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PETROLOGY AND GEOCHEMISTRY OF QUATERNARY VOLCANIC ROCKS FROM MAKUSHIN VOLCANO, CENTRAL ALEUTIAN ARC

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1.0 Introduction

Unalaska Island is located in the eastern Aleutian Islands, and is in the approximate center of the Aleutian volcanic arc. Quaternary geology of the northern part of northern Unalaska Island is dominated by Makushin Volcano and its satellitic vents. Remnants of precursors to Makushin Volcano are scattered throughout northern Unalaska Island and indicate a record of subareal, flow dominated volcanism spanning at least the last million years.

Makushin Volcano and its satellitic vents are the erupted products of the magmatic system which is the ultimate heat source for the Makushin geothermal system. A detailed study of the chemistry and petrology of these lavas and tuffs was undertaken in order to further the understanding of the geothermal system. The chemistry of erupted lavas provides direct information about the physio-chemical processes involved in magma production, and can be used to infer the existence of such things as long lived shallow magma chambers or regional geotherms which are sufficiently elevated to induce partial melting of the crust. If sufficient detail of chemistry and stratigraphy is known, then mass and heat flux through the crust as a function of time can also be inferred.

In this study we report on chemical data from over 160 samples, and mineral composition data from 25 of these. These data support the following conclusions.

1) There has not been a single, shallow level magma chamber which has fed all vents over the course of their collective lifetimes.

2) The magmatic plumbing system which fed Makushin Volcano for most of its life is of relatively small volume and is frequently resupplied by magma from a deeper chamber or chambers.

3) In the early Holocene several large, spatially separated magma bodies rose through the crust and erupted to form the satellitic centers and a several km^3 lava eruption from Makushin Volcano (the Lava Ramp). This event represented a magma flux through the crust of at least an order of magnitude greater than typical for Makushin Volcano.

4) A residue from the magma influx responsible for the formation of the Lava Ramp probably resides at a shallow depth beneath Makushin Volcano, and has been fractionating since the formation of the Lava Ramp. This shallow chamber is bigger, more silicic and longer lived than normal for Makushin Volcano and is probably the heat source for the geothermal field.

2.0 General Geology

The general geology of northern Unalaska is described by Drewes and others (1961), Parmentier and others (1983) and Nye and others (1984). A brief distillation of these reports is presented here.

The oldest rocks exposed on northern Unalaska Island are those of the Unalaska Formation. The dominant lithologic package of the Unalaska Formation consists of tuffs interbedded with minor volcaniclastic sediments, dikes, sills and flows. Stratigraphically lower parts of the formation are dominantly flows. In the Dutch Harbor area this Formation is lower Miocene in age (Lankford and Hill, 1979), but in the Makushin Volcano region it ranges into the Pliocene.

The lower Unalaska Formation tuffs are intruded by a gabbronorite stock which is younger than early Pliocene. The gabbro is unconformably overlain by the upper part of the Unalaska Formation. The gabbro is the geothermal reservoir host rock, probably because it is competent enough to maintain open fractures whereas the Unalaska Formation is not.

Both the Unalaska Formation and the gabbronorite are unconformably overlain by the Quaternary volcanic rocks which are the subject of this report. These rocks are predominately basalt and andesite flows, with subordinate dacite flows and pyroclastic rocks. The young volcanic rocks range in age from Pleistocene to Holocene and occur as caps on ridges above Pleistocene glacial valleys, the active Makushin Volcano, young satellite vents, flank vents and pyroclastic deposits of northern Unalaska Island.

Rocks units are only gently deformed, and, excepting the Holocene volcanoes, are heavily dissected by Pleistocene glaciation.

3.0 Pleistocene and Holocene Volcanic Rocks

Pleistocene and Holocene volcanic rocks cover older rocks on the northern and western portions of northern Unalaska Island (fig. 1). This section will discuss the petrology and chemistry of these volcanic rocks in detail. Pleistocene flows cap ridges over most of the northern half of northern Unalaska and form eroded pinnacles just east of Makushin Volcano. The modern volcanic field is dominated by Makushin Volcano, which is 2055 m high and a few tens to several tens of km^3 in volume. There are also several satellitic vents which, along with Makushin Volcano itself, form a broad SW-NE trending band (fig. 1). These vents are, from the SW, Pakushin Cone (about 1050 m high, 1-2 km^3), Sugarloaf (580 m high), Table Top Mtn (800 m high, about 1 km^3) and Wide Bay Cone (about 640 m high, about 0.5 km^3).

There are also extremely small volume eruptive centers at Cape Wislow and on a linear fracture radiating from Makushin to the NW. Small explosion pits and cinder cones along this fracture are termed the Pt. Kadin Vents (Drewes and others, 1961). There is also a large volume (at least 5 km^3) package of coeruptive flows, termed the Lava Ramp, which erupted from Makushin Volcano and fill upper Makushin and Driftwood Valleys.

3.1 Rock Unit Nomenclature

The Quaternary volcanic rocks of northern Unalaska Island have been assigned to two major lithologic units, QTvc and Qhv, which correspond to chemically and mineralogically inhomogeneous and homogeneous deposits, respectively (Nye and others, 1984). These are roughly equivalent to the Makushin Volcanics and Eider Point Basalt of Drewes and others (1961). QTvc refers to Tertiary (?) to latest Holocene lavas and pyroclastic rocks which have erupted from the Makushin polygenetic stratovolcano. These eruptive products can be of extremely variable chemical composition and texture even between adjacent flows. Qhv refers to large volume eruptions from smaller monogenetic vents over relatively short time spans and which are homogeneous in chemical composition and texture (see below). While the unit Qhv is not confined by the definition to any particular time period, these lavas seem to be almost wholly early Holocene.

We will show that the differences between QTvc and Qhv are as follows: QTvc is made up eruptive products of a volcano which is relatively long lived, and whose shallow level plumbing system is of relatively low volume and is either intermittent or is frequently reinjected with new material that is different in some or all of the following: composition; temperature, T; partial pressure of water, PH_2O; and oxygen fugacity, fO_2. Frequent resupply or complete refilling of the relatively small volume shallow system with comparatively large volumes of new magma can produce dramatic changes in composition on an eruption by eruption basis (see below).

Qhv, on the other hand, is made up of eruptive products of short lived (monogenetic), relatively large volume, eruptions. These eruptions are usually, but not always, from satellite vents. Magmas in such eruptions are of fairly uniform composition because the shallow level plumbing system is short lived and therefore not reinjected. The major Qhv centers are Pakushin Cone, Table Top, Wide Bay Cone and what we call the Lava Ramp, which is the thick package of flows which issued from the summit or upper east flank of Makushin and flowed down Driftwood Valley. Sugarloaf and the Point Kadin vents are smaller Qhv centers.

3.2 Sample Number Nomenclature

Major, minor and trace element and phase chemistry are reported in appendices 1,2 and 3. Sample locations and schematic geology are reported on plate 1. A systematic numbering system ("map numbers" in the appendices) has been imposed on all samples. Qhv samples have been given two letter prefixes which refer to their location. These prefixes are: PC, Pakushin Cone; PK, Point Kadin Vents; LR, Lava Ramp; SL, sugarloaf; CW Cape Wislow; TT Table Top Mountain; and WB; Wide Bay Cone.

QTvc samples are all prefixed by an M followed by either a number, referring to age of Makushin Volcano analyses, or a letter, referring to location of Pleistocene remnants. Ages of Makushin Volcano analyses are assigned on stratigraphic position and degree of glacial dissection and are only semiquantitative. The QTvc Makuhsin Volcano abbreviations are; M1, late Holocene blocks and bombs, these are the most recent eruptive products; M2, Holocene flows, blocks, bombs and caldera rim remnants; M3, early Holocene samples; M4, late (?) Pleistocene; M5, Pleistocene, these flows have undergone substantial glacial erosion but are still clearly derived from Makushin Volcano, some may only predate Holocene glacial advances. QTvc abbreviations for areally restricted Pleistocene samples are: Mc, Eider Point-Cape Cheerful area; Md, immediately east of Driftwood Valley; Me, immediately west of Driftwood Valley; Mf, Point Kovrishka area; Mg, upper Nateekin Valley and the ridge between Nateekin and Makushin valleys; and Mh, upper Glacier valley.

A graphical key to sample numbers forms an inset to Plate 1.

3.3 Ages

Ages of samples of Quaternary volcanic rocks from northern Unalaska Island are poorly constrained. The radiometric dates available are in table 1. Dated Pleistocene rocks range from

0.26 ± 0.01 to 0.93 ± 0.03 m.y. Ages are restricted at individual localities and vary between localities. Given the paucity of data this observation is only suggestive of migration of the eruptive center with time.

The oldest samples (0.90 and 0.93 ± 0.03 m.y.) are from the ridge east of Driftwood Valley. The one dated Eider Point flow is younger, at 0.69 ± 0.06 m.y. Flows west of Driftwood are substantially younger; a stratigraphically high flow is 0.38 ± 0.04 m.y., and a dike intruding this package is 0.26 ± 0.01 m.y. The youngest dated Pleistocene flows are from the Point Kovrishka area and are 0.30 ± 0.02 to 0.34 ± 0.04 m.y.

In the absence of abundant radiometric dates, preliminary ages have been assigned to other samples on the basis of the extent of glacial erosion. These ages are admittedly imprecise, but form the basis of the sample numbering scheme outlined in section 3.2. The two great uncertainties in these "glacial" ages are 1) the difficulty of assigning Makushin Volcano samples to "Pleistocene" vs "pre-Neoglacial" ages since the amount of erosion caused by neoglacial advances is unknown and 2) the difficulty of assigning ages to post-Pleistocene deposits since the downvalley limit of the neoglacial advances is not known at Makushin.

Consideration of glacial activity indicates that the major satellitic centers (Pakushin Cone, Table Top, Wide Bay Cone and Sugarloaf) as well as the Lava Ramp are all between 11,000 and about 3,000 years old. All occupy Pleistocene glacial valleys and are thus younger than 11,000 yrs (i.e. younger than the retreat of massive Pleistocene ice sheets, see Black, 1981, and references therein). Also, these centers are all older than 3,000 yrs, since they have been glaciated, and this is the age of the last major Holocene glacial advance (Black, 1981). It may be possible, with further work, to refine these ages. If it could be shown that the 3,000 yr advance did not reach low levels at Makuhsin then the major Qhv deposits could be assigned to the 11,000 - 7,000 yr bracket. Alternatively, if it could be shown that the 7,000 yr glacial advance was especially vigorous, then the Qhv centers could, perhaps, be assigned to the 7,000 - 3,000 yr interval. A focused ^{14}C dating program would be useful.

3.4 Chemistry Overview

The Quaternary volcanic rocks at Makushin have major and trace element compositions typical of convergent margin magmas. They form a broad continuum of mafic to silicic compositions, with abundant rocks of intermediate SiO_2, have low TiO_2 and high ratios of alkali metals to small, highly charged cations (see Gill, 1981; Ewart, 1982; and Pearce, 1982, for review). Analyses and analytical methods are given in appendix 2. Most analyses fall on, or slightly above, the tholeiitic (TH) - calcalkaline (CA) dividing line of Miyashiro (1974) on a plot of FeO*(total iron as FeO)/MgO vs. SiO_2 (fig. 2). Analyses span the range basalt to dacite, with most analyses in the andesite range. With increasing SiO_2 Na_2O, K_2O, Rb, Ba, Ce, Nd, Nb, Zr and Y increase, MgO, FeO*, Ni, Cr and Sr and, to a lesser extent, Al_2O_3, decrease and P_2O_5 and TiO_2 remain fairly constant (appendix 4). V contents remain fixed over much of the range of compositions, but decrease dramatically in the high SiO_2 samples (appendix 4). Al_2O_3 and Sr contents vary considerably in the low SiO_2 samples, and have a more restricted range at high SiO_2 (appendix 4). Such variations may be due to plagioclase accumulation. Note that the low SiO_2 samples tend to have higher total phenocryst contents than the high SiO_2 samples (fig. 3).

Variations in chemistry are qualitatively compatible with a petrogenetic mechanism dominated by crystal fractionation of a parental basaltic melt. There are, however, variations in chemistry that preclude an interpretation of simple fractionation of a single, long lived, crustal magma chamber. Such variations require mixing between batches of magma at different degrees of fractionation as well as introduction into the shallow system of successive batches of magma with differing chemical compositions.

Magma mixing within the shallow level system is demonstrated by compatible element (e.g. Mg, Cr, Ni) vs. incompatible element (e.g. Rb, K, Zr) systematics. Mg, Cr and Ni are preferentially partitioned into mafic silicate minerals during crystalization, hence their concentration drops during fractional crystalization. Incompatible elements are excluded from those mineral species that form phenocrysts in the Makushin magmas, and are concentrated in the residual liquid during fractionation. If the variations in composition of the Makushin suite are produced wholly by crystal fractionation then lava compositions should lie along curved fractionation paths such as the model paths in figure 4. Compositions which lie above the fractionation curves in these figures are produced either by mixing of less fractionated high Mg, low Rb compositions with evolved low Mg, high Rb compositions, or by crystal accumulation. Crystal accumulation cannot be called on for many of the lavas that lie above the fractionation lines since many of these samples have very low phenocryst contents. Mixing is likely to happen when a new batch of little fractionated magma intrudes into the upper crust and mixes with a shallow, evolved magma chamber.

Resupply of the shallow level magmatic system with newly arriving batches of magma from depth is also demonstrated by variations in K/Y ratios (fig. 5). K and Y are both enriched in the melt during crystal fractionation, but at equal rates. Because they have the same bulk distribution coefficients, D_{bulk} ($D_{bulk}=C_s/C_l$, where C_s is the concentration in phenocrysts and C_l is the concentration of an element in the liquid), the K/Y ratio will not change during fractional crystalization. The wide range of K/Y values at Makushin especially from QTvc samples, thus precludes fractionation of a single magma chamber, or fractionation of a single homogeneous parent composition, at Makushin and requires resupply of new aliquots of parent magma of subtly different composition to the shallow level magmatic system. This observation is corroborated by similar behavior of other incompatible element ratios, such as Rb/Y, Zr/Y, Rb/Zr and K/Rb.

3.5 Mineralogy Overview

The lavas erupted from Makushin and its flank vents are usually porphyritic, with phenocrysts generally less than a few mm maximum diameter, and contain phenocrysts of plagioclase + augite ± olivine ± orthopyroxene ± titanomagnetite. Diopside occurs in a few of the most mafic samples. Hydrous phases are absent from the lavas, but hornblende has been reported from Holocene tephra (Arce, 1983). With rare exceptions plagioclase is the dominant phase, comprising as much as half the rock, and usually over half the modal mineralogy. Augite is usually next most abundant and comprises less than 10% of the rock. Amounts of opx and ol are usually subordinate to augite. Olivine is generally restricted to basalts and opx to andesites and dacites. Magnetite is common as a microphenocryst, but rarely comprises more than 1% of the rock. Chrome spinel is included in diopside and forsteritic olivine. Total phenocryst contents correlate roughly with SiO_2 concentration (fig. 3). In some cases, but definitely not all, the low SiO_2 concentration of extremely porphyritic rocks may be an artifact of crystal accumulation. That is, there is no clear relationship between total phenocryst content and the amount of displacement of whole rock compositions from model MgO - Rb fractionation paths (see fig. 4 and discussion in 3.4, above).

Compositions of phenocrysts span a fairly wide range altogether (pl=An_{48}-An_{95}, ol=Fo_{36}-Fo_{91}, aug=En_{75}-En_{95}, opx=En_{62}-En_{74}, appendix 3, figs. 6, 7). Compositions of phenocrysts from individual samples are, as expected, of more restricted compositional range, although in some cases compositions within single samples span half the compositional range of all samples together. Plagioclase, olivine and augite are usually normally zoned. Plagioclase crystal often have complex oscillatory zoning, and frequently have concentric spongy zones within the crystal. Rims are usually only a few mole percent anorthite (An) poorer than cores, although extreme cases of zoning over a few tens of percent An exist. Augite and diopside are generally normally zoned by a few percent ferrosilite (Fs), and occasionally (especially in PC-06 and PC-09 from the basal pyroclastic unit from Pakushin Cone) have complex oscillatory zoning. Olivine is usually normally zoned, frequently in excess of 10 mole percent forsterite (Fo), between core and rim. Orthopyroxene is frequently reverse zoned by a few mole percent En. In addition to being zoned, mafic silicate phenocrysts can be rimmed by different minerals. Rims of opx and pigeonite are not uncommon on augite and olivine, and augite rims on opx occur infrequently.

Chemical equilibria between silicate liquids, pyroxenes and olivine, and between pyroxenes, are known from experimental petrology. The extent to which minerals in a given sample do or do not conform to the known equilibria can be used to trace the history of crystals in a magma and thus infer petrogenetic processes. The ratio of FeO/MgO between liquids and silicates, and between different silicates, is largely independent of temperature and pressure and is expressed as the iron-magnesium exchange coefficient $KD^{Fe/Mg}(i-j)$, which equals molar $(FeO/MgO)_i/(FeO/MgO)_j$, where i and j are either mineral species or the host liquid. $KD^{Fe/Mg}(ol-l)$, $KD^{Fe/Mg}(cpx-l)$ and $KD^{Fe/Mg}(opx-cpx)$ are 0.30, 0.25 and 1.20, respectively (Roeder, 1974; Grove and others, 1982; and Lindsley, 1983). $KD^{Fe/Mg}(ol-l)$ and $KD^{Fe/Mg}(cpx-l)$ are independent of temperature. $KD^{Fe/Mg}(opx-cpx)$ is temperature dependent, but will vary less than 10% over the temperature range of Makushin magmas (Lindsley, 1983). From the three known $KD^{Fe/Mg}$s, $KD^{Fe/Mg}(opx-l)$ and $KD^{Fe/Mg}(ol-cpx)$ can be calculated by simple algebra and should be 0.30 and 1.20, respectively.

Apparent $KD^{Fe/Mg}$s for all analyzed samples from Makushin and its flank vents are in table 2. In all cases $KD^{Fe/Mg}$s were calculated using the most magnesian core of each mineral and the whole rock composition. Using the most magnesian cores and whole rocks alleviates the need to correct for in situ fractionation and will reflect true equilibrium if the liquid, before crystallization, was multiply saturated with all phenocryst phases. A second set of $KD^{Fe/Mg}$s for LR-02 is included using the compositions of anomalously Mg rich cpx and olivine.

In general, the apparent $KD^{Fe/Mg}$s are not acceptably close ($\pm$ 0.02) to equilibrium $KD^{Fe/Mg}$s. Apparent values of $KD^{Fe/Mg}(xl-l)$ which are smaller than equilibrium values indicate that the crystals are too magnesian and that at least part of the population of that species must be xenocrysts. Apparent values of $KD^{Fe/Mg}(xl-l)$ which are greater than equilibrium values indicate that crystals are too iron rich to be in equilibrium with the enclosing magma. Such crystals are also usually xenocrysts, but in the few cases where all $KD^{Fe/Mg}(xl-l)$ are equally large, all $KD^{Fe/Mg}(xl-xl)$ approach equilibrium and the whole rock compositions are enough above model MgO-Rb fractionation lines, then selective concentration of phenocrysts in the host magma may have occurred. Md-14 is a case in point.

The first order conclusion that can be drawn from consideration of mineral-mineral and mineral-liquid equilibria is that those samples for which microprobe data exist rarely represent liquid compositions. In situ crystal accumulation is rarely a sufficient explanation for the apparent disequilibria. Instead, and especially in cases where some mineral species are too magnesian, and others too ferroan, complex processes involving crystal accumulation, magma mixing and selective crystal entrainment of pieces of young cumulate bodies are required to explain the disequilibrium. Detailed microprobe studies sufficient to discriminate multiple populations within individual mineral species could possibly provide enough evidence to sort out the relative contributions of such processes.

3.6 QTvc - Central Vent Lavas

Analyzed samples of QTvc span the range of all analyses of northern Unalaska lavas. These compositions are graphically depicted in silica variation diagrams in appendix 4, and run from basalt to dacite. These analyses define continuous, moderately tightly clustered, linear or curvilinear arrays on the variation diagrams. In reconnaissance interpretations of the Makushin magmatic system such clustered arrays have been used as permissive evidence that the entire Makushin system is comagmatic and related to a single, large, long lived magma chamber (Swanson and others, 1983; Swanson 1983).

However, such an analysis breaks down under close scrutiny. This close scrutiny suggests that the plumbing system giving rise to QTvc lavas is, on the whole, relatively small and temporally discontinuous. Several lines of evidence specifically require a rather complicated picture of the shallow plumbing system feeding QTvc. First, lavas which are spatially and/or temporally restricted span a wide range of composition. Figure 8 shows select elements as a function of SiO_2, with QTvc samples from different locations and ages are plotted as separate symbols. In figure 9 Qhv samples have been plotted as separate symbols by area. In figure 8 note the wide degree of overlap between different groups and the wide compositional spread within groups. Such inhomogeneity within groups yet constancy between groups is best interpreted as representing eruption from a fairly small, frequently resupplied magma chamber. Such a chamber would fractionate rather rapidly because of its small size (thus high rate of heat loss) and could erupt anything from basalt to dacite within a fairly short time period. Such a chamber must also be resupplied at frequent intervals, thus permitting such features as the factor of two variation in K_2O at a given SiO_2 concentration of the Pleistocene Makushin Volcano analyses, widespread mineralogical disequilibrium (table 2), and scatter above the Mg-Rb fractionation path (fig. 4).

Frequent resupply of a small chamber is also indicated by the wide range in K/Y ratios shown in figure 5. K/Y ratios will not vary as a function of the extent of fractional crystalization, and thus can only vary if the K/Y ratios of the parental magma changes. Most Makushin units have K/Y ratios which vary beyond the range of analytical imprecision. This requires either eruption of successive, different, magma batches or mixing of incoming magma with a preexisting, shallow magma chamber (consideration of mineral equilibria suggest that the latter may be a more common mechanism).

Consideration of Mg-Rb systematics also requires complicated plumbing feeding Makushin Volcano. Samples which lie above model fractionation lines in figure 4 are a product of mafic phenocryst accumulation, magma mixing, or both. Note that in figure 4 those samples which plot above the model fractionation lines are usually Pleistocene QTvc. Consideration of mineral-melt equilibria (section 3.5, table 2) suggests that only some of these compositions can arise by in situ accumulation of phenocrysts. Magma mixing or selected xenocryst entrainment is required when $KD^{Fe/Mg}{}_{(xl-xl)}$ are not equilibrium values or when $KD^{Fe/Mg}{}_{(xl-l)}$ are not equally smaller than equilibrium values.

Holocene lava and tephra (M1 and M2 samples) are generally more siliceous than older QTvc. 62% of all M1 and M2 analyses are >58% SiO_2. 70% of all analyzed samples over 58%

SiO_2, and virtually all dacites, are M1 and M2 series. This suggests that there is currently an evolved, shallow chamber which, since it is more evolved than normal for the volcano, may have been in place for a comparatively long time. Evidence from whole rock and mineral chemistry requires that this chamber has been periodically reinjected, as noted for other QTvc, above.

3.7 Qhv - Homogeneous Volcanics

Qhv samples are erupted products of short-lived relatively high volume eruptions. Such eruptions typically form monogenetic flank vents and volcanoes, but in one case such an eruption came from the central Makushin Volcano. Geomorphic evidence requires that all major Qhv deposits were emplaced between 11,000 and 3,000 years before present (see Section 3.3).

There are 3 major Qhv centers (Pakushin cone, the Lava Ramp and Table Top Mtn) and 4 smaller centers (Sugarloaf Cone, Wide Bay Cone, the Point Kadin vents and the deposit at Cape Wislow). These will be described individually below. In contrast to QTvc, Qhv centers are either chemically homogeneous or have distinct, recognizable features.

Figure 9 shows that analyses from individual Qhv centers are restricted to relatively small portions of the total compositional spread, especially with respect to temporally or spatially related QTvc (fig.8). This chemical homogeneity extends to elemental ratios which will not change during fractional crystalization. For instance, K/Y ratios from Qhv centers are tightly grouped, especially compared to temporally or spatially related QTvc (fig. 5). This chemical homogeneity suggests that samples from individual Qhv centers are comagmatic. Differences in composition between centers, especially differences in K/Y, require that individual Qhv centers are not produced from a common magma chamber.

Pakushin Cone is the southernmost Qhv vent, and is about 7 km SSW of Makushin's summit. The basal and distal parts of the cone are pyroclastic material, at least the basal part of which contains large bombs of basalt containing olivine and aluminous diopside xenocrysts. The bulk of the cone is made up of basalt and basaltic andesite (50-55% SiO_2) spatter and flows. The flows on the lower part of the edifice have been glaciated but the nested cinder cones and vents within the summit crater have not been modified by ice movement.

Compared to other lavas at Makushin, the Pakushin lavas have high Al_2O_3 (and thus low CaO/Al_2O_3), FeO^* and MgO contents that decrease rapidly with increasing SiO_2, high Na_2O, K_2O and Sr, normal Rb and low Y and Zr. Pakushin lavas have high K/Y ratios. Pakushin lavas, save the basal pyroclastic units, have hand specimen appearances unique at Makushin and rare in general. This unique appearance is produced by radiating bundles of plagioclase laths such that plagioclase crystals in hand specimen are of equal size and coin-shaped morphology. Such textures have been reported from plagioclase crystalization experiments at moderately high degrees of undercooling (Lofgren, 1974).

On incompatible-compatible element variation diagrams the Pakushin lavas define a mixing trend between evolved basaltic andesite lying on the fractionation trend and a very high Mg composition (fig. 10). Mineral compositions and consideration of mineral-melt equilibria suggest that the high Mg material is xenocrystic diopside and olivine.

The Lava Ramp is the most voluminous set of Qhv flows. These flows issued from the summit or high east flank of Makushin and flowed down Makushin Valley, then down Driftwood Valley to within 1 km of the present coast. These flows have no soil or erosional debris between them, suggesting that this package of flows was emplaced in a geologically short time period. These flows are more siliceous than the Pakushin flows and range from 54-59% SiO_2, and have compositions typical of other Makushin magmas. In two places (the D-1 drill core and at Makushin Canyon) vertical sections of 180 and 200 m, respectively, were sampled and analyzed. Both sections are broadly isochemical (e.g. fig. 11), although the upper 40 m of the D-1 core is progressively less fractionated toward the surface. The Lava Ramp appears vertically isochemical but it is horizontally zoned. The distal portions of the package tend to be less fractionated. They have lower SiO_2, K_2O and FeO^*/MgO (fig. 12) and higher CaO/Al_2O_3, suggesting eruption of a large, zoned magma chamber. However, the zonation in the magma chamber was not neccessarily produced by in situ fractionation of a closed system. On incompatible-compatible element variation diagrams (see fig. 10 for an example) the Lava Ramp samples fall on a tight linear trend subparallel to, and above the model fractionation line. This requires fractionation in a chamber with lower D_{Mg} or higher Ci_{Zr}, either of which is incompatible with fractionation within the same chamber which produced the Pakushin lavas.

A model fractionation path with D_{Mg} of 1.8 is given in figure 4. The Lava Ramp samples fall near this model fractionation path, but form a straight chord to the path, suggesting that magma mixing between two compositions which both fall on the fractionation trend has occurred. A mixing hypothesis for Lava Ramp samples is corroborated by widespread mineral disequilibrium, both with other crystals and with the host melt. At a first approximation olivine is near, or slightly more magnesian than equilibrium with the liquid, and is usually normally zoned. Orthopyroxene, and, to a lesser extent, augite, is too iron rich for equilibrium with the host liquid and is reversely zoned.

Mixing between two discreet magma batches is indicated, and our preferred scenario follows. We suspect that a relatively small chamber of residual two pyroxene andesite existed under the summit of Makushin. During the same time of construction as other Qhv centers a large volume of olivine-plagioclase phyric basaltic-andesite rose from depth and entered the preexisting static magma chamber, causing, by virtue of its higher temperature, convective overturn, vesiculation, and mixing of the entire system. A combination of volume problems and gas pressure then caused eruption, with lava dominated by newly arriving, more mafic, magma erupting first.

Sugarloaf, at the head of Driftwood Valley, has the composition appropriate for the mafic end member of the mixture which forms the Lava Ramp.

Table Top and Wide Bay Cone together form the other voluminous Qhv centers. These features are formed of basalts of uniform composition which hold down the most mafic end of the Makushin compositional array. These basalts are distinct in hand specimen and carry large xenocrysts of olivine and clinopyroxene with subordinate, much smaller plagioclase phenocrysts.

4.0 Relation of the Shallow Magma System to Geothermal Resources

Magmas of northern Unalaska Island are, in the broadest sense, related by fractional crystalization. This does not, however, imply fractionation of a single magma chamber with a lifetime long with respect to the age of the volcanic system. Widespread mineral/mineral and mineral/liquid disequilibrium, variations in incompatible/incompatible element ratios of spatially and temporally related QTvc samples, and wide compositional ranges of QTvc samples all provide abundant evidence that the plumbing system feeding QTvc is not simple.

Magma mixing, xenocryst entrainment, resupply of the magmatic system by parent magmas of different compositions and, perhaps, crustal assimilation, must all occur in addition to simple crystal fractionation. It is important to a full understanding of the geothermal system to quantify the extent to which the different processes operate. By virtue of the large data base at Makushin we are in an unusually good position to do this, although answers can only be semiquantitative.

In order to produce the wide range in ratios of two incompatible elements, and in order to produce the widespread chemical disequilibria, newly arriving batches of magma must be large with respect to the size of the static magma chamber, or else their effect would be masked by the shallow chamber. If the static chamber is to be of roughly constant size then the volume of incoming material must be equivalent to the volume of erupted material in any magmatic episode. While we have little knowledge of the average volume of juvenile material ejected in a single eruption at Makushin, eruptions of other arc volcanoes are routinely 10^{-1} to 10^{-2} km^3, and eruptions of 1 to 10 km^3 are extremely rare (Simkin and others, 1981).

If eruptions at Makushin are 10^{-1} to 10^{-2} km^3, the incomining batch of magma is large with respect to the shallow chamber, and the chamber remains roughly at constant volume then the shallow chamber must be on the order of 10^{-1} to 1 km^3. These figures are only time integrated averages. If there are large repose times between eruptions then such a chamber might well completely solidify between eruptions, and during periods of increased volcanic activity the chamber might be larger. In any case, a shallow chamber volume of hundreds, or even tens, of km^3 seems very unlikely.

If repose times between eruptions are on the order of 10^2 years (Arce, 1983, summarizes the historic record), and volumes are as described above, then magma supply rates to the upper crust must be on the order of 10^{-2} or 10^{-3} km^3/yr. Given reasonable estimates of temperature drops during crustal residence (fig. 7) heat supply rates to the shallow crust of 10^{13} to 10^{14} cal/yr are indicated. These heat supply rates are insufficient to explain even the surface heat flux of small geothermal systems (e.g. Ellis and Mahon, 1977, p. 340).

Eruption of unusually large volumes of material over fairly short time periods occurred during the early Holocene and produced the Qhv centers. Magma flux during the early Holocene was several tens of times greater than average for Makushin Volcano. One of these batches of magma erupted though Makushin Volcano to produce the Lava Ramp. The uncharacteristically silicic nature of Holocene Makushin Volcano magma (M1, M2 samples) suggests that a relatively large batch of magma was left behind by the Lava Ramp eruption, and that that batch has been fractionating with time. Mineral data require that the modern magma chamber has also been reinjected by new magma, but the silicic nature of the Holocene magmas suggests that the modern chamber is big enough to overwhelm the newly injected material. This is notably uncharacteristic of Makushin Volcano's typical behavior.

We propose that this unusually large Holocene chamber is the ultimate heat source for the Makushin geothermal system. Volcanic centers with similarly anomalously high volume, Holocene, eruptions may also host significant geothermal systems, and search for such voluminous Holocene systems may be a viable exploration tool in areas where there is little background knowledge.

Acknowledgements

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Table 1. K/Ar age determinations.

sample # (lab #)	map #	K2O (wt %)	sample wt (g)	$^{40}Ar_{rad}$ (mol/g) $\times 10^{-11}$	$\frac{^{40}Ar_{rad}}{^{40}K}$ $\times 10^{-3}$	$\frac{^{40}Ar_{rad}}{^{40}Ar_{tot}}$	age ± 1S (m.y.)
M10 (83055)	Md-10	1.492 1.497 1.495	13.5314	0.196	0.0530	0.281	0.91±0.03
				0.191	0.0516	0.274	0.89+0.90 0.90±0.03
M14 (83059)	Md-14	1.760 1.780 1.770	10.2882	0.238	0.0543	0.106	0.93±0.03
M30 (83057)	Mc-18	0.680 0.670 0.675	9.6739	0.0671	0.0401	0.0190	0.69±0.06
M34 (83060)	Me-01	1.040 1.050 1.045	11.0586	0.0564	0.0218	0.0299	0.38±0.04*
M39 (84052)	Me-06	1.638 1.592 1.615	13.8055	0.0599	0.0150	0.0992	0.26±0.01*
M44c (83061)	M3-13c	1.187 1.197 1.192	10.7545	-0.0111	-0.00377	-0.0084	zero (unmeasurable)
M47 (83062)	Mf-03	1.330 1.330 1.330	12.2446	0.565	0.0171	0.0201	0.30±0.02
M49 (83063)	Mf-05	1.250 1.250 1.250	7.7701	0.0616	0.0199	0.0357	0.34±0.04*

rad=radiogenic; lambda +lambda $=0.581\times10^{-10}yr^{-1}$; $^{40}K/K_{total}=1.167\times10^{-4}$ mol/mol; * =minimum age; all samples analysed in the DGGS/UAF GI cooperative K/Ar laboratory, J. Blum, analyst.

Table 2. FeO/MgO exchange coefficients ($KD^{Fe/Mg}$) for all Makushin samples. Values indicative of equilibrium are underlined. All KDs are calculated using the whole rock FeO/MgO and the FeO/MgO ratios of the most magnesian phenocrysts. Whole rock FeO is derived from FeO* with an assumed Fe^{3+}/Fe^{2+} ratio of 0.175.

map #	ol/l	cpx/l	opx/l	ol/cpx	opx/cpx
LR-02	0.431	0.360	0.400	<u>1.195</u>	<u>1.110</u>
	<u>0.291</u>	0.175		1.660	
LR-06a	0.235	0.330	0.428	0.713	<u>1.297</u>
LR-06f	<u>0.292</u>	0.453	0.417	0.646	0.922
LR-11	0.391	<u>0.240</u>	0.421	1.624	1.751
LR-12b	<u>0.283</u>	0.372	0.416	0.716	<u>1.116</u>
LR-12n	<u>0.313</u>	0.288	<u>0.289</u>	<u>1.090</u>	<u>1.005</u>
M1-01	0.198	0.183	<u>0.296</u>	<u>1.081</u>	1.621
M1-51c		0.205	0.250		<u>1.222</u>
M1-51d	0.214	0.160	<u>0.319</u>	1.337	1.993
Mc-18	0.438	0.213		2.060	
Md-04	0.582	0.431	0.508	1.349	<u>1.177</u>
Md-14		0.529	0.581		<u>1.099</u>
Me-03	0.365	0.165		2.215	
Me-06		0.646	0.861		1.332
Me-07	0.200	0.058		3.439	
Mf-01	0.260	0.191		1.363	
Mf-04	0.402	0.394		<u>1.019</u>	
PC-02	0.417	0.293		1.425	
PC-06	0.245	<u>0.262</u>		0.938	
PC-09	0.251	0.341		0.737	
PC-11		<u>0.261</u>	0.357		1.370
PK-02		<u>0.242</u>			
TT-10	0.377	0.332		<u>1.136</u>	
TT-22				<u>1.175</u>	
WB-05				2.469	

Figure Captions

Figure 1. Map of northern Unalaska Island showing locations of volcanic vents, generalized geology of Quaternary units and geography.

Figure 2. FeO*(total iron as FeO)/MgO diagram. The tholeiitic (Th) - calcalkaline (Ca) dividing line is from Miyashiro (1974). Symbols are as follows: stars, late Holocene Makushin Volcano (M1 series); crosses, middle and early Holocene Makushin Volcano (M2, M3 and M4 series); small pluses, Pleistocene QTvc (M5, Mc, Md, Me, Mf, Mg and Mh series); triangles, Lava Ramp (LR); inverted triangles Sugarloaf (SL); hexagons, Pakushin Cone (PC); squares, Point Kadin Vents (PK); upright diamonds, Table Top Mountain (TT); and sideways diamonds, Wide Bay Cone (WB).

Figure 3. Volume percent phenocrysts versus SiO_2.

Figure 4. MgO versus Rb for all Makuhsin analyses. Symbols as in Figure 2, with the addition of large plusses, which are calculated fractional crystallization paths at increments of 10% fractionation. The model assumes D_{Rb}=0.03, Ci_{Rb}=7 ppm, D_{MgO}=1.8 (upper line) or 2.2 (lower line), and Ci_{MgO}=10.0 wt %. The values for D_{MgO} span acceptible values when D's are estimated on $\log_{element}$ vs. $\log_{Rb}$ diagrams. Slopes on log-log diagrams are an accurate measure the empiracal bulk distribution coefficients (Ds) for a system. The inset shows the effect of crystal accumulation and magma mixing, in addition to fractional crystallization, on Mg-Rb systematics. Tic marks on all lines are 10% increments.

Figure 5. K/Y ratios for different spatially and/or temporally related samples. Since K and Y have the same empirical Ds (measured from the slopes on $\log_{element}$-$\log_{Rb}$ diagrams), the K/Y ratio cannot vary outside the analytical precision (<10%) among comagmatic samples. Note the wide range in K/Y among most M groups compared to LR, PC and TT samples.

Figure 6. Compositions of all Makushin analyses of augite, diopside, pigeonite, orthopyroxene and olivine. Cpx thermal stabilities and 3 phase pyroxene triangles are from Lindsley (1983), and provide temperature estimates for those samples with coexisting pyroxenes.

Figure 7. Compositions of all Makushin analyses of plagioclase.

Figure 8. SiO_2 vs. Al_2O_3 (fig. 8a), FeOt (total iron as FeO, fig. 8b), K_2O (fig. 8c) and Zr (fig. 8d) for QTvc samples only. Symbols are: stars, Holcene Makushin Volcano (M1, M2, M3); squares, Pleistocene Makushin Volcano (M4, M5); triangles, Eider Point-Cape Cheerful area (Mc); inverted triangles, west of Driftwood Valley (Md); hexagons, east of Driftwood Valley (Me); upright diamonds, Cape Kovrishka area (Mf); sideways diamonds, upper Nateekin and Makushin valleys (Mg, Mh).

Figure 9. SiO_2 vs. Al_2O_3 (fig. 9a), FeOt (total iron as FeO, fig. 9b), K_2O (fig. 9c) and Zr (fig. 9d) for Qhv samples only. Symbols are: triangles, Lava Ramp (LR); inverted triangles, Sugarloaf (SL); hexagons, Pakushin Cone (PC); squares, Point Kadin Vents (PK); diamonds, Table Top Mtn. (TT); and sideways diamonds, Wide Bay Cone (WB).

