0.007	0.007	0.007
Fe ²⁺	0.086	0.071	0.075	0.082	0.087	0.089	0.084	0.080
Mn	0.003	0.004	0.003	0.003	0.002	0.001	0.003	0.002
Ni	0	0	0	0.002	0.002	0	0	0
Mg	0.856	0.854	0.827	0.823	0.797	0.779	0.744	0.771
Ca	0.887	0.895	0.893	0.967	0.859	0.855	0.848	0.872
Na	0.085	0.088	0.094	0.093	0.010	0.111	0.135	0.119
K	0.004	0	0	0	0	0	0	0
Oxygens	6	6	6	6	6	6	6	6
Cations	4.034	4.027	4.021	4.016	4.026	4.030	4.036	4.026

*Total Fe as FeO

Table 4. (Continued). SD2-L111--interstitial garnets.

	Gi			Gj			Gk		Gl		Gm	
	1	2	3	1	2	3	1	2	1	2	1	2
SiO ₂	41.3	41.9	42.2	42.0	42.5	42.2	41.9	42.0	41.9	41.7	41.9	41.6
TiO ₂	0.18	0.06	0.04	0.03	0.03	0.09	0	0	0.11	0.06	0	0
Al ₂ O ₃	23.6	23.2	23.2	23.0	23.2	23.5	23.2	23.4	22.9	23.1	23.2	23.1
Cr ₂ O ₃	0.32	0.21	0.23	0.29	0.25	0.33	0.29	0.25	0.28	0.29	0.26	0.28
*FeO	12.3	11.7	11.9	11.6	11.4	11.8	11.5	11.3	11.7	11.4	11.5	11.7
MnO	0.45	0.51	0.50	0.46	0.56	0.37	0.47	0.51	0.59	0.50	0.46	0.42
NiO	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0.01
MgO	18.0	17.9	17.9	17.8	18.4	18.1	17.9	18.2	17.6	17.9	17.9	17.9
CaO	5.4	5.4	5.4	5.6	5.4	5.6	5.5	5.4	5.7	5.6	5.5	5.4
Na ₂ O	0.0	0.03	0.04	0.0	0.07	0.0	0	0.03	0.06	0.09	0.07	0.05
K ₂ O	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
Total	101.54	100.92	101.6	100.76	101.8	102.05	100.69	101.03	100.91	100.65	100.85	100.49
Si	1.472	1.498	1.499	1.503	1.503	1.493	1.497	1.496	1.501	1.492	1.500	1.494
Ti	0.005	0.002	0.001	0.001	0.001	0.002	0	0	0.003	0.002	0	0
Al	0.991	0.976	0.974	0.971	0.968	0.980	0.979	0.983	0.966	0.978	0.978	0.978
Cr	0.009	0.006	0.006	0.008	0.007	0.009	0.008	0.007	0.008	0.008	0.007	0.008
*Fe ²⁺	0.367	0.349	0.355	0.347	0.338	0.348	0.343	0.337	0.349	0.342	0.343	0.352
Mn	0.013	0.015	0.014	0.014	0.017	0.011	0.014	0.015	0.018	0.015	0.014	0.013
Ni	0.000	0.000	0.000	0.000	0.000	0.000	0	0	0	0	0	0
Mg	0.959	0.956	0.951	0.950	0.969	0.953	0.956	0.965	0.941	0.959	0.952	0.957
Ca	0.206	0.206	0.207	0.213	0.204	0.214	0.210	0.205	0.220	0.213	0.212	0.209
Na	0.000	0.002	0.002	0.000	0.005	0.000	0	0.002	0.004	0.006	0.005	0.003
K	0.000	0.000	0.0	0.000	0.000	0.000	0	0	0	0	0	0
Oxygens	6.000	6.000	6.000	6.000	6.000	6.000	6	6	6	6	6	6
Cations	4.002	4.010	4.009	4.007	4.012	4.010	4.007	4.010	4.010	4.015	4.011	4.014

*Total Fe as FeO

Table 4. (Continued). SD2-L111--spinel.

	Sa				Sb	
	1	2	3	4	1	2
SiO ₂	0.06	0.03	0.03	0.03	0.10	0.04
TiO ₂	0	0	0	0	0.02	0.03
Al ₂ O ₃	61.99	61.74	61.95	61.80	63.04	63.16
Cr ₂ O ₃	4.12	3.94	3.94	4.01	3.98	4.09
Fe ₂ O ₃	4.38	3.84	NA	4.07	3.27	3.34
FeO	8.84	9.33	12.92	9.06	10.27	9.95
MnO	0.24	0.24	0.13	0.21	0.15	0.15
MiO	0.34	0.31	0.33	0.35	0.36	0.39
MgO	21.49	20.91	21.57	21.17	20.77	21.10
CaO	0	0.01	0	0	0.01	0
Na ₂ O	0	0	0	0	0.04	0.01
K ₂ O	0.01	0	0	0	0.01	0
Total	101.46	100.35	100.87	100.7	102.03	102.26
Si	0.001	0.001	0.001	0.001	0.003	0.001
Ti	0	0	0	0	0	0.001
Al	1.833	1.846	1.853	1.841	1.856	1.854
Cr	0.082	0.079	0.079	0.080	0.079	0.080
Fe ³⁺	0.083	0.073	NA	0.077	0.062	0.063
Fe ²⁺	0.185	0.198	0.274	0.192	0.215	0.207
Mn	0.005	0.005	0.003	0.210	0.003	0.003
Ni	0.007	0.006	0.010	0.350	0.007	0.008
Mg	0.804	0.791	0.816	21.17	0.773	0.783
Ca	0	0	0	0	0	0
Na	0	0	0	0	0.002	0
K	0	0	0	0	0	0
Oxygens	4	4	4	4	4	4
Cations	3.000	2.999	3.033	3.001	2.999	3.000

Table 5. SD2-L172--garnet rims around spinel.

	Ga			Gb				
	1	2	3	1	2	3	4	5
SiO ₂	41.3	41.7	42.0	41.8	41.9	41.8	41.7	41.3
TiO ₂	0.04	0.06	0.0	0.07	0.0	0.07	0.03	0.0
Al ₂ O ₃	23.8	23.7	23.4	23.7	23.2	23.4	23.2	22.9
Cr ₂ O ₃	0.65	0.62	0.65	0.63	0.68	0.69	0.66	0.74
*FeO	10.7	10.8	10.7	11.1	11.0	10.9	10.7	10.9
MnO	0.59	0.59	0.56	0.50	0.67	0.56	0.68	0.52
NiO	0.04	0.06	0.04	0.05	0.0	0.02	0.0	0.08
MgO	19.9	20.2	20.1	19.8	19.59	19.6	19.7	19.6
CaO	4.0	4.0	4.03	4.04	4.18	4.2	4.2	4.3
Na ₂ O	0.0	0.0	0.04	0.06	0.07	0.08	0.10	0.07
K ₂ O	0.0	0.0	0.0	0.02	0.02	0.01	0.01	0.0
Total	101.08	101.77	101.60	101.74	101.38	101.35	100.87	100.61
Si	1.466	1.47	1.483	1.474	1.487	1.481	1.484	1.478
Ti	0.001	0.002	0.0	0.002	0.0	0.002	0.001	0.0
Al	0.997	0.986	0.975	0.985	0.970	0.976	0.972	0.968
Cr	0.018	0.017	0.018	0.017	0.019	0.019	0.019	0.021
*Fe	0.318	0.319	0.316	0.328	0.326	0.324	0.318	0.328
Mn	0.018	0.018	0.017	0.015	0.020	0.017	0.021	0.016
Ni	0.001	0.002	0.001	0.001	0.0	0.0	0.0	0.002
Mg	1.055	1.062	1.057	1.044	1.035	1.037	1.044	1.047
Ca	0.153	0.151	0.152	0.153	0.159	0.160	0.160	0.165
Na	0.0	0.0	0.003	0.004	0.005	0.005	0.007	0.005
K	0.0	0.0	0.0	0.001	0.001	0.0	0.0	0.0
Oxygens	6	6	6	6	6	6	6	6
Cations	4.027	4.027	4.022	4.024	4.022	4.021	4.026	4.030

*Total Fe as FeO

Table 5. (Continued). SD2-L172--Garnet rims around spinel.

	Gc						Gd		
	1	2	3	4	5	6	1	2	3
SiO ₂	41.8	41.4	41.4	40.8	41.0	40.9	41.5	41.4	41.2
TiO ₂	0.06	0.09	0.0	0.11	0.16	0.04	0.23	0.0	0.05
Al ₂ O ₃	23.3	23.5	22.5	23.3	23.3	23.3	23.2	22.9	23.4
Cr ₂ O ₃	0.72	0.64	0.8	0.66	0.89	0.77	0.66	0.62	0.63
*FeO	10.9	10.4	11.0	10.9	10.8	11.1	10.6	10.5	10.9
MnO	0.54	0.52	0.61	0.64	0.65	0.69	0.54	0.60	0.56
NiO	0.0	0.03	0.0	0.03	0.0	0.0	0.0	0.03	0.01
MgO	19.2	19.2	18.6	18.7	18.9	19.1	18.5	18.5	18.42
CaO	4.6	4.6	4.8	4.9	4.8	4.6	5.5	5.8	5.95
Na ₂ O	0.1	0.02	0.07	0.05	0.05	0.07	0.05	0.09	0.04
K ₂ O	0.0	0.0	0.0	0.0	0.01	0.0	0.02	0.0	0.01
Total	101.26	100.33	99.83	100.15	100.7	100.6	100.69	100.61	101.2
Si	1.484	1.479	1.495	1.47	1.469	1.467	1.482	1.483	1.471
Ti	0.002	0.002	0.0	0.003	0.004	0.001	0.006	0.0	0.001
Al	0.976	0.99	0.957	0.99	0.982	0.984	0.976	0.97	0.985
Cr	0.02	0.018	0.023	0.019	0.025	0.022	0.019	0.018	0.018
*Fe	0.324	0.311	0.331	0.328	0.325	0.333	0.318	0.317	0.324
Mn	0.016	0.016	0.019	0.019	0.020	0.021	0.016	0.018	0.017
Ni	0.0	0.001	0.0	0.001	0.0	0.0	0.0	0.001	0.0
Mg	1.017	1.022	1.003	1.004	1.011	1.021	0.986	0.990	0.980
Ca	0.174	0.175	0.186	0.188	0.186	0.178	0.209	0.224	0.228
Na	0.007	0.002	0.005	0.004	0.003	0.005	0.003	0.006	0.003
K	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0
Oxygens	6	6	6	6	6	6	6	6	6
Cations	4.02	4.016	4.019	4.026	4.025	4.032	4.016	4.027	4.027

*Total Fe as FeO

Table 5. (Continued). SD2-L172--interstitial garnets.

	Ge			Gf		
	1	2	3	1	2	3
SiO ₂	40.6	40.4	40.4	40.3	40.7	40.6
TiO ₂	0.1	0.04	0.07	0.09	0.0	0.13
Al ₂ O ₃	22.6	22.9	22.6	22.8	22.7	22.8
Cr ₂ O ₃	0.61	0.68	0.53	0.81	0.70	0.85
*FeO	10.7	10.7	10.8	11.2	11.0	10.9
MnO	0.56	0.61	0.6	0.65	0.64	0.60
NiO	0.0	0.01	0	0.0	0.02	0.0
MgO	18.4	18.6	18.3	18.6	18.2	18.6
CaO	4.7	4.9	4.8	4.7	4.8	4.7
Na ₂ O	0.03	0.11	0.06	0.07	0.05	0.09
K ₂ O	0.02	0	0.0	0.01	0.01	0.0
Total	98.47	99.04	98.22	99.29	98.93	99.33
Si	1.484	1.47	1.483	1.465	1.484	1.475
Ti	0.003	0.001	0.002	0.003	0.0	0.003
Al	0.975	0.983	0.976	0.979	0.975	0.975
Cr	0.018	0.020	0.015	0.023	0.020	0.024
*Fe ²⁺	0.328	0.326	0.332	0.343	0.336	0.331
Mn	0.017	0.019	0.019	0.020	0.020	0.018
Ni	0.0	0.0	0.0	0.0	0.0	0.0
Mg	1.005	1.012	0.999	1.012	0.992	1.006
Ca	0.186	0.193	0.190	0.183	0.190	0.184
Na	0.002	0.008	0.004	0.005	0.003	0.006
K	0.001	0.0	0.0	0.0	0.0	0.0
Oxygens	6	6	6	6	6	6
Cations	4.019	4.032	4.020	4.033	4.020	4.022

*Total Fe as FeO

Table 5. (Continued). SD2-L172--garnet exsolution lamellae.

	Gg			Gh		Gi			Gj	
	1	2	3	1	2	1	2	3	1	2
SiO ₂	41.23	41.40	41.31	41.48	41.25	40.86	40.31	40.44	40.10	40.40
TiO ₂	0.09	0	0.06	0.03	0	0.17	0.07	0.13	0.05	0.06
Al ₂ O ₃	23.22	22.76	21.23	23.43	23.61	22.57	22.51	22.52	22.37	22.38
Cr ₂ O ₃	0.68	0.77	0.55	0.70	0.76	0.88	0.90	0.88	1.11	1.10
*FeO	11.06	10.67	10.27	11.12	11.00	10.60	10.67	10.67	10.48	10.92
MnO	0.58	0.52	0.46	0.59	0.65	0.57	0.60	0.60	0.51	0.53
NiO	0	0.04	0.01	0.02	0.08	0	0.01	0	0.05	0
MgO	18.77	18.65	18.42	19.34	19.29	18.81	18.93	18.91	18.55	18.43
CaO	4.9	4.78	6.39	4.54	4.83	4.51	4.51	4.52	4.97	4.92
Na ₂ O	0.07	0.09	0.16	0.01	0.02	0.07	0.05	0.05	0.05	0.06
K ₂ O	0	0.01	0.06	0	0	0	0	0.01	0.01	0.01
Total	100.6	99.69	98.92	101.26	101.49	99.04	98.56	98.73	98.25	98.81
Si	1.476	1.493	1.508	1.474	1.465	1.483	1.473	1.475	1.472	1.476
Ti	0.002	0	0.002	0.001	0	0.005	0.002	0.003	0.002	0.002
Al	0.981	0.968	0.914	0.982	0.989	0.967	0.970	0.969	0.968	0.965
Cr	0.019	0.022	0.016	0.020	0.760	0.025	0.026	0.026	0.032	0.032
*Fe ²⁺	0.331	0.322	0.314	0.331	0.327	0.322	0.326	0.326	0.322	0.334
Mn	0.018	0.016	0.014	0.018	0.020	0.018	0.018	0.018	0.016	0.016
Ni	0	0.001	0	0.001	0.002	0	0	0	0.001	0
Mg	1.002	1.003	1.002	1.025	1.022	1.019	1.032	1.029	1.015	1.005
Ca	0.188	0.185	0.250	0.173	0.184	0.175	0.177	0.177	0.196	0.193
Na	0.005	0.007	0.011	0.001	0.002	0.005	0.004	0.003	0.003	0.004
K	0	0	0.003	0	0	0	0	0	0	0
Oxygens	6	6	6	6	6	6	6	6	6	6
Cations	4.022	4.017	4.034	4.026	4.032	4.019	4.028	4.026	4.027	4.027

*Total Fe as FeO

Table 5. (Continued). SD2-L172--orthopyroxene.

	Pa					
	1	2	3	4	5	6
SiO ₂	55.77	55.61	55.79	55.92	56.08	55.96
TiO ₂	0.04	0	0.06	0.05	0.06	0
Al ₂ O ₃	0.98	0.78	0.94	1.13	1.26	1.07
Cr ₂ O ₃	0.06	0.04	0.10	0.13	0.08	0.09
*FeO	6.16	6.12	6.00	6.08	6.42	6.09
MnO	0.14	0.10	0.11	0.18	0.15	0.05
NiO	0.11	0.06	0.11	0.10	0.07	0.11
MgO	35.44	35.06	35.47	35.78	35.35	35.53
CaO	0.22	0.17	0.18	0.21	0.19	0.17
Na ₂ O	0	0.04	0.05	0	0.01	0
K ₂ O	0.02	0.01	0.01	0.01	0.01	0.01
Total	98.94	97.99	98.82	99.59	99.68	99.08
Si	1.947	1.958	1.949	1.94	1.944	1.948
Ti	0.001	0	0.002	0.001	0.001	0
Al	0.040	0.032	0.039	0.046	0.052	0.044
Cr	0.002	0.001	0.003	0.003	0.002	0.003
*Fe ²⁺	0.180	0.180	0.175	0.177	0.186	0.177
Mn	0.004	0.003	0.003	0.005	0.004	0.002
Ni	0.003	0.002	0.003	0.003	0.002	0.003
Mg	1.845	1.841	1.848	1.851	1.828	1.845
Ca	0.008	0.006	0.007	0.008	0.007	0.006
Na	0	0.003	0.003	0	0	0
K	0.001	0.001	0.001	0	0	0
Oxygens	6	6	6	6	6	6
Cations	4.031	4.027	4.033	4.034	4.026	4.028

*Total Fe as FeO

Table 5. (Continued). SD2-L172--orthopyroxene.

	Pb				Pc		Pd	
	1	2	3	4	1	2	1	2
SiO ₂	56.6	55.9	56.4	56.2	56.1	55.6	55.6	56.2
TiO ₂	0.05	0.0	0.12	0.0	0.04	0.1	0.77	0.0
Al ₂ O ₃	0.74	0.91	1.20	1.20	1.40	1.08	0.97	1.40
Cr ₂ O ₃	0.01	0.03	0.03	0.07	0.05	0.12	0.07	0.11
*FeO	6.10	6.06	5.90	6.00	6.10	6.21	6.10	6.30
MnO	0.11	0.07	0.08	0.09	0.12	0.07	0.11	0.16
NiO	0.05	0.10	0.16	0.08	0.01	0.17	0.0	0.0
MgO	35.3	35.9	35.2	35.7	35.3	35.32	35.3	35.6
CaO	0.17	0.15	0.18	0.19	0.18	0.24	0.18	0.24
Na ₂ O	0.04	0.0	0.08	0.04	0.02	0.07	0.0	0.05
K ₂ O	0.0	0.02	0.0	0.0	0.01	0.01	0.02	0.01
Total	99.13	99.24	99.14	99.56	99.28	99.04	98.42	99.99
Si	1.966	1.946	1.957	1.946	1.948	1.942	1.949	1.941
Ti	0.001	0.0	0.003	0.0	0.001	0.003	0.002	0.0
Al	0.03	0.037	0.047	0.049	0.057	0.044	0.04	0.055
Cr	0.0	0.001	0.001	0.002	0.001	0.003	0.002	0.003
*Fe ²⁺	0.178	0.176	0.173	0.175	0.177	0.181	0.179	0.181
Mn	0.003	0.002	0.002	0.003	0.003	0.002	0.003	0.005
Ni	0.001	0.003	0.005	0.002	0.0	0.005	0.0	0.0
Mg	1.829	1.864	1.818	1.845	1.826	1.839	1.845	1.834
Ca	0.006	0.005	0.007	0.007	0.007	0.009	0.007	0.009
Na	0.003	0.0	0.006	0.002	0.002	0.005	0.0	0.003
K	0.0	0.001	0.0	0.0	0.0	0.001	0.001	0.0
Oxygens	6	6	6	6	6	6	6	6
Cations	4.017	4.035	4.019	4.031	4.022	4.034	4.028	4.031

*Total Fe as FeO

Table 5 (Continued). SD2-L172-clinopyroxene and spinel.

	Ca		Cb						Cc			S	
	1	2	1	2	1	2	3	4	5	6	7	1	2
SiO ₂	54.4	54.3	53.9	53.4	53.5	54.7	54.04	52.73	54.52	54.35	54.56	0.02	0
TiO ₂	0.38	0.39	0.66	0.49	0.54	0.58	0.69	0.60	0.31	0.46	0.42	0.18	0.24
Al ₂ O ₃	3.8	4.1	5.5	6.4	4.7	4.5	6.08	6.74	3.1	3.51	2.99	50.42	50.45
Cr ₂ O ₃	0.67	0.70	0.62	0.6	0.69	0.75	0.64	0.58	0.61	0.60	0.54	17.68	17.23
*FeO	2.4	2.5	2.4	2.2	2.3	2.3	2.29	2.33	2.25	2.24	2.12	14.68	15.15
MnO	0.03	0.07	0.09	0.13	0.03	0.05	0.05	0.02	0.01	0	0.02	0.51	0.5
NiO	0.13	0.1	0.18	0.07	0.12	0.02	0.02	0.12	0.1	0.11	0.17	0.35	0.38
MgO	15.6	15.4	15.0	14.3	14.9	15.1	14.23	14.03	16.23	15.83	16.49	18.98	18.75
CaO	21.5	21.4	21.0	20.7	21.8	21.3	20.74	20.69	22.19	21.79	22.39	0	0
Na ₂ O	21.2	21.2	2.32	2.7	2.2	2.2	2.99	3.1	2.01	2.02	1.93	0	0
K ₂ O	0.01	0.03	0.02	0.02	0.02	0.02	0	0.01	0.01	0.02	0.01	0.01	0.01
Total	101.21	101.21	101.64	101.03	100.88	101.60	101.77	100.95	101.34	100.93	100.64	102.83	102.71
Si	1.95	1.895	1.918	1.909	1.924	1.945	1.919	1.892	1.951	1.95	1.948	0.001	0
Ti	0.011	0.011	0.017	0.013	0.015	0.016	0.018	0.016	0.008	0.012	0.011	0.003	0.005
Al	0.158	0.17	0.232	0.268	0.197	0.19	0.255	0.285	0.131	0.149	0.126	1.552	1.556
Cr	0.019	0.02	0.017	0.017	0.015	0.021	0.018	0.016	0.017	0.017	0.015	0.365	0.357
*Fe ²⁺	0.071	0.073	0.07	0.067	0.07	0.068	0.068	0.07	0.067	0.067	0.063	0.321	0.332
Mn	0.001	0.001	0.003	0.004	0.001	0.001	0.002	0.001	0	0	0.001	0.011	0.011
Ni	0.044	0.003	0.005	0.003	0.004	0	0.001	0.003	0.003	0.003	0.005	0.007	0.008
Mg	0.833	0.8	0.793	0.762	0.803	0.802	0.754	0.751	0.867	0.847	0.878	0.739	0.732
Ca	0.827	0.801	0.803	0.793	0.84	0.814	0.79	0.796	0.851	0.838	0.857	0	0
Na	0.152	0.148	0.159	0.189	0.156	0.15	0.206	0.216	0.139	0.14	0.134	0	0
K	0.0	0.001	0.001	0.001	0.001	0.001	0	0.001	0.001	0.001	0	0	0
Oxygens	6	6	6	6	6	6	6	6	6	6	6	4	4
Cations	4.026	3.923	4.02	4.029	4.029	4.008	4.031	4.047	4.035	4.024	4.038	2.999	3.001

*Total Fe as FeO

Table 5. (Continued). SD2-L172--olivine.

	0a	0b	0c	0d	0e	0f	0g	0h		0i	
								1	2	1	2
SiO ₂	39.9	39.8	40.7	40.6	40.3	41.0	40.5	40.3	39.6	40.0	40.2
TiO ₂	0	0	0	0	0.02	0	0	0	0	0	0
Al ₂ O ₃	0	0	0	0	0	0	0	0	0	0	0
Cr ₂ O ₃	0	0	0	0	0	0	0	0	0	0	0
*FeO	9.77	9.57	9.74	9.68	9.48	9.77	9.78	9.77	9.9	9.71	9.73
MnO	0.09	0.12	0.03	0.17	0.05	0.10	0	0.05	0.13	0.07	0.10
NiO	0.31	0.37	0.39	0.38	0.39	0.45	0.38	0.46	0.42	0.46	0.28
MgO	50.49	49.87	50.27	50.53	50.35	50.3	50.35	50.67	50.18	50.09	50.23
CaO	0.02	0.03	0	0	0.01	0	0	0.02	0	0.01	0.02
Na ₂ O	0.08	0	0.02	0	0.03	0.02	0	0.04	0.03	0.07	0.05
K ₂ O	0	0.01	0	0	0	0	0	0	0	0.01	0.01
Total	100.68	99.8	101.12	101.41	100.62	101.6	101.04	101.32	100.31	100.44	100.57
Si	0.975	0.981	0.987	0.984	0.983	0.989	0.985	0.978	0.973	0.98	0.981
Ti	0	0	0	0	0.001	0	0	0	0	0	0
Al	0	0	0	0	0	0	0	0	0	0	0
Cr	0	0	0	0	0	0	0	0	0	0	0
Fe ²⁺	0.2	0.197	0.198	0.196	0.193	0.197	0.199	0.199	0.203	0.199	0.199
Mn	0.002	0.003	0.001	0.003	0.001	0.002	0	0.001	0.003	0.001	0.002
Ni	0.006	0.007	0.007	0.007	0.007	0.009	0.007	0.009	0.009	0.009	0.005
Mg	1.839	1.831	1.819	1.825	1.831	1.812	1.825	1.833	1.837	1.829	1.83
Ca	0.001	0.001	0	0	0	0	0	0.001	0	0	0.001
Na	0.004	0	0.001	0	0.001	0.001	0	0.002	0.001	0.003	0.002
K	0	0.001	0	0	0	0	0	0	0	0	0
Oxygens	4	4	4	4	4	4	4	4	4	4	4
Cations	3.027	3.02	3.013	3.015	3.018	3.011	3.015	3.023	3.027	3.021	3.019

*Total Fe as FeO

Table 6. Chemistry of other special textural features.

	NX2-W1		SD2-L164			SD2-W10			IM42-L58			
	Pa		Pb			Pc			G			
	1*	2**	1	2	3†	1	2	3	1	2	3	4
SiO ₂	56.25	57.16	51.78	51.16	51.79	52.81	52.5	53.53	41.08	40.13	41.03	40.83
TiO ₂	0.20	0.16	0.06	0.06	0.03	0.23	0.09	0.15	0.100	0.11	0.11	0.15
Al ₂ O ₃	1.94	1.51	7.56	7.33	6.87	3.81	4.28	3.09	17.09	16.77	17.12	17.04
Cr ₂ O ₃	0.37	0.24	0.76	0.53	0.54	0.00	0.0	0.00	8.00	7.99	8.00	8.16
FeO	5.59	6.42	7.8	8.85	8.31	12.27	12.8	11.73	6.51	6.34	6.29	6.34
MnO	0.16	0.12	0.16	0.11	0.16	0.23	0.25	0.18	0.32	0.32	0.30	0.32
NiO	NA	0.04	0.03	0.02	0.08	0.0	0.0	0.00	0.03	0.02	0.02	0.03
MgO	34.69	35.45	30.45	30.66	30.7	29.58	29.24	30.24	19.94	19.98	20.71	20.46
CaO	0.50	0.48	0.44	0.23	0.48	0.3	0.34	0.28	6.92	6.73	6.11	6.41
Na ₂ O	0.12	0.06	0	0.05	0.04	0.02	0.03	0.04	0.00	0.01	0.00	0.00
K ₂ O	0.0	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Total	99.82	101.65	99.37	99.0	99.0	99.26	99.53	99.24	99.99	98.4	99.74	99.74
Si	1.941	1.943	1.809	1.811	1.828	1.89	1.879	1.910	2.991	2.969	2.987	2.974
Ti	0.005	0.004	0.001	0.001	0.001	0.006	0.002	0.004	0.004	0.004	0.004	0.006
Al	0.079	0.061	0.311	0.306	0.285	0.161	0.181	0.130	1.465	1.461	1.466	1.462
Cr	0.010	0.007	0.021	0.015	0.015	0.00	0.00	0.00	0.459	0.467	0.458	0.468
Fe ²⁺	0.161	0.183	0.228	0.262	0.245	0.368	0.383	0.350	0.395	0.391	0.382	0.385
Mn	0.005	0.004	0.004	0.003	0.005	0.007	0.008	0.005	0.019	0.020	0.017	0.019
Ni	NA	0.001	0.008	0.0	0.003	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mg	1.786	1.797	1.59	1.619	1.616	1.579	1.561	1.609	2.162	2.202	2.245	2.221
Ca	0.018	0.018	0.016	0.008	0.019	0.012	0.013	0.011	0.538	0.532	0.476	0.500
Na	0.008	0.004	0.00	0.004	0.003	0.001	0.002	0.003	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oxygens	6	6	6	6	6	6	6	6	12	12	12	12
Cations	4.013	4.022	3.988	4.03	4.02	4.024	4.029	4.022	8.033	8.046	8.035	8.035

*Average of three spots

** Average of seven spots

†Average of three grains

Table 7. SD2-D19--olivine.

	0a			0b			0c		
	1	2	3	1	2	3	1	2	3
	(euhedral tablets)			(rounded neoblasts)			(coarse olivine)		
SiO ₂	39.3	39.52	39.77	40.12	39.73	39.84	40.14	39.45	39.98
TiO ₂	0	0	0	0	0	0.02	0.06	0	0.05
Al ₂ O ₃	0	0	0	0	0	0	0	0	0
Cr ₂ O ₃	0	0	0	0	0	0	0	0	0
FeO	13.07	12.86	13.39	13.17	12.61	13.17	13.00	13.00	13.19
MnO	0.15	0.08	0.15	0.13	0.13	0.13	0.08	0.09	0.09
NiO	0.22	0.14	0.1	0.2	0.11	0.14	0.06	0.15	0.18
MgO	47.51	47.46	47.21	47.45	47.43	47.04	46.95	47.52	47.61
CaO	0.06	0.06	0.04	0.06	0.08	0.06	0.06	0.05	0.06
Na ₂ O	0.01	0.02	0.01	0	0	0	0.02	0.02	0
K ₂ O	0	0	0	0	0	0	0	0	0
Total	100.32	100.14	100.67	101.13	100.09	100.4	100.37	100.28	101.16
Si	0.978	0.983	0.986	0.988	0.987	0.989	0.994	0.981	0.985
Ti	0	0	0	0	0	0	0.001	0	0.001
Al	0	0	0	0	0	0	0	0	0
Cr	0	0	0	0	0	0	0	0	0
Fe ²⁺	0.272	0.268	0.278	0.272	0.262	0.274	0.269	0.27	0.272
Mn	0.003	0.002	0.003	0.003	0.003	0.003	0.002	0.002	0.002
Ni	0.004	0.003	0.002	0.004	0.002	0.003	0.001	0.003	0.004
Mg	1.763	1.76	1.745	1.744	1.757	1.741	1.735	1.752	1.749
Ca	0.002	0.001	0.001	0.001	0.002	0.002	0.001	0.001	0.002
Na	0	0.001	0	0	0	0	0.001	0.001	0
K	0	0	0	0	0	0	0	0	0
Oxygens	4	4	4	4	4	4	4	4	4
Cations	3.002	3.018	3.015	3.012	3.013	3.012	3.004	3.02	3.015

Table 6. (Continued). SD2-H13--olivine.

	Od			Oe			Of		
	1	2	3	1	2	3	1	2	3
	(euhedral olivine tablets)			(rounded neoblasts)			(coarse olivine)		
SiO ₂	40.52	40.94	40.28	41.00	40.03	40.75	40.65	40.86	40.96
TiO ₂	0.07	0.05	0.04	0.07	0.14	0.14	0.14	0.7	0.04
Al ₂ O ₃	0	0	0	0	0	0	0	0	0
Cr ₂ O ₃	0	0.03	0	0	0.02	0	0.01	0	0
FeO	8.02	8.2	7.92	8.00	8.18	8.01	7.92	8.09	8.15
MnO	0.05	0.13	0.08	0.12	0.04	0.08	0.06	0.07	0.05
NiO	0.29	0.37	0.35	0.29	0.41	0.3	0.26	0.44	0.34
MgO	52.08	51.87	51.33	50.97	51.86	51.66	51.23	51.5	51.62
CaO	0.09	0.06	0.07	0.08	0.07	0.06	0.04	0.04	0.05
Na ₂ O	0.03	0.03	0.01	0.02	0.04	0.05	0.02	0.06	0.06
K ₂ O	0	0	0.01	0.01	0	0.01	0	0	0
Total	101.15	101.68	100.1	100.56	101.19	101.06	100.33	101.13	101.27
Si	0.977	0.982	0.981	0.992	0.976	0.983	0.986	0.985	0.986
Ti	0.001	0.001	0.001	0.001	0.002	0.003	0.002	0.001	0.001
Al	0	0	0	0	0	0	0	0	0
Cr	0	0.001	0	0	0	0	0	0	0
Fe ²⁺	0.162	0.165	0.161	0.162	0.165	0.162	0.161	0.163	0.164
Mn	0.001	0.003	0.002	0.002	0.001	0.002	0.001	0.002	0.001
Ni	0.006	0.007	0.007	0.006	0.008	0.006	0.005	0.008	0.007
Mg	1.872	1.856	1.864	1.84	1.866	1.858	1.854	1.852	1.853
Ca	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001
Na	0.002	0.001	0.001	0.001	0.002	0.002	0.001	0.003	0.003
K	0	0	0	0	0	0	0	0	0
Oxygens	4	4	4	4	4	4	4	4	4
Cations	3.023	3.018	3.019	3.006	3.022	3.018	3.011	3.015	3.016

Nearly as much variation is present within individual garnet exsolution lamellae as from lamella to lamella in the same or in different clinopyroxene grains (Analyses Ge, Gf, Gg, Gh; Table 4). Garnet exsolution lamellae contain less FeO than do garnet rims around spinel (average of 12 garnet rim analyses = 11.85 weight percent FeO, average of 12 garnet exsolution analyses = 11.45 percent). Average FeO content of interstitial garnets, that is, elongate garnets similar in appearance to garnet rims around spinel but occurring between pyroxenes, is 11.65 weight percent FeO (Analyses Gi, Gj, Gk, Gl, Gm; Table 4), intermediate between rims around spinel and exsolution lamellae. Garnet exsolution lamellae in clinopyroxene may contact interstitial garnets at the host pyroxene grain boundary. No chemical trends were noted within either the exsolution lamellae or the interstitial garnets (Gg, Gi, and Gh, Gj; Table 4) as the contact is approached. The only apparent difference between these two types of garnet is the slightly higher FeO content of interstitial garnets.

SD2-L172

No significant variations were noted across the garnet rims that form between brown spinel and orthopyroxene (Ga, Gb; Table 5) or olivine (Gc; Table 5) in the spinel + garnet lherzolite nodule SD2-L172. Garnets between spinel and clinopyroxene (Gd, Table 5) are poorer in MgO and richer in CaO than garnet rims elsewhere in the nodule. Interstitial garnets (Gf; Table 5) and garnet granules enclosing small angular olivine grains (Ge; Table 5) both relatively distant from garnet rimming spinel, are not significantly different from garnets more closely related to spinel.

Some chemical variation exists within and between garnet exsolved from clinopyroxenes of SD2-L172. For example, Al_2O_3 ranges from 21.23 to 23.22 weight percent within a single garnet exsolution lamella (Gg; Table 5). Less variation exists within garnet exsolution lamellae in orthopyroxene (Gi, Gj; Table 5) and Al_2O_3 , Cr_2O_3 , MgO and CaO tend to be most distinctive of specific lamellae. The major compositional differences between garnets exsolved from clinopyroxene (Gg, Gh; Table 5) and those exsolved from orthopyroxene (Gi, Gj; Table 5) in SD2-L172 is in SiO_2 and Cr_2O_3 contents. Garnets exsolved from orthopyroxene hosts contain more Cr_2O_3 and less SiO_2 than those from clinopyroxene hosts.

Zoned Garnet

Rim and core of zoned garnets of Iron Mountain xenolith IM42-L58 were analyzed by Smith (1977). Compositions change abruptly at the core/rim interface rather than gradually across the garnet grain. MgO content is slightly greater in the rims (G_1 , G_2 ; Table 6) while CaO is slightly higher in the core (G_3 , G_4 ; Table 6). Cr_2O_3 content is relatively constant throughout the crystal.

Orthopyroxene

SD2-L111

Chemistry of the edges of orthopyroxene grains adjacent to garnets in SD2-L111 were compared to the interiors of the orthopyroxene grains to determine if evidence of reaction and disequilibrium could be detected. The orthopyroxene grains are relatively homogeneous chemically (Pa, Pb; Table 4). A rough-edged orthopyroxene intergrowth

(exsolution?) in clinopyroxene was also analyzed (Pc, Pd; Table 4) and it has higher FeO and Al_2O_3 and lower MgO than edges and interiors of coarse orthopyroxene grains.

SD2-L172

Points in orthopyroxene grains adjacent to garnet exsolution lamellae of nodule SD2-L172 contain slightly less Al_2O_3 than points away from garnet lamellae (Pa; Table 5). Three of the four pairs of analyses at edges of orthopyroxene grains adjacent to garnets rimming spinel reveal a similar decrease in Al_2O_3 when compared to the interiors of the orthopyroxene grains (Pb, Pc, Pd; Table 5). Sample NX2-W1 in which garnet rims brown spinel was analyzed by Eggler (pers. commun., 1979) and orthopyroxenes nearer spinel surrounded by garnet (Pa; Table 6) were found to contain more Al_2O_3 than orthopyroxene grains away from the rimmed spinel (Pa₂; Table 6).

Other Special Orthopyroxene Features

Orthopyroxene exsolution lamellae in clinopyroxene of brown spinel-bearing websterite xenolith SD2-L164 (Pb₁, Pb₂; Table 6) contain more Al_2O_3 than the average of analyses from three coarse orthopyroxene grains (Pb₃; Table 6).

A euhedral orthopyroxene inclusion in clinopyroxene from spinel + garnet clinopyroxenite SD2-W10 (Pc₁, Pc₂; Table 6) contains more Al_2O_3 than the average coarse orthopyroxenes from this nodule (Pc₃; Table 6).

Clinopyroxene

SD2-L111

Analyses of edges and interiors of clinopyroxene grains adjacent to garnet rims around spinel of SD2-L111 show some significant chemical differences (Ca, Cb; Table 4). Interiors are considerably richer in Al_2O_3 and poorer in MgO than edges of clinopyroxenes adjacent to the garnet rims. Weight percent TiO_2 , Cr_2O_3 , FeO and Na_2O are also higher while CaO is lower in the interiors of the grains. Similar trends are observed within single clinopyroxene grains between points adjacent to garnet exsolution lamellae and points within the interiors of the clinopyroxene grain away from exsolution lamellae (Cc, Table 4). Within a single clinopyroxene grain, TiO_2 , Al_2O_3 , Cr_2O_3 , FeO and Na_2O are generally higher and CaO and MgO lower at points immediately adjacent to the lamellae. These chemical trends correspond to an increase in diopside content of clinopyroxene at points immediately adjacent to garnets.

SD2-L172

Points analyzed in SD2-L172 clinopyroxenes adjacent to garnet exsolution lamellae differ significantly from points within the interior of the clinopyroxene host away from the exsolved garnets (Cc; Table 5). Interiors are richer in TiO_2 , Al_2O_3 , and Na_2O , slightly richer in FeO , and poorer in CaO and MgO . Differences in Cr_2O_3 content noted in SD2-L111 are not present in SD2-L172. Edges of clinopyroxenes adjacent to garnets surrounding spinel (Ca; Table 5) do not differ from interiors (Cb; Table 5) of these grains as was the case in SD2-L111.

Spinel

Comparison of spinel interiors and edges adjacent to garnet rims in nodule SD2-L111 (Sa, Sb; Table 4) reveals inhomogeneities within spinel grains but no consistent trends. One edge and one interior analysis of brown spinel of nodule SD2-L172 were made. The interior of this spinel grain appears richer in TiO_2 and FeO and poorer in Cr_2O_3 and MgO on the basis of these analyses, however, additional analyses will be required to substantiate these findings.

Olivine

Tiny angular olivine grains surrounded by garnet granules were analyzed (Oa, Ob, Oc, Od, Oe; Table 5) and compared to edges and interiors of coarser olivine grains (Of, Og, Oh, Oi; Table 5) in nodule SD2-L172. No chemical differences were observed between the various habits of olivine.

Chemistry of euhedral olivine tablets (Oa, Od; Table 7), tiny spherical neoblasts (Ob, Oe; Table 7), and typical coarse olivine grains (Oc, Of; Table 7) in garnet harzburgite SD2-H13 and dunite SD2-D19 were compared. The three olivine habits show no distinct chemical differences.

CHAPTER IV

WHOLE ROCK CHEMISTRY

The relatively unaltered quality of xenoliths from the Sloan and Nix diatremes, hence the abundance of modal data and mineral chemistry analyses, enabled calculation of whole rock chemistry for many xenoliths of Groups I, II, IV, and V. Fresh mineral phases in xenoliths of Schaffer-Ferris-Aultman and Iron Mountain kimberlites are relatively scarce and modal analyses are subject to much error due to the severe alteration of these xenoliths, thus whole rock chemistry is not available for many xenoliths of Groups I and V nor for any of the Group III xenoliths.

Results of whole rock chemistry calculations performed on fresh xenoliths from the Sloan and Nix diatremes are shown in Figures 33-37 and Plates 17-21 in which CaO , Na_2O , TiO_2 , Al_2O_3 and Cr_2O_3 have been plotted against $\text{FeO/MgO} + \text{FeO}$, and ranges of these oxides are given in Table 8. Group II spinel harzburgites contain the lowest $\text{FeO/MgO} + \text{FeO}$ values of all nodules. Group I xenoliths are slightly higher in $\text{FeO/MgO} + \text{FeO}$ and porphyroclastic and granuloblastic nodules have the highest values in this group. Most garnet-free, spinel-bearing xenoliths of Group V have $\text{FeO/MgO} + \text{FeO}$ values roughly equal to those of Group I nodules. Granular garnet $\pm$ brown spinel xenoliths of Group V have generally higher $\text{FeO/MgO} + \text{FeO}$ ratios than do garnet-free spinel peridotites of Group V. The $\text{FeO/MgO} + \text{FeO}$ range of these garnet $\pm$ spinel xenoliths is wide and encompasses that of the

Table 8. Ranges in whole rock chemistry of fresh nodules shown in Figures 33-37.

Group	CaO	Na ₂ O	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	100 x (FeO/MgO+FeO)
Group I	0.2-7.5	0.02-0.81	0.02-0.34	0.1-9.01	0.06-3.56	13.1-17.7
Group II	0.1-1.6	0.01-0.10	0.00-0.05	0.2-2.5	0.06-1.42	11.5-14.7
Group IV	6.3-15.9	0.13-2.03	0.13-0.8	7.8-27.4	0.0-1.32	12.1-43.4
Group V	0.3-21.65	0.03-1.82	0.0-0.6	0.65-20.2	0.07-2.48	12.1-31.8

*All oxides are given in weight percent.

Nodules of Group III are severely altered hence the lack of modal and mineral chemistry analyses prevents calculation of whole rock chemistry.

Mineral chemistry (Table 2) is considered sufficient for the monomineralic dunites of Group VI, hence these nodules are excluded from Table 8.

spinel-free garnet websterites and pyroxenites of Group V. However, for Group V xenoliths in general, $\text{FeO/MgO} + \text{FeO}$ increases with increasing quantities of garnet, from low in the garnet-free, spinel peridotites, to moderate in garnet $\pm$ spinel peridotites, to high in spinel-free, garnet pyroxenites. Group IV websterites and clinopyroxenites have the highest $\text{FeO/MgO} + \text{FeO}$ of all nodules. Xenoliths of Group IV that contain green spinel and/or garnet exsolved from pyroxenes, along with several spinel-free garnet pyroxenites (e.g., SD2-L106, SD2-P1, SD2-W7) of Group IV have the highest $\text{FeO/MgO} + \text{FeO}$ values. One Group IV xenolith (NX4-L20) that plots outside of the Group IV field has a much lower $\text{FeO/MgO} + \text{FeO}$ ratio than other Group IV xenoliths. This may be due to the relatively low garnet content (3.9 volume percent) of this xenolith.

Plots of CaO and Na_2O versus $\text{FeO/MgO} + \text{FeO}$ (Figs. 33, 34, Plates 17, 18; Table 8) are quite similar; CaO and Na_2O content generally increases with increasing quantities of clinopyroxene in the xenoliths. Groups I and II harzburgites thus have very low CaO and Na_2O contents. One small Group I xenolith (SD2-W11) with unusually high CaO consists of only about 5 grains of ortho- and clinopyroxene. This is evidently a fragment of a xenolith and the relatively high clinopyroxene content is responsible for its unusually high CaO content. Group IV pyroxenite xenoliths are richest in Na_2O and CaO . Group V xenoliths are intermediate in CaO and Na_2O content between Group IV and Groups I and II, although a few Group V xenoliths have greater Na_2O and CaO than xenoliths from other groups. All of these Group V xenoliths that are enriched in Na_2O and CaO are olivine-free and they include two garnet-free, brown spinel-bearing nodules

The first of these is the fact that the
 system is not a simple one. It is a
 complex one, and it is not possible to
 describe it in a few words. It is a
 system of many parts, and it is not
 possible to describe it in a few words.

Figure 33. Results of whole rock chemistry calculations on fresh (Sloan and Nix) xenoliths--CaO versus $100 \times \text{FeO}/\text{MgO} + \text{FeO}$.

Large numerals label fields in which the majority of xenoliths from each group plot. Small numerals indicate nodules that plot outside their group's field as outlined.

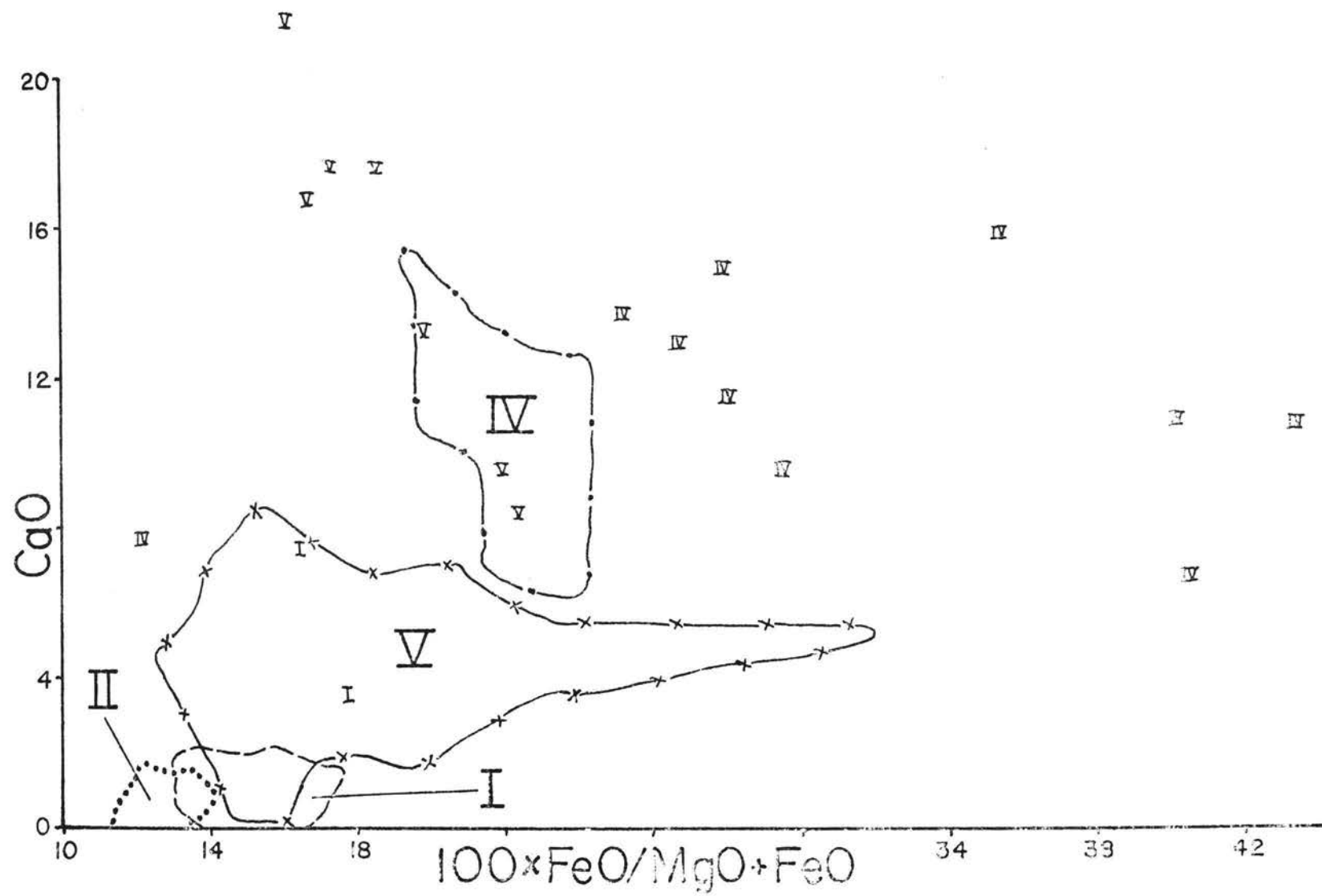
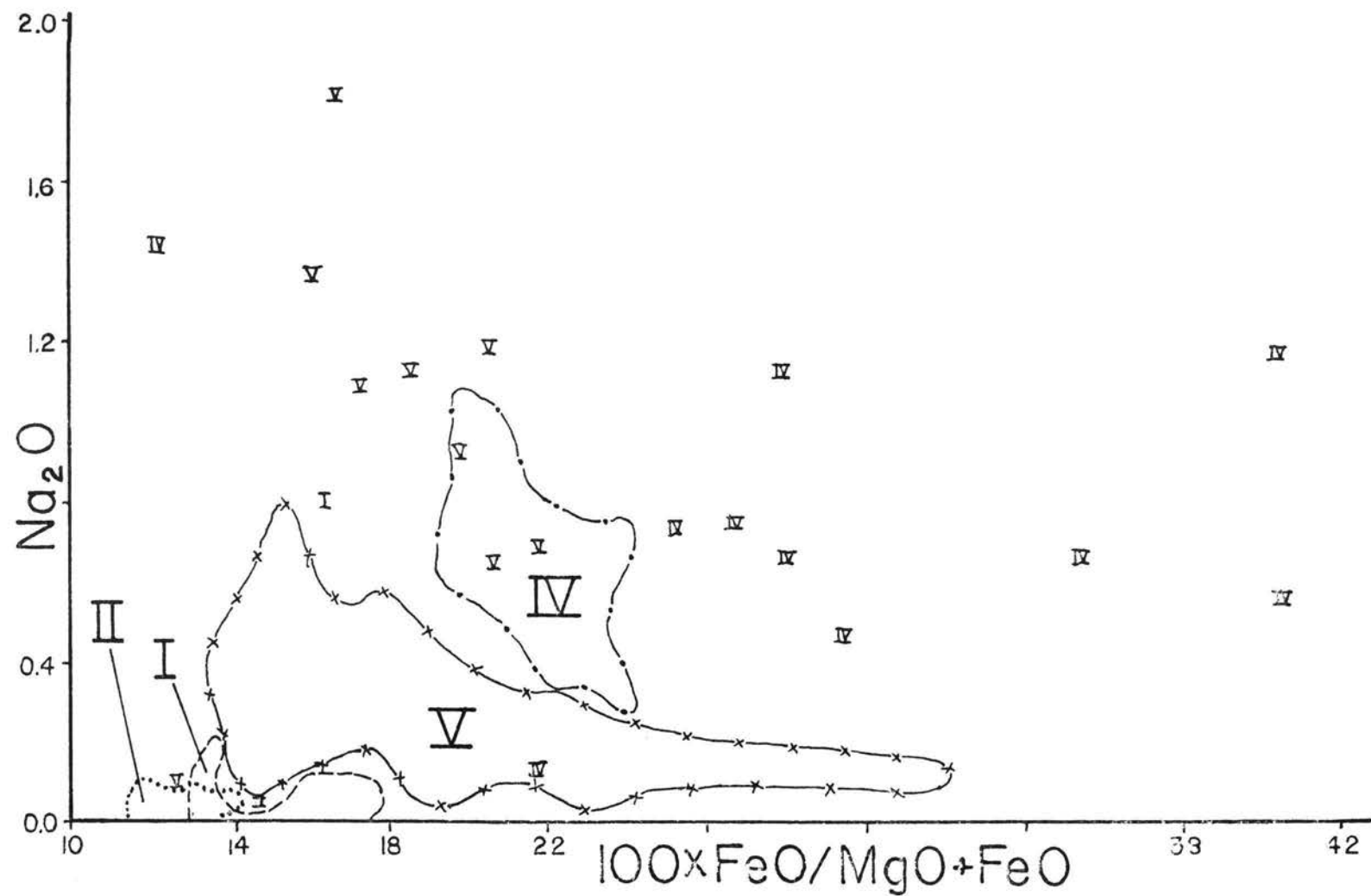


Figure 34. Results of whole rock chemistry calculations on fresh (Sloan and Nix) nodules--
NaO versus $100 \times \text{FeO} / \text{MgO} + \text{FeO}$.

Large numerals label fields in which the majority of xenoliths from each group plot. Small numerals indicate nodules that plot outside their group's field as outlined.



(SD2-L164, SD2-W8) and one xenolith with brown spinel rimmed by garnet (SD2-W9).

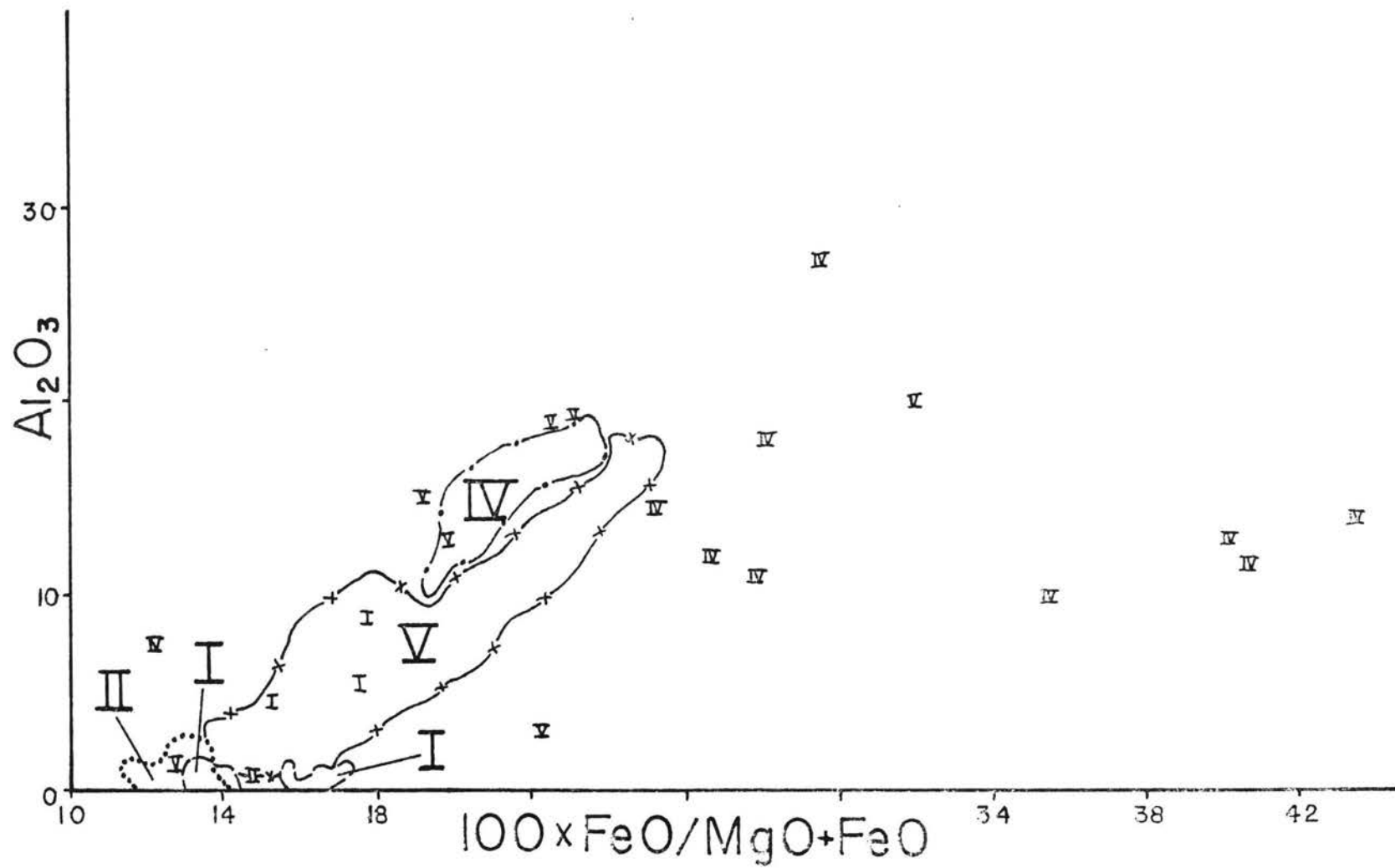
Xenoliths of Groups I and II contain the least Al_2O_3 (Fig. 35, Plate 19, Table 8). Spinel peridotites of Group V also contain relatively little Al_2O_3 . Garnet-bearing xenoliths of Group V generally have the greatest Al_2O_3 of Group V xenoliths; however, garnet wehrlite SD2-L40 is an exception, containing about 3.0 weight percent Al_2O_3 . The Al_2O_3 content of Group V encompasses, at higher values the Al_2O_3 contents of most Group IV xenoliths.

Group II xenoliths contain the least TiO_2 of the xenoliths plotted (Fig. 36, Plate 20, Table 8). The Group I field nearly completely engulfs the garnet-free spinel peridotites of Group V, and xenoliths with porphyroclastic and granuloblastic textures are among the highest in TiO_2 of Group I xenoliths. Garnet $\pm$ spinel xenoliths of Group V contain TiO_2 values similar to those of other Group V xenoliths but their higher $\text{FeO}/\text{MgO} + \text{FeO}$ ratios set them apart from the garnet-free spinel peridotites of Group V. Group IV websterites and clinopyroxenites have the highest TiO_2 levels of all nodules plotted.

A plot of Cr_2O_3 versus $\text{FeO}/\text{MgO} + \text{FeO}$ (Fig. 37, Plate 21, Table 8) emphasizes the low Cr_2O_3 content of Group II and IV xenoliths. Mineral phases (pyroxenes and garnet) of Group IV xenoliths are characteristically low in Cr_2O_3 thus low Cr_2O_3 in the whole rock chemistry results are to be expected. Although pyroxenes and garnets of Group II harzburgites generally contain more Cr_2O_3 than those of Group IV xenoliths, the Cr_2O_3 content in Group II nodules is diluted by the abundant olivine in these nodules. Xenoliths of Groups I and V exhibit wide ranges of Cr_2O_3 content and the Group I field overlaps extensively with

Figure 35. Results of whole rock chemistry calculations on fresh (Sloan and Nix) xenoliths--
 Al_2O_3 versus $100 \times \text{FeO}/\text{MgO} + \text{FeO}$.

Large numerals label fields in which the majority of xenoliths from each group plot. Small numerals indicate nodules that plot outside their group's field as outlined.



1. The first part of the paper is devoted to a study of the properties of the function $f(x)$ defined by the equation $f(x) = \sum_{n=0}^{\infty} a_n x^n$, where a_n are the coefficients of the power series. It is shown that $f(x)$ is a continuous function of x and that it satisfies the functional equation $f(x) = x f(x^2)$.

2. In the second part, the function $f(x)$ is studied for $x > 1$. It is shown that $f(x)$ is a decreasing function of x and that it satisfies the inequality $f(x) < 1/x$.

3. The third part of the paper is devoted to a study of the properties of the function $g(x)$ defined by the equation $g(x) = \sum_{n=0}^{\infty} b_n x^n$, where b_n are the coefficients of the power series. It is shown that $g(x)$ is a continuous function of x and that it satisfies the functional equation $g(x) = x g(x^2)$.

4. In the fourth part, the function $g(x)$ is studied for $x > 1$. It is shown that $g(x)$ is a decreasing function of x and that it satisfies the inequality $g(x) < 1/x$.

Figure 36. Results of whole rock chemistry calculations on fresh (Sloan and Nix) xenoliths--
TiO₂ versus 100 X FeO/MgO + FeO.

Large numerals label fields in which the majority of xenoliths from each group plot. Small numerals indicate nodules that plot outside their group's field as outlined.

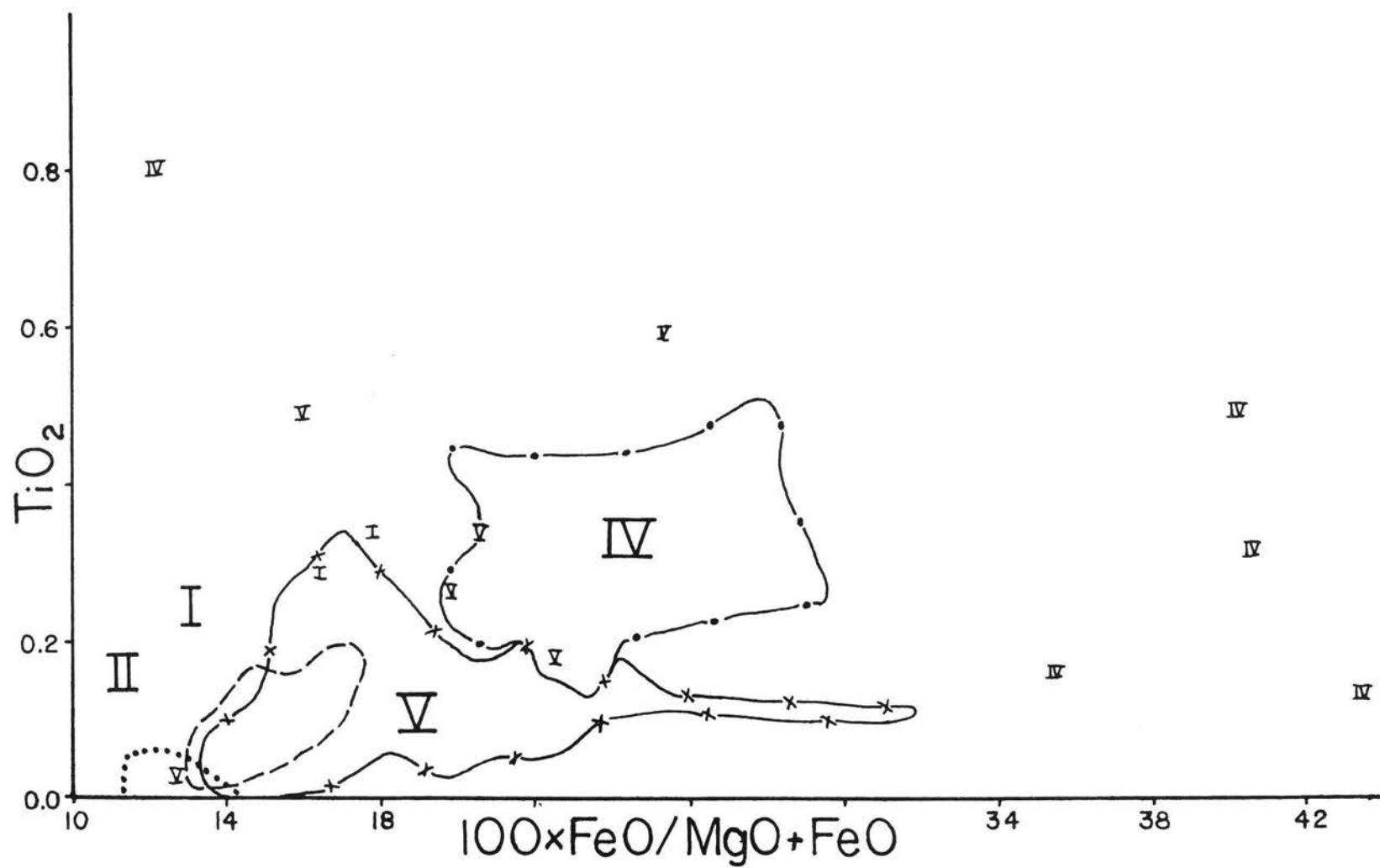
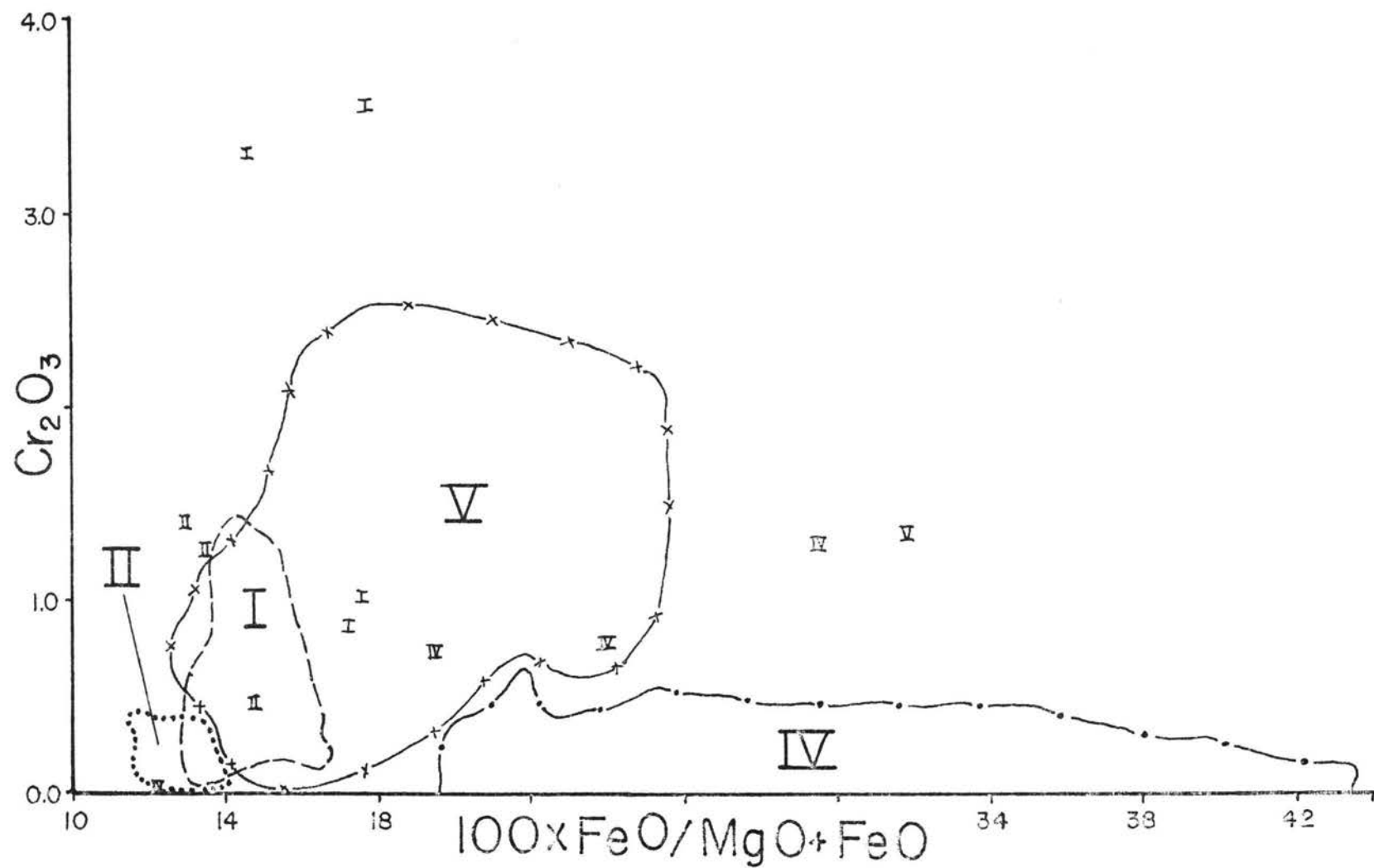


Figure 37. Results of whole rock chemistry calculations on fresh (Sloan and Nix) xenoliths--
 Cr_2O_3 versus $100 \times \text{FeO}/\text{MgO} + \text{FeO}$.

Large numerals label fields in which the majority of xenoliths from each group plot. Small numerals indicate nodules that plot outside their group's field as outlined.



that of Group V. Two Group I xenoliths (SD2-L4 and SD2-L133) exhibit very high Cr_2O_3 contents (3.32 and 3.56 weight percent Cr_2O_3 respectively). Garnets of xenolith SD2-L4 have the highest Cr_2O_3 values of all Group I xenoliths (see Appendix 2) and this is reflected in whole rock chemistry. Clinopyroxenes and garnets of xenoliths SD2-L133 are not exceptionally high in Cr_2O_3 but this sample contains abundant garnet (23.6 volume percent) which is largely responsible for whole rock Cr_2O_3 values.

CHAPTER V

GEOOTHERMOMETRY AND GEOBAROMETRY

Introduction

The modern approach to geothermobarometry of garnet-bearing peridotite nodules was pioneered by Davis and Boyd (1966), who calibrated the non-isostructural solvus between calcium-poor orthopyroxene and diopsidic clinopyroxene at high pressures and by MacGregor (1974) who determined the content of alumina in orthopyroxenes in equilibrium with garnet in the system $\text{MgO-Al}_2\text{O}_3\text{-SiO}_2$. Many efforts have been made to find other geothermometers and barometers and also to modify the data of Davis and Boyd (1966) and MacGregor (1974) so that their thermometers and barometers are more clearly applicable to natural rock systems that contain more elements than the systems on which the laboratory experiments were made. These methods have been summarized by Eggler (1979).

All geothermobarometric estimates used in this study have been generated by the program TEMPEST (A.A. Finnerty and F.R. Boyd, unpublished). Given chemical analyses for appropriate minerals, TEMPEST computes temperatures of equilibration according to the experimental data of Lindsley and Dixon (1976), Wells (1977), Wood and Banno (1973), Raheim and Green (1974), O'Neill and Wood (1979), Kawasaki and Matsui (1977), Bishop (1978), Ellis and Green (1979) and Mercier (1976). The geothermometer of Evans and Frost (1975) was added to the program by

D.H. Eggler (pers. commun., 1980). Pressures of equilibration are computed according to geobarometers of MacGregor (1974), Akella (1976) and Wood (1974).

Pressure and temperature conditions of formation were estimated in this manner for a number of xenoliths from the Sloan and Nix kimberlites and for a single fresh garnet orthopyroxenite xenolith from Iron Mountain. It is assumed that temperature and pressure ranges obtained for these xenoliths are comparable to texturally and chemically similar xenoliths from other Colorado-Wyoming kimberlites in which alteration of principal primary mineral phases prevents direct application of geothermobarometry.

Group I Garnet Peridotites

Garnet peridotites that are generally characterized by spherical garnets and euhedral olivine tablets and classified according to mineral chemistry as Group I exhibit temperatures between 1000⁰ and 1500⁰C and pressures between about 45 and 80 kb (Fig. 38). Temperatures were established by the Lindsley and Dixon (1976) geothermometer based on diopside ↔ enstatite equilibria. The Lindsley and Dixon (1976) solvus does not differ significantly from that of Davis and Boyd, but has been determined by more modern electron microprobe techniques. Pressures were established using the geobarometer of Wood (1974) based on the solubility of alumina in orthopyroxene (corrected for Ti, Ca and Cr) which crystallized in equilibrium with garnet. These methods are preferred for this group of garnet peridotites in that experimental procedures are well documented and results are consistent and widely accepted.

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Figure 38. Geothermobarometric estimates for fresh garnet peridotite nodules of Group I.

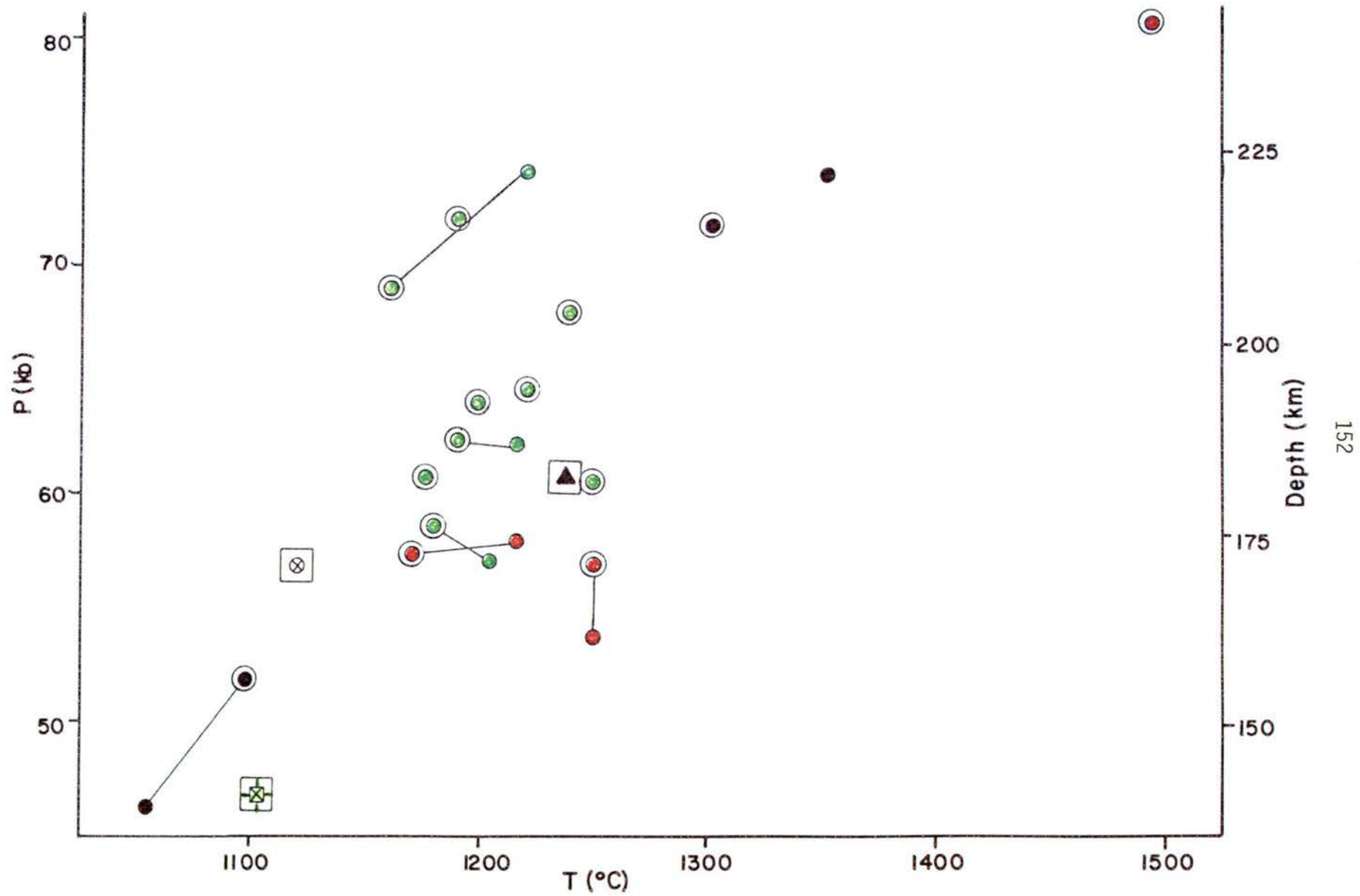
Colors indicate textures, symbols indicate rock types (see LEGEND, Figure 2a).

Circled symbols indicate temperatures estimated utilizing the methods of Kawasaki and Matsui (1977). Corresponding pressure estimates are those obtained by averaging the results of Akella (1976) with those of Wood (1974).

Symbols enclosed by squares indicate estimates of temperatures by the methods of Lindsley and Dixon (1976) and pressures by the methods of MacGregor (1974).

Symbols not enclosed by circles or squares are plotted at temperatures estimated by the methods of Lindsley and Dixon (1976) and at pressure estimates of Wood (1974).

Lines connect two different estimates of temperature and pressure for the same nodule.



The Lindsley and Dixon (1976) geothermometer could not be used for several xenoliths that lack clinopyroxene analyses. In these cases the geothermometer of Kawasaki and Matsui (1977) based on partitioning of Fe^{2+} and Mg^{2+} between olivine and garnet was employed. This thermometer was chosen because in a comparison of geothermometers (Fig. 38), Kawasaki's results are closest to those of Lindsley and Dixon. At the temperatures of equilibration estimated by the Kawasaki and Matsui (1977) geothermometer, an average of the pressure estimates produced by Wood's (1974) and Akella's (1976) (both based on solubility of Al_2O_3 in orthopyroxene coexisting with garnet) geobarometers most closely approximated the Wood (1974) barometer used in conjunction with the Lindsley and Dixon (1976) thermometer for clinopyroxene-bearing xenoliths. This average is thus the pressure plotted (Fig. 38) for those xenoliths with temperatures determined by the Kawasaki (1979) geothermometer.

No garnet was recoverable for analysis in two Group I samples (SD2-L60, SD2-L150) therefore the geobarometer of MacGregor (1974) was used in place of that of Wood (1974). This method is based, as is Wood's on Al_2O_3 solubility in orthopyroxene but equilibration with garnet (or spinel) may be inferred and garnet analyses are not required for computation of pressures. Pressures obtained using MacGregor's (1974) barometer are generally similar to those of Wood (1974) for these xenoliths but results using MacGregor's methods may range between 13.9 kb lower to 4.6 kb higher than those of Wood.

Spinel Peridotites of Groups II and V

Pressures of equilibration of garnet-free spinel harzburgites of Group II and peridotites and olivine websterites of Group V are relatively tightly restricted between 10 and 20 kb while temperatures range from 600 - 900°C (Fig. 39). Most spinel harzburgites of Group II exhibit pressures of equilibration about 2-3 kb higher than the spinel peridotites and olivine websterites of the Websterite Group (Group V). Pressures were computed using MacGregor's (1974) geobarometer and the geothermometer of Evans and Frost (1975). The Evans and Frost (1975) geothermometer is based on a study of changing Al_2O_3 content of chrome-spinel coexisting with chlorite and two magnesium silicate minerals during progressive metamorphism. Commonly, only the thermometers of Evans and Frost (1975), Mercier (1976), Wells (1977), and Wood and Banno (1973) could be utilized since other geothermometers require garnet analyses. The latter two thermometers are based on enstatite $\leftrightarrow$ diopside equilibria. The thermometer of Mercier (1976) estimates temperatures from analysis of a single pyroxene known to once have been in equilibrium with a second pyroxene and either garnet or spinel. Results obtained using the Evans and Frost (1975) method were most consistent. Wells' (1977) geothermometer yielded erratic results commonly 100°C higher or lower than results obtained utilizing the method of Evans and Frost. Estimates determined by the Wood and Banno (1973) and Mercier (1976) methods give even higher temperatures. Mercier's single pyroxene geothermometer results are coupled with very low pressures, often less than 10 kb. Temperatures of equilibration of the spinel-bearing xenoliths are apparently too

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Figure 39. Estimates of temperatures and pressures of equilibration for fresh spinel peridotites of Groups II and V.

Colors indicate textures, symbols indicate rock types (see LEGEND, Fig. 2a).

Circled symbols are Sloan 2 spinel harzburgites of Group II. All others are Group V spinel peridotites.

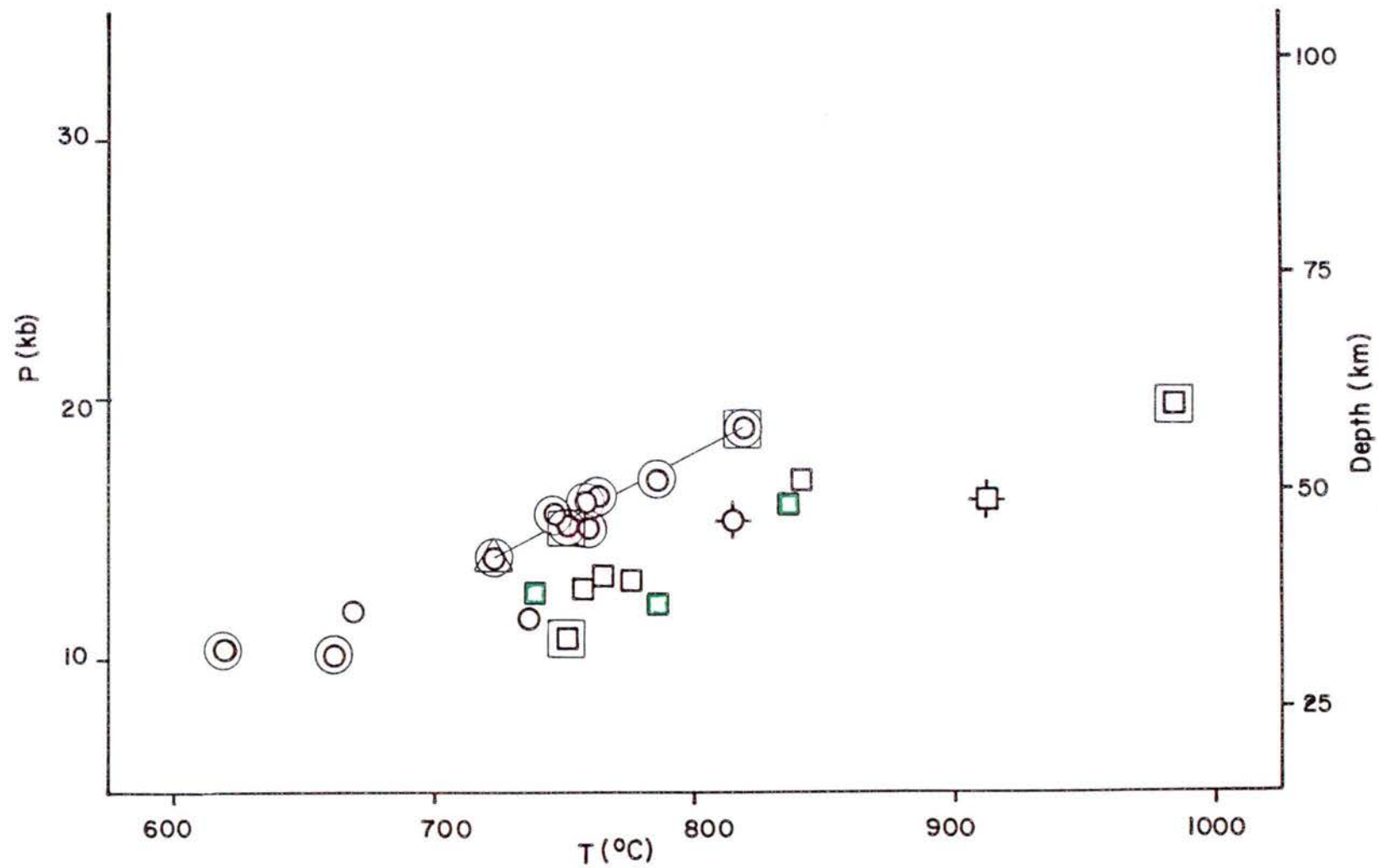
Symbols enclosed by squares indicate estimates of temperatures by the methods of Wells (1977).

Symbols enclosed by triangles indicate temperature estimates by the methods of Lindsley and Dixon (1976).

All other symbols are plotted at temperatures estimated by the Evans and Frost (1975) method.

All pressures are estimated by the methods of Macgregor (1974).

Lines connect two different estimates of temperatures and pressures for the same nodule.



low for these geothermometers to be effective as they are generally calibrated for temperatures greater than 800°C.

Olivine-Free Pyroxenites and Websterites
of Groups IV and V

The geothermometer of Lindsley and Dixon (1976) and the geobarometer of MacGregor (1974) have been applied to olivine-free, garnet $\pm$ spinel websterites and pyroxenite xenoliths of Groups IV and V. Most of these nodules equilibrated at temperatures between 650⁰ - 850⁰C and at pressures between 15-25 kb (Fig. 40) according to estimates by these methods. These xenoliths are categorized according to mineral chemistry into Groups IV and V but this distinction is not reflected by equilibration pressure and temperature data.

Two Sloan 2 garnet orthopyroxenites exhibit the highest temperatures and pressures of xenoliths of this group. The garnet orthopyroxenite from Iron Mountain also plots among the higher pressure and temperature xenoliths. Spinel-bearing pyroxenite SD2-L164 plots at a temperature similar to the garnet pyroxenites but at much lower pressures (~5 kb).

None of the geothermometer/barometer methods is readily applicable to garnet + spinel xenoliths of Group IV. Lindsley and Dixon (1976) temperatures are not available because Ca/Ca + Mg values for clinopyroxenes are greater than 0.5 and the Evans and Frost (1975) method requires ferric iron data for spinel. Data based on the Wells (1977) method, the closest available approximation to Lindsley and Dixon (1976) temperatures, are erratic and widely variable in comparison (Fig. 40). Temperature and pressure conditions of formation of the

Figure 40. Geothermobarometric estimates for fresh olivine-free pyroxenites and websterites of Groups IV and V.

Colors indicate textures, symbols indicate rock type (see LEGEND, Fig. 2a).

Circled symbols are nodules of Group IV. All others are of Group V.

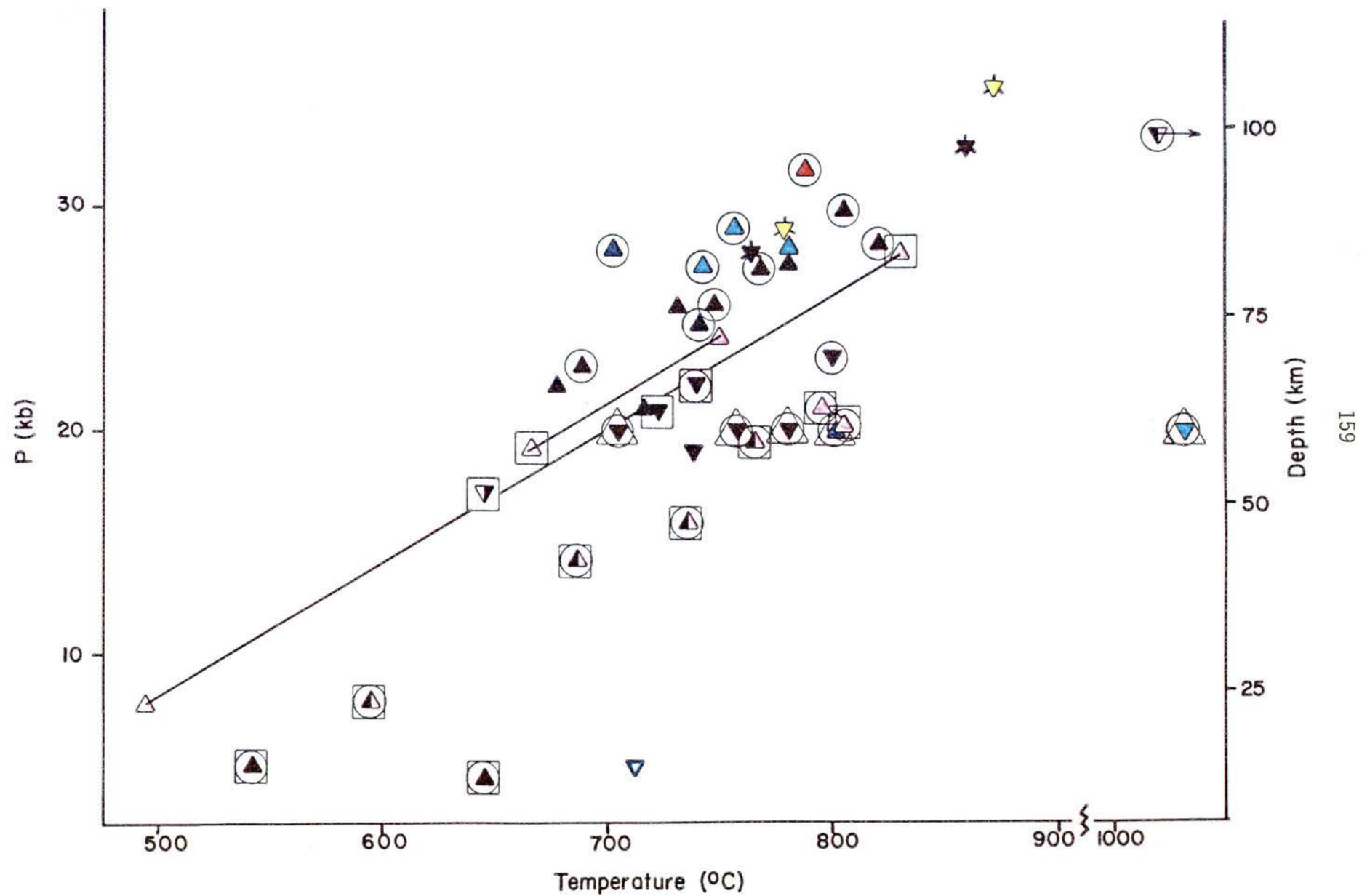
Symbols enclosed by squares indicate temperature estimates by the methods of Wells (1977) and pressures by the methods of MacGregor (1974).

Symbols enclosed by triangles indicate temperature estimates by the methods of Lindsley and Dixon (1976) assuming a pressure of 20 kb.

All other estimates of temperature have been calculated using the Lindsley and Dixon (1976) thermometer and the MacGregor (1975) barometer.

Lines connect temperature/pressure estimates for the same nodule by two different methods.

Arrow indicates point (SD2-W10) plots off-scale at 1290°C.



garnet + green spinel xenoliths therefore cannot be considered at all definitive. Results do seem to imply, however, that garnet + green spinel xenoliths equilibrated at lower pressure and temperature than the majority of other olivine-free pyroxenite xenoliths of Groups IV and V. An exception is xenolith SD2-W10 for which temperature estimates are anomalously high. This nodule is very enriched in iron, possibly due to metasomatic alteration, thus lack of equilibrium may have influenced temperature estimates. The re-equilibrated texture of this xenolith suggests, however, that the nodule may have been subjected to such high temperatures as could be necessary, or at least helpful, for such extensive recrystallization.

Garnet $\pm$ Brown Spinel Peridotites of Group V

Xenoliths of Group V that contain granular garnets commonly rimming red-brown spinel equilibrated roughly between 650⁰ - 800⁰C and 15 - 25 kb according to the geothermometer of O'Niell and Wood (1979) and the geobarometer of MacGregor (1974) (Fig. 41). As in the case of the garnet-free spinel peridotites, temperatures and pressures of garnet $\pm$ brown spinel xenoliths are probably too low for Lindsley and Dixon (1976) thermometry to be effective. A method such as O'Niell and Wood's (1979) is probably preferable because an Fe-Mg exchange thermometer is more sensitive at low temperatures than at high temperatures.

The Evans and Frost (1975) geothermometer was compared to that of O'Niell and Wood (1979) for garnet $\pm$ spinel peridotites of Group V for which spinel analyses are available (Fig. 41). The

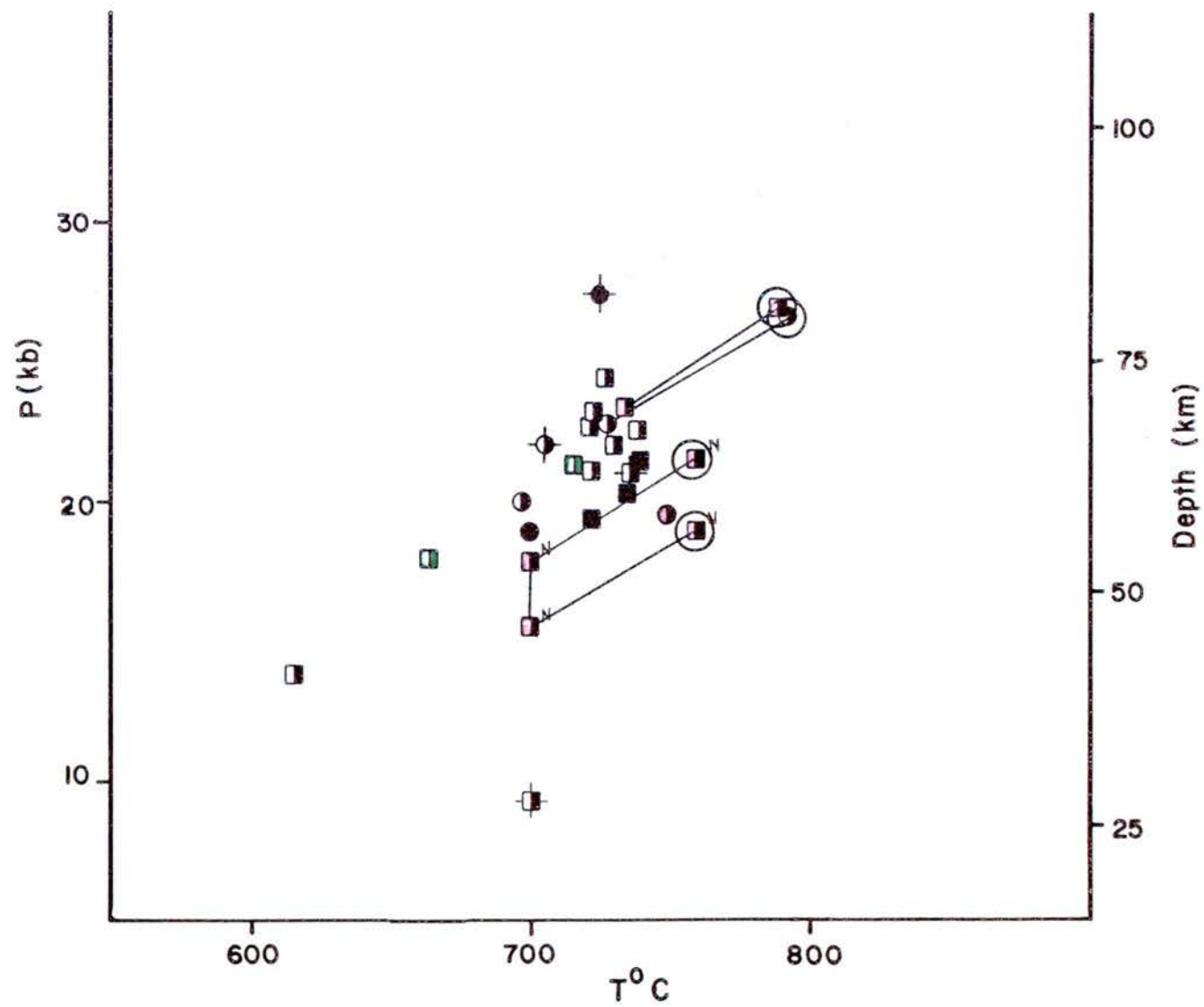
Figure 41. Geothermobarometric estimates for fresh garnet $\pm$ brown spinel peridotites of Group V.

Colors indicate textures, symbols indicate rock type (see LEGEND, Fig. 2a).

All pressure estimates are derived utilizing the barometer of MacGregor (1974).

Circled symbols indicate temperature estimates by the thermometer of Evans and Frost (1975). All others are by the methods of O'Niell and Wood (1979).

Vertical line connects two different temperature estimates for the nodule NX2-W1 based on two different orthopyroxene analyses (see text for explanation). Other lines connect two different estimates of temperatures and pressures.



Evans and Frost geothermometer fairly consistently results in temperatures from 50-100°C higher and pressures about 5 kb greater than temperature estimates by the method of O'Neill and Wood (1979). This suggests that the proximity of temperature and pressure estimates for garnet ± spinel peridotites and garnet-free spinel peridotites as shown in Fig. may be too close.

Use of two different orthopyroxene analyses from sample NX2-W1 (orthopyroxene near the spinel-bearing end of the nodule versus orthopyroxene away from spinel) results in two slightly different estimates of pressure conditions for this xenolith due to the slightly different Al_2O_3 contents in the two orthopyroxene analyses. Higher Al_2O_3 content of orthopyroxene near spinel + garnet results in a lower estimate of pressure of equilibration. Orthopyroxene chemistry illustrates the lack of attainment of equilibrium among the phases in this xenolith, apparently in relation to the reaction relationship between spinel and garnet.

Ilmenite-bearing garnet wehrlite SD2-L40 of Group V contains mineral phases that commonly plot very near or within Group I fields. This xenolith appears to have equilibrated at higher temperature and pressure than other garnet-bearing xenoliths of the Websterite Group (Fig. 41).

Summary

Pressure and temperature conditions of formation of the rock groups discussed above are compiled in Fig. 42. The increase of temperature with depth below the earth's surface as defined by these estimated conditions of formation of Colorado-Wyoming peridotite and

1. The first part of the paper is devoted to the study of the properties of the function $f(x)$ defined by the equation

$$f(x) = \int_0^x \frac{1}{1+t^2} dt, \quad (1)$$

where x is a real number. It is shown that the function $f(x)$ is continuous and differentiable for all values of x .

2. In the second part of the paper, the properties of the function $f(x)$ are studied for $x > 0$. It is shown that the function $f(x)$ is increasing and concave down for all values of x .

3. In the third part of the paper, the properties of the function $f(x)$ are studied for $x < 0$. It is shown that the function $f(x)$ is decreasing and concave up for all values of x .

4. In the fourth part of the paper, the properties of the function $f(x)$ are studied for $x = 0$. It is shown that the function $f(x)$ is continuous and differentiable at $x = 0$.

Figure 42. Pressure/temperature diagram summarizes relationships between xenolith groups detailed in Figs. 38-41.

Dashed outline field defined by fresh Group I garnet peridotites.

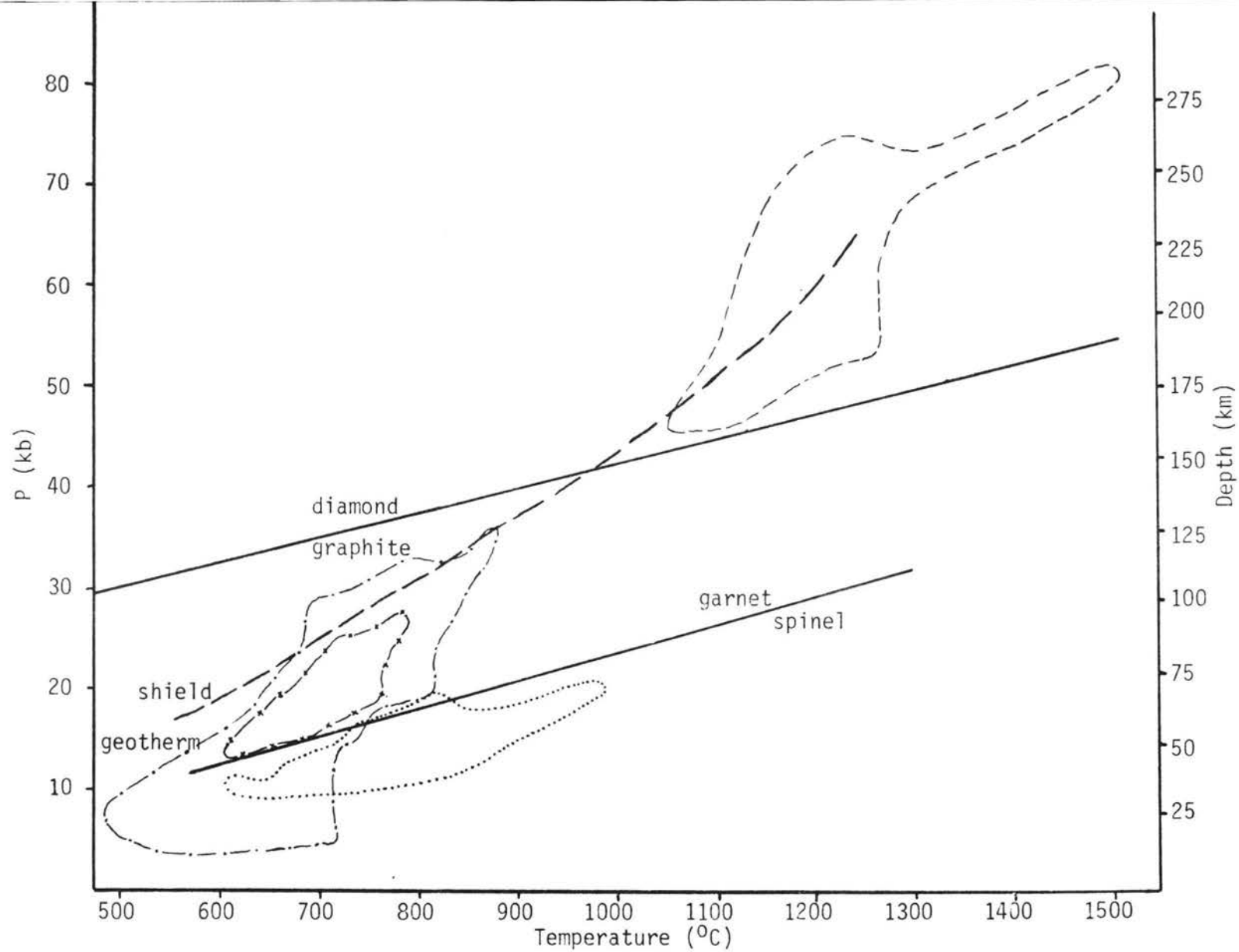
Dotted outline field defined by fresh spinel peridotites of groups II and V.

Dash-dot pattern outlines field defined by fresh olivine-free pyroxenites of Groups IV and V.

Dash-x pattern outlines field defined by the fresh garnet $\pm$ brown spinel peridotites of Group V.

The shield geotherm of Clark and Ringwood (1964) is indicated by heavy dashed line.

Diamond-graphite and garnet-spinel reaction lines are represented by solid lines.



pyroxenites is quite consistent with the shield geotherm of Clark and Ringwood (1964).

The diamond/graphite equilibrium curve crosses the geotherm and separates the higher pressure and temperature xenoliths of Group I from those of Groups II, IV and V. This is consistent with the fact that a diamond-bearing peridotite xenolith from the Schaffer 3 kimberlite diatreme belongs to Group I.

Nearly all spinel (garnet-free) peridotites plot below MacGregor's (1974) determination of the spinel/garnet equilibrium curve (Fig. 42). However, xenoliths in which spinel coexists with garnet are present to approximately 23 kb pressure. Spinel-bearing xenoliths from Colorado-Wyoming peridotites thus define a slightly higher maximum pressure for the stability field of spinel than is indicated by MacGregor (1974) for the system $\text{MgO-Al}_2\text{O}_3\text{-SiO}_2$.

CHAPTER VI

INTERPRETATION OF RESULTS

Garnet Peridotites of Group I

Garnet peridotites that comprise Group I xenoliths are generally similar to peridotite xenoliths described from numerous kimberlite localities throughout the world (e.g., pyrope peridotites of Yakutia kimberlites, Sobolev, 1977; "common peridotite" xenoliths of the Matsoku kimberlite pipe, Lesotho, Cox, et al., 1973; sheared and granular ultramafic nodules from Monastery Mine, South Africa, Boyd and Nixon, 1975). Such nodules have been studied extensively and several theories concerning their origin have been proposed.

Boyd and Nixon (e.g., 1973, 1975, 1978) have been involved in numerous studies of xenolith suites since they proposed in 1973 that two groups of lherzolites from Lesotho kimberlites with contrasting textures and compositions define the limbs of a "kinked" or inflected geotherm. Granular (equivalent to coarse equant or tabular) lherzolites were found to be depleted in Na, Ti, Fe, Ca and Al relative to porphyroclastic lherzolites (Boyd and Nixon, 1975). These are the elements that fractionate into the liquid during partial melting and escape of the liquid may have caused the depletion. The lherzolites with granular textures were shown to have pressures and temperatures of formation that plot fairly close to the estimated shield geotherm of Clark and Ringwood (1964). The lherzolites with sheared (equivalent

to porphyroclastic) textures define an inflected limb of the geotherm, plotting at higher temperatures than points along the geotherm for a given pressure. The explanation for this phenomenon called for an extensive zone within the mantle that consists of undepleted or "primitive," sheared lherzolite which underlies a zone of depleted, granular lherzolite. It was suggested that the sheared zone is related to plate movement and is a potential source of magma derivation.

More recently Gurney and Harte (1979) have suggested that porphyroclastic peridotites may form the immediate envelope about a protokimberlite (?) magma derived at depth and intruded into a shallower level of the mantle. This intrusion creates a horizontal temperature gradient at the shallower level and diffusion metasomatism occurs between the melt and rocks immediately adjacent to it. Thus, compositional differences and greater temperatures of equilibration result in the porphyroclastic xenoliths immediately adjacent to the melt while coarse grained peridotite is more representative of the composition and texture of mantle material into which the magma was intruded. This does not appear to be applicable to Group I xenoliths of Colorado-Wyoming kimberlites.

Compositionally, most xenoliths of Group I can be considered to be depleted. Perhaps the most obvious evidence that Group I garnet peridotites from the Sloan 2 kimberlite have undergone some partial melting is the fact that nearly all are harzburgites with less than 3.0 volume percent diopside. Diopside is the first mineral phase to be eliminated during partial melting of garnet peridotite, and garnet harzburgite is the residual assemblage (O'Hara et al.,

1975). Whole rock and mineral chemistry of Sloan 2 xenoliths also indicates that Group I xenoliths are depleted in Al_2O_3 , Na_2O and CaO relative to Groups IV and V.

Textural/chemical correlations are not clearly defined in Colorado-Wyoming Group I peridotites. Clinopyroxenes of porphyroclastic xenoliths contain more FeO and slightly more TiO_2 but less CaO than their less deformed counterparts while sheared xenoliths of Boyd and Nixon's (1975) Lesotho nodules are enriched in CaO , FeO and TiO_2 as well as Al_2O_3 and Na_2O . Whole rock chemistry also indicates that Group I Sloan 2 xenoliths with porphyroclastic or granuloblastic textures are enriched in FeO and TiO_2 over most other xenoliths from that group. Metasomatism resulting from infiltration of material derived from the kimberlite magma at depth may be responsible for the introduction of ilmenite (Harte et al., 1975; Lawless, 1978) in ilmenite-bearing Group I xenoliths. Clinopyroxenes and garnets of these Group I ilmenite-bearing xenoliths are low in Cr_2O_3 and rich in FeO relative to those of most other Group I xenoliths. Thus it appears that FeO and TiO_2 are enriched in some xenoliths and that deformation and recrystallization could have aided in diffusion and exchange of these elements. No correlation can be drawn involving CaO , Na_2O and Al_2O_3 therefore it appears that FeO and TiO_2 metasomatism is a more likely mechanism of the enrichment than is relative enrichment through lack of depletion by partial melting.

Garnets from Schaffer-Ferris-Aultman Group I xenoliths are low in Cr_2O_3 and CaO , and high in MgO and Al_2O_3 relative to Sloan-Nix-Moen Group I garnets while garnets from Iron Mountain xenoliths are generally intermediate between garnets of nodules from the other two

kimberlite groups. Eggler, et al. (1979) have suggested, based on variations in megacryst chemistry between pipe clusters, that each of the three clusters of kimberlite pipes has its own distinct conduit system to a depth of approximately 200 km. CaO/MgO and $\text{Cr}_2\text{O}_3/\text{Al}_2\text{O}_3$ variations in the garnets in xenoliths from the three kimberlite clusters might be controlled by pressure and temperature conditions or bulk compositional variations predominating in the regions of the mantle that the three separate conduits have tapped. Very localized inhomogeneities within the mantle would thus be implied as the surface exposures of the Schaffer-Ferris Aultman and Sloan-Nix-Moen kimberlite pipe clusters are separated by less than 20 kilometers.

The geotherm as defined by estimates of pressures and temperatures of equilibration of Sloan 2 garnet harzburgites (Fig. 42) is not kinked. Group I xenoliths with porphyroclastic textures do exhibit temperatures slightly higher than the average for the rest of the Group I nodules. However, several xenoliths from Group V of much lower pressure and temperature origin have porphyroclastic textures as well. Group I xenoliths of Colorado-Wyoming kimberlites thus appear similar to the ultramafic nodules from the Bulfontein pipes of Kimberley, South Africa (Boyd and Nixon, 1978; Lawless, 1978). However, Kimberley xenoliths exhibit more extensively sheared textures than have been observed in Colorado-Wyoming xenoliths and there are no peridotite xenoliths at Kimberley, regardless of texture, that have equilibration temperatures greater than 1100°C . All estimates of temperature of equilibration that have been made for Colorado-Wyoming Group I xenoliths are greater than 1100°C .

The general similarity of temperatures and pressures of equilibration of Group I xenoliths and lack of textural correlations with temperature and pressure is not readily compatible with the suggestion by Boyd and Nixon (1975) that sheared xenoliths originate from greater depths. Nor is it particularly compatible with the proposal by Gurney and Harte (1979) that intrusion of high temperature magma into shallower mantle levels generates a horizontal temperature gradient at that level such that xenoliths immediately adjacent to the magma exhibit higher temperatures and pressures of equilibration. In order to better fit a kimberlite emplacement/xenolith derivation model to Colorado-Wyoming Group I xenoliths, relatively non-forceful emplacement (hence lack of severe shearing) of the protokimberlite (?) melt and low thermal conductivity and/or a very gradual thermal gradient developed out from the rising melt would, at minimum, be necessary. Very localized zones of more intense shearing that may or may not be associated with metasomatic exchange between the melt and the xenoliths are implied by textures and chemical evidence. Furthermore, since xenoliths with sheared textures exhibit a wide range of temperatures and pressures of equilibration (e.g., porphyroclastic xenoliths are found in both Groups I and V) some of the shearing may have been caused by processes not directly related to kimberlite formation and intrusion. If kimberlite intrusion occurs along zones of weakness through the mantle and crust, earlier movement along these zones might have deformed some of the rocks picked up by kimberlite upon its passage through these zones.

Spinel Peridotites--Groups II, III, and V

Information on garnet-free spinel-bearing xenoliths in kimberlites is quite scarce. Presumably this is due to their paucity relative to garnet peridotite xenoliths in kimberlite. Such scarcity is not, however, demonstrated in Colorado-Wyoming xenolith suites where approximately 33 percent of xenoliths collected are spinel peridotites (see Fig. 3). This is contradictory to the speculation of Boyd and MacGregor (1964) that a spinel peridotite layer of the mantle is present beneath the oceanic crust but thins significantly or is absent beneath the continents.

Whole rock chemistry of spinel peridotite xenoliths from the Sloan and Nix kimberlites indicates that these xenoliths are generally similar to spinel peridotite nodules occurring in alkali basalt suites (Ringwood, 1975). TiO_2 , CaO and Na_2O content of Group V spinel peridotites is generally higher and that of Group II is generally lower than the average content of these oxides in spinel peridotite nodules from basalts. Al_2O_3 and Cr_2O_3 contents of Group II and Group V spinel peridotites are very similar to those of spinel peridotites from basalts. Total iron content of the latter is generally greater than that in Sloan-Nix spinel peridotites.

Whole rock and mineral chemistry suggests that Group II and III xenoliths differ from other spinel peridotites found in Colorado-Wyoming kimberlites because they represent material that has been partially melted and the liquid, presumably of basaltic composition, has been removed before the xenoliths were incorporated in the kimberlite and brought to the surface. The spinel peridotites of Group V, including spinel harzburgites, lherzolites and olivine-websterites,

appear to be more primitive, i.e., richer in basaltic constituents than Groups II and III xenoliths. Exceptions to this are the three spinel lherzolites with mosaic porphyroclastic textures that have mineral and bulk chemical compositions very close to those of spinel harzburgites of Group II. It appears that deformation by shearing may be associated with depletion in these xenoliths rather than acting as a mechanism that aids in metasomatic enrichment. In general, Group II and III spinel peridotites appear to be more depleted than spinel peridotite nodules from alkali basalts, and there is little correlation between texture and chemistry among the nodules of these groups.