Figure 10. MgO vs. Zr for Lava Ramp and Pakushin Cone samples, and for a model fractional crystallization path. Values for D's and Ci_{Zr} are taken from regressions of all Makushin data and represent empiracal best estimates for these values at Makushin. The Pakushin data fall on a mixing trend between fractionated magma and ferromagnesian phenocrysts. The Lava Ramp

data require magma mixing and/or fractionation at lower D_{Mg} or higher Ci_{Zr} than at Pakushin (either of which preclude comagmatism between Pakushin and the Lava Ramp).

Figure 11. FeOt(total iron as FeO)/MgO vs. depth below the surface for the two vertical sections through the lava ramp. The Makushin Canyon section also has higher CaO/Al_2O_3 and lower SiO_2 and incompatible trace elements.

Figure 12. FeOt/MgO vs km from an arbitrary location on the SE flank of Makushin Volcano for all Lava Ramp analyses.

fig 1

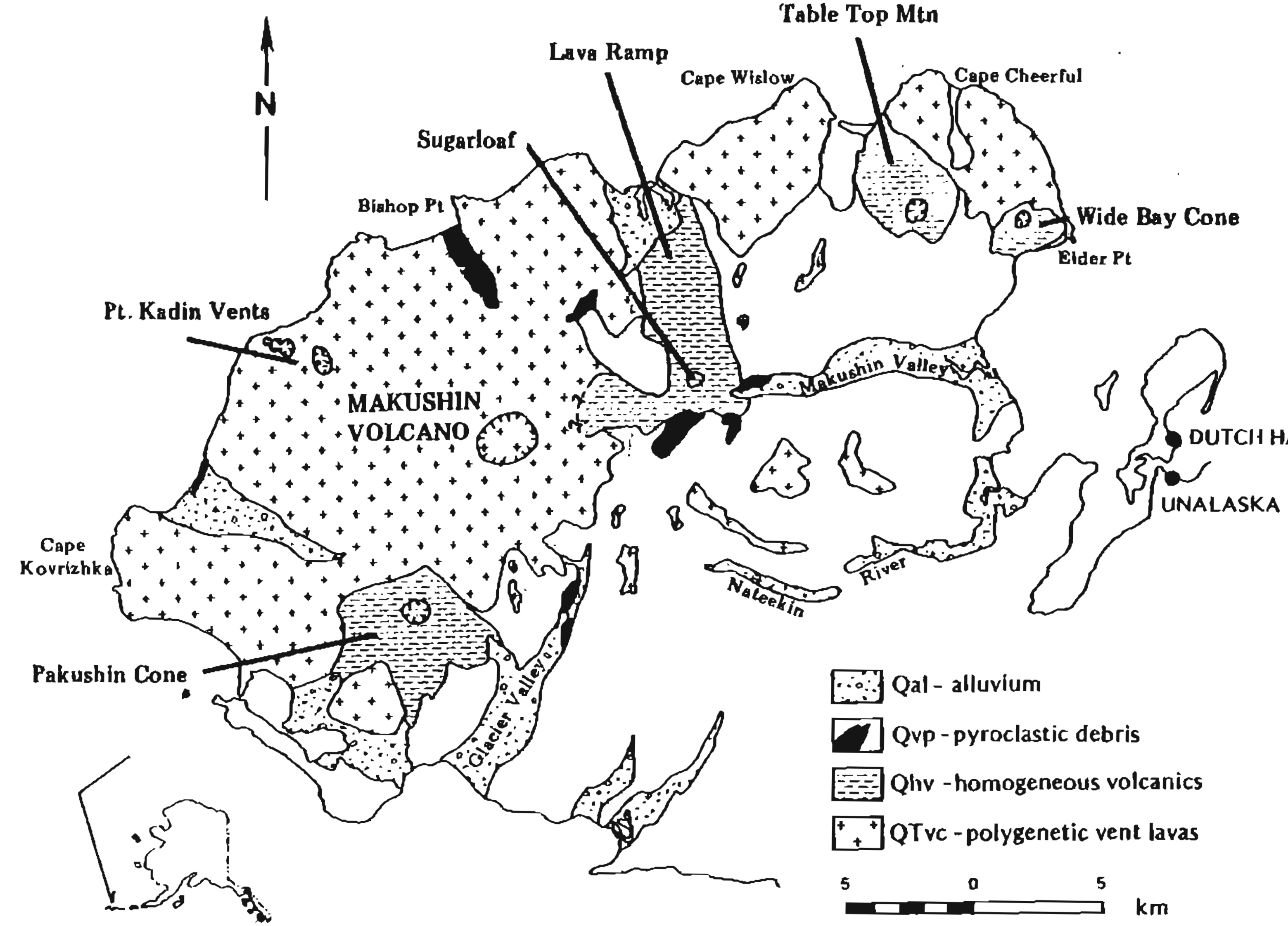

N
Table Top Mtn
Lava Ramp
Cape Wislow
Cape Cheerful
Sugarloaf
Bishop Pt
Wide Bay Cone
Elder Pt
Pt. Kadin Vents
Makushin Valley
MAKUSHIN
VOLCANO
DUTCH HARBOR
UNALASKA
Cape
Kovrizhka
River
Nateekin
Pakushin Cone
Glacier Valley
Qal - alluvium
Qvp - pyroclastic debris
Qhv - homogeneous volcanics
QTvc - polygenetic vent lavas
5
0
5
km

fig 2

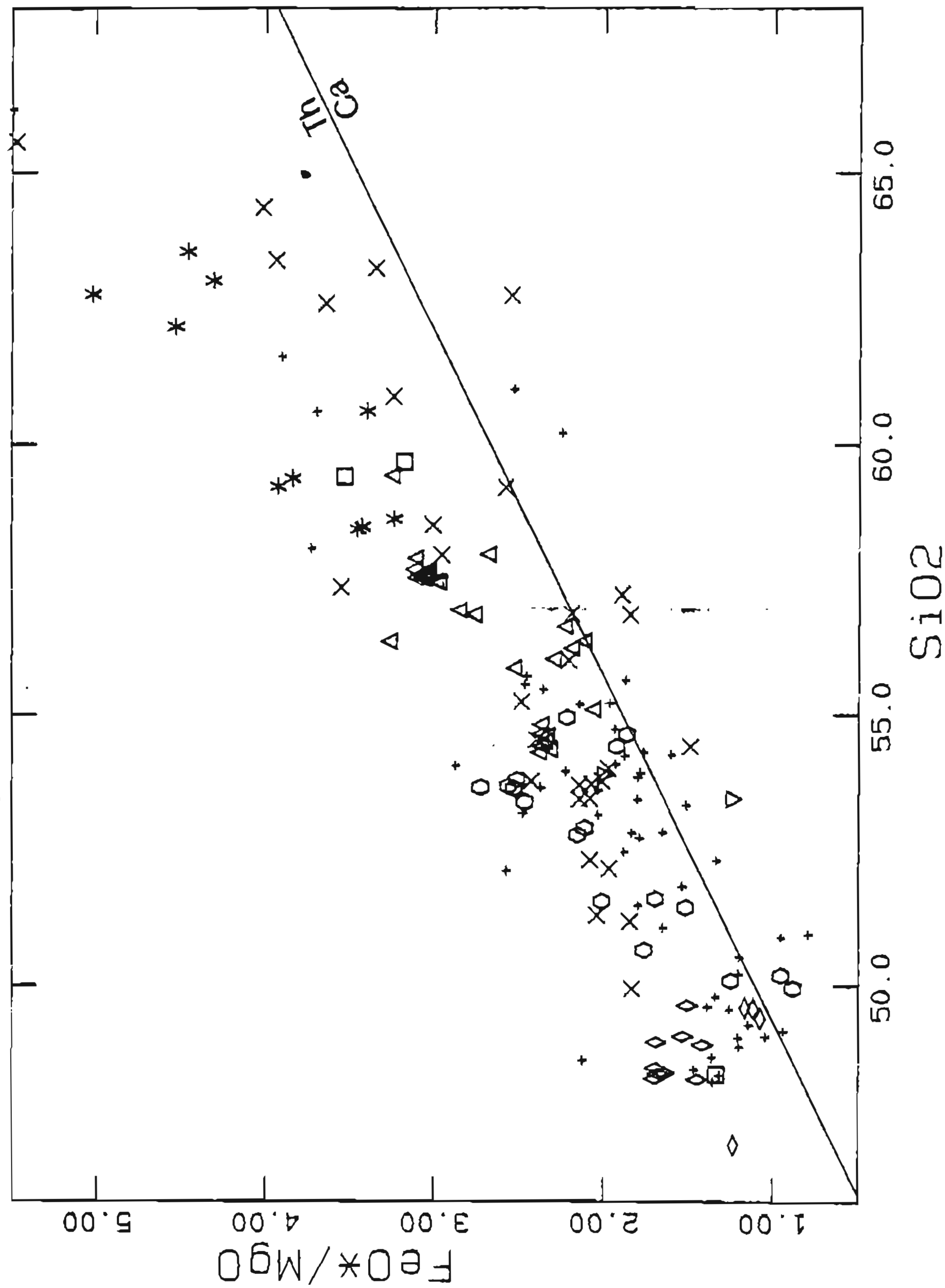


fig 3

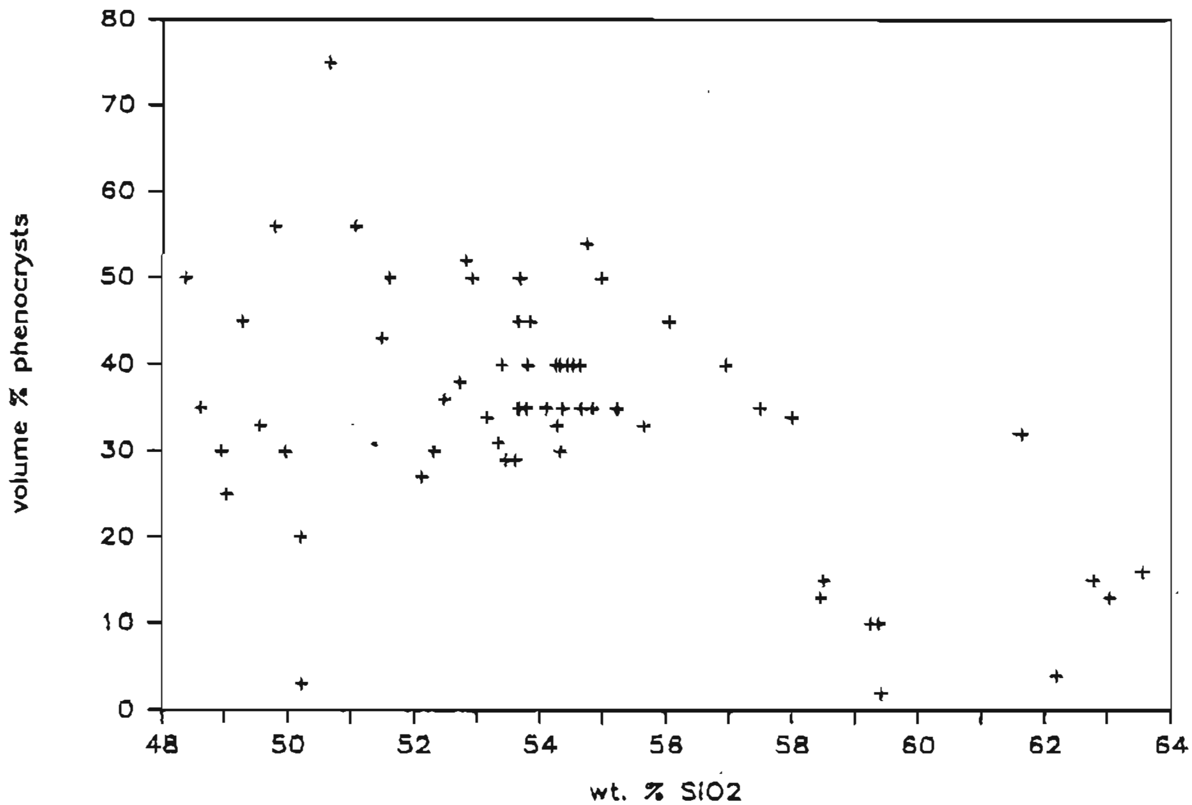

80
70
60
50
40
30
20
10
0
volume % phenocrysts
48
50
52
54
56
58
60
62
64
wt. % SIO2

fig 4

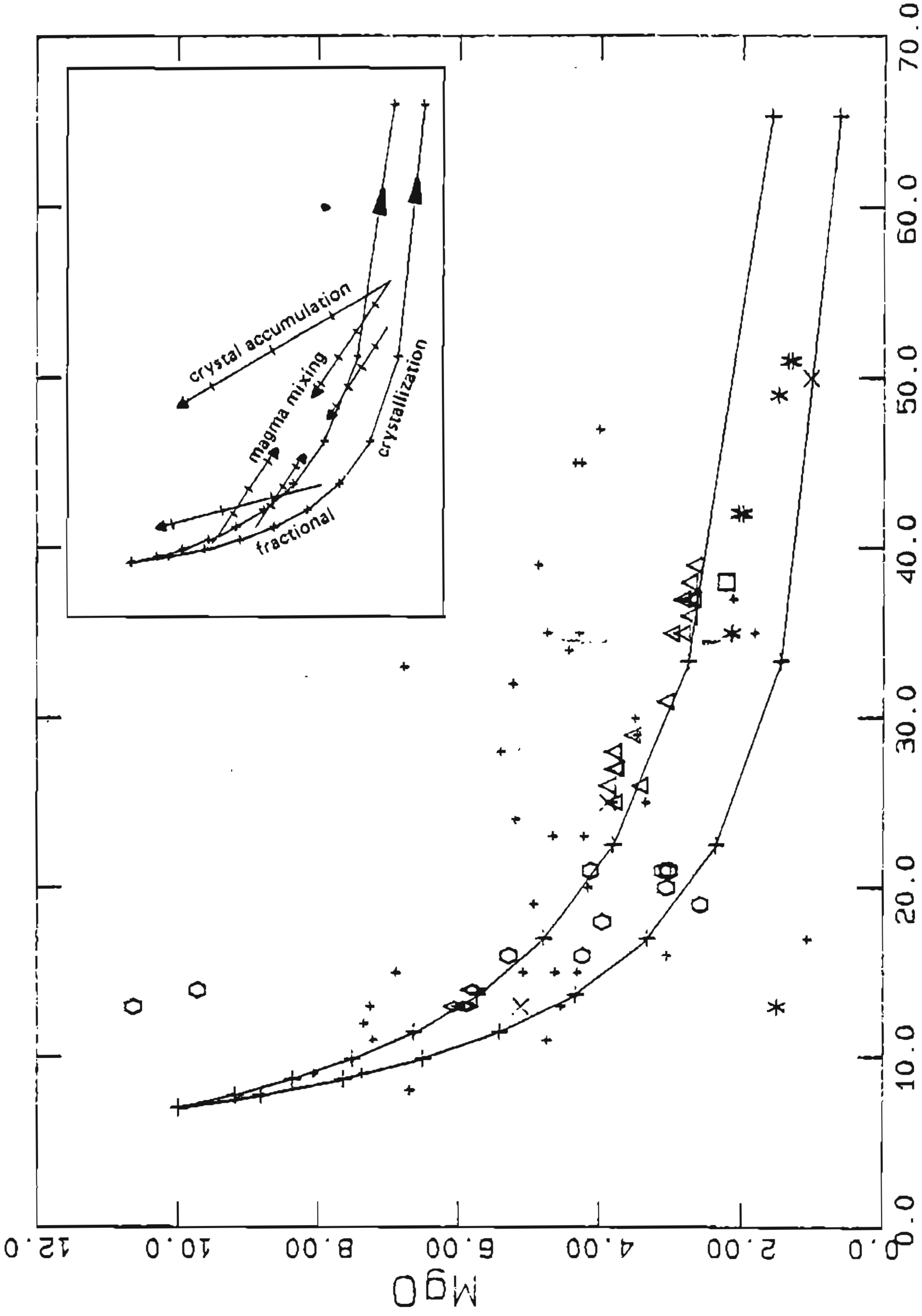

crystal accumulation
magma mixing
fractional
crystallization
MgO
Rb
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
2.00
4.00
6.00
8.00
10.0
12.0

Fig 5

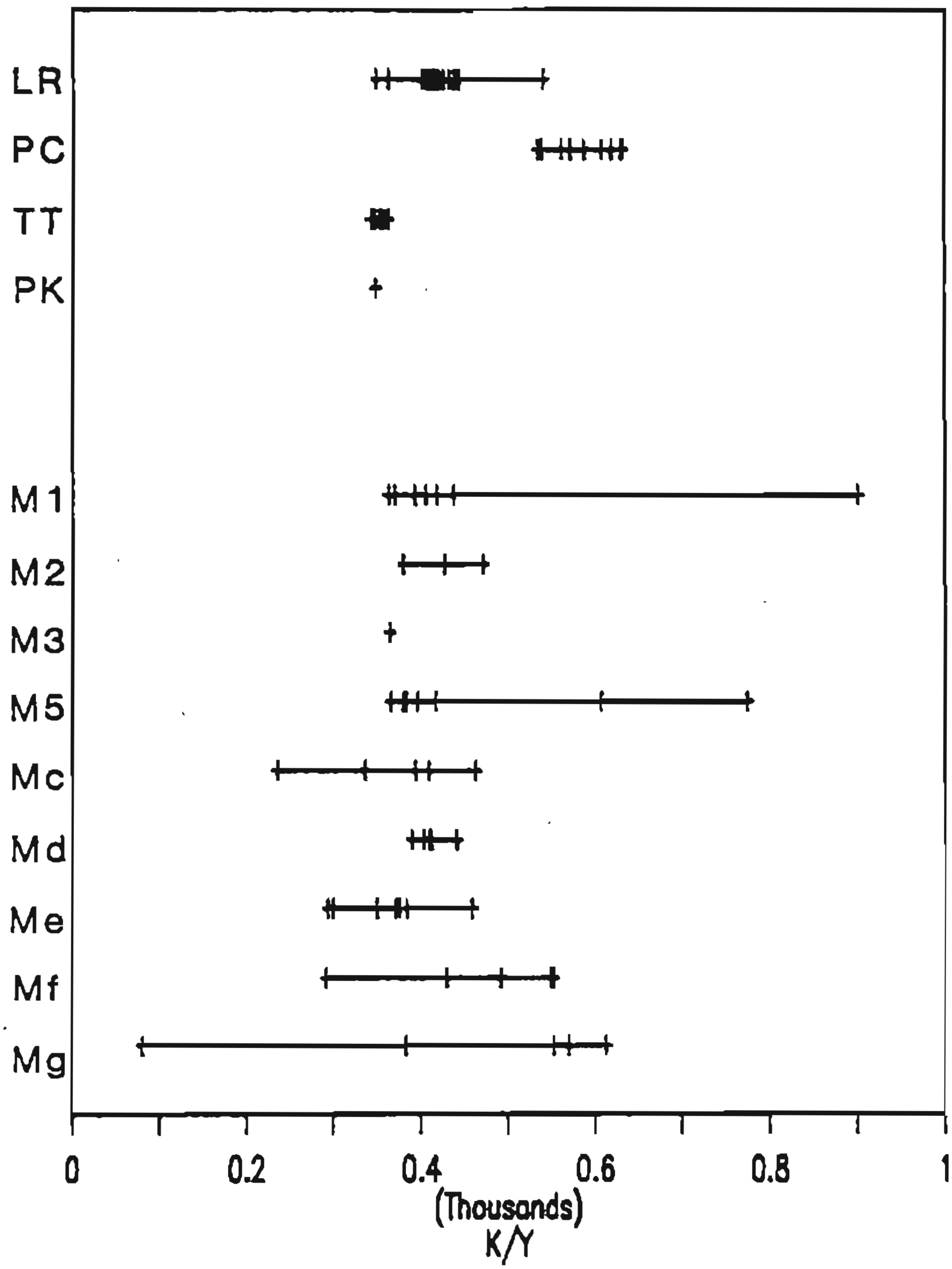


fig 6

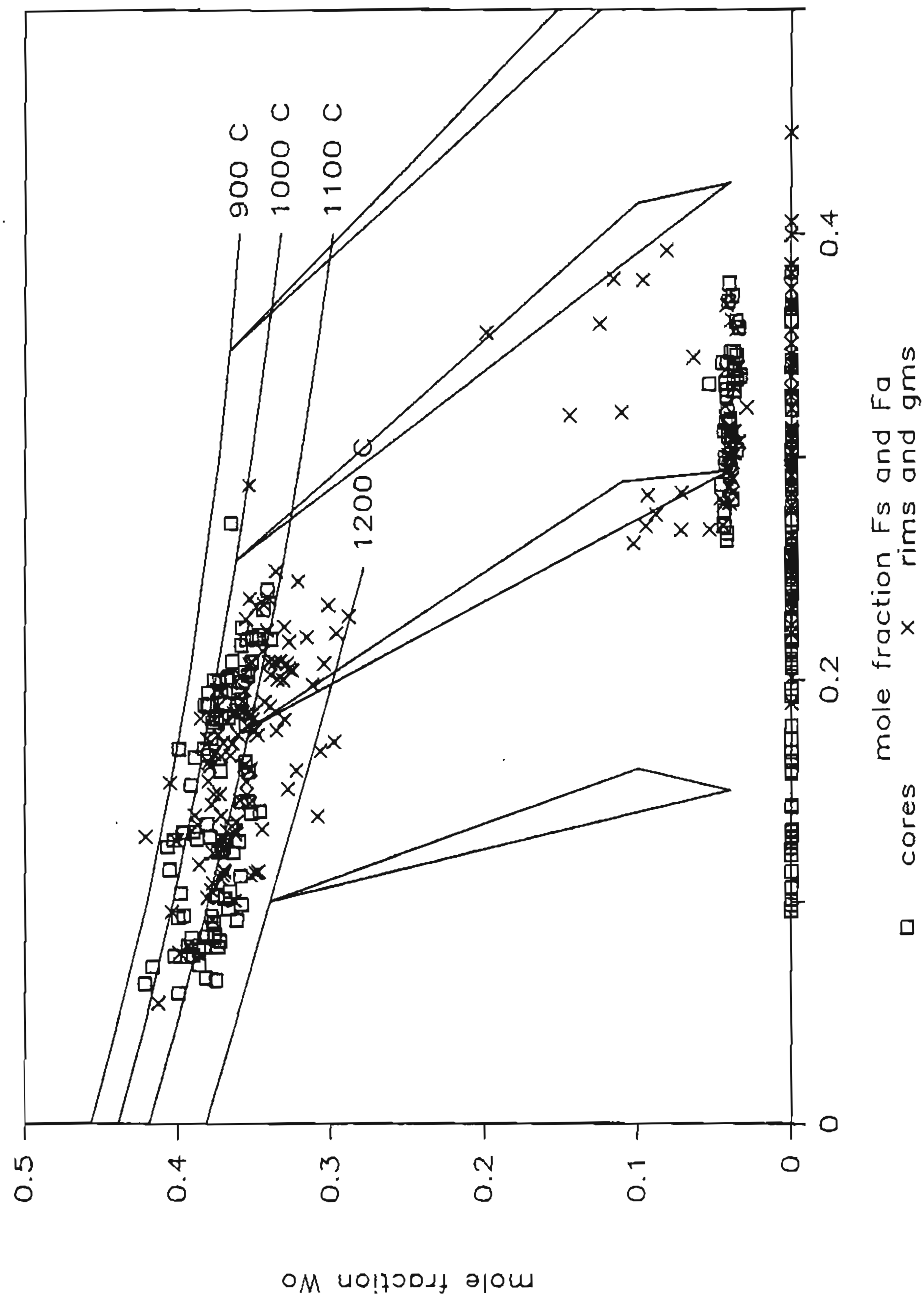
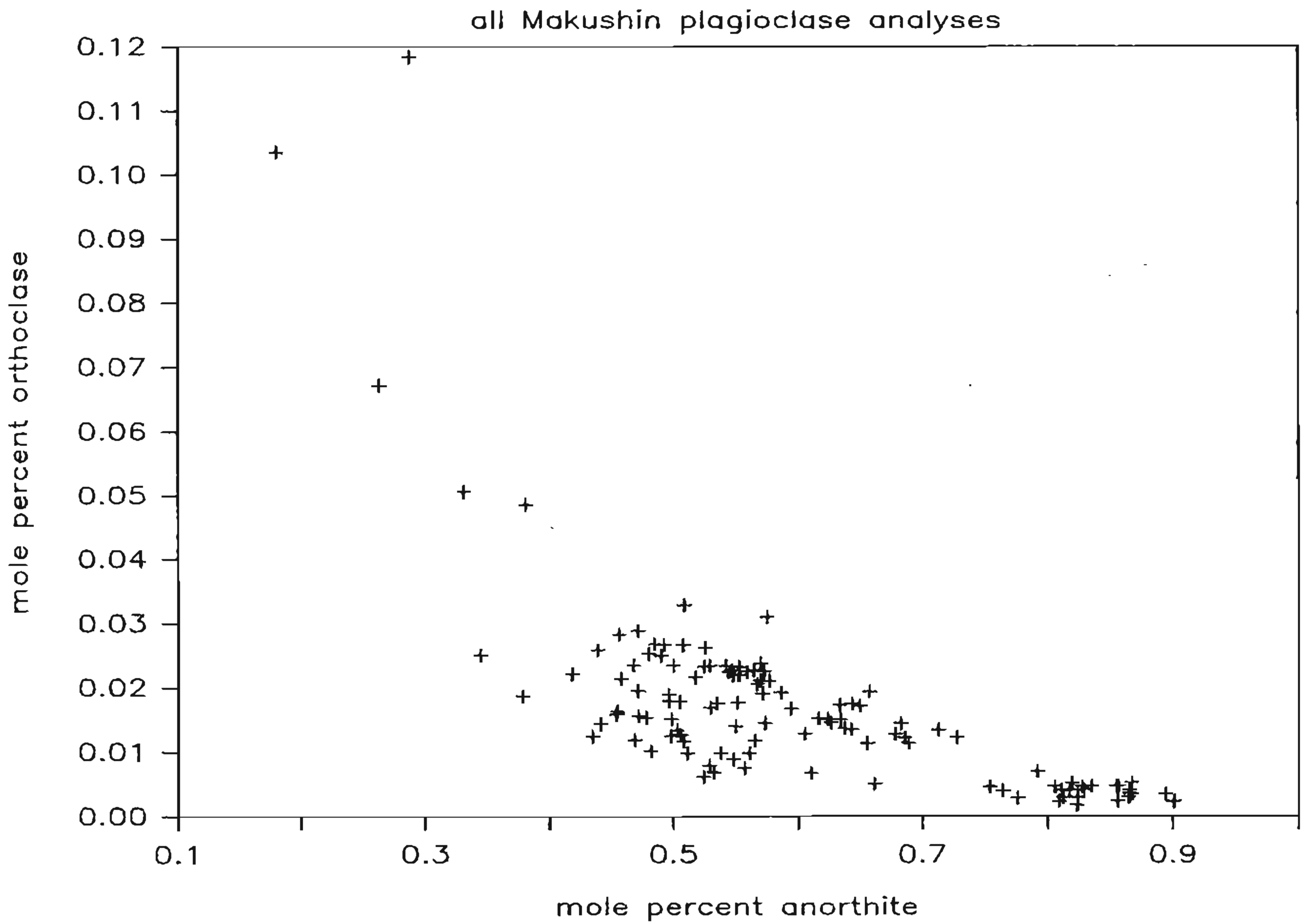

900 C
1000 C
1100 C
1200 C
mole fraction Fs and Fa
□ cores
× rims and gms
mole fraction Wo
0
0.1
0.2
0.3
0.4
0.5
0
0.2
0.4

fig 7


all Makushin plagioclase analyses
mole percent orthoclase
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0.1
0.3
0.5
0.7
0.9
mole percent anorthite