Olivine-Free Clinopyroxenites, Websterites
and Orthopyroxenites--Groups IV and V

It is generally accepted that olivine-free xenoliths such as those that comprise Group IV form from either recrystallized partial melts or as cumulates from partial melts (O'Hara et al., 1975; Gurney and Harte, 1979; Hatton, 1979). Either source is generally compatible with the relatively common occurrence of phlogopite, sulfides and rutile in these xenoliths, their textural similarity to cumulates, and their bulk and mineral chemistry which indicate enrichment in basaltic constituents relative to xenoliths and minerals of other groups.

The wide range in chemical composition exhibited by olivine-free xenoliths of Groups IV and V could be due to many factors that have an effect on their composition. The chemical and temperature/pressure differences among Group IV and V pyroxenites could be the result of variations in degree of partial melting or early versus late cumulation and settling, possibly from a common melt source. There

seems to be a gradation from the high temperature and pressure garnet orthopyroxenites which could represent a product of a greater degree of partial melting and/or an early formed cumulate, to the lower temperature and pressure xenoliths relatively enriched in Na_2O , CaO and TiO_2 which may represent liquid fractions derived from small degrees of melting or residual liquids left after cumulation and settling of higher temperature, more refractory compositions.

The pressure and temperature conditions under which partial melting occurs will largely determine mineralogy. Brown spinel-bearing (garnet-free) pyroxenites SD2-L164, SD2-W8 and NX4-C10 presumably formed at lower pressures than did most garnet pyroxenites of Groups IV and V, according to the experimental determinations of the garnet/spinel phase boundary (MacGregor, 1970). The orthopyroxene lamellae in clinopyroxene of these xenoliths may have exsolved during cooling. Greater Al_2O_3 content in the lamellae indicate the exsolution took place at pressures lower than those prevailing during primary crystallization of these nodules.

Several pyroxenites of Group IV are very iron rich. Secondary phlogopite, sulfides and grain boundary alteration are present in these xenoliths although they are not a great deal more abundant than in other Group IV and V pyroxenites. Bulk rock iron enrichment appears unrelated to enrichment in other elements, however, clinopyroxenes in these xenoliths contain relatively high levels of Al_2O_3 and TiO_2 and garnets are high in CaO . Metasomatism may have been involved but variations in other conditions of influence such as temperature and pressure also appear to have been responsible for the chemical differences observed in these xenoliths.

Thus the division between Groups IV and V olivine-free xenoliths may be an artificial one. Nearly a full spectrum of conditions of formation and/or reequilibration, hence composition, is exhibited.

Garnet + Spinel Xenoliths--Groups IV and V

Green spinel surrounded by garnet and associated with garnet exsolved from pyroxenes in olivine-free xenoliths of Group IV is similar in composition to spinel reported by Nixon et al. (1978) in alkremite xenoliths from several South African kimberlites. Beeson and Jackson (1970) have made a study of xenoliths with similar textural features in garnet $\pm$ spinel pyroxenite xenoliths from Salt Lake Crater, Hawaii. The occurrence of reddish-brown spinel rimmed by garnet such as that found in peridotite xenoliths of Group V may be quite unique.

Mineral and bulk chemistry of garnet + green spinel pyroxenites of Group IV indicate that these xenoliths are among the richest in FeO and are also high in TiO_2 , CaO, Na_2O and Al_2O_3 and low in Cr_2O_3 . This is generally consistent with derivation by partial melting of garnet peridotite, perhaps via a path similar to that described by Nixon et al. (1978) for alkremite xenoliths but under conditions within the spinel rather than the garnet stability field. Although estimates of pressures and temperatures of equilibration for garnet + green spinel xenoliths are not conclusive due to lack of applicable geothermometers and barometers, garnet + green spinel xenoliths seem to have equilibrated in the upper-most mantle, near granulite facies conditions of the lower crust (Evans and Frost, 1974).

Garnet rimming green spinel in Group IV xenoliths is invariably associated with garnet exsolved from pyroxenes. Elongate

interstitial garnets are present throughout these xenoliths, and nearly completely rim other constituents as well as spinel. Such textures suggest that these xenoliths were originally spinel pyroxenites and that garnet has been derived chiefly or exclusively through exsolution from pyroxene. Garnet rims are not significantly different chemically from garnet exsolution lamellae or other interstitial garnets in these xenoliths, and clinopyroxene grains adjacent to rims around spinel show chemical variations identical to those observed in clinopyroxenes adjacent to garnet exsolution lamellae. However, reconstruction of the original clinopyroxene composition in one garnet + green spinel xenolith from Group IV on the basis that all garnet was derived by exsolution from clinopyroxene, resulted in higher Al_2O_3 than observed in any clinopyroxenes of Colorado-Wyoming xenoliths. Thus, some garnet may have been present in the xenolith before exsolution occurred, or garnet may have been derived from sources other than exsolution (e.g., through reaction between orthopyroxene and spinel; MacGregor, 1970).

Exsolution of garnet from pyroxene may have been caused by a decrease in temperature and/or an increase in pressure (Harte and Gurney, 1975). The exsolution may therefore have occurred during late stages of the emplacement of kimberlite as the xenoliths and surrounding kimberlite cooled. However, the fact that a (green) spinel-bearing pyroxenite (IM20-W5) contains no garnet rims nor exsolved garnet seems to attest against cooling as a cause for garnet's appearance since all such xenoliths underwent cooling but not all developed garnet rims and exsolved garnet. This garnet-free spinel pyroxenite might therefore be used as evidence for an increase in pressure as the cause of the exsolution.

The high Fe character of garnet + green spinel xenoliths of Group IV without relative enrichment of other elements suggests that diffusion associated with exsolution may have been accompanied by infiltration metasomatism particularly of FeO. The high iron character and reequilibrated texture of sample SD2-W10 seems to indicate that it has undergone a quite different sequence of events. Garnet may have been derived largely from exsolution from pyroxenes but this xenolith must have been held for a time at higher temperatures in order to allow for extensive recrystallization to a coarse equant texture.

Garnet rims around brown spinel in xenoliths of Group V do not appear to be directly related to exsolution as is garnet surrounding green spinel in Group IV xenoliths. Garnet that rims brown spinel in several xenoliths of Group V may be associated with garnet exsolved from pyroxenes but more commonly no sign of exsolution is apparent. Pyroxenes that could serve as potential sources of exsolved garnet are generally less abundant in these xenoliths than in garnet + green spinel xenoliths of Group IV. Thus it does not seem likely that garnet rims around brown spinel in Group V xenoliths are entirely exsolution products.

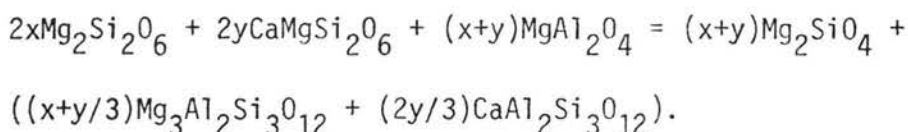
The vermicular habit of the brown spinel and the surrounding garnet in these xenoliths appears generally similar to one that might result upon quenching an interstitial melt. Spinel and garnet would melt only after clinopyroxene, however, and clinopyroxene does not show signs of having been melted.

Sobolev (1977) suggests that textures similar to those in Group V garnet + spinel xenoliths from kimberlites of the USSR are the result of replacement. Edwards (1954) describes grain boundaries

with concave boundaries or "bitten" appearance as observed in minerals adjacent garnet rims as characteristic of replacement. A replacement origin is accepted here as a possibility for the formation of the garnet rims although it is not known what type of source could be responsible for introduction of the garnet into these xenoliths.

The fact that relatively few xenoliths contain spinel rimmed by garnet implies that a selective or restricted mechanism was involved in the derivation of this assemblage. Access of volatiles to certain xenoliths might have fluxed the formation of garnet rims around spinel, however, no evidence such as hydrous mineral phases is present in these nodules to substantiate this suggestion.

The coexistence of garnet and spinel in xenoliths of Group V may be a result of the following reaction proposed by MacGregor (1970, 1974):



Garnet + spinel xenoliths of Group V possibly represent samples from a zone within the mantle characterized by the coexistence of garnet and spinel as postulated by MacGregor (1970). Assuming this to be the case, there is a problem in determining the direction of the reaction.

Evidence that the reaction is proceeding from left to right (pressure decreases and/or temperature increases) includes the following:

(1) The small angular olivine grains present amid the granular garnets of the rims around spinel might represent either products or remnants of incompletely reacted primary grains. The chemical similarity and locally apparent optical continuity between these fragments and nearby coarse olivine grains suggests that they are reactants.

2) Spinel will form at the expense of garnet with an increase in temperature or a decrease in pressure or both (MacGregor, 1974). It seems more likely that peridotite xenoliths might be lifted, possibly by a hot protokimberlite magma, into the lower pressure spinel stability field, rather than forced downward or cooled.

3) The association of garnet exsolved from pyroxenes in spinel + garnet xenoliths SD2-L11 and SD2-L172 indicates that these xenoliths have been subjected to an increase in pressure and/or a decrease in temperature at some time in their history (e.g., upon cooling of the xenolith after kimberlite emplacement). If a decrease in temperature were responsible for the exsolution and for the formation of garnet rims, all of the spinel-bearing peridotites of similar composition should have been effected. Also, late stage FeO metasomatism has been suggested as a possible cause of relative iron enrichment in other xenoliths exhibiting exsolved garnet. If FeO were available during a reaction of spinel to form garnet upon cooling, the small angular olivine grains amid garnet granules would be expected to show some iron enrichment.

Evidence that suggests the reaction is proceeding from right to left (pressure increases and/or temperature decreases) includes the following:

1) If spinel has formed at the expense of garnet, spinel must have replaced garnet from the garnet's core outward. It does not seem likely that spinel would react first at the garnet's core when other studies (e.g., Reid, et al., 1975) show that garnet from lherzolites such as those of Group I breaks down to spinel and orthopyroxene

at garnet grain boundaries to form the common kelyphite alteration product.

2) Olivine fragments enclosed by garnet may not vary in composition from coarser olivine grains in the nodule because there are no other components involved in the reaction (e.g., FeO) that olivine would tend to incorporate, i.e., temperatures and pressures prevailing during reaction may be similar to those that governed the composition of the original, coarse-grained olivine in the nodule, thus primary and reaction-produced olivine compositions are similar.

3) The vermicular habit of spinel in many garnet + spinel peridotites is identical to that in garnet-free spinel peridotites and it appears in several xenoliths that garnet mimics this shape.

4) An increase in pressure rather than a decrease in temperature may be the major cause of the reaction. If these xenoliths represent samples from a zone within the mantle where garnet and spinel can coexist, only small undulations would be required to subject (garnet-free) spinel peridotites such as those of Group V, which are similar to garnet + spinel xenoliths in composition and conditions of formation, to pressure conditions in which garnet is stable.

The evidence appears to favor reaction of spinel and pyroxenes to form garnet and olivine. Further study, however is required before a firm conclusion can be drawn.

Most garnet in (spinel-free) peridotites of Group V is very similar in appearance and chemistry to garnets associated with brown spinel and it is assumed that such xenoliths were originally spinel-bearing. However, Group V garnet wehrlite SD2-L40 is unusual in that its garnets appear similar to spherical garnets of Group I. Mineral

chemistry of this xenolith is similar to that of both Groups I and V as is typical of ilmenite-bearing xenoliths. Temperature and pressure estimates are in the range of Groups IV and V. It is a unique nodule and unique circumstances have evidently been operative in its development. The distinctive high FeO, low MgO character of its garnet and olivine and resulting Fe/Mg partition coefficient between these minerals suggests that either this xenolith was a Group I xenolith, reequilibrated at lower temperature and pressure, or that metasomatism has introduced ilmenite and caused replacement of Mg by Fe, or both.

Group VI Dunites

There are generally two hypotheses concerning the origin of dunites (O'Hara, et al., 1975): 1) they are cumulates from liquids fractionating olivine only; and 2) they represent the residuum after extreme partial melting. Dunite nodules from the Thaba Putsoa kimberlite pipe, South Africa (Boyd and Nixon, 1975) are Fe-rich (Fo_{89}) and also contain significant Ti, Ca and Al. Their chemical nature suggests that they represent cumulates rather than residual dunite. A dunite from the Matsoku kimberlite pipe (Gurney et al., 1975) of composition Fo_{95} exhibited the highest Fo value reported in the rock suite studied and was interpreted as extremely depleted mantle material, as the more refractory Mg is highly enriched over Fe.

Chemistry of olivine from the Sloan 2 kimberlite suggests that both residual and cumulate dunites may be present: the former is represented by olivine of composition Fo_{92-93} while cumulate origin is suggested by olivine of composition Fo_{88-90} .

Euhedral olivine tablets are found only in dunites and Group I garnet lherzolites which suggests that these neoblasts are formed under a restricted set of conditions to which only xenoliths of Groups I and VI have been subjected.

A Comment on the Websterite Group

When mineralogy, chemistry and conditions of formation are considered collectively, the Websterite Group (Group V) is not an inhomogeneous "catch all" category as may have originally appeared. It is composed chiefly of two types of xenoliths--spinel lherzolites and garnet + (brown) spinel peridotites. These are very similar in mineral and bulk composition and are separated by relatively slight temperature (approximately 50°C) and pressure (approximately 5 kb) differences, the latter seemingly having the greatest control on the mineralogical variety present. Most xenoliths of the Websterite Group are bounded by depleted Group II garnet harzburgites at lower temperatures and by Group IV garnet websterites and clinopyroxenites at higher temperatures. Spinel harzburgites that are slightly less depleted than the bulk of Group II xenoliths would plot with Group V as would early formed cumulates or slightly depleted cumulates whose clinopyroxenes and garnets contain more Cr_2O_3 than other xenoliths of Group IV. It thus seems natural that there should be overlap among these chemically related groups of xenoliths that were derived under similar temperature and pressure conditions.

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APPENDICES

APPENDIX I

Appendix I. Results of modal analyses on fresh (vol. %) nodules with coarse equant textures.

	NX4-L1	NX4-L2	NX4-L3	NX4-L4	NX4-L5	NX4-L6	NX4-L9	NX4-L20	SD2-D8	SD2-D25
Olivine	57.2	43.0	36.6	42.3	50.4	25.1	37.7		32.1	86.1
Altered olivine	28.7	40.9	40.9	36.2	31.8	24.7	18.0		5.7	
Orthopyroxene	9.3	1.4	10.5	8.3	4.7	30.2	21.8	14.3	50.1	13.1
Exsolved orthopyroxene										
Altered orthopyroxene	2.2	4.8	1.5	1.9	2.1	7.2	0.3	5.2	5.3	
Clinopyroxene	2.2	7.8	10.3	9.4	6.8	12.0	21.1	67.1		
Altered clinopyroxene	0.4	2.1	0.2	0.4		0.7	9.5			
Garnet							3.5			0.8
Exsolved garnet							0.4			
Altered garnet										
Green spinel										
Brown spinel	trace	trace	trace	1.5	3.8	0.8	0.3			
Altered spinel					0.4					
Phlogopite										
Chromite										
Rutile										
Ilmenite										
Sulfides										
Opaques									6.8*	
Intergranular alt.										
Total pt. count	540	516	543	520	528	510	578	231	529	240

*ilmenite (?)

Appendix I. (Continued). Coarse equant textured nodules.

	SD2- L2	SD2- L3	SD2- L6	SD2- L7	SD2- L8	SD2- L10	SD2- L13	SD2- L15	SD2- L16	SD2- L17	SD2- L18	SD2- L19	SD2- L20	SD2- L21	SD2- L22	SD2- L23	SD2- L24	SD2- L25
Olivine	74.0	69.1	69.6	64.8	64.6	47.7	37.3	54.3	52.9	53.4	54.6	48.4	37.3	47.6	50.4	40.7	72.5	29.0
Altered olivine							2.2	20.9	21.5	21.8	17.8	15.9	15.4	38.6	25.9	20.0	15.3	43.0
Orthopyroxene	25.3	29.1	27.9	33.9	29.2	8.5		20.2	19.9	8.6	10.3	20.8	40.2	2.0	14.9	31.4	6.3	1.0
Exsolved orthopyroxene																		
Altered orthopyroxene								2.6	2.7	0.2	1.6	1.4	2.4	1.4	0.4	2.8		12.0
Clinopyroxene	0.6	1.6	2.5	0.7	4.7	9.9	trace	1.0	0.2	10.5	9.1	8.8	0.2	3.2	3.5	3.9	1.0	0.6
Altered clinopyroxene								0.2		0.3	0.7		0.8					
Garnet						30.0	44.1											
Exsolved garnet																		
Altered garnet							9.0											
Green spinel																		
Brown spinel	0.1	0.2	trace	0.5	1.5	3.8		0.1	0.5	2.7	0.5	0.7	0.2	3.9	3.9		0.7	0.3
Altered spinel														0.8				
Phlogopite																		
Chromite																		
Rutile																		
Ilmenite																		
Sulfides																		
Opaque																		
Intergranular alt.							7.2	0.6	1.8	2.5	0.7	4.6	3.9	4.1	1.8	0.9	1.1	4.2
																		14.1
Total pts. count	659	567	767	430	548	679	222	683	563	408	580	283	415	492	228	459	287	707

Appendix I. (Continued). Coarse equant nodules.

	SD2- L28	SD2- L31	SD2- L32	SD2- L34	SD2- L35	SD2- L37	SD2- L38	SD2- L39	SD2- L40	SD2- L42	SD2- L46	SD2- L47	SD2- L50	SD2- L51	SD2- L54	SD2- L55	SD2- L58
Olivine	7.8	49.0	58.1	68.6	56.0	28.6	48.3	38.1	40.9						39.4	65.8	44.6
Altered Olivine	1.7	18.5	9.9	12.8	12.9	10.6	32.5	15.0	23.4						18.3	26.6	23.5
Orthopyroxene	54.4	24.7	15.7	10.5	20.1	44.4	12.7	13.2	1.2	1.5				1.5	16.0	3.1	11.1
Exsolved orthopyroxene																	
Altered orthopyroxene	1.4	4.1	0.2	1.1	1.7	5.6	3.3	2.1	0.6						8.3	0.6	1.8
Clinopyroxene	9.6	0.9	1.4	3.5	6.6	8.7	2.2	3.6	26.3	53.5	55.0	46.9	46.9	63.7	9.9	1.1	10.8
Altered clinopyroxene			0.2			0.7	3.4	0.2	2.3	2.8		3.4			0.2		3.5
Garnet	2.3		11.8					24.5	4.7	27.8	44.6	20.4	53.1	34.8	7.3		
Exsolved garnet																	
Altered garnet			1.2					1.3	0.3	11.1		17.5			0.5		
Green spinel																	
Brown spinel	17.4	0.5		1.2	0.2	1.2		2.1								0.8	2.9
Phlogopite																	
Chromite																	
Rutile								trace		0.2	0.3	0.7	trace				
Ilmenite									0.3								
Sulfides										0.2		0.5	trace				
Opaque																	
Intergranular alt.	0.3	2.3	1.4	3.5	2.3		0.7			2.9		10.7				2.0	1.8
Total pts. count	345	778	415	86	471	426	584	559	342	686	257	411	232	430	436	357	341

Appendix I. (Continued). Coarse equant nodules.

	SD2- L59	SD2- L62	SD2- L64	SD2- L65	SD2- L68	SD2- L70	SD2- L71	SD2- L72	SD2- L73	SD2- L74	SD2- L77	SD2- L78	SD2- L79	SD2- L80	SD2- L81	SD2- L86	SD2- L88	SD2- L90
Olivine	40.5	62.1	65.3	47.4		28.3	49.2	36.7	49.8	48.7								50.0
Altered Olivine	6.9	18.7	12.1	12.3		38.4	29.3	13.6	18.9	8.3								23.7
Orthopyroxene	29.0	10.6	13.7	33.5	33.6	14.8	14.7	23.7	24.4	31.8		1.5	23.2	8.7	23.1	25.0	22.9	19.8
Exsolved orthopyroxene																		
Altered orthopyroxene	1.0	1.3	0.5	5.9	9.8	1.6	1.8	5.0	4.4	0.8		0.1	0.6	3.2	4.3	6.4	0.9	4.7
Clinopyroxene	2.5	1.5	6.3		4.7	12.5	8.9	14.0	0.6	8.6	55.0	34.4	23.4	21.4	6.7	12.9	25.4	0.9
Altered clinopyroxene		0.2	0.2		1.4	2.4	0.4	2.0			1.3	4.9	0.1	8.4	0.5	3.6	0.8	0.4
Garnet	15.0	2.9			31.8			3.0			33.4	35.4	32.9	17.9	37.7	34.3	30.2	30.2
Exsolved garnet																		
Altered garnet	4.4	0.6			10.3			1.3			2.8	6.6	16.4	18.2	7.2	13.6	16.4	
Green spinel																		
Brown spinel	0.7		1.8	0.9		0.5	0.4		0.9	1.9								0.5
Altered spinel																		
Phlogopite											trace	trace	trace					
Chromite		trace																
Rutile											0.2	0.3	0.3	0.5	0.9		0.3	
Ilmenite																		
Sulfides														0.4			0.3	
Opaque							0.2						0.1					
Intergranular alt.		2.0			8.4	1.4	0.7	0.6	0.8		7.4	16.8	2.2	21.3	19.5	4.3	2.7	0.2
Total pts. counted	407	940	825	424	214	424	838	536	630	374	611	987	718	793	554	140	916	1149

Appendix 1. (Continued). Coarse equant nodules.

	SD2- L95	SD2- L97	SD2- L102	SD2- L104	SD2- L106	SD2- L109	SD2- L121	SD2- L125	SD2- L126	SD2- L129	SD2- L134	SD2- L137	SD2- L138	SD2- L139	SD2- L148	SD2- L151	SD2- L152	SD2- L154
Olivine	45.8	50.0	56.6				43.0	33.8	62.3	49.0	40.8	53.6	46.2	37.0	38.6	26.1	12.5	47.8
Altered olivine	23.2	14.7	23.6				12.5	19.2	18.2	20.2	19.1	18.6	25.7	12.0	43.6	45.0	5.4	24.2
Orthopyroxene	11.0	9.4	4.2				6.0	17.6	9.5	23.8	23.9	5.9	9.4	15.7	3.3	11.3	25.6	6.8
Exsolved orthopyroxene																		
Altered orthopyroxene	2.4	0.2	2.1				0.9	2.7	1.2	1.3	5.8	0.7	2.5	1.3	0.6	2.2	3.6	1.2
Clinopyroxene	6.2	4.1	1.6	53.4	66.1	51.1	11.5	7.4	6.8	5.3	8.4	20.3	16.3	28.0	7.8	13.5	4.6	19.1
Altered clinopyroxene	1.7		0.4	5.6	0.6	4.5	0.2	0.6	0.5	0.1	0.3	0.5		0.9	1.7	1.8	0.3	0.7
Garnet		16.5	7.6	31.3	28.1	23.3	22.9								4.2		32.7	
Exsolved garnet																		
Altered garnet		4.5	1.6	5.0	5.2	10.9	0.7								0.1		7.8	
Green spinel																		
Brown spinel	1.6	0.6					2.3	0.4	0.7	0.1	1.7	0.2	trace	4.9		trace	7.5	0.2
Altered spinel								1.8				0.1						
Phlogopite						trace												
Chromite			trace															
Rutile				trace														
Ilmenite																		
Sulfides				0.3	trace	4.8												
Opaque									0.7	0.1								
Intergranular alt	8.1		2.5	4.4		6.2		16.5										
Total pts counted	629	532	765	339	363	403	433	699	411	698	703	816	448	788	691	222	774	414

Appendix I. (Continued). Coarse equant nodules.

	SD2- L156	SD2- L159	SD2- L161	SD2- L162	SD2- L163	SD2- L164	SD2- L166	SD2- L168	SD2- L170	SD2- L178	SD2- L179	SD2- L180	SD2- L181
Olivine	34.9	16.4	39.5	59.5			60.8	41.4	47.4	29.4	51.4	60.2	55.5
Altered olivine	11.2	10.7	32.3	33.6			20.9	25.3	21.1	18.9	25.3	22.2	31.8
Orthopyroxene	33.0	38.3	7.0		0.8	5.4	14.7	18.7	21.2	38.0	17.9	3.5	7.5
Exsolved orthopyroxene						2.7							
Altered orthopyroxene	3.0	2.4	2.3		1.2	0.7	2.6	6.6	2.1	2.2	3.8	0.4	2.5
Clinopyroxene	16.2	18.0	16.4	5.7	78.1	86.9	0.6	3.0	5.7	9.2	1.3	11.9	1.0
Altered clinopyroxene		0.2	1.8	1.1	1.0	3.2		0.2	0.5			0.6	
Garnet					15.1								0.9
Exsolved garnet													
Altered garnet					3.8								0.7
Green spinel													
Brown spinel	1.7	13.7	0.7			1.1	0.3	4.6	2.0	2.4	0.3	1.2	
Altered spinel		0.2					0.1	0.2					
Phlogopite													
Chromite													
Rutile													
Ilmenite													
Sulfides													
Opakes													
Intergranular alt.													
Total pts counted	464	532	440	262	502	567	722	667	802	371	609	487	796

Appendix I. (Continued). Coarse equant nodules.

	SD2-L183	SD2-L184	SD2-L185	SD2-L186	SD2-L188	SD2-L189	SD2-P1	SD2-W6	SD2-W7	SD2-W11
Olivine	30.3	54.3	48.9	58.1	51.3	25.4	52.3			
Altered olivine	48.5	18.6	15.9	13.3	25.3	9.2	5.6			
Orthopyroxene	4.0	15.9	6.9	9.9	18.6	23.0	17.0	4.9	4.4	48.5
Exsolved orthopyroxene										
Altered orthopyroxene	13.5	3.3	3.2	1.3	3.7	3.3	0.7	0.8	1.1	28.0
Clinopyroxene	2.5	4.9	7.5	6.2		19.5		61.2	51.3	22.5
Altered clinopyroxene		0.5	0.2					1.9	5.9	1.0
Garnet			15.7	8.8	1.1	16.9	20.9	25.8	30.5	
Exsolved garnet										
Altered garnet			1.3	0.6		0.9	1.5	5.4	6.8	trace
Green spinel										
Brown spinel	1.1	2.1	0.3	1.8		1.8				
Altered spinel		0.4								
Plagioclase							0.7			
Chromite										
Rutile										
Ilmenite										
Sulfides							1.3			
Opakes										
Intergranular alt.										
Total pts. counted	445	571	597	616	538	544	604	485	524	404

Appendix I. (Continued). Nodules with tabular textures; nodules with transitional-porphyroclastic textures.

	Tabular textures				Transitional-porphyroclastic textures							
	SD2- L5	SD2- L82	SD2- L87	SD2- L188	SD2- L4	SD2- L9	SD2- L27	SD2- L60	SD2- L66	SD2- L75	SD2- L76	SD2- L96
Olivine	75.7			51.3	51.6	47.0	39.4	2.8	46.0	83.7	43.4	54.4
Altered olivine				25.3	25.1	33.2	56.9	40.1	23.5	9.5	18.4	12.8
Orthopyroxene	23.0	23.1	27.2	18.6	8.6	9.3	2.9	10.4	8.2	5.4	17.3	20.2
Exsolved orthopyroxene												
Altered orthopyroxene		17.5	0.7	3.7	4.9	1.9	0.8	7.2	0.5		4.2	3.1
Clinopyroxene	0.2	2.3	26.3			7.0		1.8	12.8		1.9	6.3
Altered clinopyroxene			0.1			0.6		0.3	0.5		1.1	1.0
Garnet		41.4	29.1	1.1	5.0				5.1	0.7		
Exsolved garnet												
Altered garnet		11.6	13.6		2.4				0.8	0.7		
Green spinel												
Brown spinel	1.0					0.9						2.2
Altered spinel												
Phlogopite			trace									
Chromite												
Rutile												
Ilmenite												
Sulfides												
Opaque			0.1						0.3			
Intergranular alt.		4.2	2.9		2.4	0.1		37.3	2.2		13.6	
Total pts counted	552	527	760	538	593	979	588	340	587	147	359	687

Appendix I. (Continued). Transitional-porphyroclastic nodules.

	SD2- L98	SD2- L99	SD2- L100	SD2- L101	SD2- L103	SD2- L123	SD2- L127	SD2- L128	SD2- L130	SD2- L149	SD2- L150	SD2- L160	SD2- L167
Olivine	59.9	40.7	50.0	42.0	55.8	77.8	55.5	37.4	38.6	35.7	8.7	36.2	46.1
Altered olivine	20.2	32.4	30.2	42.3	26.4	17.7	12.4	12.5	14.2	30.5		29.0	24.1
Orthopyroxene	11.2	15.8	11.1	8.4	11.9	2.0	21.4	36.4	4.3	23.3	25.0	13.0	15.9
Exsolved orthopyroxene													
Altered orthopyroxene	3.1	6.5	4.0	6.2	4.3	0.5	1.2	1.5	0.7	2.0			2.6
Clinopyroxene	0.8		2.7	0.4	0.2	0.9	8.1	8.5	21.5	6.8	64.6	18.2	9.3
Altered clinopyroxene	0.2		0.2	0.3		0.1		0.2	1.5	0.4		0.3	1.1
Garnet	1.5		1.1	0.2		0.9			11.1				
Exsolved garnet						0.1							
Altered garnet	1.2		0.6	0.2					0.5				
Green spinel													
Brown spinel		0.8*					0.9	1.3	0.4	1.3		3.3	0.7
Altered spinel								0.2					0.2
Phlogopite													
Chromite			0.1										
Rutile													
Ilmenite											1.6		
Sulfides													
Opaque								0.5	0.9				
Intergranular alt.	1.9	4.8			1.4		0.4	1.4	6.1				
Total pts counted	519	398	1212	963	586	787	971	847	805	544	184	362	536

*Probably Secondary

Appendix I. (Continued). Transitional-porphyroclastic; nodules with porphyroclastic textures.

	Transitional-porphyroclastic							Porphyroclastic					
	SD2- L169	SD2- L171	SD2- L174	SD2- L175	SD2- L176	SD2- L177	SD2- H13	SD2- L2	SD2- L57	SD2- L61	SD2- L69	SD2- L120	SD2- L133
Olivine	53.5	53.1	39.5	35.1	61.2	52.2	73.6	66.4	49.1	12.4	50.5	58.3	40.6
Altered olivine	20.6	21.2	12.7	15.4	23.1	21.2	17.1		23.5		33.1	15.1	3.3
Orthopyroxene	19.3	18.9	20.6	26.8	4.8	11.0	2.4	25.7	17.8	52.9	8.0	12.6	30.2
Exsolved orthopyroxene													
Altered orthopyroxene	4.1	3.8	1.2	3.5	1.2	2.0	1.9		2.0	1.0	4.7	1.7	0.4
Clinopyroxene		1.9	16.8	16.0	7.5	11.7		6.4	1.6	14.1	0.8	1.1	1.8
Altered clinopyroxene			0.3	0.2	0.7	0.9						0.3	
Garnet	1.1						4.3				1.4	7.6	4.4
Exsolved garnet													
Altered garnet	1.3						0.6						
Green spinel											1.5	3.4	19.2
Brown spinel		1.1	8.3	2.7	1.4	1.0		1.0	3.8	4.2			
Altered spinel			0.6	0.4									
Plagioclase													
Chromite													
Rutile													
Ilmenite													trace
Sulfides													
Opaque								0.5					
Intergranular alt.									2.2	15.5			
Total pts counted	533	1014	730	564	415	693	700	860	848	524	921	357	542

Appendix I. (Continued). Nodules with mosaic-porphyroclastic textures; nodules with porphyroblastic-coarse textures; nodules with porphyroblastic-granuloblastic textures.

	Mosaic-Porphyroclastic			Porphyroblastic-Coarse						Porphyroblastic-granuloblastic			
	SD2- L91	SD2- L92	SD2- L93	SD2- L41	SD2- L44	SD2- L48	SD2- L52	SD2- L83	SD2- L84	SD2- L43	SD2- L49	SD2- L89	SD2- W8
Olivine	38.5	42.2	42.0										
Altered olivine	7.8	14.8	13.5										
Orthopyroxene	41.0	26.8	29.4	12.7	35.2	6.9	10.5	3.3	21.7	8.0		7.6	17.7
Exsolved orthopyroxene													10.0
Altered orthopyroxene	5.0	2.6	6.4	0.4	2.2		0.7	1.4	2.0	0.5			7.0
Clinopyroxene	5.7	10.6	4.2	21.4	4.2	39.6	38.1	32.9	15.7	52.0	41.8	45.9	60.6
Altered clinopyroxene	0.4	1.6	0.7	0.5		1.2	1.1	1.4	0.4	1.0	2.3	0.3	2.9
Garnet				48.6	43.2	36.2	27.8	46.7	43.5	9.2	29.8	14.7	
Exsolved garnet													
Altered garnet				13.4	11.5	14.6	11.7	10.7	7.1	9.8	19.2	15.3	
Green spinel													
Brown spinel	1.6	1.5	2.8										1.7
Altered spinel													
Phlogopite							0.9					3.1	
Chromite													
Rutile					0.2					0.3	0.4	1.4	
Ilmenite													
Sulfides				0.3		0.2	0.4			0.8	2.2	0.6	
Opaque													
Intergranular alt.			1.0	2.7	3.4	1.3	8.8	3.6	9.6	18.4	4.1	11.0	
Total pts counted	766	616	578	560	548	904	982	638	715	400	724	353	345

Appendix I. (Continued). Nodules with textures dominated by exsolution.

	HX4- L7	SD2- L11	SD2- L111	SD2- L112	SD2- L113	SD2- L114	SD2- L115	SD2- L132	SD2- L172	SD2- L173	SD2- W9	SD2- W10
Olivine		26.1							30.2			
Altered olivine		17.8							9.7			
Orthopyroxene	14.8	28.2	13.7	8.4	20.7	8.2		35.2	24.7	10.6	2.4	3.4
Exsolved orthopyroxene			1.2	5.6	1.5		9.9			0.6	4.0	
Altered orthopyroxene	2.4	4.1	0.8		0.9	0.3		0.4	2.2		1.9	0.2
Clinopyroxene	40.2	1.8	46.1	62.9	54.0	31.4	75.0	35.3	8.5	62.8	74.6	69.3
Altered clinopyroxene	0.4				1.1	1.7		1.6		0.7	1.6	0.4
Garnet	23.7	6.7	11.3	14.4	15.3	9.2	11.7	20.6	15.7	15.9	7.8	24.9
Exsolved garnet	4.8	4.8	5.7	8.6	2.0	4.5	3.4	3.4	1.7	3.3	5.0	trace
Altered garnet	1.3	1.2	0.2		1.6			3.7	1.6		1.7	1.7
Green spinel	11.1		10.1	trace		34.5				4.4		trace
Brown spinel		4.5							5.5		1.0	
Altered spinel	1.3	0.3				6.2				0.7		
Phlogopite												
Chromite												
Rutile												
Ilmenite												
Sulfides												
Opaque			0.3			0.7			0.1			
Intergranular alt.		4.5	10.5		0.9	3.1						
Total pts counted	540	779	1470	556	816	576	324	984	689	549	578	522

APPENDIX II

MINERAL CHEMISTRY

Mineral analyses are arranged by Group (see text for explanation), then in alphanumeric order unless otherwise specified.

ABBREVIATIONS:

CHR	Chromite
CPX	Clinopyroxene
GAR, GT	Garnet
IL, ILM	Ilmenite
MIC	Mica
OL, OLV	Olivine
OPX	Orthopyroxene
PHLOG	Phlogopite
RU	Rutile
SPN	Spinel group minerals

APPENDIX II
GROUP I NODULES
SLOAN KIMBERLITES

	MN2-I	1 MN2-I	1 SD2-D	8 SD2-D	8 SD2-D	25 SD2-D	25 SD2-D	25 SD2-D	25 SD2-D	13 SD2-H	13 SD2-H	13 SD2-H	13 SD2-H	4 SD2-I	4 SD2-I	4 SD2-I	4 SD2-I	27 SD2-I	27
	GAR	SPH	OL	OPX	GAR	OL	OPX	GAR	OL	OPX	GAR	OL	OPX	OL	OPX	OL	OPX		
SiO2	41.96	.07	40.48	56.15	40.95	40.67	57.39	39.89	40.71	57.27	40.11	41.84	53.42	40.89	57.21				
TiO2	.04	.02	.10	.26	1.34	0.00	.38	.60	.08	.10	.72	0.00	.08	0.00	.16				
Al2O3	16.60	9.02	0.00	.99	15.60	0.00	.79	12.76	0.00	.64	11.06	0.00	.70	0.00	.68				
Cr2O3	9.00	56.34	0.00	.32	8.67	0.00	.40	13.46	.01	.60	15.26	.10	.75	0.00	.44				
FeO	7.20	19.46	9.89	6.79	7.37	9.56	5.16	6.74	8.06	4.88	6.54	7.98	4.80	7.81	4.72				
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
MnO	.51	.38	.16	.12	.55	.14	.14	.75	.07	.21	.38	.09	.15	.12	.13				
NiO	.15	.16	.34	.03	.01	.48	.15	.07	.34	.07	0.00	.38	.08	.41	.12				
MgO	18.34	12.29	50.12	34.30	19.71	50.65	34.61	18.41	51.57	35.12	18.24	51.72	35.75	51.33	34.74				
CaO	7.34	0.00	.02	.71	6.80	0.00	.98	8.14	.06	1.00	8.54	.06	.87	.06	1.02				
Na2O	.01	0.00	.07	.12	.11	.04	.27	.12	.04	.30	.07	.05	.72	.06	.23				
K2O	0.00	0.00	0.00	.01	0.00	0.00	0.00	.03	0.00	.01	0.00	0.00	0.00	0.00	0.00				
TOTAL	101.15	97.74	101.18	99.80	101.11	101.54	100.27	100.97	100.94	100.20	100.92	102.22	101.82	100.68	99.45				
Si	3.039	.001	.984	1.951	1.487	.984	1.971	1.479	.983	1.968	2.974	.996	1.969	.989	1.976				
Ti	0.000	0.000	.002	.007	.037	0.000	.010	.017	.002	.003	.039	0.000	.002	0.000	.004				
Al	1.415	.353	0.000	.040	.668	0.000	.032	.558	0.000	.026	.966	0.000	.027	0.000	.028				
Cr	.514	1.481	0.000	.009	.749	0.000	.011	.395	0.000	.016	.894	.001	.020	0.000	.012				
Fe2+	.436	.540	.201	.198	.224	.193	.148	.209	.163	.140	.222	.158	.108	.158	.136				
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.122	0.000	.026	0.000	.000				
Mn	.029	.010	.003	.003	.017	.003	.004	.023	.002	.006	.021	.001	.004	.002	.004				
Ni	.008	.003	.007	.001	0.000	.009	.004	.002	.007	.002	0.000	.007	.002	.410	.003				
Mg	1.979	.608	1.816	1.778	1.067	1.827	1.773	1.018	1.857	1.890	2.015	1.834	1.796	1.851	1.790				
Ca	.569	0.000	.001	.026	.265	0.000	.036	.324	.002	.037	.676	.001	.030	.002	.038				
Na	0.000	0.000	.003	.008	.608	.002	.018	.009	.002	.020	.008	.002	.014	.003	.015				
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	.001	0.000	0.000	0.000	0.000	0.000				
CATIONS	7.989	2.996	3.017	4.021	4.022	3.018	4.007	4.035	3.018	4.019	7.997	3.000	3.998	3.415	4.006				
HG/HG+FE	.819	.530	.900	.900	.826	.904	.923	.830	.919	.928	.877	.921	.943	.921	.929				
CA/CA+MG	.223	0.000	.001	.014	.199	0.000	.020	.241	.001	.020	.251	.001	.016	.001	.021				
CR/CR+AL	.266	.808	0.000	.184	.272	0.000	.256	.414	0.000	.381	.481	1.000	.426	0.000	.300				

	SD2-L 69	SD2-L 69	SD2-L 69	SD2-L 69	SD2-L 69	SD2-L 69	SD2-L 69	SD2-L 69	SD2-L 75	SD2-L 75	SD2-L 75	SD2-L 76	SD2-L 76	SD2-L 76
	CPX	OPX	GAR	OL	CPX	GAR	OL	OPX	GAR	OL	OPX	GAR	OL	OPX
SiO2	54.55	57.10	40.03	40.30	54.50	40.97	41.25	58.00	41.15	40.82	56.98	41.41	40.81	57.84
TiO2	.05	.02	.76	.02	.36	1.18	.03	.19	1.20	.05	.29	.29	.05	.09
Al2O3	1.10	.56	12.14	.02	1.72	14.70	.02	.82	16.10	0.00	.72	18.12	0.00	.60
Cr2O3	.95	.24	13.31	.08	2.05	9.11	.07	.51	8.59	0.00	.43	7.05	0.00	.30
FeO	2.74	5.45	6.50	7.95	3.25	7.60	9.07	5.54	7.99	9.82	5.88	6.57	7.66	4.73
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.04	.11	.36	.12	.12	.36	.15	.14	.56	.13	.10	.44	.08	.14
NiO	.03	.05	0.00	.34	.05	0.00	.37	.10	.02	.42	.17	0.00	.33	.10
MgO	19.42	35.21	18.18	49.70	18.30	19.03	50.48	34.80	19.11	49.63	34.39	20.42	51.52	36.06
CaO	20.84	.79	8.54	.04	17.55	7.03	.05	.94	6.41	.07	.94	5.90	.03	.61
Na2O	.87	.13	.01	.01	1.64	.10	.06	.24	.07	.08	.21	.01	.05	.15
K2O	.06	.02	0.00	0.00	.03	0.00	0.00	0.00	0.00	0.00	.01	0.00	.01	.01
TOTAL	100.65	99.68	99.83	98.58	99.57	100.08	101.55	101.28	101.20	101.02	100.12	100.21	100.54	100.63
Si	1.962	1.972	2.993	.995	1.972	3.014	.993	1.974	2.985	.992	1.967	1.494	.987	1.972
Ti	.001	0.000	.042	0.000	.009	.064	0.000	.004	.066	.001	.007	.008	.001	.003
Al	.047	.022	1.068	0.000	.073	1.274	0.000	.033	1.378	0.000	.029	.771	0.000	.024
Cr	.027	.006	.785	.001	.058	.529	.001	.013	.493	0.000	.012	.201	0.000	.008
Fe2+	.082	.158	.406	.164	.098	.466	.182	.157	.485	.200	.170	.198	.155	.135
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.001	.003	.021	.002	.003	.021	.003	.004	.035	.002	.003	.014	.002	.004
Ni	.001	.002	0.000	.006	.001	0.000	.007	.002	.001	.003	.005	0.000	.006	.003
Mg	1.042	1.814	2.025	1.830	.986	2.086	1.813	1.765	2.068	1.798	1.771	1.100	1.858	1.833
Ca	.804	.028	.682	0.000	.681	.553	.001	.034	.498	.002	.035	.228	.001	.022
Na	.060	.009	0.000	0.000	.114	.013	.002	.016	.009	.004	.014	.002	.002	.010
K	.003	.002	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.030	4.016	8.022	2.998	3.996	8.020	3.002	4.002	8.018	3.007	4.013	4.016	3.012	4.014
MG/MG+FE	.927	.920	.833	.918	.910	.817	.909	.918	.810	.900	.912	.847	.923	.931
CA/CA+MG	.436	.015	.252	0.000	.409	.210	.001	.019	.194	.001	.019	.172	.001	.012
CR/CR+AL	.365	.214	.424	1.000	.443	.293	1.000	.283	.263	0.000	.293	.207	0.000	.250

	SD2-L 98	SD2-L 98	SD2-L 98	SD2-L 98	SD2-L100	SD2-L100	SD2-L100	SD2-L100	SD2-L101	SD2-L101	SD2-L101	SD2-L101	SD2-L102	SD2-L102	SD2-L102
	CPX	GAR	OL	OPX	CPX	GAR	OL	OPX	CPX	GAR	OL	OPX	CPX	GAR	OL
SiO2	54.69	40.28	40.48	56.46	54.64	39.93	41.23	57.16	55.34	39.90	40.43	56.85	54.70	41.49	40.99
TiO2	.43	1.48	.04	.29	.22	.89	.05	.11	.18	.88	0.00	.12	.07	.16	0.00
Al2O3	1.56	14.21	0.00	.70	1.38	12.12	.05	.76	1.40	12.44	.02	.73	1.91	19.52	.02
Cr2O3	1.93	9.96	0.00	.40	2.46	12.87	.09	.65	2.52	12.71	.07	.66	1.96	5.07	0.00
FeO	3.68	8.61	9.98	6.32	2.78	6.76	8.12	4.82	2.86	6.94	8.24	5.04	2.32	7.15	8.09
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.18	.63	.09	.07	.17	.37	.11	.14	.12	.41	.13	.14	.12	.36	.12
NiO	.10	.08	.48	.17	.06	0.00	.35	.11	.09	0.00	.38	.09	.05	0.00	.35
MgO	18.41	18.74	49.85	33.94	18.52	18.38	51.46	35.43	18.52	18.26	50.34	34.93	17.27	20.69	50.70
CaO	17.57	7.71	.08	.90	18.05	8.08	.05	.95	17.73	8.05	.05	.93	19.70	5.15	.04
Na2O	1.72	.11	.05	.25	1.51	.15	0.00	.24	1.54	.11	.02	.18	1.71	.05	0.00
K2O	.03	0.00	0.00	.01	.04	0.00	0.00	0.00	.04	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	100.30	101.31	101.05	99.51	99.83	99.55	101.51	100.37	100.34	99.70	99.68	99.67	99.81	99.64	100.31
Si	1.972	2.959	.986	1.965	1.975	2.995	.988	1.961	1.987	2.987	.990	1.963	1.979	2.991	.995
Ti	.012	.082	.001	.008	.005	.048	0.000	.002	.004	.048	0.000	.003	.001	.008	0.000
Al	.067	1.231	0.000	.029	.058	1.069	.001	.030	.059	1.096	0.000	.029	.081	1.658	0.000
Cr	.055	.579	0.000	.011	.070	.761	.001	.017	.070	.751	.001	.017	.055	.288	0.000
Fe2+	.111	.529	.204	.184	.083	.422	.162	.138	.085	.433	.168	.145	.070	.429	.164
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.005	.039	.002	.002	.004	.022	.002	.003	.003	.024	.002	.004	.003	.021	.002
Ni	.003	.005	.010	.005	.001	0.000	.006	.002	.002	0.000	.007	.002	.001	0.000	.006
Mg	.990	2.053	1.810	1.762	.997	2.053	1.839	1.812	.990	2.036	1.836	1.798	.931	2.223	1.833
Ca	.679	.568	.002	.033	.699	.649	0.000	.034	.682	.644	0.000	.034	.763	.397	0.000
Na	.120	.016	.002	.017	.105	.020	0.000	.016	.106	.015	0.000	.011	.120	.006	0.000
K	.001	0.000	0.000	0.000	.001	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.015	8.061	3.017	4.016	3.998	8.039	2.999	4.015	3.989	8.034	3.004	4.006	4.004	8.021	3.000
MG/MG+FE	.899	.795	.899	.905	.923	.829	.919	.929	.921	.825	.916	.925	.930	.838	.918
CA/CA+MG	.407	.217	.001	.018	.412	.240	0.000	.018	.408	.240	0.000	.019	.450	.152	0.000
CR/CR+AL	.451	.320	0.000	.275	.547	.416	.500	.362	.543	.407	1.000	.370	.404	.148	0.000

	SD2-L102	SD2-L102	SD2-L103	SD2-L103	SD2-L120	SD2-L120	SD2-L120	SD2-L123	SD2-L123	SD2-L123	SD2-L133	SD2-L133	SD2-L133	SD2-L133
	OPX	SPH	OL	OPX	GAR	OL	OPX	GAR	OL	OPX	CPX	GAR	OL	OPX
SiO2	57.38	.14	41.05	57.32	41.34	41.37	56.08	40.77	41.92	56.63	54.80	42.09	41.50	57.95
TiO2	.04	.75	.02	.05	.52	0.00	.17	.70	0.00	.03	.14	.64	0.00	.07
Al2O3	.72	11.81	0.00	.66	20.41	0.00	.68	14.73	0.00	2.56	1.48	17.42	.04	.89
Cr2O3	.30	55.25	0.00	.44	3.50	.04	.25	10.05	.07	.68	.96	6.79	.11	.43
FeO	4.79	1.46	7.86	4.78	7.32	9.31	5.54	6.87	8.06	4.73	3.42	6.68	8.25	4.96
Fe2O3	0.00	43.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.13	.31	.15	.13	.35	.09	.14	.36	.12	.14	.10	.32	.10	.14
NiO	.06	0.00	.25	.17	0.00	.42	.13	.04	.42	.09	.06	.04	.35	.07
MgO	35.81	12.60	51.59	35.66	21.41	48.27	35.76	20.17	49.21	35.91	19.61	20.06	49.93	34.45
CaO	.53	0.00	.07	1.00	5.05	.04	.68	6.71	.06	.45	17.90	6.13	.09	1.19
Na2O	.07	.01	.01	.14	.05	.01	.14	.05	.02	.03	.97	.04	.02	.14
K2O	0.00	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	.01	.03	0.00	0.00	0.00
TOTAL	99.83	125.48	101.00	100.36	99.95	99.55	99.57	100.45	99.88	101.26	99.47	100.21	100.39	100.29
Si	1.970	.003	.989	1.965	2.960	1.015	1.945	2.982	1.018	1.922	1.979	3.034	1.006	1.983
Ti	.001	.018	0.000	.002	.027	0.000	.004	.039	0.000	.001	.003	.034	0.000	.001
Al	.028	.454	0.000	.027	1.723	0.000	.027	1.269	0.000	.102	.063	1.479	0.000	.035
Cr	.008	1.426	0.000	.012	.197	0.000	.006	.580	.001	.018	.026	.387	.001	.011
Fe2+	.137	.399	.158	.136	.437	.190	.160	.418	.163	.133	.103	.402	.167	.141
Fe3+	0.000	.076	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.003	.008	.003	.004	.021	.001	.004	.021	.002	.004	.002	.019	.001	.003
Ni	.001	0.000	.005	.004	0.000	.008	.003	.002	.008	.002	.001	0.000	.005	.002
Mg	1.833	.613	1.854	1.822	2.284	1.766	1.849	2.198	1.783	1.816	1.056	2.156	1.804	1.757
Ca	.019	0.000	.002	.038	.386	0.000	.024	.526	.001	.016	.692	.472	.002	.043
Na	.004	0.000	0.000	.009	.006	0.000	.009	.006	0.000	.001	.067	.004	0.000	.009
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000
CATIONS	4.004	2.997	3.011	4.019	8.041	2.980	4.031	8.041	2.976	4.015	3.993	7.987	2.987	3.985
MG/MG+FE	.930	.606	.921	.931	.839	.903	.920	.840	.916	.932	.911	.843	.915	.926
CA/CA+MG	.010	0.000	.001	.020	.145	0.000	.013	.193	.001	.009	.396	.180	.001	.024
CR/CR+AL	.722	.759	0.000	.308	.103	0.000	.182	.314	1.000	.150	.292	.207	1.000	.239

	SD2-L150	SD2-L150	SD2-L150	SD2-L162	SD2-L162	SD2-L169	SD2-L169	SD2-L169	SD2-L188	SD2-L188	SD2-W 11	SD2-W 11	SD3- 2	SD3- 2
	CPX	OPAQ	OPX	CPX	OL	GAR	OL	OPX	OL	OPX	CPX	OPX	CPX	GAR
SiO2	53.83	.09	56.54	55.12	41.62	39.76	40.60	56.03	41.17	58.50	54.40	57.71	54.92	41.80
TiO2	.35	55.23	.15	.22	.01	.21	.03	0.00	0.00	.10	.38	.23	.19	.59
Al2O3	1.83	.12	1.05	1.32	0.00	12.93	0.00	.58	0.00	.70	1.85	.73	1.63	19.31
Cr2O3	.72	8.36	.13	2.28	0.00	14.15	0.00	.51	0.00	.48	.83	.17	1.00	4.29
FeO	3.60	23.68	6.30	2.26	8.08	6.71	7.87	4.91	7.52	4.35	4.00	6.39	3.03	7.00
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.20	.46	0.00	.17	.19	.58	.06	.22	.15	.15	.16	.18	.15	.32
NiO	.03	.20	0.00	.07	.34	.10	.32	.17	.35	.08	.04	.08	.06	0.00
MgO	17.72	13.90	33.61	17.13	50.90	18.03	51.03	35.23	50.77	35.05	18.91	33.59	19.02	20.79
CaO	19.35	.04	.93	20.08	.02	8.34	.08	.88	.07	.96	17.58	1.07	18.50	5.53
Na2O	1.59	.05	.14	1.84	.02	.07	.03	.13	.01	.19	1.72	.22	1.13	.04
K2O	.05	.03	0.00	.06	0.00	0.00	0.00	0.00	0.00	0.00	.03	.01	.03	0.00
TOTAL	99.27	102.16	98.85	100.55	101.18	100.88	100.02	98.66	100.04	100.56	99.90	100.38	99.66	99.67
Si	1.967	.003	1.974	1.985	1.000	2.953	.988	1.958	.999	1.991	1.968	1.987	1.982	3.004
Ti	.010	1.390	.004	.006	0.000	.012	.001	0.000	0.000	.003	.010	.006	.004	.003
Al	.079	.005	.043	.056	0.000	1.132	0.000	.024	0.000	.028	.079	.030	.068	1.635
Cr	.021	.221	.004	.065	0.000	.831	0.000	.014	0.000	.013	.024	.005	.028	.242
Fe2+	.110	.663	.184	.068	.163	.417	.160	.144	.153	.124	.121	.184	.091	.419
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.006	.013	0.000	.005	.004	.036	.001	.006	.003	.004	.005	.005	.004	.019
Ni	.001	.005	0.000	.002	.007	.006	.006	.004	.007	.002	.001	.002	.001	0.000
Mg	.965	.693	1.750	.920	1.825	1.997	1.852	1.836	1.837	1.779	1.020	1.725	1.023	2.228
Ca	.758	.001	.035	.775	0.000	.664	.002	.033	.002	.035	.682	.039	.715	.424
Na	.113	.003	.009	.128	.001	.010	.001	.009	0.000	.013	.121	.015	.078	.004
K	.002	.001	0.000	.003	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	.001	0.000
CATIONS	4.032	2.998	4.003	4.013	3.000	8.058	3.011	4.028	3.001	3.992	4.032	3.998	3.995	7.978
MG/MG+FE	.898	.511	.905	.931	.918	.827	.920	.927	.923	.935	.894	.904	.918	.842
CA/CA+MG	.440	.001	.020	.457	0.000	.250	.001	.018	.001	.019	.401	.022	.411	.160
CR/CR+AL	.210	.978	.085	.537	0.000	.423	0.000	.368	0.000	.317	.233	.143	.292	.129

APPENDIX II

GROUP I NODULES

SCHAFFER-FERRIS-AULTMAN KIMBERLITES

	AD1-L 1	FD1- 4	SH3- 3	SH3- 3	SH3- 4	SH3- 4	SH3- 5	SH3- 5	SH3- 8	SH3- 8	SH3-L 3	SH3-L 3	SH3-L 5	SH3-L 5
	CPX	GAR	CPX	GAR	CPX	GAR	CPX	GAR	GAR	SPN	GAR	SPN	CPX	GAR
SiO2	54.76	42.33	54.95	42.21	54.73	42.63	55.11	42.33	42.06	.37	40.75	.32	54.67	41.05
TiO2	.26	.39	.21	.51	.20	.44	.22	.46	.20	1.02	.09	.30	.22	.52
Al2O3	1.67	19.38	1.95	18.74	1.97	19.05	1.91	19.07	19.76	22.26	14.32	7.52	1.80	18.69
Cr2O3	2.31	4.40	1.61	5.54	1.46	5.14	1.57	5.18	4.17	37.09	12.26	61.06	1.59	5.55
FeO	2.87	6.55	2.84	6.90	2.74	6.58	2.78	6.82	7.09	22.73	5.99	11.30	2.68	6.29
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.30	0.00	0.00
MnO	.08	.33	.11	.38	.12	.32	.12	.31	.35	.23	.38	.27	.13	.29
NiO	0.00	0.00	.04	0.00	.07	.06	.06	0.00	0.00	.27	0.00	.07	.07	.01
MgO	16.87	21.52	18.28	20.99	18.90	21.68	18.14	21.13	19.93	13.84	21.41	14.23	18.21	21.39
CaO	20.43	5.04	18.25	5.50	17.45	5.18	18.42	5.46	7.00	0.00	4.71	.01	18.38	5.72
Na2O	1.52	.08	1.58	.07	1.64	.10	1.45	.04	.03	0.00	.03	.04	1.45	.05
K2O	.03	0.00	.03	0.00	.03	0.00	.03	0.00	0.00	0.00	0.00	0.00	.03	0.00
TOTAL	100.80	100.02	99.85	100.84	99.31	101.18	99.81	100.80	100.59	97.81	99.94	132.42	99.23	99.56
Si	1.971	3.022	1.980	3.010	1.976	3.011	1.986	3.012	2.998	.011	2.985	.009	1.981	2.965
Ti	.006	.021	.005	.027	.005	.022	.005	.023	.010	.023	.004	.006	.005	.027
Al	.070	1.630	.083	1.574	.083	1.585	.080	1.600	1.659	.814	1.236	.291	.076	1.589
Cr	.065	.247	.045	.312	.041	.286	.044	.290	.234	.910	.709	1.584	.044	.315
Fe2+	.085	.390	.084	.410	.051	.317	.083	.405	.330	.383	.365	.401	.081	.379
Fe3+	0.000	0.000	0.000	0.000	.032	.070	0.000	0.000	.092	.206	0.000	0.000	0.000	0.000
Mn	.002	.019	.003	.021	.003	.019	.003	.017	.021	.005	.021	.006	.003	.017
Ni	0.000	0.000	0.000	0.000	.001	.002	.001	0.000	0.000	.006	0.000	.001	.002	0.000
Mg	.905	2.291	.982	2.231	1.017	2.282	.974	2.241	2.117	.639	2.337	.695	.984	2.301
Ca	.780	.383	.705	.420	.674	.392	.710	.416	.533	0.000	.370	0.000	.713	.440
Na	.105	.010	.110	.008	.114	.012	.100	.004	.004	0.000	.004	.001	.101	.006
K	.001	0.000	.001	0.000	.001	0.000	.001	0.000	0.000	0.000	0.000	0.000	.001	0.000
CATIONS	3.998	8.013	3.998	8.013	3.998	7.998	3.987	8.008	7.998	2.997	8.031	2.994	3.991	8.039
MG/MG+FE	.914	.855	.921	.845	.952	.878	.921	.847	.865	.625	.865	.634	.924	.859
CA/CA+MG	.465	.143	.418	.158	.399	.147	.422	.157	.201	0.000	.137	0.000	.420	.161
CR/CR+AL	.481	.132	.352	.165	.331	.153	.355	.153	.124	.528	.365	.845	.367	.165

	SH3-L 6	SH3-L 6	SH3-L 7	SH3-L 8	SH3-L 11	SH3-L 11	SH3-L 12	SH3-L 12	SH3-L 12	SH3-L 14	SH3-L 14	SH3-L 15	SH3-L 15
	CPX	GAR	GAR	GAR	CPX	GAR	CPX	GAR	IL	CPX	GAR	CPX	GAR
SiO2	54.87	41.12	41.56	40.49	54.88	41.00	54.63	42.10	.18	53.94	42.04	54.13	41.37
TiO2	.32	.47	.10	.40	.42	.63	.28	.33	54.01	.22	.49	.29	.15
Al2O3	1.73	17.66	18.87	15.74	1.66	17.97	1.63	21.82	.69	2.02	20.57	2.01	16.91
Cr2O3	1.73	6.91	6.35	10.40	1.71	7.26	.64	2.08	2.05	1.31	3.88	1.22	9.36
FeO	2.78	6.65	6.97	6.65	2.81	6.42	3.36	9.63	26.28	2.69	6.32	2.75	6.14
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.13	.33	.48	.66	.16	.42	.06	.34	.90	.16	.38	.18	.51
NiO	.05	0.00	.01	.02	.06	.02	.05	0.00	.09	.07	0.00	.06	.07
MgO	18.43	20.62	20.07	18.61	18.73	20.62	17.23	20.11	14.91	18.40	21.62	18.41	21.13
CaO	18.42	6.06	6.35	7.74	19.17	6.13	20.49	4.96	.04	18.80	5.25	18.81	5.11
Na2O	1.43	.05	.04	.05	1.71	.06	1.28	.03	0.00	1.78	.08	1.74	.04
K2O	.04	0.00	0.00	0.00	.05	0.00	.01	0.00	0.00	.05	0.00	.04	0.00
TOTAL	99.93	99.87	100.80	100.76	101.36	100.53	99.66	101.40	99.15	99.44	100.63	99.64	100.79
Si	1.978	2.979	1.491	1.481	1.959	1.478	1.982	2.981	.005	1.960	1.489	1.962	1.489
Ti	.008	.025	.003	.011	.011	.017	.007	.017	1.381	.006	.013	.008	.004
Al	.073	1.507	.798	.679	.070	.764	.069	1.820	.027	.087	.859	.086	.718
Cr	.048	.395	.180	.301	.048	.207	.018	.116	.055	.038	.109	.035	.267
Fe2+	.083	.401	.209	.204	.084	.194	.101	.569	.747	.082	.187	.083	.185
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.003	.019	.015	.020	.005	.013	.001	.019	.026	.005	.011	.006	.015
Ni	.001	0.000	0.000	.001	.002	.001	.001	0.000	.002	.002	0.000	.002	.002
Mg	.990	2.226	1.074	1.015	.997	1.108	.932	2.121	.755	.997	1.143	.995	1.135
Ca	.710	.470	.244	.304	.734	.237	.796	.376	.001	.732	.199	.731	.197
Na	.099	.006	.003	.004	.118	.004	.089	.004	0.000	.126	.005	.122	.003
K	.001	0.000	0.000	0.000	.002	0.000	0.000	0.000	0.000	.002	0.000	.002	0.000
CATIONS	3.994	8.028	4.017	4.020	4.030	4.023	3.996	8.023	2.999	4.037	4.015	4.032	4.015
MG/MG+FE	.923	.847	.837	.833	.922	.851	.902	.788	.503	.924	.859	.923	.860
CA/CA+MG	.418	.174	.185	.230	.424	.176	.461	.151	.001	.423	.148	.424	.148
CR/CR+AL	.397	.208	.184	.307	.407	.213	.207	.060	.671	.304	.113	.289	.271

SH3-L 16 SH3-L 16 SH3-L 17 SH3-L 17 SH3-L 17 SH3-L 22 SH3-L 22 SH3-L 58 SH3-L 58 SH3-L 65 SH3-L 66 SH3-L 66 SH3-L 67

	CPX	GAR	CPX	GAR	IL	CPX	GAR	CPX	GAR	CPX	CPX	GAR	GAR
SiO2	55.01	42.21	54.51	41.34	1.18	54.16	42.02	53.85	41.60	55.40	54.78	41.16	41.73
TiO2	.11	.23	.27	.36	54.02	.40	.86	.50	.66	.31	.15	.31	.57
Al2O3	1.42	21.21	1.63	21.32	.77	2.02	21.62	1.93	18.89	1.25	2.07	19.00	18.61
Cr2O3	.68	2.93	.68	2.23	2.23	.16	.60	1.81	6.04	1.64	1.93	5.74	6.32
FeO	2.48	6.43	3.29	9.64	27.38	5.14	11.23	2.47	5.82	2.94	2.32	6.75	5.81
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.16	.30	.09	.37	.59	.11	.36	.14	.46	.18	.09	.40	.47
NiO	.06	0.00	.05	0.00	0.00	.05	.01	.03	0.00	.01	.07	.06	0.00
MgO	18.95	21.90	17.05	20.11	14.23	17.92	18.65	18.45	21.54	18.98	17.02	19.98	21.58
CaO	19.66	5.26	20.50	5.14	.07	17.94	4.85	18.55	5.69	18.97	19.37	5.58	5.83
Na2O	.84	.01	1.23	.03	.02	1.27	.05	1.81	.11	1.35	1.94	.05	.09
K2O	.04	0.00	.01	0.00	0.00	.01	.01	.04	0.00	.05	.01	0.00	0.00
TOTAL	99.41	100.48	99.31	100.54	100.49	99.18	100.26	99.58	100.81	101.08	99.75	99.03	101.01
Si	1.989	2.986	1.987	2.961	.003	1.979	3.019	1.953	1.482	1.978	1.981	2.992	1.486
Ti	.002	.012	.006	.019	.922	.010	.044	.014	.018	.008	.003	.017	.015
Al	.060	1.767	.069	1.800	.021	.085	1.830	.082	.794	.053	.088	1.627	.781
Cr	.019	.162	.019	.126	.040	.004	.034	.052	.170	.046	.054	.328	.178
Fe2+	.074	.380	.099	.576	.430	.156	.674	.075	.173	.088	.070	.409	.173
Fe3+	0.000	0.000	0.000	0.000	.090	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.004	.017	.002	.021	.011	.003	.021	.004	.014	.006	.002	.023	.014
Ni	.001	0.000	.001	0.000	0.000	.001	0.000	.001	0.000	0.000	.002	.002	0.000
Mg	1.021	2.309	.926	2.147	.481	.975	1.996	.998	1.145	1.011	.917	1.262	1.146
Ca	.762	.398	.800	.393	0.000	.702	.373	.721	.217	.726	.750	.433	.223
Na	.058	0.000	.086	.004	0.000	.089	.006	.127	.008	.094	.136	.006	.006
K	.001	0.000	0.000	0.000	0.000	0.000	0.000	.002	0.000	.002	0.000	0.000	0.000
CATIONS	3.991	8.031	3.995	8.047	1.998	4.004	7.997	4.029	4.021	4.012	4.003	7.099	4.022
MG/MG+FE	.932	.859	.903	.788	.528	.862	.748	.930	.869	.920	.929	.755	.869
CA/CA+MG	.427	.147	.463	.155	0.000	.419	.157	.419	.159	.418	.450	.255	.163
CR/CR+AL	.241	.084	.216	.065	.656	.045	.018	.388	.176	.465	.380	.168	.186

	SH3-L 74	SH3-L 81	SH3-L 86	SH3-L 87	SH3-L 87	SH3-L 87	SH3-L 97	SH3-L103	SH3-L103	SH3-L160	SH3-L160	SH11-L 1
	GAR	GAR	CPX	CHR	CPX	GAR	CPX	CPX	GAR	CPX	ILM	CPX
SiO2	40.66	41.53	54.40	.14	54.34	40.94	53.58	53.90	40.42	53.98	.07	55.20
TiO2	1.21	.88	.05	3.83	.36	.51	.09	.03	.08	.15	38.75	.14
Al2O3	14.60	17.72	.50	6.23	1.49	14.17	1.28	1.33	15.82	1.03	.40	2.50
Cr2O3	11.09	7.53	3.20	52.63	2.52	11.43	3.83	2.31	10.65	.14	.88	2.53
FeO	5.55	5.29	2.06	21.36	2.59	6.88	2.31	2.27	6.85	4.68	46.81	1.49
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.64	.50	.23	.38	.11	.43	.20	.17	.68	.10	.21	.05
NiO	.01	.01	.07	.31	.07	.05	.05	.08	.02	.04	.17	0.00
MgO	20.00	21.46	16.57	13.27	17.50	18.02	15.52	17.49	18.67	16.30	5.39	16.15
CaO	7.20	6.06	20.51	.02	18.89	7.60	18.91	19.99	7.70	22.10	.02	20.20
Na2O	.07	.11	2.17	0.00	1.73	.04	2.78	1.71	.03	1.04	.01	2.09
K2O	0.00	0.00	.03	0.00	.01	0.00	.03	.07	0.00	0.00	0.00	.01
TOTAL	101.03	101.09	99.79	98.17	99.61	100.07	98.58	99.35	100.92	99.56	92.71	100.36
Si	1.479	1.482	1.986	.003	1.973	3.021	1.980	1.969	1.478	1.983	.001	1.980
Ti	.033	.024	.001	.096	.009	.028	.002	.001	.002	.003	.749	.003
Al	.626	.746	.022	.246	.063	1.232	.056	.057	.682	.044	.012	.105
Cr	.319	.213	.092	1.386	.071	.667	.112	.067	.308	.003	.017	.071
Fe2+	.169	.158	.063	.430	.078	.424	.071	.069	.210	.143	.540	.044
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.020	.051	.007	.009	.003	.026	.006	.005	.021	.002	.004	.001
Ni	0.000	0.000	.002	.007	.002	.002	.002	.002	.001	.001	.003	0.000
Mg	1.085	1.142	.902	.657	.946	1.981	.855	.953	1.019	.892	.207	.863
Ca	.281	.232	.803	0.000	.734	.600	.749	.783	.302	.870	0.000	.775
Na	.005	.007	.154	0.000	.121	.004	.199	.121	.002	.073	0.000	.145
K	0.000	0.000	.002	0.000	0.000	0.000	.001	.003	0.000	0.000	0.000	0.000
CATIONS	4.017	4.055	4.034	2.834	4.000	7.985	4.033	4.030	4.025	4.014	1.533	3.987
MG/MG+FE	.865	.878	.935	.604	.924	.824	.923	.932	.829	.862	.277	.951
CA/CA+MG	.206	.169	.471	0.000	.437	.232	.467	.451	.229	.494	0.000	.473
CR/CR+AL	.338	.222	.807	.849	.530	.351	.667	.540	.311	.064	.586	.403

APPENDIX II
GROUP I NODULES
IRON MOUNTAIN KIMBERLITES

	1M42-L	3 1M42-L	3 1M42-L	1	0420-0.150 0.00-0.00	0420-0.150 0.00-0.00	1M42-L	61M42-L	61M42-L	61M42-L	81M42-L	201M42-L	211M42-L	21
	CPX	GAR	GAR	CPX	CPX	GAR	CPX	GAR	SPN	CPX	CPX	CPX	GAR	
SiO2	54.75	41.78	41.90	54.72	53.45	42.61	54.19	40.78	.16	55.39	54.04	53.91	41.09	
TiO2	.23	.61	.01	.06	.96	.48	.07	.10	.83	.08	.25	.43	1.02	
Al2O3	1.76	17.80	21.00	.15	3.99	20.82	2.14	16.75	8.16	1.47	3.60	1.90	15.74	
Cr2O3	1.50	7.37	4.45	1.57	1.47	2.45	2.23	9.37	57.32	1.45	2.42	2.17	9.68	
FeO	2.90	6.57	7.23	2.79	2.41	7.63	2.10	7.30	19.02	2.58	2.56	2.98	6.83	
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
MnO	.10	.34	.47	.11	.09	.26	.13	.48	.36	.03	.10	.18	.32	
NiO	.06	.01	.02	.04	.02	0.00	.05	0.00	.13	.05	0.00	.10	.04	
MgO	19.30	20.82	20.52	16.39	15.00	21.44	16.84	18.91	12.47	17.63	14.46	18.82	19.77	
CaO	18.34	6.34	5.80	22.71	20.13	5.05	19.70	6.84	0.00	20.78	17.19	18.31	6.45	
Na2O	1.26	.03	0.00	1.19	2.32	.02	1.94	0.00	.04	1.41	3.40	1.64	0.00	
K2O	.02	0.00	.01	0.00	0.00	0.00	0.00	.03	0.00	.02	0.00	.04	0.00	
TOTAL	100.22	101.67	101.41	99.73	99.84	100.76	99.39	100.56	98.49	100.89	98.02	100.48	100.94	
Si	1.968	2.977	2.966	2.000	1.957	3.013	1.970	2.973	.004	1.986	1.986	1.943	2.981	
Ti	.005	.031	0.000	.001	.002	.025	.001	.005	.020	.002	.006	.011	.055	
Al	.074	1.495	1.751	.005	.146	1.735	.090	1.438	.317	.062	.155	.080	1.346	
Cr	.042	.414	.248	.045	.041	.137	.064	.540	1.500	.041	.070	.061	.554	
Fe2+	.086	.391	.426	.084	.042	.450	.063	.444	.526	.080	.078	.088	.413	
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Mn	.002	.019	.027	.003	.003	.014	.003	.028	.009	.001	.002	.005	.019	
Ni	.001	0.000	0.000	.001	0.000	0.000	.001	0.000	.002	.001	0.000	.002	0.000	
Mg	1.034	2.209	2.165	.892	.854	2.260	.912	2.054	.615	.941	.792	1.011	2.138	
Ca	.706	.483	.438	.889	.838	.382	.767	.534	0.000	.798	.676	.707	.500	
Na	.037	.004	0.000	.083	.108	.002	.136	0.000	.001	.097	.242	.114	0.000	
K	.001	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000	.001	0.000	
CATIONS	4.006	8.023	8.021	4.003	3.991	8.018	4.007	8.017	2.994	4.009	4.007	4.023	8.006	
MG/MG+FE	.923	.850	.836	.914	.953	.834	.935	.822	.539	.922	.910	.920	.838	
CA/CA+MG	.406	.179	.168	.499	.495	.145	.457	.206	0.000	.459	.460	.412	.190	
CR/CR+AL	.362	.217	.124	.900	.219	.073	.416	.273	.826	.398	.311	.433	.292	

	CPX	GAR	CPX	CPX	CPX	CPX	GAR	GAR	CPX	GAR	GARZ1*	GARZ1A*	GARZ2*	GARZ2A*
SiO ₂	54.04	40.79	54.63	55.07	54.74	55.32	40.93	40.13	54.44	41.48	41.08	40.13	41.08	40.83
TiO ₂	.32	.98	.08	.11	.17	.36	.82	.03	.07	.11	.10	.11	.11	.15
Al ₂ O ₃	1.85	15.07	.39	.64	2.61	1.89	17.99	16.20	2.10	18.34	17.09	16.77	17.12	17.04
Cr ₂ O ₃	2.32	10.54	2.00	2.33	1.72	1.34	5.78	9.77	2.85	7.49	8.00	7.99	8.00	8.16
FeO	3.04	7.04	1.92	2.13	2.02	3.33	7.47	7.33	1.93	7.29	6.51	6.34	6.29	6.34
Fe ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.13	.43	.05	.03	.03	.15	.36	.45	.07	.53	.32	.32	.30	.32
NiO	.11	.04	.06	.04	.07	.07	.01	.08	.03	0.00	.03	.02	.02	.03
MgO	18.52	19.60	16.59	16.82	15.84	18.41	20.22	18.60	16.27	19.76	19.94	19.98	20.71	20.46
CaO	18.00	7.06	22.38	22.09	21.14	17.62	5.54	7.53	19.97	6.00	6.73	6.11	6.41	6.41
Na ₂ O	1.79	0.00	1.27	1.39	1.73	1.31	.05	0.00	2.27	0.00	0.00	.01	0.00	0.00
K ₂ O	.04	0.00	0.00	0.00	0.00	.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	100.16	101.55	99.37	100.65	100.07	99.83	99.17	100.12	100.00	101.00	99.99	98.40	99.74	99.74
Si	1.955	2.960	1.997	1.990	1.977	1.990	2.985	2.955	1.971	2.984	2.991	2.969	2.987	2.974
Ti	.008	.053	.002	.002	.004	.009	.045	0.000	.001	.005	.004	.004	.004	.006
Al	.078	1.288	.016	.026	.111	.079	1.545	1.405	.089	1.553	1.465	1.461	1.466	1.462
Cr	.065	.604	.057	.065	.048	.038	.332	.568	.081	.425	.459	.467	.458	.468
Fe ²⁺	.091	.426	.058	.063	.061	.099	.454	.449	.058	.437	.395	.391	.382	.385
Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.003	.025	.001	0.000	.001	.004	.021	.026	.001	.030	.019	.020	.017	.019
Ni	.002	.002	.001	0.000	.001	.001	0.000	.004	0.000	0.000	0.000	0.000	0.000	0.000
Mg	.997	2.119	.904	.905	.851	.987	2.198	2.042	.878	2.126	2.162	2.202	2.245	2.221
Ca	.697	.547	.876	.854	.818	.679	.432	.594	.774	.461	.538	.532	.476	.500
Na	.125	0.000	.089	.096	.121	.090	.006	0.000	.158	0.000	0.000	0.000	0.000	0.000
K	.001	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.022	8.024	4.001	4.001	3.993	3.977	8.018	8.043	4.011	8.021	8.033	8.046	8.035	8.035
MG/MG+FE	.916	.833	.940	.935	.933	.909	.829	.820	.938	.829	.846	.849	.855	.852
CA/CA+MG	.411	.205	.492	.486	.490	.408	.164	.225	.469	.178	.199	.195	.175	.184
CR/CR+AL	.455	.319	.781	.714	.302	.325	.177	.288	.476	.215	.239	.242	.238	.242

* GARZ1, GARZ1A = garnet interiors

* GARZ2, GARZ21 = garnet rims

	661M42-1	661M42-1	661M42-1	691M42-1	711M42-1	711M42-1	711M42-1	771M42-1	771M42-1	791M42-1	791M42-1	791M42-1
	CPX	GAR	GAR	CPX	GAR	CPX	GAR	CPX	GAR	CPX	GAR	SPR
SiO2	54.39	41.67	41.37	54.97	40.56	55.07	41.28	54.58	41.77			.11
TiO2	.29	.43	1.18	.35	.86	.22	.25	.14	.06			.89
Al2O3	1.89	13.36	16.66	6.91	16.66	1.91	17.44	2.58	21.57			12.81
Cr2O3	1.34	7.04	8.07	.09	7.57	2.86	8.68	2.55	3.38			51.49
FeO	3.14	7.12	7.10	2.64	7.28	2.26	6.87	1.68	7.79			20.61
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
MnO	.16	.32	.36	.05	.34	.13	.45	.09	.54			.39
RiO	.06	0.00	0.00	.01	.02	.05	0.00	.03	0.00			.08
MgO	19.33	20.66	20.20	12.63	20.16	16.66	19.61	15.56	21.03			12.03
CaO	17.95	6.07	6.55	17.77	6.42	19.17	6.77	21.09	5.03			0.00
Na2O	1.34	0.00	0.00	3.79	.06	2.03	0.00	2.03	0.00			0.00
K2O	.02	0.00	.01	0.00	0.00	.02	0.00	0.00	0.00			0.00
TOTAL	99.91	101.67	101.50	99.26	99.93	100.38	101.35	100.33	101.17			98.41
Si	1.960	2.968	2.974	1.977	2.963	1.983	2.972	1.970	2.956			.002
Ti	.007	.023	.063	.009	.047	.005	.012	.003	.002			.021
Al	.079	1.541	1.411	.292	1.434	.080	1.479	.109	1.799			.491
Cr	.038	.395	.458	.002	.437	.080	.494	.072	.187			1.326
Fe2+	.094	.422	.426	.079	.443	.067	.412	.049	.461			.561
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			0.000
Mn	.004	.019	.021	.001	.019	.003	.025	.002	.031			.010
Ri	.001	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000			.001
Mg	1.039	2.193	2.164	.679	2.195	.894	2.105	.837	2.219			.584
Ca	.693	.462	.504	.684	.501	.739	.522	.815	.380			0.000
Na	.093	0.000	0.000	.264	.008	.141	0.000	.141	0.000			0.000
K	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			0.000
CATIONS	4.009	8.023	8.021	3.987	8.047	3.993	8.021	3.998	8.035			2.996
MG/MG+FE	.917	.839	.836	.896	.832	.930	.836	.945	.828			.510
CA/CA+MG	.400	.174	.189	.502	.186	.453	.199	.493	.146			0.000
CR/CR+AL	.325	.204	.245	.007	.234	.500	.250	.398	.094			.730

APPENDIX II
GROUP II NODULES

	SD2-L	1 SD2-L	1 SD2-L	1 SD2-L	1 SD2-L	3 SD2-L	3 SD2-L	3	SD2-L	3 SD2-L	5 SD2-L	5 SD2-L	5 SD2-L	5 SD2-L	6 SD2-L	6 SD2-L	6 SD2-L	6
	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN		
SiO2	54.43	42.34	57.08	.08	54.48	42.04	57.61	.06	54.30	42.46	57.73	.09	54.04	40.69	55.06	.09		
TiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.06	0.00	0.00	.01		
Al2O3	2.58	0.00	2.99	42.00	2.67	0.00	2.67	41.70	2.74	.02	2.59	43.09	2.56	0.00	2.53	40.89		
Cr2O3	.80	0.00	.52	27.50	.84	0.00	.43	28.18	.88	0.00	.37	26.74	.75	0.00	.47	27.41		
FeO	1.24	7.00	4.59	11.56	1.30	7.03	4.64	11.68	1.32	7.05	4.59	11.45	1.50	7.23	4.80	11.49		
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
MnO	.09	.10	.13	.19	.06	.09	.11	.18	.03	.13	.14	.18	.09	.10	.21	.23		
NiO	.04	.38	.07	.13	.06	.37	.02	.13	.06	.33	.07	.08	.16	.44	.12	.15		
MgO	17.11	52.46	35.93	18.91	17.28	52.50	36.34	18.88	17.24	53.06	36.64	19.34	17.57	51.61	35.05	18.84		
CaO	23.31	.01	.17	0.00	23.10	.02	.26	.01	23.03	0.00	.26	0.00	23.42	.01	.40	.01		
Na2O	.84	0.00	.01	.02	.69	.02	.02	0.00	.80	.01	.04	0.00	.72	0.00	.04	.02		
K2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
TOTAL	100.44	102.29	101.40	100.39	100.48	102.07	102.10	100.82	100.50	103.06	102.43	100.97	100.89	100.08	98.73	99.14		
Si	1.957	1.001	1.927	.001	1.959	.997	1.930	0.000	1.951	.997	1.924	.002	1.940	.987	1.918	.002		
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.002	0.000	0.000	0.000		
Al	.108	0.000	.115	1.358	.113	0.000	.105	1.445	.116	0.000	.101	1.377	.109	0.000	.106	1.342		
Cr	.022	0.000	.013	.595	.023	0.000	.011	.610	.024	0.000	.010	.573	.021	0.000	.013	.602		
Fe2+	.025	.137	.128	.273	.039	.139	.129	.225	.077	.138	.085	.213	.045	.147	.140	.211		
Fe3+	.012	0.000	0.000	.042	0.000	0.000	0.000	.042	.012	.006	.042	.046	0.000	0.000	0.000	.056		
Mn	.002	.002	.003	.004	.001	.001	.003	.004	.002	.002	.004	.004	.003	.002	.006	.005		
Ni	.001	.007	.001	.002	.001	.007	0.000	.002	.001	.006	.002	.004	.003	.009	.003	.003		
Mg	.917	1.849	1.808	.772	.925	1.855	1.815	.771	.922	1.856	1.821	.782	.941	1.868	1.821	.780		
Ca	.897	0.000	.006	0.000	.890	0.000	.009	0.000	.888	0.000	.009	0.000	.902	0.000	.015	0.000		
Na	.058	0.000	0.000	0.000	.047	0.000	.001	0.000	.056	0.000	.002	0.000	.050	0.000	.003	0.000		
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
CATIONS	3.999	2.996	4.001	2.997	3.998	2.999	4.003	2.999	3.999	2.999	4.000	2.998	4.018	3.013	4.025	2.998		
MG/MG+FE	.973	.931	.934	.776	.960	.930	.934	.774	.972	.931	.955	.786	.954	.927	.929	.787		
CA/CA+MG	.494	0.000	.003	0.000	.490	0.000	.005	0.000	.491	0.000	.005	0.000	.489	0.000	.008	0.000		
CR/CR+AL	.169	0.000	.102	.305	.169	0.000	.095	.312	.171	0.000	.090	.294	.162	0.000	.109	.319		

	SDZ-1	SDZ-1	SDZ-1	SDZ-1	SDZ-1	SDZ-1	SDZ-1	SDZ-1	SDZ-1	SDZ-1	SDZ-1	SDZ-1	SDZ-1	SDZ-1	SDZ-1	SDZ-1
	CPX	Ol	OPX	SPH	CPX	Ol	OPX	SPH	CPX	Ol	OPX	CPX	Ol	OPX	SPH	
SiO2	53.91	41.80	57.26	.08	53.96	41.14	55.18	.03	54.36	41.29	55.39	54.20	41.44	55.31	.04	
TiO2	0.00	0.00	0.00	0.00	.01	.07	.10	.12	.01	.06	0.00	0.00	.01	0.00	.01	
Al2O3	2.65	.04	2.62	41.21	2.07	0.00	2.49	33.68	2.59	0.00	2.61	2.34	0.00	2.68	42.86	
Cr2O3	.85	0.00	.41	27.86	.83	0.00	.59	35.40	.86	0.00	.31	.67	0.00	.32	27.00	
FeO	1.30	7.14	4.65	11.80	1.61	8.11	5.09	11.85	1.29	7.23	4.81	1.24	7.28	4.72	11.99	
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
MnO	.09	.13	.14	.18	0.00	.05	.20	.09	0.00	.06	.21	0.00	.04	.19	.29	
NiO	.08	.38	.09	.13	.10	.42	.13	.20	.07	.42	.12	.12	.38	.13	.32	
MgO	17.42	52.14	36.43	19.16	17.94	51.28	34.76	16.29	17.31	51.61	35.50	17.40	51.87	35.30	18.78	
CaO	22.13	0.00	.29	.01	24.20	0.00	.65	0.00	23.80	0.00	.30	24.09	0.00	.37	.03	
Na2O	.84	.05	.04	0.00	.26	.05	.07	.05	.84	.03	.06	.75	.04	.05	.05	
K2O	0.00	0.00	0.00	0.00	.03	0.00	0.00	0.00	0.00	0.00	0.00	.01	0.00	0.00	0.00	
TOTAL	99.35	101.68	101.93	100.43	101.11	101.12	99.26	98.52	101.13	100.90	99.31	100.82	101.06	99.02	101.37	
Si	1.957	.996	1.918	.001	1.938	.991	1.918	.001	1.946	.993	1.917	1.947	.994	1.918	.001	
Ti	0.000	0.000	0.000	0.000	0.000	.001	.003	.003	0.000	.001	0.000	0.000	0.000	0.000	0.000	
Al	.113	0.000	.103	1.333	.088	0.000	.102	1.128	.109	0.000	.106	.099	0.000	.110	1.379	
Cr	.023	0.000	.011	.607	.024	0.000	.016	.795	.024	0.000	.009	.019	0.000	.009	.583	
Fe2+	.029	.142	.079	.213	.048	.163	.148	.282	.039	.145	.140	.037	.146	.136	.274	
Fe3+	.010	0.000	.050	.058	0.000	0.000	0.000	.072	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Mn	.002	.002	.004	.004	0.000	.001	.006	.022	0.000	.001	.006	0.000	.001	.006	.006	
Ni	.002	.007	.002	.002	.003	.002	.003	.004	.002	.008	.003	.003	.007	.003	.007	
Mg	.941	1.852	1.812	.787	.961	1.842	1.803	.690	.924	1.857	1.832	.932	1.856	1.826	.764	
Ca	.862	0.000	.010	0.000	.932	0.000	.024	0.000	.913	0.000	.012	.928	0.000	.012	.001	
Na	.052	.002	.002	0.000	.025	.002	.004	.003	.058	.002	.004	.052	.002	.003	.002	
K	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CATIONS	3.997	3.001	3.998	3.005	4.020	3.008	4.027	3.000	4.015	3.007	4.029	4.017	3.006	4.023	3.017	
MG/MG+FE	.970	.929	.958	.787	.952	.919	.924	.710	.960	.928	.929	.962	.927	.931	.736	
CA/CA+MG	.473	0.000	.005	0.000	.492	0.000	.013	0.000	.497	0.000	.007	.499	0.000	.007	.001	
CR/CR+AL	.169	0.000	.096	.313	.214	0.000	.136	.413	.180	0.000	.078	.161	0.000	.076	.297	

	SD2-L 21	SD2-L 21	SD2-L 21	SD2-L 21	SD2-L 22	SD2-L 22	SD2-L 22	SD2-L 22	SD2-L 23	SD2-L 23	SD2-L 23	SD2-L 23
	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH
SiO2	54.15	40.69	55.11	.04	53.77	40.97	54.98	.12	54.25	41.04	55.91	.11
TiO2	.18	0.00	.04	.11	.05	0.00	0.00	0.00	0.00	.05	.08	.04
Al2O3	2.42	0.00	2.50	43.98	2.44	0.00	2.58	44.44	2.55	0.00	2.73	46.36
Cr2O3	.66	.03	.42	25.26	.61	0.00	.31	26.78	.79	0.00	.36	24.09
FeO	1.45	7.16	4.74	9.58	1.68	7.92	5.03	10.06	1.30	7.27	5.00	10.61
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.01	.10	.12	.58	.13	.14	.14	.63	0.00	.07	.12	.92
NiO	0.00	.41	.14	.16	.01	.38	.02	.05	.05	.48	.17	0.00
MgO	17.70	51.31	35.23	19.13	17.13	52.20	35.91	19.21	17.21	51.89	35.27	18.49
CaO	23.26	.02	.40	0.00	24.89	.01	.45	0.00	23.79	0.00	.39	.10
Na2O	.78	.02	.06	0.00	.71	.01	.05	.05	.30	.02	.04	0.00
K2O	0.00	0.00	0.00	0.00	.01	.01	.01	0.00	0.00	0.00	0.00	.04
TOTAL	100.61	99.74	98.76	98.84	101.43	101.64	99.43	101.34	100.74	100.82	100.07	100.76
Si	1.946	.990	1.918	.001	1.931	.982	1.903	.008	1.949	.988	1.920	.003
Ti	.005	0.000	.001	.002	.001	0.000	0.000	0.000	0.000	.001	.002	.001
Al	.102	0.000	.102	1.400	.105	0.000	.105	1.387	.108	0.000	.110	1.475
Cr	.019	.001	.012	.539	.017	0.000	.009	.560	.022	0.000	.010	.514
Fe2+	.044	.146	.138	.216	.051	.159	.146	.223	.039	.147	.144	.240
Fe3+	0.000	0.000	0.000	.055	0.000	0.000	0.000	.054	0.000	0.000	0.000	0.000
Mn	0.000	.002	.004	.013	.004	.003	.004	.014	0.000	.001	.003	.021
Ni	0.000	.008	.004	.003	0.000	.007	.001	.001	.002	.009	.005	0.000
Mg	.949	1.860	1.829	.770	.918	1.866	1.854	.758	.922	1.864	1.807	.748
Ca	.896	0.000	.015	0.000	.959	0.000	.017	0.000	.916	0.000	.014	.003
Na	.054	.001	.004	0.000	.050	0.000	.004	.002	.056	.001	.003	0.000
K	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000	.002
CATIONS	4.015	3.008	4.027	2.999	4.037	3.017	4.043	3.007	4.014	3.011	4.018	3.007
MG/MG+FE	.956	.927	.930	.781	.947	.921	.927	.773	.959	.927	.926	.757
CA/CA+MG	.486	0.000	.008	0.000	.511	0.000	.009	0.000	.498	0.000	.008	.004
CR/CR+AL	.157	1.000	.105	.278	.139	0.000	.079	.288	.169	0.000	.083	.258

502-E 35 502-E 36 502-E 37 502-E 38 502-E 39 502-E 40 502-E 41 502-E 42 502-E 43 502-E 44 502-E 45 502-E 46 502-E 47 502-E 48 502-E 49 502-E 50

	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH
SiO2	54.31	41.11	55.35	.03	53.79	41.46	56.09	.03	53.71	40.87	54.99	.04
TiO2	.01	.01	.08	.11	0.00	0.00	.01	0.00	.08	0.00	.02	.04
Al2O3	2.02	0.00	2.22	33.58	2.65	0.00	2.59	41.79	2.56	0.00	2.50	43.19
Cr2O3	.83	0.00	.44	35.58	.81	0.00	.33	27.64	.78	0.00	.44	25.78
FeO	1.71	8.06	5.22	12.20	1.26	6.94	4.66	9.40	1.43	7.16	4.80	9.68
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.00	.10	.23	.84	.10	.11	.10	.62	.06	.11	.20	.62
NiO	.10	.44	.05	.19	.02	.39	.01	.23	.01	.42	.09	.16
MgO	17.97	51.16	34.89	16.10	16.99	52.10	35.42	18.56	17.55	51.63	35.11	18.73
CaO	23.58	0.00	.45	0.00	23.26	0.00	.25	0.00	23.47	.01	.27	0.00
Na2O	.35	.02	.07	.04	.91	.02	.02	.04	.73	.01	.02	.03
K2O	.04	0.00	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	100.92	100.90	99.00	98.67	99.80	101.02	99.48	98.31	100.38	100.21	98.44	98.27
Si	1.950	.992	1.926	.001	1.950	.994	1.930	.001	1.938	.990	1.919	.001
Ti	0.000	0.000	.002	.002	0.000	0.000	0.000	0.000	.002	0.000	.001	.001
Al	.086	0.000	.091	1.127	.113	0.000	.105	1.354	1.560	0.000	.103	1.386
Cr	.023	0.000	.012	.801	.023	0.000	.009	.601	.022	0.000	.012	.555
Fe2+	.051	.163	.152	.291	.038	.139	.134	.216	.043	.145	.140	.220
Fe3+	0.000	0.000	0.000	.067	0.000	0.000	0.000	.045	0.000	0.000	0.000	.056
Mn	0.000	.002	.007	.020	.003	.002	.003	.015	.002	.002	.006	.014
Ni	.003	.009	.001	.004	.001	.007	0.000	.005	0.000	.003	.003	.004
Mg	.962	1.842	1.810	.634	.918	1.863	1.818	.761	.945	1.865	1.828	.760
Ca	.903	0.000	.017	0.000	.904	0.000	.009	0.000	.908	0.000	.010	0.000
Na	.024	.001	.005	.002	.064	.001	.001	.002	.051	0.000	.001	.001
K	.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.000	3.000	4.023	2.999	4.014	3.006	4.009	3.000	5.471	3.010	4.023	2.998
MG/MG+FE	.950	.919	.923	.702	.960	.931	.931	.779	.956	.928	.929	.776
CA/CA+MG	.486	0.000	.009	0.000	.496	0.000	.005	0.000	.490	0.000	.005	0.000
CR/CR+AL	.211	0.000	.117	.415	.169	0.000	.079	.307	.014	0.000	.104	.286

	SD2-L	55SD2-L	65SD2-L	55SD2-L	55SD2-L	SD2-L	65SD2-L	65SD2-L	SD2-L	65SD2-L	SD2-L	73SD2-L	73SD2-L	73SD2-L
	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH		
SiO2	54.05	40.78	56.80	.04	53.09	41.55	56.44	.05	53.61	40.63	56.34	.07		
TiO2	.06	0.00	.03	.05	.03	.06	.02	.01	.06	0.00	.08	.08		
Al2O3	2.76	0.00	2.73	42.84	2.26	0.00	2.53	44.25	2.63	0.00	2.54	45.18		
Cr2O3	.79	0.00	.33	26.58	.59	0.00	.34	24.86	.85	0.00	.26	24.11		
FeO	1.61	7.27	4.98	9.73	1.34	6.81	4.29	8.24	1.37	7.27	4.99	9.44		
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
MnO	.05	.10	.14	.63	.10	.13	.16	.68	.02	.11	.15	.56		
NiO	.03	.41	0.00	.18	0.00	.37	.01	.16	.03	.40	0.00	.16		
HgO	18.97	51.57	35.46	18.78	18.06	51.95	35.66	19.76	17.34	51.67	35.24	19.34		
CaO	21.82	.01	.22	0.00	23.35	.01	.43	0.00	23.73	.01	.50	0.00		
Na2O	.80	0.00	0.00	.03	.71	.02	.02	0.00	.88	0.00	0.00	0.00		
K2O	0.00	0.00	0.00	0.00	.03	.01	0.00	0.00	0.00	0.00	.01	0.00		
TOTAL	100.94	100.14	100.69	98.86	99.56	100.91	99.90	98.01	100.52	100.09	100.11	98.94		
Si	1.931	.989	1.933	.001	1.933	.996	1.933	.001	1.934	.986	1.932	.002		
Ti	.002	0.000	.001	.001	.001	.001	.001	0.000	.002	0.000	.002	.002		
Al	.116	0.000	.109	1.370	.097	0.000	.102	1.410	.112	0.000	.103	1.431		
Cr	.022	0.000	.009	.570	.017	0.000	.009	.531	.024	0.000	.007	.512		
Fe2+	.048	.148	.142	.221	.041	.137	.123	.186	.041	.148	.143	.212		
Fe3+	0.000	0.000	0.000	.057	0.000	0.000	0.000	.055	0.000	0.000	0.000	.050		
Mn	.002	.002	.004	.014	.003	.003	.005	.016	.001	.002	.004	.013		
Ni	.001	.008	0.000	.004	0.000	.007	0.000	.003	.001	.008	0.000	.003		
Mg	1.011	1.865	1.800	.759	.980	1.858	1.821	.796	.933	1.870	1.802	.775		
Ca	.836	0.000	.008	0.000	.911	0.000	.016	0.000	.918	0.000	.018	0.000		
Na	.056	0.000	0.000	.092	.050	.001	.001	0.000	.062	0.000	0.000	0.000		
K	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
CATIONS	4.025	3.012	4.006	2.999	4.034	3.003	4.011	2.998	4.023	3.014	4.011	3.000		
MG/MG+FE	.955	.926	.927	.774	.960	.931	.937	.811	.958	.927	.926	.785		
CA/CA+MG	.453	0.000	.004	0.000	.482	0.000	.009	0.000	.496	0.000	.010	0.000		
CR/CR+AL	.159	0.000	.076	.294	.149	0.000	.081	.274	.176	0.000	.064	.264		

	SD2-I 90	SD2-I 90	SD2-L 90	SD2-L 90	SD2-I 183	SD2-I 183	SD2-L 183	SD2-L 183
	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN
SiO2	54.20	41.04	55.97	.07	53.57	40.40	56.07	.08
TiO2	0.00	0.00	0.00	.08	0.00	0.00	.02	0.00
Al2O3	2.21	0.00	2.23	31.02	2.76	0.00	2.07	40.34
Cr2O3	.92	0.00	.47	37.38	.95	0.00	.29	30.19
FeO	1.65	7.91	5.13	13.30	1.65	8.66	6.04	14.21
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.06	.13	.16	1.12	.12	.14	.25	.67
NiO	.03	.34	.04	.28	.03	.43	.10	.08
MgO	17.25	50.97	35.01	14.92	17.07	51.11	34.91	15.78
CaO	23.48	0.00	.52	.04	24.12	0.00	.32	.01
Na2O	.56	0.00	0.00	.02	.70	.04	.02	.05
K2O	.02	0.00	0.00	0.00	.02	0.00	.01	.01
TOTAL	100.38	100.39	99.53	98.23	100.99	100.78	100.10	101.42
Si	1.956	.994	1.932	.002	1.928	.981	1.934	.002
Ti	0.000	0.000	0.000	.002	0.000	0.000	0.000	0.000
Al	.093	0.000	.094	1.059	.117	0.000	.084	1.314
Cr	.025	0.000	.012	.856	.027	0.000	.008	.660
Fe2+	.049	.160	.147	.372	.050	.176	.174	.329
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.024
Mn	.001	.002	.004	.027	.004	.003	.008	.016
Ni	0.000	.006	0.000	.007	.001	.009	.003	.002
Mg	.926	1.840	1.801	.644	.917	1.850	1.796	.650
Ca	.912	0.000	.018	.001	.931	0.000	.012	0.000
Na	.038	0.000	0.000	.001	.049	.002	.001	.003
K	.001	0.000	0.000	0.000	.001	0.000	0.000	0.000
CATIONS	4.001	3.002	4.003	2.921	4.025	3.021	4.020	3.000
MG/MG+FE	.950	.920	.925	.667	.948	.913	.912	.664
CA/CA+MG	.496	0.000	.010	.002	.504	0.000	.007	0.000
CR/CR+AL	.212	0.000	.113	.447	.188	0.000	.087	.334

14M42-C 101M42-L 141M42-L 141M42-L 221M42-L 221M42-L 461M42-L 461M42-L 501M42-L 501M42-L 601M42-L 701M42-L 701M42-L 821M42-L 82

	CPX	CPX	SPN	CPX	SPN	CPX	SPN	CPX	SPN	CPX	CPX	SPN	CPX	SPN
SiO2	54.51	54.58	.05	53.31	.13	55.02	.14	52.37	.11	54.70	54.92	.13	54.63	.07
TiO2	.11	0.00	.05	.12	.08	.05	.04	.45	.11	.05	.34	.33	.27	.36
Al2O3	3.48	3.07	32.67	3.36	37.34	2.49	34.06	4.61	43.62	2.54	3.39	29.38	3.96	21.72
Cr2O3	1.43	1.36	37.80	1.40	31.80	1.09	34.96	1.41	26.19	.86	1.68	40.52	2.25	47.10
FeO	1.41	1.13	13.17	1.41	15.02	1.25	13.66	1.32	12.91	1.01	1.24	14.89	1.15	14.62
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.12	.09	.21	.08	.27	.09	.24	.08	.19	.04	0.00	.33	.06	.35
NiO	.02	0.00	.01	.02	.10	.04	.03	.08	.13	.05	.05	.11	.02	.09
MgO	15.97	15.76	16.12	16.57	14.99	16.69	15.39	15.51	17.23	16.57	15.70	14.29	14.55	14.05
CaO	21.82	21.96	0.00	23.17	.02	23.12	0.00	22.25	.01	22.95	21.78	.02	19.92	.01
Na2O	1.56	1.58	0.00	1.13	.04	1.15	0.00	1.91	.05	1.08	1.78	.07	2.71	0.00
K2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	100.48	99.53	100.08	100.57	99.79	100.99	98.52	99.99	100.55	99.85	100.88	100.07	99.52	98.37
Si	1.957	1.976	0.000	1.923	.003	1.967	.003	1.900	.002	1.973	1.961	.003	1.974	.001
Ti	.002	0.000	0.000	.003	.001	.001	0.000	.011	.001	.001	.008	.007	.006	.008
Al	.146	.130	1.114	.142	1.263	.104	1.175	.197	1.415	.106	.142	1.026	.168	.794
Cr	.041	.038	.865	.040	.721	.030	.809	.040	.569	.024	.047	.949	.063	1.156
Fe2+	.042	.034	.318	.042	.360	.037	.334	.039	.296	.029	.037	.369	.034	.379
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.003	.002	.005	.002	.006	.002	.005	.002	.004	.001	0.000	6.008	.001	.009
Ni	0.000	0.000	0.000	0.000	.001	0.000	0.000	.002	.002	.001	.001	.001	0.000	.001
Mg	.854	.850	.695	.891	.641	.890	.671	.837	.707	.891	.835	.631	.783	.649
Ca	.838	.851	0.000	.895	0.000	.885	0.000	.864	0.000	.886	.833	0.000	.771	0.000
Na	.108	.110	0.000	.079	.001	.080	0.000	.134	.002	.075	.123	.003	.189	0.000
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	3.991	3.991	2.997	4.017	2.997	3.996	2.997	4.026	2.998	3.987	3.987	8.997	3.989	2.997
MG/MG+FE	.953	.962	.686	.955	.640	.960	.668	.955	.705	.968	.958	.631	.958	.631
CA/CA+MG	.495	.500	0.000	.501	0.000	.499	0.000	.508	0.000	.499	.499	0.000	.496	0.000
CR/CR+AL	.219	.226	.437	.220	.363	.224	.408	.169	.287	.185	.249	.481	.273	.593

APPENDIX II
GROUP IV NODULES

1M20-W 51M20-W 5 NX4-L 20 NX4-L 20 SD1-E 2 SD1-E 2 SD1-E 2 SD2-L 12 SD2-L 12 SD2-L 29 SD2-L 29 SD2-L 41 SD2-L 41 SD2-L 42 SD2-L 42

	CPX	SPH	CPX	OPX	CPX	GAR	OPX	CPX	GAR	CPX	GAR	CPX	GAR	CPX	GAR
SiO2	49.57	.20	50.91	54.39	54.84	43.43	58.98	54.57	43.21	55.60	43.16	54.55	42.99	55.36	43.72
TiO2	.81	.02	.88	.16	.36	.09	.07	.32	.13	.29	.18	.26	.14	.29	.14
Al2O3	7.43	64.10	8.17	4.55	3.23	23.96	.91	3.30	23.35	3.43	23.57	2.85	23.64	3.11	24.09
Cr2O3	0.00	.07	0.00	0.00	.18	.26	.07	.18	.22	.26	.30	.18	.32	.13	.17
FeO	4.38	17.90	1.87	5.72	1.77	7.62	4.41	1.80	7.56	2.74	10.27	1.71	7.82	1.79	7.69
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.11	.11	.05	.16	.05	.32	.09	.01	.30	.06	.43	.03	.32	.06	.33
NiO	.01	0.00	.03	.03	0.00	0.00	.07	.02	0.00	.05	0.00	.04	0.00	.04	0.00
MgO	14.23	17.00	14.52	33.45	16.78	22.34	37.48	16.67	22.28	16.27	20.63	16.81	22.27	17.16	22.09
CaO	23.06	.16	22.51	.20	21.88	4.39	.21	21.13	4.20	19.97	3.89	22.71	4.37	21.59	4.40
Na2O	.32	0.00	1.61	0.00	1.63	.04	.04	1.71	.07	2.41	.07	1.57	.07	1.84	.05
K2O	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	99.97	99.56	100.56	99.16	100.77	102.45	102.33	99.71	101.42	101.08	102.50	100.21	101.94	101.37	102.68
Si	1.819	.004	1.833	1.902	1.960	2.989	1.969	1.965	2.995	1.983	3.004	1.965	2.978	1.968	2.997
Ti	.321	0.000	.024	.004	.009	.004	.001	.008	.006	.007	.008	.006	.006	.007	.006
Al	.021	1.956	.347	.186	.135	1.943	.035	.139	1.907	.144	1.932	.120	1.929	.129	1.945
Cr	0.000	0.000	0.000	0.000	.004	.012	.001	.004	.012	.006	.016	.004	.016	.003	.008
Fe2+	.133	.387	.056	.166	.052	.438	.122	.026	.353	.081	.596	.050	.451	.053	.440
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.028	.024	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.003	.002	.001	.005	.001	.018	.002	0.000	.016	.001	.024	0.000	.018	.001	.018
Ni	0.000	0.000	.001	.001	0.000	0.000	.002	0.000	0.000	.001	0.000	0.000	0.000	.001	0.000
Mg	.777	.657	.779	1.729	.394	2.292	1.865	.895	2.299	.864	2.138	.903	2.299	.910	2.257
Ca	.907	.003	.869	.007	.838	.323	.007	.815	.319	.763	.290	.857	.323	.822	.322
Na	.022	0.000	.113	0.000	.115	.004	.002	.118	.008	.167	.008	.109	.008	.126	.006
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.003	3.009	4.023	4.000	4.008	8.023	4.006	3.998	7.999	4.017	8.016	4.014	8.028	4.020	7.999
MG/MG+FE	.854	.629	.933	.912	.945	.840	.939	.972	.867	.914	.782	.948	.836	.945	.837
CA/CA+MG	.539	.005	.527	.004	.484	.124	.004	.477	.122	.469	.119	.487	.123	.475	.125
CR/CR+AL	0.000	0.000	0.000	0.000	.029	.006	.028	.028	.006	.040	.008	.032	.008	.023	.004

	SD2-L 52	SD2-L 52	SD2-L 52	SD2-L 77	SD2-L 77	SD2-L 78	SD2-L 78	SD2-L 78	SD2-L 79	SD2-L 79	SD2-L 79	SD2-L 79	SD2-L 80	SD2-L 80	SD2-L 80
	CPX	GAR	PHLOG	CPX	GAR	CPX	GAR	RU	CPX	GAR	MIC	OPX	CPX	GAR	OPX
SiO2	54.34	42.20	40.40	53.68	41.51	54.56	42.79	.14	55.11	43.00	41.08	58.19	54.82	42.74	57.82
TiO2	.65	.13	1.35	.44	.15	.35	.16	96.46	.36	.20	1.71	.07	.40	.21	.09
Al2O3	3.07	23.89	13.11	3.18	23.78	3.17	23.29	1.47	2.88	23.63	13.18	.89	3.24	22.86	.94
Cr2O3	0.00	0.00	0.00	.08	.25	.15	.22	.42	.14	.24	.03	.03	.43	.73	.09
FeO	2.07	7.88	2.22	1.92	7.80	1.74	8.16	1.52	1.62	7.23	1.94	4.83	1.73	7.50	4.16
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.10	.35	.08	.01	.35	.06	.33	.11	.05	.28	0.00	.07	.01	.29	.09
NiO	.07	.04	.08	.01	.02	.04	0.00	.17	.03	0.00	.14	.04	.06	.03	.13
MgO	17.67	21.16	24.96	16.88	21.47	16.33	21.53	.38	16.79	21.39	25.29	36.59	16.32	21.00	35.91
CaO	20.47	4.68	.04	22.17	4.70	21.44	4.60	.02	22.15	4.43	.02	.19	21.64	4.59	.25
Na2O	1.76	.04	.20	1.65	.02	1.93	.08	.06	1.50	.05	.13	0.00	1.80	.03	.05
K2O	.02	.01	10.24	0.00	0.00	0.00	0.00	.01	0.00	0.00	9.89	.01	0.00	0.00	0.00
TOTAL	100.22	100.38	92.68	100.02	100.05	99.77	101.16	100.76	100.63	100.45	93.41	100.91	100.45	99.98	99.53
Si	1.953	1.486	1.594	1.941	2.938	1.970	2.994	.011	1.972	3.009	2.935	1.972	1.966	3.019	1.982
Ti	.018	.003	.040	.012	.008	.009	.009	5.780	.009	.010	.090	.002	.010	.010	.002
Al	.130	.992	.610	.136	1.986	.135	1.922	.139	.121	1.949	1.107	.035	.137	1.903	.037
Cr	0.000	0.000	0.000	.002	.014	.004	.012	.027	.003	.012	0.000	.001	.011	.039	.002
Fe2+	.062	.232	.074	.058	.462	.053	.478	.101	.048	.423	.116	.137	.051	.441	.119
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.003	.010	.002	0.000	.022	.002	.019	.007	.001	.016	0.000	.002	0.000	.016	.002
Ni	.002	.001	.002	0.000	.002	.001	0.000	.011	0.000	0.000	.006	.001	.001	0.000	.003
Mg	.947	1.111	1.470	.910	2.266	.879	2.247	.046	.895	2.230	2.693	1.850	.872	2.210	1.835
Ca	.789	.177	.002	.860	.356	.830	.345	.002	.848	.331	0.000	.007	.832	.346	.008
Na	.123	.003	.016	.115	.002	.135	.011	.009	.103	.006	.017	0.000	.125	.002	.003
K	.001	0.000	.516	0.000	0.000	0.000	0.000	.001	0.000	0.000	.898	0.000	0.000	0.000	0.000
CATIONS	4.028	4.015	4.326	4.034	8.056	4.018	8.037	6.134	4.000	7.986	7.862	4.007	4.005	7.986	3.993
Mg/(Mg+Fe)	.939	.827	.952	.940	.831	.943	.825	.313	.949	.841	.959	.931	.945	.834	.939
Ca/(Ca+Mg)	.154	.137	.001	.486	.136	.486	.133	.042	.487	.129	0.000	.004	.488	.135	.004
Cr/(Cr+Al)	0.000	0.000	0.000	.014	.007	.029	.006	.163	.024	.006	0.000	.028	.074	.020	.051