35

Fig 8a

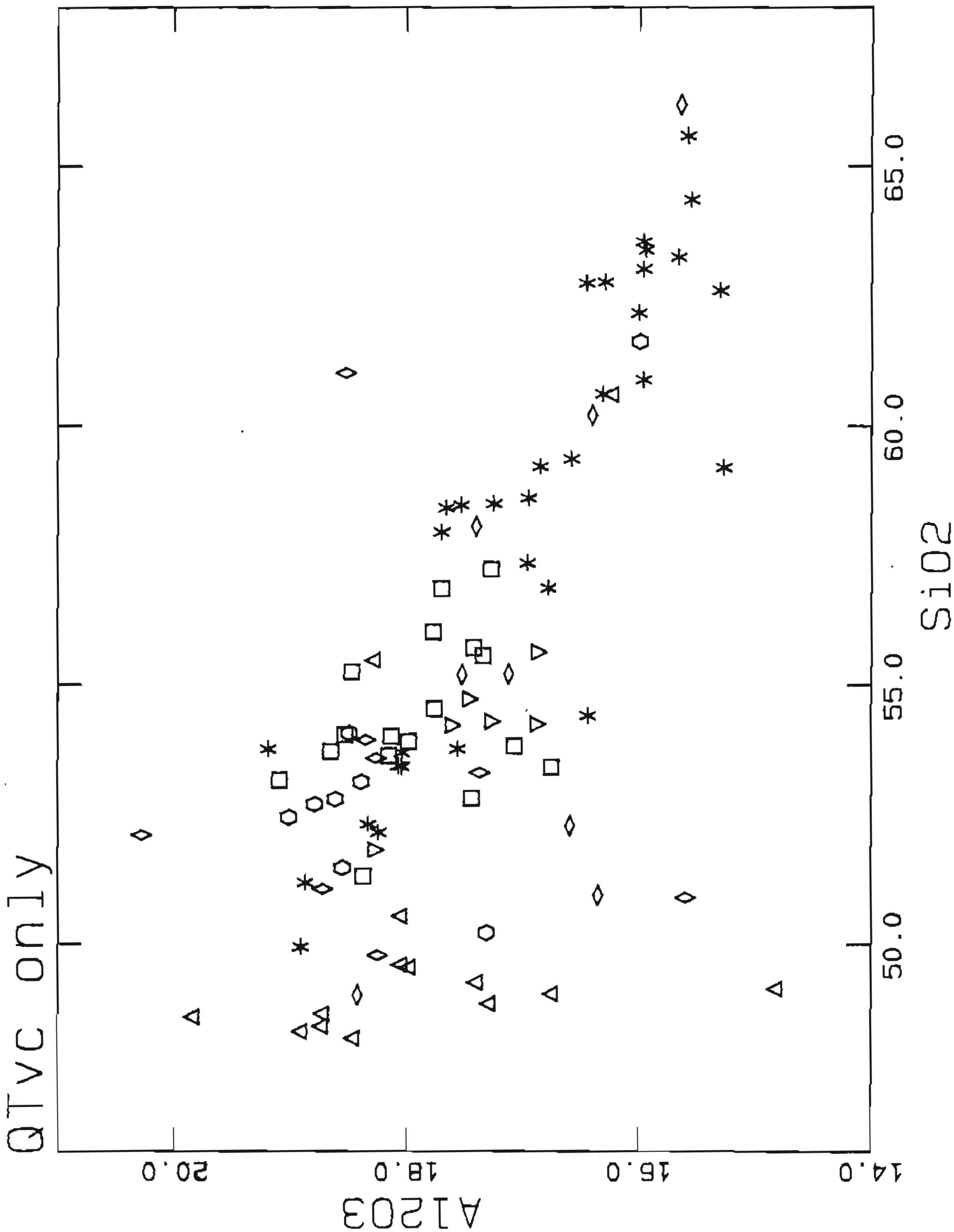


fig 8b

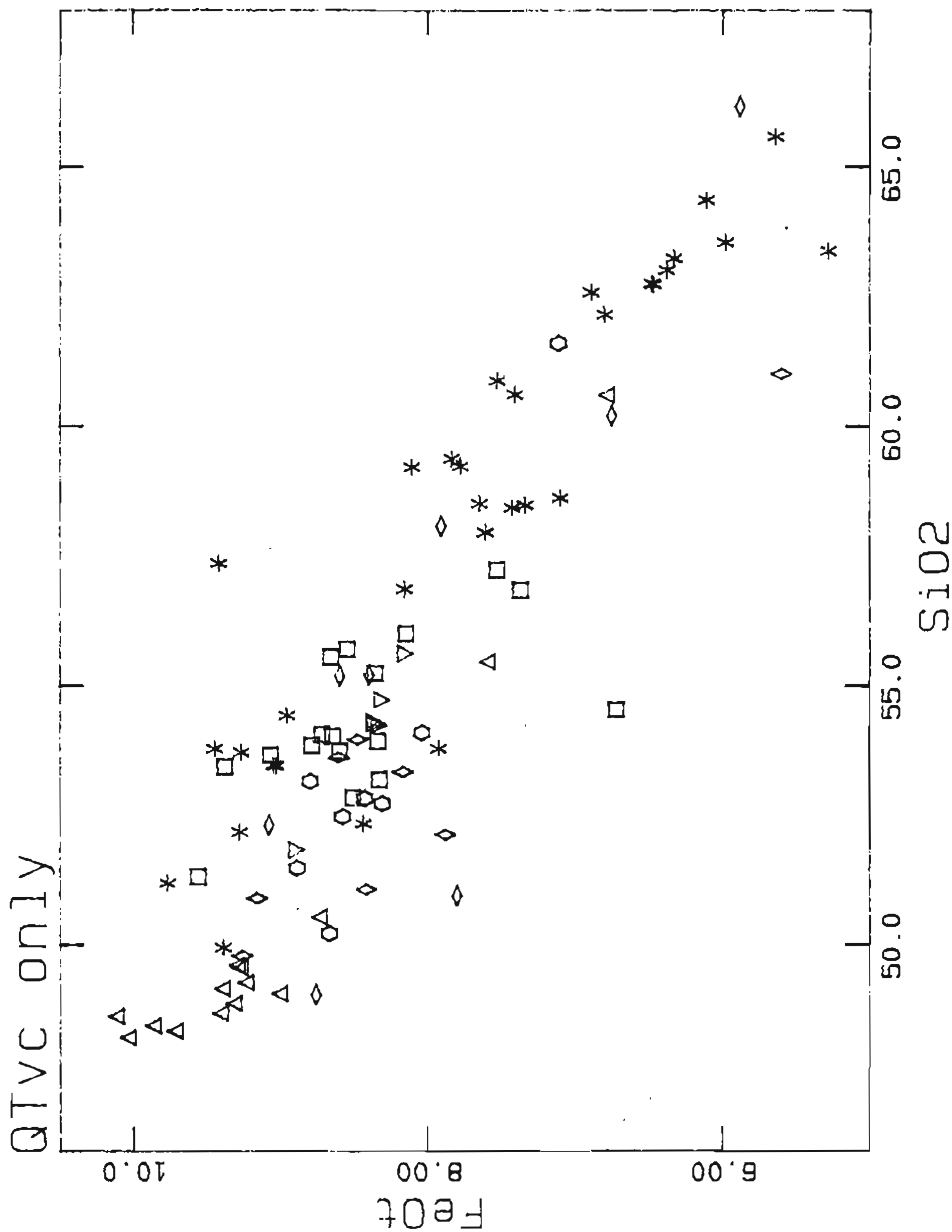


Fig 8c

37

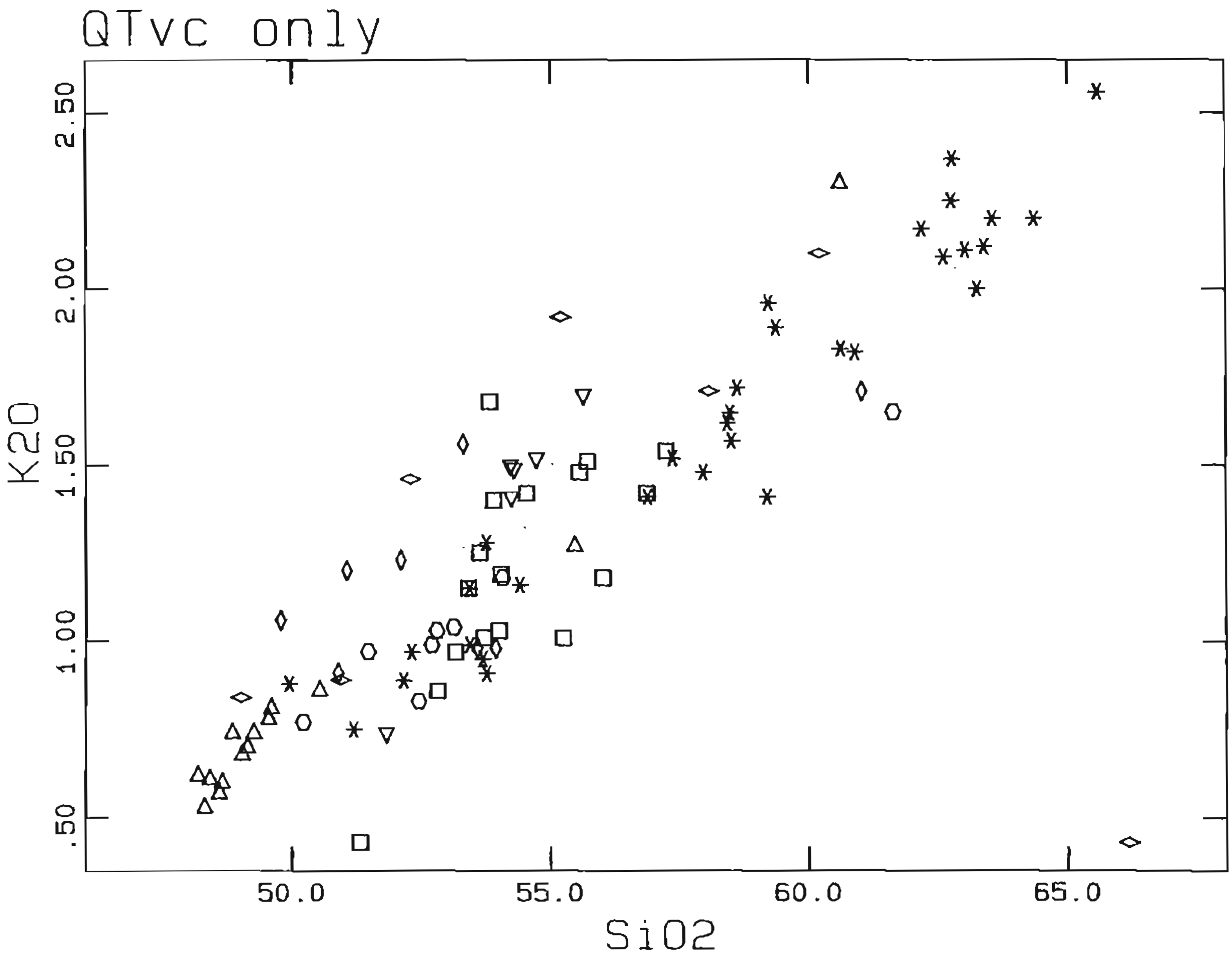


fig 8d

38

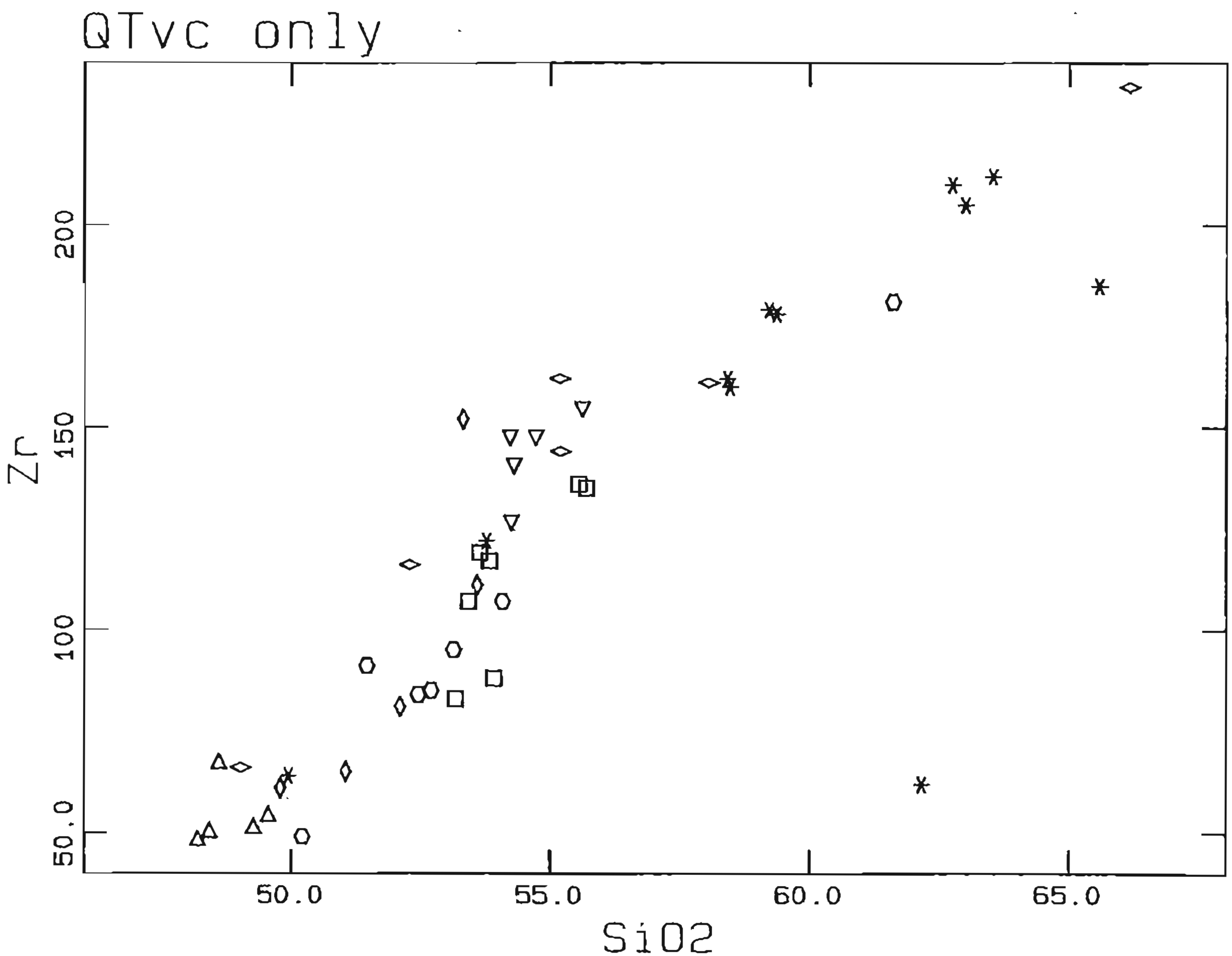


Fig 9a

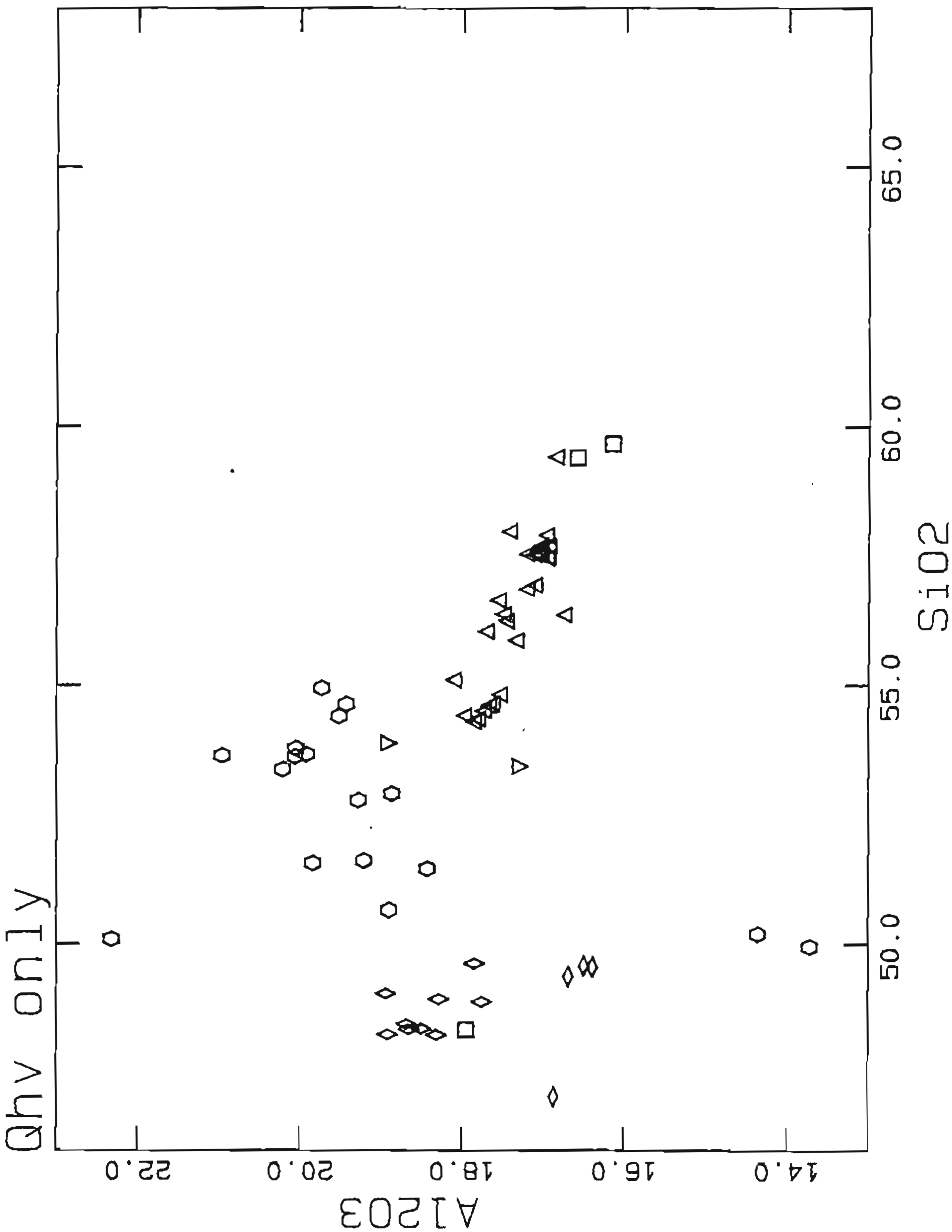


Fig 9b

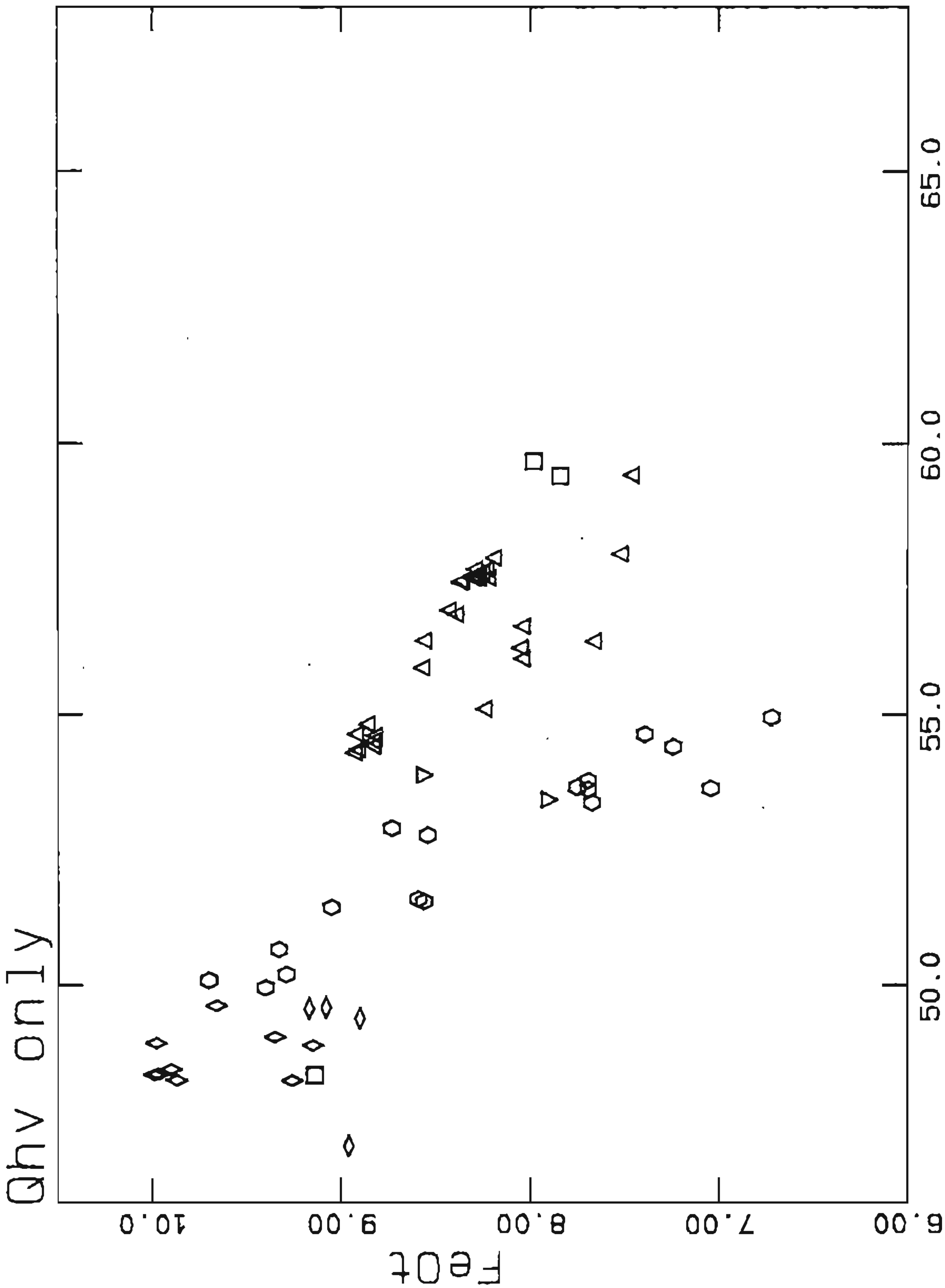


fig 9c

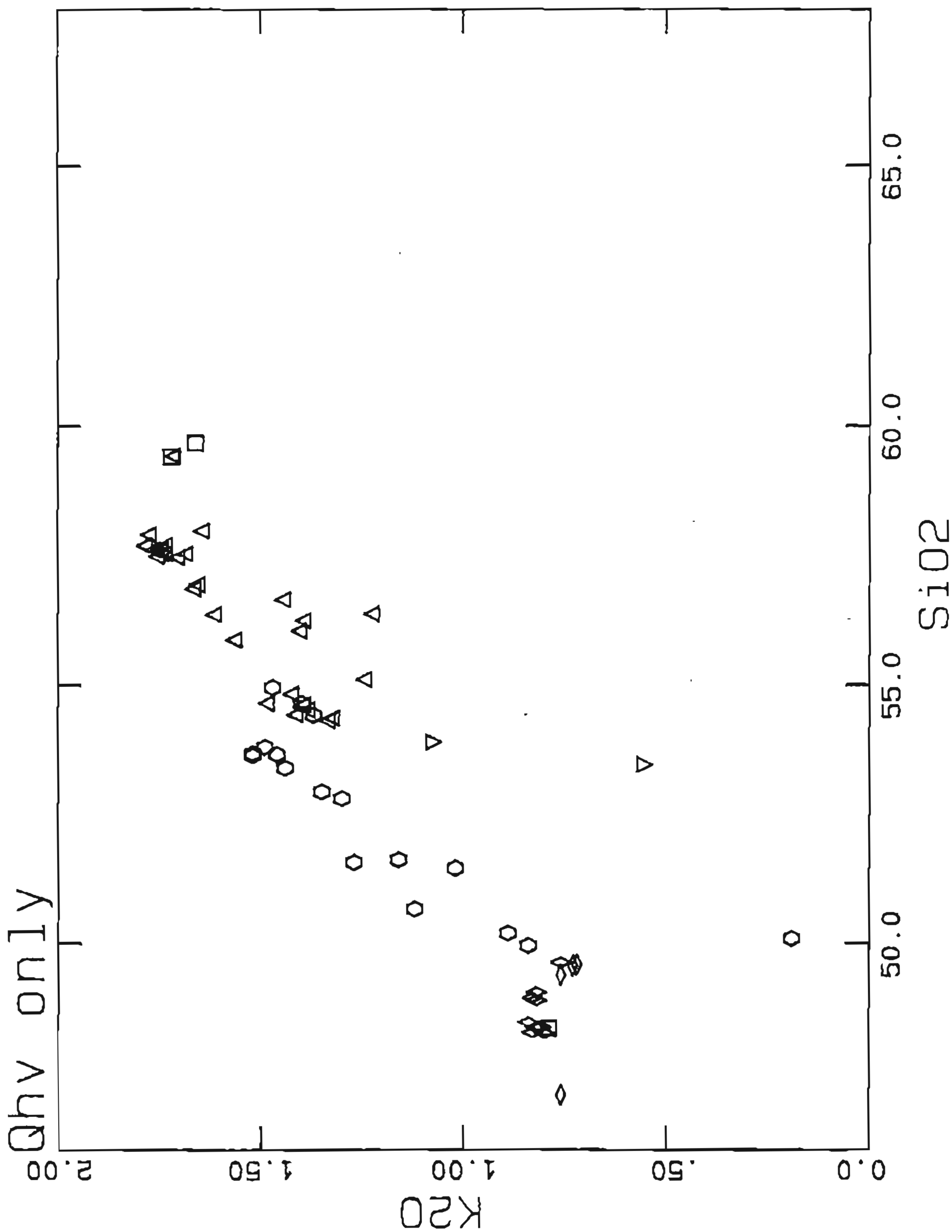


fig 9d

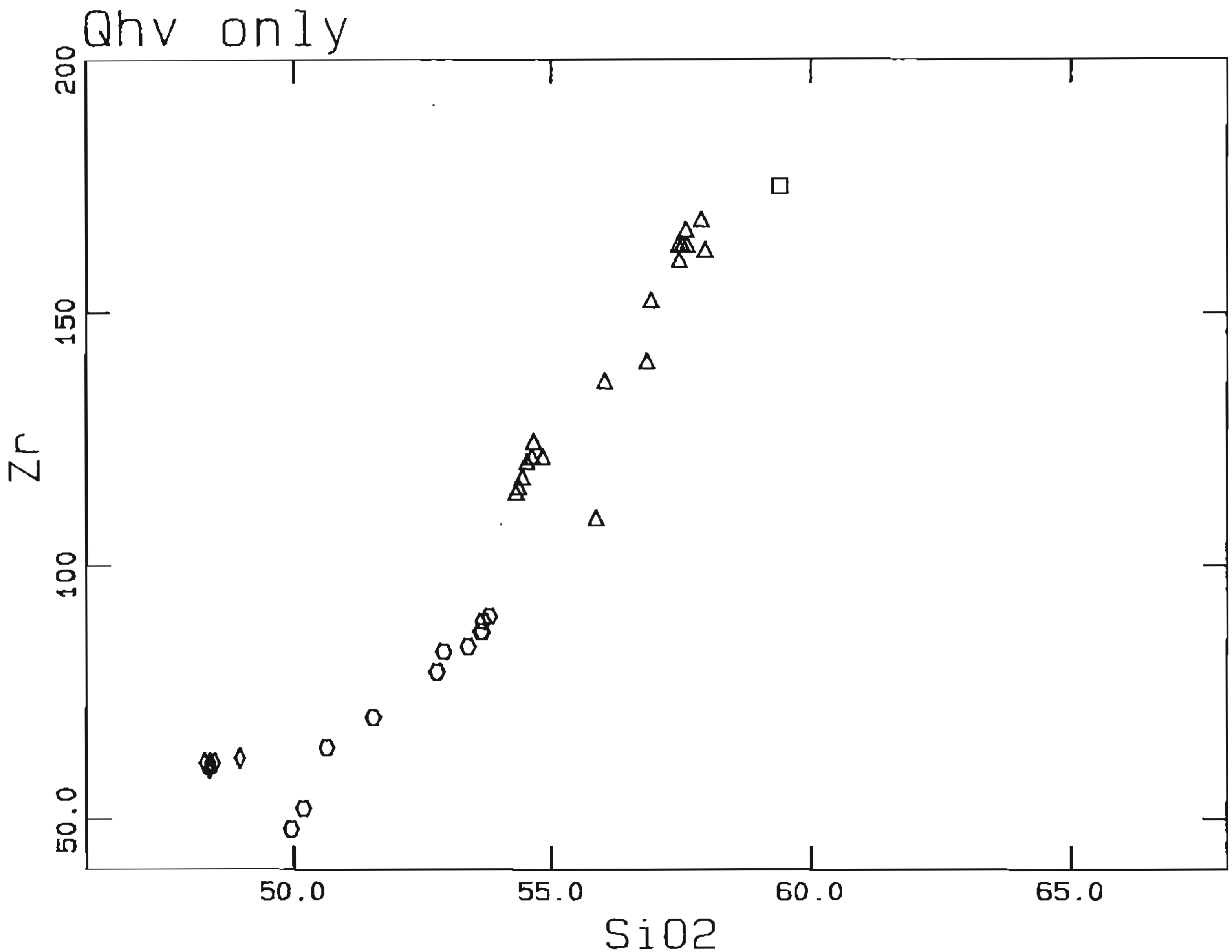


Fig 10

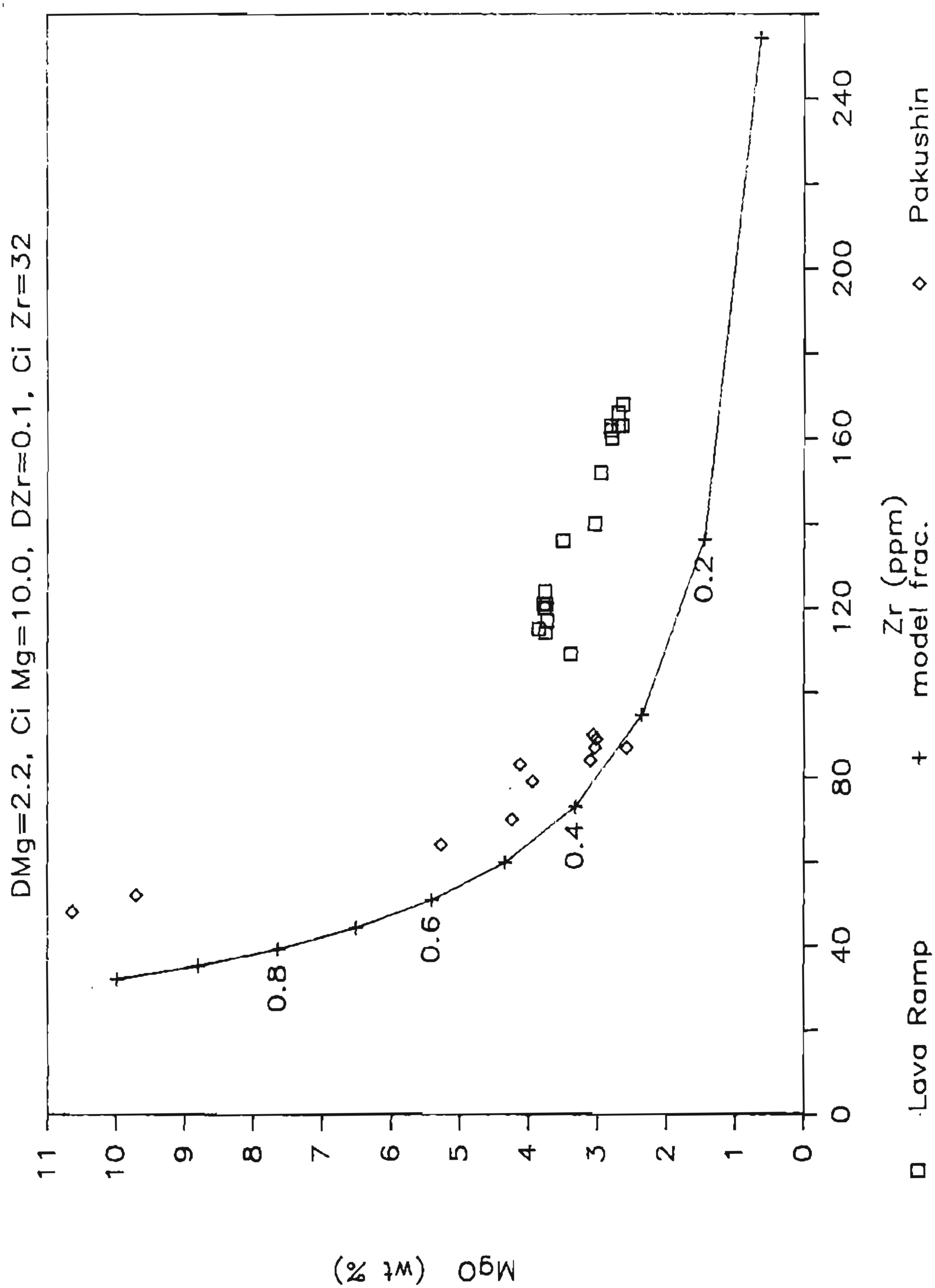

DMg=2.2, Ci Mg=10.0, DZr=0.1, Ci Zr=32
MgO (wt %)
Zr (ppm)
0.8
0.6
0.4
0.2
Lava Ramp
model frac.
Pakushin

fig 11

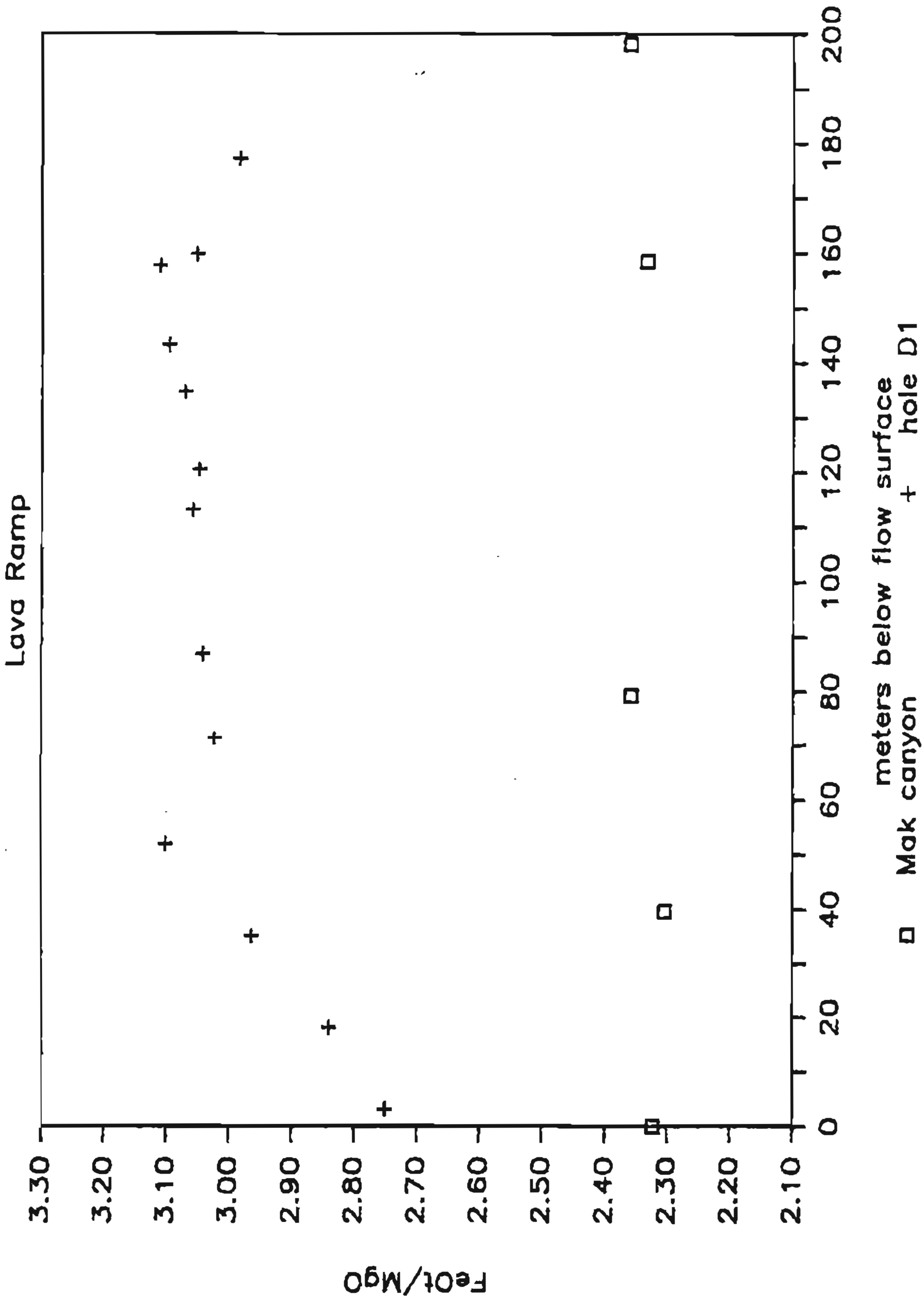
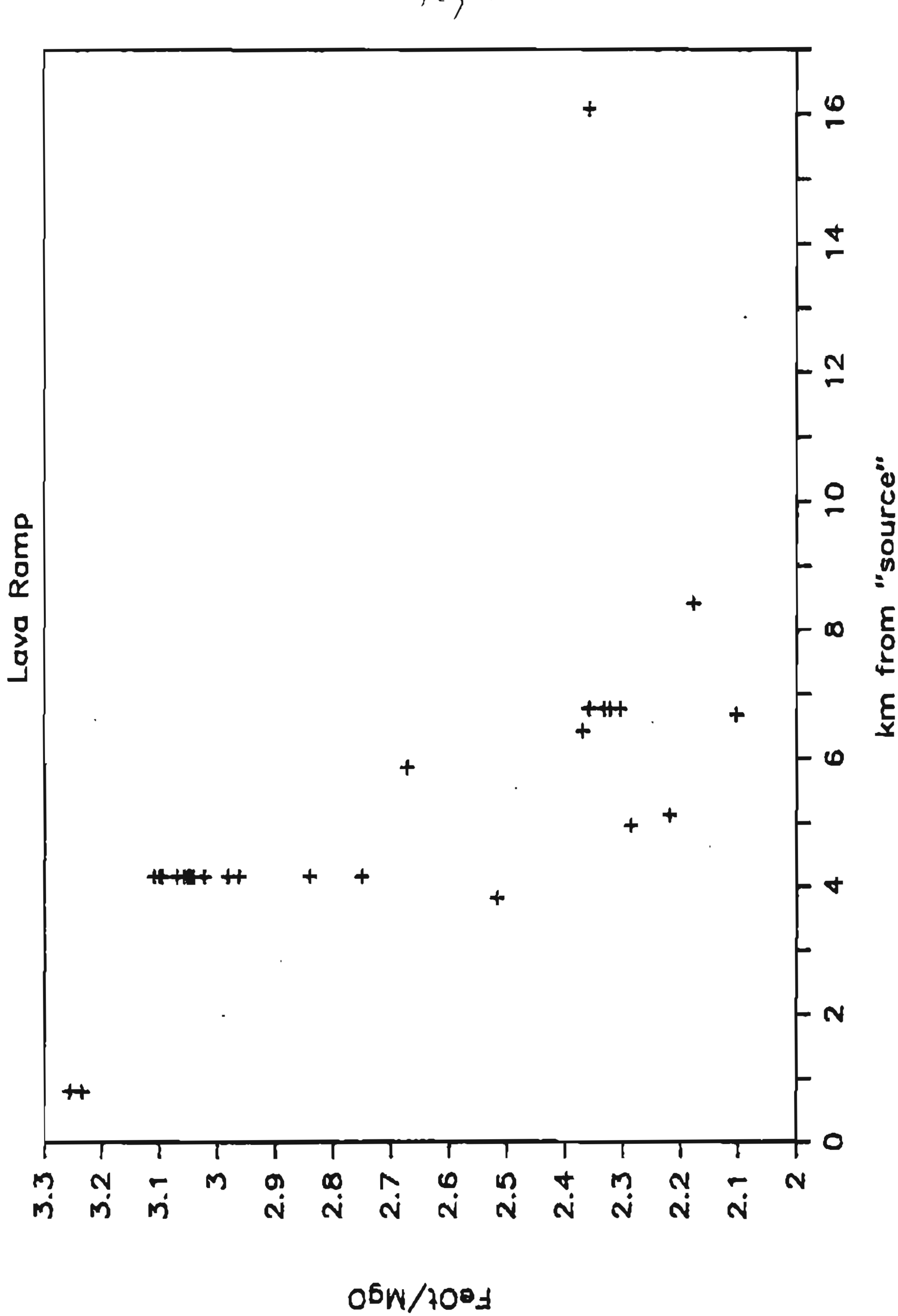

Lava Ramp
FeOt/MgO
3.30
3.20
3.10
3.00
2.90
2.80
2.70
2.60
2.50
2.40
2.30
2.20
2.10
0
20
40
60
80
100
120
140
160
180
200
meters below flow surface
□ Mak canyon
+ hole D1

fig 12


Lava Ramp
km from "source"
FeOt/MgO
0 2 4 6 8 10 12 14 16
3.3 3.2 3.1 3 2.9 2.8 2.7 2.6 2.5 2.4 2.3 2.2 2.1 2

Appendix 1 - Sample Descriptions

Samples are listed alphabetically by map number (see section 3.2). Ages are estimates based on relative glacial stratigraphy. Mineralogy is either based on point counts by Swanson (n=400-500) or visual estimates by Nye (++=dominant constituant; +=major; -=minor; tr=trace). Field numbers consisting of single integers are from Drewes and others (1961).

Makushin sample descriptions

map no.	field no.	map unit	location	age	comments	mineralogy plag	ol	cpx	opx	mt	% ph	comments
	83mq63	Tg										
	83mq85	Tg										
	83mn03	Tu	W of Glacier	Tertiary	lava flow (?)							
CW-01	u620b	Qhv	Cape Wislow	Holocene (?)								
CW-02	g4482un	Qhv	Cape Wislow	Holocene								
LR-02	83mn65	Qhv	Lava Ramp	early Holocene	lower Drift.	+		+	-	-	40	
LR-03	27r81m	Qhv	Lava Ramp	early Holocene								
LR-04	u35r82	Qhv	Lava Ramp	early Holocene	Driftwood Val							
LR-05	u6271	Qhv	Lava Ramp	early Holocene								
LR-06a	83mn52	Qhv	Lava Ramp	early Holocene	Mak Canyon	+	-	+	+	-	40	
LR-06b	83mn53	Qhv	Lava Ramp	early Holocene	Mak Canyon	+	-	+	+	-	35	
LR-06c	83mn54	Qhv	Lava Ramp	early Holocene	Mak Canyon	++	-	+	+	-	35	
LR-06e	83mn56	Qhv	Lava Ramp	early Holocene	Mak Canyon	++	-	+	-	-	40	
LR-06f	83mn57	Qhv	Lava Ramp	early Holocene	Mak Canyon	++	-	+	+	-	35	
LR-07	83mn40	Qhv	Lava Ramp	early Holocene	Mak Canyon	+		+	-	-	40	
LR-08	12	Qhv	Lava Ramp	early Holocene								
LR-09	m3	Qhv	Lava Ramp	early Holocene		27	tr	4	3	tr	34	
LR-10	u186r1	Qhv	Lava Ramp	early Holocene	upper end							
LR-11	m19	Qhv	Lava Ramp	early Holocene		33	1	8	2	1	45	
LR-12a	d1-360	Qhv	Lava Ramp	early Holocene	TG hole D1							
LR-12b	d1-409	Qhv	Lava Ramp	early Holocene	TG hole D1	+	tr	+	+	-	40	
LR-12c	d1-465	Qhv	Lava Ramp	early Holocene	TG hole D1							
LR-12d	d1-520	Qhv	Lava Ramp	early Holocene	TG hole D1							
LR-12e	d1-584	Qhv	Lava Ramp	early Holocene	TG hole D1							
LR-12f	d1-635	Qhv	Lava Ramp	early Holocene	TG hole D1							
LR-12g	d1-721	Qhv	Lava Ramp	early Holocene	TG hole D1							
LR-12h	d1-745	Qhv	Lava Ramp	early Holocene	TG hole D1							
LR-12i	d1-792	Qhv	Lava Ramp	early Holocene	TG hole D1							
LR-12j	d1-820	Qhv	Lava Ramp	early Holocene	TG hole D1							
LR-12k	d1-867	Qhv	Lava Ramp	early Holocene	TG hole D1							
LR-12m	d1-874	Qhv	Lava Ramp	early Holocene	TG hole D1							
LR-12n	d1-931	Qhv	Lava Ramp	early Holocene	TG hole D1	+	-	+	+	-	35	
LR-13	83mq102	Qhv	Lava Ramp	early Holocene								
LR-14a	u203r5	Qhv	Lava Ramp	early Holocene	upper end							
LR-14b	u203r7	Qhv	Lava Ramp	early Holocene	upper end							
M1-01	83mn41	QTvc	Mak canyon	late Holocene	ashflow block	+	-	+	-	-	10	
M1-02	u190r1	QTvc	Mak Val, near E1	late Holocene	ashflow block							
M1-03	u52r82	QTvc	Mak Val, near E1	late Holocene	ashflow block							
M1-05	83mn63	QTvc	Makushin flank, E	late Holocene	bomb	++	tr	+	tr		10	
M1-07	83mn66	QTvc	Makushin flank, NE	late Holocene	cinders	++		+	+	-	15	tuff ?
M1-13b	m44b	QTvc	Makushin flank, W	late Holocene	loose block	2		1	1		4	
M1-51b	m43b	QTvc	caldera rim	late Holocene	young bomb	12	tr	1	1	1	15	
M1-51c	m43c	QTvc	caldera rim	late Holocene	young bomb	14		1	1		16	
M1-51d	m43f	QTvc	caldera rim	late Holocene	young bomb	11	tr	1	1		13	

Makushin sample descriptions

map no.	field no.	map unit	location	age	comments	mineralogy plag	ol	cpx	opx	mt	% ph	comments
M2-08	83mn67	QTvc	Makushin flank, NE	Holocene	lava flow							
M2-09	u29r82	QTvc	Makushin flank, N	Holocene	above FF #7							
M2-10	u45r82	QTvc	Makushin flank, N	Holocene	above FF #7							
M2-11	u49r82	QTvc	Makushin flank, N	Holocene ?	dike ?							
M2-12	21	QTvc	Makushin flank, NW	Holocene	lava flow							
M2-15	10	QTvc	Makushin flank, S	Holocene								
M2-16	83mn83	QTvc	Makushin flank, S	Holocene	lava flow	+		+	-	-	35	
M2-17	u57s1	QTvc	Makushin flank, S	Holocene	flow							
M2-25	u66r82	QTvc	Makushin flank, S	Holocene	flow, high alt.							
M2-26	u67r82	QTvc	Makushin flank, S	Holocene	flow, high alt.							
M2-32a	u208r1	QTvc	Makushin flank, E	Holocene								
M2-35	16	QTvc	Makushin flank, S	Holocene								
M2-51a	m43a	QTvc	caldera rim	late Holocene	young bomb	10		2		1	13	
M2-52a	u28r82a	QTvc	caldera rim	Holocene	caldera rim							
M2-52b	u28r82b	QTvc	caldera rim	Holocene	caldera rim							
M2-52c	u28r82c	QTvc	caldera rim	Holocene	caldera rim							
M2-52d	u28r82d	QTvc	caldera rim	Holocene	caldera rim							
M2-53	u646	QTvc	caldera rim	Holocene	caldera rim							
M2-54	u645	QTvc	caldera rim	Holocene								
M2-55	u642	QTvc	caldera rim	Holocene	caldera rim							
M3-13a	m44a	QTvc	Makuhsin flank, W	early Holocene								
M3-13c	m44c	QTvc	Makuhsin flank, W	early Holocene		21	2	4	1	1	29	
M3-24	u64r82	QTvc	Makushin flank, SE	early Holocene ?								
M4-27a	u194r4	QTvc	upper Glacier	late(?) Pleistocene								
M4-27b	u194r5	QTvc	upper Glacier	late(?) Pleistocene								
M4-29	u34sl	QTvc	upper Glacier	late(?) Pleistocene								
M4-30	u36sl	QTvc	upper Glacier	late(?) Pleistocene								
M4-31	u54s1	QTvc	upper Glacier	late(?) Pleistocene								
M4-32	u208r2	QTvc	Makushin flank, E	late(?) Pleistocene								
M4-33	u48s1	QTvc	Makushin flank, E	late(?) Pleistocene								
M4-34	u207r1	QTvc	Makushin flank, E	late(?) Pleistocene								
M4-36	u647	QTvc	Makushin flank, SE	late(?) Pleistocene								
M5-04	m18	QTvc	Makushin flank, E	Pleistocene								
M5-05	u634	QTvc	Makushin flank, NE	Pleistocene								
M5-14	u59s1	QTvc	Makushin flank, SW	Pleistocene								
M5-18	83mn11	QTvc	Makushin flank, S	Pleistocene		++		+	+	-	45	
M5-19	83mn10	QTvc	Makushin flank, S	Pleistocene								
M5-20	83mn09	QTvc	Makushin flank, S	Pleistocene		+		+	-	-	45	
M5-21	83mq24	QTvc	Makushin flank, S	Pleistocene								
M5-22	83mq25	QTvc	Makushin flank, S	Pleistocene								
M5-23	83mq27	QTvc	Makushin flank, S	Pleistocene								
Mc-01	u201r1	QTvc	Eider Point	Pleistocene								
Mc-02	u163r1	QTvc	Eid Pt - C Ch	Pleistocene'	W8 Cone ?????							
Mc-03	u147r1	QTvc	Eid Pt - C Ch	Pleistocene								

Makushin sample descriptions

map no.	field no.	map unit	location	age	comments	mineralogy plag	ol	cpx	opx	mt	% ph	comments
Mc-04	u152r1	QTvc	Eid Pt - C Ch	Pleistocene								
Mc-05	83mn80	QTvc	Eid Pt - C Ch	Pleistocene								
Mc-06	83mn79	QTvc	Eid Pt - C Ch	Pleistocene		++	+				35	
Mc-07	83mn78	QTvc	Eid Pt - C Ch	Pleistocene								
Mc-08	u160r1	QTvc	Eid Pt - C Ch	Pleistocene								
Mc-09	m32	QTvc	Eid Pt - C Ch	Pleistocene		21	6	6			33	
Mc-11	u167r1	QTvc	Eid Pt - C Ch	Pleistocene								
Mc-11a	u158r2	QTvc	Eid Pt - C Ch	Pleistocene								
Mc-11b	u158r3	QTvc	Eid Pt - C Ch	Pleistocene								
Mc-13	5	QTvc	Eid Pt - C Ch	Pleistocene								
Mc-18	m30	QTvc	Eid Pt - C Ch	Pleistocene		28	8	9			45	
Md-04	m4	QTvc	E of Driftwood	Pleistocene		30	1	4	4	1	40	
Md-06	m6	QTvc	E of Driftwood	Pleistocene		47		3	3	1	54	
Md-10	m10	QTvc	E of Driftwood	Pleistocene		20	tr	7	3	tr	30	
Md-14	m14	QTvc	E of Driftwood	Pleistocene		20	2	7	4	tr	33	
Md-16	m16	QTvc	E of Driftwood	Pleistocene		18		5	7	2	33	
Md-20	8	QTvc	E of Driftwood	Pleistocene								
Me-01	m34	QTvc	W of Driftwood	Pleistocene		31		3			34	
Me-02	m35	QTvc	W of Driftwood	Pleistocene		33	1	4			38	
Me-03	m36	QTvc	W of Driftwood	Pleistocene		30	2	3	tr	tr	35	
Me-04	m37	QTvc	W of Driftwood	Pleistocene		29	4	3			36	
Me-05	m38	QTvc	W of Driftwood	Pleistocene		45		5	1	1	52	
Me-06	m39	QTvc	W of Driftwood	Pleistocene		3		tr			3	
Me-07	m40	QTvc	W of Driftwood	Pleistocene		20	5	7		tr	32	
Me-09	m42	QTvc	W of Driftwood	Pleistocene		34		6	3		43	
Mf-01	m45	QTvc	Point Kovrishka	Pleistocene		14	3	8	5	1	31	
Mf-02	m46	QTvc	Point Kovrishka	Pleistocene		21	1	5	2		29	
Mf-03	m47	QTvc	Point Kovrishka	Pleistocene		26	1	tr		tr	27	
Mf-04	m48	QTvc	Point Kovrishka	Pleistocene		47	8	1	tr		56	
Mf-05	m49	QTvc	Point Kovrishka	Pleistocene		46	tr	10			56	
Mf-16	mk3a	QTvc	Point Kovrishka	Pleistocene								
Mf-17	mk15	QTvc	Point Kovrishka	Pleistocene								
Mf-20	11	QTvc	S of Pakushin	Pleistocene								
Mg-01	6	QTvc	S of Mak Valley	Pleistocene								
Mg-03	18	QTvc	S of Mak Valley	Pleistocene								
Mg-04	83mn49	Tu	S of Driftwood	early Pleist. ?	sill							
Mg-05	83mn36	QTvc	upper Nateekin	Pleistocene		+	tr	+	-	-	35	ol resorbed
Mg-06	83mn39	QTvc	upper Nateekin	Pleistocene		+	-	+	-	-	35	
Mg-07	83mn34	Tu	upper Nateekin	Pleistocene (?)	dike							
Mg-08	83mn33	QTvc	upper Nateekin	Pleistocene		+	+	+		-	30	
Mh-05	83mn23	Tu	E of Glacier	Pleistocene		+	+	+			25	
PC-01	83mn01	Qhv	Pakushin Cone	early Holocene								
PC-02	m21	Qhv	Pakushin Cone	early Holocene		39	5	6			50	
PC-03	83mn82	Qhv	Pakushin Cone	early Holocene		+	+	-		-	75	

Makushin sample descriptions

map no.	field no.	map unit	location	age	comments	mineralogy plag	ol	cpx	opx	mt	% ph	comments
PC-04	83mn84	Qhv	Pakushin Cone	early Holocene		++	-	-		-	35	
PC-05	83mn85	Qhv	Pakushin Cone	early Holocene		++	-	+	+	-	40	
PC-06	83mn86	Qhv	Pakushin Cone	early Holocene	basal pyro.		+	+		-	20	
PC-07	7	Qhv	Pakushin Cone	early Holocene								
PC-08	83mn29	Qhv	Pakushin Cone	early Holocene		++	tr	+	-	-	35	
PC-09	83mn25	Qhv	Pakushin Cone	early Holocene	basal pyro.		+	+			30	
PC-10	83mn24	Qhv	Pakushin Cone	early Holocene		+	-	+		-	40	cpx pl mt clots
PC-11	m20	Qhv	Pakushin Cone	early Holocene		40	5	3	3		50	
PC-12	83mn28	Qhv	Pakushin Cone	early Holocene	summit cone	++		+	-	-	50	
PC-13	83mn27	Qhv	Pakushin Cone	early Holocene	summit cone							
PC-14	83mn26	Qhv	Pakushin Cone	early Holocene	summit cone	+	-	+	-	+	50	cpx in clots
PC-15	u58s1	Qhv	Pakushin Cone	early Holocene	summit							
PC-20	u70r82	Qhv	Pakushin Cone	early Holocene								
PC-50	u5154h	Qhv	Pakushin Cone	early Holocene								
PK-01	u638b	Qhv	Pt Kadin Vents	Holocene								
PK-02	m52	Qhv	Pt Kadin Vents	early Holocene		2	-	tr			2	
PK-03	u638a	Qhv	Pt Kadin vents	late Holocene								
PK-04	u638c	Qhv	Pt Kadin vents	late Holocene								
PK-05	g4782un	Qhv	Pt Kadin vents	late Holocene								
SL-01	u6281	Qhv	Sugarloaf	early Holocene								
SL-02	u55r82	Qhv	Sugarloaf	early Holocene								
TT-01	u164r3	Qhv	Table Top	early Holocene								
TT-02	83mn73	Qhv	Table Top	early Holocene	bomb, crater	+	+	+		-	30	cpx clots
TT-04	83mn74	Qhv	Table Top	early Holocene	flow at base							
TT-05	u173r1	Qhv	Table Top	early Holocene								
TT-06	83mn75	Qhv	Table Top	early Holocene	flow at base							
TT-07	3	Qhv	Table Top	early Holocene								
TT-08	u165r1	Qhv	Table Top	early Holocene								
TT-09	83mn76	Qhv	Table Top	early Holocene	flow at base							
TT-10	83mn77	Qhv	Table Top	early Holocene	flow at base	+	+				50	
WB-01	u26s1	Qhv	Wide Bay Cone	early Holocene								
WB-02	u24s1	Qhv	Wide Bay Cone	early Holocene								
WB-03	u145r1	Qhv	Wide Bay Cone	early Holocene								
WB-04	4	Qhv	Wide Bay Cone	early Holocene								
WB-06	u202r	Qhv	Wide Bay Cone	early Holocene								

Appendix 2 - Whole Rock Analyses

Samples are listed alphabetically by map number. All analyses are by XRF at DGGS, Fairbanks. Major elements are reported normalized volatile free, with the original LOI and totals preserved. Those samples with FeO have FeO determined by standard titration methods. Where weight gained by the oxidation of iron exceeds water dissolved in the rock LOI is negative.

Those samples with complete trace element analyses were analyzed by Nye at UCSC. For these trace element analyses concentrations are accurate to at least 5% relative or 1 ppm, whichever is greater. In addition, V, Cr, Ni, Ba and Ce are accurate to 3% relative, but are no better than ± 2-3 ppm. Detection limits for all elements are a few ppm except for Ni and Ba, which have limits of 5-10 ppm due to tube interferences. Precision is much better than accuracy.

Those samples with only Rb, Sr, Y, Zr and Nb reported were analyzed by B. Farris at the DGGS XRF laboratory. Precision and accuracy are similar to the UCSC values.

DGGS and UCSC data from samples analyzed in both labs compare favorably, with the exception of Nb, where DGGS data are systematically 1-2 ppm higher than UCSC data. It is unclear which lab produces the most accurate Nb data.

K, P and Ti are calculated from the major element data.

Makushin whole rock compositions - normalized to 100% anhydrous - original totals and LOIs

map no.				CW-01	CW-02	LR-02	LR-03	LR-04	LR-05	LR-06a	LR-06b	LR-06c	LR-06e	LR-06f	LR-07
field no.	83mq63	83mq85	83mn03	u620b	g4482un	83mn65	27r81m	u35r82	u6271	83mn52	83mn53	83mn54	83mn56	83mn57	83mn40
SiO2	50.55	54.13	53.12	51.32		54.43		55.11	56.24	54.62	54.36	54.83	54.52	54.65	54.31
TiO2	0.85	1.03	0.92	0.94		0.99		0.94	1.03	1.00	0.99	1.00	0.99	1.00	0.99
Al2O3	16.46	18.01	16.64	19.23		17.95		18.08	17.43	17.65	17.78	17.51	17.71	17.60	17.83
Fe2O3	10.84	10.26	9.76	8.45		9.80		4.16	2.62	9.79	9.89	9.83	9.80	9.90	9.91
FeO				1.77				4.48	5.68						
MnO	0.19	0.15	0.15	0.22		0.18		0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
MgO	7.29	4.38	6.06	4.27		3.74		4.01	3.69	3.79	3.86	3.75	3.78	3.77	3.76
CaO	10.72	6.63	9.27	9.32		7.93		8.06	7.65	7.83	8.03	7.84	7.95	7.86	8.11
Na2O	2.45	3.79	2.69	3.22		3.38		3.40	3.87	3.54	3.39	3.44	3.48	3.37	3.38
K2O	0.52	1.42	1.24	1.00		1.41		1.24	1.39	1.39	1.32	1.42	1.38	1.48	1.33
P2O5	0.13	0.18	0.16	0.27		0.20		0.32	0.22	0.21	0.20	0.21	0.21	0.20	0.19
LOI			1.11	0.00		0.11		0.25	0.00	-0.41	-0.38	-0.04	-0.02	0.00	-0.46
Total	98.86	98.33	100.29	97.89		100.42		99.92	99.48	100.57	100.12	100.24	100.24	100.74	100.03
Rb		10	35			27				28	26	27	27	28	25
K	4283	11820	10295	8311		11669		10328	11539	11509	10986	11755	11426	12279	11070
Ba															
Sr		367	471			484				481	495	485	484	475	492
La															
Ce															
Nd															
Y		21	23			27				28	27	28	28	28	26
P	574	799	704	1159		870			960	908	868	914	914	866	825
Zr		79	108			117				121	115	121	120	124	114
Nb		5.7	6.6			6.5				6.7	6.5	6.5	6.3	6.7	6.4
Ti	5094	6158	5501	5634		5917		5654	6175	5996	5906	5978	5920	6010	5906
V															
Cr															
Ni															
FeO*/MgO	1.34	2.11	1.45	2.19		2.36		2.05	2.18	2.32	2.31	2.36	2.33	2.36	2.37
CaO/Al2O3	0.65	0.37	0.56	0.48		0.44		0.45	0.44	0.44	0.45	0.45	0.45	0.45	0.45
K/Rb		1182	294			432				411	423	435	423	439	443
Rb/Sr		0.027	0.074			0.056				0.058	0.053	0.056	0.056	0.059	0.051
Ba/La															
Rb/Y		0.48	1.52			1.00				1.00	0.96	0.96	0.96	1.00	0.96
Rb/Zr		0.13	0.32			0.23				0.23	0.23	0.22	0.23	0.23	0.22
Ce/Y															
Zr/Nb		13.9	16.4			18.0				18.1	17.7	18.6	19.0	18.5	17.8
Zr/Y		3.8	4.7			4.3				4.3	4.3	4.3	4.3	4.4	4.4
Y/Nb		3.7	3.5			4.2				4.2	4.2	4.3	4.4	4.2	4.1

Makushin whole rock compositions - normalized to 100% anhydrous - original totals and LOIs

map no.	LR-08	LR-09	LR-10	LR-11	LR-12a	LR-12b	LR-12c	LR-12d	LR-12e	LR-12f	LR-12g	LR-12h	LR-12i	LR-12j	LR-12k
field no.	12	m3	u186r1	m19	d1-360	d1-409	d1-465	d1-520	d1-584	d1-635	d1-721	d1-745	d1-792	d1-820	d1-867
SiO2	56.38	57.99	56.59	56.04	56.86	56.94	57.46	57.91	57.70	57.63	57.53	57.61	57.61	57.54	57.70
TiO2	0.00	0.96	1.00	1.01	1.01	1.02	1.04	1.04	1.02	1.02	1.03	1.04	1.04	1.03	1.06
Al2O3	17.47	17.39	17.51	17.68	17.18	17.08	16.93	16.94	17.01	17.05	17.04	17.03	17.00	17.18	16.91
Fe2O3	2.84	2.17	2.35	2.41	9.31	9.35	9.29	9.09	9.14	9.15	9.21	9.18	9.19	9.12	9.21
FeO	5.99	5.56	6.01	5.86											
MnO	0.00	0.18	0.18	0.18	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
MgO	4.06	2.81	3.62	3.51	3.04	2.96	2.82	2.64	2.72	2.71	2.71	2.71	2.69	2.65	2.66
CaO	8.23	6.78	7.38	7.81	6.77	6.75	6.42	6.22	6.28	6.32	6.41	6.31	6.38	6.39	6.31
Na2O	3.56	4.13	3.67	3.89	3.78	3.85	3.94	3.99	4.01	3.97	3.98	3.96	3.94	3.95	3.96
K2O	1.22	1.64	1.44	1.40	1.66	1.65	1.70	1.77	1.73	1.74	1.68	1.76	1.74	1.74	1.78
P2O5	0.25	0.39	0.25	0.21	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.23
LOI	0.28	0.04	0.00	0.08	-0.38	-0.15	-0.11	0.05	0.00	0.32	-0.02	-0.04	0.08	-0.35	-0.33
Total	98.73	99.54	99.66	100.77	100.47	100.13	99.89	100.15	100.04	100.06	99.94	99.97	99.97	99.65	99.94
Rb		35		29	31	35	37	39		36		38		37	
K	10129	13616	11984	11622	13747	13659	14113	14679	14356	14482	13952	14609	14461	14445	14737
Ba		523		454											
Sr		397		436	418	396	379	373		370		379		380	
La		16		15											
Ce		34		30											
Nd		22		18											
Y		39		32	31	34	34	36		35		35		35	
P	1091	1702	1094	916	952	957	960	959	960	963	961	960	961	960	1001
Zr		162		136	140	152	163	168		163		166		163	
Nb		6		5.6	7.2	6.7	7.5	7.3		7.3		7		7.3	
Ti	0	5756	6010	6055	6063	6098	6235	6229	6112	6131	6177	6234	6242	6175	6338
V		156		209											
Cr		14		23											
Ni		5		8											
FeO*/MgO	2.10	2.67	2.24	2.29	2.75	2.84	2.96	3.10	3.02	3.04	3.06	3.05	3.07	3.10	3.11
CaO/Al2O3	0.47	0.39	0.42	0.44	0.39	0.40	0.38	0.37	0.37	0.37	0.38	0.37	0.38	0.37	0.37
K/Rb		389		401	443	390	381	376		402		384		390	
Rb/Sr		0.088		0.067	0.074	0.088	0.098	0.105		0.097		0.100		0.097	
Ba/La		33		30											
Rb/Y		0.90		0.91	1.00	1.03	1.09	1.08		1.03		1.09		1.06	
Rb/Zr		0.22		0.21	0.22	0.23	0.23	0.23		0.22		0.23		0.23	
Ce/Y		0.87		0.94											
Zr/Nb		27.0		24.3	19.4	22.7	21.7	23.0		22.3		23.7		22.3	
Zr/Y		4.2		4.3	4.5	4.5	4.8	4.7		4.7		4.7		4.7	
Y/Nb		6.5		5.7	4.3	5.1	4.5	4.9		4.8		5.0		4.8	

Makushin whole rock compositions - normalized to 100% anhydrous - original totals and LOIs

map no.	LR-12m	LR-12n	LR-13	LR-14a	LR-14b	M1-01	M1-02	M1-03	M1-05	M1-07	M1-13b	M1-51b	M1-51c	M1-51d	M2-08
field no.	d1-874	d1-931	83mq102	u203r5	u203r7	83mn41	u190r1	u52r82	83mn63	83mn66	m44b	m43b	m43c	m43f	83mn67
SiO2	57.53	57.48	55.87	58.30	59.43	59.38	59.44	60.62	59.23	62.77	62.18	58.49	63.55	58.44	65.58
TiO2	1.03	1.03	1.00	1.17	1.09	1.10	1.08	1.12	1.10	0.92	1.07	1.13	0.94	1.11	0.75
Al2O3	17.09	16.92	17.31	17.30	16.82	16.58	17.19	16.31	16.85	16.29	16.00	17.53	15.96	17.66	15.58
Fe2O3	9.18	9.28	9.52	3.89	2.34	8.71	1.61	1.75	8.65	7.20	1.70	2.02	1.86	2.57	6.27
FeO				4.42	5.34		5.75	5.84			5.27	5.52	4.31	5.12	
MnO	0.18	0.18	0.18	0.20	0.19	0.18	0.19	0.19	0.18	0.17	0.19	0.18	0.18	0.19	0.17
MgO	2.71	2.80	3.40	2.43	2.30	2.04	2.22	2.18	1.98	1.29	1.50	2.14	1.34	2.15	1.03
CaO	6.34	6.46	7.32	6.04	5.93	5.48	6.03	5.72	5.47	4.09	4.52	6.49	4.23	6.35	3.29
Na2O	3.99	3.88	3.64	4.30	4.55	4.39	4.42	4.17	4.31	4.64	5.12	4.61	5.17	4.56	4.55
K2O	1.73	1.75	1.56	1.67	1.71	1.89	1.74	1.83	1.96	2.37	2.17	1.65	2.20	1.62	2.56
P2O5	0.23	0.22	0.20	0.29	0.30	0.25	0.31	0.27	0.26	0.26	0.28	0.24	0.26	0.23	0.21
LOI	-0.39	0.08	-0.24	0.87	0.00	-0.38	-0.04	-0.18	-0.16	0.04	0.30	0.22	0.22	0.48	1.35
Total	99.72	99.80	100.33	101.07	100.32	100.42	99.96	98.17	100.66	100.73	100.12	99.86	99.72	99.48	101.01
Rb	37	37	26	0.2		42			42	51	13	35	51	35	50
K	14346	14569	12960	13826	14233	15730	14477	15194	16303	19705	18016	13698	18264	13449	21241
Ba														493	
Sr	380	373	497			357			354	306	577	385	297	374	268
La														13	
Ce														35	
Nd														20	
Y	35	35	24			40			39	45	20	37	45	37	45
P	1003	963	868		1305	1082			1125	1127	1222	1047	1135	1004	920
Zr	163	160	109			178			179	210	62	160	212	162	185
Nb	7.1	7.2	6.4			7.7			7.4	7.9	5.8	7.2	8.1	5.8	6.3
Ti	6168	6192	6021	7008	6514	6602	6504	6705	6600	5537	6415	6774	5635	6654	4512
V														148	
Cr														6	
Ni														1	
FeO*/MgO	3.05	2.98	2.52	3.26	3.24	3.84	3.24	3.41	3.92	5.02	4.53	3.43	4.47	3.46	5.46
CaO/Al2O3	0.37	0.38	0.42	0.35	0.35	0.33	0.35	0.35	0.32	0.25	0.28	0.37	0.27	0.36	0.21
K/Rb	388	394	498	69130		375			388	386	1386	391	358	384	425
Rb/Sr	0.097	0.099	0.052			0.118			0.119	0.167	0.023	0.091	0.172	0.094	0.187
Ba/La														38	
Rb/Y	1.06	1.06	1.08			1.05			1.08	1.13	0.65	0.95	1.13	0.95	1.11
Rb/Zr	0.23	0.23	0.24			0.24			0.23	0.24	0.21	0.22	0.24	0.22	0.27
Ce/Y														0.95	
Zr/Nb	23.0	22.2	17.0			23.1			24.2	26.6	10.7	22.2	26.2	27.9	29.4
Zr/Y	4.7	4.6	4.5			4.5			4.6	4.7	3.1	4.3	4.7	4.4	4.1
Y/Nb	4.9	4.9	3.8			5.2			5.3	5.7	3.4	5.1	5.6	6.4	7.1

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Makushin whole rock compositions - normalized to 100% anhydrous - original totals and LOIs

map no.	M2-09	M2-10	M2-11	M2-12	M2-15	M2-16	M2-17	M2-25	M2-26	M2-32a	M2-35	M2-51a	M2-52a	M2-52b	M2-52c
field no.	u29r82	u45r82	u49r82	21	10	83mn83	u57s1	u66r82	u67r82	u208r1	16	m43a	u28r82a	u28r82b	u28r82c
SiO2	54.42	60.89	58.52	62.59	53.79	53.78	53.00	52.17	53.46	53.71	56.88	63.02	57.97	57.37	63.25
TiO2	1.01	1.16	1.12	0.99	0.92	1.12	1.06	1.05	1.06	1.02	0.98	1.00	1.09	1.22	0.98
Al2O3	16.44	15.96	17.25	15.30	19.19	17.56	18.56	18.24	18.07	18.04	16.78	15.96	17.70	16.96	15.66
Fe2O3	7.71	2.86	1.72	1.69	3.20	10.51	2.87	3.83	2.68	2.86	2.81	3.23	2.35	3.63	2.66
FeO	2.02	4.96	6.11	5.37	5.05		5.97	5.83	6.64	6.70	5.63	3.47	5.49	6.16	3.94
MnO	0.19	0.19	0.18	0.19	0.17	0.19	0.18	0.19	0.19	0.28	0.17	0.18	0.18	0.20	0.17
MgO	6.02	2.32	2.54	1.89	3.94	3.89	4.10	4.71	4.34	4.32	3.72	1.48	2.57	2.65	1.89
CaO	7.77	5.45	6.83	4.67	9.30	7.84	9.46	9.88	9.28	8.48	7.64	4.34	7.09	6.31	4.70
Na2O	3.01	4.08	3.92	4.87	3.35	3.62	3.64	3.06	3.11	3.43	3.72	4.98	3.85	3.68	4.46
K2O	1.16	1.82	1.57	2.09	0.91	1.28	0.98	0.89	0.99	0.95	1.41	2.11	1.48	1.52	2.00
P2O5	0.23	0.30	0.24	0.35	0.18	0.21	0.18	0.14	0.17	0.20	0.26	0.23	0.23	0.30	0.29
LOI	0.75	0.17	0.00	0.18	0.16	-0.01	-0.44	0.08	-0.21	0.00	0.57	0.54	0.44	0.81	0.86
Total	99.69	99.54	98.38	100.82	99.70	100.51	99.97	98.15	98.77	99.72	100.08	99.40	97.85	97.45	99.39
Rb						25	0.41					49			
K	9649	15121	12995	17349	7555	10654	8155	7365	8219	7909	11705	17516	12272	12628	16598
Ba															
Sr						446						298			
La															
Ce															
Nd															
Y						28						41			
P				1527	786	912				875	1135	1004			
Zr						122						205			
Nb						7						7.7			
Ti	6059	6938	6703	5934	5516	6739	6375	6296	6360	6132	5875	5995	6524	7320	5902
V															
Cr															
Ni															
FeO*/MgO	1.49	3.24	3.01	3.65	2.01	2.43	2.08	1.97	2.08	2.14	2.19	4.31	2.96	3.56	3.35
CaO/Al2O3	0.47	0.34	0.40	0.31	0.48	0.45	0.51	0.54	0.51	0.47	0.46	0.27	0.40	0.37	0.30
K/Rb						426	19891					357			
Rb/Sr						0.056						0.164			
Ba/La															
Rb/Y						0.89						1.20			
Rb/Zr						0.20						0.24			
Ce/Y						0.00									
Zr/Nb						17.4						26.6			
Zr/Y						4.4						5.0			
Y/Nb						4.0						5.3			

Makushin whole rock compositions - normalized to 100% anhydrous - original totals and LOIs

map no.	M2-52d	M2-53	M2-54	M2-55	M3-13a	M3-13c	M3-24	M4-27a	M4-27b	M4-29	M4-30	M4-31	M4-32	M4-33	M4-34
field no.	u28r82d	u646	u645	u642	m44a	m44c	u64r82	u194r4	u194r5	u34sl	u36sl	u54s1	u208r2	u48s1	u207r1
SiO2	64.36	61.15	62.75	64.19	49.96	53.45	51.19	56.02	55.25	57.25	56.86	63.09	53.72	54.02	56.34
TiO2	0.96	1.16	0.62	1.01	1.04	1.13	1.04	1.02	1.00	0.90	0.90	0.80	1.02	1.07	1.08
Al2O3	15.55	15.77	16.45	16.14	18.91	18.04	18.87	17.77	18.47	17.27	17.70	16.96	18.65	18.13	18.34
Fe2O3	1.60	5.28	0.00	2.87	6.90	3.15	5.92	3.18	4.60	2.85	2.74	1.83	6.28	3.50	2.54
FeO	4.68	3.63	6.47	2.76	3.18	6.20	4.45	5.29	4.22	4.96	4.90	3.58	2.94	5.50	4.66
MnO	0.18	0.13	0.16	0.15	0.19	0.20	0.21	0.20	0.17	0.18	0.17	0.15	0.18	0.20	0.17
MgO	1.52	3.24	2.54	1.36	5.12	4.21	5.29	3.69	3.36	3.97	3.99	1.51	4.14	4.38	2.89
CaO	4.27	5.65	4.86	4.09	10.17	8.43	9.41	8.30	8.11	7.50	7.53	4.99	8.47	8.54	8.62
Na2O	4.43	2.38	3.77	5.01	3.49	3.79	2.72	3.11	3.61	3.32	3.64	4.81	3.41	3.46	3.63
K2O	2.20	1.46	2.25	2.15	0.88	1.15	0.75	1.18	1.01	1.54	1.42	2.03	1.01	1.03	1.47
P2O5	0.25	0.15	0.14	0.27	0.15	0.25	0.15	0.23	0.19	0.25	0.15	0.25	0.18	0.19	0.26
LOI	0.00	2.13	0.00	0.47	0.47	0.22	1.20	0.00	0.00	0.00	0.00	-0.02	0.00	-0.06	0.57
Total	98.18	103.53	100.45	100.82	99.07	100.84	98.54	98.08	98.85	99.71	100.24	100.14	100.23	100.40	100.71
Rb		1.4		0.35	13							0.16		0.46	0.14
K	18264	12090	18678	17820	7307	9547	6226	9818	8398	12822	11760	16867	8365	8513	12175
Ba															
Sr					600										
La															
Ce															
Nd															
Y					20										
P			608		655	1091		1023	839	1094	653		784		
Zr					64										
Nb					5.7										
Ti	5740	6935	3700	6070	6236	6774	6220	6112	6004	5411	5383	4824	6100	6389	6501
V															
Cr															
Ni															
FeO*/MgO	4.03	2.58	2.55	3.94	1.83	2.15	1.85	2.21	2.49	1.90	1.85	3.47	2.08	1.97	2.40
CaO/Al2O3	0.27	0.36	0.30	0.25	0.54	0.47	0.50	0.47	0.44	0.43	0.43	0.29	0.45	0.47	0.47
K/Rb		8636		50915	562							105419		18506	86968
Rb/Sr					0.022										
Ba/La															
Rb/Y					0.65										
Rb/Zr					0.20										
Ce/Y															
Zr/Nb					11.2										
Zr/Y					3.2										
Y/Nb					3.5										

Makushin whole rock compositions - normalized to 100% anhydrous - original totals and LOIs

map no.	M4-36	M5-04	M5-05	M5-14	M5-18	M5-19	M5-20	M5-21	M5-22	M5-23	Mc-01	Mc-02	Mc-03	Mc-04	Mc-05
field no.	u647	m18	u634	u59s1	83mn11	83mn10	83mn09	83mq24	83mq25	83mq27	u201r1	u163r1	u147r1	u152r1	83mn80
SiO2	52.01	53.19	53.22	55.25	53.65	53.92	53.84	53.43	55.57	55.72	50.69	56.15	49.20	49.84	48.43
TiO2	1.14	1.05	1.01	1.08	1.03	0.77	0.91	0.98	1.01	0.98	0.88	0.95	0.91	0.95	0.97
Al2O3	18.62	19.09	17.57	18.94	18.15	17.98	17.07	16.75	17.34	17.42	12.16	18.49	17.40	18.13	18.72
Fe2O3	5.50	2.29	2.32	5.36	10.08	9.26	9.77	10.43	9.63	9.50	2.54	4.47	7.26	4.10	10.95
FeO	4.73	6.27	6.49	4.10							7.39	3.64	2.83	5.64	
MnO	0.18	0.18	0.19	0.14	0.18	0.16	0.17	0.18	0.18	0.18	0.20	0.16	0.18	0.17	0.17
MgO	4.74	3.36	5.18	3.10	3.82	4.67	4.88	5.20	3.51	3.48	10.30	3.25	7.79	6.72	6.71
CaO	9.25	10.19	9.66	7.72	8.14	8.65	8.88	8.59	7.47	7.43	12.51	8.10	10.90	10.90	10.65
Na2O	3.17	3.24	3.30	2.76	3.47	3.05	2.65	3.13	3.61	3.57	2.43	3.25	2.64	2.54	2.69
K2O	0.44	0.97	0.87	1.22	1.25	1.40	1.68	1.15	1.48	1.51	0.72	1.29	0.75	0.81	0.61
P2O5	0.21	0.16	0.19	0.35	0.23	0.13	0.14	0.15	0.20	0.20	0.19	0.25	0.15	0.19	0.11
LOI	1.09	1.32	0.53	0.87	-0.15	0.32	0.36	0.18	-0.08	-0.22	0.00	0.98	0.57	0.16	-0.23
Total	102.06	100.90	100.53	100.87	99.94	100.28	100.28	99.71	99.83	100.53	99.16	100.98	100.57	100.16	100.15
Rb	0.97	25			25	23	39	24	30	29					8
K	3618	8054	7193	10096	10368	11627	13958	9509	12297	12524	5957	10670	6186	6756	5045
Ba															
Sr		408			464	573	410	427	410	417					631
La															
Ce															
Nd															
Y		22			27	15	23	25	31	30					15
P		698			1003	568	611	658	874	866	817				478
Zr		83			119	88	117	107	136	135					50
Nb		5.9			6.9	6.5	6.8	6.4	6.9	6.7					4.7
Ti	6806	6296	6040	6494	6169	4618	5460	5903	6060	5891	5299	5703	5433	5722	5793
V															
Cr															
Ni															
FeO*/MgO	2.04	2.48	1.66	2.88	2.38	1.78	1.80	1.80	2.47	2.45	0.94	2.36	1.20	1.39	1.47
CaO/Al2O3	0.50	0.53	0.55	0.41	0.45	0.48	0.52	0.51	0.43	0.43	1.03	0.44	0.63	0.60	0.57
K/Rb	3730	322			415	506	358	396	410	432					631
Rb/Sr		0.061			0.054	0.040	0.095	0.056	0.073	0.070					0.013
Ba/La															
Rb/Y		1.14			0.93	1.53	1.70	0.96	0.97	0.97					0.53
Rb/Zr		0.30			0.21	0.26	0.33	0.22	0.22	0.21					0.16
Ce/Y															
Zr/Nb		14.1			17.2	13.5	17.2	16.7	19.7	20.1					10.6
Zr/Y		3.8			4.4	5.9	5.1	4.3	4.4	4.5					3.3
Y/Nb		3.7			3.9	2.3	3.4	3.9	4.5	4.5					3.2

Makushin whole rock compositions - normalized to 100% anhydrous - original totals and LOIs

map no.	Mc-06	Mc-07	Mc-08	Mc-09	Mc-11	Mc-11a	Mc-11b	Mc-13	Mc-18	Md-04	Md-06	Md-10	Md-14	Md-16	Md-20
field no.	83mn79	83mn78	u160r1	m32	u167r1	u158r2	u158r3	5	m30	m4	m6	m10	m14	m16	8
SiO2	48.61	48.20	49.48	49.56	61.61	48.53	49.10	50.55	49.27	54.24	54.74	54.31	55.64	54.26	51.83
TiO2	1.09	0.94	0.88	0.92	1.00	0.97	0.98	0.86	0.89	0.99	1.06	0.98	1.08	1.05	0.91
Al2O3	19.83	18.45	16.89	17.97	16.49	18.98	18.87	18.04	17.39	17.62	17.47	17.28	16.88	16.89	18.28
Fe2O3	11.23	11.14	3.94	3.91	3.65	4.60	4.11	2.60	3.50	3.26	3.25	2.64	4.46	3.53	3.10
FeO			5.52	5.74	3.60	5.60	5.78	6.38	6.07	5.42	5.41	6.01	4.16	5.21	6.12
MnO	0.18	0.17	0.18	0.18	0.18	0.18	0.18	0.14	0.18	0.17	0.17	0.17	0.15	0.17	0.17
MgO	4.75	7.38	8.65	7.36	1.86	7.39	6.95	7.27	8.06	4.45	4.30	4.75	4.36	5.24	5.81
CaO	10.74	10.39	11.10	10.60	4.15	10.52	10.66	10.48	10.93	8.73	8.47	8.87	7.86	8.74	10.26
Na2O	2.86	2.62	2.53	2.81	4.72	2.54	2.62	2.68	2.83	3.19	3.42	3.23	3.50	3.29	2.64
K2O	0.57	0.62	0.69	0.78	2.34	0.53	0.61	0.86	0.74	1.50	1.52	1.49	1.70	1.41	0.74
P2O5	0.15	0.10	0.15	0.17	0.42	0.15	0.14	0.14	0.13	0.42	0.20	0.27	0.21	0.20	0.14
LOI	-0.16	-0.16	-0.10	1.13	0.33	1.17	0.61	0.27	0.28	0.11	0.10	0.13	1.52	0.87	0.96
Total	100.06	100.29	99.90	100.86	100.33	101.17	100.61	99.85	100.72	99.07	99.26	98.93	100.40	99.52	99.93
Rb	11	9		12					9	33.9	34.8	35	45	32.1	
K	4722	5124	5694	6475	19408	4418	5025	7140	6144	12415	12642	12352	14105	11697	6123
Ba									227	421	437			395	
Sr	500	655		611					550	428	405	417	370	407	
La									8	14	11			14	
Ce									13	31	32			27	
Nd									8	19	19			16	
Y	20	13		14					15	32	31	28	35	29	
P	653	434		742				611	567	1852	880	1193	927	885	617
Zr	67	48		54					51	147.9	147.9	141	155	126.5	
Nb	6.2	4.5		5.3					3.6	6.2	7.4	7.8	6.8	6.1	
Ti	6520	5610	5261	5515	5972	5839	5866	5156	5336	5937	6348	5886	6487	6320	5452
V									258	248.4	241.2			250	
Cr									130	58.6	56.3			90.7	
Ni									40	17.6	16.3			33	
FeO*/MgO	2.13	1.36	1.05	1.26	3.70	1.32	1.36	1.20	1.14	1.88	1.94	1.77	1.87	1.60	1.53
CaO/Al2O3	0.54	0.56	0.66	0.59	0.25	0.55	0.56	0.58	0.63	0.50	0.48	0.51	0.47	0.52	0.56
K/Rb	429	569		540					683	366	363	353	313	364	
Rb/Sr	0.022	0.014		0.020					0.016	0.079	0.086	0.084	0.122	0.079	
Ba/La									28	31	40			28	
Rb/Y	0.55	0.69		0.86					0.60	1.07	1.13	1.25	1.29	1.13	
Rb/Zr	0.16	0.19		0.22					0.18	0.23	0.24	0.25	0.29	0.25	
Ce/Y									0.87	0.97	1.03			0.95	
Zr/Nb	10.8	10.7		10.2					14.2	23.9	20.0	18.1	22.8	20.7	
Zr/Y	3.4	3.7		3.9					3.4	4.7	4.8	5.0	4.4	4.4	
Y/Nb	3.2	2.9		2.6					4.2	5.1	4.1	3.6	5.1	4.7	

Makushin whole rock compositions - normalized to 100% anhydrous - original totals and LOIs

map no.	Me-01	Me-02	Me-03	Me-04	Me-05	Me-06	Me-07	Me-09	Mf-01	Mf-02	Mf-03	Mf-04	Mf-05	Mf-16	Mf-17
field no.	m34	m35	m36	m37	m38	m39	m40	m42	m45	m46	m47	m48	m49	mk3a	mk15
SiO2	53.15	52.72	54.09	52.47	52.82	50.22	61.62	51.48	53.33	53.61	52.12	49.79	51.07	61.02	50.90
TiO2	1.14	0.99	0.96	1.03	1.00	0.83	1.11	1.01	0.94	1.04	1.08	0.93	0.94	0.75	0.65
Al2O3	18.39	18.79	18.49	19.01	18.61	17.31	15.99	18.55	17.37	18.26	20.28	18.25	18.72	18.52	15.60
Fe2O3	2.81	2.45	2.98	2.40	2.79	3.67	0.99	4.35	3.17	2.84	3.56	3.77	3.40	0.00	0.00
FeO	6.27	6.10	5.36	6.41	5.93	5.37	6.21	4.97	5.32	6.05	4.67	5.87	5.36	5.60	9.16
MnO	0.19	0.18	0.18	0.18	0.18	0.16	0.21	0.18	0.16	0.19	0.18	0.18	0.17	0.12	0.18
MgO	4.32	4.64	4.16	4.56	4.59	7.22	1.82	4.94	5.41	4.23	3.06	6.90	5.09	2.21	9.58
CaO	8.76	9.44	8.78	9.35	9.29	11.51	4.92	10.22	9.44	9.18	9.86	10.04	10.60	6.35	10.06
Na2O	3.65	3.50	3.63	3.57	3.58	2.79	5.18	3.15	3.10	3.45	3.70	3.02	3.24	3.59	2.75
K2O	1.04	0.99	1.18	0.83	1.03	0.77	1.65	0.97	1.56	0.98	1.23	1.06	1.20	1.71	0.91
P2O5	0.28	0.20	0.20	0.17	0.20	0.15	0.29	0.17	0.19	0.16	0.25	0.18	0.22	0.14	0.21
LOI	0.02	0.02	0.09	0.08	0.06	0.06	0.06	1.15	0.20	0.15	0.44	0.34	0.36	0.00	0.00
Total	98.93	99.41	99.40	98.76	99.44	100.86	99.68	99.71	99.09	98.79	98.66	99.92	100.60	99.58	100.59
Rb	14.9	15	19.9	13		10.5	34.6	19	28	23	15.8	15	14.7		
K	8645	8185	9780	6898	8520	6424	13667	8086	12928	8164	10227	8837	9938	14172	7593
Ba	336		364	300		229	446		443		339		245		
Sr	573	612	553	536		467	351	497	566	398	733	690	619		
La	13		10	6		6	15		16		8		8		
Ce	24		26	21		15	32		34		24		18		
Nd	15		15	13		9	21		18		16		11		
Y	25	22	26	23		14	47	21	26	28	24	16	18		
P	1235	878	879	752	878	649	1270	753	839	708	1111	789	958	614	911
Zr	95.3	85	107	84		49.4	181.3	91	151.5	111	80.5	61	65.2		
Nb	4.5	5.5	4.7	4.6		2.9	6.2	6.6	8.3	5.8	3.8	5.1	3.3		
Ti	6849	5911	5735	6197	5972	4996	6680	6083	5638	6260	6470	5599	5622	4515	3874
V	298.2		254.4	280.6		259.4	75.6		261		286.6		255.6		
Cr	20.2		18.1	33.9		143.7	3.3		75.2		9.5		65.8		
Ni	2.7		11.1	8.1		63.8	0		33.4		4.9		22.6		
FeO*/MgO	2.04	1.79	1.93	1.88	1.84	1.20	3.91	1.80	1.51	2.04	2.57	1.34	1.65	2.54	0.96
CaO/Al2O3	0.48	0.50	0.47	0.49	0.50	0.66	0.31	0.55	0.54	0.50	0.49	0.55	0.57	0.34	0.64
K/Rb	580	546	491	531		612	395	426	462	355	647	589	676		
Rb/Sr	0.026	0.025	0.036	0.024		0.023	0.099	0.038	0.050	0.058	0.022	0.022	0.024		
Ba/La	25		36	55		36	30		27		45		32		
Rb/Y	0.60	0.68	0.77	0.57		0.75	0.74	0.90	1.06	0.82	0.66	0.94	0.81		
Rb/Zr	0.16	0.18	0.19	0.15		0.21	0.19	0.21	0.18	0.21	0.20	0.25	0.23		
Ce/Y	0.96		0.99	0.91		1.07	0.69		1.28		1.02		0.97		
Zr/Nb	21.2	15.5	22.8	18.3		17.0	29.2	13.8	18.3	19.1	21.2	12.0	19.8		
Zr/Y	3.9	3.9	4.1	3.7		3.5	3.9	4.3	5.8	4.0	3.4	3.8	3.6		
Y/Nb	5.5	4.0	5.5	5.0		4.8	7.5	3.2	3.2	4.8	6.3	3.1	5.5		