	SD2-L 43	SD2-L 43	SD2-L 43	SD2-L 46	SD2-L 46	SD2-L 47	SD2-L 47	SD2-L 48	SD2-L 48	SD2-L 49	SD2-L 49	SD2-L 50	SD2-L 50	SD2-L 50
	CPX	GAR	OPX	CPX	GAR	CPX	GAR	CPX	GAR	CPX	GAR	CPX	GAR	OPX
SiO2	54.36	42.36	57.00	54.41	42.99	55.11	43.73	55.52	43.77	54.30	42.94	54.75	43.29	58.04
TiO2	.37	.13	.01	.26	.11	.33	.14	.37	.11	.34	.10	.34	.12	.07
Al2O3	3.18	23.40	.57	3.32	23.66	3.16	23.77	3.27	24.13	3.25	23.52	3.25	23.79	1.59
Cr2O3	.30	.43	0.00	.23	.30	.30	.49	.23	.37	.39	.59	.28	.36	.36
FeO	1.71	7.42	4.48	1.77	7.48	1.78	7.63	1.73	7.57	1.64	7.29	1.74	7.60	4.77
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.02	.34	.17	.05	.34	.03	.34	.06	.29	.04	.32	.04	.30	.09
NiO	.02	0.00	.04	.03	0.00	.05	0.00	.08	0.00	.03	0.00	.02	0.00	.06
MgO	16.30	21.66	36.49	16.18	21.85	16.73	22.41	16.58	22.03	16.16	21.79	16.70	22.29	36.74
CaO	21.89	4.41	.21	21.92	4.47	21.80	4.34	21.83	4.41	21.80	4.68	21.81	4.33	.19
Na2O	1.75	.02	.06	1.71	.04	1.69	.04	1.75	.03	1.70	.05	1.72	0.00	0.00
K2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.01	0.00	0.00
TOTAL	99.90	100.17	99.03	99.88	101.24	100.98	102.89	101.42	102.71	99.65	101.28	100.66	102.08	101.91
Si	1.957	2.977	1.970	1.959	2.988	1.967	2.996	1.969	3.000	1.961	2.985	1.961	1.494	1.951
Ti	.009	.006	0.000	.006	.004	.008	.006	.009	.004	.009	.004	.008	.003	.001
Al	.134	1.937	.023	.140	1.938	.132	1.920	.136	1.950	.137	1.926	.136	.967	.063
Cr	.008	.022	0.000	.006	.016	.008	.026	.006	.018	.010	.030	.067	.009	.009
Fe2+	.006	.357	.129	.009	.366	.052	.436	.051	.433	.023	.348	.051	.219	.134
Fe3+	.044	.078	0.000	.044	.068	0.000	0.000	0.000	0.000	.026	.074	0.000	0.000	0.000
Mn	0.000	.019	.005	.001	.018	0.000	.018	.001	.016	.001	.018	.001	.008	.002
Ni	0.000	0.000	.001	0.000	0.000	.001	0.000	.002	0.000	0.000	0.000	0.000	0.000	.001
Mg	.874	2.268	1.881	.869	2.264	.890	2.288	.876	2.252	.869	2.258	.891	1.146	1.840
Ca	.844	.332	.008	.845	.332	.833	.317	.829	.324	.844	.349	.836	.160	.006
Na	.121	.002	.004	.119	.004	.116	.004	.120	.002	.118	.006	.119	0.000	0.000
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	3.997	7.998	4.021	3.998	7.998	4.007	8.011	3.999	7.999	3.998	7.998	4.010	4.006	4.007
MG/MG+FE	.993	.864	.936	.990	.861	.945	.840	.945	.839	.974	.866	.946	.840	.932
CA/CA+MG	.491	.128	.004	.493	.128	.483	.122	.486	.126	.493	.134	.484	.123	.003
CR/CR+AL	.056	.011	0.000	.041	.008	.057	.013	.042	.009	.068	.015	.049	.009	.125

	SD2-L 83	SD2-L 83	SD2-L 83	SD2-L 84	SD2-L 84	SD2-L 84	SD2-L 85	SD2-L 85	SD2-L 85	SD2-L 85	SD2-L 85	SD2-L 86	SD2-L 86	SD2-L 86
	CPX	GAR	OPX	CPX	GAR	OPX	CPX	GAR	OPX	RU	CPX	GAR	OPX	
SiO2	55.27	42.40	56.96	54.22	42.51	57.21	54.55	42.72	57.93	.08	55.54	42.56	57.76	
TiO2	.34	.05	.03	.46	.12	.16	.36	.24	.05	96.28	.34	.14	.21	
Al2O3	2.94	24.07	.73	3.30	23.75	.79	2.93	23.67	.69	.09	3.01	22.91	1.00	
Cr2O3	.12	.13	0.00	.33	.63	.03	.44	.27	.06	.56	.48	.97	.06	
FeO	1.99	7.94	4.56	1.81	7.67	4.37	1.69	7.09	3.98	.14	1.82	8.23	4.91	
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
MnO	.10	.40	.15	0.00	.33	.10	.04	.29	.10	0.00	.06	.36	0.00	
NiO	.09	.02	.04	0.00	0.00	.11	.01	0.00	.11	.02	.10	.03	.07	
MgO	16.53	21.30	36.29	16.14	21.46	37.11	16.66	21.54	36.36	.04	16.07	21.13	35.95	
CaO	21.86	4.63	.24	21.42	4.70	.21	21.84	4.55	.17	.04	21.34	4.58	.56	
Na2O	1.96	.04	.04	2.01	.06	.06	1.58	.01	.03	0.00	1.93	.04	.12	
K2O	.02	0.00	.01	.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	101.22	100.98	99.05	99.70	101.23	100.15	100.10	100.38	99.48	97.25	100.69	100.95	100.64	
Si	1.972	1.484	1.968	1.960	1.485	1.955	1.963	2.996	1.984	0.000	1.985	2.992	1.967	
Ti	.009	.001	.001	.012	.003	.004	.009	.012	.001	.991	.009	.007	.005	
Al	.124	.994	.030	.141	.978	.032	.124	1.955	.027	.001	.127	1.900	.040	
Cr	.003	.004	0.000	.009	.017	.001	.011	.014	.001	.006	.014	.054	.002	
Fe2+	.059	.233	.132	.054	.224	.125	.050	.414	.113	.001	.054	.484	.140	
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Mn	.003	.012	.004	0.000	.010	.003	.001	.016	.002	0.000	.002	.022	0.000	
Ni	.002	.001	.001	0.000	0.000	.003	0.000	0.000	.002	0.000	.003	.002	.002	
Mg	.879	1.112	1.870	.871	1.118	1.892	.893	2.251	1.856	0.000	.857	2.216	1.876	
Ca	.836	.174	.009	.831	.176	.008	.841	.341	.006	0.000	.818	.345	.020	
Na	.135	.002	.002	.141	.004	.004	.109	0.000	.001	0.000	.134	.006	.008	
K	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CATIONS	4.023	4.017	4.017	4.019	4.015	4.027	4.001	7.999	3.993	.999	4.003	8.028	4.010	
MG/MG+FE	.937	.827	.934	.942	.833	.938	.947	.845	.943	0.000	.941	.821	.929	
CA/CA+MG	.487	.135	.005	.488	.136	.004	.485	.132	.003	0.000	.488	.135	.011	
CR/CR+AL	.024	.004	0.000	.060	.017	.030	.081	.007	.036	.857	.099	.028	.048	

	SD2-L 87	SD2-L 87	SD2-L 87	SD2-L 88	SD2-L 88	SD2-L 88	SD2-L 89	SD2-L 89	SD2-L 104	SD2-L 104	SD2-L 106	SD2-L 106	SD2-L 109	SD2-L 109	SD2-L 109
	CPX	GAR	OPX	CPX	GAR	OPX	CPX	GAR	CPX	GAR	CPX	GAR	CPX	GAR	PHLOG
SiO2	53.56	42.91	58.16	54.84	43.00	58.13	54.71	43.17	53.96	42.16	52.85	40.35	54.96	41.80	41.01
TiO2	.51	.17	.12	.37	.22	.10	.30	.19	.32	.14	.16	.17	.48	.19	1.78
Al2O3	3.53	23.27	.86	3.00	23.25	1.10	3.01	23.72	3.05	23.60	1.58	21.55	3.21	23.42	12.75
Cr2O3	.27	.63	0.00	.36	.48	.12	0.00	0.00	0.00	.01	.18	.67	0.00	0.00	0.00
FeO	1.91	8.20	4.71	1.67	7.39	4.47	1.77	7.40	1.85	7.81	3.70	15.18	2.08	7.99	2.05
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.02	.32	.08	.05	.33	.17	.07	.32	.04	.39	.08	.38	.10	.31	.01
NiO	.02	.03	.03	.03	0.00	.11	0.00	0.00	.03	.05	0.00	.01	.01	.02	.02
MgO	16.50	21.32	36.60	16.72	21.26	35.62	16.57	21.63	16.41	21.48	16.63	14.18	16.47	20.94	25.33
CaO	21.70	4.76	.20	21.69	4.55	.18	21.63	4.37	21.69	4.50	22.44	6.99	22.05	4.52	0.00
Na2O	1.98	.01	0.00	.65	.01	.04	1.85	0.00	1.92	.07	1.13	.02	1.86	.04	.14
K2O	0.00	0.00	.01	0.00	0.00	0.00	.01	.01	.01	0.00	.02	0.00	.03	0.00	10.36
TOTAL	100.00	101.62	100.77	99.38	100.49	99.99	99.92	100.81	99.28	100.21	98.77	99.50	101.25	99.23	93.45
Si	1.937	1.496	1.973	1.966	3.014	1.984	1.972	1.506	1.962	1.487	1.956	1.498	1.961	1.489	1.603
Ti	.014	.004	.003	.009	.010	.002	.008	.004	.009	.004	.005	.005	.013	.005	.052
Al	.150	.957	.034	.126	1.921	.044	.128	.976	.131	.982	.069	.944	.135	.984	.588
Cr	.008	.017	0.000	.009	.026	.003	0.000	0.000	0.000	0.000	.005	.020	0.000	0.000	0.000
Fe2+	.058	.239	.134	.049	.432	.127	.053	.216	.056	.231	.115	.472	.062	.238	.067
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	0.000	.010	.002	.001	.018	.003	.002	.009	.001	.012	.003	.012	.003	.009	0.000
Ni	.001	.001	.001	0.000	0.000	.002	0.000	0.000	.001	.002	0.000	0.000	0.000	.001	.001
Hg	.890	1.108	1.852	.893	2.222	1.817	.891	1.175	.890	1.130	.918	.786	.876	1.113	1.476
Ca	.842	.178	.007	.833	.341	.006	.836	.164	.846	.170	.891	.278	.843	.173	0.000
Na	.139	0.000	0.000	.114	0.000	.002	.129	0.000	.135	.005	.081	.002	.129	.002	.010
K	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	.001	0.000	.001	0.000	.001	0.000	.517
CATIONS	4.039	4.010	4.006	4.000	7.984	3.990	4.020	4.000	4.032	4.023	4.044	4.017	4.023	4.014	4.314
MG/MG+FE	.939	.823	.933	.948	.837	.935	.944	.839	.941	.830	.889	.625	.934	.824	.957
CA/CA+MG	.486	.138	.004	.483	.133	.003	.484	.127	.487	.131	.493	.261	.490	.135	0.000
CR/CR+AL	.051	.017	0.000	.067	.013	.064	0.000	0.000	0.000	0.000	.068	.021	0.000	0.000	0.000

	SD2-L110	SD2-L110	SD2-L117	SD2-L117	SD2-L117	SD2-P 1	SD2-P 1	SD2-P 1	SD2-W 6	SD2-W 6	SD2-W 6	SD2-W 6	SD2-W 7	SD2-W 7	SD2-W 7
	CPX	GAR	CPX	GT	OPX	CPX	GAR	OPX	CPX	GAR	OPX	CPX	GAR	OPX	
SiO2	51.71	38.94	54.54	42.18	57.55	50.26	40.89	55.01	54.58	42.40	56.14	55.39	40.92	57.06	
TiO2	.53	.13	.42	.20	.12	1.00	.07	.06	.21	.16	.02	.14	.12	.05	
Al2O3	4.46	21.16	3.30	22.84	.86	6.23	22.32	2.38	2.14	22.77	1.28	5.64	22.75	.40	
Cr2O3	0.00	.14	.41	.64	.07	.22	.30	.07	.31	1.45	.11	.08	.08	0.00	
FeO	9.79	26.79	1.73	7.55	4.04	5.91	18.48	12.90	1.87	8.18	5.08	4.00	18.03	12.37	
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
MnO	.19	1.16	.02	.28	.08	.11	.59	.10	.10	.36	.12	.06	.44	.12	
NiO	.07	.03	.03	0.00	.14	.02	.05	.07	.05	0.00	.21	0.00	.07	0.00	
H2O	12.44	7.75	15.93	21.48	36.57	13.38	13.28	30.00	16.69	20.46	35.93	13.32	14.28	30.08	
CaO	19.44	5.60	21.40	4.63	.20	20.70	5.47	.27	23.06	5.26	.24	17.78	3.84	.24	
Na2O	1.96	.09	1.78	.06	.02	2.39	.03	.02	1.10	.03	.06	4.04	.01	.11	
K2O	0.00	.01	0.00	0.00	0.00	.01	0.00	.02	.02	0.00	.01	.02	0.00	.01	
TOTAL	100.59	101.80	99.56	99.86	99.65	100.23	101.48	100.90	100.13	101.07	99.20	100.47	100.54	100.44	
Si	1.917	2.981	1.972	1.984	1.969	1.852	1.501	1.937	1.973	1.493	1.946	1.986	1.504	2.007	
Ti	.015	.008	.010	.010	.003	.028	.002	.002	.006	.004	0.000	.004	.002	.001	
Al	.195	1.911	.140	1.904	.034	.271	.966	.099	.091	.946	.052	.238	.986	.016	
Cr	0.000	.008	.011	.035	.001	.006	.009	.002	.009	.041	.003	.002	.002	0.000	
Fe2+	.304	1.716	.052	.446	.115	.182	.568	.380	.057	.241	.147	.120	.554	.364	
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Mn	.006	.075	0.000	.017	.002	.003	.018	.003	.003	.011	.003	.002	.014	.004	
Ni	.002	.002	0.000	0.000	.003	.001	.001	.002	.002	0.000	.006	.001	.002	0.000	
Mg	.688	.885	.858	2.266	1.865	.736	.727	1.575	.899	1.074	1.857	.712	.782	1.578	
Ca	.773	.459	.828	.349	.007	.818	.215	.010	.893	.199	.009	.683	.151	.009	
Na	.141	.013	.124	.008	.001	.171	.002	.001	.077	.002	.004	.281	.001	.007	
K	0.000	0.000	0.000	0.000	0.000	.001	0.000	.001	.001	0.000	0.000	.001	0.000	0.000	
CATIONS	4.041	8.058	3.995	7.019	4.000	4.069	4.009	4.012	4.011	4.011	4.027	4.030	3.998	3.986	
MG/MG+FE	.694	.340	.943	.836	.942	.802	.561	.806	.940	.817	.927	.856	.585	.813	
CA/CA+MG	.529	.342	.491	.133	.004	.526	.228	.006	.498	.156	.005	.490	.162	.006	
CR/CR+AL	0.000	.004	.073	.018	.029	.022	.009	.020	.090	.042	.055	.008	.002	0.000	

APPENDIX II
GROUP V NODULES
SLOAN-NIX-MOEN KIMBERLITES

	HN2-L 2	NX2- 2	NX2- 2	NX2- 2	NX2- 2	HX2- 7	NX2- 7	NX2- 7	NX2- 7	NX4-C 10	NX4-C 10	NX4-C 10
	GAR	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN	CPX	OPX	SPN
SiO2	41.70	53.22	41.14	56.66	.11	53.22	41.48	56.47	.09	52.00	54.85	.03
TiO2	1.00	.07	0.00	0.00	.01	.27	0.00	.04	.08	.47	.08	.09
Al2O3	20.84	4.26	0.00	2.57	48.36	4.89	.05	3.14	50.85	7.49	5.22	59.65
Cr2O3	.74	.88	0.00	.24	16.33	.95	0.00	.34	16.22	.67	.25	7.74
FeO	11.09	1.98	9.30	6.36	13.61	1.59	8.56	5.61	11.29	2.38	7.69	12.14
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.35	.10	.14	.16	.16	.08	.10	.17	.16	.14	.15	.18
NiO	.11	.06	.40	.05	.30	.06	.39	.10	.29	.04	.09	.38
MgO	18.99	16.61	50.68	35.26	18.95	15.99	49.65	34.59	20.30	13.57	31.73	19.75
CaO	4.99	21.91	.02	.23	0.00	21.02	0.00	.29	0.00	22.54	.33	0.00
Na2O	.07	1.18	0.00	.02	0.00	1.67	0.00	.03	0.00	1.17	.05	0.00
K2O	0.00	0.00	0.00	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	99.88	100.27	101.68	101.55	97.83	99.75	100.23	100.78	99.28	100.47	100.44	99.96
Si	3.013	1.915	.991	1.925	0.000	1.920	1.007	1.927	0.000	1.875	1.894	0.000
Ti	.053	.001	0.000	0.000	0.000	0.000	0.000	.001	.001	.013	.002	.001
Al	1.774	.095	0.000	.023	1.552	0.000	.001	.126	1.591	.317	.211	1.811
Cr	.040	.024	0.000	.006	.352	0.000	0.000	.009	.340	.019	.006	.157
Fe2+	.667	.015	.187	.180	.222	0.000	.174	.143	.190	.071	.222	.235
Fe3+	0.000	.044	0.000	0.000	.088	0.000	0.000	.012	.060	0.000	0.000	0.000
Mn	.021	.002	.002	.004	.003	0.000	0.000	.004	.003	.004	.004	.003
Ni	.004	.001	.007	.001	.006	0.000	.007	.002	.006	0.000	.002	.007
Mg	2.044	.891	1.819	1.785	.770	0.000	1.798	1.759	.803	.729	1.633	.758
Ca	.396	.844	0.000	.008	0.000	0.000	0.000	.010	0.000	.870	.011	0.000
Na	.008	.081	0.000	.001	0.000	0.000	0.000	.001	0.000	.081	.003	0.000
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	8.010	3.913	3.006	3.938	2.993	1.920	2.987	3.999	2.994	3.979	3.988	2.972
MG/MG+FE	.754	.983	.997	.908	.776	0.000	.912	.922	.809	.911	.880	.763
CA/CA+MG	.159	.486	0.000	.004	0.000	0.000	0.000	.006	0.000	.544	.007	0.000
CR/CR+AL	.022	.202	0.000	.176	.185	0.000	0.000	.067	.176	.057	.028	.080

	HX4-L	1 NX4-L	1 NX4-L	1 NX4-L	1 NX4-L	2 NX4-L	2 NX4-L	2 NX4-L	2 NX4-L	3 NX4-L	3 NX4-L	3 NX4-L	4 NX4-L	4 NX4-L	4 NX4-L	4
	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN	CPX	OL	OPX	CPX	OL	OPX	SPN	
SiO2	53.49	40.72	57.32	.02	52.04	40.87	55.83	.02	53.07	40.89	57.17	53.32	40.75	55.12	.06	
TiO2	.03	0.00	.02	0.00	.38	.01	.07	0.00	0.00	.01	.02	.08	.01	.04	0.00	
Al2O3	2.64	0.00	2.57	43.77	5.95	0.00	3.90	55.41	3.90	0.00	30.00	3.74	0.00	2.80	47.99	
Cr2O3	.83	0.00	.42	24.90	.63	0.00	.71	12.07	.88	0.00	.30	.73	0.00	.23	19.63	
FeO	1.87	8.31	5.12	11.85	2.19	9.25	6.08	10.27	1.82	8.64	5.51	1.66	8.15	5.57	10.86	
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
MnO	.09	.13	.20	.71	.07	.17	.18	.32	.03	.17	.15	.08	.14	.14	.53	
NiO	.02	.33	0.00	.07	.02	.36	.08	.12	.03	.34	.08	0.00	.34	.01	.18	
MgO	17.70	50.43	34.36	17.42	15.13	49.67	33.56	19.74	16.63	50.33	33.84	16.56	50.53	34.19	18.79	
CaO	22.53	.01	.51	.01	21.32	.01	.35	0.00	22.25	0.00	.81	22.59	0.00	.34	0.00	
Na2O	.61	.03	.08	.01	1.91	.03	.08	0.00	1.10	.03	.09	1.31	.01	.10	0.00	
K2O	.01	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	99.82	99.96	100.61	98.76	99.69	100.37	100.34	97.95	99.76	100.41	127.97	100.12	99.93	98.54	97.69	
Si	1.939	.993	1.953	0.000	1.890	.997	1.917	0.000	1.925	.994	1.946	1.928	.993	1.926	.002	
Ti	.001	0.000	.001	0.000	.010	0.000	.002	0.000	0.000	0.000	.001	.002	0.000	.001	0.000	
Al	.113	0.000	.103	1.412	.255	0.000	.158	1.702	.167	0.000	.120	.160	0.000	.115	1.526	
Cr	.024	0.000	.011	.539	.020	0.000	.006	.249	.025	0.000	.008	.022	0.000	.006	.419	
Fe2+	.057	.170	.146	.271	.067	.189	.175	.224	.055	.176	.157	.050	.166	.163	.245	
Fe3+	0.000	0.000	0.000	.049	0.000	0.000	0.000	.043	0.000	0.000	0.000	0.000	0.000	0.000	.052	
Mn	.003	.003	.006	.016	.002	.004	.005	.007	.003	.003	.004	.003	.003	.004	.013	
Ni	.001	.006	0.000	.002	.001	.007	.002	.007	.001	.007	.002	0.000	.007	0.000	.004	
Mg	.957	1.834	1.747	.710	.820	1.806	1.719	.767	.899	1.825	1.718	.893	1.837	1.781	.740	
Ca	.876	0.000	.019	0.000	.830	0.000	.013	0.000	.865	0.000	.029	.876	0.000	.013	0.000	
Na	.043	.001	.005	0.000	.135	.002	.005	0.000	.073	.002	.006	.092	0.000	.006	0.000	
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CATIONS	4.014	3.007	3.991	2.999	4.030	3.005	4.002	2.999	4.018	3.007	3.991	4.026	3.006	4.015	3.001	
Mg/Mg+Fe	.944	.915	.923	.724	.924	.905	.908	.774	.942	.912	.916	.947	.917	.916	.751	
Ca/CA+MG	.478	0.000	.011	0.000	.503	0.000	.008	0.000	.490	0.000	.017	.495	0.000	.007	0.000	
CR/CR+AL	.175	0.000	.096	.276	.073	0.000	.037	.128	.130	0.000	.063	.121	0.000	.050	.215	

	NX4-L	5 NX4-L	5 NX4-L	5 NX4-L	5 NX4-L	6 NX4-L	6 NX4-L	6 NX4-L	6 NX4-L	9 NX4-L	9 NX4-L	9 NX4-L	9
	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH	
SiO ₂	53.01	40.77	56.32	.03	52.56	40.74	55.54	.03	53.24	41.70	56.31	.06	
TiO ₂	.06	0.00	.05	.02	.40	0.00	.02	.06	.05	.06	.02	0.00	
Al ₂ O ₃	5.04	0.00	2.90	53.12	5.61	0.00	3.28	54.83	4.98	0.00	3.89	54.45	
Cr ₂ O ₃	.73	0.00	.13	13.74	.67	0.00	.11	12.30	.80	0.00	.32	14.27	
FeO	1.95	8.99	6.18	10.00	2.14	9.67	6.36	9.83	1.81	8.58	5.53	9.69	
Fe ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
MnO	.03	.17	.03	.46	.12	.19	.14	.42	.12	.12	.21	.36	
MgO	.01	.32	.02	.74	0.00	.40	.04	.32	.03	.36	.07	.24	
HgO	16.33	19.38	35.32	19.24	15.35	40.87	34.01	19.83	16.45	50.04	33.20	19.83	
CaO	21.28	.01	.73	0.00	21.81	.01	.32	0.00	21.35	0.00	.51	0.00	
Na ₂ O	1.36	0.00	.02	.03	1.72	0.00	.07	.02	1.46	.04	.05	.03	
K ₂ O	.02	0.00	.02	0.00	0.00	.01	.02	.01	0.00	.01	.01	0.00	
TOTAL	99.92	69.64	101.17	96.88	100.38	100.89	99.91	97.65	100.29	100.91	100.12	98.93	
Si	1.915	1.000	1.919	.001	1.897	.991	1.919	.001	1.915	1.006	1.932	.002	
Ti	.002	0.000	.001	0.000	.011	0.000	.001	.001	.001	.001	0.000	0.000	
Al	.215	0.000	.113	1.660	.239	0.000	.133	1.683	.211	0.000	.158	1.679	
Cr	.021	0.000	.004	.288	.019	0.000	.003	.253	.023	0.000	.009	.295	
Fe ²⁺	.059	.184	.176	.273	.065	.197	.184	.214	.055	.173	.159	.212	
Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.061	0.000	0.000	0.000	.025	
Mn	.001	.004	.002	.010	.004	.004	.004	.009	.004	.002	.006	.008	
Mg	0.009	.006	.001	.005	0.000	.008	.001	.007	.001	.007	.002	.005	
Hg	.880	1.806	1.796	.760	.826	1.809	1.753	.770	.883	1.801	1.698	.773	
Ca	.824	0.000	.230	0.000	.844	0.000	.012	0.000	.823	0.000	.018	0.000	
Na	.095	0.000	.020	.002	.120	0.000	.005	.001	.102	.002	.003	.002	
K	.001	0.000	.020	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	
CATIONS	4.013	3.900	4.282	2.999	4.025	3.909	4.016	3.900	4.018	2.992	3.985	3.901	
Mg/Mg+Fe	.937	.903	.911	.736	.927	.902	.905	.783	.941	.912	.914	.785	
Ca/CA+MG	.484	0.000	.114	0.000	.505	0.000	.007	0.000	.482	0.000	.010	0.000	
CR/CR+AL	.089	0.000	.034	.148	.074	0.000	.022	.131	.098	0.000	.054	.149	

	SD2-L	2 SD2-L	2 SD2-L	2 SD2-L	2 SD2-L	8 SD2-L	8 SD2-L	8 SD2-L	8 SD2-L	8 SD2-L	9 SD2-L	9 SD2-L	9 SD2-L	9
	CPX	Ol	OPX	SPN	CPX	GAR	Ol	OPX	SPN	CPX	Ol	OPX	SPN	
SiO2	53.13	40.91	56.88	.07	53.98	47.63	41.35	57.52	.05	52.49	40.59	56.35	.08	
TiO2	.48	0.00	.08	.02	.48	.09	0.00	.11	0.00	0.00	.02	.01	.02	
Al2O3	6.04	0.00	3.47	56.27	4.63	22.40	0.00	1.33	56.53	4.36	0.00	2.78	47.63	
Cr2O3	1.04	0.00	.35	12.32	.91	1.23	0.00	.23	9.89	.98	0.00	.29	19.37	
FeO	1.78	8.55	5.63	10.90	7.21	10.03	8.79	5.80	9.99	1.76	8.94	5.86	13.03	
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
MnO	.11	.12	.16	.11	.09	.59	.10	.15	.32	.17	.18	.13	.23	
NiO	.04	.35	.05	.22	.05	0.00	.38	.09	.16	.03	.42	.05	.14	
MgO	14.78	51.27	34.68	20.38	15.08	19.65	48.72	34.95	19.75	15.93	50.35	34.24	13.41	
CaO	20.91	.01	.24	0.00	20.48	4.61	.02	.26	0.00	22.93	0.00	.35	0.00	
Na2O	1.67	0.00	.05	0.00	2.25	.04	0.00	.02	.02	1.06	.02	.01	0.00	
K2O	.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.01	0.00	
TOTAL	99.99	101.21	101.59	100.29	100.16	101.27	99.36	100.46	96.76	99.71	100.52	100.08	99.41	
Si	1.914	.987	1.924	.001	1.942	3.013	1.014	1.969	.001	1.910	.988	1.938	.001	
Ti	.012	0.000	.002	0.000	.012	.004	0.000	.002	0.000	0.000	0.000	0.000	0.000	
Al	.255	0.000	.138	1.717	.196	1.866	0.000	.053	1.745	.187	0.000	.112	1.524	
Cr	.029	0.000	.009	.252	.025	.063	0.000	.006	.205	.028	0.000	.008	.426	
Fe2+	.053	.172	.159	.209	.042	.559	.180	.166	.219	.054	.182	.168	.253	
Fe3+	0.000	0.000	0.000	.026	.024	.034	0.000	0.000	.049	0.000	0.000	0.000	.042	
Mn	.003	.002	.004	.002	.002	.033	.001	.004	.007	.005	.004	.003	.004	
Ni	0.000	.006	.001	.003	.001	0.000	.007	.002	.003	.001	.008	.002	.002	
Mg	.792	1.843	1.749	.787	.808	2.069	1.781	1.783	.770	.865	1.823	1.756	.745	
Ca	.806	0.000	.008	0.000	.739	.347	0.000	.009	0.000	.895	0.000	.012	0.000	
Na	.116	0.000	.003	0.000	.156	.004	0.000	.001	.001	.075	.001	0.000	0.000	
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CATIONS	3.980	3.010	3.997	2.997	3.997	7.997	2.933	3.995	3.000	4.020	3.011	3.999	2.997	
MG/(MG+FE)	.937	.915	.917	.790	.951	.787	.908	.915	.779	.941	.909	.913	.746	
CA/CA+MG	.504	0.000	.005	0.000	.494	.144	0.000	.005	0.000	.509	0.000	.007	0.000	
CR/CR+AL	.102	0.000	.061	.128	.113	.035	0.000	.102	.105	.130	0.000	.067	.218	

	SD2-L 10	SD2-L 10	SD2-L 10	SD2-L 10	SD2-L 10	SD2-L 11	SD2-L 11	SD2-L 11	SD2-L 11	SD2-L 11	SD2-L 13	SD2-L 13	SD2-L 13	SD2-L 13
	CPX	GAR	OL	OPX	SPN	CPX	GAR	OL	OPX	SPN	CPX	CPX	GAR	OPX
SiO2	54.00	42.57	41.75	57.66	.01	53.32	42.17	41.65	57.67	.05	54.80	54.72	42.88	58.14
TiO2	.51	.10	0.00	.11	.15	.31	.07	0.00	.08	.07	.29	.29	.10	.05
Al2O3	4.44	22.47	.02	1.41	42.65	6.01	22.79	.02	1.73	54.26	3.29	3.26	22.80	.97
Cr2O3	1.17	1.55	.09	.32	23.46	.66	.94	0.00	.24	12.56	.83	.84	1.16	.20
FeO	2.26	10.54	7.98	6.05	11.65	1.96	9.97	9.09	5.77	11.14	1.77	1.77	7.72	4.52
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.09	.60	.14	.13	.64	.06	.55	.13	.13	.10	.09	.02	.35	.10
MgO	.03	0.00	.36	.04	.12	.06	.02	.30	.05	.31	.06	.05	0.00	.10
MgO	15.34	19.46	51.92	35.54	17.16	15.31	18.90	43.70	34.75	20.74	16.11	16.17	21.75	37.26
CaO	20.63	4.86	.04	.30	0.00	20.90	4.91	.01	.30	0.00	21.11	20.67	4.40	.17
Na2O	2.13	.01	.02	0.00	.02	1.88	.03	0.00	.03	0.00	2.07	2.02	.07	.04
K2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	100.65	102.16	102.32	101.56	95.86	100.47	100.35	99.90	100.75	99.23	100.42	99.31	101.23	101.55
Si	1.936	2.992	.992	1.956	.001	1.910	1.505	1.016	1.966	0.000	1.953	1.972	2.988	1.953
Ti	.014	.004	0.000	.002	.003	.003	.002	0.000	.002	0.000	.007	.007	.004	.001
Al	.187	1.861	0.000	.056	1.399	.253	.959	0.000	.069	1.676	.137	.137	1.874	.038
Cr	.032	.084	.001	.008	.516	.018	.027	0.000	.006	.260	.023	.023	.063	.004
Fe2+	.035	.559	.158	.171	.271	.036	.298	.196	.164	.186	.052	.033	.364	.030
Fe3+	.032	.060	0.000	0.000	.079	.022	0.000	0.000	0.000	.058	0.000	.020	.086	.044
Mn	.002	.035	.002	.003	.015	.001	.017	.002	.003	.001	.002	0.000	.020	.002
Mg	0.000	0.000	.006	.001	.003	.001	.001	.005	.001	.006	.001	.001	0.000	.002
Mg	.819	2.039	1.839	1.797	.712	.817	1.006	1.772	1.766	.810	.859	.868	2.260	1.859
Ca	.794	.265	0.000	.010	0.000	.802	.188	0.000	.010	0.000	.810	.797	.331	.008
Na	.147	0.000	0.000	0.000	.001	.140	.002	0.000	.001	0.000	.143	.141	.008	.003
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	3.998	7.999	2.998	4.004	3.000	3.998	4.005	2.980	3.988	2.997	3.997	3.999	7.998	3.991
MG/MG+FL	.959	.735	.921	.913	.724	.958	.771	.905	.915	.813	.943	.963	.861	.959
CA/CA+MG	.492	.152	0.000	.006	0.000	.495	.157	0.000	.006	0.000	.485	.479	.128	.004
CR/CR+AL	.146	.043	1.000	.125	.269	.066	.027	0.000	.030	.134	.144	.144	.033	.095

	SD2-L 14	SD2-L 14	SD2-L 14	SD2-L 14	SD2-L 17	SD2-L 17	SD2-L 17	SD2-L 17	SD2-L 18	SD2-L 18	SD2-L 18	SD2-L 18	SD2-L 19	SD2-L 19	SD2-L 19	SD2-L 19
	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH
SiO2	53.10	40.60	56.02	.10	53.03	40.23	53.92	.06	52.42	40.97	55.16	.04	51.73	40.73	55.35	.06
TiO2	.08	0.00	.08	.04	.27	.04	.12	.08	.24	.04	.01	.14	.33	0.00	.02	.06
Al2O3	4.67	0.00	2.84	55.37	6.69	0.00	4.86	58.27	4.46	0.00	3.01	49.87	6.83	0.00	3.94	59.12
Cr2O3	.54	0.00	.08	10.33	.59	0.00	.26	10.40	.96	0.00	.29	18.91	.70	0.00	.20	10.11
FeO	1.88	9.40	6.24	11.70	2.43	10.63	6.90	10.91	2.04	9.26	5.91	10.69	2.15	9.86	6.46	10.64
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.14	.17	.15	.15	.11	.25	.16	.32	.17	.12	.15	.51	.07	.15	.20	.34
NaO	0.00	.36	0.00	.30	0.00	.37	.07	.39	0.00	.27	.02	.13	0.00	.39	.06	.35
BqO	15.45	49.88	34.34	20.70	15.03	49.79	33.07	19.96	16.73	50.14	33.65	19.05	14.63	50.56	34.21	20.37
CaO	21.80	0.00	.25	0.00	21.30	0.00	.43	.02	22.39	.01	.54	.02	21.18	.01	.32	0.00
Na2O	1.71	.01	0.00	0.00	1.96	.06	.04	.01	.95	.01	.07	.05	1.95	.03	.07	.01
K2O	.01	0.00	.01	0.00	0.00	0.00	.01	0.00	.02	0.00	.01	0.00	.01	.01	0.00	0.00
TOTAL	99.38	100.42	100.01	98.69	101.46	101.42	99.84	100.42	100.38	100.82	98.82	99.41	99.58	101.74	100.83	101.06
Si	1.931	.991	1.930	.007	1.890	.981	1.873	.002	1.895	.994	1.924	.001	1.880	.984	1.893	.002
Ti	.002	0.000	.001	0.000	.007	.030	.003	.002	.007	.001	0.000	.003	.009	0.000	0.000	.001
Al	.200	0.000	.120	1.709	.231	0.000	.199	1.743	.190	0.000	.124	1.543	.292	0.000	.159	1.752
Cr	.016	0.000	.003	.213	.017	0.000	.007	.209	.023	0.000	.008	.394	.020	0.000	.006	.201
Fe2+	.057	.192	.180	.184	.074	.217	.201	.231	.062	.188	.172	.236	.066	.199	.186	.224
Fe3+	0.000	0.000	0.000	.072	0.000	0.000	0.000	.043	0.000	0.000	0.000	.053	0.000	0.000	0.000	.047
Mn	.004	.003	.004	.003	.003	.005	.005	.007	.005	.002	.004	.011	.002	.003	.006	.007
Na	0.000	.007	0.000	.006	0.000	.007	.002	.008	0.000	.005	0.000	.003	0.000	.008	.002	.007
Bq	.888	1.816	1.770	.808	.799	1.307	1.714	.755	.902	1.314	1.752	.748	.794	1.821	1.749	.763
Ca	.520	0.000	.010	0.000	.814	0.000	.016	.001	.863	0.000	.020	.001	.825	0.000	.012	0.000
Na	.120	0.000	0.000	0.000	.135	.003	.003	.001	.066	.001	.004	.003	.138	.002	.004	.001
K	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	3.738	3.009	4.018	2.997	4.020	3.050	4.024	3.002	4.024	3.005	4.008	3.001	4.026	3.017	4.022	3.000
HG/MG+H	.940	.904	.908	.815	.915	.893	.895	.766	.936	.906	.911	.760	.923	.901	.904	.773
CA/CA+MG	.369	0.000	.006	0.000	.505	0.000	.009	.001	.490	0.000	.011	.001	.510	0.000	.007	0.000
CR/CR+M	.074	0.000	.024	.111	.057	0.000	.034	.107	.123	0.000	.061	.203	.064	0.000	.036	.103

	SD2-1 24	SD2-1 24	SD2-1 24	SD2-1 24	SD2-1 28	SD2-1 28	SD2-1 28	SD2-1 28	SD2-1 28	SD2-1 32	SD2-1 32	SD2-1 32	SD2-1 32	SD2-1 32	SD2-1 32
	CPX	OL	OPX	SPH	CPX	GAR	OL	OPX	SPH	CPX	GAR	OL	OPX	SPH	
SiO ₂	53.43	40.80	54.66	.04	52.01	41.85	40.50	54.92	.04	53.63	41.32	40.26	56.07	.06	
TiO ₂	.25	.04	.11	.15	.36	.03	.01	.05	.06	.42	.11	0.00	.07	.25	
Al ₂ O ₃	4.47	0.00	3.41	52.08	6.36	24.08	0.00	3.65	54.98	3.90	22.43	0.00	1.11	32.92	
Cr ₂ O ₃	.82	0.00	.26	16.15	.65	.39	0.00	.14	11.14	.93	1.38	0.00	.12	31.93	
FeO	2.13	9.43	6.60	13.08	2.28	11.06	9.72	6.39	9.07	2.25	10.84	9.83	6.25	13.83	
Fe ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
MnO	0.00	.17	.15	.78	.11	.67	.07	.17	.40	.12	.63	.17	.15	.74	
Na ₂ O	.11	.45	.01	0.00	.04	.05	.35	.07	.26	.09	.04	.33	.03	.14	
K ₂ O	15.86	50.23	33.93	18.27	15.06	20.00	50.47	33.64	20.28	15.04	18.61	49.02	34.79	15.11	
CaO	22.11	0.00	.55	.09	20.93	3.61	.01	.43	0.00	20.74	4.92	.01	.27	.01	
Na ₂ CO ₃	1.46	.01	.02	0.00	2.17	.66	.01	.07	.04	2.38	.03	.05	.04	0.00	
K ₂ CO ₃	.01	0.00	0.00	.04	.02	0.00	0.00	0.00	0.00	.01	0.00	.01	0.00	0.00	
TOTAL	100.70	101.13	99.70	100.68	99.99	101.30	101.14	99.53	96.27	99.47	100.31	99.68	98.90	94.99	
Si	1.923	.989	1.899	.001	1.884	1.473	.983	1.907	.001	1.951	1.486	.992	1.956	.002	
Al	.007	.001	.003	.003	.010	.001	0.000	.001	.001	.011	.003	0.000	.002	.005	
Cr	.190	0.000	.140	1.632	.272	.100	0.000	.149	1.686	.167	.951	0.000	.027	1.122	
Fe ²⁺	.023	0.000	.007	.340	.019	.011	0.000	.004	.229	.027	.039	0.000	.003	.073	
Fe ³⁺	.064	.191	.192	.291	.069	.326	.197	.186	.197	.069	.326	.203	.183	.334	
Mn	0.000	.004	.004	.017	.003	.020	.001	.005	.083	0.000	0.000	0.000	0.000	.134	
Na	.003	.009	0.000	0.000	.001	.001	.007	.002	.009	.004	.019	.003	.005	.018	
Cl	.000	1.816	1.758	.723	.814	1.050	1.827	1.742	.787	.816	.998	1.801	1.810	.651	
Ca	.002	0.000	.020	.003	.813	.136	0.000	.016	0.000	.809	.190	.001	.010	0.000	
Na	.102	0.000	.002	0.000	.153	.004	.001	.005	.002	.168	.002	.002	.003	0.000	
K	0.000	0.000	0.000	.002	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CATIONS	4.014	3.010	4.025	3.012	4.039	3.122	3.016	4.017	3.000	4.023	4.015	3.009	4.000	2.342	
MG/MG+FI	.930	.905	.902	.713	.922	.763	.903	.904	.800	.922	.754	.899	.908	.661	
CA/CA+MG	.001	0.000	.011	.004	.000	.115	0.000	.009	0.000	.498	.160	.001	.005	0.000	
CR/CR+AL	.108	0.000	.043	.172	.065	.099	0.000	.026	.120	.139	.039	0.000	.100	.061	

	SD2-L 34	SD2-L 34	SD2-L 34	SD2-L 34	SD2-L 35	SD2-L 35	SD2-L 35	SD2-L 35	SD2-L 35	SD2-L 37	SD2-L 37	SD2-L 37	SD2-L 37
	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH	
SiO2	52.61	40.79	55.56	.05	51.96	40.72	54.70	.07	52.18	40.23	52.85	.05	
TiO2	.03	.05	0.00	.06	.31	.06	.10	.07	.46	0.00	.12	.13	
Al2O3	3.86	0.00	2.34	47.82	6.46	0.00	4.54	56.84	.48	0.00	4.75	57.66	
Cr2O3	.91	0.00	.17	20.79	.75	0.00	.25	10.14	.80	0.00	.47	10.16	
FeO	1.47	7.63	5.33	10.26	2.00	9.23	5.83	9.89	2.38	10.08	6.38	9.80	
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
MnO	.10	.18	.13	.56	.15	.18	.19	.32	.04	.19	.23	.29	
MgO	.10	.31	0.00	.14	0.00	.41	.05	.14	0.00	.47	.12	.25	
MgO	16.62	51.47	35.02	18.95	14.43	50.11	33.13	19.89	15.25	49.83	32.55	20.54	
CaO	22.66	.01	.31	.02	21.06	.01	.78	0.00	21.17	0.00	.85	0.00	
Na2O	1.56	.01	0.00	0.00	2.00	.02	.09	0.00	1.86	.01	.09	.03	
K2O	0.00	0.00	.01	0.00	0.00	0.00	0.00	.01	0.00	0.00	0.00	0.00	
TOTAL	99.92	100.45	98.92	98.65	99.12	100.74	99.66	97.37	94.62	100.81	98.41	98.91	
Si	1.911	.987	1.931	.001	1.895	.990	1.894	.002	1.878	.983	1.865	.001	
Ti	.001	.001	0.000	.001	.008	.001	.003	.001	.013	0.000	.003	.003	
Al	.165	0.000	.096	1.510	.278	0.000	.185	1.753	.275	0.000	.198	1.733	
Cr	.026	0.000	.005	.440	.022	0.000	.007	.210	.023	0.000	.013	.205	
Fe2+	.045	.155	.155	.230	.061	.188	.169	.217	.072	.206	.188	.209	
Fe3+	0.000	0.000	0.000	.045	0.000	0.000	0.000	.031	0.000	0.000	0.000	.056	
Mn	.003	.004	.005	.013	.005	.004	.005	.007	.001	.004	.007	.006	
Mg	.003	.006	0.000	.003	0.000	.008	.001	.003	0.000	.009	.003	.005	
Mg	.900	1.859	1.815	.757	.785	1.817	1.711	.776	.818	1.815	1.713	.781	
Ca	.883	0.000	.011	0.000	.623	0.000	.029	0.000	.817	0.000	.032	0.000	
Na	.110	.001	0.000	0.000	.141	.001	.006	0.000	.130	.001	.006	.001	
K	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CATIONS	4.047	3.013	4.019	3.000	4.018	3.009	4.010	3.000	4.027	3.018	4.028	3.000	
HL/HG+H	.952	.923	.921	.767	.928	.906	.910	.781	.919	.898	.901	.739	
CA/CA+MG	.495	0.000	.006	0.000	.512	0.000	.017	0.000	.500	0.000	.018	0.000	
CR/CR+AL	.136	0.000	.050	.226	.073	0.000	.036	.107	.077	0.000	.062	.106	

	SD2-L 39	SD2-L 39	SD2-L 39	SD2-L 39	SD2-L 39	SD2-L 39	SD2-L 40	SD2-L 40	SD2-L 40	SD2-L 40	SD2-L 44	SD2-L 44	SD2-L 44	SD2-L 45	SD2-L 45	SD2-L 45
	CPX	GAR	OL	OPX	SPN	CPX	GAR	IL	OL	OPX	CPX	GAR	OPX	CPX	GAR	OPX
SiO2	52.71	41.61	40.76	56.25	.03	53.80	41.14	.13	40.09	57.51	55.63	43.70	59.06	53.98	42.52	58.28
TiO2	.46	.06	0.00	.01	.22	.08	.15	42.03	0.00	.05	.37	.14	.07	.40	.14	.07
Al2O3	3.74	22.63	0.00	1.19	40.75	1.42	20.91	.80	0.00	.70	3.25	23.13	.92	3.33	23.12	.88
Cr2O3	.88	.91	0.00	.16	25.50	.66	2.28	4.87	0.00	.15	.66	.87	.16	.56	.82	.12
FeO	1.98	9.46	8.60	5.55	11.26	2.88	13.05	42.40	13.00	8.24	1.85	7.61	4.45	1.96	7.79	4.39
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.08	.48	.12	.20	.65	.11	.73	.23	.16	.19	.05	.34	.11	.06	.36	.08
HfO	0.00	.01	.35	.07	.13	.02	0.00	.31	.21	.05	.10	.03	.10	.07	0.00	.05
MgO	15.67	19.34	50.58	35.21	17.41	16.74	16.33	7.49	47.59	34.73	16.17	22.09	38.08	15.84	21.30	37.01
CaO	20.83	4.60	.02	.40	0.00	22.86	5.90	.05	.01	.28	21.24	4.70	.17	21.33	4.64	.20
Na2O	2.40	.05	.01	.05	.06	.91	.01	0.00	0.00	.02	2.20	.09	.05	1.92	.05	.03
K2O	.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	98.76	99.15	100.44	99.09	96.01	99.48	100.50	98.31	101.06	101.92	101.52	102.70	103.17	99.45	100.74	101.11
Si	1.934	1.499	.991	1.955	.001	1.962	2.998	.002	.988	1.962	1.971	3.002	1.958	1.955	2.982	1.968
Ti	.013	.002	0.000	0.000	.004	.002	.006	.756	0.000	.001	.009	.006	0.000	.010	.006	.001
Al	.162	.961	0.000	.049	1.332	.060	1.796	.022	0.000	.028	.135	1.871	.036	.141	1.910	.035
Cr	.026	.026	0.000	.004	.559	.018	.130	.092	0.000	.004	.018	.046	.003	.016	.045	.003
Fe2+	.061	.285	.175	.161	.261	.031	.729	.476	.268	.234	.054	.436	.122	.014	.381	.124
Fe3+	0.000	0.000	0.000	0.000	.101	.056	.064	.372	0.000	0.000	0.000	0.000	0.000	.044	.076	0.000
Mn	.003	.015	.003	.006	.015	.003	.042	.004	.002	.005	.001	.018	.002	.001	.021	.002
Hf	0.000	0.000	.007	.002	.003	0.000	0.000	.005	.003	.001	.002	0.000	.001	.001	0.000	.001
Mg	.858	1.039	1.833	1.825	.720	.910	1.772	.267	1.748	1.767	.853	2.262	1.831	.854	2.225	1.863
Ca	.819	.178	0.000	.015	0.000	.893	.459	.001	0.000	.010	.805	.345	.005	.828	.348	.007
Na	.171	.003	0.000	.004	.003	.063	0.000	0.000	0.000	.001	.150	.012	.002	.134	.006	.002
E	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONF	4.048	4.008	3.009	4.021	2.999	3.998	7.996	1.997	3.009	4.013	3.998	7.998	4.010	3.998	8.000	4.006
MG/MG+1	.934	.785	.913	.919	.734	.967	.709	.359	.867	.883	.940	.838	.939	.984	.854	.938
CA/CA+MG	.488	.146	0.000	.008	0.000	.495	.206	.004	0.000	.006	.486	.132	.003	.492	.135	.004
CR/CR+AL	.138	.026	0.000	.075	.296	.231	.067	.807	0.000	.125	.118	.024	.077	.102	.023	.079

	SD2-L 51	SD2-L 51	SD2-L 51	SD2-L 54	SD2-L 54	SD2-L 54	SD2-L 54	SD2-L 57	SD2-L 57	SD2-L 57	SD2-L 57	SD2-L 58	SD2-L 58	SD2-L 58	SD2-L 58
	CPX	GAR	OPX	CPX	GAR	OL	OPX	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN
SiO2	55.03	43.29	58.54	54.13	42.12	40.79	56.74	53.10	40.57	55.66	.09	53.73	40.32	54.88	.07
TiO2	.38	.17	.11	.40	.07	0.00	.10	.38	0.00	.07	.06	.29	.10	.09	.02
Al2O3	3.12	22.14	1.70	3.77	22.50	0.00	1.47	5.21	0.00	2.88	51.46	5.81	0.00	3.39	57.39
Cr2O3	1.42	2.24	.44	.85	1.34	0.00	.19	.89	0.00	.25	14.64	.60	0.00	.12	10.49
FeO	1.34	7.71	4.63	2.08	9.93	8.93	5.41	1.66	8.48	5.60	11.07	2.34	10.13	6.56	10.36
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.05	.45	.10	.06	.59	.14	.16	.11	.14	.13	.16	.11	.13	.22	.34
MgO	.03	.03	.09	0.00	.01	.36	.05	.03	.34	.10	.29	.03	.32	.06	.27
MgO	16.30	20.98	36.25	15.51	18.92	50.21	33.56	15.29	51.23	34.73	20.29	14.93	49.71	33.67	20.03
CaO	21.66	5.38	.75	20.97	4.87	0.00	1.37	21.50	0.00	.20	0.00	22.13	.01	.35	0.00
Na2O	1.88	.05	.11	2.36	0.00	.01	.17	1.62	0.00	.03	.02	1.71	.01	.01	.01
K2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.01	0.00	0.00
TOTAL	101.21	102.44	102.72	100.13	100.35	100.44	99.22	99.79	100.76	99.65	98.08	101.68	100.74	99.35	98.98
Si	1.959	3.008	1.954	1.954	1.504	.993	1.970	1.919	.983	1.922	.001	1.912	.985	1.911	.002
Ti	.009	.008	.002	.011	.002	0.000	.003	.009	0.000	.001	0.000	.008	.002	.002	0.000
Al	.130	1.813	.072	.161	.948	0.000	.060	.221	0.000	.116	1.622	.244	0.000	.139	1.734
Cr	.040	.122	.011	.024	.038	0.000	.005	.025	0.000	.006	.309	.017	0.000	.003	.213
Fe2+	.040	.446	.128	.063	.297	.182	.157	.050	.171	.161	.064	.070	.207	.191	.222
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.183	0.000	0.000	0.000	.050
Mn	.001	.024	.002	.002	.018	.003	.005	.003	.002	.003	.003	.003	0.000	.007	.007
K	0.000	0.000	.002	0.000	0.000	.007	.001	0.000	.006	.002	.006	.001	.006	.002	.005
Mg	.865	2.171	1.803	.835	1.008	1.623	1.738	.823	1.851	1.787	.808	.792	1.811	1.748	.765
Ca	.625	.399	.026	.812	.187	0.000	.051	.832	0.000	.007	0.000	.844	0.000	.013	0.000
Na	.129	.006	.006	.165	0.000	0.000	.011	.113	0.000	.001	0.000	.118	.001	0.000	.001
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	3.998	7.997	4.006	4.027	4.002	3.003	4.001	3.995	3.013	4.006	2.996	4.009	3.015	4.016	2.999
Mg/MG+L	.956	.830	.934	.930	.772	.909	.917	.943	.915	.917	.927	.919	.897	.901	.775
CA/CA+MG	.488	.155	.014	.493	.156	0.000	.029	.503	0.000	.004	0.000	.516	0.000	.007	0.000
CR/CR+AL	.235	.063	.133	.130	.039	0.000	.077	.102	0.000	.049	.160	.065	0.000	.021	.109

	SD2-L 59	SD2-L 59	SD2-L 59	SD2-L 59	SD2-L 59	SD2-L 61	SD2-L 61	SD2-L 61	SD2-L 61	SD2-L 64	SD2-L 64	SD2-L 64	SD2-L 64
	CPX	GAR	OL	OPX	SPN	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN
SiO2	52.95	41.86	41.13	56.98	.04	53.42	40.87	55.80	.07	51.11	40.63	55.15	.01
TiO2	.36	.10	.03	.07	.39	.49	.03	.21	.07	.30	0.00	.05	0.00
Al2O3	3.41	22.41	0.00	1.23	33.01	4.71	0.00	3.05	51.54	6.31	0.00	4.39	57.90
Cr2O3	1.02	1.21	0.00	.17	31.43	.63	0.00	.17	15.29	.66	0.00	.26	9.37
FeO	2.10	10.00	8.68	5.84	13.25	1.87	8.95	6.25	9.61	2.14	9.52	6.30	8.63
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.08	.53	.19	.17	.75	.09	.09	.06	.41	.10	.13	.07	.20
NiO	0.00	0.00	.41	.04	.17	.13	.47	.09	.30	0.00	.36	.02	.12
MgO	15.83	18.96	50.47	35.01	15.23	15.48	50.67	33.97	19.53	15.39	49.99	34.00	21.11
CaO	20.49	4.83	0.00	.30	0.00	21.38	.04	.21	.01	20.94	.03	.42	0.00
Na2O	2.22	.04	.01	.05	.01	1.67	.05	.03	0.00	1.96	.01	.07	.02
K2O	.02	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00	.02	.01	.02	0.00
TOTAL	98.48	99.94	100.93	99.86	94.28	99.87	101.17	99.84	96.83	98.93	100.68	100.75	97.36
Si	1.946	1.502	.995	1.964	.001	1.930	.988	1.926	.002	1.872	.990	1.891	0.000
Ti	.010	.003	.001	.002	.009	.013	0.000	.005	.001	.008	0.000	.001	0.000
Al	.148	.948	0.000	.050	1.135	.201	0.000	.124	1.615	.273	0.000	.178	1.749
Cr	.030	.034	0.000	.005	.725	.018	0.000	.005	.321	.019	0.000	.007	.190
Fe2+	.065	.300	.175	.168	.323	.057	.181	.181	.214	.066	.194	.181	.185
Fe3+	0.000	0.000	0.000	0.000	.121	0.000	0.000	0.000	.057	0.000	0.000	0.000	.061
Mn	.003	.016	.004	.005	.019	.003	.002	.002	.009	.003	.003	.002	.004
Ni	0.000	0.000	.008	.001	.004	.004	.009	.003	.006	0.000	.007	0.000	.002
Mg	.868	1.014	1.821	1.800	.662	.834	1.828	1.749	.774	.841	1.816	1.738	.807
Ca	.807	.186	0.000	.011	0.000	.828	.001	.008	0.000	.823	.001	.015	0.000
Na	.158	.003	.001	.004	.001	.117	.002	.002	0.000	.139	.001	.005	.001
K	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	.001	0.000
CATIONS	4.036	4.006	3.005	4.010	3.000	4.005	3.011	4.005	2.999	4.045	3.012	4.019	2.999
Mg/MG+FE	.930	.772	.912	.915	.672	.936	.910	.906	.783	.927	.903	.906	.814
CA/CA+MG	.482	.155	0.000	.006	0.000	.498	.001	.005	0.000	.495	.001	.009	0.000
CR/CR+AL	.169	.035	0.000	.091	.390	.082	0.000	.039	.166	.065	0.000	.038	.098