Makushin whole rock compositions - normalized to 100% anhydrous - original totals and LOIs

map no.	Mf-20	Mg-01	Mg-03	Mg-04	Mg-05	Mg-06	Mg-07	Mg-08	Mh-05	PC-01	PC-02	PC-03	PC-04	PC-05	PC-06
field no.	11	6	18	83mn49	83mn36	83mn39	83mn34	83mn33	83mn23	83mn01	m21	83mn82	83mn84	83mn85	83mn86
SiO2	53.97	50.96	60.23	66.17	55.22	55.20	58.09	52.31	49.03	51.56	51.60	50.66	53.66	53.39	50.20
TiO2	1.20	0.55	0.82	0.97	0.90	0.98	1.09	0.93	0.73	0.88	0.95	0.92	0.85	0.89	0.70
Al2O3	18.35	16.35	16.40	15.64	17.12	17.52	17.40	16.59	18.42	19.84	19.21	18.90	20.96	20.21	14.36
Fe2O3	3.51	3.21	3.50	6.54	9.33	9.55	8.79	10.10	9.74	9.51	3.25	10.37	7.82	8.52	10.33
FeO	5.32	4.91	3.60								5.67				
MnO	0.18	0.14	0.15	0.14	0.16	0.16	0.18	0.16	0.15	0.16	0.18	0.17	0.15	0.16	0.18
MgO	3.81	9.83	3.00	1.07	4.27	4.01	2.12	6.79	7.27	4.25	5.06	5.29	2.58	3.11	9.72
CaO	8.52	10.93	6.30	4.79	7.92	7.41	6.17	8.92	11.17	9.18	9.41	9.35	8.58	8.41	11.17
Na2O	3.81	2.11	3.70	3.99	2.99	3.07	4.22	2.59	2.48	3.18	3.32	3.07	3.72	3.66	2.32
K2O	0.98	0.89	2.10	0.43	1.92	1.92	1.71	1.46	0.84	1.27	1.16	1.12	1.46	1.44	0.89
P2O5	0.35	0.12	0.20	0.26	0.17	0.18	0.23	0.14	0.17	0.17	0.19	0.16	0.21	0.20	0.12
LOI	0.34	0.60	0.64	3.91	0.40	0.74	0.02	0.25	-0.01	-0.01	0.16	-0.10	-0.15	0.00	0.08
Total	100.05	100.30	100.61	99.78	100.08	100.18	100.14	100.09	99.99	100.38	98.83	100.16	99.70	99.72	99.60
Rb				17	45	47	37	33	13	16		16	19	21	14
K	8136	7389	17435	3550	15907	15945	14179	12140	6973	10502	9629	9274	12139	11988	7424
Ba															
Sr				581	410	413	376	406	628	742		707	765	731	565
La															
Ce															
Nd															
Y				44	26	28	37	22	13	17		15	20	19	13
P	1528	524	873	1138	744	790	1003	612	742	739	829	696	918	875	526
Zr				234	144	162	161	116	66	70		64	87	84	52
Nb				8.4	7.3	8.5	6.6	6.3	5.2	5.3		5.4	5.5	5.7	5.2
Ti	7195	3298	4916	5816	5413	5848	6527	5584	4376	5255	5695	5501	5103	5351	4217
V															
Cr															
Ni															
FeO*/MgO	2.23	0.79	2.25	5.48	1.96	2.14	3.74	1.34	1.21	2.01	1.70	1.77	2.72	2.47	0.96
CaO/Al2O3	0.46	0.67	0.38	0.31	0.46	0.42	0.35	0.54	0.61	0.46	0.49	0.49	0.41	0.42	0.78
K/Rb				209	353	339	383	368	536	656		580	639	571	530
Rb/Sr				0.029	0.110	0.114	0.098	0.081	0.021	0.022		0.023	0.025	0.029	0.025
Ba/La															
Rb/Y				0.39	1.73	1.68	1.00	1.50	1.00	0.94		1.07	0.95	1.11	1.08
Rb/Zr				0.07	0.31	0.29	0.23	0.28	0.20	0.23		0.25	0.22	0.25	0.27
Ce/Y															
Zr/Nb				27.9	19.7	19.1	24.4	18.4	12.7	13.2		11.9	15.8	14.7	10.0
Zr/Y				5.3	5.5	5.8	4.4	5.3	5.1	4.1		4.3	4.4	4.4	4.0
Y/Nb				5.2	3.6	3.3	5.6	3.5	2.5	3.2		2.8	3.6	3.3	2.5

Makushin whole rock compositions - normalized to 100% anhydrous - original totals and LOIs

map no.	PC-07	PC-08	PC-09	PC-10	PC-11	PC-12	PC-13	PC-14	PC-15	PC-20	PC-50	PK-01	PK-02	PK-03	PK-04
field no.	7	83mn29	83mn25	83mn24	m20	83mn28	83mn27	83mn26	u58s1	u70r82	u5154h	u638b	m62	u638a	u638c
SiO2	51.44	53.64	49.96	53.80	54.97	53.68	52.79	52.92	54.41	54.42	50.09	59.68	59.41	49.05	
TiO2	0.89	0.91	0.66	0.87	0.89	0.91	0.91	0.95	0.94	0.87	0.98	1.20	1.23	0.94	
Al2O3	18.43	20.06	13.72	20.05	19.73	19.92	19.28	18.87	19.50	19.52	22.32	16.15	16.58	18.21	
Fe2O3	3.32	8.55	10.44	8.54	2.32	8.61	9.49	9.70	2.95	3.06	0.00	2.07	2.01	4.02	
FeO	6.06				4.63				4.75	4.48	9.70	6.12	6.03	5.66	
MnO	0.18	0.16	0.17	0.16	0.17	0.16	0.17	0.18	0.18	0.17	0.18	0.21	0.21	0.18	
MgO	5.98	3.04	10.64	3.06	3.03	3.02	3.96	4.13	3.99	3.76	7.76	2.51	2.22	6.95	
CaO	9.52	8.21	11.25	8.00	8.39	8.23	8.47	8.21	8.11	8.13	6.22	5.59	5.52	11.45	
Na2O	2.98	3.70	2.20	3.79	4.16	3.74	3.47	3.49	3.51	3.84	2.44	4.52	4.81	2.56	
K2O	1.02	1.52	0.84	1.49	1.47	1.52	1.30	1.35	1.40	1.37	0.19	1.66	1.72	0.80	
P2O5	0.18	0.21	0.13	0.24	0.24	0.21	0.18	0.19	0.27	0.39	0.12	0.29	0.26	0.18	
LOI	0.36	-0.24	-0.13	-0.08	0.02	-0.19	0.01	0.10	0.00	0.01	0.00	0.00	0.24	-0.07	
Total	99.74	100.09	100.42	100.13	100.71	100.14	100.37	99.99	101.76	100.89	99.27	99.62	99.93	99.97	
Rb		21	13	20		21	18	21					38	0.04	
K	8467	12577	6935	12343	12205	12577	10753	11220	11628	11356	1577	13750	14279	6653	
Ba													524		
Sr		728	538	702		723	630	616					356		
La													17		
Ce													37		
Nd													23		
Y		20	13	21		20	20	20					41		
P	785	913	564	1045	1048	913	783	830	1162		524	1270	1135		
Zr		87	48	90		89	79	83					175		
Nb		5.5	5.2	5.6		6.1	5.2	5.9					6.4		
Ti	5335	5438	3935	5205	5336	5438	5436	5702	5618	5230	5875	7221	7374	5656	
V													134		
Cr													4		
Ni													0		
FeO*/MgO	1.51	2.53	0.88	2.51	2.22	2.57	2.16	2.11	1.86	1.93	1.25	3.18	3.53	1.33	
CaO/Al2O3	0.52	0.41	0.82	0.40	0.43	0.41	0.44	0.44	0.42	0.42	0.28	0.35	0.33	0.63	
K/Rb		599	533	617		599	597	534					376	166318	
Rb/Sr		0.029	0.024	0.028		0.029	0.029	0.034					0.107		
Ba/La													31		
Rb/Y		1.05	1.00	0.95		1.05	0.90	1.05					0.93		
Rb/Zr		0.24	0.27	0.22		0.24	0.23	0.25					0.22		
Ce/Y													0.90		
Zr/Nb		15.8	9.2	16.1		14.6	15.2	14.1					27.3		
Zr/Y		4.4	3.7	4.3		4.5	4.0	4.2					4.3		
Y/Nb		3.6	2.5	3.8		3.3	3.8	3.4					6.4		

Makushin whole rock compositions - normalized to 100% anhydrous - original totals and LOIs

map no.	PK-05	SL-01	SL-02	TT-01	TT-02	TT-04	TT-05	TT-06	TT-07	TT-08	TT-09	TT-10	WB-01	WB-02	WB-03
field no.	g4782un	u6281	u55r82	u164r3	83mn73	83mn74	u173r1	83mn75	3	u165r1	83mn76	83mn77	u26s1	u24s1	u145r1
SiO2		53.45	53.90	49.51	48.95	48.47	49.06	48.27	49.64	48.92	48.38	48.37	48.96	49.45	49.58
TiO2		0.90	0.98	0.95	0.94	0.95	0.96	0.94	0.96	0.95	0.93	0.93	0.98	0.92	0.88
Al2O3		17.32	18.94	17.98	18.29	18.69	18.94	18.92	17.85	18.57	18.50	18.66	17.55	16.71	16.39
Fe2O3		3.62	3.42	3.89	11.09	11.00	4.10	10.97	6.72	3.74	11.08	11.11	4.67	3.76	3.37
FeO		4.65	5.49	5.76			5.66		3.61	6.02			5.12	5.53	6.14
MnO		0.16	0.19	0.18	0.18	0.19	0.19	0.19	0.20	0.18	0.19	0.19	0.19	0.18	0.18
MgO		6.35	4.27	6.53	5.89	5.83	6.10	5.80	6.42	6.49	6.07	5.95	7.56	8.30	8.22
CaO		9.83	8.03	11.40	11.12	11.31	11.41	11.35	11.23	11.47	11.42	11.34	11.39	11.68	12.03
Na2O		2.96	3.36	2.79	2.57	2.57	2.53	2.59	2.41	2.67	2.48	2.50	2.60	2.56	2.31
K2O		0.56	1.08	0.83	0.83	0.84	0.82	0.83	0.76	0.81	0.81	0.82	0.79	0.76	0.73
P2O5		0.20	0.35	0.17	0.15	0.15	0.22	0.16	0.20	0.17	0.14	0.14	0.18	0.15	0.18
LOI		0.00	0.62	0.18	-0.08	-0.17	0.00	-0.19	0.56	0.46	-0.17	-0.35	2.17	0.20	0.00
Total		97.80	100.98	100.52	99.93	100.18	99.65	100.19	100.28	100.69	100.05	99.94	102.65	100.41	100.50
Rb				0.34	13	14		14		0.23	13	13	0.48	0.21	
K		4649	8934	6892	6890	6949	6831	6864	6309	6732	6710	6788	6565	6316	6030
Ba															
Sr					592	574		578			571	585			
La															
Ce															
Nd															
Y					19	20		20			19	19			
P		873			655	652	963	696	873		610	609			782
Zr					62	61		61			61	60			
Nb					5.8	5.8		5.9			6.4	5.6			
Ti		5396	5854	5705	5635	5675	5775	5614	5755	5712	5563	5559	5863	5521	5249
V															
Cr															
Ni															
FeO*/MgO		1.25	2.00	1.42	1.69	1.70	1.53	1.70	1.50	1.45	1.64	1.68	1.23	1.07	1.12
CaO/Al2O3		0.57	0.42	0.63	0.61	0.61	0.60	0.60	0.63	0.62	0.62	0.61	0.65	0.70	0.73
K/Rb				20271	530	496		490		29270	516	522	13676	30074	
Rb/Sr					0.022	0.024		0.024			0.023	0.022			
Ba/La															
Rb/Y					0.68	0.70		0.70			0.68	0.68			
Rb/Zr					0.21	0.23		0.23			0.21	0.22			
Ce/Y															
Zr/Nb					10.7	10.5		10.3			9.5	10.7			
Zr/Y					3.3	3.1		3.1			3.2	3.2			
Y/Nb					3.3	3.4		3.4			3.0	3.4			

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Makushin whole rock compositions - normalized to 100% anhydrous - original totals and LOIs

map no.	WB-04	
field no.	4	
SiO2	~~55.50~~	49.60
TiO2	~~0.98~~	0.88
Al2O3	~~18.46~~	16.50
Fe2O3	~~3.58~~	3.20
FeO	~~6.94~~	6.20
MnO	~~0.20~~	0.18
MgO	~~8.74~~	7.80
CaO	~~1.79~~	11.60
Na2O	~~2.80~~	2.50
K2O	~~0.81~~	0.72
P2O5	~~0.20~~	0.18
LOI	~~0.37~~	0.49
Total	~~89.94~~	99.85
Rb		
K	~~6724~~	5977
Ba		
Sr		
La		
Ce		
Nd		
Y		
P	~~873~~	785
Zr		
Nb		
Ti	5875	5276
V		
Cr		
Ni		
FeO*/MgO	1.16	
CaO/Al2O3	~~0.10~~	0.70
K/Rb		
Rb/Sr		
Ba/La		
Rb/Y		
Rb/Zr		
Ce/Y		
Zr/Nb		
Zr/Y		
Y/Nb		

Appendix 3 - Mineral Analyses

Mineral analyses are reported in the order plagioclase, olivine, Ca-rich clinopyroxene, orthopyroxene, pigeonite and magnetite/spinel. Analyses within each group are alphabetized by map number. Cores and rims from the same grain are enclosed by parentheses.

Olivine and plagioclase data are recast into atomic amounts assuming that there is no Fe^{+3}. Pyroxenes are recalculated by the method of Lindsley (1983), where non-quadrilateral components and Fe^{3+} are calculated stoichiometrically. Spinels are recalculated on the ulvospinel basis and assume that the minerals are stoichiometrically correct.

Analyses were obtained from the Washington State University fully automated Cameca microprobe. Those analyses from samples with field numbers starting with "m" are by S.E. Swanson, all others are by C.J. Nye.

Makushin plagioclase compositions

	LR-11 m19 (core 3	LR-11 m19 rim) 4	LR-11 m19 (core 7	LR-11 m19 mid 8	LR-11 m19 rim) 9	LR-11 m19 (core 19	LR-11 m19 rim) 20	LR-11 m19 gms 25	LR-11 m19 gms 29	M1-51c m43c (core 1	M1-51c m43c rim) 2	M1-51c m43c (core 3	M1-51c m43c rim) 4	M1-51c m43c (core 5	M1-51c m43c rim) 6
wt% oxides															
SiO2	53.93	62.28	43.14	54.02	50.88	50.87	52.71	58.39	53.22	56.20	55.61	55.58	56.31	54.86	56.26
Al2O3	25.91	21.41	32.88	26.07	27.74	26.46	25.57	24.41	27.36	26.45	26.31	26.68	26.54	27.01	26.24
FeO	0.65	0.46	0.71	0.59	0.62	0.50	0.64	0.81	0.98	0.50	0.51	0.50	0.43	0.53	0.60
CaO	9.56	3.31	16.96	9.29	11.56	9.37	8.27	6.56	10.16	9.09	9.15	10.03	9.56	10.62	9.87
Na2O	5.49	8.36	1.47	5.75	4.76	5.25	5.83	7.34	5.61	6.03	6.05	5.58	5.91	5.21	5.95
K2O	0.42	1.79	0.05	0.33	0.25	0.29	0.42	0.89	0.41	0.27	0.28	0.26	0.27	0.29	0.27
tot	95.96	97.61	95.21	96.05	95.81	92.74	93.44	98.40	97.74	98.54	97.91	98.63	99.02	98.52	99.19
atoms per 8 oxygens															
Si	2.5370	2.8374	2.0961	2.5365	2.4157	2.4775	2.5409	2.6641	2.4720	2.5640	2.5565	2.5396	2.5587	2.5145	2.5581
Al	1.4370	1.1499	1.8834	1.4432	1.5527	1.5192	1.4532	1.3130	1.4983	1.4226	1.4259	1.4372	1.4217	1.4595	1.4066
Fe	0.0256	0.0175	0.0289	0.0232	0.0246	0.0204	0.0258	0.0309	0.0381	0.0191	0.0196	0.0191	0.0163	0.0203	0.0228
Ca	0.4819	0.1616	0.8830	0.4674	0.5881	0.4890	0.4272	0.3207	0.5057	0.4444	0.4507	0.4911	0.4655	0.5216	0.4809
Na	0.5008	0.7385	0.1385	0.5235	0.4382	0.4958	0.5449	0.6494	0.5053	0.5334	0.5393	0.4944	0.5207	0.4630	0.5246
K	0.0252	0.1040	0.0031	0.0198	0.0151	0.0180	0.0258	0.0518	0.0243	0.0157	0.0164	0.0152	0.0157	0.0170	0.0157
tot	5.0075	5.0089	5.0330	5.0135	5.0346	5.0198	5.0179	5.0299	5.0436	4.9992	5.0084	4.9965	4.9986	4.9958	5.0087
An	0.4904	0.1795	0.8644	0.4717	0.5730	0.4965	0.4394	0.3306	0.5002	0.4545	0.4553	0.4983	0.4720	0.5297	0.4783
Ab	0.4969	0.7355	0.1352	0.5180	0.4208	0.4944	0.5461	0.6355	0.4881	0.5369	0.5358	0.4941	0.5198	0.4623	0.5137
Or	0.0250	0.1036	0.0030	0.0196	0.0145	0.0180	0.0259	0.0507	0.0235	0.0158	0.0163	0.0151	0.0156	0.0169	0.0153

Makushin plagioclase compositions

	M1-51d	M1-51d	M1-51d	M1-51d	M1-51d	M1-51d	M1-51d	M1-51d	Mc-18	Mc-18	Mc-18	Mc-18	Mc-18	Mc-18	Md-04
	m43f	m43f	m43f	m43f	m43f	m43f	m43f	m43f	m30	m30	m30	m30	m30	m30	m04
	(core	rim)	(core	rim)	(core	rim)	(core	rim)	(core	rim)	(core	rim)	gms	gms	(core
	14	15	16	17	18	19	20	21	22	23	24	25	19	21	18
wt% oxides															
SiO2	47.11	48.44	50.95	48.74	47.40	47.34	47.99	46.94	46.73	49.36	45.32	52.40	55.48	52.87	53.68
Al2O3	32.33	31.07	29.55	31.24	32.36	32.12	31.38	31.88	32.63	29.85	33.31	27.78	26.68	28.04	27.67
FeO	0.55	0.70	0.62	0.69	0.69	0.72	0.61	0.82	0.73	1.11	0.82	1.09	1.19	1.40	0.72
CaO	16.45	15.58	13.69	15.26	16.29	16.45	15.76	16.25	16.49	14.10	17.27	12.00	10.05	11.71	11.20
Na2O	1.96	2.66	3.88	2.76	2.09	2.15	2.52	2.10	1.89	3.52	1.49	4.53	5.72	4.57	4.63
K2O	0.03	0.07	0.09	0.08	0.05	0.04	0.05	0.07	0.07	0.20	0.06	0.29	0.47	0.33	0.38
tot	98.43	98.52	98.78	98.77	98.88	98.82	98.31	98.06	98.54	98.14	98.27	98.09	99.59	98.92	98.28
atoms per 8 oxygens															
Si	2.1989	2.2566	2.3539	2.2620	2.2032	2.2042	2.2406	2.2033	2.1821	2.3081	2.1300	2.4334	2.5254	2.4352	2.4734
Al	1.7790	1.7064	1.6095	1.7092	1.7732	1.7631	1.7273	1.7642	1.7963	1.6456	1.8456	1.5209	1.4318	1.5226	1.5030
Fe	0.0215	0.0273	0.0240	0.0268	0.0268	0.0280	0.0238	0.0322	0.0285	0.0434	0.0322	0.0423	0.0453	0.0539	0.0277
Ca	0.8227	0.7777	0.6777	0.7588	0.8113	0.8207	0.7884	0.8173	0.8251	0.7065	0.8697	0.5971	0.4902	0.5779	0.5530
Na	0.1774	0.2403	0.3476	0.2484	0.1884	0.1941	0.2281	0.1911	0.1711	0.3192	0.1358	0.4079	0.5049	0.4082	0.4137
K	0.0018	0.0042	0.0053	0.0047	0.0030	0.0024	0.0030	0.0042	0.0042	0.0119	0.0036	0.0172	0.0273	0.0194	0.0223
tot	5.0012	5.0124	5.0179	5.0099	5.0059	5.0125	5.0113	5.0123	5.0074	5.0346	5.0169	5.0187	5.0248	5.0172	4.9931
An	0.8226	0.7640	0.6610	0.7534	0.8116	0.8087	0.7756	0.8105	0.8282	0.6888	0.8650	0.5941	0.4926	0.5861	0.5721
Ab	0.1771	0.2351	0.3373	0.2454	0.1879	0.1908	0.2238	0.1887	0.1711	0.3076	0.1346	0.3990	0.4938	0.4059	0.4183
Or	0.0018	0.0041	0.0051	0.0047	0.0030	0.0023	0.0029	0.0041	0.0042	0.0115	0.0036	0.0168	0.0267	0.0193	0.0226

Makushin plagioclase compositions

	Md-04 m04 rim) 19	Md-04 m04 (core 20	Md-04 m04 rim) 21	Md-04 m04 gms 22	Md-04 m04 gms 23	Md-14 m14 (core 1	Md-14 m14 rim) 2	Md-14 m14 (core 3	Md-14 m14 rim) 4	Md-14 m14 (core 5	Md-14 m14 rim) 6	Md-14 m14 gms 7	Md-14 m14 gms 8	Md-14 m14 gms 9	Me-03 m36 (core 14
wt% oxides															
SiO2	54.10	54.60	54.83	54.18	53.59	52.11	54.06	54.89	54.66	53.70	54.65	52.99	51.98	59.66	45.37
Al2O3	26.91	27.01	28.86	27.19	27.73	29.19	28.14	27.26	27.60	28.32	27.10	28.28	29.13	24.82	33.32
FeO	0.87	0.61	0.80	1.01	1.00	0.70	0.78	0.65	0.69	0.75	0.60	0.97	0.99	0.82	0.51
CaO	10.62	10.42	10.13	10.60	10.97	12.55	11.25	10.73	11.03	11.80	10.75	12.28	12.75	7.14	17.34
Na2O	4.87	5.20	5.43	5.46	4.79	4.14	5.21	5.37	4.94	4.87	5.29	4.23	4.07	7.52	1.62
K2O	0.38	0.45	0.46	0.38	0.38	0.25	0.40	0.41	0.40	0.40	0.41	0.26	0.26	0.45	0.04
tot	97.75	98.29	100.51	98.82	98.46	98.94	99.84	99.31	99.32	99.84	98.80	99.01	99.18	100.41	98.20
atoms per 8 oxygens															
Si	2.5038	2.5108	2.4674	2.4884	2.4682	2.3952	2.4587	2.5022	2.4907	2.4447	2.5035	2.4332	2.3889	2.6645	2.1317
Al	1.4683	1.4643	1.5311	1.4723	1.5057	1.5818	1.5089	1.4650	1.4827	1.5199	1.4636	1.5309	1.5783	1.3068	1.8457
Fe	0.0337	0.0235	0.0301	0.0388	0.0385	0.0269	0.0297	0.0248	0.0263	0.0286	0.0230	0.0372	0.0381	0.0306	0.0200
Ca	0.5266	0.5134	0.4884	0.5217	0.5414	0.6181	0.5483	0.5241	0.5385	0.5756	0.5277	0.6042	0.6279	0.3417	0.8730
Na	0.4370	0.4637	0.4738	0.4863	0.4278	0.3690	0.4595	0.4747	0.4365	0.4299	0.4699	0.3766	0.3627	0.6512	0.1476
K	0.0224	0.0264	0.0264	0.0223	0.0223	0.0147	0.0232	0.0238	0.0233	0.0232	0.0240	0.0152	0.0152	0.0256	0.0024
tot	4.9918	5.0021	5.0172	5.0297	5.0040	5.0057	5.0282	5.0146	4.9979	5.0219	5.0116	4.9973	5.0110	5.0205	5.0204
An	0.5465	0.5255	0.5076	0.5176	0.5586	0.6262	0.5441	0.5248	0.5523	0.5725	0.5290	0.6160	0.6339	0.3441	0.8554
Ab	0.4432	0.4620	0.4792	0.4720	0.4315	0.3683	0.4457	0.4642	0.4372	0.4179	0.4600	0.3781	0.3606	0.6394	0.1443
Or	0.0228	0.0263	0.0267	0.0216	0.0225	0.0146	0.0225	0.0233	0.0233	0.0226	0.0235	0.0153	0.0152	0.0252	0.0023

Makushin plagioclase compositions

	Me-03 m36 rim) 15	Me-03 m36 (core 16	Me-03 m36 rim) 17	Me-03 m36 gms 18	Me-03 m36 gms 19	Me-06 m39 (core 1	Me-06 m39 rim) 2	Me-06 m39 core 3	Me-06 m39 core 4	Me-06 m39 (core 5	Me-06 m39 rim) 6	Me-06 m39 (core 10	Me-06 m39 rim) 11	Me-06 m39 (core 14	Me-06 m39 rim) 15
wt% oxides															
SiO2	54.12	46.64	55.63	54.62	56.02	50.76	55.83	51.82	52.80	50.03	52.55	53.58	54.63	54.14	53.16
Al2O3	27.14	32.46	26.10	26.37	25.97	26.74	24.32	25.89	26.08	26.62	25.08	27.72	27.05	27.70	28.05
FeO	0.84	0.65	1.02	0.95	0.95	0.47	0.65	0.65	0.62	0.49	0.61	0.53	0.53	0.61	0.59
CaO	11.03	16.83	10.10	10.24	9.48	10.27	7.53	9.50	9.26	10.15	8.19	10.87	10.42	10.96	11.35
Na2O	5.30	1.95	5.66	5.55	5.95	5.06	6.85	5.65	5.79	5.10	5.88	4.96	5.51	5.33	5.00
K2O	0.31	0.08	0.33	0.31	0.41	0.13	0.32	0.17	0.20	0.10	0.20	0.15	0.17	0.12	0.13
tot	98.74	98.61	98.84	98.04	98.78	93.43	95.50	93.68	94.75	92.49	92.51	97.81	98.31	98.86	98.28
atoms per 8 oxygens															
Si	2.4870	2.1794	2.5462	2.5226	2.5617	2.4582	2.6254	2.5014	2.5158	2.4490	2.5546	2.4752	2.5095	2.4783	2.4511
Al	1.4703	1.7882	1.4083	1.4358	1.4000	1.5267	1.3483	1.4733	1.4650	1.5362	1.4374	1.5097	1.4649	1.4949	1.5247
Fe	0.0323	0.0254	0.0390	0.0367	0.0363	0.0190	0.0256	0.0262	0.0247	0.0201	0.0248	0.0205	0.0204	0.0234	0.0228
Ca	0.5431	0.8427	0.4953	0.5067	0.4645	0.5329	0.3794	0.4914	0.4728	0.5324	0.4266	0.5381	0.5129	0.5376	0.5607
Na	0.4722	0.1767	0.5023	0.4970	0.5276	0.4751	0.6246	0.5288	0.5349	0.4841	0.5543	0.4443	0.4908	0.4731	0.4470
K	0.0182	0.0048	0.0193	0.0183	0.0239	0.0080	0.0192	0.0105	0.0122	0.0062	0.0124	0.0088	0.0100	0.0070	0.0076
tot	5.0231	5.0172	5.0105	5.0171	5.0140	5.0200	5.0224	5.0316	5.0253	5.0280	5.0100	4.9965	5.0084	5.0143	5.0139
An	0.5349	0.8267	0.4965	0.5048	0.4682	0.5287	0.3779	0.4816	0.4692	0.5238	0.4349	0.5477	0.5110	0.5319	0.5564
Ab	0.4569	0.1725	0.4940	0.4863	0.5193	0.4676	0.6104	0.5131	0.5245	0.4733	0.5580	0.4482	0.4842	0.4649	0.4402
Or	0.0176	0.0047	0.0189	0.0179	0.0235	0.0079	0.0188	0.0102	0.0119	0.0061	0.0125	0.0089	0.0098	0.0069	0.0075

Makushin plagioclase compositions

	Me-06	Me-06	Me-07	Me-07	Me-07	Me-07	Me-07	Me-07	Me-07	Me-07	Me-07	Mf-01	Mf-01	Mf-01	Mf-01
	m39	m39	m40	m40	m40	m40	m40	m40	m40	m40	m40	m45	m45	m45	m45
	gms	gms	(rim	core)	(rim	core)	(rim	core)	gms	gms	gms	(core	rim)	(core	rim)
	16	19	1	2	3	4	5	6	7	8	9	13	14	15	16
wt% oxides															
SiO2	58.30	56.13	51.49	45.20	50.72	44.29	50.14	43.92	51.28	55.19	52.64	52.92	49.84	53.55	49.03
Al2O3	24.44	26.01	28.97	33.18	28.95	34.11	29.24	33.91	28.70	26.97	28.01	28.17	29.34	28.15	30.30
FeO	1.23	0.79	1.41	0.95	1.33	0.76	1.19	0.76	1.31	0.90	1.08	0.67	0.83	0.56	0.88
CaO	8.14	8.98	12.85	17.54	13.20	18.09	13.45	18.23	13.06	10.14	11.56	11.48	13.78	11.41	14.56
Na2O	6.24	6.27	3.94	1.49	3.94	1.10	3.91	1.20	4.11	5.41	4.72	4.66	3.54	4.76	3.01
K2O	0.37	0.25	0.30	0.09	0.30	0.04	0.20	0.06	0.24	0.57	0.54	0.36	0.25	0.41	0.21
tot	98.72	98.43	98.96	98.45	98.44	98.39	98.13	98.08	98.70	99.18	98.55	98.26	97.58	98.84	97.99
atoms per 8 oxygens															
Si	2.6522	2.5692	2.3787	2.1250	2.3604	2.0841	2.3414	2.0769	2.3777	2.5187	2.4339	2.4434	2.3369	2.4557	2.2934
Al	1.3108	1.4036	1.5778	1.8390	1.5883	1.8923	1.6098	1.8904	1.5688	1.4510	1.5268	1.5334	1.6219	1.5219	1.6709
Fe	0.0468	0.0302	0.0545	0.0374	0.0518	0.0299	0.0465	0.0301	0.0508	0.0343	0.0418	0.0259	0.0325	0.0215	0.0344
Ca	0.3968	0.4404	0.6361	0.8836	0.6582	0.9121	0.6730	0.9237	0.6488	0.4958	0.5727	0.5680	0.6923	0.5607	0.7297
Na	0.5504	0.5565	0.3529	0.1358	0.3555	0.1004	0.3540	0.1100	0.3695	0.4787	0.4232	0.4172	0.3219	0.4233	0.2730
K	0.0215	0.0146	0.0177	0.0054	0.0178	0.0024	0.0119	0.0036	0.0142	0.0332	0.0319	0.0212	0.0150	0.0240	0.0125
tot	4.9784	5.0145	5.0177	5.0261	5.0321	5.0211	5.0367	5.0347	5.0298	5.0118	5.0302	5.0091	5.0205	5.0070	5.0140
An	0.4189	0.4418	0.6431	0.8668	0.6493	0.9009	0.6553	0.8936	0.6372	0.5088	0.5751	0.5765	0.6826	0.5698	0.7277
Ab	0.5682	0.5502	0.3506	0.1325	0.3447	0.0989	0.3408	0.1061	0.3579	0.4750	0.4117	0.4146	0.3127	0.4199	0.2689
Or	0.0222	0.0144	0.0176	0.0053	0.0173	0.0024	0.0115	0.0035	0.0137	0.0329	0.0310	0.0211	0.0145	0.0238	0.0123

Makushin plagioclase compositions

	Mf-01	Mf-01	Mf-04	Mf-04	Mf-04	Mf-04	Mf-04	PC-02	PC-02	PC-02	PC-02	PC-02	PC-02	PC-02	PC-11
	m45	m45	m48	m48	m48	m48	m48	m21	m21	m21	m21	m21	m21	m21	m20
	gms	gms	(core	rim)	(core	rim)	gms	(core	rim)	(core	rim	rim)	gms	gms	(core
	17	18	12	13	17	18	14	17	18	19	20	21	15	16	1
wt% oxides															
SiO2	49.33	50.86	51.96	50.93	45.60	58.02	52.76	46.68	53.11	47.09	47.22	53.37	53.12	54.11	46.44
Al2O3	29.94	29.19	28.70	28.52	32.77	24.74	27.92	32.59	27.72	32.35	31.93	27.77	27.63	27.24	32.76
FeO	0.88	1.05	1.38	1.38	0.77	0.79	1.24	0.71	1.01	0.85	0.99	1.11	1.17	1.15	0.68
CaO	14.22	12.60	12.54	12.77	17.10	7.44	11.25	16.84	11.54	16.84	15.84	11.26	11.51	11.01	16.84
Na2O	3.17	3.63	4.18	4.09	1.61	6.70	4.80	2.06	4.87	2.09	2.31	5.06	4.77	5.14	1.85
K2O	0.23	0.32	0.26	0.30	0.08	0.84	0.39	0.09	0.36	0.07	0.12	0.31	0.33	0.41	0.08
tot	97.77	97.65	99.02	97.99	97.93	98.53	98.36	98.97	98.61	99.29	98.41	98.88	98.53	99.06	98.65
atoms per 8 oxygens															
Si	2.3106	2.3733	2.3961	2.3787	2.1493	2.6455	2.4414	2.1752	2.4503	2.1875	2.2088	2.4546	2.4529	2.4822	2.1692
Al	1.6533	1.6058	1.5603	1.5704	1.8210	1.3299	1.5231	1.7903	1.5077	1.7717	1.7609	1.5057	1.5042	1.4732	1.8040
Fe	0.0345	0.0410	0.0532	0.0539	0.0304	0.0301	0.0480	0.0277	0.0390	0.0330	0.0387	0.0427	0.0452	0.0441	0.0266
Ca	0.7137	0.6300	0.6196	0.6391	0.8636	0.3635	0.5578	0.8408	0.5705	0.8382	0.7939	0.5549	0.5695	0.5412	0.8428
Na	0.2879	0.3284	0.3738	0.3704	0.1471	0.5924	0.4307	0.1861	0.4357	0.1883	0.2095	0.4512	0.4271	0.4572	0.1676
K	0.0137	0.0191	0.0153	0.0179	0.0048	0.0489	0.0230	0.0054	0.0212	0.0041	0.0072	0.0182	0.0194	0.0240	0.0048
tot	5.0136	4.9976	5.0183	5.0303	5.0162	5.0102	5.0239	5.0254	5.0243	5.0228	5.0191	5.0273	5.0183	5.0218	5.0149
An	0.7126	0.6573	0.6238	0.6331	0.8544	0.3803	0.5643	0.8188	0.5670	0.8166	0.7912	0.5515	0.5714	0.5421	0.8342
Ab	0.2836	0.3360	0.3705	0.3605	0.1449	0.5896	0.4258	0.1803	0.4241	0.1827	0.2073	0.4405	0.4204	0.4472	0.1651
Or	0.0135	0.0195	0.0152	0.0174	0.0047	0.0486	0.0228	0.0052	0.0206	0.0040	0.0071	0.0178	0.0191	0.0235	0.0047

Makushin plagioclase compositions

	PC-11 m20 rim) 2	PC-11 m20 (core 3	PC-11 m20 rim) 4	PC-11 m20 (core 5	PC-11 m20 rim) 6	PC-11 m20 gms 7	PC-11 m20 gms 8	PK-02 m52 (rim 2	PK-02 m52 core) 3	PK-02 m52 (core 4	PK-02 m52 rim) 5	PK-02 m52 (core 6	PK-02 m52 rim) 7	PK-02 m52 gms 8	PK-02 m52 gms 9
wt% oxides															
SiO2	56.74	44.34	52.35	46.64	55.87	53.12	54.98	48.35	51.86	53.90	56.32	54.58	53.07	55.07	54.62
Al2O3	26.23	33.99	28.82	32.59	26.13	27.91	26.49	28.63	26.09	28.23	25.16	27.67	27.95	26.86	26.53
FeO	0.82	0.56	0.73	0.74	0.76	0.91	0.93	0.59	0.49	0.55	1.00	0.50	0.62	0.94	0.86
CaO	9.61	18.61	12.06	16.51	8.97	11.07	9.83	11.69	9.34	11.28	8.97	10.94	11.38	10.25	10.14
Na2O	5.95	1.14	4.35	1.96	5.89	5.01	5.77	4.06	5.20	4.80	5.86	5.20	4.93	5.54	5.54
K2O	0.51	0.04	0.22	0.05	0.48	0.24	0.47	0.11	0.20	0.20	0.36	0.17	0.17	0.22	0.23
tot	99.86	98.68	98.53	98.49	98.10	98.26	98.47	93.43	93.18	98.96	97.67	99.06	98.12	98.88	97.92
atoms per 8 oxygens															
Si	2.5654	2.0826	2.4131	2.1800	2.5656	2.4532	2.5277	2.3534	2.5077	2.4633	2.5970	2.4897	2.4517	2.5186	2.5220
Al	1.3981	1.8821	1.5661	1.7959	1.4146	1.5196	1.4358	1.6429	1.4873	1.5210	1.3678	1.4880	1.5223	1.4483	1.4442
Fe	0.0310	0.0220	0.0281	0.0289	0.0292	0.0351	0.0358	0.0240	0.0198	0.0210	0.0386	0.0191	0.0240	0.0360	0.0332
Ca	0.4656	0.9366	0.5957	0.8269	0.4414	0.5478	0.4842	0.6097	0.4839	0.5524	0.4432	0.5347	0.5633	0.5023	0.5017
Na	0.5216	0.1038	0.3888	0.1776	0.5245	0.4486	0.5144	0.3832	0.4876	0.4254	0.5240	0.4599	0.4416	0.4913	0.4960
K	0.0294	0.0024	0.0129	0.0030	0.0281	0.0141	0.0276	0.0068	0.0123	0.0117	0.0212	0.0099	0.0100	0.0128	0.0135
tot	5.0111	5.0295	5.0047	5.0123	5.0034	5.0184	5.0254	5.0201	4.9986	4.9947	4.9917	5.0013	5.0129	5.0093	5.0107
An	0.4716	0.9002	0.6051	0.8232	0.4570	0.5498	0.4849	0.6099	0.4981	0.5650	0.4583	0.5376	0.5606	0.5055	0.5028
Ab	0.5131	0.0996	0.3898	0.1763	0.5277	0.4439	0.5012	0.3833	0.4956	0.4299	0.5301	0.4579	0.4351	0.4882	0.4905
Or	0.0289	0.0023	0.0130	0.0030	0.0283	0.0140	0.0269	0.0068	0.0125	0.0118	0.0214	0.0098	0.0099	0.0128	0.0134

Makushin plagioclase compositions

	PK-02	TT-22	TT-22	TT-22	TT-22	TT-22	TT-22	TT-22	WB-05	WB-05	WB-05	WB-05	WB-05	WB-05
	m52	m29	m29	m29	m29	m29	m29	m29	m22	m22	m22	m22	m22	m22
	gms	(core	rim)	(core	rim)	gms	gms	gms	(core	rim)	(core	rim)	gms	gms
	1	17	18	19	20	14	15	16	17	18	19	20	15	16
wt% oxides														
SiO2	51.53	45.61	51.00	45.48	55.27	50.23	54.43	61.02	47.31	50.57	45.89	53.37	53.31	63.21
Al2O3	26.71	32.61	28.92	33.23	26.60	29.55	28.10	23.07	31.48	29.33	32.78	27.21	27.15	22.96
FeO	0.79	0.92	1.04	0.83	0.85	0.94	1.13	1.07	0.83	1.12	0.56	1.14	1.28	0.97
CaO	9.76	17.40	13.32	17.57	9.69	13.77	11.10	5.13	16.35	13.61	16.98	11.03	11.30	5.04
Na2O	5.23	1.48	4.09	1.52	5.79	3.49	4.97	7.94	2.19	3.57	1.58	5.03	4.72	6.91
K2O	0.19	0.06	0.24	0.07	0.44	0.21	0.38	1.18	0.08	0.22	0.08	0.38	0.36	1.98
tot	94.21	98.08	98.61	98.70	98.64	98.19	100.11	99.41	98.24	98.42	97.87	98.16	98.12	101.07
atoms per 8 oxygens														
Si	2.4744	2.1492	2.3666	2.1307	2.5329	2.3393	2.4678	2.7474	2.2175	2.3503	2.1596	2.4716	2.4707	2.7908
Al	1.5120	1.8116	1.5821	1.8353	1.4371	1.6225	1.5020	1.2246	1.7396	1.6071	1.8187	1.4856	1.4834	1.1951
Fe	0.0317	0.0363	0.0404	0.0325	0.0326	0.0366	0.0428	0.0403	0.0325	0.0435	0.0220	0.0442	0.0496	0.0358
Ca	0.5022	0.8785	0.6623	0.8820	0.4758	0.6872	0.5392	0.2475	0.8212	0.6778	0.8562	0.5473	0.5612	0.2384
Na	0.4870	0.1352	0.3680	0.1381	0.5145	0.3152	0.4369	0.6932	0.1990	0.3217	0.1442	0.4517	0.4242	0.5916
K	0.0116	0.0036	0.0142	0.0042	0.0257	0.0125	0.0220	0.0678	0.0048	0.0130	0.0048	0.0225	0.0213	0.1115
tot	5.0189	5.0144	5.0335	5.0228	5.0187	5.0132	5.0107	5.0208	5.0146	5.0135	5.0055	5.0227	5.0103	4.9632
An	0.5077	0.8666	0.6428	0.8646	0.4805	0.6856	0.5524	0.2631	0.8049	0.6781	0.8559	0.5479	0.5695	0.2873
Ab	0.4866	0.1329	0.3523	0.1348	0.5064	0.3106	0.4377	0.6874	0.1942	0.3177	0.1434	0.4422	0.4214	0.6283
Or	0.0116	0.0035	0.0136	0.0041	0.0253	0.0123	0.0220	0.0672	0.0047	0.0129	0.0048	0.0220	0.0211	0.1185

Makushin olivine compositions

	LR-02 83mn65 core 1012	LR-02 83mn65 (core 1013	LR-02 83mn65 rim) 1014	LR-02 83mn65 (core 1015	LR-02 83mn65 rim) 1016	LR-02 83mn65 (core 1017	LR-02 83mn65 rim) 1018	LR-06a 83mn52 (core 1113	LR-06a 83mn52 rim) 1114	LR-06a 83mn52 (core 1115	LR-06a 83mn52 rim) 1116	LR-06a 83mn52 (core 1117	LR-06a 83mn52 rim) 1118	LR-06a 83mn52 core 1119	LR-06a 83mn52 core 1120
wt% oxides															
SiO2	36.58	38.28	37.70	36.93	36.86	36.83	36.99	38.51	37.43	38.51	37.43	38.73	37.18	38.30	38.19
TiO2	0.01	0.01	0.01	0.00	0.05	0.01	0.06	0.01	0.02	0.01	0.02	0.01	0.00	0.00	0.01
Al2O3	0.04	0.04	0.22	0.03	0.04	0.02	0.03	0.02	0.04	0.02	0.04	0.02	0.04	0.01	0.04
FeO	31.51	22.91	26.38	29.15	30.70	30.19	30.30	22.78	30.36	22.78	30.36	19.35	27.86	25.05	23.22
MnO	0.64	0.44	0.54	0.59	0.68	0.61	0.68	0.42	0.70	0.42	0.70	0.31	0.49	0.44	0.39
MgO	31.33	39.10	34.63	33.65	31.89	32.72	32.15	38.57	33.03	38.57	33.03	41.51	34.46	37.76	39.02
CaO	0.23	0.16	0.19	0.21	0.28	0.20	0.18	0.14	0.24	0.14	0.24	0.13	0.17	0.16	0.16
NiO	0.04	0.09	0.00	0.01	0.06	0.11	0.03	0.05	0.02	0.05	0.02	0.06	0.04	0.02	0.09
Cr2O3	0.02	0.03	0.00	0.00	0.04	0.04	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.02	0.00
tot	100.40	101.06	99.67	100.57	100.60	100.73	100.43	100.50	101.85	100.50	101.85	100.13	100.24	101.76	101.12
atoms per 4 oxygens															
Si	0.9945	0.9896	1.0044	0.9903	0.9960	0.9915	0.9985	0.9993	0.9951	0.9993	0.9951	0.9930	0.9933	0.9921	0.9880
Ti	0.0002	0.0002	0.0002	0.0000	0.0010	0.0002	0.0012	0.0002	0.0004	0.0002	0.0004	0.0002	0.0000	0.0000	0.0002
Al	0.0013	0.0012	0.0069	0.0009	0.0013	0.0006	0.0010	0.0006	0.0013	0.0006	0.0013	0.0006	0.0013	0.0003	0.0012
Fe2+	0.7164	0.4953	0.5878	0.6537	0.6937	0.6797	0.6840	0.4944	0.6750	0.4944	0.6750	0.4149	0.6225	0.5427	0.5024
Mn	0.0147	0.0096	0.0122	0.0134	0.0156	0.0139	0.0155	0.0092	0.0158	0.0092	0.0158	0.0067	0.0111	0.0097	0.0085
Mg	1.2694	1.5064	1.3750	1.3447	1.2842	1.3127	1.2934	1.4916	1.3087	1.4916	1.3087	1.5861	1.3721	1.4576	1.5045
Ca	0.0067	0.0044	0.0054	0.0060	0.0081	0.0058	0.0052	0.0039	0.0068	0.0039	0.0068	0.0036	0.0049	0.0044	0.0044
Ni	0.0009	0.0019	0.0000	0.0002	0.0013	0.0024	0.0007	0.0010	0.0004	0.0010	0.0004	0.0012	0.0009	0.0004	0.0019
Cr	0.0004	0.0006	0.0000	0.0000	0.0009	0.0009	0.0002	0.0000	0.0002	0.0000	0.0002	0.0002	0.0000	0.0004	0.0000
tot	3.0045	3.0093	2.9919	3.0093	3.0020	3.0076	2.9997	3.0002	3.0038	3.0002	3.0038	3.0064	3.0060	3.0076	3.0112
Fo	0.6392	0.7526	0.7005	0.6729	0.6493	0.6589	0.6541	0.7511	0.6597	0.7511	0.6597	0.7927	0.6879	0.7287	0.7497
Fa	0.3608	0.2474	0.2995	0.3271	0.3507	0.3411	0.3459	0.2489	0.3403	0.2489	0.3403	0.2073	0.3121	0.2713	0.2503

Makushin olivine compositions

	LR_06f	LR_06f	LR_06f	LR_06f	LR-11	LR-11	LR-12b	LR-12b	LR-12b	LR-12n	LR-12n	M1-01	M1-01	M1-01	M1-01
	83mn57	83mn57	83mn57	83mn57	m19	m19	DI-409	DI-409	DI-409	DI-931	DI-931	83mn41	83mn41	83mn41	83mn41
	(core	rim)	(core	rim)	(core	rim)	core	core	micro	core	core	(core	rim)	core	rim
	1122	1123	1124	1125	15	17	1050	1052	1054	1054	1056	1012	1013	1014	1015
wt% oxides															
SiO2	38.33	37.08	38.44	36.80	35.28	37.88	37.71	38.02	38.68	37.02	37.28	37.17	37.37	37.44	37.25
TiO2	0.00	0.00	0.01	0.02	nd	nd	0.03	0.03	0.00	0.02	0.04	0.02	0.04	0.00	0.05
Al2O3	0.04	0.05	0.02	0.06	0.03	0.65	0.05	0.03	0.02	0.01	0.07	0.07	0.05	0.01	0.06
FeO	24.38	31.29	22.91	32.12	26.22	24.65	28.01	25.66	20.81	28.69	27.90	26.20	26.60	24.39	27.22
MnO	0.41	0.63	0.42	0.73	0.52	0.40	0.57	0.49	0.40	0.57	0.57	0.49	0.49	0.43	0.56
MgO	38.41	30.03	38.96	31.10	34.54	38.58	34.93	37.45	40.42	34.01	34.98	35.91	35.40	37.75	34.35
CaO	0.17	0.28	0.17	0.27	0.19	0.30	0.17	0.14	0.19	0.17	0.20	0.15	0.20	0.19	0.17
NiO	0.09	0.00	0.04	0.02	nd	nd	0.04	0.07	0.05	0.01	0.05	0.06	0.00	0.00	0.01
Cr2O3	0.00	0.00	0.00	0.00	nd	nd	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.01
tot	101.83	99.36	100.97	101.12	96.78	102.46	101.52	101.89	100.57	100.51	101.09	100.07	100.15	100.23	99.68
atoms per 4 oxygens															
Si	0.9894	1.0159	0.9938	0.9955	0.9755	0.9733	0.9940	0.9873	0.9942	0.9908	0.9879	0.9876	0.9931	0.9843	0.9979
Ti	0.0000	0.0000	0.0002	0.0004	0.0000	0.0000	0.0006	0.0006	0.0000	0.0004	0.0008	0.0004	0.0008	0.0000	0.0010
Al	0.0012	0.0016	0.0006	0.0019	0.0010	0.0197	0.0016	0.0009	0.0006	0.0003	0.0022	0.0022	0.0016	0.0003	0.0019
Fe2+	0.5263	0.7169	0.4953	0.7267	0.6063	0.5297	0.6175	0.5573	0.4473	0.6422	0.6183	0.5822	0.5912	0.5363	0.6098
Mn	0.0090	0.0146	0.0092	0.0167	0.0122	0.0087	0.0127	0.0108	0.0087	0.0129	0.0128	0.0110	0.0110	0.0096	0.0127
Mg	1.4776	1.2261	1.5011	1.2538	1.4233	1.4773	1.3722	1.4494	1.5484	1.3566	1.3815	1.4219	1.4020	1.4791	1.3714
Ca	0.0047	0.0082	0.0047	0.0078	0.0056	0.0083	0.0048	0.0039	0.0052	0.0049	0.0057	0.0043	0.0057	0.0054	0.0049
Ni	0.0019	0.0000	0.0008	0.0004	nd	nd	0.0008	0.0015	0.0010	0.0002	0.0011	0.0013	0.0000	0.0000	0.0002
Cr	0.0000	0.0000	0.0000	0.0000	nd	nd	0.0002	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0004	0.0002
tot	3.0100	2.9833	3.0057	3.0032	3.0240	3.0169	3.0045	3.0116	3.0055	3.0085	3.0102	3.0109	3.0053	3.0153	3.0001
Fo	0.7374	0.6310	0.7519	0.6331	0.7013	0.7361	0.6897	0.7223	0.7758	0.6787	0.6908	0.7095	0.7034	0.7339	0.6922
Fa	0.2626	0.3690	0.2481	0.3669	0.2987	0.2639	0.3103	0.2777	0.2242	0.3213	0.3092	0.2905	0.2966	0.2661	0.3078

Makushin olivine compositions

	M1-51d	M1-51d	M1-51d	M1-51d	Mc-18	Mc-18	Mc-18	.Mc-18	Mc-18	Mc-18	Mc-18	Mc-18	Mc-18	Md-04	Md-04
	m43f	m43f	m43f	m43f	m30	m30	m30	m30	m30	m30	m30	m30	m30	m04	m04
	core	rim	core	rim	(core	rim)	(core	rim)	(core	rim)	core	core	core	(core	rim)
	1	2	12	13	1	2	3	4	5	6	7	8	9	14	15
wt% oxides															
SiO2	37.32	37.41	38.20	38.48	38.01	37.90	38.75	37.42	38.62	37.95	38.43	38.61	37.71	36.65	35.65
TiO2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Al2O3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
FeO	26.15	26.42	24.10	23.98	23.54	25.04	19.87	26.28	20.12	22.91	18.53	18.95	22.74	30.59	37.26
MnO	0.60	0.56	0.49	0.37	0.48	0.51	0.34	0.63	0.37	0.40	0.36	0.34	0.49	0.48	0.76
MgO	36.48	36.00	38.38	39.21	38.44	36.55	42.20	35.25	41.60	39.39	43.55	43.66	39.37	32.83	26.04
CaO	0.20	0.20	0.18	0.15	0.28	0.26	0.21	0.20	0.19	0.21	0.28	0.19	0.25	0.17	0.23
NiO	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr2O3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	100.75	100.59	101.35	102.19	100.75	100.26	101.37	99.78	100.90	100.86	101.15	101.75	100.56	100.72	99.94
atoms per 4 oxygens															
Si	0.9847	0.9893	0.9899	0.9871	0.9892	0.9979	0.9840	0.9972	0.9866	0.9836	0.9737	0.9736	0.9808	0.9879	1.0031
Ti	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Al	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Fe2+	0.5770	0.5843	0.5223	0.5145	0.5123	0.5514	0.4220	0.5857	0.4299	0.4966	0.3927	0.3996	0.4946	0.6896	0.8768
Mn	0.0134	0.0125	0.0108	0.0080	0.0106	0.0114	0.0073	0.0142	0.0080	0.0088	0.0077	0.0073	0.0108	0.0110	0.0181
Mg	1.4345	1.4188	1.4822	1.4991	1.4909	1.4342	1.5970	1.4000	1.5838	1.5215	1.6445	1.6408	1.5260	1.3188	1.0920
Ca	0.0057	0.0057	0.0050	0.0041	0.0078	0.0073	0.0057	0.0057	0.0052	0.0058	0.0076	0.0051	0.0070	0.0049	0.0069
Ni	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	3.0153	3.0107	3.0101	3.0129	3.0108	3.0021	3.0160	3.0028	3.0134	3.0164	3.0263	3.0264	3.0192	3.0121	2.9969
Fo	0.7131	0.7083	0.7394	0.7445	0.7442	0.7223	0.7910	0.7050	0.7865	0.7539	0.8073	0.8041	0.7552	0.6567	0.5546
Fa	0.2869	0.2917	0.2606	0.2555	0.2558	0.2777	0.2090	0.2950	0.2135	0.2461	0.1927	0.1959	0.2448	0.3433	0.4454

Makushin olivine compositions

	Md-04	Md-04	Me-03	Me-03	Me-03	Me-03	Me-03	Me-03	Me-07	Me-07	Me-07	Me-07	Me-07	Me-07	Me-07
	m04	m04	m36	m36	m36	m36	m36	m36	m40	m40	m40	m40	m40	m40	m40
	(core	rim)	core	rim	core	rim	core	rim	(core	rim)	(core	rim)	(core	rim)	(core
	16	17	1	2	5	6	9	10	12	13	14	15	16	17	10
wt% oxides															
SiO2	35.60	36.27	37.52	37.46	38.40	37.49	37.32	37.43	36.20	35.62	36.18	36.41	36.61	36.20	37.23
TiO2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Al2O3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
FeO	33.58	34.91	26.05	28.42	23.28	27.11	26.28	27.74	31.55	32.73	27.81	29.69	27.57	28.70	24.81
MnO	0.65	0.67	0.44	0.45	0.32	0.47	0.53	0.58	0.56	0.56	0.41	0.56	0.59	0.53	0.42
MgO	30.39	28.74	36.58	34.95	38.80	35.14	36.05	34.48	30.40	30.56	36.06	34.28	35.83	35.58	37.30
CaO	0.19	0.27	0.15	0.24	0.17	0.25	0.21	0.21	0.22	0.18	0.21	0.18	0.23	0.20	0.24
NiO	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr2O3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	100.41	100.86	100.74	101.52	100.97	100.46	100.39	100.44	98.93	99.65	100.67	101.12	100.83	101.21	100.00
atoms per 4 oxygens															
Si	0.9798	0.9976	0.9882	0.9896	0.9939	0.9952	0.9885	0.9971	1.0000	0.9838	0.9652	0.9748	0.9735	0.9647	0.9835
Ti	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Al	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Fe2+	0.7730	0.8031	0.5738	0.6279	0.5039	0.6018	0.5821	0.6180	0.7289	0.7560	0.6205	0.6648	0.6131	0.6397	0.5482
Mn	0.0152	0.0156	0.0098	0.0101	0.0070	0.0106	0.0119	0.0131	0.0131	0.0131	0.0093	0.0127	0.0133	0.0120	0.0094
Mg	1.2466	1.1781	1.4358	1.3760	1.4966	1.3902	1.4230	1.3688	1.2515	1.2579	1.4338	1.3678	1.4200	1.4132	1.4686
Ca	0.0056	0.0080	0.0042	0.0068	0.0047	0.0071	0.0060	0.0060	0.0065	0.0053	0.0060	0.0052	0.0066	0.0057	0.0068
Ni	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	3.0202	3.0024	3.0118	3.0104	3.0061	3.0048	3.0115	3.0029	3.0000	3.0162	3.0348	3.0252	3.0265	3.0353	3.0165
Fo	0.6173	0.5947	0.7145	0.6867	0.7481	0.6979	0.7097	0.6890	0.6320	0.6246	0.6979	0.6729	0.6984	0.6884	0.7282
Fa	0.3827	0.4053	0.2855	0.3133	0.2519	0.3021	0.2903	0.3110	0.3680	0.3754	0.3021	0.3271	0.3016	0.3116	0.2718

Makushin olivine compositions

	Me-07	Mf-01	Mf-01	Mf-01	Mf-01	Mf-04	Mf-04	Mf-04	Mf-04	Mf-04	Mf-04	Mf-04	PC-02	PC-02	PC-02
	m40	m45	m45	m45	m45	m48	m48	m48	m48	m48	m48	m48	m21	m21	m21
	rim)	(core	rim)	(core	rim)	(core	rim)	(core	rim	rim)	(core	rim)	(core	rim)	(core
	11	7	6	9	10	1	2	3	4	5	24	25	1	2	5
wt% oxides															
SiO2	36.80	38.76	37.45	39.17	38.23	38.19	38.60	38.34	35.86	36.49	38.84	36.02	37.78	37.62	38.13
TiO2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Al2O3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
FeO	28.95	17.08	25.81	15.22	21.60	19.97	20.47	20.19	34.14	28.39	19.41	30.12	24.13	25.17	23.42
MnO	0.57	0.44	0.42	0.24	0.32	0.43	0.45	0.32	0.90	0.61	0.30	0.74	0.54	0.54	0.42
MgO	33.04	43.88	36.62	45.62	39.05	41.59	40.58	40.83	28.81	35.11	42.14	32.50	37.82	37.13	38.77
CaO	0.12	0.18	0.21	0.20	0.23	0.25	0.22	0.31	0.21	0.23	0.24	0.23	0.22	0.28	0.23
NiO	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr2O3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	99.48	100.34	100.51	100.45	99.43	100.43	100.32	99.99	99.92	100.83	100.93	99.61	100.49	100.74	100.97
atoms per 4 oxygens															
Si	0.9969	0.9827	0.9879	0.9825	0.9979	0.9811	0.9935	0.9893	0.9948	0.9743	0.9881	0.9832	0.9890	0.9875	0.9889
Ti	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Al	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Fe2+	0.6559	0.3622	0.5694	0.3193	0.4715	0.4291	0.4406	0.4357	0.7920	0.6339	0.4130	0.6876	0.5283	0.5526	0.5080
Mn	0.0131	0.0094	0.0094	0.0051	0.0071	0.0094	0.0098	0.0070	0.0211	0.0138	0.0065	0.0171	0.0120	0.0120	0.0092
Mg	1.3339	1.6580	1.4396	1.7053	1.5191	1.5924	1.5566	1.5701	1.1911	1.3971	1.5978	1.3221	1.4755	1.4525	1.4986
Ca	0.0035	0.0049	0.0059	0.0054	0.0064	0.0069	0.0061	0.0086	0.0062	0.0066	0.0065	0.0067	0.0062	0.0079	0.0064
Ni	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	3.0031	3.0173	3.0121	3.0175	3.0021	3.0189	3.0065	3.0107	3.0052	3.0257	3.0119	3.0168	3.0110	3.0125	3.0111
Fo	0.6704	0.8207	0.7166	0.8423	0.7631	0.7877	0.7794	0.7828	0.6006	0.6879	0.7946	0.6579	0.7364	0.7244	0.7468
Fa	0.3296	0.1793	0.2834	0.1577	0.2369	0.2123	0.2206	0.2172	0.3994	0.3121	0.2054	0.3421	0.2636	0.2756	0.2532

Makushin olivine compositions

	PC-02	PC-02	PC-02	PC-06	PC-06	PC-06	PC-06	PC-06	PC-06	PC-06	PC-06	PC-06	PC-06	PC-06	PC-06
	m21	m21	m21	83mn86	83mn86	83mn86	83mn86	83mn86	83mn86	83mn86	83mn86	83mn86	83mn86	83mn86	83mn86
	rim)	(core	rim)	(core	rim)	(core		1029 to 1037 is profile across single crystal						rim)	core
	6	9	10	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038
wt% oxides															
SiO2	37.74	38.02	37.14	39.43	38.14	40.11	39.91	39.86	39.65	40.12	39.86	40.11	39.34	38.98	39.84
TiO2	nd	nd	nd	0.00	0.01	0.03	0.01	0.00	0.00	0.51	0.02	0.03	0.00	0.02	0.00
Al2O3	nd	nd	nd	0.12	0.01	0.03	0.02	0.02	0.03	0.31	0.03	0.02	0.06	0.06	0.02
FeO	26.55	24.00	25.64	13.69	21.44	12.06	12.51	12.42	12.31	12.78	12.36	12.10	12.35	17.10	12.70
MnO	0.70	0.59	0.66	0.29	0.51	0.19	0.24	0.16	0.19	0.16	0.22	0.24	0.18	0.41	0.22
MgO	35.55	37.80	35.70	45.92	40.11	47.80	47.43	47.00	47.64	47.55	47.15	47.96	47.12	41.05	46.94
CaO	0.28	0.27	0.29	0.22	0.22	0.16	0.17	0.13	0.19	0.17	0.15	0.17	0.17	0.20	0.19
NiO	nd	nd	nd	0.12	0.08	0.16	0.12	0.17	0.13	0.13	0.17	0.14	0.13	0.09	0.13
Cr2O3	nd	nd	nd	0.05	0.03	0.02	0.04	0.00	0.00	0.04	0.04	0.04	0.02	0.00	0.05
tot	100.82	100.68	99.43	99.84	100.55	100.56	100.45	99.76	100.14	101.77	100.00	100.81	99.37	97.91	100.09
atoms per 4 oxygens															
Si	0.9961	0.9925	0.9917	0.9883	0.9856	0.9896	0.9882	0.9928	0.9844	0.9811	0.9907	0.9877	0.9847	1.0111	0.9908
Ti	nd	nd	nd	0.0000	0.0002	0.0006	0.0002	0.0000	0.0000	0.0094	0.0004	0.0006	0.0000	0.0004	0.0000
Al	nd	nd	nd	0.0035	0.0003	0.0009	0.0006	0.0006	0.0009	0.0089	0.0009	0.0006	0.0018	0.0018	0.0006
Fe2+	0.5860	0.5239	0.5726	0.2870	0.4634	0.2488	0.2591	0.2587	0.2556	0.2614	0.2569	0.2492	0.2585	0.3710	0.2641
Mn	0.0156	0.0130	0.0149	0.0062	0.0112	0.0040	0.0050	0.0034	0.0040	0.0033	0.0046	0.0050	0.0038	0.0090	0.0046
Mg	1.3983	1.4705	1.4207	1.7152	1.5447	1.7576	1.7502	1.7446	1.7627	1.7329	1.7465	1.7600	1.7578	1.5869	1.7397
Ca	0.0079	0.0076	0.0083	0.0059	0.0061	0.0042	0.0045	0.0035	0.0051	0.0045	0.0040	0.0045	0.0046	0.0056	0.0051
Ni	nd	nd	nd	0.0024	0.0017	0.0032	0.0024	0.0034	0.0026	0.0026	0.0034	0.0028	0.0026	0.0019	0.0026
Cr	nd	nd	nd	0.0010	0.0006	0.0004	0.0008	0.0000	0.0000	0.0008	0.0008	0.0008	0.0004	0.0000	0.0010
tot	3.0039	3.0075	3.0083	3.0095	3.0137	3.0092	3.0109	3.0069	3.0152	3.0047	3.0081	3.0111	3.0142	2.9876	3.0085
Fo	0.7047	0.7373	0.7127	0.8567	0.7693	0.8760	0.8711	0.8709	0.8734	0.8689	0.8718	0.8760	0.8718	0.8105	0.8682
Fa	0.2953	0.2627	0.2873	0.1433	0.2307	0.1240	0.1289	0.1291	0.1266	0.1311	0.1282	0.1240	0.1282	0.1895	0.1318

Makushin olivine compositions

	PC-06 83mn86 core 1039	PC-06 83mn86 core 1040	PC-06 83mn86 micro 1041	PC-06 83mn86 core 1042	PC-06 83mn86 core 1043	PC-09 83mn25 (core 1001	PC-09 83mn25 core 1002	PC-09 83mn25 mid 1003	PC-09 83mn25 rim) 1004	PC-09 83mn25 (core 1005	PC-09 83mn25 core) 1007	PC-09 83mn25 core 1008	PC-09 83mn25 (core 1009	PC-09 83mn25 core) 1010	PC-09 83mn25 core 1011
wt% oxides															
SiO2	39.87	39.86	38.26	39.02	38.78	40.36	40.09	40.36	38.97	39.26	39.30	38.79	39.64	39.32	39.79
TiO2	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Al2O3	0.01	0.03	0.05	0.03	0.04	0.05	0.02	0.02	0.05	0.02	0.04	0.07	0.05	0.03	0.02
FeO	9.83	10.87	22.18	15.86	16.50	9.34	9.49	10.28	18.86	14.38	13.57	15.57	11.75	12.61	10.33
MnO	0.18	0.24	0.51	0.28	0.33	0.16	0.16	0.18	0.38	0.30	0.25	0.28	0.19	0.21	0.18
MgO	49.08	47.69	40.36	44.31	44.21	49.49	48.76	48.61	42.11	42.75	45.80	44.80	48.03	46.40	48.65
CaO	0.19	0.19	0.22	0.20	0.24	0.17	0.17	0.18	0.21	0.20	0.18	0.16	0.18	0.19	0.25
NiO	0.19	0.17	0.06	0.11	0.09	0.17	0.17	0.15	0.08	0.13	0.13	0.14	0.14	0.18	0.19
Cr2O3	0.04	0.01	0.00	0.02	0.09	0.05	0.03	0.07	0.04	0.01	0.01	0.03	0.04	0.04	0.10
tot	99.39	99.06	101.64	99.84	100.28	99.79	98.90	99.85	100.70	97.05	99.28	99.84	100.02	98.98	99.55
atoms per 4 oxygens															
Si	0.9864	0.9934	0.9809	0.9880	0.9816	0.9911	0.9940	0.9944	0.9915	1.0140	0.9899	0.9817	0.9831	0.9894	0.9854
Ti	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007
Al	0.0003	0.0009	0.0015	0.0009	0.0012	0.0014	0.0006	0.0006	0.0015	0.0006	0.0012	0.0021	0.0015	0.0009	0.0006
Fe2+	0.2034	0.2266	0.4756	0.3359	0.3493	0.1918	0.1968	0.2118	0.4013	0.3106	0.2859	0.3296	0.2437	0.2654	0.2140
Mn	0.0038	0.0051	0.0111	0.0060	0.0071	0.0033	0.0034	0.0038	0.0082	0.0066	0.0053	0.0060	0.0040	0.0045	0.0038
Mg	1.8096	1.7714	1.5421	1.6721	1.6677	1.8112	1.8018	1.7849	1.5967	1.6455	1.7193	1.6898	1.7752	1.7400	1.7957
Ca	0.0050	0.0051	0.0060	0.0054	0.0065	0.0045	0.0045	0.0048	0.0057	0.0055	0.0049	0.0043	0.0048	0.0051	0.0066
Ni	0.0038	0.0034	0.0012	0.0022	0.0018	0.0034	0.0034	0.0030	0.0016	0.0027	0.0026	0.0028	0.0028	0.0036	0.0038
Cr	0.0008	0.0002	0.0000	0.0004	0.0018	0.0010	0.0006	0.0014	0.0008	0.0002	0.0002	0.0006	0.0008	0.0008	0.0020
tot	3.0131	3.0060	3.0184	3.0111	3.0169	3.0077	3.0052	3.0046	3.0074	2.9856	3.0094	3.0169	3.0158	3.0098	3.0125
Fo	0.8990	0.8866	0.7643	0.8327	0.8268	0.9042	0.9015	0.8939	0.7991	0.8412	0.8574	0.8368	0.8793	0.8677	0.8935
Fa	0.1010	0.1134	0.2357	0.1673	0.1732	0.0958	0.0985	0.1061	0.2009	0.1588	0.1426	0.1632	0.1207	0.1323	0.1065

Makushin olivine compositions

	TT-10 83mn77 (core 1105	TT-10 83mn77 rim) 1106	TT-10 83mn77 (core 1107	TT-10 83mn77 rim) 1108	TT-10 83mn77 (core 1109	TT-10 83mn77 rim) 1110	TT-10 83mn77 (core 1111	TT-10 83mn77 rim) 1112	TT-22 m29 (core 9	TT-22 m29 rim) 10	TT-22 m29 (core 11	TT-22 m29 rim) 12	WB-05 m22 core 1	WB-05 m22 rim 2	WB-05 m22 core 3
wt% oxides															
SiO2	37.88	37.77	37.41	37.07	38.12	36.31	37.96	36.86	38.11	35.99	38.31	36.51	38.61	37.67	38.21
TiO2	0.00	0.00	0.00	0.00	0.02	0.04	0.00	0.02	nd	nd	nd	nd	nd	nd	nd
Al2O3	0.05	0.05	0.06	0.06	0.05	0.03	0.04	0.05	nd	nd	nd	nd	nd	nd	nd
FeO	21.39	25.27	22.96	27.97	22.13	33.09	21.97	31.53	20.80	33.65	21.84	32.31	21.95	23.20	21.62
MnO	0.48	0.59	0.44	0.67	0.48	0.73	0.39	0.69	0.38	0.85	0.52	0.89	0.34	0.41	0.51
MgO	39.73	35.18	37.92	33.10	39.26	30.02	39.67	31.91	39.89	30.05	39.67	31.11	40.44	38.21	40.19
CaO	0.21	0.26	0.25	0.25	0.25	0.27	0.23	0.27	0.22	0.30	0.25	0.30	0.21	0.24	0.19
NiO	0.00	0.01	0.04	0.01	0.06	0.01	0.09	0.02	nd	nd	nd	nd	nd	nd	nd
Cr2O3	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.00	nd	nd	nd	nd	nd	nd	nd
tot	99.76	99.14	99.08	99.13	100.37	100.50	100.36	101.35	99.40	100.84	100.59	101.12	101.55	99.73	100.72
atoms per 4 oxygens															
Si	0.9864	1.0073	0.9889	1.0032	0.9895	0.9944	0.9850	0.9918	0.9923	0.9864	0.9905	0.9902	0.9877	0.9894	0.9859
Ti	0.0000	0.0000	0.0000	0.0000	0.0004	0.0008	0.0000	0.0004	nd	nd	nd	nd	nd	nd	nd
Al	0.0015	0.0016	0.0019	0.0019	0.0015	0.0010	0.0012	0.0016	nd	nd	nd	nd	nd	nd	nd
Fe2+	0.4658	0.5636	0.5076	0.6330	0.4804	0.7579	0.4768	0.7095	0.4529	0.7713	0.4722	0.7329	0.4696	0.5096	0.4665
Mn	0.0106	0.0133	0.0099	0.0154	0.0106	0.0169	0.0086	0.0157	0.0084	0.0197	0.0114	0.0204	0.0074	0.0091	0.0111
Mg	1.5419	1.3982	1.4939	1.3349	1.5188	1.2252	1.5342	1.2797	1.5479	1.2274	1.5285	1.2575	1.5418	1.4957	1.5454
Ca	0.0059	0.0074	0.0071	0.0072	0.0070	0.0079	0.0064	0.0078	0.0061	0.0088	0.0069	0.0087	0.0058	0.0068	0.0053
Ni	0.0000	0.0002	0.0009	0.0002	0.0013	0.0002	0.0019	0.0004	nd	nd	nd	nd	nd	nd	nd
Cr	0.0004	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	nd	nd	nd	nd	nd	nd	nd
tot	3.0126	2.9918	3.0101	2.9959	3.0094	3.0043	3.0143	3.0070	3.0077	3.0136	3.0095	3.0098	3.0123	3.0106	3.0141
Fo	0.7680	0.7127	0.7464	0.6783	0.7597	0.6178	0.7629	0.6433	0.7736	0.6141	0.7640	0.6318	0.7665	0.7459	0.7681
Fa	0.2320	0.2873	0.2536	0.3217	0.2403	0.3822	0.2371	0.3567	0.2264	0.3859	0.2360	0.3682	0.2335	0.2541	0.2319

8

Makushin olivine compositions

	WB-05
	m22
	rim
	4
wt% oxides	
SiO2	37.13
TiO2	nd
Al2O3	nd
FeO	29.02
MnO	0.61
MgO	32.17
CaO	0.23
NiO	nd
Cr2O3	nd
tot	99.16
atoms per 4 oxygens	
Si	1.0087
Ti	nd
Al	nd
Fe2+	0.6593
Mn	0.0140
Mg	1.3025
Ca	0.0067
Ni	nd
Cr	nd
tot	2.9913
Fo	0.6639
Fa	0.3361