	SD2-L 66	SD2-L 66	SD2-L 66	SD2-L 66	SD2-L 68	SD2-L 68	SD2-L 68	SD2-L 70	SD2-L 70	SD2-L 70	SD2-L 70	SD2-L 71	SD2-L 71	SD2-L 71	SD2-L 71
	CPX	GAR	OL	OPX	CPX	GAR	OPX	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN
SiO2	54.91	41.54	40.76	56.41	54.94	43.02	58.46	52.68	39.94	56.13	.05	53.24	40.60	53.76	.05
TiO2	.24	.05	0.00	.07	.36	.12	.08	.29	.01	.06	.07	.33	.06	.05	.04
Al2O3	3.30	21.81	0.00	1.22	3.37	22.66	.87	6.04	0.00	3.59	56.63	6.22	0.00	4.25	58.60
Cr2O3	.79	1.18	0.00	.23	.94	1.33	.16	.80	0.00	.27	11.01	.78	0.00	.27	9.64
FeO	2.12	11.25	9.18	6.07	1.99	8.05	4.50	1.88	9.73	6.11	11.20	1.96	9.76	6.31	11.39
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.05	.55	.09	.13	.08	.38	.09	.11	.16	.18	.14	0.00	.05	.23	0.00
NiO	.03	0.00	.32	.05	.02	0.00	.03	.03	.44	.04	.28	.09	.40	.13	.35
MgO	15.58	18.98	49.64	35.25	15.55	21.05	36.67	15.06	49.93	34.09	20.32	15.40	49.78	33.46	20.66
CaO	21.36	4.85	.01	.20	20.70	4.70	.22	21.27	.01	.32	.01	21.98	0.00	.78	.05
Na2O	1.80	.05	0.00	.02	2.04	0.00	.07	1.57	.02	.05	0.00	1.62	.06	.14	.03
K2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	100.18	100.26	100.00	99.65	99.99	101.31	101.15	99.73	100.24	100.84	99.71	101.62	100.71	99.38	100.81
Si	1.979	2.992	.997	1.952	1.978	1.506	1.976	1.904	.980	1.917	0.000	1.894	.989	1.876	.001
Ti	.006	.003	0.000	.001	.009	.003	.002	.290	0.000	.001	0.000	.009	.001	.002	.001
Al	.139	1.853	0.000	.048	.143	.935	.034	.256	0.000	.144	1.735	.261	0.000	.176	1.772
Cr	.022	.067	0.000	.006	.026	.036	.004	.024	0.000	.007	.226	.022	0.000	.008	.196
Fe2+	.064	.678	.187	.174	.059	.235	.127	.056	.200	.174	.207	.058	.199	.184	.244
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.036	0.000	0.000	0.000	0.000
Mn	.001	.034	.001	.003	.002	.010	.002	.003	.003	.005	.002	0.000	.001	.006	0.000
Ni	0.000	0.000	.005	.001	0.000	0.000	0.000	0.000	.009	.001	.005	.002	.008	.003	.007
Mg	.844	2.039	1.809	1.818	.834	1.098	1.847	.811	1.827	1.735	.787	.817	1.809	1.742	.790
Ca	.832	.374	0.000	.007	.798	.175	.007	.823	0.000	.011	0.000	.838	0.000	.028	.001
Na	.125	.007	0.000	.001	.143	0.000	.004	.109	.001	.003	0.000	.112	.003	.009	.002
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.012	8.047	2.999	4.011	3.992	3.998	4.003	4.276	3.020	3.998	2.998	4.013	3.010	4.034	3.014
MG/MG+FE	.930	.750	.906	.913	.934	.824	.936	.935	.901	.909	.792	.934	.901	.904	.764
CA/CA+MG	.496	.155	0.000	.004	.439	.137	.004	.504	0.000	.006	0.000	.506	0.000	.016	.001
CR/CR+AL	.137	.035	0.000	.111	.154	.037	.105	.086	0.000	.046	.115	.078	0.000	.043	.100

	SD2-L 72	SD2-L 72	SD2-L 72	SD2-L 72	SD2-L 74	SD2-L 74	SD2-L 74	SD2-L 74	SD2-L 81	SD2-L 81	SD2-L 81	SD2-L 82	SD2-L 82	SD2-L 82
	CPX	GAR	OL	OPX	CPX	OL	OPX	SPN	CPX	GAR	OPX	CPX	GAR	OPX
SiO2	53.99	41.78	40.65	57.16	52.83	40.46	54.71	.08	54.09	42.73	57.75	54.64	42.67	57.49
TiO2	.42	.13	.08	.26	.46	.10	.05	.06	.38	.23	.11	.56	.15	.20
Al2O3	5.38	22.08	0.00	1.47	6.34	0.00	4.20	59.58	3.26	22.91	.96	3.04	21.25	.84
Cr2O3	.82	1.29	0.00	.24	.71	0.00	.20	9.09	.81	1.26	0.00	.66	.81	.03
FeO	2.31	11.04	9.89	6.44	2.23	10.15	6.77	10.62	2.08	8.81	4.88	2.22	7.99	4.86
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.13	.55	.09	.09	0.00	.08	.22	.24	0.00	.29	.09	.07	.34	.04
NiO	.08	.05	.37	.15	.03	.45	.17	.22	.03	.02	0.00	.10	.02	.13
MgO	14.65	19.28	49.41	34.73	14.87	49.33	33.27	20.38	16.28	20.65	36.23	16.32	21.34	35.82
CaO	20.25	4.90	.03	.31	20.61	0.00	.57	.02	21.39	4.90	.20	20.76	4.77	.20
Na2O	2.40	.04	.04	.04	1.81	.05	.08	0.00	2.21	.06	0.00	2.07	.05	.06
K2O	0.00	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	100.43	101.14	100.56	100.90	99.89	100.62	100.24	100.29	100.53	101.86	100.22	100.44	99.39	99.67
Si	1.941	2.982	.992	1.956	1.906	.989	1.893	.002	1.948	1.494	1.971	1.965	3.046	1.974
Ti	.011	.007	.001	.007	.012	.002	.002	.001	.010	.006	.003	.015	.008	.005
Al	.228	1.858	0.000	.059	.270	0.000	.171	1.777	.139	.945	.039	.129	1.789	.034
Cr	.023	.073	0.000	.007	.020	0.000	.006	.182	.023	.035	0.000	.019	.046	.001
Fe2+	.069	.659	.202	.184	.067	.208	.196	.225	.063	.258	.140	.067	.477	.140
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.035	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.004	.033	.002	.003	0.000	.002	.006	.005	0.000	.009	.003	.002	.020	.001
Ni	.002	.003	.007	.004	.001	.009	.004	.004	.001	0.000	0.000	.003	.001	.004
Mg	.786	2.052	1.799	1.772	.800	1.799	1.716	.769	.875	1.077	1.844	.875	2.272	1.835
Ca	.773	.375	.001	.011	.798	0.000	.021	0.000	.826	.184	.007	.800	.365	.008
Na	.168	.005	.002	.003	.127	.002	.006	0.000	.154	.004	0.000	.144	.006	.004
K	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.005	8.047	3.006	4.007	4.001	3.011	4.021	3.000	4.039	4.012	4.007	4.019	8.030	4.006
MG/MG+FE	.919	.757	.899	.906	.923	.896	.897	.774	.933	.807	.929	.929	.826	.929
CA/CA+MG	.496	.155	.001	.006	.499	0.000	.012	0.000	.486	.146	.004	.478	.138	.004
CR/CR+AL	.092	.038	0.000	.106	.069	0.000	.034	.093	.142	.036	0.000	.123	.025	.029

	SD2-L 91	SD2-L 91	SD2-L 91	SD2-L 91	SD2-L 92	SD2-L 92	SD2-L 92	SD2-L 92	SD2-L 92	SD2-L 93	SD2-L 93	SD2-L 93	SD2-L 93	SD2-L 95	SD2-L 95
	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN	OL	OPX	
SiO2	54.05	40.27	56.54	.14	54.02	40.85	56.06	.15	53.81	40.60	55.98	.17	40.21	54.91	
TiO2	.01	.05	.10	.02	.03	.03	.01	0.00	.06	.07	0.00	.07	0.00	.09	
Al2O3	2.76	.09	2.51	40.22	2.24	.02	2.53	39.68	7.42	0.00	2.76	38.92	0.00	4.45	
Cr2O3	.93	.07	.30	26.71	.72	.01	.36	27.43	.77	.01	.48	28.34	0.00	.31	
FeO	1.65	7.77	5.81	12.37	1.62	7.83	5.22	12.73	1.53	8.00	5.07	13.07	9.86	6.30	
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
MnO	.09	.13	.13	.21	.11	.11	.11	.24	.06	.13	.13	.29	.13	.14	
NiO	.04	.40	.14	.17	.03	.45	.13	.25	.04	.41	.10	.26	.36	.07	
MgO	17.48	49.78	34.54	17.54	27.96	50.72	35.11	18.24	16.79	51.24	34.91	17.90	50.15	33.23	
CaO	23.19	.02	.33	0.00	23.75	.01	.32	.02	23.83	.61	.59	.04	.01	.57	
Na2O	.59	0.00	.02	0.00	.47	0.00	.02	.07	.57	.02	.01	.06	.01	.05	
K2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	100.79	98.58	100.42	97.38	110.95	100.03	99.87	98.81	99.88	101.09	100.03	99.12	100.73	100.12	
Si	1.942	.994	1.938	.003	1.948	.994	1.929	.004	1.951	.984	1.924	.004	.981	1.895	
Ti	0.000	0.000	.003	0.000	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	.002	
Al	.116	.002	.101	1.349	.094	0.000	.102	1.313	.103	0.000	.111	1.291	0.000	.180	
Cr	.026	0.000	.008	.601	.020	0.000	.009	.608	.021	0.000	.013	.630	0.000	.008	
Fe2+	.049	.160	.167	.246	.048	.159	.149	.222	.045	.162	.145	.237	.201	.181	
Fe3+	0.000	0.000	0.000	.048	0.000	0.000	0.000	.076	0.000	0.000	0.000	.070	0.000	0.000	
Mn	.002	.002	.004	.004	.003	.002	.003	.005	.001	.002	.003	.006	.002	.004	
Ni	0.000	.007	.004	.003	0.000	.008	.003	.005	.001	.008	.002	.005	.006	.001	
Mg	.935	1.831	1.766	.744	.953	1.840	1.800	.763	.907	1.852	1.788	.750	1.824	1.709	
Ca	.892	0.000	.012	0.000	.906	0.000	.011	0.000	.925	0.000	.021	0.000	0.000	.020	
Na	.040	0.000	.002	0.000	.032	0.000	.001	.003	.039	0.000	0.000	.002	0.000	.003	
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CATIONS	4.002	2.996	4.005	2.998	4.004	3.003	4.007	2.999	3.994	3.008	4.007	2.995	3.014	4.003	
Mg/(Mg+Fe)	.950	.920	.914	.752	.952	.920	.924	.775	.953	.920	.925	.760	.901	.904	
Ca/(Ca+Mg)	.488	0.000	.007	0.000	.487	0.000	.006	0.000	.505	0.000	.012	0.000	0.000	.012	
Cr/(Cr+Al)	.183	0.000	.073	.308	.175	0.000	.081	.317	.169	0.000	.105	.328	0.000	.043	

ERRATA

	SD2-L 95	SD2-L 96	SD2-L 96	SD2-L 96	SD2-L 96	SD2-L 97	SD2-L 97	SD2-L 97	SD2-L 97	SD2-L 97	SD2-L 99	SD2-L 99	SD2-L 99	SD2-L 99
	SPN	CPX	OL	OPX	SPN	CPX	GAR	OL	OPX	CHR	CPX	OL	OPX	
SiO2	.10	53.84	40.96	56.30	.06	53.86	41.80	41.80	57.13	.02	55.35	41.33	57.73	
TiO2	.09	.01	0.00	.13	.03	.40	.10	.10	.07	.27	.03	.02	.11	
Al2O3	57.82	3.80	0.00	2.59	46.86	3.69	21.99	21.99	1.27	17.88	1.84	0.00	.84	
Cr2O3	8.14	.83	0.00	.22	19.87	1.08	1.44	1.44	.26	52.03	1.23	0.00	.18	
FeO	11.40	1.83	9.41	6.20	10.59	2.30	9.91	9.91	5.70	13.67	1.24	7.14	4.21	
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
MnO	.11	.11	.08	.10	.57	.06	.54	.54	.11	1.37	.13	.13	.09	
NiO	.32	.11	.44	.18	.28	.03	0.00	0.00	.09	.13	.04	.39	.08	
MgO	19.84	16.25	50.38	34.07	18.39	15.52	19.49	19.49	35.86	13.25	16.87	52.21	36.05	
CaO	.02	22.52	.02	.30	.02	20.61	4.76	4.76	.23	.02	22.43	0.00	.28	
Na2O	0.00	1.02	.03	.01	0.00	2.00	.02	.02	.05	0.00	1.36	.07	.04	
K2O	0.00	0.00	0.00	0.00	0.00	.01	0.00	0.00	0.00	.01	.02	0.00	.01	
TOTAL	97.84	100.32	101.32	100.10	96.67	99.56	100.05	100.05	100.77	98.65	100.54	101.29	99.62	
Si	.002	1.940	.991	1.939	.002	1.954	2.999	.994	1.952	.001	1.987	.990	1.978	
Ti	.001	0.000	0.000	.003	.001	.010	.004	0.000	.001	.006	.001	0.000	.003	
Al	1.792	.162	0.000	.105	1.496	.157	1.859	0.000	.050	.653	.078	0.000	.034	
Cr	.169	.024	0.000	.006	.426	.031	.080	0.000	.006	1.275	.035	0.000	.005	
Fe2+	.218	.055	.190	.179	.240	.069	.594	.177	.162	.059	.037	.143	.121	
Fe3+	0.000	0.000	0.000	0.000	.074	0.000	0.000	0.000	0.000	.354	0.000	0.000	0.000	
Mn	.002	.003	.002	.003	.013	.001	.031	.001	.003	.036	.004	.003	.003	
Ni	.006	.003	.009	.005	.006	0.000	0.000	.007	.002	.003	.001	.007	.002	
Mg	.777	.874	1.817	1.750	.742	.839	2.084	1.823	1.826	.612	.903	1.865	1.842	
Ca	0.000	.870	.001	.011	0.000	.801	.364	0.000	.003	.001	.863	0.000	.010	
Na	0.000	.072	.001	.001	0.000	.140	.002	0.000	.003	0.000	.094	.003	.003	
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	0.000	
CATIONS	2.967	4.003	3.011	4.002	3.000	4.002	8.017	3.002	4.013	2.990	4.004	3.011	4.001	
Mg/Mg+Fe	.781	.941	.905	.907	.756	.924	.778	.912	.919	.912	.961	.929	.938	
Ca/Ca+Mg	0.000	.499	.001	.006	0.000	.488	.149	0.000	.004	.002	.489	0.000	.005	
Cr/Cr+Al	.086	.129	0.000	.054	.222	.165	.041	0.000	.107	.661	.310	0.000	.128	

	SD2-L121	SD2-L121	SD2-L121	SD2-L121	SD2-L124	SD2-L124	SD2-L124	SD2-L124	SD2-L125	SD2-L125	SD2-L125	SD2-L125
	CPX	GAR	OL	OPX	CPX	GAR	OL	OPX	CPX	OL	OPX	SPN
SiO2	53.23	42.71	41.79	57.53	54.04	42.25	41.20	57.45	53.04	40.97	55.10	.02
TiO2	.32	.18	0.00	.11	.39	.18	0.00	.13	.27	.01	.14	.01
Al2O3	3.49	22.59	0.00	1.19	3.50	22.25	0.00	1.36	6.24	0.00	3.84	58.55
Cr2O3	.89	1.17	.02	.20	1.00	1.44	.02	.29	.64	0.00	.16	9.85
FeO	2.57	10.54	9.32	6.24	1.94	10.28	9.35	6.04	2.15	9.67	6.25	10.51
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.08	.53	.13	.10	.08	.55	.09	.15	.15	.17	.15	.21
NiO	.05	.01	.41	.05	.12	0.00	.42	.04	0.00	.37	.08	.27
MgO	15.18	19.36	48.94	34.33	15.61	18.61	48.57	34.31	15.30	49.63	32.88	19.97
CaO	20.66	4.56	.02	.25	21.21	4.91	.02	.30	21.10	0.00	.63	0.00
Na2O	2.18	.02	.02	.04	1.86	.02	0.00	.04	1.78	.04	.10	0.00
K2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.02	0.00	0.00	0.00
TOTAL	98.65	101.67	100.65	100.04	99.75	100.49	99.67	100.11	100.69	100.86	99.33	99.39
Si	1.955	3.012	1.014	1.979	1.958	3.019	1.011	1.974	1.901	.996	1.915	0.000
Ti	.008	.008	0.000	.002	.010	.008	0.000	.003	.007	0.000	.004	0.000
Al	.151	1.877	0.000	.047	.148	1.872	0.000	.054	.264	0.000	.157	1.772
Cr	.025	.064	0.000	.005	.028	.080	0.000	.007	.018	0.000	.004	.200
Fe2+	.079	.621	.188	.178	.058	.614	.191	.173	.065	.197	.182	.226
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.027
Mn	.002	.031	.002	.002	.002	.031	.001	.004	.004	.004	.004	.005
Ni	.001	0.000	.008	.001	.003	0.000	.008	0.000	0.000	.007	.002	.006
Mg	.831	2.035	1.770	1.760	.842	1.981	1.776	1.757	.818	1.799	1.705	.764
Ca	.813	.343	0.000	.009	.822	.375	0.000	.011	.811	0.000	.023	0.000
Na	.155	.002	0.000	.002	.129	.002	0.000	.002	.124	.002	.007	0.000
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000
CATIONS	4.020	7.993	2.982	3.985	4.000	7.982	2.987	3.985	4.013	3.005	4.003	3.000
MG/MG+FI	.913	.766	.904	.908	.936	.763	.903	.910	.926	.901	.904	.772
CA/CA+MG	.495	.144	0.000	.005	.494	.159	0.000	.006	.498	0.000	.013	0.000
CR/CR+AL	.142	.033	0.000	.096	.159	.041	0.000	.115	.064	0.000	.025	.101

	SD2-L126	SD2-L126	SD2-L126	SD2-L126	SD2-L127	SD2-L127	SD2-L127	SD2-L127	SD2-L128	SD2-L128	SD2-L128	SD2-L128	SD2-L129	SD2-L129	SD2-L129	SD2-L129
	CPX	OL	OPX	SPN	CPX	OL	OPX	SPH	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN
SiO2	53.62	41.29	55.66	.02	51.23	40.52	54.30	.04	52.00	40.69	55.36	.08	51.53	40.48	54.77	.03
TiO2	.01	.03	.10	.05	.53	.01	.18	.13	.29	0.00	.01	0.00	.42	.04	.12	.05
Al2O3	4.04	0.00	2.83	49.39	5.63	0.00	4.07	54.81	5.90	0.00	3.58	58.67	6.67	0.00	4.37	61.28
Cr2O3	.86	0.00	.26	19.74	.81	0.00	.37	13.32	.64	0.00	.10	10.33	.62	0.00	.19	8.02
FeO	1.78	8.61	5.39	11.67	2.33	9.58	6.79	10.88	2.09	9.42	6.14	9.71	2.65	10.02	7.02	10.27
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.13	.18	.14	.51	.16	.20	.17	.36	.08	.10	.19	.40	.15	.19	.16	.13
NiO	.05	.35	.07	.12	.07	.48	.04	.21	0.00	.33	.04	.37	.04	.47	.06	.31
MgO	16.62	50.57	33.80	18.19	14.66	50.37	33.49	19.56	15.02	50.80	34.35	20.73	15.32	50.12	33.20	20.99
CaO	22.26	0.00	1.04	0.00	22.08	0.00	.54	0.00	21.18	0.00	.26	0.00	20.61	0.00	.60	0.00
Na2O	1.06	.04	.07	0.00	1.68	.03	.03	.05	1.94	.01	.03	0.00	1.83	.04	.02	.02
K2O	.02	0.00	0.00	0.00	.01	0.00	.01	0.00	0.00	0.00	.01	.01	.01	0.00	0.00	0.00
TOTAL	100.45	101.07	99.36	99.69	99.19	101.19	99.99	99.36	99.14	101.35	100.07	100.30	99.85	101.36	100.51	101.10
Si	1.929	.997	1.930	0.000	1.880	.984	1.884	.001	1.897	.984	1.908	.002	1.870	.983	1.890	.001
Ti	0.000	.001	.003	.001	.015	0.000	.005	.002	.008	0.000	0.000	0.000	.012	.001	.003	.001
Al	.171	0.000	.116	1.558	.244	0.000	.166	1.666	.254	0.000	.146	1.747	.285	0.000	.178	1.795
Cr	.025	0.000	.007	.418	.024	0.000	.010	.272	.018	0.000	.003	.206	.018	0.000	.005	.157
Fe2+	.054	.174	.156	.261	.072	.195	.197	.234	.064	.191	.177	.205	.080	.204	.203	.213
Fe3+	0.000	0.000	0.000	.021	0.000	0.000	0.000	.057	0.000	0.000	0.000	.043	0.000	0.000	0.000	.045
Mn	.004	.004	.004	.012	.005	.004	.005	.008	.002	.002	.005	.009	.005	.003	.005	.003
Ni	.001	.007	.002	.003	.002	.009	.001	.004	0.000	.006	.001	.008	.001	.009	.002	.006
Mg	.892	1.820	1.748	.726	.802	1.824	1.733	.752	.817	1.832	1.766	.780	.829	1.815	1.708	.778
Ca	.859	0.000	.039	0.000	.869	0.000	.020	0.000	.829	0.000	.010	0.000	.802	0.000	.022	0.000
Na	.074	.002	.005	0.000	.120	.001	.002	.002	.137	.001	.002	0.000	.129	.002	.001	.001
K	.001	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.010	3.005	4.010	3.000	4.034	3.017	4.023	2.998	4.026	3.016	4.018	3.000	4.031	3.017	4.017	3.000
MG/MG+FE	.943	.913	.918	.736	.918	.903	.898	.763	.927	.906	.909	.792	.912	.899	.894	.785
CA/CA+MG	.491	0.000	.022	0.000	.520	0.000	.011	0.000	.504	0.000	.006	0.000	.492	0.000	.013	0.000
CR/CR+AL	.128	0.000	.057	.212	.090	0.000	.057	.140	.066	0.000	.020	.105	.059	0.000	.027	.080

	SD2-L130	SD2-L130	SD2-L130	SD2-L130	SD2-L130	SD2-L134	SD2-L134	SD2-L134	SD2-L134	SD2-L137	SD2-L137	SD2-L137	SD2-L137
	CPX	GAR	OL	OPX	SPN	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN
SiO2	54.57	41.65	40.71	56.85	.02	51.74	40.60	54.42	.05	51.63	41.77	54.99	.03
TiO2	.34	.10	0.00	.22	.15	.50	0.00	.09	.04	.38	.06	.08	.12
Al2O3	3.39	21.92	0.00	1.22	44.40	6.10	0.00	4.23	54.10	5.77	0.00	3.56	56.66
Cr2O3	.85	1.13	0.00	.10	22.02	.79	0.00	.35	12.51	.80	0.00	.28	12.31
FeO	2.40	11.23	10.00	6.48	12.04	2.01	9.31	5.99	9.31	2.18	9.30	6.64	10.57
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.08	.60	.06	.02	.56	.10	.11	.14	.44	.13	.13	.13	.28
NiO	.09	.06	.47	.11	.10	.01	.24	.03	.24	.03	.45	.02	.26
MgO	15.43	19.06	49.72	34.52	17.39	15.49	49.27	32.48	19.90	15.19	50.65	33.68	20.13
CaO	20.72	4.84	.03	.20	0.00	20.52	.01	.80	0.00	21.96	0.00	.51	0.00
Na2O	2.32	.02	.07	.04	.04	1.89	.01	.14	.02	1.53	.02	.03	.02
K2O	0.00	.12	0.00	.01	0.00	.01	0.00	0.00	.01	0.00	0.00	.01	0.00
TOTAL	100.19	100.73	101.06	99.77	96.72	99.16	99.55	98.67	96.62	99.60	102.38	99.93	100.38
Si	1.969	2.989	.990	1.965	.001	1.885	.998	1.904	.001	1.882	.998	1.905	.001
Ti	.009	.006	0.000	.006	.003	.014	0.000	.003	.001	.010	.001	.002	.002
Al	.144	1.855	0.000	.050	1.432	.262	0.000	.174	1.677	.248	0.000	.145	1.701
Cr	.024	.064	0.000	.003	.476	.023	0.000	.004	.260	.023	0.000	.008	.248
Fe2+	.072	.674	.204	.188	.276	.061	.191	.176	.205	.066	.186	.192	.225
Fe3+	0.000	0.000	0.000	0.000	.086	0.000	0.000	0.000	.060	0.000	0.000	0.000	.046
Mn	.002	.036	.002	0.000	.013	.003	.002	.004	.010	.004	.003	.004	.006
Ni	.003	.003	.009	.003	.002	0.000	.005	0.000	.005	.001	.008	.001	.005
Mg	.831	2.040	1.803	1.779	.709	.842	1.806	1.904	.780	.826	1.805	1.740	.764
Ca	.802	.372	.001	.007	0.000	.802	0.000	.030	0.000	.858	0.000	.019	0.000
Na	.162	.003	.003	.003	.002	.133	.001	.004	.001	.108	.001	.002	.001
K	0.000	.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.018	8.053	3.012	4.004	3.000	4.025	3.003	4.203	3.000	4.026	3.002	4.018	2.999
MG/MG+FE	.920	.752	.898	.904	.720	.932	.904	.915	.792	.926	.907	.901	.772
CA/CA+MG	.491	.154	.001	.004	0.000	.488	0.000	.016	0.000	.510	0.000	.011	0.000
CR/CR+AL	.143	.033	0.000	.057	.249	.081	0.000	.022	.134	.085	0.000	.052	.127

	SD2-L138	SD2-L138	SD2-L138	SD2-L138	SD2-L139	SD2-L139	SD2-L139	SD2-L139	SD2-L148	SD2-L148	SD2-L148	SD2-L148	SD2-L149	SD2-L149	SD2-L149	SD2-L149
	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN	CPX	GAR	OL	OPX	CPX	OL	OPX	SPN
SiO2	51.93	41.57	53.79	.15	53.60	40.96	55.27	.02	52.28	42.50	41.42	56.40	51.07	41.61	55.01	.03
TiO2	.29	.04	.07	0.00	.42	0.00	.20	.07	.73	.06	.06	.12	.48	.05	.10	.09
Al2O3	6.31	0.00	4.65	56.72	5.67	0.00	3.84	56.57	5.48	23.25	0.00	1.06	5.78	0.00	3.16	54.58
Cr2O3	.73	0.00	.31	10.68	.68	0.00	.17	11.49	.74	.85	0.00	.11	.96	0.00	.22	14.76
FeO	2.85	9.65	6.73	9.92	2.00	9.18	6.19	10.24	2.74	10.78	9.58	6.92	2.16	9.22	6.64	11.27
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.13	.17	.13	.36	.16	.20	.14	.27	.09	.60	.13	.13	.13	.17	.15	.38
NiO	.08	.46	.03	.16	.05	.42	.05	.24	.03	.13	.49	.03	.07	.38	.01	.24
MgO	16.62	50.36	33.22	19.99	14.85	50.67	33.64	20.00	14.76	18.82	50.50	34.98	15.12	50.74	34.14	19.48
CaO	19.38	0.00	.42	0.00	21.41	0.00	.34	0.00	20.44	5.06	0.00	.21	21.81	0.00	.34	.01
Na2O	1.61	.05	.04	.01	1.91	.04	.06	0.00	2.43	.02	.04	.03	1.58	.07	.02	.02
K2O	.01	0.00	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00	.01	.01	0.00	.01	0.00
TOTAL	99.94	102.30	99.39	97.99	100.76	101.47	99.90	98.90	99.72	102.07	102.22	100.00	99.17	102.24	99.80	100.86
Si	1.877	.996	1.875	.004	1.920	.989	1.908	.001	1.902	1.500	.993	1.952	1.872	.995	1.908	.001
Ti	.008	.001	.002	0.000	.011	0.000	.005	.001	.020	.001	.001	.003	.013	.001	.003	.002
Al	.269	0.000	.191	1.739	.240	0.000	.156	1.722	.235	.966	0.000	.043	.250	0.000	.129	1.652
Cr	.021	0.000	.009	.220	.019	0.000	.005	.235	.021	.024	0.000	.003	.028	0.000	.006	.300
Fe2+	.086	.193	.196	.216	.060	.185	.179	.221	.083	.318	.192	.200	.066	.185	.193	.242
Fe3+	0.000	0.000	0.000	.034	0.000	0.000	0.000	.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.044
Mn	.004	.003	.004	.008	.005	.004	.004	.006	.003	.018	.003	.004	.004	.003	.004	.008
Ni	.002	.009	.001	.003	.001	.008	.001	.005	.001	.004	.009	.001	.002	.007	0.000	.005
Mg	.896	1.800	1.727	.775	.793	1.824	1.732	.770	.801	.988	1.806	1.806	.827	1.810	1.765	.746
Ca	.751	0.000	.016	0.000	.823	0.000	.013	0.000	.797	.191	0.000	.008	.857	0.000	.013	0.000
Na	.113	.002	.003	.001	.132	.002	.004	0.000	.172	.001	.002	.002	.113	.003	.002	.001
K	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.027	3.004	4.024	3.000	4.005	3.012	4.007	3.001	4.035	4.011	3.006	4.022	4.032	3.004	4.023	3.001
MG/MG+FE	.912	.903	.898	.782	.930	.908	.906	.777	.906	.757	.904	.900	.926	.907	.901	.755
CA/CA+MG	.456	0.000	.009	0.000	.509	0.000	.007	0.000	.499	.162	0.000	.004	.509	0.000	.007	0.000
CR/CR+AL	.072	0.000	.045	.112	.073	0.000	.031	.120	.082	.024	0.000	.065	.101	0.000	.044	.154

	SD2-L151	SD2-L151	SD2-L151	SD2-L151	SD2-L152	SD2-L152	SD2-L152	SD2-L152	SD2-L152	SD2-L154	SD2-L154	SD2-L154	SD2-L154
	CPX	OL	OPX	SPN	CPX	GAR	OL	OPX	SPN	CPX	OL	OPX	SPN
SiO2	51.50	40.41	54.59	.01	52.65	41.38	40.53	56.51	.02	52.64	40.79	54.79	0.00
TiO2	.46	.02	.14	.05	.42	.12	0.00	.12	.14	.45	.01	.12	0.00
Al2O3	5.95	0.00	3.82	56.80	3.99	22.43	0.00	1.36	43.36	5.96	0.00	3.36	56.47
Cr2O3	.82	0.00	.30	12.14	.87	1.13	0.00	.16	22.77	.61	0.00	.22	12.93
FeO	2.19	9.98	6.94	11.15	2.12	9.60	8.72	5.71	10.09	2.15	10.00	7.10	11.43
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.13	.23	.16	.23	.06	.51	.11	.16	.60	.11	.21	.15	.25
NiO	.06	.48	.03	.17	0.00	0.00	.34	.01	.21	.17	.50	.02	.27
MgO	14.84	50.23	33.11	19.75	15.75	19.30	50.36	34.76	18.22	14.84	50.12	33.78	19.54
CaO	22.33	0.00	.93	.01	20.78	4.76	.01	.26	0.00	22.26	0.00	.25	0.00
Na2O	1.46	.04	.05	.02	2.45	.02	0.00	.04	.05	1.68	.04	.01	0.00
K2O	.01	0.00	0.00	0.00	0.00	0.00	.01	.01	0.00	0.00	0.00	0.00	0.00
TOTAL	99.75	101.39	100.07	100.33	99.09	99.25	100.08	99.10	95.46	100.87	101.67	99.80	100.89
Si	1.877	.981	1.895	0.000	1.926	1.493	.989	1.961	0.000	1.893	.987	1.904	0.000
Ti	.013	0.000	.004	.001	.011	.003	0.000	.003	.003	.012	0.000	.003	0.000
Al	.256	0.000	.156	1.711	.172	.955	0.000	.056	1.406	.252	0.000	.137	1.702
Cr	.024	0.000	.008	.245	.025	.032	0.000	.004	.495	.018	0.000	.006	.261
Fe2+	.067	.203	.202	.238	.065	.290	.178	.166	.232	.064	.202	.206	.244
Fe3+	0.000	0.000	0.000	.042	0.000	0.000	0.000	0.000	.094	0.000	0.000	0.000	.037
Mn	.004	.005	.005	.005	.002	.015	.002	.005	.014	.003	.004	.004	.005
Ni	.002	.009	.001	.003	0.000	0.000	.007	0.000	.005	.004	.010	.001	.006
Mg	.806	1.819	1.714	.752	.859	1.038	1.834	1.799	.747	.795	1.808	1.750	.745
Ca	.872	0.000	.035	0.000	.815	.184	0.000	.010	0.000	.858	0.000	.009	0.000
Na	.103	.002	.003	.001	.174	.001	0.000	.003	.003	.117	.002	0.000	0.000
K	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.024	3.019	4.023	2.998	4.050	4.011	3.010	4.007	2.999	4.016	3.013	4.020	3.000
MG/MG+FE	.923	.900	.895	.760	.930	.782	.912	.916	.763	.925	.900	.895	.753
CA/CA+MG	.520	0.000	.020	0.000	.487	.151	0.000	.006	0.000	.519	0.000	.005	0.000
CR/CR+AL	.086	0.000	.049	.125	.127	.032	0.000	.067	.260	.067	0.000	.042	.133

	SD2-L156	SD2-L156	SD2-L156	SD2-L156	SD2-L159	SD2-L159	SD2-L159	SD2-L159	SD2-L160	SD2-L160	SD2-L160	SD2-L160	SD2-L160
	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN	CPX	GAR	OL	OPX	SPN
SiO2	52.91	41.34	55.94	.07	50.93	40.58	55.34	.02	53.28	42.51	41.20	56.59	.01
TiO2	.22	.01	.09	.02	.44	0.00	.20	.07	.15	.11	.02	.08	0.00
Al2O3	5.26	0.00	4.03	51.01	5.54	0.00	3.61	54.46	4.37	22.48	0.00	3.20	51.75
Cr2O3	1.05	0.00	.42	18.10	.81	0.00	.23	14.34	.79	1.41	0.00	.22	16.94
FeO	1.79	7.93	5.10	9.63	2.03	9.54	6.10	11.18	1.91	10.20	8.63	5.61	9.75
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.10	.15	.16	.49	.14	.13	.15	.33	.06	.59	.19	.16	.51
NiO	.05	.36	.04	.14	.09	.42	.05	.17	.01	.01	.37	.10	.14
MgO	15.72	50.70	33.65	19.64	15.14	50.46	33.31	19.17	16.37	19.08	50.22	34.04	19.60
CaO	21.32	0.00	.69	0.00	21.73	0.00	.54	.01	22.03	4.74	0.00	.35	0.00
Na2O	1.62	0.00	.09	.02	1.68	.03	.05	.01	1.26	.02	.03	.07	.02
K2O	.01	0.00	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	.01	.01	0.00
TOTAL	100.05	100.49	100.21	99.12	98.54	101.16	99.58	99.76	100.23	101.15	100.67	100.43	98.72
Si	1.910	1.000	1.917	.002	1.878	.985	1.917	.001	1.922	3.015	.999	1.936	0.000
Ti	.006	.010	.002	0.000	.012	0.000	.005	.001	0.000	.004	0.000	.002	0.000
Al	.224	0.000	.163	1.589	.241	0.000	.147	1.675	.186	1.878	0.000	.129	1.607
Cr	.030	0.000	.011	.378	.024	0.000	.006	.296	.022	.077	0.000	.006	.353
Fe2+	.054	.160	.146	.213	.063	.194	.177	.244	.058	.604	.175	.161	.215
Fe3+	0.000	0.000	0.000	.029	0.000	0.000	0.000	.026	0.000	0.000	0.000	0.000	.040
Mn	.003	.003	.005	.011	.004	.003	.004	.007	.002	.035	.004	.005	.011
Ni	.001	.007	.001	.003	.003	.003	.001	.004	0.000	0.000	.007	.003	.003
Mg	.846	1.829	1.720	.774	.833	1.826	1.721	.746	.880	2.018	1.815	1.737	.770
Ca	.825	0.000	.025	0.000	.859	0.000	.020	0.000	.852	.360	0.000	.013	0.000
Na	.113	0.000	.006	.001	.120	.001	.003	.001	.083	.002	.001	.005	.001
K	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000
CATIONS	4.013	3.009	3.996	3.000	4.037	3.017	4.001	3.001	4.010	7.993	3.001	3.998	3.000
MG/MG+FE	.940	.920	.922	.784	.930	.904	.907	.754	.938	.770	.912	.915	.782
CA/CA+MG	.494	0.000	.014	0.000	.508	0.000	.011	0.000	.492	.151	0.000	.007	0.000
CR/CR+AL	.118	0.000	.063	.192	.091	0.000	.039	.150	.106	.039	0.000	.044	.180

	SD2-L161	SD2-L161	SD2-L161	SD2-L161	SD2-L163	SD2-L163	SD2-L163	SD2-L164	SD2-L164	SD2-L164	SD2-L166	SD2-L166	SD2-L166	SD2-L166
	CPX	OL	OPX	SPN	CPX	GAR	OPX	CPX	OPX	SPN	CPX	OL	OPX	SPN
SiO2	51.88	40.17	54.18	0.00	52.09	42.70	56.55	49.73	51.79	.04	51.98	40.28	54.80	.01
TiO2	.43	.08	.10	.04	.32	.00	.06	.51	.03	0.00	.59	.06	.26	.05
Al2O3	4.96	0.00	3.67	55.06	4.83	23.40	1.42	7.78	6.87	57.34	5.65	0.00	3.87	54.32
Cr2O3	.62	0.00	.25	13.81	.78	.92	.20	.91	.54	11.50	.85	0.00	.32	15.04
FeO	2.17	9.88	6.94	11.45	2.18	8.58	5.32	2.49	8.31	12.71	2.19	8.67	6.04	10.26
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.13	.20	.15	.22	.08	.35	.08	.16	.16	.34	.11	.18	.15	.23
NiO	.05	.46	.02	.25	.07	.17	.10	.01	.08	.42	.07	.43	.02	.23
HgO	15.29	49.80	32.98	19.36	15.59	19.98	35.66	14.10	30.70	18.58	15.34	51.06	33.40	20.07
CaO	22.52	0.00	1.25	0.00	22.02	5.42	.36	22.83	.48	0.00	21.27	0.00	1.13	0.00
Na2O	1.39	.04	.10	0.00	1.52	.01	.02	1.44	.04	.01	1.86	.06	.11	0.00
K2O	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00	.01	.01	0.00	.01	0.00
TOTAL	99.44	100.63	99.65	100.19	99.48	101.61	99.77	99.96	99.00	100.95	99.92	100.74	100.11	100.21
Si	1.896	.982	1.891	0.000	1.901	1.500	1.948	1.824	1.828	.001	1.887	.979	1.895	0.000
Ti	.012	.001	.003	.001	.009	.002	.002	.015	.001	0.000	.016	.001	.007	.001
Al	.214	0.000	.151	1.673	.208	.968	.058	.330	.285	1.735	.242	0.000	.158	1.648
Cr	.018	0.000	.007	.281	.023	.026	.006	.026	.015	.233	.024	0.000	.009	.306
Fe2+	.066	.202	.203	.247	.067	.252	.153	.079	.245	.273	.067	.176	.175	.221
Fe3+	0.000	0.000	0.000	.044	0.000	0.000	0.000	0.000	0.000	.030	0.000	0.000	0.000	.044
Mn	.004	.004	.004	.005	.003	.010	.002	.005	.005	.007	.003	.004	.004	.005
Ni	.001	.009	.001	.005	.002	.004	.003	0.000	.003	.009	.002	.008	0.000	.005
Hg	.833	1.816	1.717	.744	.848	1.044	1.832	.781	1.616	.711	.830	1.851	1.722	.770
Ca	.882	0.000	.047	0.000	.861	.204	.013	.883	.019	0.000	.828	0.000	.042	0.000
Na	.098	.002	.006	0.000	.108	.002	.001	.094	.003	.001	.131	.003	.007	0.000
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.024	3.016	4.030	3.000	4.030	4.012	4.018	4.037	4.020	3.000	4.030	3.022	4.019	3.000
MG/MG+FE	.927	.900	.894	.751	.927	.806	.923	.908	.868	.723	.925	.913	.908	.777
CA/CA+MG	.514	0.000	.027	0.000	.504	.163	.007	.531	.012	0.000	.499	0.000	.024	0.000
CR/CR+AL	.078	0.000	.044	.144	.100	.026	.094	.073	.050	.118	.090	0.000	.054	.157

	SD2-L167	SD2-L167	SD2-L167	SD2-L167	SD2-L168	SD2-L168	SD2-L168	SD2-L168	SD2-L168	SD2-L170	SD2-L170	SD2-L170	SD2-L170
	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH	CPX	OL	OPX	SPH	
SiO2	51.43	40.41	54.65	.02	52.45	40.78	54.95	.13	51.12	40.09	53.93	.05	
TiO2	.51	.05	.12	.13	.13	.04	.04	.14	.50	.05	.13	.10	
Al2O3	6.19	0.00	3.72	57.54	3.23	0.00	2.60	46.93	5.40	0.00	3.35	54.98	
Cr2O3	.79	0.00	.18	11.67	1.10	0.00	.40	22.90	.80	0.00	.24	14.33	
FeO	2.21	9.40	6.91	10.22	2.01	8.59	6.15	12.59	1.89	9.12	5.97	10.72	
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
MnO	.11	.20	.13	.27	.15	.17	.16	.56	.16	.19	.20	.44	
NiO	.07	.49	.07	.29	.06	.41	.04	.24	.12	.49	.14	.25	
HgO	14.70	50.41	33.88	20.62	16.49	51.20	14.29	18.12	15.23	50.93	34.17	19.85	
CaO	21.32	0.00	.29	.01	23.27	0.00	.71	.02	22.24	.02	.36	.02	
Na2O	2.00	.02	.02	0.00	.76	.04	.01	0.00	1.64	.02	.03	0.00	
K2O	.01	0.00	0.00	0.00	.01	0.00	.01	0.00	.01	.01	0.00	0.00	
TOTAL	99.34	100.98	99.97	100.77	99.66	101.23	99.36	101.63	99.11	100.92	98.52	100.74	
Si	1.879	.982	1.895	0.000	1.916	.985	1.914	.003	1.876	.975	1.893	.001	
Ti	.014	.001	.003	.002	.004	.001	.001	.003	.014	.001	.003	.002	
Al	.267	0.000	.152	1.711	.139	0.000	.107	1.455	.234	0.000	.139	1.660	
Cr	.023	0.000	.005	.233	.032	0.000	.011	.476	.023	0.000	.007	.290	
Fe2+	.068	.191	.200	.216	.061	.174	.179	.277	.058	.185	.175	.044	
Fe3+	0.000	0.000	0.000	.051	0.000	0.000	0.000	.057	0.000	0.000	0.000	0.000	
Mn	.004	.004	.004	.006	.005	.003	.005	.012	.005	.004	.006	.230	
Ni	.002	.010	.002	.006	.002	.008	.001	.005	.003	.009	.004	.010	
Hg	.801	1.828	1.752	.775	.898	1.843	1.781	.710	.834	1.847	1.789	.005	
Ca	.835	0.000	.011	0.000	.911	0.000	.027	.001	.875	.001	.014	.758	
Na	.142	.001	.001	0.000	.054	.002	.001	0.000	.117	.001	.002	0.000	
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CATIONS	4.035	3.017	4.025	3.000	4.022	3.016	4.027	2.999	4.039	3.023	4.032	3.000	
MG/MG+FL	.922	.905	.898	.782	.936	.914	.909	.719	.935	.909	.911	.102	
CA/CA+MG	.510	0.000	.006	0.000	.504	0.000	.015	.001	.512	.001	.008	.993	
CR/CR+AI	.079	0.000	.032	.120	.187	0.000	.093	.247	.089	0.000	.048	.149	

	SD2-L171	SD2-L171	SD2-L171	SD2-L171	SD2-L172	SD2-L172	SD2-L172	SD2-L172	SD2-L174	SD2-L174	SD2-L174	SD2-L174
	CPX	OL	OPX	SPN	CPX	GAR	OPX	SPN	CPX	OL	OPX	SPN
SiO2	52.29	40.68	55.49	.04	53.93	41.69	56.19	.01	51.59	40.69	55.34	.02
TiO2	.13	.04	.04	.16	.54	.03	.08	.21	.49	0.00	.24	.12
Al2O3	2.90	0.00	2.20	39.87	4.84	23.66	1.10	50.43	5.23	0.00	3.88	53.26
Cr2O3	.85	0.00	.34	30.16	.59	.64	.05	17.46	.72	0.00	.32	14.79
FeO	1.99	8.65	6.23	13.98	2.25	10.74	6.10	14.92	1.83	8.73	5.54	10.38
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.07	.17	.13	.75	.02	.58	.09	.50	.14	.16	.11	.34
NiO	.06	.45	.02	.20	.10	.05	.10	.37	.01	.37	.08	.29
MgO	16.63	51.25	34.75	16.26	15.15	20.08	35.26	18.86	15.19	50.88	32.91	19.34
CaO	23.40	0.00	.60	.03	21.40	4.01	.19	0.00	21.81	0.00	1.11	0.00
Na2O	.76	.03	.03	.03	2.51	.01	.05	0.00	1.63	.03	.10	0.00
K2O	0.00	0.00	0.00	0.00	.01	0.00	.01	.01	.02	0.00	0.00	0.00
TOTAL	99.08	101.27	99.83	101.48	101.34	101.49	99.22	102.77	98.66	100.86	99.63	98.54
Si	1.921	.982	1.922	.001	1.927	1.473	1.953	0.000	1.895	0.000	1.914	.001
Ti	.003	.001	.001	.003	.015	.001	.002	.004	.014	0.000	.006	.002
Al	.126	0.000	0.000	1.280	.204	.986	.045	1.554	.227	0.000	.158	1.655
Cr	.025	0.000	0.000	.650	.017	.018	.001	.361	.021	0.000	.009	.308
Fe2+	.061	.175	.175	.319	.067	.317	.177	.250	.056	0.000	.160	.229
Fe3+	0.000	0.000	0.000	.063	0.000	0.000	0.000	.076	0.000	0.000	0.000	.031
Mn	.002	.004	.004	.017	.001	.017	.003	.011	.004	0.000	.003	.008
Ni	.002	.009	.009	.004	.003	.001	.003	.008	0.000	0.000	.002	.006
Mg	.911	1.846	1.846	.660	.807	1.058	1.828	.736	.832	0.000	1.698	.760
Ca	.922	0.000	0.000	.001	.820	.152	.007	0.000	.859	0.000	.041	0.000
Na	.054	.001	.001	.001	.174	.001	.004	0.000	.117	0.000	.007	0.000
K	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000	.001	0.000	0.000	0.000
CATIONS	4.027	3.018	3.958	2.999	4.036	4.024	4.023	3.000	4.026	0.000	3.998	3.000
MG/MG+FE	.937	.913	.913	.674	.923	.769	.912	.746	.937	0.000	.914	.768
CA/CA+MG	.503	0.000	0.000	.002	.504	.126	.004	0.000	.508	0.000	.024	0.000
CR/CR+AL	.166	0.000	0.000	.337	.077	.018	.022	.189	.085	0.000	.054	.157

SD2-L175 SD2-L175 SD2-L175 SD2-L175 SD2-L176 SD2-L176 SD2-L176 SD2-L177 SD2-L177 SD2-L177 SD2-L177 SD2-L177 SD2-L178 SD2-L178 SD2-L178 SD2-L178

	CPX	OL	OPX	SPN	CPX	OL	OPX	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN
SiO2	51.56	40.53	54.78	.02	53.58	41.33	55.60	51.57	40.29	55.05	0.00	51.55	40.58	55.01	.04
TiO2	.42	.01	.10	.01	.42	0.00	.19	.40	.04	.14	.01	.39	.04	.13	0.00
Al2O3	5.36	0.00	3.53	55.46	5.15	0.00	3.15	5.85	0.00	3.28	56.42	5.38	0.00	3.32	56.03
Cr2O3	.80	0.00	.25	13.79	.68	0.00	.16	.92	0.00	.20	12.54	.76	0.00	.19	13.07
FeO	2.19	9.11	6.50	10.75	1.90	8.89	5.73	2.27	9.19	6.60	10.48	2.15	9.07	6.55	10.56
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.11	.18	.11	.24	.18	.17	.12	.11	.21	.17	.21	.11	.18	.15	.25
RtO	.02	.42	.02	.23	.04	.39	.11	.05	.40	.06	.25	.03	.48	.02	.22
HqO	15.34	50.74	33.80	19.89	15.37	50.78	34.07	15.07	50.63	34.31	20.05	15.00	50.57	34.20	20.04
CaO	21.87	0.00	.61	0.00	21.65	0.00	.32	21.87	0.00	.27	0.00	22.29	0.00	.33	0.00
Na2O	1.59	.03	.05	.01	1.75	.05	.05	1.64	.03	.01	.01	1.57	.04	0.00	.01
K2O	.01	0.00	0.00	0.00	.01	0.00	0.00	.01	0.00	.01	0.00	.01	0.00	.01	0.00
TOTAL	99.27	101.02	99.75	100.40	100.73	101.61	99.50	99.76	100.79	100.10	99.97	99.24	100.96	99.91	100.22
Si	1.886	.983	1.901	.001	1.922	.994	1.923	1.878	.980	1.903	0.000	1.888	.985	1.905	.001
Ti	.012	0.000	.002	0.000	.011	0.000	.005	.011	.001	.004	0.000	.011	.001	.003	0.000
Al	.231	0.000	.145	1.673	.218	0.000	.128	.251	0.000	.134	1.703	.232	0.000	.136	1.689
Cr	.023	0.000	.007	.279	.019	0.000	.004	.027	0.000	.006	.254	.022	0.000	.005	.264
Fe2+	.067	.185	.189	.230	.057	.179	.166	.069	.187	.191	.224	.066	.184	.190	.226
Fe3+	0.000	0.000	0.000	.046	0.000	0.000	0.000	0.000	0.000	0.000	.043	0.000	0.000	0.000	.045
Mn	.003	.004	.003	.005	.006	.003	.004	.003	.004	.005	.005	.004	.004	.004	.005
Rt	.001	.008	.001	.005	.001	.008	.003	.001	.008	.002	.005	.001	.009	0.000	.004
Hq	.837	1.836	1.749	.759	.822	1.821	1.758	.819	1.837	1.769	.765	.819	1.830	1.766	.764
Ca	.858	0.000	.023	0.000	.832	0.000	.012	.854	0.000	.010	0.000	.875	0.000	.012	0.000
Na	.113	.002	.004	.001	.121	.002	.003	.116	.002	0.000	0.000	.112	.002	0.000	0.000
K	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.031	3.018	4.024	2.999	4.010	3.007	4.006	4.029	3.019	4.024	2.999	4.030	3.015	4.021	2.998
HG/HG+LI	.926	.908	.902	.767	.935	.911	.914	.922	.908	.903	.774	.925	.909	.903	.772
CA/CA+HG	.506	0.000	.013	0.000	.503	0.000	.007	.510	0.000	.006	0.000	.517	0.000	.007	0.000
CR/CR+AL	.091	0.000	.046	.143	.080	0.000	.030	.097	0.000	.043	.130	.087	0.000	.035	.135

	SD2-L179	SD2-L179	SD2-L179	SD2-L179	SD2-L180	SD2-L180	SD2-L180	SD2-L180	SD2-L181	SD2-L181	SD2-L181	SD2-L181
	CPX	OL	OPX	SPN	CPX	OL	OPX	SPN	CPX	GAR	OL	OPX
SiO2	52.52	40.34	55.53	.02	52.76	40.89	55.37	.01	52.98	42.69	40.68	55.89
TiO2	.16	0.00	.02	.07	.41	.06	.15	.02	.57	.09	.04	.13
Al2O3	3.19	0.00	2.39	36.10	5.22	0.00	3.45	55.90	4.84	23.13	0.00	1.39
Cr2O3	1.27	0.00	.38	34.47	.74	0.00	.23	12.68	.98	.98	0.00	.25
FeO	1.95	8.06	5.64	13.54	1.95	9.37	6.21	12.03	2.61	10.46	9.08	6.45
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.13	.17	.13	.77	.13	.15	.20	0.00	.10	.65	.12	.14
NiO	.05	.44	0.00	.17	.08	.13	.12	.31	.04	.13	.42	.01
MgO	16.66	51.30	34.82	16.03	15.68	50.33	34.03	20.12	14.27	19.24	50.50	34.55
CaO	22.22	0.00	.56	0.00	21.89	.01	.44	.02	20.24	4.75	0.00	.74
Na2O	1.19	.03	.03	0.00	1.58	.06	.06	.03	2.82	.01	.03	.09
K2O	.02	0.00	.01	0.00	0.00	0.00	0.00	0.00	.01	0.00	0.00	.01
TOTAL	99.36	100.34	99.51	101.25	100.44	101.30	100.26	101.12	99.46	102.13	100.87	99.65
Si	1.921	.981	1.924	0.000	1.902	.990	1.908	0.000	1.931	1.500	.987	1.942
Ti	.004	0.000	0.000	.002	.011	.001	.004	0.000	.016	.003	.001	.003
Al	.138	0.000	.098	1.186	.222	0.000	.140	1.708	.208	.958	0.000	.057
Cr	.037	0.000	.011	.750	.021	0.000	.006	.260	.028	.027	0.000	.007
Fe2+	.060	.164	.164	3.150	.059	.190	.179	.261	.080	.308	.184	.188
Fe3+	0.000	0.000	0.000	.520	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.004	.003	.004	.180	.004	.002	.006	0.000	.003	.020	.003	.004
Ni	.001	.009	0.000	.040	.002	.008	.003	.007	.001	.003	.008	0.000
Mg	.909	1.861	1.800	6.650	.843	1.814	1.746	.778	.776	1.008	1.828	1.791
Ca	.871	0.000	.021	0.000	.846	0.000	.016	.001	.791	.178	0.000	.027
Na	.084	.001	.002	0.000	.110	.002	.004	.002	.200	.002	.002	.006
K	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.030	3.019	4.024	12.478	4.020	3.007	4.012	3.017	4.034	4.007	3.013	4.025
MG/MG+FL	.938	.919	.916	.679	.935	.905	.907	.749	.907	.766	.909	.905
CA/CA+MG	.489	0.000	.012	0.000	.501	0.000	.009	.001	.505	.150	0.000	.015
CR/CR+AL	.211	0.000	.101	.387	.086	0.000	.041	.132	.119	.027	0.000	.109