Makushin clinopyroxene analyses

	LR-02 83mn65 core 2012	LR-02 83mn65 core 2013	LR-02 83mn65 (core 2014	LR-02 83mn65 rim) 2015	LR-02 83mn65 core 2016	LR-02 83mn65 rim 2017	LR-02 83mn65 core 2020	LR-02 83mn65 (core 2021	LR-02 83mn65 rim) 2022	LR-02 83mn65 (core 2023	LR-02 83mn65 rim) 2024	LR-06a 83mn52 (core 2084	LR-06a 83mn52 rim) 2085	LR-06a 83mn52 (core 2086	LR-06a 83mn52 rim) 2087
wt% oxides															
SiO2	52.10	51.54	51.23	50.48	51.56	51.16	51.58	50.83	51.17	51.39	51.02	51.68	51.38	50.98	51.73
TiO2	0.36	0.56	0.60	0.64	0.51	0.57	0.56	0.47	0.61	0.53	0.60	0.59	0.61	0.55	0.58
Al2O3	2.59	1.86	1.97	2.42	1.64	2.04	1.71	1.81	1.84	1.91	1.86	1.63	1.95	1.74	1.43
FeO	7.36	11.85	11.73	10.82	11.26	10.79	11.46	11.53	11.01	10.98	11.38	11.91	11.02	13.11	14.22
MnO	0.22	0.46	0.47	0.39	0.46	0.38	0.40	0.46	0.44	0.39	0.37	0.48	0.45	0.49	0.53
MgO	17.37	14.75	13.96	15.73	14.66	15.03	15.06	14.57	14.93	14.91	15.07	14.45	14.94	14.28	13.32
CaO	20.26	18.40	19.26	17.62	18.85	19.38	18.35	18.38	18.48	18.91	18.42	18.27	18.71	17.67	17.34
Na2O	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
NiO	0.00	0.00	0.01	0.02	0.00	0.00	0.01	0.01	0.03	0.00	0.01	0.05	0.02	0.00	0.00
Cr2O3	0.00	0.00	0.03	0.00	0.00	0.00	0.02	0.00	0.03	0.03	0.00	0.00	0.01	0.03	0.04
tot	100.26	99.42	99.26	98.12	98.94	99.35	99.15	98.06	98.54	99.05	98.73	99.06	99.09	98.85	99.19
atoms per 6 oxygens															
Si	1.9147	1.9423	1.9388	1.9179	1.9501	1.9270	1.9453	1.9423	1.9407	1.9394	1.9342	1.9545	1.9381	1.9422	1.9684
Ti	0.0100	0.0159	0.0171	0.0183	0.0145	0.0161	0.0159	0.0135	0.0174	0.0150	0.0171	0.0168	0.0173	0.0158	0.0166
Al t	0.0853	0.0577	0.0612	0.0821	0.0499	0.0730	0.0547	0.0577	0.0593	0.0606	0.0658	0.0455	0.0619	0.0578	0.0316
Al o	0.0270	0.0250	0.0267	0.0263	0.0232	0.0176	0.0214	0.0239	0.0229	0.0244	0.0173	0.0272	0.0248	0.0203	0.0326
Fe3+	0.0384	0.0009	0.0000	0.0192	0.0000	0.0232	0.0009	0.0068	0.0007	0.0052	0.0143	0.0000	0.0022	0.0051	0.0000
Fe2+	0.1878	0.3726	0.3713	0.3246	0.3562	0.3167	0.3606	0.3617	0.3485	0.3413	0.3466	0.3767	0.3454	0.4126	0.4525
Mn	0.0068	0.0147	0.0151	0.0126	0.0147	0.0121	0.0128	0.0149	0.0141	0.0125	0.0119	0.0154	0.0144	0.0158	0.0171
Mg	0.9514	0.8284	0.7874	0.8907	0.8263	0.8437	0.8465	0.8297	0.8439	0.8386	0.8514	0.8144	0.8399	0.8108	0.7554
Ca	0.7978	0.7430	0.7810	0.7173	0.7639	0.7822	0.7416	0.7526	0.7510	0.7647	0.7482	0.7404	0.7562	0.7213	0.7070
Na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ni	0.0000	0.0000	0.0003	0.0006	0.0000	0.0000	0.0003	0.0003	0.0009	0.0000	0.0003	0.0015	0.0006	0.0000	0.0000
Cr	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000	0.0006	0.0000	0.0009	0.0009	0.0000	0.0000	0.0003	0.0009	0.0012
tot	4.0192	4.0005	3.9997	4.0096	3.9989	4.0116	4.0005	4.0034	4.0004	4.0026	4.0071	3.9924	4.0011	4.0026	3.9823
Ac	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0384	0.0009	0.0000	0.0192	0.0000	0.0232	0.0009	0.0068	0.0007	0.0052	0.0143	0.0000	0.0022	0.0051	0.0000
CrCaTs	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000	0.0006	0.0000	0.0009	0.0009	0.0000	0.0000	0.0003	0.0009	0.0012
AlCaTs	0.0270	0.0250	0.0267	0.0263	0.0232	0.0176	0.0214	0.0239	0.0229	0.0244	0.0173	0.0272	0.0248	0.0203	0.0326
Wo	0.3662	0.3585	0.3767	0.3359	0.3704	0.3707	0.3593	0.3610	0.3632	0.3671	0.3583	0.3566	0.3645	0.3475	0.3366
En	0.5293	0.4425	0.4236	0.4867	0.4400	0.4575	0.4493	0.4450	0.4507	0.4498	0.4560	0.4399	0.4503	0.4324	0.4149
Fs	0.1045	0.1990	0.1997	0.1774	0.1896	0.1718	0.1914	0.1940	0.1861	0.1831	0.1856	0.2035	0.1852	0.2201	0.2485
mg#	83.5	69.0	68.0	73.3	69.9	72.7	70.1	69.6	70.8	71.1	71.1	68.4	70.9	66.3	62.5

Makushin clinopyroxene analyses

	LR-06a	LR-06a	LR-06a	LR-06a	LR-06a	LR-06a	LR-06a	LR-06a	LR-06a	LR-06f	LR-06f	LR-06f	LR-06f	LR-06f	LR-11
	83mn52	83mn52	83mn52	83mn52	83mn52	83mn52	83mn52	83mn52	83mn52	83mn57	83mn57	83mn57	83mn57	83mn57	m19
	(core	rim)	(core	rim	rim)	gms	(core	rim	rim)	(core	rim)	on opx	(core	rim)	(core
	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2098.5	2099	2100	6
wt% oxides															
SiO2	51.29	51.03	51.50	51.71	52.06	51.08	52.02	51.86	50.93	51.87	51.10	52.24	51.86	51.27	48.99
TiO2	0.56	0.59	0.57	0.49	0.46	0.76	0.48	0.52	0.72	0.32	0.70	0.56	0.54	0.58	0.63
Al2O3	2.20	2.33	1.65	1.54	1.82	2.22	1.29	1.48	3.46	0.99	3.10	1.52	1.55	1.92	2.22
FeO	9.73	10.14	12.67	11.74	9.34	12.99	13.91	13.56	9.43	15.27	10.67	13.48	12.72	11.15	11.30
MnO	0.32	0.36	0.53	0.39	0.34	0.51	0.54	0.56	0.32	0.55	0.33	0.53	0.51	0.41	0.37
MgO	14.90	15.25	13.92	15.70	16.69	15.38	13.60	13.51	15.34	11.55	14.96	16.00	13.98	15.26	15.05
CaO	19.68	19.20	18.06	17.68	18.66	16.36	17.58	17.69	19.40	18.65	18.85	15.09	18.27	18.21	18.23
Na2O	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.39
NiO	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.02	0.02	nd
Cr2O3	0.02	0.01	0.02	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.00	nd
tot	98.7	98.92	98.92	99.25	99.38	99.3	99.43	99.2	99.6	99.2	99.73	99.44	99.46	98.82	97.18
atoms per 6 oxygens															
Si	1.9350	1.9236	1.9564	1.9468	1.9400	1.9278	1.9723	1.9689	1.8996	1.9898	1.9109	1.9618	1.9597	1.9378	1.8923
Ti	0.0159	0.0167	0.0163	0.0139	0.0129	0.0216	0.0137	0.0148	0.0202	0.0092	0.0197	0.0158	0.0153	0.0165	0.0183
Al t	0.0650	0.0764	0.0436	0.0532	0.0600	0.0722	0.0277	0.0311	0.1004	0.0102	0.0891	0.0382	0.0403	0.0622	0.1077
Al o	0.0329	0.0271	0.0303	0.0151	0.0200	0.0266	0.0300	0.0351	0.0517	0.0346	0.0476	0.0291	0.0287	0.0233	0.0000
Fe3+	0.0000	0.0156	0.0000	0.0104	0.0139	0.0024	0.0000	0.0000	0.0083	0.0000	0.0021	0.0000	0.0000	0.0060	0.0711
Fe2+	0.3070	0.3041	0.4025	0.3593	0.2771	0.4076	0.4411	0.4305	0.2858	0.4899	0.3316	0.4234	0.4020	0.3465	0.2939
Mn	0.0102	0.0115	0.0171	0.0124	0.0107	0.0163	0.0173	0.0180	0.0101	0.0179	0.0105	0.0169	0.0163	0.0131	0.0121
Mg	0.8378	0.8567	0.7881	0.8809	0.9269	0.8651	0.7685	0.7644	0.8527	0.6603	0.8337	0.8955	0.7873	0.8596	0.8664
Ca	0.7956	0.7755	0.7351	0.7132	0.7451	0.6616	0.7142	0.7196	0.7753	0.7666	0.7553	0.6072	0.7397	0.7375	0.7545
Na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.0292
Ni	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0000	0.0006	0.0000	0.0006	0.0006	nd
Cr	0.0006	0.0003	0.0006	0.0000	0.0003	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0006	0.0003	0.0000	nd
tot	3.9999	4.0078	3.9900	4.0052	4.0070	4.0012	3.9850	3.9832	4.0042	3.9786	4.0011	3.9884	3.9903	4.0030	4.0455
Ac	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0292
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0000	0.0156	0.0000	0.0104	0.0139	0.0024	0.0000	0.0000	0.0083	0.0000	0.0021	0.0000	0.0000	0.0060	0.0419
CrCaTs	0.0006	0.0003	0.0006	0.0000	0.0003	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0006	0.0003	0.0000	0.0000
AlCaTs	0.0329	0.0271	0.0303	0.0151	0.0200	0.0266	0.0300	0.0351	0.0517	0.0346	0.0476	0.0291	0.0287	0.0233	0.0000
Wo	0.3810	0.3663	0.3521	0.3439	0.3554	0.3163	0.3420	0.3423	0.3576	0.3660	0.3528	0.2888	0.3554	0.3541	0.3563
En	0.4530	0.4677	0.4288	0.4660	0.4962	0.4647	0.4181	0.4208	0.4811	0.3640	0.4631	0.4829	0.4267	0.4603	0.4806
Fs	0.1660	0.1660	0.2190	0.1901	0.1484	0.2190	0.2400	0.2370	0.1613	0.2700	0.1841	0.2283	0.2179	0.1856	0.1631
mg#	73.2	73.8	66.2	71.0	77.0	68.0	63.5	64.0	74.9	57.4	71.5	67.9	66.2	71.3	74.7

Makushin clinopyroxene analyses

	LR-11	LR-11	LR-11	LR-11	LR-11	LR-11	LR-11	LR-11	LR-11	LR-12b	LR-12b	LR-12b	LR-12b	LR-12b	LR-12b
	m19	m19	m19	m19	m19	m19	m19	m19	m19	DI-409	DI-409	DI-409	DI-409	DI-409	DI-409
	rim)	(core	rim)	gm	gm	gm	gm	gm	gm	(core	rim)	(core	rim)	gms	(core
	5	23	22	13	14	18	19	28	30	2056	2057	2058	2059	2060	2061
wt% oxides															
SiO2	49.16	49.37	49.32	48.60	41.50	44.57	43.05	49.36	48.94	51.68	51.85	51.96	52.20	51.78	51.50
TiO2	0.57	0.52	0.53	0.62	0.48	0.47	0.40	0.57	0.56	0.57	0.54	0.52	0.53	0.51	0.59
Al2O3	2.02	2.33	1.67	3.46	2.27	1.50	1.48	1.41	1.24	1.35	1.39	1.53	1.70	1.25	1.79
FeO	11.34	9.73	13.31	12.35	6.61	9.29	8.64	13.72	14.37	13.33	13.58	12.64	11.19	13.52	12.94
MnO	0.34	0.33	0.51	0.37	0.16	0.35	0.37	0.54	0.62	0.58	0.58	0.54	0.48	0.61	0.48
MgO	15.46	15.35	14.38	12.34	14.70	13.67	12.79	14.90	14.10	13.72	13.75	14.02	14.88	13.92	13.60
CaO	18.41	19.84	18.50	15.67	12.84	15.05	14.91	16.87	16.96	17.59	17.66	18.44	18.64	17.98	18.45
Na2O	0.28	0.36	0.24	0.83	0.31	0.27	0.41	0.26	0.32	nd	nd	nd	nd	nd	nd
NiO	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.01	0.02	0.03	0.03	0.01	0.00
Cr2O3	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.00	0.02	0.00	0.04	0.01	0.02
tot	97.58	97.83	98.46	94.24	78.87	85.17	82.05	97.63	97.11	98.83	99.39	99.68	99.69	99.59	99.37
atoms per 6 oxygens															
Si	1.8928	1.8880	1.9009	1.9224	1.9203	1.9436	1.9466	1.9133	1.9159	1.9682	1.9656	1.9594	1.9552	1.9615	1.9515
Ti	0.0165	0.0150	0.0154	0.0184	0.0167	0.0154	0.0136	0.0166	0.0165	0.0163	0.0154	0.0147	0.0149	0.0145	0.0168
Al t	0.1072	0.1120	0.0991	0.0776	0.0797	0.0564	0.0534	0.0867	0.0841	0.0318	0.0344	0.0406	0.0448	0.0385	0.0485
Al o	0.0000	0.0000	0.0000	0.0838	0.0441	0.0207	0.0255	0.0000	0.0000	0.0288	0.0277	0.0274	0.0303	0.0173	0.0314
Fe3+	0.0742	0.0820	0.0684	0.0000	0.0021	0.0048	0.0006	0.0535	0.0511	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fe2+	0.2910	0.2292	0.3607	0.4086	0.2537	0.3340	0.3261	0.3913	0.4193	0.4246	0.4305	0.3986	0.3505	0.4283	0.4101
Mn	0.0111	0.0107	0.0167	0.0124	0.0063	0.0129	0.0142	0.0177	0.0206	0.0187	0.0186	0.0172	0.0152	0.0196	0.0154
Mg	0.8871	0.8749	0.8260	0.7275	1.0137	0.8884	0.8619	0.8608	0.8226	0.7787	0.7768	0.7879	0.8306	0.7858	0.7680
Ca	0.7595	0.8130	0.7640	0.6642	0.6366	0.7032	0.7224	0.7007	0.7114	0.7178	0.7173	0.7451	0.7481	0.7298	0.7491
Na	0.0209	0.0267	0.0179	0.0637	0.0278	0.0228	0.0359	0.0195	0.0243	nd	nd	nd	nd	nd	nd
Ni	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.0003	0.0006	0.0009	0.0009	0.0003	0.0000
Cr	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.0000	0.0006	0.0000	0.0012	0.0003	0.0006
tot	4.0603	4.0514	4.0690	3.9785	4.0011	4.0024	4.0003	4.0601	4.0659	3.9852	3.9877	3.9919	3.9918	3.9960	3.9914
Ac	0.0209	0.0267	0.0179	0.0000	0.0021	0.0048	0.0006	0.0195	0.0243	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Jd	0.0000	0.0000	0.0000	0.0637	0.0257	0.0180	0.0255	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0533	0.0554	0.0504	0.0000	0.0000	0.0000	0.0000	0.0339	0.0268	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CrCaTs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0012	0.0003	0.0006
AlCaTs	0.0000	0.0000	0.0000	0.0201	0.0185	0.0827	0.0000	0.0000	0.0000	0.0288	0.0277	0.0274	0.0303	0.0173	0.0314
Wo	0.3531	0.3788	0.3568	0.3220	0.3091	0.3503	0.3612	0.3334	0.3423	0.3445	0.3445	0.3588	0.3583	0.3561	0.3585
En	0.4871	0.4922	0.4477	0.4341	0.5526	0.4722	0.4634	0.4583	0.4356	0.4242	0.4217	0.4257	0.4512	0.4167	0.4182
Fs	0.1598	0.1289	0.1955	0.2438	0.1383	0.1775	0.1753	0.2083	0.2221	0.2313	0.2337	0.2154	0.1904	0.2271	0.2233
mg#	75.3	79.2	69.6	64.0	80.0	72.7	72.6	68.7	66.2	64.7	64.3	66.4	70.3	64.7	65.2

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Makushin clinopyroxene analyses

	LR-12b	LR-12n	LR-12n	LR-12n	LR-12n	M1-01	M1-01	M1-01	M1-01	M1-01	M1-01	M1-01	M1-01	M1-01	M1-01
	DI-409	DI-931	DI-931	DI-931	DI-931	83mn41	83mn41	83mn41	83mn41	83mn41	83mn41	83mn41	83mn41	83mn41	83mn41
	rim)	(core	rim)	core	rim	core	(core	rim)	(core	rim)	core	(core	rim)	core	rim
	2062	2063	2064	2066	2067	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
wt% oxides															
SiO2	52.17	51.30	51.26	51.61	51.36	51.04	51.18	49.57	51.53	51.47	51.40	51.48	51.00	51.58	50.70
TiO2	0.53	0.61	0.53	0.60	0.54	0.52	0.60	0.90	0.51	0.57	0.52	0.54	0.51	0.53	0.63
Al2O3	1.59	2.19	1.41	1.81	1.28	1.53	2.36	2.48	1.37	1.67	1.45	1.47	1.78	1.62	2.63
FeO	12.37	10.45	13.44	12.20	13.87	12.15	9.28	13.59	11.54	11.33	11.36	11.45	11.48	10.10	8.77
MnO	0.47	0.43	0.57	0.48	0.57	0.55	0.33	0.60	0.51	0.48	0.44	0.56	0.44	0.38	0.23
MgO	14.44	14.27	13.11	14.03	14.01	14.24	15.34	15.40	14.20	14.16	14.32	14.29	14.36	15.00	15.34
CaO	17.95	19.34	17.96	18.76	17.46	18.72	19.31	15.60	19.15	18.98	19.31	18.83	19.20	19.47	20.67
Na2O	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
NiO	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.03	0.00	0.00
Cr2O3	0.00	0.00	0.03	0.01	0.00	0.06	0.00	0.03	0.00	0.00	0.00	0.01	0.03	0.00	0.01
tot	99.52	98.59	98.31	99.5	99.1	98.81	98.41	98.17	98.81	98.66	98.83	98.63	98.83	98.68	98.98
atoms per 6 oxygens															
Si	1.9632	1.9422	1.9671	1.9481	1.9569	1.9438	1.9309	1.9010	1.9567	1.9537	1.9510	1.9561	1.9377	1.9488	1.9066
Ti	0.0150	0.0174	0.0153	0.0170	0.0155	0.0149	0.0170	0.0260	0.0146	0.0163	0.0148	0.0154	0.0146	0.0151	0.0178
Al t	0.0368	0.0578	0.0329	0.0519	0.0431	0.0562	0.0691	0.0990	0.0433	0.0463	0.0490	0.0439	0.0623	0.0512	0.0934
Al o	0.0337	0.0399	0.0309	0.0286	0.0144	0.0125	0.0358	0.0131	0.0180	0.0284	0.0158	0.0219	0.0174	0.0209	0.0232
Fe3+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0121	0.0000	0.0331	0.0000	0.0000	0.0035	0.0000	0.0149	0.0002	0.0342
Fe2+	0.3893	0.3309	0.4313	0.3851	0.4420	0.3749	0.2928	0.4028	0.3665	0.3597	0.3571	0.3639	0.3499	0.3190	0.2416
Mn	0.0150	0.0138	0.0185	0.0153	0.0184	0.0177	0.0105	0.0195	0.0164	0.0154	0.0141	0.0180	0.0142	0.0122	0.0073
Mg	0.8098	0.8051	0.7498	0.7893	0.7955	0.8082	0.8625	0.8802	0.8036	0.8010	0.8100	0.8092	0.8131	0.8446	0.8597
Ca	0.7238	0.7845	0.7385	0.7588	0.7128	0.7639	0.7806	0.6410	0.7791	0.7719	0.7853	0.7666	0.7816	0.7882	0.8329
Na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ni	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0003	0.0000	0.0000	0.0000	0.0009	0.0000	0.0009	0.0000	0.0000
Cr	0.0000	0.0000	0.0009	0.0003	0.0000	0.0018	0.0000	0.0009	0.0000	0.0000	0.0000	0.0003	0.0009	0.0000	0.0003
tot	3.9866	3.9916	3.9852	3.9945	3.9989	4.0061	3.9996	4.0165	3.9981	3.9927	4.0018	3.9954	4.0075	4.0001	4.0171
Ac	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0121	0.0000	0.0331	0.0000	0.0000	0.0035	0.0000	0.0149	0.0002	0.0342
CrCaTs	0.0000	0.0000	0.0009	0.0003	0.0000	0.0018	0.0000	0.0009	0.0000	0.0000	0.0000	0.0003	0.0009	0.0000	0.0003
AlCaTs	0.0337	0.0399	0.0309	0.0286	0.0144	0.0125	0.0358	0.0131	0.0180	0.0284	0.0158	0.0219	0.0174	0.0209	0.0232
Wo	0.3450	0.3723	0.3533	0.3649	0.3492	0.3687	0.3724	0.2970	0.3806	0.3718	0.3830	0.3722	0.3742	0.3835	0.3876
En	0.4423	0.4449	0.4105	0.4268	0.4184	0.4312	0.4686	0.4823	0.4254	0.4336	0.4282	0.4331	0.4375	0.4475	0.4781
Fs	0.2126	0.1828	0.2362	0.2083	0.2324	0.2000	0.1591	0.2207	0.1940	0.1947	0.1888	0.1947	0.1883	0.1690	0.1343
mg#	67.5	70.9	63.5	67.2	64.3	68.3	74.7	68.6	68.7	69.0	69.4	69.0	69.9	72.6	78.1

Makushin clinopyroxene analyses

	M1-01	M1-01	M1-51c	M1-51c	M1-51c	M1-51c	M1-51c	M1-51c	M1-51c	M1-51d	M1-51d	M1-51d	M1-51d	M1-51d	M1-51d
	83mn41	83mn41	m43c	m43c	m43c	m43c	m43c	m43c	m43c	m43f	m43f	m43f	m43f	m43f	m43f
	(core	rim)	(core	rim)	(core	rim)	core	core	core	(core	rim)	(core	rim)	(core	rim
	2035	2036	9	10	13	14	15	16	17	5	6	7	8	9	10
wt% oxides															
SiO2	50.85	50.44	50.91	51.47	51.47	51.32	51.56	51.54	51.20	51.31	50.80	50.85	50.33	51.94	51.63
TiO2	0.61	0.63	0.57	0.48	0.48	0.47	0.51	0.63	0.52	0.55	0.60	0.73	0.65	0.29	0.63
Al2O3	2.49	2.78	2.18	1.31	1.59	1.32	1.73	1.78	1.50	1.61	1.74	2.72	3.62	1.15	2.49
FeO	9.03	8.74	12.57	11.91	12.20	12.61	12.78	11.90	12.80	11.65	11.59	8.54	8.13	11.43	9.46
MnO	0.32	0.31	0.70	0.63	0.65	0.75	0.82	0.61	0.66	0.48	0.41	0.34	0.22	0.54	0.33
MgO	14.74	14.97	14.33	14.37	14.21	14.21	14.16	14.29	14.09	14.85	14.48	15.54	15.35	14.89	15.73
CaO	20.37	20.67	18.20	19.40	19.34	18.98	18.79	19.30	18.76	19.94	19.41	20.83	21.57	19.18	19.99
Na2O	nd	nd	0.28	0.30	0.31	0.21	0.29	0.25	0.32	nd	nd	nd	nd	nd	nd
NiO	0.00	0.00	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr2O3	0.00	0.01	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	98.41	98.55	99.74	99.87	100.25	99.87	100.64	100.3	99.85	100.39	99.03	99.55	99.87	99.42	100.26
atoms per 6 oxygens															
Si	1.9232	1.9060	1.9207	1.9391	1.9334	1.9392	1.9320	1.9315	1.9343	1.9248	1.9291	1.9007	1.8755	1.9587	1.9162
Ti	0.0174	0.0179	0.0162	0.0136	0.0136	0.0134	0.0144	0.0178	0.0148	0.0155	0.0171	0.0205	0.0182	0.0082	0.0176
Al t	0.0768	0.0940	0.0793	0.0609	0.0666	0.0608	0.0680	0.0685	0.0657	0.0752	0.0709	0.0993	0.1245	0.0413	0.0838
Al o	0.0343	0.0298	0.0176	0.0000	0.0038	0.0000	0.0084	0.0101	0.0011	0.0000	0.0070	0.0206	0.0345	0.0098	0.0251
Fe3+	0.0078	0.0281	0.0294	0.0337	0.0357	0.0341	0.0309	0.0229	0.0351	0.0441	0.0295	0.0376	0.0536	0.0151	0.0235
Fe2+	0.2779	0.2481	0.3672	0.3416	0.3476	0.3645	0.3696	0.3501	0.3693	0.3214	0.3386	0.2293	0.1998	0.3454	0.2701
Mn	0.0103	0.0099	0.0224	0.0201	0.0207	0.0240	0.0260	0.0194	0.0211	0.0153	0.0132	0.0108	0.0069	0.0172	0.0104
Mg	0.8309	0.8430	0.8057	0.8068	0.7955	0.8002	0.7907	0.7981	0.7933	0.8302	0.8195	0.8657	0.8525	0.8368	0.8701
Ca	0.8255	0.8369	0.7357	0.7832	0.7784	0.7685	0.7544	0.7750	0.7594	0.8015	0.7898	0.8343	0.8613	0.7750	0.7950
Na	nd	nd	0.0205	0.0219	0.0226	0.0154	0.0211	0.0182	0.0234	nd	nd	nd	nd	nd	nd
Ni	0.0000	0.0000	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr	0.0000	0.0003	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	4.0039	4.0141	4.0147	4.0209	4.0178	4.0200	4.0155	4.0115	4.0175	4.0280	4.0148	4.0188	4.0268	4.0076	4.0117
Ac	0.0000	0.0000	0.0205	0.0219	0.0226	0.0154	0.0211	0.0182	0.0234	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0078	0.0281	0.0089	0.0118	0.0131	0.0187	0.0099	0.0047	0.0117	0.0441	0.0295	0.0376	0.0536	0.0151	0.0235
CrCaTs	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AlCaTs	0.0343	0.0298	0.0176	0.0000	0.0038	0.0000	0.0084	0.0101	0.0011	0.0000	0.0070	0.0206	0.0345	0.0098	0.0251
Wo	0.3917	0.3893	0.3546	0.3857	0.3808	0.3749	0.3681	0.3801	0.3733	0.3787	0.3766	0.3880	0.3866	0.3751	0.3732
En	0.4558	0.4718	0.4433	0.4316	0.4309	0.4295	0.4306	0.4309	0.4276	0.4479	0.4411	0.4838	0.4969	0.4424	0.4783
Fs	0.1524	0.1388	0.2021	0.1827	0.1883	0.1956	0.2013	0.1890	0.1991	0.1734	0.1822	0.1282	0.1165	0.1826	0.1485
mg#	74.9	77.3	68.7	70.3	69.6	68.7	68.1	69.5	68.2	72.1	70.8	79.1	81.0	70.8	76.3

Makushin clinopyroxene analyses

	M1-51d	Mc-18	Mc-18	Mc-18	Mc-18	Mc-18	Mc-18	Mc-18	Mc-18	Md-04	Md-04	Md-04	Md-04	Md-04	Md-04
	m43f	m30	m30	m30	m30	m30	m30	m30	m30	m04	m04	m04	m04	m04	m04
	rim)	(core	rim)	(core	rim)	(core	rim)	gm	gm	(core	rim)	core	gm	rim	rim
	11	10	11	12	13	16	17	15	20	1	2	3	5	11	13
wt% oxides															
SiO2	50.80	50.93	49.02	49.04	48.91	50.42	51.04	49.77	50.51	50.90	51.28	50.45	50.75	48.75	50.83
TiO2	0.62	0.30	0.63	0.63	0.62	0.29	0.69	0.75	0.63	0.69	0.65	0.69	0.75	0.69	0.76
Al2O3	2.24	4.40	4.62	5.00	4.56	4.87	2.21	3.24	2.34	2.14	1.88	2.17	1.93	5.01	1.98
FeO	9.52	5.36	8.04	8.02	7.76	5.10	8.97	9.30	9.30	11.70	11.66	11.62	12.75	6.32	11.59
MnO	0.31	0.10	0.18	0.22	0.23	0.14	0.35	0.24	0.31	0.38	0.43	0.38	0.35	0.09	0.37
MgO	15.52	16.65	15.10	14.63	14.94	16.55	16.34	15.63	16.07	14.75	15.06	15.05	15.34	14.93	15.38
CaO	20.00	20.99	20.60	20.57	20.91	21.40	19.67	19.25	19.16	18.78	18.62	18.72	17.45	22.59	17.77
Na2O	nd	0.30	0.37	0.43	0.37	0.40	0.39	0.33	0.34	nd	nd	nd	nd	0.25	0.29
NiO	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr2O3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	99.01	99.03	98.56	98.54	98.3	99.17	99.66	98.51	98.66	99.34	99.58	99.08	99.32	98.63	98.97
atoms per 6 oxygens															
Si	1.9136	1.8800	1.8460	1.8454	1.8469	1.8600	1.9020	1.8788	1.9026	1.9228	1.9306	1.9122	1.9204	1.8316	1.9201
Ti	0.0176	0.0083	0.0178	0.0178	0.0176	0.0080	0.0193	0.0213	0.0178	0.0196	0.0184	0.0197	0.0213	0.0195	0.0216
Al t	0.0864	0.1200	0.1540	0.1546	0.1531	0.1400	0.0980	0.1212	0.0974	0.0772	0.0694	0.0878	0.0796	0.1684	0.0799
Al o	0.0131	0.0714	0.0511	0.0673	0.0500	0.0718	0.0000	0.0230	0.0065	0.0181	0.0140	0.0091	0.0065	0.0535	0.0083
Fe3+	0.0381	0.0319	0.0672	0.0516	0.0679	0.0521	0.0593	0.0555	0.0551	0.0200	0.0186	0.0394	0.0304	0.0760	0.0284
Fe2+	0.2618	0.1335	0.1860	0.2008	0.1772	0.1053	0.2202	0.2381	0.2378	0.3497	0.3485	0.3289	0.3731	0.1226	0.3377
Mn	0.0099	0.0031	0.0057	0.0070	0.0074	0.0044	0.0110	0.0077	0.0099	0.0122	0.0137	0.0122	0.0112	0.0029	0.0118
Mg	0.8713	0.9159	0.8475	0.8205	0.8408	0.9099	0.9075	0.8793	0.9021	0.8304	0.8450	0.8501	0.8651	0.8360	0.8658
Ca	0.8073	0.8302	0.8312	0.8294	0.8461	0.8459	0.7854	0.7787	0.7733	0.7601	0.7511	0.7603	0.7075	0.9094	0.7193
Na	nd	0.0215	0.0270	0.0314	0.0271	0.0286	0.0282	0.0242	0.0248	nd	nd	nd	nd	0.0182	0.0212
Ni	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	4.0191	4.0160	4.0336	4.0258	4.0339	4.0260	4.0310	4.0278	4.0276	4.0100	4.0093	4.0197	4.0152	4.0380	4.0142
Ac	0.0000	0.0215	0.0270	0.0314	0.0271	0.0286	0.0282	0.0242	0.0248	0.0000	0.0000	0.0000	0.0000	0.0182	0.0212
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0381	0.0105	0.0402	0.0203	0.0408	0.0234	0.0311	0.0314	0.0303	0.0200	0.0186	0.0394	0.0304	0.0578	0.0072
CrCaTs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AlCaTs	0.0131	0.0714	0.0511	0.0673	0.0500	0.0718	0.0000	0.0230	0.0065	0.0181	0.0140	0.0091	0.0065	0.0535	0.0083
Wo	0.3780	0.3741	0.3700	0.3710	0.3777	0.3753	0.3771	0.3621	0.3682	0.3611	0.3592	0.3559	0.3353	0.3991	0.3519
En	0.4783	0.5462	0.5166	0.5054	0.5140	0.5599	0.5012	0.5020	0.4999	0.4496	0.4537	0.4644	0.4644	0.5241	0.4662
Fs	0.1437	0.0796	0.1134	0.1237	0.1083	0.0648	0.1216	0.1359	0.1318	0.1893	0.1871	0.1797	0.2003	0.0769	0.1819
mg#	76.9	87.3	82.0	80.3	82.6	89.6	80.5	78.7	79.1	70.4	70.8	72.1	69.9	87.2	71.9

Makushin clinopyroxene analyses

	Md-14	Md-14	Md-14	Md-14	Md-14	Md-14	Md-14	Md-14	Md-14	Md-14	Me-03	Me-03	Me-03	Me-03	Me-03
	m14	m14	m14	m14	m14	m14	m14	m14	m14	m14	m36	m36	m36	m36	m36
	(core	rim)	(core	rim)	(core	rim)	gm	gm	rim	rim	(core	rim)	(core	rim)	(core
	10	11	12	13	22	23	21	24	15	18	3	4	7	8	12
wt% oxides															
SiO2	52.38	51.22	51.81	50.51	51.06	51.29	49.02	51.06	50.84	50.00	49.70	49.48	49.93	49.08	50.24
TiO2	0.67	0.89	0.75	0.73	0.65	0.67	1.04	0.65	0.73	0.74	0.52	0.66	0.56	0.67	0.51
Al2O3	1.57	2.93	2.18	2.39	1.79	1.65	2.93	1.79	1.73	2.83	4.38	5.49	4.53	4.94	3.43
FeO	12.64	12.34	12.28	12.57	13.05	12.95	13.27	13.05	14.26	9.77	7.84	6.88	6.74	8.59	7.10
MnO	0.42	0.33	0.35	0.46	0.46	0.47	0.41	0.46	0.49	0.29	0.26	0.15	0.14	0.25	0.19
MgO	14.39	14.54	13.67	14.62	14.56	14.68	14.72	14.56	15.46	15.90	15.68	15.25	15.55	14.72	15.67
CaO	17.75	17.56	18.49	17.80	18.23	18.18	17.51	18.23	15.43	19.13	20.84	21.92	22.48	20.21	21.46
Na2O	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.38	0.31	0.27	0.40	0.34
NiO	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr2O3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	99.82	99.81	99.53	99.08	99.8	99.89	98.9	99.8	98.94	98.66	99.6	100.14	100.2	98.86	98.94
atoms per 6 oxygens															
Si	1.9650	1.9202	1.9507	1.9168	1.9292	1.9344	1.8742	1.9292	1.9337	1.8900	1.8506	1.8286	1.8464	1.8443	1.8791
Ti	0.0189	0.0251	0.0212	0.0208	0.0185	0.0190	0.0299	0.0185	0.0209	0.0210	0.0146	0.0183	0.0156	0.0189	0.0143
Al t	0.0350	0.0798	0.0493	0.0832	0.0708	0.0656	0.1258	0.0708	0.0663	0.1100	0.1494	0.1714	0.1536	0.1557	0.1209
Al o	0.0345	0.0497	0.0475	0.0237	0.0090	0.0077	0.0063	0.0090	0.0112	0.0161	0.0428	0.0677	0.0439	0.0632	0.0303
Fe3+	0.0000	0.0000	0.0000	0.0178	0.0249	0.0199	0.0597	0.0249	0.0133	0.0518	0.0775	0.0670	0.0786	0.0546	0.0619
Fe2+	0.3966	0.3869	0.3867	0.3811	0.3875	0.3885	0.3646	0.3875	0.4403	0.2571	0.1667	0.1456	0.1298	0.2153	0.1602
Mn	0.0133	0.0105	0.0112	0.0148	0.0147	0.0150	0.0133	0.0147	0.0158	0.0093	0.0082	0.0047	0.0044	0.0080	0.0060
Mg	0.8045	0.8124	0.7671	0.8268	0.8199	0.8251	0.8388	0.8199	0.8763	0.8957	0.8701	0.8399	0.8570	0.8244	0.8735
Ca	0.7135	0.7054	0.7460	0.7238	0.7380	0.7347	0.7173	0.7380	0.6288	0.7748	0.8315	0.8680	0.8907	0.8138	0.8600
Na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.0274	0.0222	0.0194	0.0291	0.0247
Ni	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	3.9813	3.9899	3.9796	4.0089	4.0124	4.0100	4.0299	4.0124	4.0067	4.0259	4.0387	4.0335	4.0393	4.0273	4.0309
Ac	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0274	0.0222	0.0194	0.0291	0.0247
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0000	0.0000	0.0000	0.0178	0.0249	0.0199	0.0597	0.0249	0.0133	0.0518	0.0500	0.0448	0.0593	0.0255	0.0372
CrCaTs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AlCaTs	0.0345	0.0497	0.0475	0.0237	0.0090	0.0077	0.0063	0.0090	0.0112	0.0161	0.0428	0.0677	0.0439	0.0632	0.0303
Wo	0.3395	0.3278	0.3492	0.3411	0.3521	0.3535	0.3257	0.3521	0.3021	0.3535	0.3693	0.3777	0.3938	0.3626	0.3962
En	0.4424	0.4553	0.4327	0.4510	0.4400	0.4395	0.4700	0.4400	0.4645	0.5023	0.5293	0.5303	0.5265	0.5054	0.5102
Fs	0.2181	0.2168	0.2181	0.2079	0.2079	0.2070	0.2043	0.2079	0.2334	0.1442	0.1014	0.0919	0.0797	0.1320	0.0936
mg#	67.0	67.7	66.5	68.4	67.9	68.0	69.7	67.9	66.6	77.7	83.9	85.2	86.8	79.3	84.5

Makushin clinopyroxene analyses

	Me-03 m36 rim) 13	Me-03 m36 gm 21	Me-06 m39 (core 12	Me-06 m39 rim) 13	Me-07 m40 (core 18	Me-07 m40 rim) 19	Me-07 m40 (core 20	Me-07 m40 rim) 21	Me-07 m40 (core 22	Me-07 m40 rim) 23	Me-07 m40 gm 24	Me-07 m40 gm 28	Me-07 m40 gm 29	Mf-01 m45 (core 1	Mf-01 m45 rim) 2
wt% oxides															
SiO2	49.43	50.96	50.74	51.08	48.47	49.89	48.28	48.14	47.95	47.95	50.09	50.28	49.71	51.04	47.71
TiO2	0.96	0.83	0.55	0.51	0.51	0.37	0.76	0.65	0.84	0.84	0.44	0.53	0.64	0.40	1.13
Al2O3	2.29	2.59	1.68	1.66	4.32	3.05	4.58	4.20	4.21	4.21	1.87	2.20	2.76	1.25	5.29
FeO	11.67	12.81	10.46	10.77	5.87	5.67	7.08	6.92	9.26	9.26	9.59	9.04	9.93	11.47	8.76
MnO	0.37	0.41	0.47	0.44	0.14	0.18	0.14	0.13	0.25	0.25	0.28	0.23	0.33	0.49	0.21
MgO	14.88	16.06	14.56	15.09	15.46	16.17	15.02	15.11	14.57	14.57	16.82	16.06	15.47	14.33	14.33
CaO	18.72	16.39	19.32	19.35	22.28	22.47	21.87	21.71	20.50	20.50	17.95	19.21	18.96	20.28	20.79
Na2O	0.32	0.32	0.35	0.28	0.26	0.26	0.27	0.24	0.35	0.35	0.27	0.30	0.26	0.33	0.28
NiO	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr2O3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	98.64	100.37	98.13	99.18	97.31	98.06	98	97.1	97.93	97.93	97.31	97.85	98.06	99.59	98.5
atoms per 6 oxygens															
Si	1.8857	1.9000	1.9329	1.9274	1.8431	1.8790	1.8313	1.8418	1.8334	1.8334	1.9115	1.9081	1.8910	1.9306	1.8100
Ti	0.0275	0.0233	0.0158	0.0145	0.0146	0.0105	0.0217	0.0187	0.0242	0.0242	0.0126	0.0151	0.0183	0.0114	0.0322
Al t	0.1143	0.1000	0.0671	0.0726	0.1569	0.1210	0.1687	0.1582	0.1666	0.1666	0.0885	0.0919	0.1090	0.0694	0.1900
Al o	0.0000	0.0138	0.0084	0.0013	0.0367	0.0145	0.0361	0.0312	0.0232	0.0232	0.0000	0.0066	0.0148	0.0000	0.0466
Fe3+	0.0593	0.0396	0.0272	0.0423	0.0911	0.0855	0.0893	0.0897	0.0952	0.0952	0.0633	0.0551	0.0575	0.0467	0.0789
Fe2+	0.3131	0.3598	0.3060	0.2976	0.0956	0.0931	0.1353	0.1318	0.2010	0.2010	0.2428	0.2318	0.2584	0.3162	0.1990
Mn	0.0120	0.0129	0.0152	0.0141	0.0045	0.0057	0.0045	0.0042	0.0081	0.0081	0.0091	0.0074	0.0106	0.0157	0.0067
Mg	0.8460	0.8924	0.8266	0.8486	0.8761	0.9076	0.8491	0.8615	0.8302	0.8302	0.9566	0.9083	0.8771	0.8078	0.8102
Ca	0.7652	0.6548	0.7886	0.7824	0.9078	0.9068	0.8889	0.8900	0.8399	0.8399	0.7340	0.7811	0.7728	0.8219	0.8451
Na	0.0237	0.0231	0.0259	0.0205	0.0192	0.0190	0.0199	0.0178	0.0259	0.0259	0.0200	0.0221	0.0192	0.0242	0.0206
Ni	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	4.0467	4.0198	4.0136	4.0212	4.0455	4.0428	4.0446	4.0448	4.0476	4.0476	4.0383	4.0275	4.0288	4.0439	4.0395
Ac	0.0237	0.0231	0.0259	0.0205	0.0192	0.0190	0.0199	0.0178	0.0259	0.0259	0.0200	0.0221	0.0192	0.0242	0.0206
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0356	0.0165	0.0014	0.0218	0.0719	0.0665	0.0694	0.0719	0.0692	0.0692	0.0433	0.0330	0.0383	0.0225	0.0583
CrCaTs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AlCaTs	0.0000	0.0138	0.0084	0.0013	0.0367	0.0145	0.0361	0.0312	0.0232	0.0232	0.0000	0.0066	0.0148	0.0000	0.0466
Wo	0.3648	0.3122	0.3894	0.3796	0.3996	0.4129	0.3917	0.3935	0.3738	0.3738	0.3453	0.3708	0.3598	0.3997	0.3701
En	0.4636	0.4901	0.4456	0.4593	0.5413	0.5325	0.5247	0.5261	0.5042	0.5042	0.5222	0.5013	0.4945	0.4314	0.5057
Fs	0.1716	0.1976	0.1650	0.1611	0.0591	0.0546	0.0836	0.0805	0.1220	0.1220	0.1325	0.1279	0.1457	0.1689	0.1242
mg#	73.0	71.3	73.0	74.0	90.2	90.7	86.3	86.7	80.5	80.5	79.8	79.7	77.2	71.9	80.3