	SD2-L184	SD2-L184	SD2-L184	SD2-L184	SD2-L185	SD2-L185	SD2-L185	SD2-L185	SD2-L186	SD2-L186	SD2-L186	SD2-L186	SD2-L186
	CPX	OL	OPX	SPN	CPX	GAR	OL	OPX	CPX	GAR	OL	OPX	SPN
SiO2	53.19	40.81	57.17	.02	53.49	41.90	40.80	58.09	53.38	42.11	40.87	57.93	.03
TiO2	.01	0.00	.02	0.00	.50	.14	0.00	.11	.55	.06	0.00	.12	.13
Al2O3	3.57	0.00	2.80	44.75	3.42	22.05	0.00	1.05	4.63	22.91	0.00	.95	43.79
Cr2O3	.95	0.00	.30	24.78	1.15	1.78	0.00	.16	.70	.86	0.00	.05	22.38
FeO	1.64	8.54	5.49	12.09	2.43	9.96	8.95	5.61	2.30	10.06	9.08	5.76	11.98
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.07	.19	.19	.74	.06	.52	.12	.14	.07	.54	.17	.11	.60
NiO	.04	.41	.04	.02	.02	.01	.35	.04	0.00	.03	.35	.07	.11
MgO	16.28	50.49	34.13	17.39	15.65	19.01	50.05	35.07	15.14	19.20	49.96	35.14	17.29
CaO	23.29	0.00	.38	0.00	20.53	4.95	.01	.35	20.48	4.62	0.00	.23	0.00
Na2O	.95	.01	.06	.01	2.48	.01	.01	.07	2.55	0.00	0.00	.05	.02
K2O	.01	0.00	0.00	0.00	0.00	0.00	.01	0.00	.01	0.00	0.00	0.00	0.00
TOTAL	100.00	100.45	100.58	99.80	99.73	100.33	100.30	100.69	99.81	100.39	100.43	100.41	96.33
Si	1.929	.992	1.951	.001	1.940	1.500	.994	1.980	1.934	1.501	.995	1.981	.001
Ti	0.000	0.000	.001	0.000	.010	.004	0.000	.002	.015	.002	0.000	.003	.003
Al	.153	0.000	.113	1.438	.150	.931	0.000	.042	.198	.963	0.000	.038	1.420
Cr	.027	0.000	.008	.534	.030	.051	0.000	.004	.020	.024	0.000	.001	.487
Fe2+	.050	.174	.157	.276	.070	.298	.182	.160	.070	.300	.185	.165	.276
Fe3+	0.000	0.000	0.000	.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.087
Mn	.002	.004	.005	.017	.002	.016	.003	.004	.002	.016	.003	.003	.014
Ni	.001	.008	.001	0.000	.001	0.000	.007	.001	0.000	.001	.007	.002	.002
Mg	.890	1.830	1.737	.706	.850	1.015	1.819	1.783	.818	1.021	1.814	1.792	.709
Ca	.905	0.000	.014	0.000	.800	.190	0.000	.013	.795	.177	0.000	.009	0.000
Na	.067	0.000	.004	.001	.180	0.000	.001	.005	.179	0.000	0.000	.003	.001
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.014	3.008	3.991	3.001	4.033	4.005	3.006	3.994	4.031	4.005	3.004	3.997	3.000
MG/MG+FE	.946	.913	.917	.719	.924	.773	.909	.918	.921	.773	.907	.916	.720
CA/CA+MG	.507	0.000	.008	0.000	.485	.158	0.000	.007	.493	.148	0.000	.005	0.000
CR/CR+AL	.150	0.000	.066	.271	.167	.052	0.000	.087	.092	.024	0.000	.026	.255

	SD2-L187	SD2-L187	SD2-L187	SD2-L187	SD2-L189	SD2-L189	SD2-L189	SD2-L189	SD2-L189	SD2-W	SD2-W	SD2-W
	CPX	OL	OPX	SPN	CPX	GAR	OL	OPX	SPN	CPX	GAR	OPX
SiO2	52.85	40.84	56.43	.01	54.76	41.94	39.91	57.17	.08	53.75	12.75	57.79
TiO2	.38	0.00	.07	.02	.57	.15	.04	.12	.74	.48	.15	.12
Al2O3	4.99	0.00	3.23	49.93	3.92	22.10	0.00	1.11	25.35	3.82	22.50	1.23
Cr2O3	.96	0.00	.24	18.72	1.19	1.93	0.00	.23	42.43	1.09	1.40	.26
FeO	1.80	8.42	5.51	10.14	2.26	9.50	8.29	5.49	15.78	2.34	9.11	5.38
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.11	.15	.17	.49	.11	.54	.08	.11	1.27	.06	.43	.11
NiO	.02	.35	.06	.10	.02	0.00	.36	.01	.33	.10	.02	.07
MgO	15.45	50.49	34.24	19.21	15.54	19.25	50.13	35.17	13.80	15.26	19.92	34.61
CaO	21.33	.01	.32	0.00	21.15	5.16	.01	.26	.50	20.38	4.77	.24
Na2O	1.94	.01	.06	.02	1.15	.02	.01	.07	.08	2.05	.04	.04
K2O	0.00	0.00	0.00	0.00	.01	0.00	0.00	0.00	.01	0.00	0.00	0.00
TOTAL	99.83	100.27	100.33	98.64	100.68	100.59	98.83	99.74	100.37	99.33	71.09	99.85
Si	1.914	.993	1.932	0.000	1.947	1.496	.986	1.969	.002	1.955	3.016	1.982
Ti	.010	0.000	.002	0.000	.015	.004	.001	.003	.016	.013	.006	.003
Al	.213	0.000	.130	1.564	.165	.930	0.000	.045	.856	.163	1.869	.049
Cr	.027	0.000	.006	.393	.033	.054	0.000	.006	.963	.031	.076	.006
Fe2+	.055	.171	.158	.011	.067	.284	.171	.158	.379	.070	.536	.154
Fe3+	0.000	0.000	0.000	.225	0.000	0.000	0.000	0.000	.149	0.000	0.000	0.000
Mn	.003	.003	.005	.236	.003	.016	.001	.003	.030	.001	.024	.003
Ni	.001	.007	.002	.002	.001	0.000	.007	0.000	.007	.002	0.000	.002
Mg	.835	1.831	1.749	.761	.824	1.024	1.847	1.806	.590	.827	2.095	1.770
Ca	.828	0.000	.012	0.000	.806	.197	0.000	.010	.001	.794	.360	.008
Na	.136	0.000	.004	.001	.155	.002	.001	.005	.040	.144	.004	.002
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000
CATIONS	4.022	3.005	4.000	3.000	4.016	4.007	3.014	4.005	3.034	4.000	7.986	3.979
Mg/(Mg+Fe)	.938	.915	.917	.986	.925	.783	.915	.920	.609	.922	.796	.920
Ca/(Ca+Mg)	.498	0.000	.007	0.000	.494	.161	0.000	.006	.002	.490	.147	.004
Cr/(Cr+Al)	.113	0.000	.044	.201	.167	.055	0.000	.118	.529	.160	.039	.109

	SD2-W	2	SD2-W	2	SD2-W	2	SD2-W	2	SD2-W	8	SD2-W	8	SD2-W	8
	CPX		GAR		OPX		SPN		CPX		OPX		SPN	
SiO ₂	51.74		42.66		55.82		.07		51.37		54.31		.07	
TiO ₂	.40		.23		.11		.02		.40		.10		0.00	
Al ₂ O ₃	7.07		22.85		4.93		53.02		7.19		5.91		55.74	
Cr ₂ O ₃	1.04		1.14		.44		13.89		.73		.33		11.63	
FeO	2.57		8.03		6.24		14.02		2.39		8.04		12.57	
Fe ₂ O ₃	0.00		0.00		0.00		0.00		0.00		0.00		0.00	
MnO	.11		.32		.17		.18		.15		.24		.37	
NiO	.18		.01		.09		.44		0.00		.08		.31	
MgO	13.34		20.98		33.40		18.76		14.24		31.24		18.07	
CaO	22.21		4.80		.32		.02		22.44		.25		0.00	
Na ₂ O	1.14		.05		.04		0.00		1.40		.09		.01	
K ₂ O	0.00		0.00		.01		0.00		.01		0.00		0.00	
TOTAL	99.80		101.07		101.57		100.42		100.32		100.59		98.77	
Si	1.880		2.994		1.896		.001		1.860		1.878		.002	
Ti	.010		.010		.002		0.000		.011		.003		0.000	
Al	.303		1.889		.196		1.649		.307		.241		1.730	
Cr	.030		.062		.011		.290		.021		.009		.240	
Fe ²⁺	.078		.470		.176		.255		.072		.233		.280	
Fe ³⁺	0.000		0.000		0.000		.054		0.000		0.000		.030	
Mn	.003		.018		.004		.003		.004		.007		.008	
Ni	.004		0.000		.002		.008		0.000		.002		.010	
Mg	.722		2.194		1.691		.738		.769		1.611		.710	
Ca	.865		.360		.011		0.000		.871		.009		0.000	
Na	.080		.006		.002		0.000		.098		.006		0.000	
K	0.000		0.000		0.000		0.000		0.000		0.000		0.000	
CATIONS	3.975		8.003		3.991		2.998		4.013		3.999		3.010	
MG/MG+FE	.903		.824		.906		.743		.914		.874		.717	
CA/CA+MG	.545		.141		.006		0.000		.531		.006		0.000	
CR/CR+AL	.090		.032		.053		.150		.064		.036		.122	

APPENDIX II
GROUP V NODULES
SCHAFFER-FERRIS-AULTMAN KIMBERLITES

AD1-L 1R AD1-L 1R SH3-L 1 SH3-L 1 SH3-L 1SH3-L 1 SH3-L 13 SH3-L 13 SH3-L 13 SH3-L 29 SH3-L 29 SH3-L 31 SH3-L 31 SH3-L 31 SH3-L 32 SH3-L 32

	CPX	GAR	CPX	OL	OPX	SPN	CPX	GAR	SPN	CPX	SPN	CPX	GAR	SPN	CPX	GAR
SiO2	53.07	42.57	50.65	40.54	54.72	.12	53.95	41.57	.18	52.62	.03	54.06	41.55	.13	53.87	41.51
TiO2	.73	.18	1.41	0.00	.36	.78	.46	.11	.68	.18	.11	.47	.11	.21	.42	.13
Al2O3	5.93	21.95	6.22	.02	3.91	45.42	3.94	22.13	21.16	3.25	44.40	4.00	22.44	45.06	3.55	22.16
Cr2O3	1.18	1.88	1.10	.01	.52	20.81	1.02	1.70	43.63	.79	24.42	.82	1.24	21.00	1.28	1.61
FeO	2.43	9.64	3.06	10.80	6.79	13.43	2.18	10.04	20.89	1.80	11.40	2.30	10.20	14.95	2.29	10.14
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.04	.49	.12	.16	.18	.20	.04	.52	.30	.12	.55	.09	.48	.13	.05	.50
NiO	.05	0.00	.04	.30	.07	.25	.05	0.00	.18	.04	.16	.05	0.00	.24	0.00	0.00
MgO	13.63	19.17	15.66	49.27	32.78	18.77	14.88	19.45	11.34	16.34	17.88	14.89	19.60	16.50	15.07	19.36
CaO	19.66	4.74	20.57	.07	.88	0.00	20.52	4.80	.02	22.54	0.00	20.81	4.98	0.00	20.82	4.86
Na2O	2.61	.02	1.22	0.00	.09	0.00	2.33	.02	.04	1.07	0.00	2.09	.05	0.00	2.14	.03
K2O	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	99.33	100.65	100.05	101.17	100.30	99.78	99.37	100.34	98.42	98.76	98.95	99.58	100.65	98.22	99.49	100.30
Si	1.928	3.028	1.837	.988	1.892	.002	1.959	2.980	.005	1.932	.001	1.961	2.968	.003	1.959	2.975
Ti	.019	.008	.038	0.000	.009	.016	.012	.004	.016	.005	.002	.013	.004	.004	.010	.006
Al	.253	1.840	.265	0.000	.159	1.458	.168	1.869	.788	.141	1.428	.170	1.889	1.484	.151	1.872
Cr	.033	.104	.031	0.000	.014	.447	.028	.094	1.091	.023	.527	.023	.069	.464	.036	.090
Fe2+	.073	.576	.054	.219	.196	.243	.066	.602	.552	.055	.260	.069	.608	.309	.069	.608
Fe3+	0.000	0.000	.038	0.000	0.000	.062	0.000	0.000	0.000	0.000	.040	0.000	0.000	.040	0.000	0.000
Mn	.001	.029	.003	.002	.005	.004	.001	.029	.007	.004	.013	.002	.027	.002	.001	.029
Ni	.001	0.000	.001	.005	.001	.004	.001	0.000	.003	.001	.004	.001	0.000	.005	0.000	0.000
Mg	.738	2.034	.846	1.791	1.689	.762	.805	2.079	.534	.895	.727	.805	2.086	.687	.816	2.068
Ca	.765	.361	.799	.001	.032	0.000	.798	.368	0.000	.887	0.000	.809	.379	0.000	.811	.372
Na	.183	.002	.085	0.000	.005	0.000	.164	.002	.001	.076	0.000	.146	.006	0.000	.150	.004
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	3.994	7.982	3.997	3.006	4.002	2.998	4.002	8.027	2.997	4.020	3.002	3.999	8.036	2.998	4.003	8.024
MG/MG+FE	.910	.779	.940	.891	.896	.758	.924	.775	.492	.942	.737	.921	.774	.690	.922	.773
CA/CA+MG	.509	.151	.486	.001	.019	0.000	.498	.150	0.000	.498	0.000	.501	.154	0.000	.498	.152
CR/CR+AL	.115	.053	.105	0.000	.081	.235	.143	.048	.581	.140	.270	.119	.035	.238	.193	.046

	SH3-L 60	SH3-L 60	SH3-L 69	SH3-L 72	SH3-L 75	SH3-L 75	SH3-L 76	SH3-L 78	SH3-L 78	SH3-L 83	SH3-L 83	SH3-L 84	SH3-L 84	SH3-L 91	SH3-L 91
	CPX	GAR	CPX	CPX	CPX	GAR	CPX	CPX	GAR	CPX	GAR	CPX	SPN	CPX	SPN
SiO2	53.37	41.95	53.02	53.42	53.08	41.24	53.16	53.24	41.80	52.18	41.59	52.58	.09	53.13	.01
TiO2	.54	.11	.51	.45	.43	.19	.40	.31	.20	.58	.12	.41	.09	.20	.19
Al2O3	4.52	22.43	4.20	2.34	3.91	22.32	4.45	3.90	22.75	5.74	22.76	4.34	48.20	3.79	38.09
Cr2O3	1.63	1.50	.93	.53	1.17	1.69	1.06	.89	1.27	.85	1.31	.77	19.90	1.25	31.45
FeO	2.35	10.29	2.30	4.28	2.18	10.19	2.41	2.15	10.04	2.14	9.48	1.82	13.01	1.53	12.74
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.14	.65	.15	.18	.15	.63	.13	.13	.59	.13	.59	.09	.52	.14	.77
NiO	.01	0.00	.01	.03	0.00	0.00	.02	.05	.01	.03	0.00	0.00	.16	.04	.11
MgO	13.97	19.20	14.85	17.94	14.96	19.07	15.13	15.07	19.31	14.42	19.48	15.67	17.13	16.04	16.28
CaO	19.43	4.57	20.62	18.77	20.98	5.01	20.28	20.73	4.90	20.61	4.97	22.38	.01	21.97	0.00
Na2O	3.51	.06	2.68	1.50	2.42	.07	2.46	2.56	.06	2.50	.06	1.50	0.00	1.70	0.00
K2O	.01	0.00	.01	.04	.02	0.00	.02	.01	0.00	.01	0.00	.01	0.00	.02	0.00
TOTAL	99.48	100.76	99.28	99.48	99.30	100.41	99.52	99.04	100.93	99.19	100.36	99.57	99.11	99.81	99.64
Si	1.945	1.496	1.937	1.950	1.939	1.480	1.934	1.947	1.487	1.905	1.485	1.914	.002	1.928	0.000
Ti	.015	.003	.014	.012	.012	.005	.011	.008	.005	.016	.003	.011	.002	.005	.004
Al	.194	.943	.181	.101	.168	.945	.191	.168	.955	.247	.958	.186	1.542	.162	1.264
Cr	.047	.042	.027	.015	.034	.048	.031	.026	.036	.025	.037	.022	.427	.036	.700
Fe2+	.072	.307	.070	.131	.067	.306	.073	.066	.299	.065	.283	.056	.023	.046	.327
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.295	0.000	0.000
Mn	.004	.020	.005	.006	.005	.019	.004	.004	.018	.004	.018	.003	.012	.004	.018
Ni	0.000	0.000	0.000	.001	0.000	0.000	.001	.002	0.000	.001	0.000	0.000	.004	.001	.002
Mg	.759	1.021	.809	.976	.815	1.021	.821	.822	1.025	.785	1.037	.851	.693	.868	.683
Ca	.759	.175	.807	.734	.822	.193	.791	.813	.187	.807	.190	.874	0.000	.855	0.000
Na	.248	.004	.190	.106	.172	.005	.174	.182	.004	.177	.004	.106	0.000	.120	0.000
K	0.000	0.000	.001	.002	.001	0.000	.001	.001	0.000	.001	0.000	.001	0.000	.001	0.000
CATIONS	4.043	4.011	4.041	4.034	4.035	4.022	4.032	4.039	4.016	4.033	4.015	4.024	3.000	4.026	2.998
MG/MG+FE	.913	.769	.920	.882	.924	.769	.918	.926	.774	.924	.786	.938	.968	.950	.676
CA/CA+MG	.500	.146	.499	.429	.502	.159	.491	.497	.154	.507	.155	.507	0.000	.496	0.000
CR/CR+AL	.195	.043	.130	.129	.168	.048	.140	.134	.036	.092	.037	.106	.217	.182	.356

APPENDIX II

NODULES WITH EXSOLVED GARNET

	NX2-W	NX2-W	NX2-W	NX2-W	NX2-W	NX2-W	NX4-L	NX4-L	NX4-L	NX4-L	SD2-L111	SD2-L111	SD2-L111	SD2-L111
	CPX	GAR	OL	OPX1 *	OPX2 *	SPH	CPX	GAR	OPX	SPH	CPX	GAR	OPX	SPH
SiO2	54.37	42.20	41.45	56.25	57.16	.11	52.47	41.43	56.02	.07	52.06	41.74	55.47	.04
TiO2	.10	.20	.06	.20	.16	.17	.87	.12	.04	.01	.58	.11	0.00	0.00
Al2O3	3.65	21.43	0.00	1.94	1.51	41.78	5.24	24.10	2.08	65.36	4.99	23.54	2.36	61.87
Cr2O3	.96	1.22	.02	.37	.24	24.51	0.00	0.00	0.00	.83	.19	.27	.02	4.03
FeO	2.42	10.92	9.02	5.59	6.42	14.98	3.01	11.18	7.20	8.55	2.48	11.88	7.18	9.17
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.13	.50	.08	.16	.12	.56	.07	.45	.16	.11	.08	.46	.12	.22
NiO	.12	.04	0.00	0.00	.04	0.00	.02	.04	.01	.35	0.00	.01	.11	.36
MgO	15.75	19.94	49.89	34.69	35.45	17.33	15.45	18.43	34.84	22.25	15.42	17.97	33.74	21.11
CaO	21.06	4.99	.01	.50	.48	.01	22.48	5.47	.23	0.00	22.85	5.54	.24	.01
Na2O	2.16	.01	.01	.12	.06	0.00	1.56	.05	.05	.03	1.39	0.00	.03	0.00
K2O	.01	0.00	0.00	0.00	.01	0.00	0.00	0.00	.01	0.00	.01	0.00	.03	0.00
TOTAL	100.73	101.45	100.54	99.82	101.65	99.45	101.17	101.27	100.64	97.56	100.04	101.52	99.30	96.81
Si	1.955	3.000	1.005	1.941	1.943	.003	1.888	1.472	1.929	.002	1.893	1.485	1.935	.001
Ti	.003	.010	.001	.005	.004	.004	.023	.003	.001	0.000	.016	.003	0.000	0.000
Al	.155	1.798	0.000	.079	.061	1.372	.222	1.010	.085	1.890	.214	.988	.097	1.843
Cr	.027	.063	.001	.010	.007	.540	0.000	0.000	0.000	.016	.005	.008	0.000	.080
Fe2+	.073	.650	.183	.161	.183	.273	.091	.332	.208	.175	.075	.354	.210	.194
Fe3+	0.000	0.000	0.000	0.000	0.000	.076	0.000	0.000	0.000	.092	0.000	0.000	0.000	.075
Mn	.004	.030	.001	.005	.004	.013	.002	.014	.005	.002	.002	.014	.003	.005
Ni	.004	.002	0.000	0.000	.001	0.000	.001	.001	0.000	.007	0.000	0.000	.003	.007
Mg	.844	2.116	1.803	1.786	1.797	.719	.829	.927	1.789	.814	.836	.953	1.756	.795
Ca	.312	.380	0.000	.018	.018	.001	.867	.208	.008	0.000	.891	.211	.009	0.000
Na	.111	0.000	0.000	.008	.004	0.000	.109	.003	.003	.001	.098	0.000	.002	0.000
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	.001	0.000	.001	0.000
CATIONS	4.028	8.054	2.994	4.013	4.022	3.001	4.032	4.020	4.029	2.999	4.031	4.016	4.016	3.000
MG/MG+FI	.920	.765	.908	.917	.908	.725	.901	.746	.396	.823	.918	.729	.893	.804
CA/CA+MG	.490	.152	0.000	.010	.010	.001	.511	.176	.004	0.000	.516	.181	.005	0.000
CR/CR+AL	.148	.036	1.000	.112	.103	.282	0.000	0.000	0.000	.008	.023	.008	0.000	.042

*OPX1 = near spine1 OPX2 = away from spine1

	SD2-L112	SD2-L112	SD2-L112	SD2-L112	SD2-L113	SD2-L113	SD2-L113	SD2-L114	SD2-L114	SD2-L114	SD2-L114	SD2-L115	SD2-L115	SD2-L115
	CPX	GAR	OPX	SPN	CPX	GT	OPX	CPX	GT	OPX	SPN	CPX	GT	OPX
SiO2	51.57	41.02	55.40	.13	51.95	41.62	56.00	52.94	41.62	56.20	.16	53.42	41.68	56.78
TiO2	.79	.02	.15	.06	.71	.07	.13	.62	.06	.11	.01	.46	.09	.13
Al2O3	5.91	23.41	1.81	63.88	5.93	23.05	2.15	4.61	23.30	1.88	62.53	4.45	22.43	1.21
Cr2O3	.03	.09	0.00	2.49	.16	.21	.06	.27	.34	.11	3.65	.59	.86	.14
FeO	3.10	12.76	7.64	12.36	2.75	11.54	7.01	2.43	10.71	6.16	12.11	2.11	10.07	5.67
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.08	.50	.20	.04	.05	.45	.13	.06	.42	.10	.05	.05	.44	.11
NiO	.07	.08	.07	.61	.04	.03	.12	.04	.02	.10	.37	.06	0.00	.14
MgO	14.48	18.10	33.97	20.97	14.75	18.45	34.25	15.24	18.69	34.77	21.42	15.33	19.27	35.13
CaO	21.84	5.15	.25	.02	21.53	5.20	.33	22.36	5.28	.22	.01	21.11	5.00	.27
Na2O	1.82	.05	.04	.01	1.47	.01	0.00	1.29	0.00	0.00	0.00	1.72	.04	.02
K2O	.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	99.70	101.18	99.53	100.57	99.34	100.63	100.18	99.86	100.44	99.65	100.31	99.30	99.88	99.60
Si	1.883	1.471	1.935	.003	1.894	2.981	1.935	1.920	1.981	1.945	.003	1.941	2.991	1.959
Ti	.022	.001	.004	0.000	.019	.002	.003	.016	.002	.002	0.000	.012	.004	.003
Al	.255	.990	.074	1.890	.254	1.944	.087	.197	1.966	.076	1.856	.189	1.898	.048
Cr	.001	.002	0.000	.049	.004	.010	.001	.007	.018	.002	.062	.016	.048	.003
Fe2+	.095	.383	.223	.209	.083	.689	.202	.073	.624	.178	.193	.064	.604	.163
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.002	.015	.006	0.000	.001	.027	.003	.001	.024	.002	0.000	.001	.025	.003
Ni	.002	.002	.002	.012	.001	0.000	.003	0.000	0.000	.002	.007	.001	0.000	.003
Mg	.788	.968	1.769	.784	.801	1.970	1.765	.824	1.995	1.773	.804	.830	2.062	1.806
Ca	.855	.198	.009	0.000	.841	.399	.011	.869	.393	.007	0.000	.821	.383	.009
Na	.129	.004	.003	0.000	.104	0.000	0.000	.090	0.000	0.000	0.000	.120	.004	.001
K	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.033	4.034	4.025	2.947	4.002	8.022	4.010	3.997	7.003	3.987	2.925	3.995	8.019	3.998
MG/MG+FE	.892	.717	.888	.790	.906	.741	.897	.919	.762	.909	.806	.928	.773	.917
CA/CA+MG	.520	.170	.005	0.000	.512	.168	.006	.513	.165	.004	0.000	.497	.157	.005
CR/CR+AL	.004	.002	0.000	.025	.016	.005	.011	.034	.009	.026	.032	.078	.025	.059

SD2-L132 SD2-L132 SD2-L132 SD2-L173 SD2-L173 SD2-L173 SD2-OP152SD2-OP152SD2-OP152SD2-W 9 SD2-W 9 SD2-W 9 SD2-W 9 SD2-W 10 SD2-W 10 SD2-W 10 SD2-W 10

	CPX	GAP	OPY	CPX	GAR	SPN	CPX	GAR	OPX	CPX	GAR	OPX	SPN	CPX	GAR	OPX	SPN
SiO2	54.50	41.89	56.70	51.74	42.15	.03	52.45	41.55	56.25	53.38	42.19	58.06	.03	51.49	40.25	53.53	.08
TiO2	.24	.17	.03	.75	.07	0.00	.66	.06	.04	.30	.05	.07	.02	.73	.07	.15	.08
Al2O3	3.79	22.75	1.08	5.95	23.33	63.86	4.76	22.82	1.92	5.13	23.06	1.24	48.48	7.99	23.14	3.09	61.03
Cr2O3	.82	1.14	.12	0.00	.01	1.67	.08	.09	.02	.62	.76	.07	19.50	0.00	0.00	0.00	1.14
FeO	1.93	9.36	6.63	2.79	10.60	8.61	2.81	11.63	7.03	1.87	8.59	4.85	9.04	8.34	16.62	11.73	13.74
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.05	.38	.05	.04	.39	.09	.05	.45	.09	.04	.33	.10	.49	.13	.49	.18	.14
NiO	.10	0.00	.02	.02	.02	.20	.01	0.00	.06	.01	.03	.13	.37	.02	0.00	0.00	.55
MgO	16.02	19.88	35.87	15.07	18.51	21.67	15.46	18.04	34.39	15.22	19.84	35.54	19.49	16.94	14.65	30.24	17.71
CaO	21.23	4.95	.21	21.91	5.22	0.00	21.95	4.98	.16	21.06	5.19	.25	0.00	14.43	5.06	.28	.03
Na2O	2.39	.04	.04	1.70	0.00	0.00	1.35	0.00	0.00	2.42	.01	.07	.01	1.81	.03	.04	.07
K2O	.01	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00	.03	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	101.08	100.56	100.75	99.98	100.30	96.13	99.58	99.62	99.96	100.05	100.08	100.38	97.43	101.88	100.31	99.24	94.57
Si	1.949	1.489	1.945	1.880	1.504	.001	1.910	3.004	1.944	1.926	1.499	1.978	.001	1.841	1.480	1.910	.002
Ti	.007	.005	.001	.021	.002	0.000	.017	.002	.001	.003	.001	.002	0.000	.002	.002	.004	.002
Al	.160	.954	.044	.255	.982	1.896	.204	1.943	.078	.218	.967	.050	1.531	.337	1.004	.130	1.863
Cr	.023	.032	.003	0.000	0.000	.033	.002	.004	0.000	.018	.021	.002	.413	0.000	0.000	0.000	.023
Fe2+	.058	.278	.190	.085	.317	.181	.085	.702	.203	.056	.255	.138	.203	.249	.512	.350	.298
Fe3+	0.000	0.000	0.000	0.000	0.000	.070	0.000	0.000	0.000	0.000	0.000	0.000	.054	0.000	0.000	0.000	.110
Mn	.002	.012	.001	.001	.012	.002	.001	.025	.002	.001	.010	.003	.011	.004	.015	.005	.003
Ni	.003	0.000	.001	.001	.001	.004	0.000	0.000	.001	0.000	.001	.003	.008	.001	0.000	0.000	.011
Mg	.855	1.054	1.836	.816	.985	.813	.839	1.943	1.772	.819	1.052	1.806	.779	.903	.803	1.609	.684
Ca	.814	.189	.008	.853	.200	0.000	.856	.336	.005	.815	.198	.009	0.000	.553	.199	.011	.001
Na	.166	.003	.003	.120	0.000	0.000	.095	0.000	0.000	.169	.001	.004	0.000	.125	.002	.003	.003
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	4.037	4.016	4.032	4.032	4.003	3.000	4.009	8.009	4.006	4.030	4.006	3.995	3.000	4.015	4.017	4.022	3.000
MG/MG+FE	.936	.791	.906	.906	.757	.818	.908	.735	.897	.936	.805	.929	.793	.784	.611	.821	.697
CA/CA+MG	.438	.152	.004	.511	.169	0.000	.505	.166	.003	.499	.158	.005	0.000	.380	.199	.007	.001
CR/CR+AL	.126	.032	.064	0.000	0.000	.017	.010	.002	0.000	.076	.021	.038	.212	0.000	0.000	0.000	.012

APPENDIX II

GROUP VI NODULES

	SD2-D 1	SD2-D 2	SD2-D 3	SD2-D 20	SD2-H 4	SD2-H 8	SD2-H 11
	OL	OL	OL	OL	OL	OL	OL
SiO2	41.85	39.92	41.99	41.75	41.38	41.86	42.05
TiO2	0.00	.04	.04	0.00	.02	0.00	.04
Al2O3	.04	.04	.02	0.00	.04	.04	.02
Cr2O3	.11	.03	.02	.02	.02	.06	.02
FeO	8.14	12.03	12.09	6.96	11.72	8.46	11.54
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.10	.11	.10	.09	.14	.13	.12
NiO	.30	.20	.23	.40	.22	.28	.28
MgO	51.87	18.52	49.23	50.52	49.83	51.96	50.16
CaO	.06	.08	.06	.02	.07	.05	.03
Na2O	.02	.02	.03	0.00	0.00	0.00	.03
K2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	102.49	70.99	103.81	99.76	103.44	102.84	104.29
Si	.994	.981	1.000	1.012	.989	.991	.994
Ti	0.000	.001	0.000	0.000	0.000	0.000	0.000
Al	0.000	.001	0.000	0.000	0.000	0.000	0.000
Cr	.001	.001	0.000	0.000	0.000	0.000	0.000
Fe2+	.162	.247	.240	.141	.234	.167	.228
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.001	.002	.001	.001	.002	.002	.002
Ni	.005	.004	.004	.007	.003	.004	.004
Mg	1.836	1.778	1.747	1.825	1.775	1.835	1.768
Ca	.001	.002	.001	0.000	.001	0.000	0.000
Na	0.000	0.000	.001	0.000	0.000	0.000	0.000
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	3.000	3.017	2.994	2.986	3.004	2.999	2.996
MG/MG+FE	.919	.878	.879	.928	.884	.917	.886
CA/CA+MG	.001	.001	.001	0.000	.001	0.000	0.000
CR/CR+AL	1.000	.500	0.000	0.000	0.000	0.000	0.000

APPENDIX II
GROUP V NODULES
IRON MOUNTAIN KIMBERLITES

1M26-C 91M26-P 641M26-P 641M26-P 641M42-L 371M42-L 371M42-L 75

	CPX	CPX	GAR	OPX	CPX	SPN	CPX
SiO2	54.40	54.33	41.89	57.67	53.58	.10	54.81
TiO2	.08	.31	.11	.04	.34	.52	.25
Al2O3	2.88	3.02	22.79	.86	2.66	23.83	3.28
Cr2O3	.91	.85	1.27	.18	1.13	41.02	1.06
FeO	1.80	1.16	6.98	3.86	2.21	24.84	1.65
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	.14	.07	.34	.09	.09	.36	.01
NiO	.01	.08	0.00	.09	.06	.09	.04
MgO	16.29	16.45	21.33	36.54	15.68	9.34	15.78
CaO	22.30	21.71	4.42	.23	22.24	0.00	21.60
Na2O	1.18	1.59	.01	.05	1.23	0.00	1.86
K2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	99.99	99.57	99.14	99.61	99.22	100.10	100.34
Si	1.965	1.964	2.982	1.974	1.960	.002	1.970
Ti	.002	.007	.004	.001	.008	.012	.006
Al	.122	.128	1.912	.034	.114	.877	.138
Cr	.025	.023	.071	.004	.032	1.013	.029
Fe2+	.054	.034	.416	.110	.067	.649	.049
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	.004	.001	.019	.002	.002	.009	0.000
Ni	0.000	.002	0.000	.002	.001	.001	.001
Mg	.876	.886	2.264	1.864	.854	.435	.845
Ca	.863	.840	.336	.008	.872	0.000	.831
Na	.082	.111	0.000	.003	.087	0.000	.128
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CATIONS	3.993	3.996	8.004	4.002	3.997	2.998	3.997
MG/MG+FE	.942	.963	.845	.944	.927	.401	.945
CA/CA+MG	.496	.487	.129	.004	.505	0.000	.496
CR/CR+AL	.170	.152	.036	.105	.219	.536	.174

APPENDIX III
WHOLE ROCK CHEMISTRY

Appendix III. Whole rock chemistry, Group I nodules.

	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO	MnO	NiO	MgO	CaO	Na ₂ O	K ₂ O	FeO FeO + MgO
SD2-D8	48.44	.18	.50	.16	8.31	.14	.18	42.08	.37	.10	.01	0.165
SD2-D25	42.26	.06	.35	.19	9.10	.15	.44	48.58	.21	.06	.00	0.158
SD2-H13	41.11	.13	1.33	1.41	7.83	.14	.30	47.69	.92	.06	.00	0.141
SD2-L4	42.93	.16	2.37	3.33	7.40	.16	.27	43.32	1.90	.07	.00	0.146
SD2-L69	42.84	.15	1.36	.90	8.57	.17	.31	46.06	.92	.10	.00	0.157
SD2-L75	41.45	.08	.37	.20	9.63	.14	.40	48.40	.24	.08	.00	0.166
SD2-L76	43.94	.08	1.55	.62	7.04	.12	.26	46.25	.60	.06	.01	0.132
SD2-L98	42.28	.19	1.25	.88	9.41	.13	.41	45.24	1.00	.10	.00	0.172
SD2-L100	43.45	.10	.77	.88	7.47	.13	.29	46.70	1.31	.10	.00	0.138
SD2-L101	42.35	.03	.27	.32	7.82	.13	.34	47.91	.46	.06	.00	0.140
SD2-L102	42.10	.04	4.71	1.26	7.59	.18	.25	42.15	1.78	.06	.00	0.153
SD2-L103	43.04	.02	.08	.05	7.48	.15	.24	49.64	.18	.03	.00	0.131
SD2-L120	42.65	.16	5.71	1.02	8.43	.17	.28	39.74	1.48	.03	.00	0.175
SD2-L123	46.16	.02	.46	.38	7.97	.13	.40	48.08	.28	.02	.00	0.142
SD2-L133	44.62	.34	9.01	3.56	6.85	.22	.14	31.78	3.67	.07	.00	0.177
SD2-W11	56.42	.29	1.17	.43	5.46	.17	.06	27.85	7.53	.81	.02	0.164
SD2-L169	43.09	.04	1.07	1.15	7.29	.13	.28	45.93	.83	.05	.00	0.137

Appendix III. Whole rock chemistry, Group II nodules.

	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO	MnO	NiO	MgO	CaO	Na ₂ O	K ₂ O	FeO FeO + MgO
SD2-L1	45.74	.00	.64	.14	6.49	.11	.32	48.89	.27	.01	.00	0.117
SD2-L3	45.73	.00	.77	.19	6.36	.09	.28	47.90	.67	.04	.00	0.117
SD2-L5	44.64	.00	1.00	.39	6.66	.13	.28	49.68	.12	.02	.00	0.118
SD2-L6	44.27	.00	.65	.13	6.48	.12	.36	46.73	1.03	.04	.00	0.122
SD2-L7	45.77	.00	1.01	.29	6.44	.13	.30	47.37	.33	.06	.00	0.120
SD2-L15	43.76	.07	.51	.16	7.47	.08	.36	47.74	.58	.06	.00	0.135
SD2-L16	43.82	.05	.47	.06	6.78	.09	.37	48.82	.13	.04	.00	0.122
SD2-L20	46.39	.01	1.10	.19	6.34	.09	.29	45.66	.20	.05	.00	0.122
SD2-L21	39.68	.02	2.54	1.42	6.89	.12	.37	47.21	1.42	.07	.00	0.127
SD2-L22	41.38	.00	2.45	1.29	7.36	.16	.30	46.97	1.40	.05	.01	0.135
SD2-L23	45.85	.05	.89	.15	6.28	.08	.37	45.24	1.63	.08	.00	0.122
SD2-L25	42.66	.02	.41	.21	7.69	.12	.39	48.84	.31	.03	.00	0.136
SD2-L31	44.70	.00	.89	.26	6.35	.11	.30	47.58	.41	.03	.00	0.118
SD2-L38	43.12	.01	.41	.09	6.61	.12	.36	48.08	1.15	.05	.00	0.121
SD2-L55	41.05	.00	.52	.27	7.14	.11	.39	50.29	.38	.01	.00	0.124
SD2-L65	45.76	.05	1.30	.39	60.3	.15	.25	46.46	.14	.02	.01	0.115
SD2-L73	43.83	.02	1.10	.33	6.72	.12	.30	47.29	.35	.01	.00	0.124
SD2-L90	43.80	.00	.65	.34	7.31	.14	.28	47.13	.55	.01	.00	0.134
SD2-L162	42.96	.03	.13	.23	7.50	.19	.31	47.55	2.01	.20	.01	0.136
SD2-L183	42.38	.00	.91	.47	8.13	.16	.37	47.25	.97	.06	.00	0.147

Appendix III. Whole rock chemistry, Group IV nodules.

	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO	MnO	NiO	MgO	CaO	Na ₂ O	K ₂ O	FeO FeO + MgO
NX4-L7	43.57	.41	18.17	.07	7.31	.24	.06	18.89	11.49	.66	.00	0.279
NX4-L20	51.34	.80	7.78	.00	2.29	.06	.03	16.56	20.11	1.44	.01	0.121
SD2-L12	47.85	.21	15.16	.20	5.21	.18	.01	19.99	11.17	.74	.00	0.207
SD2-L41	45.58	.17	18.99	.29	6.45	.26	.01	21.05	8.36	.41	.00	0.234
SD2-L42	48.65	.26	15.15	.15	5.17	.21	.02	19.98	11.71	.81	.00	0.206
SD2-L47	48.22	.41	15.43	.41	5.26	.21	.08	20.08	11.35	.70	.00	0.208
SD2-L48	47.58	.19	17.37	.37	5.68	.22	.03	20.26	10.06	.59	.00	0.219
SD2-L49	46.48	.28	17.11	.53	5.50	.23	.01	19.99	10.07	.57	.00	0.216
SD2-L50	47.68	.20	15.92	.33	5.35	.20	.01	20.15	11.03	.66	.00	0.210
SD2-L52	47.66	.40	14.12	.00	5.08	.23	.05	19.69	11.71	.83	.32	0.205
SD2-L77	46.86	.33	14.66	.18	5.20	.20	.02	19.43	12.42	.74	.00	0.242
SD2-L78	46.54	.31	16.75	.20	6.07	.24	.01	19.85	10.01	.68	.03	0.234
SD2-L79	46.53	.22	17.86	.20	5.99	.22	.01	21.85	7.33	.31	.00	0.215
SD2-L80	46.85	.42	16.16	.61	5.69	.20	.04	20.43	9.15	.53	.00	0.218
SD2-L83	45.48	.14	17.38	.12	6.12	.31	.04	20.17	9.64	.61	.01	0.233
SD2-L84	46.08	.18	17.82	.51	6.34	.25	.01	22.36	6.92	.38	.00	0.221
SD2-L85	47.40	.44	15.39	.33	5.01	.19	.01	20.12	10.77	.59	.00	0.199
SD2-L86	46.06	.17	17.71	.80	7.00	.28	.04	22.23	6.29	.30	.00	0.239
SD2-L87	47.73	.25	15.10	.45	6.08	.21	.03	22.06	8.64	.53	.00	0.216
SD2-L88	46.70	.32	17.17	.42	5.97	.25	.02	21.58	7.65	.14	.00	0.217
SD2-L104	48.45	.24	12.64	.00	4.63	.20	.04	18.78	13.67	1.06	.01	0.198
SD2-L106	47.61	.16	9.96	.39	8.52	.21	.00	15.60	15.96	.66	.01	0.353
SD2-L109	48.82	.34	12.65	.00	4.84	.20	.01	18.56	13.87	1.01	.02	0.207
SD2-L111	45.07	.35	14.83	.51	6.16	.20	.04	18.23	13.97	.75	.01	0.252
SD2-L112	48.42	.50	11.27	.05	6.50	.22	.07	16.91	15.06	1.13	.01	0.278
SD2-L113	48.37	.40	12.17	.17	6.59	.21	.04	18.18	13.04	.75	.00	0.266
SD2-L114	33.68	.25	27.54	1.32	7.90	.16	.14	18.98	9.71	.47	.00	0.294
SD2-P1	47.86	.32	11.56	.19	13.27	.30	.05	19.47	6.86	.55	.32	0.405
SD2-W6	49.72	.19	10.42	.76	4.49	.21	.03	18.69	15.33	.64	.01	0.194
SD2-W7	48.53	.13	13.68	.08	10.89	.24	.03	14.17	10.72	2.03	.01	0.434
SD2-W10	47.57	.49	13.24	.00	11.31	.26	.01	16.35	10.91	1.16	.00	0.409

Appendix III. Whole rock chemistry, Group V nodules.

	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO	MnO	NiO	MgO	CaO	Na ₂ O	K ₂ O	FeO FeO + MgO
NX4-L1	42.60	.00	.32	.07	7.79	.13	.29	47.81	.94	.06	.00	0.140
NX4-L2	43.09	.07	1.01	.11	8.11	.16	.30	44.07	3.06	.30	.00	0.155
NX4-L3	44.11	.01	3.09	.16	7.33	.15	.27	43.79	3.48	.20	.00	0.143
NX4-L4	42.90	.02	1.52	.45	7.08	.14	.27	44.00	3.25	.20	.00	0.139
NX4-L6	40.93	.01	3.00	.69	8.20	.16	.27	44.48	2.12	.14	.00	0.184
NX4-L6	46.70	.08	2.46	.27	7.34	.17	.22	38.73	4.18	.34	.01	0.159
NX4-L9	47.35	.05	2.30	.34	60.2	.13	.21	36.98	6.71	.48	.01	0.140
SD2-L2	44.71	.06	1.89	.31	7.35	.13	.26	44.14	2.13	.18	.00	0.143
SD2-L9	42.76	.02	1.18	.33	7.93	.18	.34	44.90	2.60	.14	.00	0.150
SD2-L10	42.79	.11	13.95	1.63	8.89	.40	.11	29.21	4.58	.21	.00	0.233
SD2-L11	43.58	.05	9.37	.96	8.50	.24	.16	35.35	1.93	.06	.00	0.194
SD2-L13	45.20	.09	19.48	1.01	7.23	.31	.02	24.11	3.76	.07	.00	0.231
SD2-L14	41.77	.01	1.70	.26	8.76	.17	.31	45.98	1.23	.10	.00	0.160
SD2-L17	41.98	.08	3.00	.40	9.13	.22	.29	42.46	3.37	.36	.00	0.177
SD2-L18	43.58	.07	1.20	.28	7.90	.13	.21	43.57	3.49	.16	.00	0.153
SD2-L19	44.38	.05	2.07	.21	8.23	.15	.28	42.61	2.99	.30	.01	0.162
SD2-L24	41.32	.05	.65	.16	9.21	.17	.42	48.67	.37	.03	.00	0.159
SD2-L28	40.92	.10	15.33	2.49	6.88	.22	.13	29.04	3.70	.39	.00	0.192
SD2-L32	42.45	.04	5.86	.38	9.55	.28	.22	39.12	1.75	.10	.01	0.196
SD2-L34	42.14	.04	1.09	.36	7.13	.18	.27	47.68	1.28	.09	.00	0.130
SD2-L35	44.07	.09	1.54	.14	7.93	.18	.31	43.59	2.31	.24	.00	0.154
SD2-L37	46.37	.12	2.89	.47	7.44	.18	.26	37.24	3.59	.33	.00	0.166
SD2-L39	42.20	.05	10.79	.93	8.47	.29	.16	33.65	2.93	.14	.00	0.201
SD2-L40	45.07	.06	3.01	.50	9.50	.21	.12	33.13	8.54	.31	.00	0.223

Appendix III. Whole rock chemistry, Group V nodules, continued.

	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO	MnO	NiO	MgO	CaO	Na ₂ O	K ₂ O	FeO FeO + MgO
SD2-L44	46.17	.19	19.42	.77	6.99	.30	.04	24.08	4.61	.15	.00	0.225
SD2-L51	48.99	.27	12.93	1.84	4.65	.26	.03	18.82	13.15	.93	.00	0.198
SD2-L54	45.44	.08	4.26	.36	7.56	.20	.21	37.80	3.92	.36	.00	0.167
SD2-L57	41.37	.02	2.83	.70	7.99	.14	.29	46.48	.58	.05	.00	0.147
SD2-L58	43.65	.15	3.48	.48	7.73	.13	.22	38.12	6.42	.50	.01	0.169
SD2-L59	44.41	.08	8.66	.73	8.45	.31	.18	34.87	2.46	.10	.00	0.195
SD2-L61	49.34	.25	5.93	1.18	5.69	.09	.18	30.75	6.00	.48	.00	0.156
SD2-L64	42.34	.03	2.16	.27	8.46	.12	.29	44.47	2.10	.21	.01	0.160
SD2-L66	44.19	.05	4.06	.34	8.11	.16	.20	38.12	4.50	.32	.00	0.175
SD2-L68	47.52	.13	16.14	1.03	6.78	.29	.01	24.37	4.76	.16	.00	0.218
SD2-L70	44.46	.08	2.07	.27	7.54	.15	.30	40.05	4.88	.38	.00	0.158
SD2-L71	43.72	.10	1.61	.18	8.28	.06	.33	42.98	3.14	.29	.00	0.162
SD2-L72	46.84	.19	4.08	.38	7.71	.15	.23	35.41	5.11	.56	.00	0.179
SD2-L74	44.72	.13	3.12	.33	8.28	.11	.32	40.23	2.88	.29	.00	0.171
SD2-L81	45.80	.60	17.87	1.03	7.66	.24	.02	22.75	5.33	.21	.00	0.252
SD2-L82	45.16	.17	17.79	.69	7.40	.29	.04	23.47	4.36	.09	.00	0.240
SD2-L91	46.75	.06	2.05	.78	6.53	.13	.26	40.33	2.48	.07	.00	0.139
SD2-L92	45.82	.03	1.66	.70	6.21	.11	.30	42.60	4.49	.09	.00	0.127
SD2-L93	44.47	.05	2.33	1.20	6.86	.13	.29	42.84	2.40	.06	.00	0.138
SD2-L96	43.96	.02	2.04	.63	8.05	.10	.36	43.02	2.57	.14	.00	0.158
SD2-L97	43.07	.11	20.19	1.37	9.37	.50	.01	20.11	5.23	.11	.00	0.318
SD2-L115	50.35	.34	9.23	.64	4.44	.16	.05	17.26	15.81	1.19	.00	0.205
SD2-L121	44.11	.13	11.10	.67	8.99	.31	.17	30.50	4.62	.28	.00	0.228

Appendix III. Whole rock chemistry, Group V nodules, continued.

	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO	MnO	NiO	MgO	CaO	Na ₂ O	K ₂ O	FeO FeO + MgO
SD2-L125	43.98	.07	3.32	.41	8.01	.16	.26	40.84	3.16	.30	.00	0.164
SD2-L126	43.40	.03	1.04	.27	7.65	.17	.29	45.36	2.49	.15	.00	0.143
SD2-L127	43.72	.10	1.92	.29	8.23	.19	.35	42.85	2.83	.23	.00	0.161
SD2-L128	45.88	.04	2.90	.30	7.43	.13	.20	40.41	3.06	.29	.00	0.155
SD2-L129	44.00	.09	1.47	.10	8.84	.18	.36	44.01	1.84	.19	.00	0.167
SD2-L130	45.00	.13	7.14	.64	8.19	.21	.24	31.48	6.95	.66	.03	0.206
SD2-L132	49.46	.19	13.01	1.09	5.87	.22	.09	21.01	9.60	.70	.00	0.218
SD2-L134	44.41	.09	2.79	.42	7.59	.12	.16	40.44	2.93	.29	.00	0.158
SD2-L137	44.99	.15	2.02	.29	7.16	.13	.31	39.68	6.29	.45	.00	0.153
SD2-L138	44.94	.10	1.83	.19	7.85	.16	.34	41.21	4.50	.41	.00	0.160
SD2-L139	45.52	.19	5.35	.84	6.09	.18	.23	33.32	8.41	.77	.00	0.154
SD2-L148	43.32	.15	2.70	.17	8.72	.16	.39	42.75	3.11	.35	.00	0.169
SD2-L159	44.47	.10	1.98	.36	8.06	.17	.28	43.58	2.25	.21	.00	0.156
SD2-L151	44.14	.13	1.65	.21	8.00	.20	.35	40.91	4.97	.35	.00	0.164
SD2-L152	41.58	.12	16.76	2.14	8.56	.39	.06	25.30	4.04	.15	.00	0.252
SD2-L154	44.68	.14	1.91	.20	7.71	.18	.38	39.58	6.08	.49	.00	0.163
SD2-L156	47.21	.08	3.32	.71	5.71	.15	.20	37.04	5.44	.42	.00	0.136
SD2-L159	41.56	.19	10.92	2.48	6.71	.17	.18	30.89	6.16	.49	.00	0.178
SD2-L161	43.72	.17	1.88	.27	7.75	.18	.33	39.79	5.79	.39	.00	0.163
SD2-L163	49.77	.26	9.47	.81	3.82	.15	.10	16.87	17.66	1.13	.00	0.185
SD2-L164	49.41	.48	8.15	.98	2.83	.16	.02	14.87	21.65	1.37	.00	0.160
SD2-L166	42.07	.09	.80	.12	8.28	.18	.37	48.32	.34	.08	.00	0.146
SD2-L167	43.59	.13	2.00	.26	7.97	.18	.37	42.44	3.33	.33	.00	0.158

Appendix III. Whole rock chemistry, Group V nodules, continued.

	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO	MnO	NiO	MgO	CaO	Na ₂ O	K ₂ O	FeO FeO + MgO
SD2-L168	41.73	.05	3.33	1.43	8.03	.19	.31	44.38	1.31	.07	.00	0.153
SD2-L170	42.54	.11	2.40	.46	7.93	.19	.39	43.93	2.20	.18	.01	0.153
SD2-L171	42.98	.04	1.00	.49	8.11	.17	.36	46.95	.80	.05	.00	0.147
SD2-L174	42.21	.24	9.63	2.26	5.88	.17	.17	30.57	7.80	.60	.01	0.161
SD2-L175	44.95	.13	3.86	.70	6.93	.15	.23	37.54	5.40	.41	.00	0.156
SD2-L177	43.25	.11	1.95	.32	7.71	.19	.30	42.36	4.01	.32	.00	0.154
SD2-L178	45.48	.12	3.36	.53	7.32	.16	.27	39.49	3.38	.25	.00	0.156
SD2-L179	42.59	.01	.85	.47	7.61	.17	.36	47.55	.54	.05	.00	0.138
SD2-L180	42.87	.12	1.70	.29	8.01	.15	.36	43.42	3.88	.33	.00	0.156
SD2-L181	42.03	.06	.96	.07	8.84	.14	.37	47.75	.52	.08	.00	0.156
SD2-L184	42.98	.00	1.93	.81	7.64	.20	.32	44.46	1.98	.09	.00	0.147
SD2-L185	43.37	.10	7.08	.66	8.44	.24	.20	36.46	3.49	.25	.01	0.188
SD2-L186	42.59	.07	5.39	.63	8.51	.23	.24	39.86	2.55	.22	.00	0.176
SD2-L187	44.34	.07	1.71	.37	7.00	.15	.26	42.47	3.49	.33	.00	0.142
SD2-L189	45.93	.22	8.41	1.70	6.95	.26	.11	29.43	6.66	.29	.00	0.191
SD2-W8	51.19	.33	7.67	.81	3.70	.17	.02	17.78	17.56	1.11	.01	0.172
SD2-W9	50.89	.24	8.95	.77	3.41	.10	.02	16.98	16.86	1.82	.01	0.167

APPENDIX IV

CAPTIONS FOR PLATES

PLATES

Mineral Chemistry*

Olivine (OLV)

Plate 1: MgO versus FeO

Not shown:

Group II

SD2-L1 at 52.46 MgO, 7.00 FeO
 SD2-L3 at 52.50 MgO, 7.03 FeO
 SD2-L5 at 53.06 MgO, 7.06 FeO
 SD2-L99 at 52.21 MgO, 7.14 FeO

Group V

SD2-L40 at 47.59 MgO, 13.00 FeO

Group VI

SD2-D19 at 47.52 MgO, 13.00 FeO

Orthopyroxene (OPX)

Plate 2: Al_2O_3 versus Cr_2O_3

Not shown:

Group I

SD2-L169 at 0.48 Al_2O_3 , 0.88 Cr_2O_3

Group V

SD2-L164 at 6.87 Al_2O_3 , 0.54 Cr_2O_3
 SD2-W8 at 5.91 Al_2O_3 , 0.33 Cr_2O_3

Line connects two different orthopyroxene analyses from
 sample NX2-W1.

Plate 3: CaO versus Cr_2O_3

Not shown:

Group I

SD2-L169 at 0.88 CaO, 0.88 Cr_2O_3

Line connects two different orthopyroxene analyses from
 sample NX2-W1.

*All oxides are weight percent.

Plate 4: TiO_2 versus Cr_2O_3

Not shown:

Group I

SD2-D25 at 0.38 TiO_2 , 0.40 Cr_2O_3
 SD2-L75 at 0.29 TiO_2 , 0.43 Cr_2O_3
 SD2-L98 at 0.29 TiO_2 , 0.40 Cr_2O_3
 SD2-L169 at 0.00 TiO_2 , 0.88 Cr_2O_3

Group V

SH3-L1 at 0.36 TiO_2 , 0.88 Cr_2O_3

Line connects two different orthopyroxene analyses from sample NX2-W1.

Clinopyroxene (CPX)

Plate 5: Al_2O_3 versus Cr_2O_3

Not shown:

Group I

SH3-L97 at 1.28 Al_2O_3 , 3.83 Cr_2O_3

Group IV

NX4-L20 at 8.17 Al_2O_3 , 0.00 Cr_2O_3
 SD2-W10 at 7.99 Al_2O_3 , 0.00 Cr_2O_3

Plate 6: FeO versus Cr_2O_3

Not shown:

Group II

SH3-L86 at 2.06 FeO , 3.20 Cr_2O_3
 SH3-L97 at 2.31 FeO , 3.83 Cr_2O_3

Group IV

SD2-W10 at 8.34 FeO , 0.00 Cr_2O_3

Plate 7: TiO_2 versus Cr_2O_3

Not shown:

Group I

SH3-L86 at 0.06 TiO_2 , 3.20 Cr_2O_3
 SH3-L97 at 0.09 TiO_2 , 3.83 Cr_2O_3

Group V

SH3-L1 at 1.41 TiO_2 , 1.10 Cr_2O_3

Plate 8: Na_2O versus FeO

Not shown:

Group I

IM42-L20 at 3.40 Na_2O , 2.56 FeO IM42-L71 at 3.79 Na_2O , 2.64 FeO

Group V

SH3-L60 at 3.51 Na_2O , 2.35 FeO Plate 9: $\text{Mg}/\text{Mg} + \text{Fe}$ versus $\text{Ca}/\text{Ca} + \text{Mg}$

Not shown:

Group I

SH3-L22 at 0.862 $\text{Mg}/\text{Mg} + \text{Fe}$, 0.419 $\text{Ca}/\text{Ca} + \text{Mg}$ SH3-L72 at 0.882 $\text{Mg}/\text{Mg} + \text{Fe}$, 0.429 $\text{Ca}/\text{Ca} + \text{Mg}$ SH3-L160 at 0.862 $\text{Mg}/\text{Mg} + \text{Fe}$, 0.494 $\text{Ca}/\text{Ca} + \text{Mg}$

Group IV

IM20-W5 at 0.854 $\text{Mg}/\text{Mg} + \text{Fe}$, 0.539 $\text{Ca}/\text{Ca} + \text{Mg}$ SD2-L106 at 0.889 $\text{Mg}/\text{Mg} + \text{Fe}$, 0.493 $\text{Ca}/\text{Ca} + \text{Mg}$ SD2-P1 at 0.802 $\text{Mg}/\text{Mg} + \text{Fe}$, 0.56 $\text{Ca}/\text{Ca} + \text{Mg}$ SD2-W7 at 0.856 $\text{Mg}/\text{Mg} + \text{Fe}$, 0.490 $\text{Ca}/\text{Ca} + \text{Mg}$ SD2-W10 at 0.784 $\text{Mg}/\text{Mg} + \text{Fe}$, 0.380 $\text{Ca}/\text{Ca} + \text{Mg}$

Garnet (GAR)

Plate 10: Al_2O_3 versus Cr_2O_3

Line connects analyses from core and rim of garnet from nodule
IM42-L58.

Plate 11: TiO_2 versus Cr_2O_3

Not shown:

Group I

SD2-D25 at 1.34 TiO_2 , 8.67 Cr_2O_3 SD2-L98 at 1.48 TiO_2 , 9.96 Cr_2O_3

Line connects analyses from core and rim of garnet from nodule
IM42-58.

Plate 12: CaO versus Cr₂O₃

Not shown:

Group I

SD2-H13 at 8.14 CaO, 13.46 Cr₂O₃
 SD2-L4 at 8.54 CaO, 15.26 Cr₂O₃
 SD2-L62 at 8.54 CaO, 13.31 Cr₂O₃
 SD2-L169 at 8.34 CaO, 14.15 Cr₂O₃

Line connects analyses from core and rim of garnet from nodule
 IM42-58.

Plate 13: MgO versus FeO

Not shown:

Group IV

SD2-L106 at 14.18 MgO, 15.18 FeO
 SD2-P1 at 13.28 MgO, 18.48 FeO
 SD2-W7 at 14.28 MgO, 18.03 FeO
 SD2-W10 at 14.65 MgO, 16.62 FeO

Spinel (SPN)

Plate 14: Al₂O₃ versus Cr₂O₃Plate 15: Fe²⁺ versus Mg²⁺

Fe²⁺ data is not available for all spinels analyzed.

Plate 16: Ca-Mg-Fe

Not shown:

Garnet (GAR)

SD2-W10 at 12.0 percent Ca, 47.0 percent Mg, 41.0 percent Fe
 SD2-L40 at 15.0 percent Ca, 58.5 percent Mg, 26.5 percent Fe

Whole Rock Chemistry*

Plate 17: CaO versus $100 \times (\text{FeO/MgO} + \text{FeO})$

Not shown:

Group IV

SD2-L106 at 15.96 CaO, 0.353 FeO/MgO + FeO

SD2-P1 at 6.86 CaO, 0.405 FeO/MgO + FeO

SD2-W7 at 10.72 CaO, 0.434 FeO/MgO + FeO

SD2-W10 at 10.91 CaO, 0.409 FeO/MgO + FeO

Group V

SD2-L115 at 15.18 CaO, 0.205 FeO/MgO + FeO

SD2-L163 at 17.66 CaO, 0.185 FeO/MgO + FeO

SD2-L164 at 21.64 CaO, 0.160 FeO/MgO + FeO

SD2-W8 at 17.56 CaO, 0.172 FeO/MgO + FeO

SD2-W9 at 16.86 CaO, 0.167 FeO/MgO + FeO

Plate 18: Na₂O versus $100 \times (\text{FeO/MgO} + \text{FeO})$

Not shown:

Group IV

SD2-P1 at 0.55 Na₂O, 0.405 FeO/MgO + FeO

SD2-W7 at 2.03 Na₂O, 0.434 FeO/MgO + FeO

SD2-W10 at 1.16 Na₂O, 0.409 FeO/MgO + FeO

Group V

SD2-W9 at 1.82 Na₂O, 0.167 FeO/MgO + FeO

Plate 19: Al₂O₃ versus $100 \times (\text{FeO/MgO} + \text{FeO})$

Not shown:

Group IV

SD2-P1 at 11.56 Al₂O₃, 0.406 FeO/MgO + FeO

SD2-W7 at 13.68 Al₂O₃, 0.434 FeO/MgO + FeO

SD2-W10 at 13.25 Al₂O₃, 0.409 FeO/MgO + FeO

*All oxides are weight percent.

Plate 20: TiO_2 versus $100 \times (\text{FeO/MgO} + \text{FeO})$

Not shown:

Group IV

NX4-L20 at 0.80 TiO_2 , 0.121 $\text{FeO/MgO} + \text{FeO}$
 SD2-P1 at 0.32 TiO_2 , 0.405 $\text{FeO/MgO} + \text{FeO}$
 SD2-W7 at 0.13 TiO_2 , 0.434 $\text{FeO/MgO} + \text{FeO}$
 SD2-W10 at 0.49 TiO_2 , 0.409 $\text{FeO/MgO} + \text{FeO}$

Plate 21: Cr_2O_3 versus $100 \times (\text{FeO/MgO} + \text{FeO})$

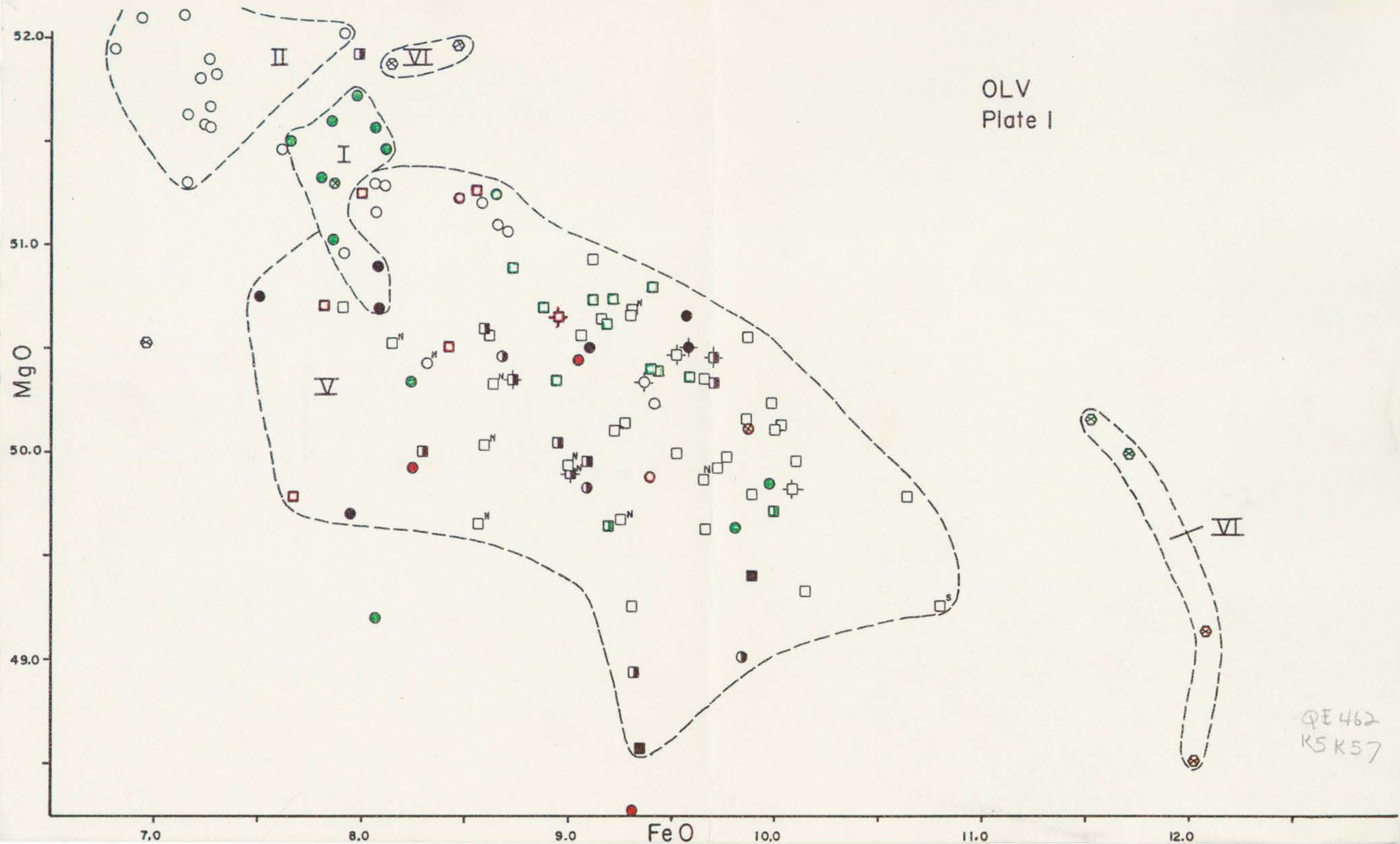
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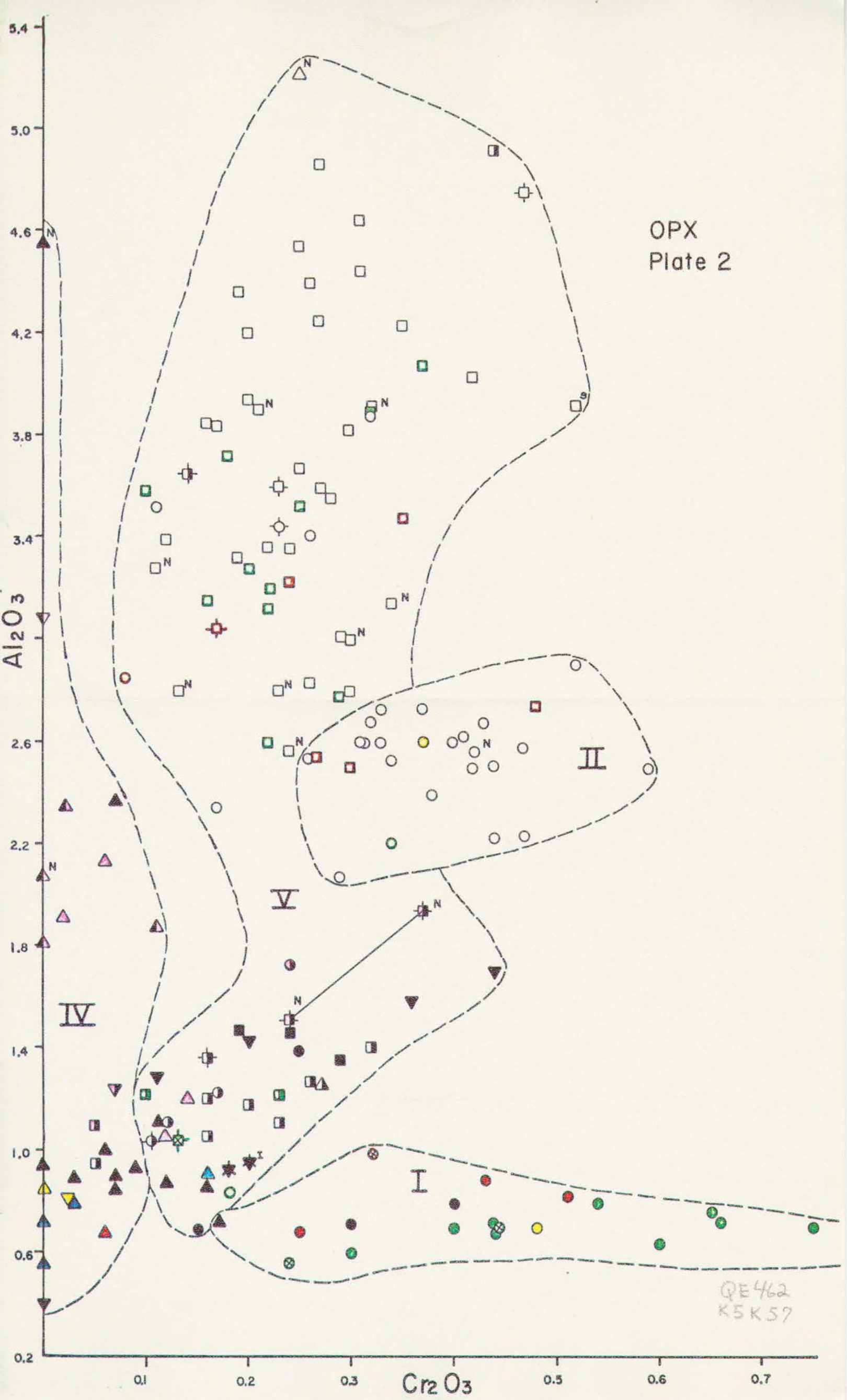
Group I

SD2-L4 at 3.33 Cr_2O_3 , 0.146 $\text{FeO/MgO} + \text{FeO}$
 SD2-L133 at 3.56 Cr_2O_3 , 0.177 $\text{FeO/MgO} + \text{FeO}$

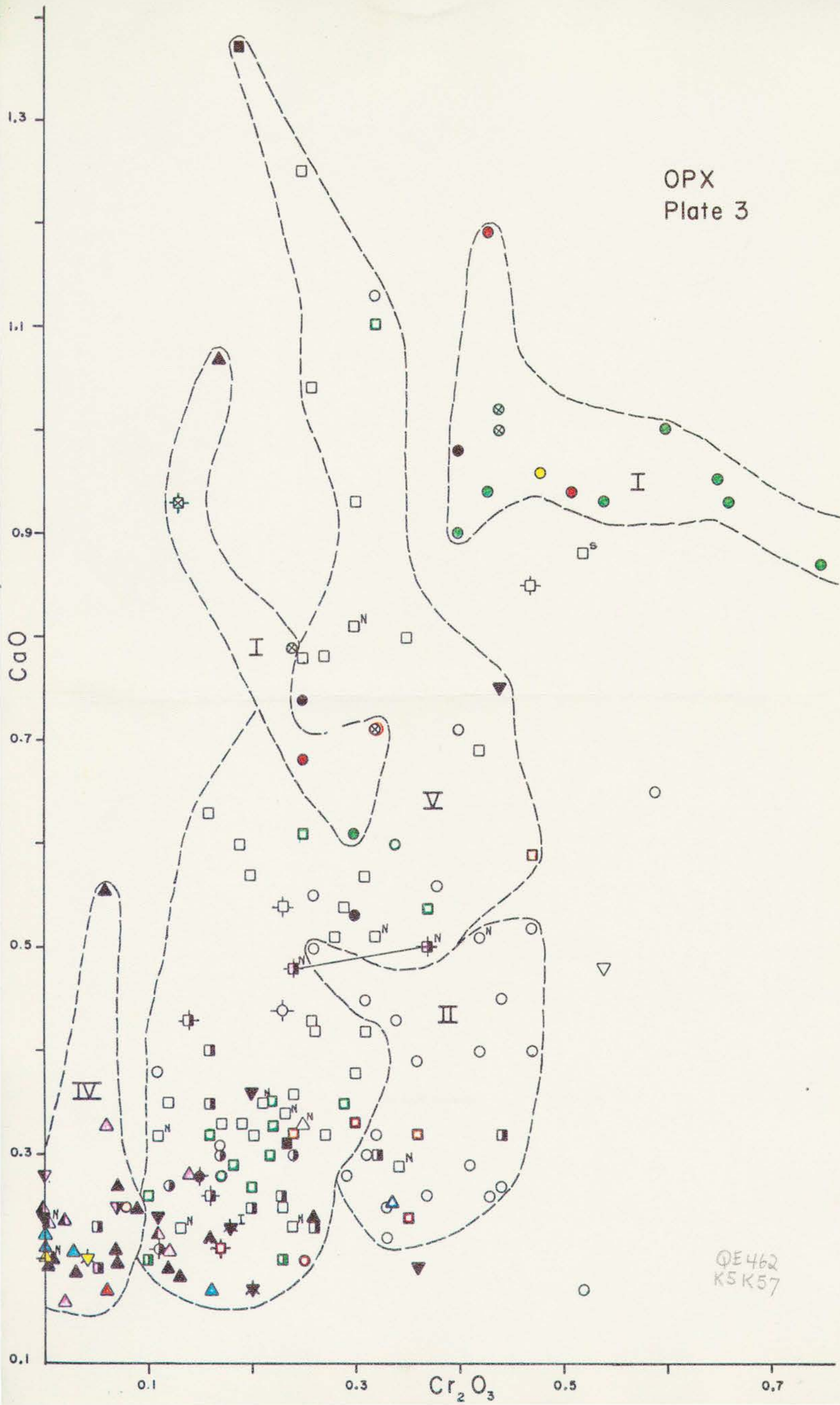
Group IV

SD2-P1 at 0.19 Cr_2O_3 , 0.405 $\text{FeO/MgO} + \text{FeO}$
 SD2-W7 at 0.08 Cr_2O_3 , 0.434 $\text{FeO/MgO} + \text{FeO}$
 SD2-W10 at 0.00 Cr_2O_3 , 0.409 $\text{FeO/MgO} + \text{FeO}$





OPX
Plate 3

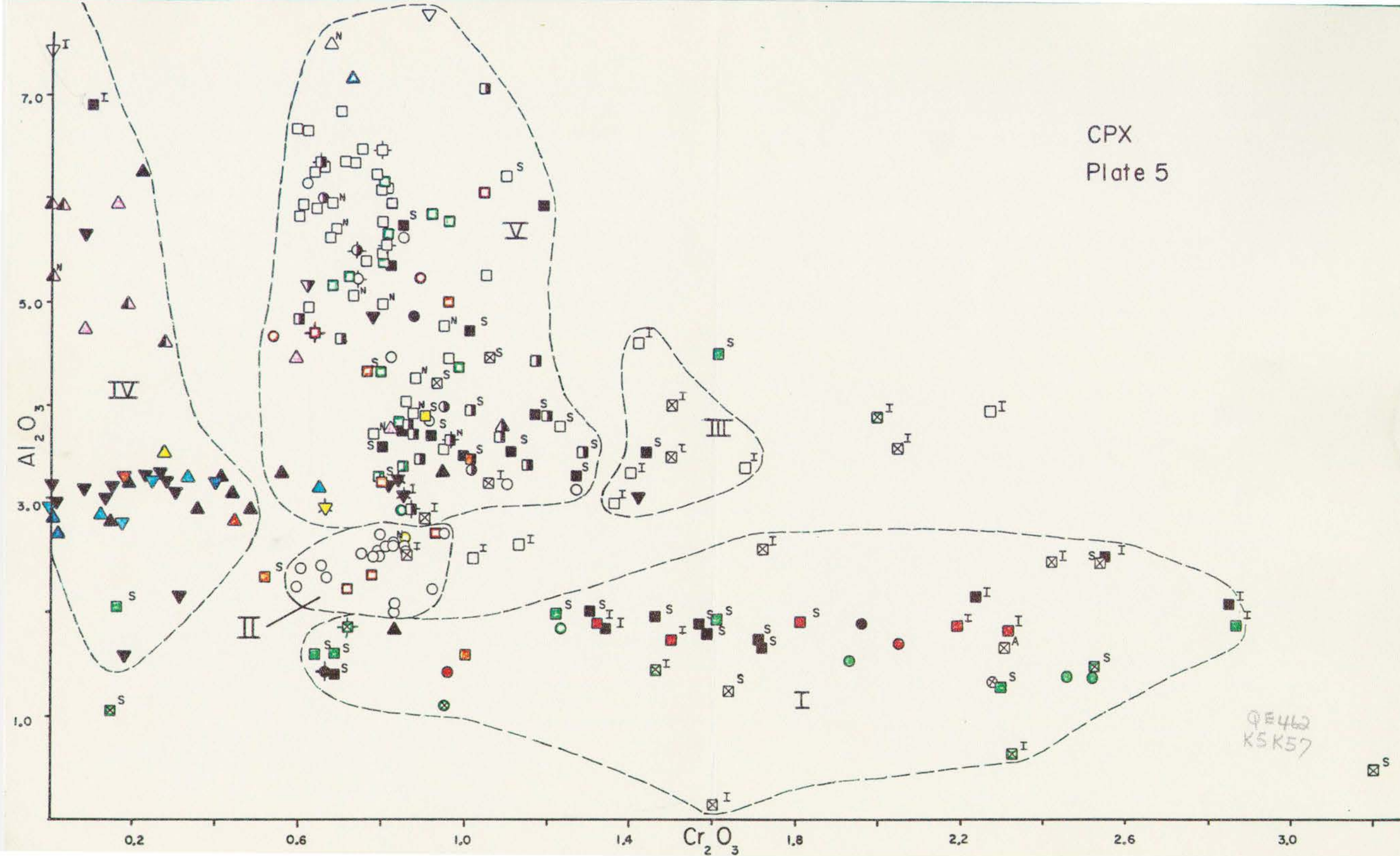


QE462
KSK57

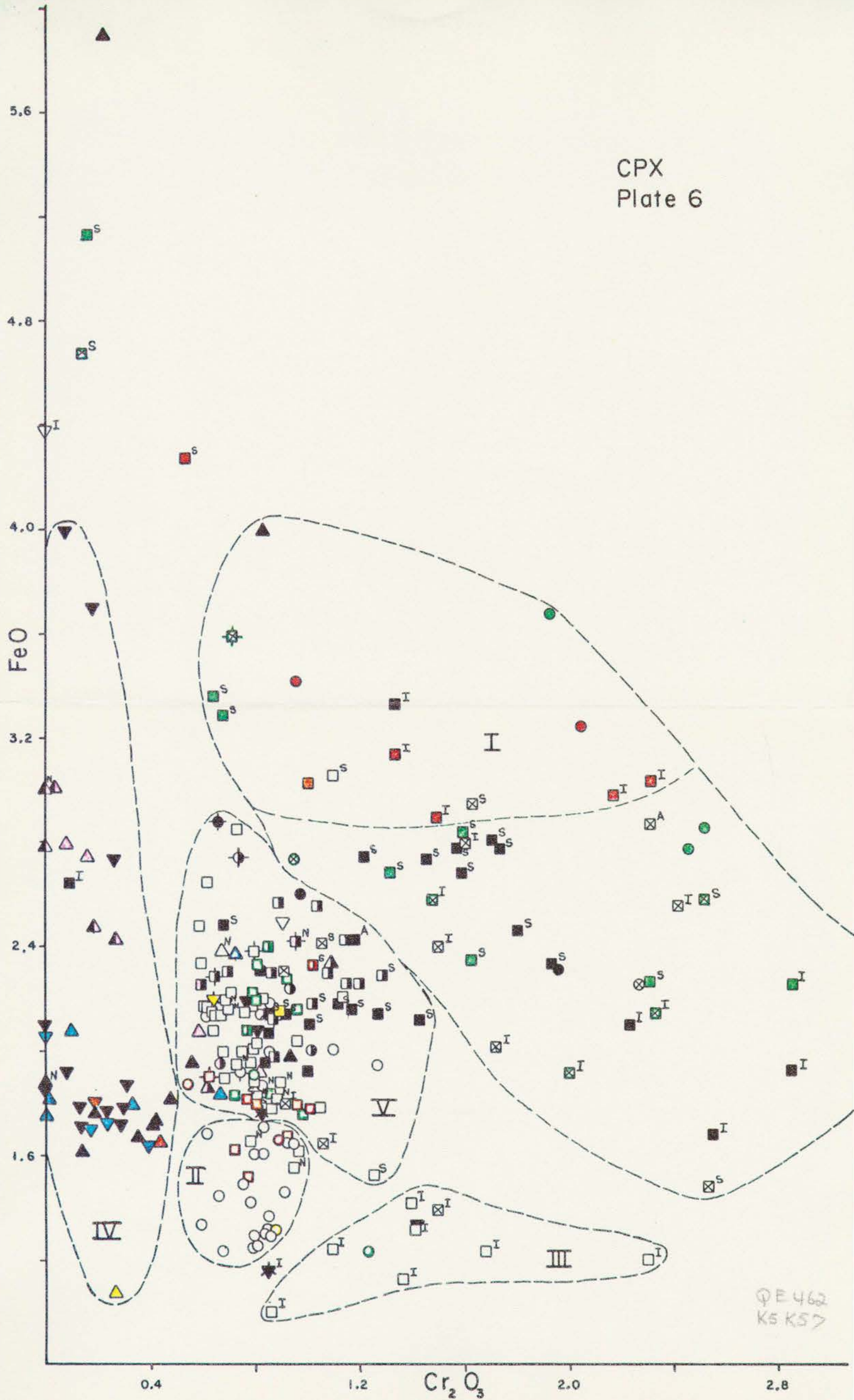
OPX
Plate 4



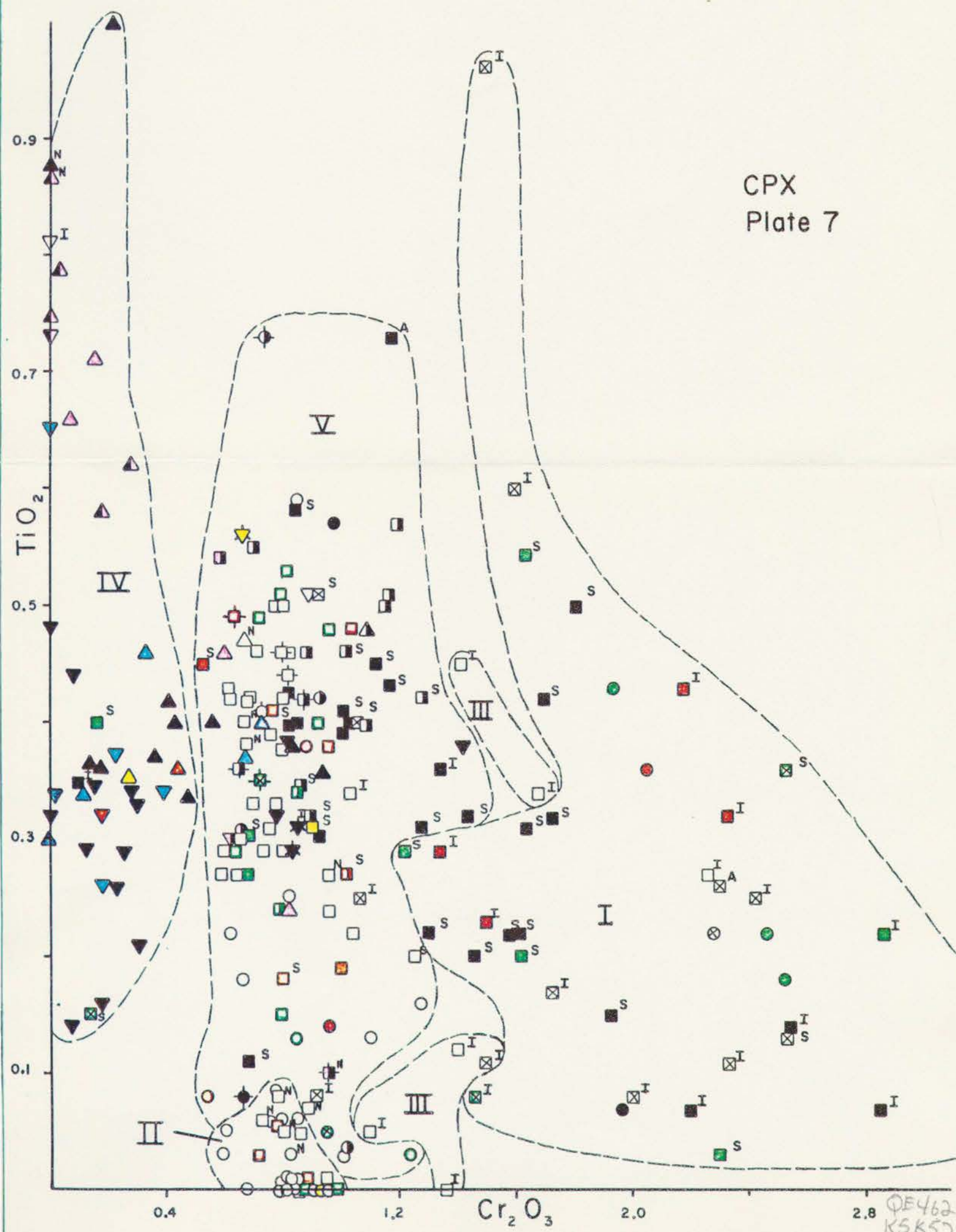
CPX
Plate 5



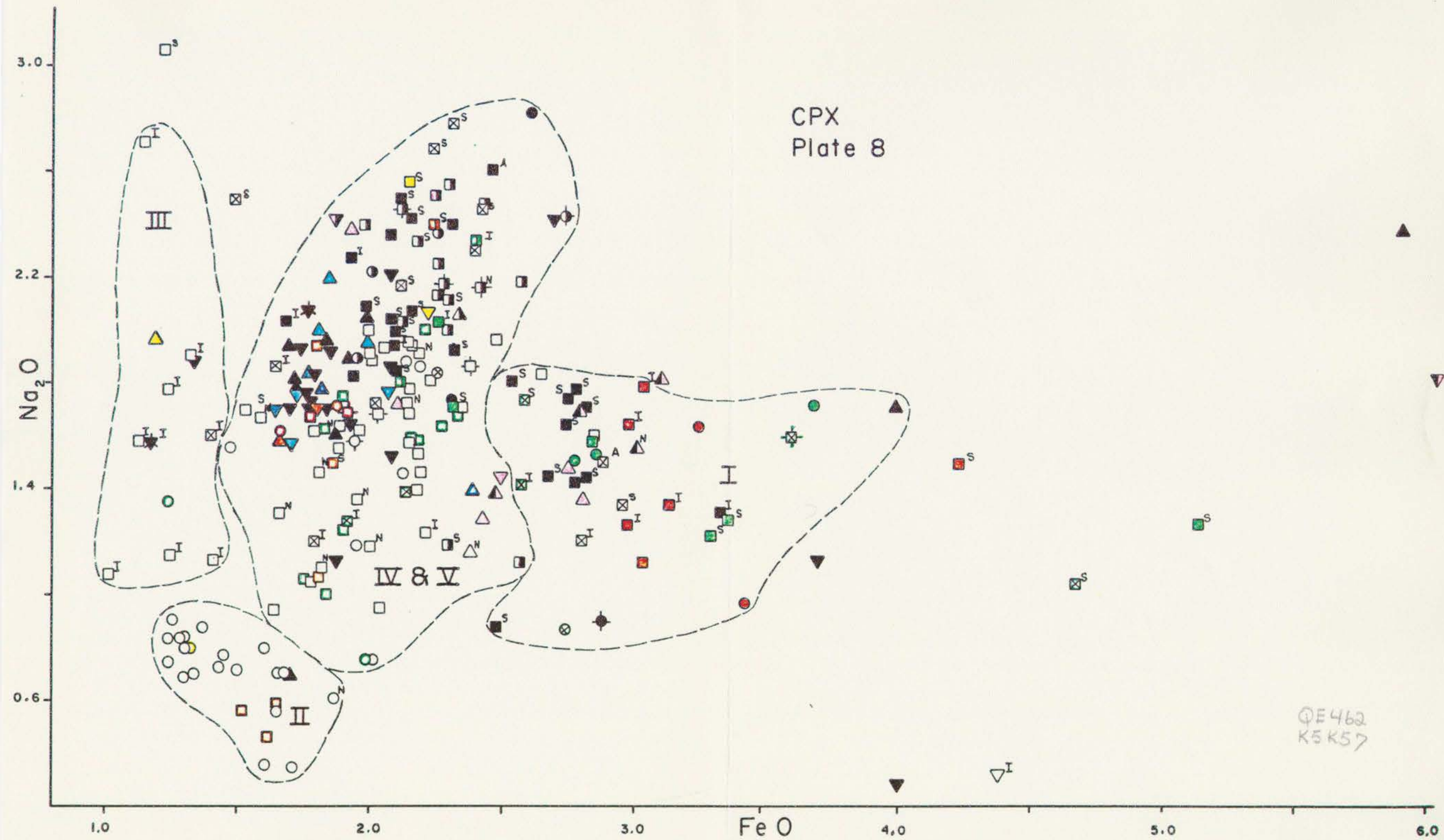
CPX
Plate 6

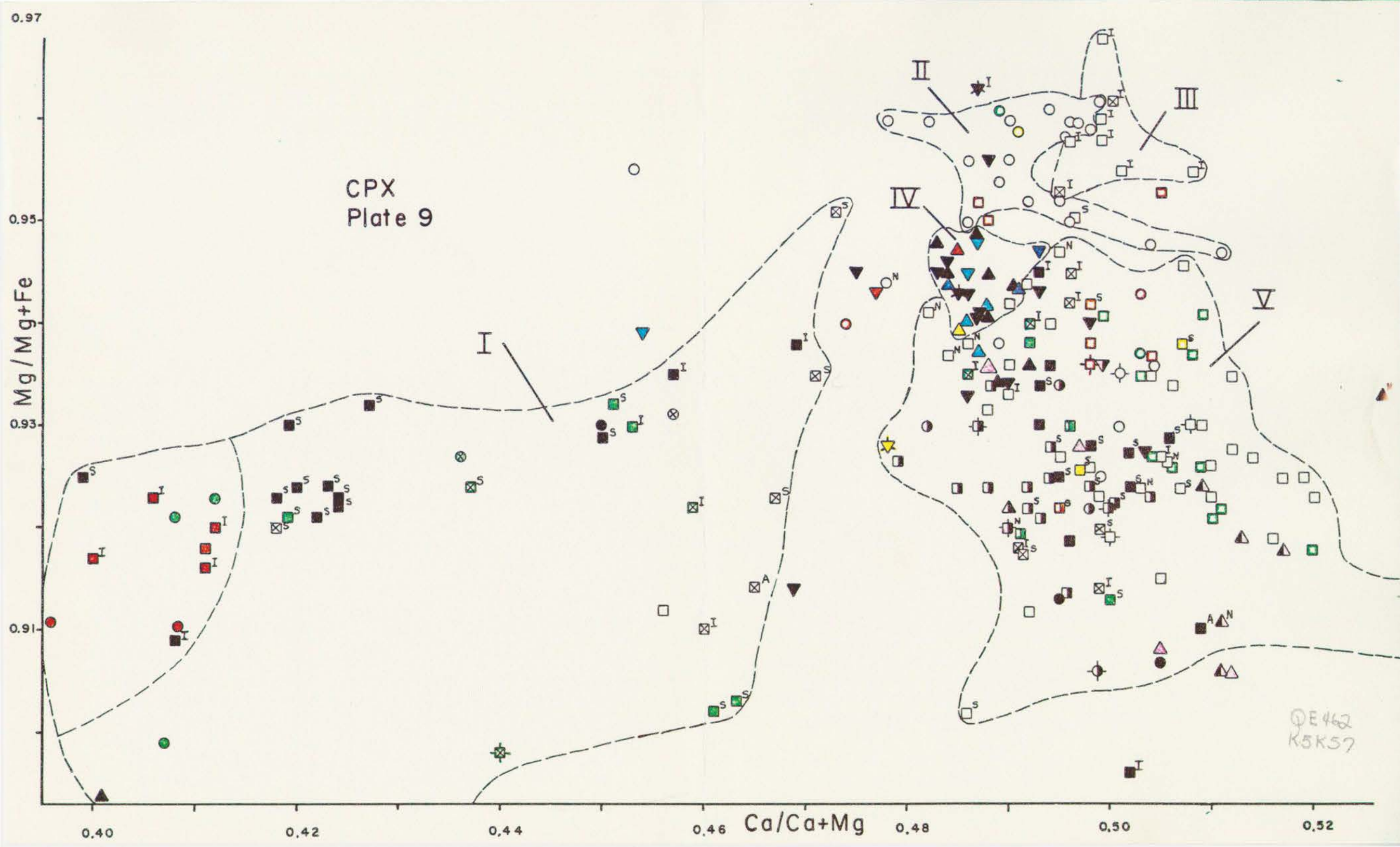


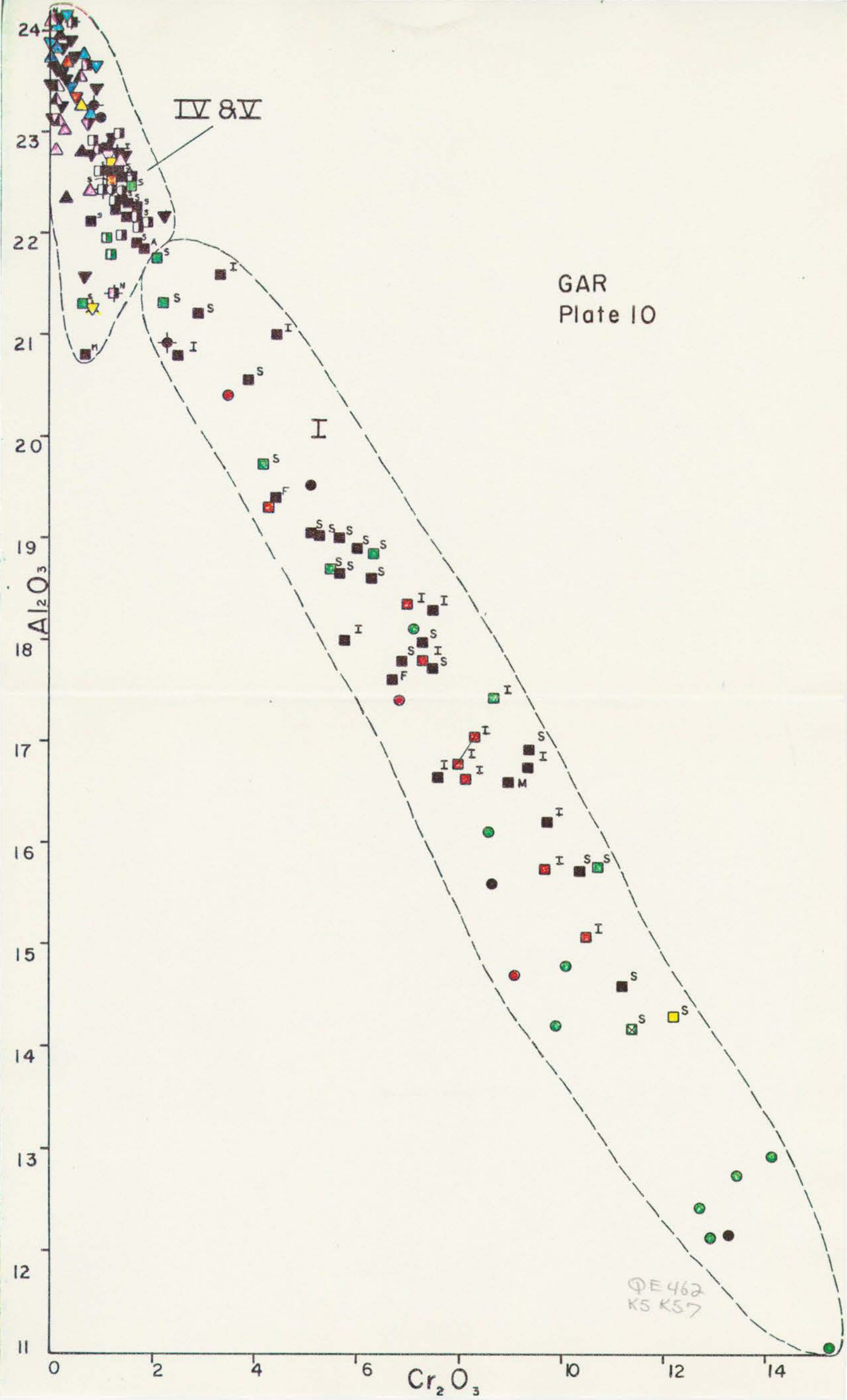
CPX
Plate 7

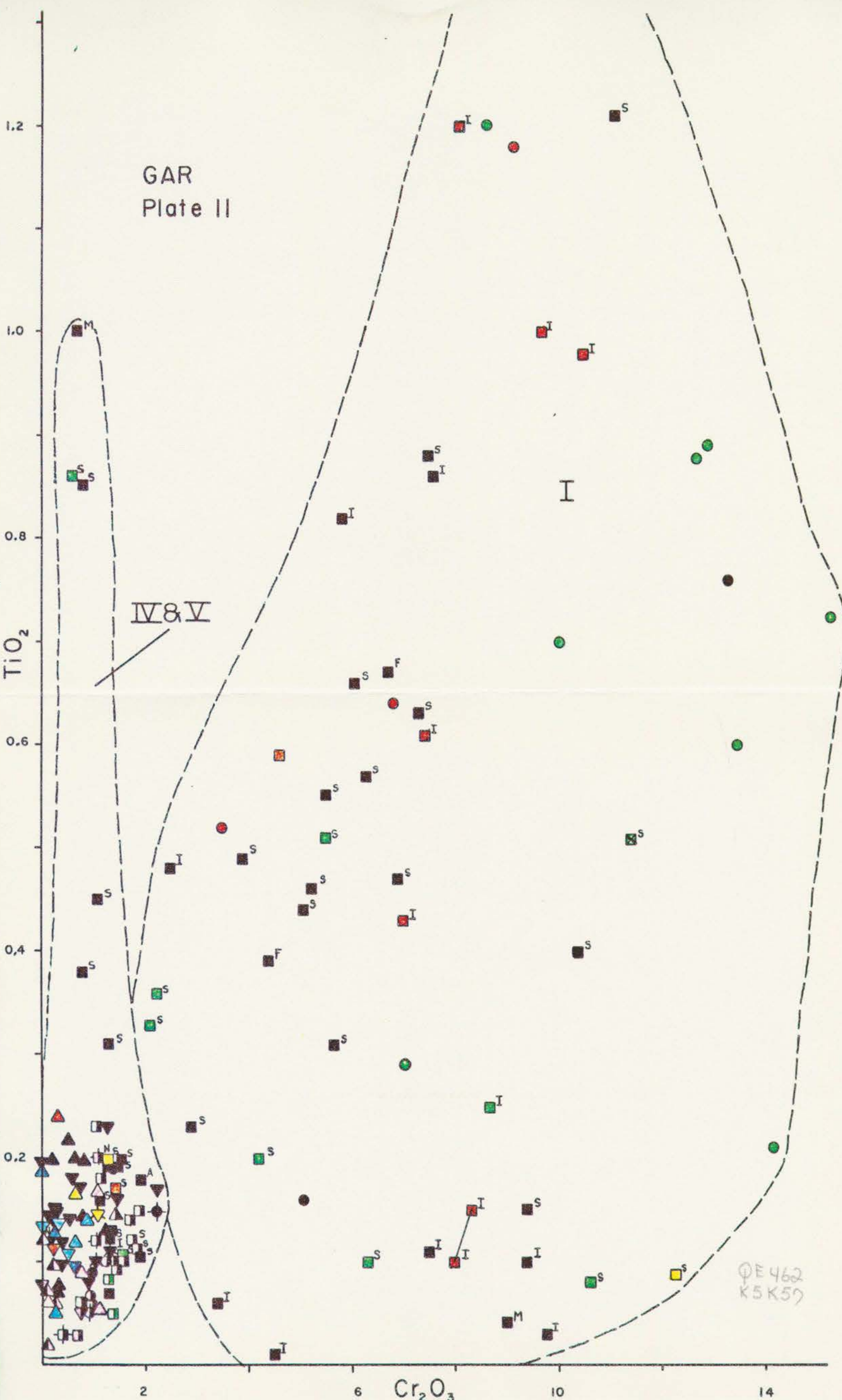


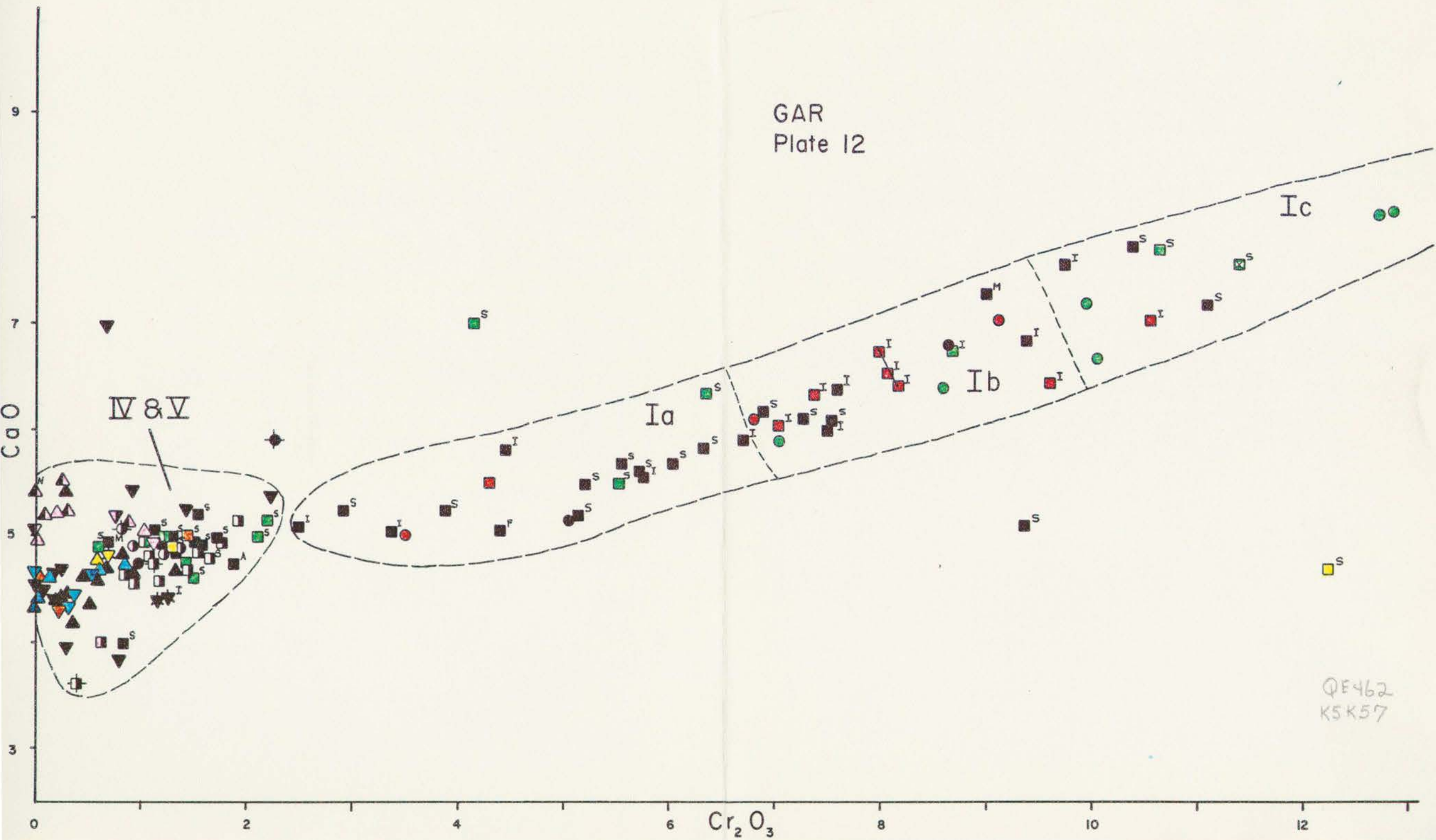
QE462
KSK57

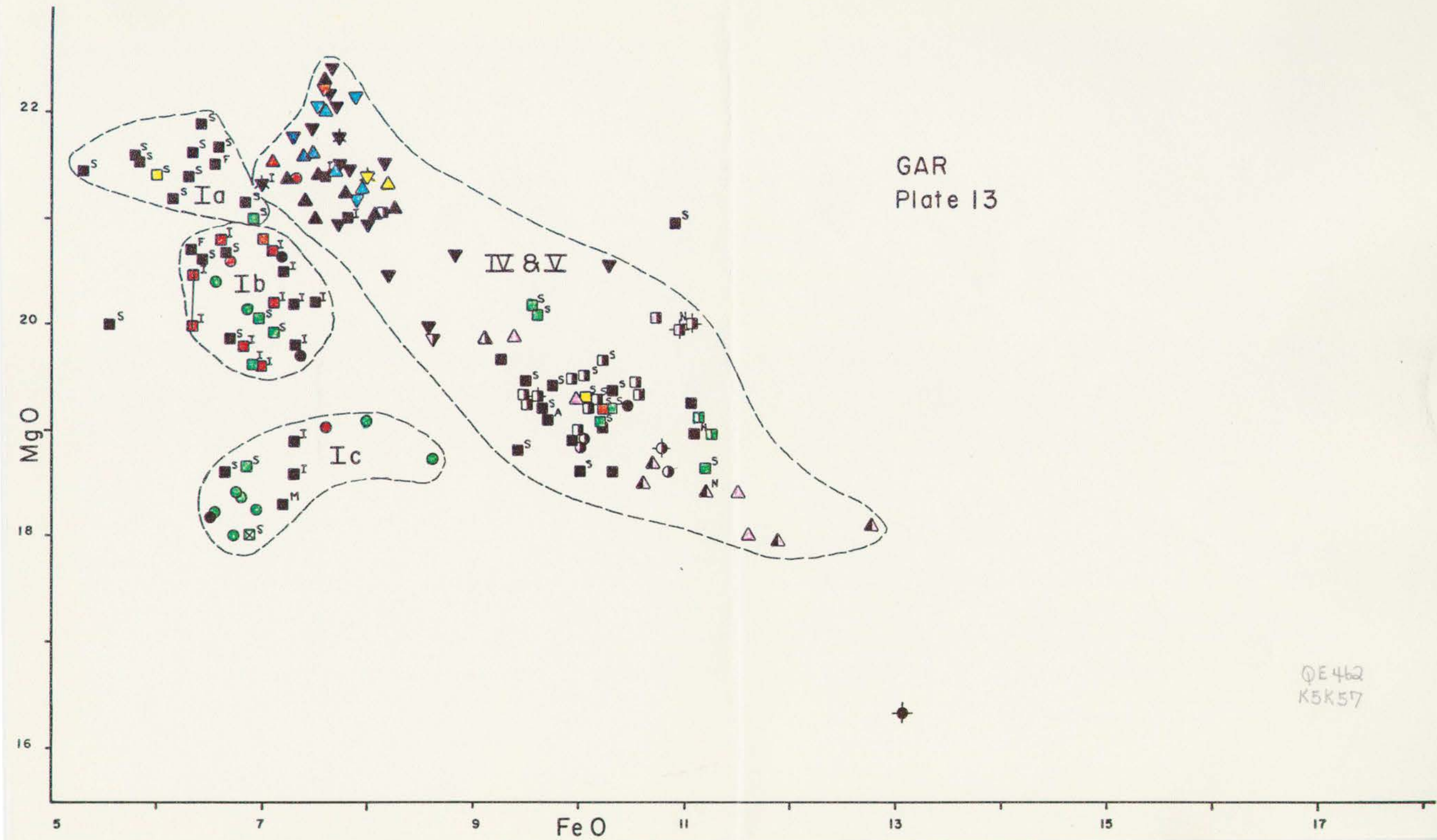












Q E 462
K5K57

SPN
Plate 14



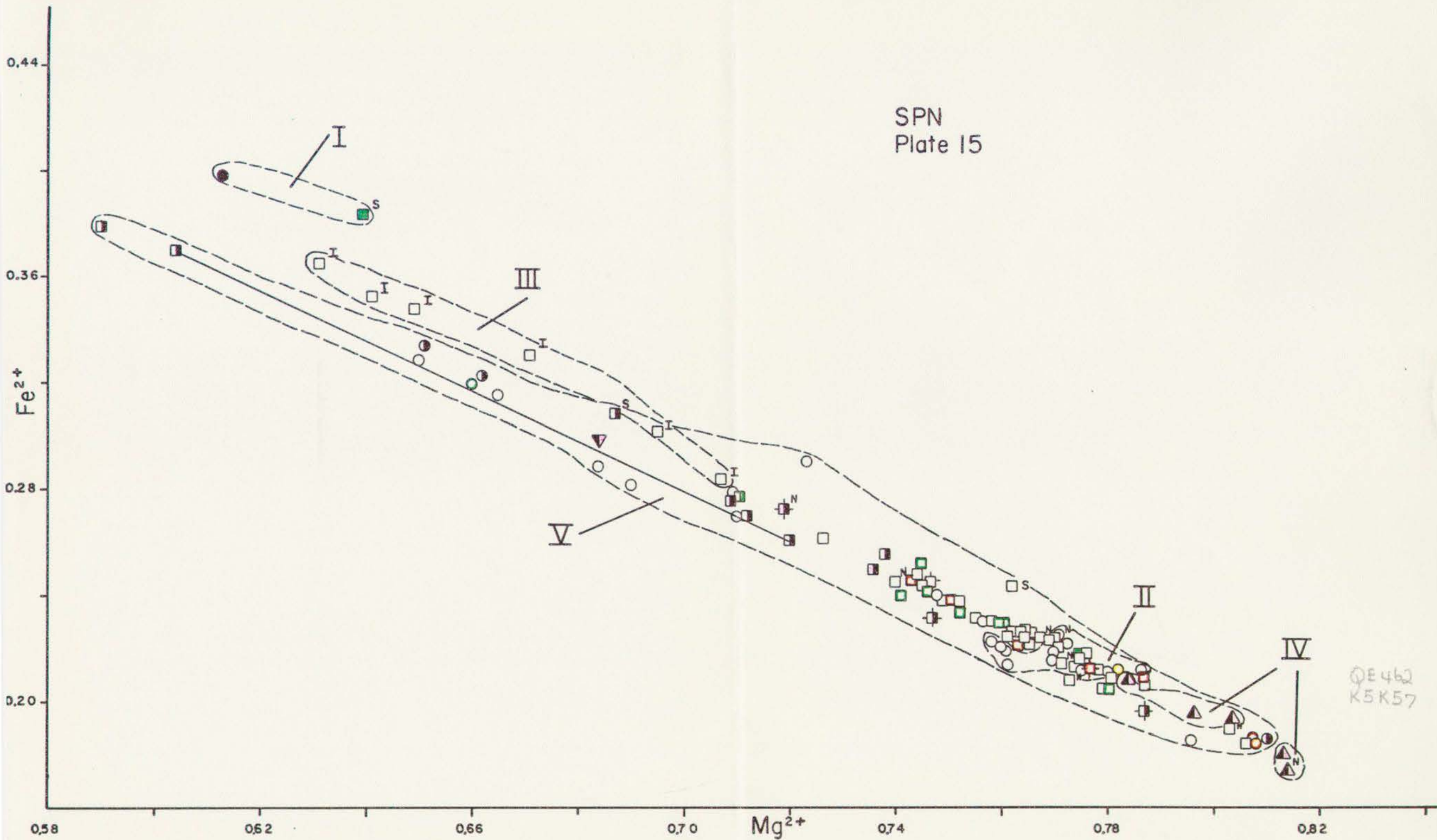


PLATE 16