Makushin clinopyroxene analyses

	Mf-01 m45 (core 3	Mf-01 m45 rim) 4	Mf-01 m45 (core 11	Mf-01 m45 rim) 12	Mf-01 m45 rim 8	Mf-01 m45 gm 19	Mf-01 m45 core 5	Mf-01 m45 core 1	Mf-01 m45 rim 2	Mf-01 m45 core 3	Mf-01 m45 rim 4	Mf-01 m45 core 11	Mf-01 m45 rim 12	Mf-01 m45 rim 8	Mf-01 m45 gm 19
wt% oxides															
SiO2	50.87	50.97	46.28	47.38	50.96	50.54	50.50	51.04	47.71	50.87	50.97	46.28	47.38	50.96	50.54
TiO2	0.61	0.67	0.92	0.83	0.38	0.60	0.52	0.40	1.13	0.61	0.67	0.92	0.83	0.38	0.60
Al2O3	3.30	2.40	6.13	5.70	2.15	2.46	2.80	1.25	5.29	3.30	2.40	6.13	5.70	2.15	2.46
FeO	6.12	8.66	7.39	8.03	8.11	8.50	7.33	11.47	8.76	6.12	8.66	7.39	8.03	8.11	8.50
MnO	0.13	0.36	0.19	0.20	0.21	0.30	0.21	0.49	0.21	0.13	0.36	0.19	0.20	0.21	0.30
MgO	16.00	15.22	13.93	14.03	16.71	17.18	16.97	14.33	14.33	16.00	15.22	13.93	14.03	16.71	17.18
CaO	22.73	20.74	22.29	21.94	19.51	19.04	20.51	20.28	20.79	22.73	20.74	22.29	21.94	19.51	19.04
Na2O	0.33	0.36	0.18	0.31	0.20	0.14	0.26	0.33	0.28	0.33	0.36	0.18	0.31	0.20	0.14
NiO	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr2O3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	100.09	99.38	97.31	98.42	98.23	98.76	99.1	99.59	98.5	100.09	99.38	97.31	98.42	98.23	98.76
atoms per 6 oxygens															
Si	1.8776	1.9073	1.7786	1.7993	1.9176	1.8956	1.8842	1.9306	1.8100	1.8776	1.9073	1.7786	1.7993	1.9176	1.8956
Ti	0.0169	0.0189	0.0266	0.0237	0.0108	0.0169	0.0146	0.0114	0.0322	0.0169	0.0189	0.0266	0.0237	0.0108	0.0169
Al t	0.1224	0.0927	0.2214	0.2007	0.0824	0.1044	0.1158	0.0694	0.1900	0.1224	0.0927	0.2214	0.2007	0.0824	0.1044
Al o	0.0212	0.0132	0.0564	0.0545	0.0130	0.0044	0.0073	0.0000	0.0466	0.0212	0.0132	0.0564	0.0545	0.0130	0.0044
Fe3+	0.0674	0.0418	0.1118	0.0987	0.0479	0.0662	0.0793	0.0467	0.0789	0.0674	0.0418	0.1118	0.0987	0.0479	0.0662
Fe2+	0.1215	0.2292	0.1258	0.1563	0.2073	0.2004	0.1494	0.3162	0.1990	0.1215	0.2292	0.1258	0.1563	0.2073	0.2004
Mn	0.0041	0.0114	0.0062	0.0064	0.0067	0.0095	0.0066	0.0157	0.0067	0.0041	0.0114	0.0062	0.0064	0.0067	0.0095
Mg	0.8801	0.8488	0.7979	0.7941	0.9371	0.9603	0.9436	0.8078	0.8102	0.8801	0.8488	0.7979	0.7941	0.9371	0.9603
Ca	0.8989	0.8316	0.9179	0.8928	0.7866	0.7652	0.8200	0.8219	0.8451	0.8989	0.8316	0.9179	0.8928	0.7866	0.7652
Na	0.0236	0.0261	0.0134	0.0228	0.0146	0.0102	0.0188	0.0242	0.0206	0.0236	0.0261	0.0134	0.0228	0.0146	0.0102
Ni	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	4.0337	4.0209	4.0559	4.0494	4.0240	4.0331	4.0397	4.0439	4.0395	4.0337	4.0209	4.0559	4.0494	4.0240	4.0331
Ac	0.0236	0.0261	0.0134	0.0228	0.0146	0.0102	0.0188	0.0242	0.0206	0.0236	0.0261	0.0134	0.0228	0.0146	0.0102
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0438	0.0157	0.0984	0.0759	0.0333	0.0560	0.0605	0.0225	0.0583	0.0438	0.0157	0.0984	0.0759	0.0333	0.0560
CrCaTs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AlCaTs	0.0212	0.0132	0.0564	0.0545	0.0130	0.0044	0.0073	0.0000	0.0466	0.0212	0.0132	0.0564	0.0545	0.0130	0.0044
Wo	0.4170	0.4013	0.3816	0.3812	0.3702	0.3524	0.3761	0.3997	0.3701	0.4170	0.4013	0.3816	0.3812	0.3702	0.3524
En	0.5123	0.4714	0.5342	0.5171	0.5158	0.5358	0.5387	0.4314	0.5057	0.5123	0.4714	0.5342	0.5171	0.5158	0.5358
Fs	0.0707	0.1273	0.0842	0.1018	0.1141	0.1118	0.0853	0.1689	0.1242	0.0707	0.1273	0.0842	0.1018	0.1141	0.1118
mg#	87.9	78.7	86.4	83.6	81.9	82.7	86.3	71.9	80.3	87.9	78.7	86.4	83.6	81.9	82.7

Makushin clinopyroxene analyses

	Mf-01	Mf-04	Mf-04	Mf-04	Mf-04	Mf-04	Mf-04	Mf-04	PC-02	PC-02	PC-02	PC-02	PC-02	PC-02	PC-06
	m45	m48	m48	m48	m48	m48	m48	m48	m21	m21	m21	m21	m21	m21	83mn86
	core	(core	rim)	(core	rim)	(core	rim)	core	(core	rim)	(core	rim)	gm	gm	(core
	5	6	7	8	9	10	11	19	3	4	7	8	11	12	2043
wt% oxides															
SiO2	50.50	50.16	49.46	49.33	49.82	51.12	50.26	49.67	51.56	51.57	51.01	50.86	50.09	50.82	51.11
TiO2	0.52	0.54	0.69	0.77	0.89	0.61	0.50	0.78	0.54	0.47	0.53	0.65	0.65	0.71	0.33
Al2O3	2.80	1.69	2.64	3.12	1.94	1.81	2.37	2.99	2.15	1.70	2.56	2.00	3.60	2.41	3.43
FeO	7.33	10.16	9.73	9.54	12.87	9.11	8.78	10.20	9.50	10.34	9.20	11.06	10.38	10.87	6.57
MnO	0.21	0.36	0.38	0.34	0.61	0.26	0.26	0.42	0.38	0.47	0.29	0.43	0.37	0.40	0.23
MgO	16.97	16.32	15.23	15.42	15.19	16.69	16.43	15.98	16.83	17.33	16.52	17.28	16.62	16.86	17.05
CaO	20.51	18.11	19.20	19.37	16.59	19.08	19.68	18.44	19.16	16.95	19.38	15.66	15.92	16.93	20.12
Na2O	0.26	0.32	0.42	0.35	0.34	0.29	0.42	0.41	0.36	0.33	0.45	0.37	0.36	0.36	nd
NiO	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.02
Cr2O3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.08
tot	99.1	97.66	97.75	98.24	98.25	98.97	98.7	98.89	100.48	99.16	99.94	98.31	97.99	99.36	98.94
atoms per 6 oxygens															
Si	1.8842	1.9136	1.8881	1.8731	1.9068	1.9161	1.8917	1.8737	1.9060	1.9275	1.8946	1.9181	1.8897	1.9014	1.8982
Ti	0.0146	0.0155	0.0198	0.0220	0.0256	0.0172	0.0142	0.0221	0.0150	0.0132	0.0148	0.0184	0.0184	0.0200	0.0092
Al t	0.1158	0.0864	0.1119	0.1269	0.0932	0.0839	0.1083	0.1263	0.0940	0.0725	0.1054	0.0819	0.1103	0.0986	0.1018
Al o	0.0073	0.0000	0.0070	0.0128	0.0000	0.0000	0.0000	0.0067	0.0000	0.0024	0.0067	0.0070	0.0498	0.0077	0.0484
Fe3+	0.0793	0.0554	0.0653	0.0702	0.0419	0.0495	0.0800	0.0754	0.0640	0.0436	0.0691	0.0381	0.0237	0.0509	0.0326
Fe2+	0.1494	0.2688	0.2454	0.2328	0.3700	0.2360	0.1964	0.2464	0.2297	0.2796	0.2167	0.3107	0.3038	0.2892	0.1715
Mn	0.0066	0.0116	0.0123	0.0109	0.0198	0.0083	0.0083	0.0134	0.0119	0.0149	0.0091	0.0137	0.0118	0.0127	0.0072
Mg	0.9436	0.9279	0.8665	0.8726	0.8665	0.9323	0.9216	0.8984	0.9272	0.9653	0.9144	0.9712	0.9344	0.9401	0.9437
Ca	0.8200	0.7403	0.7854	0.7881	0.6804	0.7663	0.7937	0.7453	0.7589	0.6788	0.7713	0.6328	0.6435	0.6787	0.8007
Na	0.0188	0.0237	0.0311	0.0258	0.0252	0.0211	0.0307	0.0300	0.0258	0.0239	0.0324	0.0271	0.0263	0.0261	nd
Ni	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.0006
Cr	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.0023
tot	4.0397	4.0432	4.0326	4.0351	4.0294	4.0307	4.0447	4.0377	4.0325	4.0218	4.0345	4.0190	4.0118	4.0255	4.0163
Ac	0.0188	0.0237	0.0311	0.0258	0.0252	0.0211	0.0307	0.0300	0.0258	0.0239	0.0324	0.0271	0.0237	0.0261	0.0000
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0027	0.0000	0.0000
FeCaTs	0.0605	0.0317	0.0342	0.0444	0.0167	0.0285	0.0494	0.0454	0.0382	0.0197	0.0367	0.0110	0.0000	0.0248	0.0326
CrCaTs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0023
AlCaTs	0.0073	0.0000	0.0070	0.0128	0.0000	0.0000	0.0000	0.0067	0.0000	0.0024	0.0067	0.0070	0.0471	0.0077	0.0484
Wo	0.3761	0.3543	0.3721	0.3655	0.3318	0.3689	0.3722	0.3466	0.3604	0.3283	0.3640	0.3074	0.2982	0.3231	0.3587
En	0.5387	0.5007	0.4893	0.5009	0.4682	0.5036	0.5176	0.5127	0.5127	0.5208	0.5142	0.5247	0.5296	0.5176	0.5427
Fs	0.0853	0.1450	0.1386	0.1336	0.2000	0.1275	0.1103	0.1406	0.1270	0.1508	0.1219	0.1679	0.1722	0.1592	0.0986
mg#	86.3	77.5	77.9	78.9	70.1	79.8	82.4	78.5	80.1	77.5	80.8	75.8	75.5	76.5	84.6

Makushin clinopyroxene analyses

	PC-06	PC-06	PC-06	PC-06	PC-06	PC-06	PC-06	PC-06	PC-06	PC-06	PC-06	PC-09	PC-09	PC-09	PC-09
	83mn86	83mn86	83mn86	83mn86	83mn86	83mn86	83mn86	83mn86	83mn86	83mn86	83mn86	83mn25	83mn25	83mn25	83mn25
	rim)	(core	core	mid	mid	mid	rim)	core	clot	core	core	(core	core	rim)	core
	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2001	2002	2003	2004
wt% oxides															
SiO2	49.37	49.71	52.21	52.62	52.98	51.42	50.91	53.66	50.89	49.75	51.24	52.31	53.24	51.32	50.40
TiO2	0.48	0.47	0.27	0.23	0.22	0.29	0.33	0.15	0.28	0.42	0.34	0.21	0.19	0.32	0.38
Al2O3	4.60	4.98	3.10	2.32	2.23	3.46	3.52	2.12	3.76	4.59	3.23	2.78	2.18	3.38	3.62
FeO	7.78	6.21	4.39	4.67	4.71	5.31	7.19	3.91	5.27	6.10	6.35	4.58	4.57	6.47	5.60
MnO	0.19	0.19	0.11	0.14	0.12	0.11	0.25	0.12	0.11	0.11	0.13	0.12	0.16	0.20	0.16
MgO	14.92	15.91	16.98	17.91	17.68	16.63	16.80	18.37	16.70	15.60	16.98	17.32	17.53	16.36	15.49
CaO	20.53	21.26	21.85	21.12	21.49	20.91	19.60	21.01	21.15	21.75	20.43	21.09	21.16	20.33	21.88
Na2O	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
NiO	0.01	0.04	0.04	0.03	0.03	0.00	0.03	0.03	0.02	0.03	0.00	0.00	0.02	0.02	0.05
Cr2O3	0.15	0.38	1.01	0.45	0.50	0.42	0.13	0.47	0.63	0.46	0.22	0.63	0.49	0.15	0.25
tot	98.03	99.15	99.96	99.49	99.96	98.55	98.76	99.84	98.81	98.81	98.92	99.04	99.54	98.55	97.83
atoms per 6 oxygens															
Si	1.8667	1.8495	1.9099	1.9299	1.9351	1.9090	1.8975	1.9496	1.8887	1.8590	1.9027	1.9262	1.9481	1.9121	1.8964
Ti	0.0136	0.0132	0.0074	0.0063	0.0060	0.0081	0.0092	0.0041	0.0078	0.0118	0.0095	0.0058	0.0052	0.0090	0.0108
Al t	0.1333	0.1505	0.0901	0.0701	0.0649	0.0910	0.1025	0.0504	0.1113	0.1410	0.0973	0.0738	0.0519	0.0879	0.1036
Al o	0.0718	0.0680	0.0436	0.0302	0.0312	0.0604	0.0521	0.0405	0.0532	0.0612	0.0441	0.0469	0.0422	0.0606	0.0570
Fe3+	0.0297	0.0450	0.0025	0.0141	0.0072	0.0021	0.0281	0.0000	0.0239	0.0425	0.0278	0.0000	0.0000	0.0050	0.0176
Fe2+	0.2163	0.1482	0.1318	0.1291	0.1367	0.1628	0.1960	0.1188	0.1397	0.1481	0.1694	0.1410	0.1399	0.1966	0.1586
Mn	0.0061	0.0060	0.0034	0.0043	0.0037	0.0035	0.0079	0.0037	0.0035	0.0035	0.0041	0.0037	0.0050	0.0063	0.0051
Mg	0.8408	0.8822	0.9257	0.9790	0.9624	0.9201	0.9332	0.9947	0.9237	0.8688	0.9397	0.9505	0.9560	0.9084	0.8686
Ca	0.8318	0.8476	0.8564	0.8300	0.8411	0.8318	0.7827	0.8179	0.8411	0.8709	0.8129	0.8321	0.8296	0.8116	0.8822
Na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ni	0.0003	0.0012	0.0012	0.0009	0.0009	0.0000	0.0009	0.0009	0.0006	0.0009	0.0000	0.0000	0.0006	0.0006	0.0015
Cr	0.0045	0.0112	0.0292	0.0130	0.0144	0.0123	0.0038	0.0135	0.0185	0.0136	0.0065	0.0183	0.0142	0.0044	0.0074
tot	4.0149	4.0225	4.0012	4.0071	4.0036	4.0011	4.0140	3.9941	4.0120	4.0213	4.0139	3.9985	3.9926	4.0025	4.0088
Ac	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0297	0.0450	0.0025	0.0141	0.0072	0.0021	0.0281	0.0000	0.0239	0.0425	0.0278	0.0000	0.0000	0.0050	0.0176
CrCaTs	0.0045	0.0112	0.0292	0.0130	0.0144	0.0123	0.0038	0.0135	0.0185	0.0136	0.0065	0.0183	0.0142	0.0044	0.0074
AlCaTs	0.0718	0.0680	0.0436	0.0302	0.0312	0.0604	0.0521	0.0405	0.0532	0.0612	0.0441	0.0469	0.0422	0.0606	0.0570
Wo	0.3629	0.3617	0.3906	0.3863	0.3941	0.3785	0.3494	0.3820	0.3727	0.3767	0.3673	0.3834	0.3867	0.3708	0.4000
En	0.5067	0.5465	0.5334	0.5422	0.5305	0.5281	0.5377	0.5521	0.5449	0.5325	0.5361	0.5369	0.5351	0.5172	0.5073
Fs	0.1304	0.0918	0.0760	0.0715	0.0753	0.0934	0.1130	0.0659	0.0824	0.0908	0.0967	0.0797	0.0783	0.1119	0.0926
mg#	79.5	85.6	87.5	88.3	87.6	85.0	82.6	89.3	86.9	85.4	84.7	87.1	87.2	82.2	84.6

Nakushin clinopyroxene analyses

	PC-09	PC-09	PC-09	PC-09	PC-09	PC-09	PC-09	PC-11	PC-11	PC-11	PC-11	PC-11	PC-11	PC-11	PC-11
	83mn25	83mn25	83mn25	83mn25	83mn25	83mn25	83mn25	m20	m20	m20	m20	m20	m20	m20	m20
	(core	mid	mid	rim)	core	(core	rim)	(core	rim)	(core	rim)	core	gm	gm	rim
	2005	2006	2007	2008	2009	2010	2011	11	12	21	22	23	16	24	10
wt% oxides															
SiO2	51.03	51.59	51.31	51.35	51.38	50.89	50.61	51.60	50.66	50.36	50.37	51.27	50.46	51.28	50.43
TiO2	0.30	0.31	0.30	0.31	0.32	0.28	0.30	0.61	0.76	0.68	0.79	0.58	0.71	0.64	0.77
Al2O3	2.94	3.03	3.00	3.12	2.91	3.52	3.39	1.72	1.92	1.91	1.90	1.83	1.74	1.73	1.66
FeO	6.67	6.39	6.24	6.54	4.85	5.21	6.64	11.04	11.85	10.40	11.95	10.09	12.33	10.83	13.59
MnO	0.21	0.17	0.18	0.16	0.12	0.16	0.20	0.46	0.48	0.42	0.54	0.44	0.59	0.42	0.60
MgO	16.88	16.73	16.65	17.05	16.43	16.65	16.84	16.33	15.68	16.24	15.26	16.85	16.06	16.39	16.18
CaO	19.39	20.59	20.41	20.16	22.13	21.04	19.04	18.28	17.82	18.48	18.05	18.54	17.05	18.44	15.44
Na2O	nd	nd	nd	nd	nd	nd	nd	0.40	0.37	0.44	0.34	0.30	0.30	0.36	0.33
NiO	0.00	0.00	0.01	0.03	0.04	0.01	0.02	nd	nd	nd	nd	nd	nd	nd	nd
Cr2O3	0.07	0.25	0.21	0.20	0.75	0.57	0.15	nd	nd	nd	nd	nd	nd	nd	nd
tot	97.49	99.06	98.31	98.92	98.93	98.33	97.19	100.44	99.54	98.93	99.2	99.9	99.24	100.09	99
atoms per 6 oxygens															
Si	1.9198	1.9133	1.9159	1.9070	1.9069	1.8970	1.9088	1.9172	1.9074	1.9000	1.9070	1.9105	1.9082	1.9125	1.9135
Ti	0.0085	0.0086	0.0084	0.0087	0.0089	0.0078	0.0085	0.0170	0.0215	0.0193	0.0225	0.0163	0.0202	0.0180	0.0220
Al t	0.0802	0.0867	0.0841	0.0930	0.0931	0.1030	0.0912	0.0828	0.0926	0.1000	0.0930	0.0895	0.0918	0.0875	0.0865
Al o	0.0502	0.0458	0.0479	0.0436	0.0342	0.0517	0.0596	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fe3+	0.0109	0.0163	0.0131	0.0262	0.0190	0.0189	0.0101	0.0487	0.0495	0.0614	0.0480	0.0570	0.0514	0.0516	0.0425
Fe2+	0.1990	0.1819	0.1817	0.1769	0.1315	0.1436	0.1993	0.2944	0.3236	0.2667	0.3303	0.2574	0.3385	0.2862	0.3888
Mn	0.0067	0.0053	0.0057	0.0050	0.0038	0.0051	0.0064	0.0145	0.0153	0.0134	0.0173	0.0139	0.0189	0.0133	0.0193
Mg	0.9464	0.9247	0.9265	0.9437	0.9088	0.9250	0.9466	0.9043	0.8799	0.9131	0.8610	0.9357	0.9051	0.9110	0.9150
Ca	0.7816	0.8182	0.8166	0.8022	0.8801	0.8404	0.7695	0.7278	0.7189	0.7471	0.7322	0.7402	0.6909	0.7369	0.6278
Na	nd	nd	nd	nd	nd	nd	nd	0.0288	0.0270	0.0322	0.0250	0.0217	0.0220	0.0260	0.0243
Ni	0.0000	0.0000	0.0003	0.0009	0.0012	0.0003	0.0006	nd	nd	nd	nd	nd	nd	nd	nd
Cr	0.0021	0.0073	0.0062	0.0059	0.0220	0.0168	0.0045	nd	nd	nd	nd	nd	nd	nd	nd
tot	4.0054	4.0082	4.0066	4.0131	4.0095	4.0094	4.0050	4.0354	4.0358	4.0533	4.0364	4.0422	4.0470	4.0429	4.0395
Ac	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0288	0.0270	0.0322	0.0250	0.0217	0.0220	0.0260	0.0243
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0109	0.0163	0.0131	0.0262	0.0190	0.0189	0.0101	0.0198	0.0225	0.0292	0.0231	0.0354	0.0294	0.0256	0.0182
CrCaTs	0.0021	0.0073	0.0062	0.0059	0.0220	0.0168	0.0045	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AlCaTs	0.0502	0.0458	0.0479	0.0436	0.0342	0.0517	0.0596	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wo	0.3592	0.3744	0.3747	0.3633	0.4024	0.3765	0.3477	0.3540	0.3482	0.3589	0.3546	0.3524	0.3307	0.3557	0.3048
En	0.5295	0.5228	0.5228	0.5362	0.5220	0.5397	0.5389	0.4874	0.4765	0.4961	0.4665	0.5079	0.4871	0.4903	0.4879
Fs	0.1113	0.1028	0.1025	0.1005	0.0756	0.0838	0.1135	0.1587	0.1753	0.1449	0.1790	0.1397	0.1822	0.1540	0.2073
mg#	82.6	83.6	83.6	84.2	87.4	86.6	82.6	75.4	73.1	77.4	72.3	78.4	72.8	76.1	70.2

Nakushin clinopyroxene analyses

	PC-11	PK-02	PK-02	TT-10	TT-10	TT-10	TT-10	TT-10	TT-10	TT-22	TT-22	TT-22	TT-22	TT-22	TT-22
	m20	m52	m52	83mn77	83mn77	83mn77	83mn77	83mn77	83mn77	m29	m29	m29	m29	m29	m29
	rim	(core	rim)	(core	rim)	core	(core	rim)	core	(core	rim)	(core	rim)	(core	rim)
	20	11	12	2077	2078	2079	2081	2082	2083	1	2	3	4	7	8
wt% oxides															
SiO2	50.06	51.02	50.59	50.98	51.23	51.49	51.10	50.85	50.63	48.71	51.08	47.08	50.42	51.23	49.91
TiO2	0.69	0.59	0.74	0.59	0.65	0.57	0.53	0.66	0.55	0.93	0.54	1.07	0.82	0.54	0.69
Al2O3	1.75	1.56	2.26	3.19	2.17	3.00	2.68	2.12	3.15	4.41	1.63	5.59	2.55	2.29	3.06
FeO	13.54	11.55	11.43	7.24	9.74	7.44	7.66	9.47	7.37	8.66	11.12	9.41	10.35	8.71	11.11
MnO	0.66	0.57	0.42	0.20	0.38	0.22	0.24	0.30	0.20	0.23	0.46	0.21	0.32	0.29	0.45
MgO	15.08	14.56	14.62	14.89	15.26	15.07	15.24	14.90	14.80	14.30	14.87	13.85	14.73	16.02	14.83
CaO	16.67	18.90	18.66	21.70	19.15	21.21	20.83	19.40	21.37	21.11	19.27	21.76	19.71	20.33	18.08
Na2O	0.35	0.28	0.34	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
NiO	nd	nd	nd	0.01	0.00	0.00	0.02	0.01	0.00	nd	nd	nd	nd	nd	nd
Cr2O3	nd	nd	nd	0.01	0.01	0.00	0.01	0.00	0.02	nd	nd	nd	nd	nd	nd
tot	98.8	99.03	99.06	98.81	98.59	99	98.31	97.71	98.09	98.35	98.97	98.97	98.9	99.41	98.13
atoms per 6 oxygens															
Si	1.9113	1.9335	1.9133	1.9097	1.9330	1.9220	1.9234	1.9357	1.9109	1.8499	1.9354	1.7917	1.9077	1.9150	1.9023
Ti	0.0198	0.0168	0.0210	0.0166	0.0184	0.0160	0.0150	0.0189	0.0156	0.0266	0.0154	0.0306	0.0233	0.0152	0.0198
Al t	0.0887	0.0665	0.0867	0.0903	0.0670	0.0780	0.0766	0.0643	0.0891	0.1501	0.0646	0.2083	0.0923	0.0850	0.0977
Al o	0.0000	0.0032	0.0141	0.0505	0.0295	0.0540	0.0423	0.0308	0.0511	0.0474	0.0082	0.0425	0.0214	0.0159	0.0398
Fe3+	0.0491	0.0296	0.0305	0.0063	0.0003	0.0000	0.0040	0.0000	0.0061	0.0496	0.0256	0.1045	0.0243	0.0387	0.0182
Fe2+	0.3833	0.3365	0.3310	0.2205	0.3071	0.2323	0.2371	0.3015	0.2265	0.2255	0.3268	0.1950	0.3032	0.2336	0.3359
Mn	0.0213	0.0183	0.0135	0.0063	0.0121	0.0070	0.0077	0.0097	0.0064	0.0074	0.0148	0.0068	0.0103	0.0092	0.0145
Mg	0.8581	0.8223	0.8240	0.8312	0.8581	0.8384	0.8549	0.8453	0.8325	0.8094	0.8397	0.7855	0.8306	0.8925	0.8424
Ca	0.6820	0.7675	0.7562	0.8710	0.7742	0.8483	0.8401	0.7913	0.8642	0.8590	0.7823	0.8873	0.7991	0.8143	0.7384
Na	0.0259	0.0206	0.0249	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ni	nd	nd	nd	0.0003	0.0000	0.0000	0.0006	0.0003	0.0000	nd	nd	nd	nd	nd	nd
Cr	nd	nd	nd	0.0003	0.0003	0.0000	0.0003	0.0000	0.0006	nd	nd	nd	nd	nd	nd
tot	4.0394	4.0148	4.0153	4.0031	4.0001	3.9960	4.0020	3.9978	4.0031	4.0248	4.0128	4.0523	4.0121	4.0193	4.0091
Ac	0.0259	0.0206	0.0249	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FeCaTs	0.0232	0.0090	0.0056	0.0063	0.0003	0.0000	0.0040	0.0000	0.0061	0.0496	0.0256	0.1045	0.0243	0.0387	0.0182
CrCaTs	0.0000	0.0000	0.0000	0.0003	0.0003	0.0000	0.0003	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AlCaTs	0.0000	0.0032	0.0141	0.0505	0.0295	0.0540	0.0423	0.0308	0.0511	0.0474	0.0082	0.0425	0.0214	0.0159	0.0398
Wo	0.3294	0.3776	0.3683	0.4069	0.3721	0.3971	0.3967	0.3802	0.4032	0.3810	0.3743	0.3701	0.3767	0.3798	0.3402
En	0.4636	0.4417	0.4507	0.4687	0.4624	0.4721	0.4723	0.4568	0.4692	0.4841	0.4504	0.5046	0.4566	0.4915	0.4717
Fs	0.2070	0.1807	0.1810	0.1244	0.1655	0.1308	0.1310	0.1629	0.1276	0.1349	0.1753	0.1252	0.1667	0.1287	0.1881
mg#	69.1	71.0	71.3	79.0	73.6	78.3	78.3	73.7	78.6	78.2	72.0	80.1	73.3	79.3	71.5

Makushin clinopyroxene analyses

	TT-22	TT-22	TT-22	TT-22	WB-05	WB-05	WB-05	WB-05	WB-05	WB-05	WB-05	WB-05	WB-05	WB-05
	m29	m29	m29	m29	m22	m22	m22	m22	m22	m22	m22	m22	m22	m22
	gm	gm	gm	gm	(core	rim	rim)	(core	rim)	(core	rim	core)		
	5	6	13	21	5	6	7	8	9	10	11	12	13	14
wt% oxides														
SiO2	50.72	51.38	50.07	49.59	50.44	48.93	48.64	48.78	47.86	50.58	47.25	50.23	50.93	47.34
TiO2	0.56	0.49	0.71	0.50	0.37	0.91	0.74	0.77	0.96	0.58	0.89	0.57	0.50	1.28
Al2O3	1.25	1.45	1.10	0.95	2.93	3.65	4.55	4.25	4.59	2.29	5.90	3.35	1.36	3.80
FeO	12.88	12.23	16.98	21.82	5.22	9.69	7.31	7.71	10.17	8.76	7.74	7.65	12.63	11.89
MnO	0.49	0.52	0.79	0.99	0.13	0.32	0.17	0.21	0.25	0.30	0.26	0.26	0.57	0.40
MgO	15.13	15.32	11.79	14.62	15.97	14.08	14.39	14.56	13.63	15.39	13.95	14.80	14.20	13.11
CaO	16.91	17.24	17.12	10.29	22.60	20.09	22.39	21.85	20.58	20.25	21.71	21.58	17.08	18.96
Na2O	nd	nd	nd	nd	0.20	0.22	0.28	0.27	0.38	0.19	0.28	0.30	0.32	0.37
NiO	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr2O3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	97.94	98.63	98.56	98.76	97.86	97.89	98.47	98.4	98.42	98.34	97.98	98.74	97.59	97.15
atoms per 6 oxygens														
Si	1.9464	1.9507	1.9516	1.9382	1.8975	1.8700	1.8392	1.8466	1.8279	1.9127	1.7993	1.8881	1.9570	1.8423
Ti	0.0162	0.0140	0.0208	0.0147	0.0105	0.0262	0.0210	0.0219	0.0276	0.0165	0.0255	0.0161	0.0144	0.0375
Al t	0.0536	0.0493	0.0484	0.0618	0.1025	0.1300	0.1608	0.1534	0.1721	0.0873	0.2007	0.1119	0.0430	0.1577
Al o	0.0030	0.0156	0.0021	0.0000	0.0274	0.0344	0.0420	0.0363	0.0346	0.0148	0.0642	0.0365	0.0186	0.0166
Fe3+	0.0183	0.0057	0.0047	0.0324	0.0542	0.0433	0.0767	0.0732	0.0824	0.0395	0.0855	0.0431	0.0000	0.0662
Fe2+	0.3951	0.3826	0.5488	0.6808	0.1100	0.2665	0.1545	0.1709	0.2424	0.2375	0.1610	0.1974	0.4059	0.3208
Mn	0.0159	0.0167	0.0261	0.0328	0.0041	0.0104	0.0054	0.0067	0.0081	0.0096	0.0084	0.0083	0.0186	0.0132
Mg	0.8653	0.8668	0.6849	0.8516	0.8953	0.8020	0.8109	0.8214	0.7758	0.8673	0.7917	0.8291	0.8132	0.7603
Ca	0.6953	0.7013	0.7150	0.4309	0.9110	0.8227	0.9072	0.8863	0.8422	0.8205	0.8858	0.8692	0.7032	0.7906
Na	nd	nd	nd	nd	0.0146	0.0163	0.0205	0.0198	0.0281	0.0139	0.0207	0.0219	0.0238	0.0279
Ni	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	4.0091	4.0028	4.0024	4.0432	4.0271	4.0216	4.0383	4.0366	4.0412	4.0197	4.0428	4.0216	3.9977	4.0331
Ac	0.0000	0.0000	0.0000	0.0000	0.0146	0.0163	0.0205	0.0198	0.0281	0.0139	0.0207	0.0219	0.0000	0.0279
Jd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0186	0.0000
FeCaTs	0.0183	0.0057	0.0047	0.0324	0.0396	0.0269	0.0561	0.0534	0.0543	0.0256	0.0649	0.0213	0.0000	0.0383
CrCaTs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AlCaTs	0.0030	0.0156	0.0021	0.0000	0.0274	0.0344	0.0420	0.0363	0.0346	0.0148	0.0642	0.0365	0.0000	0.0166
Wo	0.3370	0.3400	0.3541	0.1993	0.4220	0.3806	0.4045	0.3983	0.3767	0.3901	0.3784	0.4057	0.3516	0.3679
En	0.4551	0.4579	0.3586	0.4450	0.5148	0.4649	0.5002	0.4981	0.4749	0.4788	0.5166	0.4800	0.4325	0.4446
Fs	0.2078	0.2021	0.2873	0.3558	0.0633	0.1545	0.0953	0.1036	0.1484	0.1311	0.1050	0.1143	0.2159	0.1876
mg#	68.7	69.4	55.5	55.6	89.1	75.1	84.0	82.8	76.2	78.5	83.1	80.8	66.7	70.3

Makushin orthopyroxene analyses

	LR-02	LR-02	LR-02	LR-02	LR-02	LR-02	LR-02	LR-02	LR-02	LR-02	LR-02	LR-06a	LR-06a	LR-06a	LR-06a
	83mn65	83mn65	83mn65	83mn65	83mn65	83mn65	83mn65	83mn65	83mn65	83mn65	83mn65	83mn52	83mn52	83mn52	83mn52
	core	core	(core	rim)	core	(core	rim)	(core	rim)	(core	rim)	(core	rim)	(core	rim)
	3001	3002	3003	3004	3005	3006	3007	3008	3009	2018	2019	3047	3048	3049	3050
wt% oxides															
SiO2	52.79	52.89	53.04	53.38	52.79	52.21	53.48	52.36	53.03	52.46	52.28	52.65	53.27	53.23	53.16
TiO2	0.30	0.32	0.28	0.32	0.38	0.36	0.27	0.29	0.31	0.28	0.33	0.36	0.36	0.32	0.30
Al2O3	0.83	0.72	0.99	1.04	1.34	1.20	0.97	0.81	0.94	0.74	1.06	0.92	1.06	1.01	1.07
FeO	21.42	19.32	19.95	18.58	19.28	19.83	19.41	22.50	20.09	21.40	19.70	21.22	19.13	21.14	19.24
MnO	0.74	0.69	0.64	0.60	0.62	0.65	0.62	0.77	0.68	0.75	0.64	0.74	0.56	0.67	0.55
MgO	22.17	23.45	22.82	24.08	23.38	22.74	23.28	21.75	23.82	21.50	23.29	22.29	24.02	22.28	23.71
CaO	2.03	2.00	2.15	1.99	2.07	1.98	1.99	1.82	1.96	2.02	1.94	1.81	1.90	1.74	2.00
Na2O	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
NiO	0.04	0.01	0.03	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.03	0.00	0.02	0.03
Cr2O3	0.01	0.02	0.01	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.02
tot	100.33	99.42	99.91	99.99	99.86	98.99	100.03	100.30	100.85	99.18	99.24	100.02	100.30	100.41	100.08
atoms per 6 oxygens															
Si	1.9637	1.9662	1.9665	1.9631	1.9524	1.9548	1.9725	1.9583	1.9498	1.9745	1.9515	1.9618	1.9577	1.9708	1.9599
Ti	0.0084	0.0089	0.0078	0.0089	0.0106	0.0101	0.0075	0.0082	0.0086	0.0079	0.0093	0.0101	0.0099	0.0089	0.0083
Al t	0.0363	0.0316	0.0335	0.0369	0.0476	0.0452	0.0275	0.0357	0.0407	0.0255	0.0466	0.0382	0.0423	0.0292	0.0401
Al o	0.0001	0.0000	0.0098	0.0082	0.0108	0.0077	0.0147	0.0000	0.0000	0.0073	0.0000	0.0022	0.0036	0.0148	0.0064
Fe3+	0.0192	0.0131	0.0077	0.0109	0.0157	0.0166	0.0000	0.0194	0.0230	0.0023	0.0281	0.0158	0.0188	0.0000	0.0166
Fe2+	0.6472	0.5876	0.6109	0.5605	0.5807	0.6043	0.5987	0.6844	0.5947	0.6713	0.5869	0.6455	0.5692	0.6546	0.5767
Mn	0.0233	0.0217	0.0201	0.0187	0.0194	0.0206	0.0194	0.0244	0.0212	0.0239	0.0202	0.0234	0.0174	0.0210	0.0172
Mg	1.2290	1.2992	1.2609	1.3198	1.2887	1.2689	1.2797	1.2123	1.3052	1.2060	1.2956	1.2378	1.3156	1.2293	1.3027
Ca	0.0809	0.0797	0.0854	0.0784	0.0820	0.0794	0.0786	0.0729	0.0772	0.0815	0.0776	0.0723	0.0748	0.0690	0.0790
Na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ni	0.0012	0.0003	0.0009	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0009	0.0000	0.0009	0.0000	0.0006	0.0009
Cr	0.0003	0.0006	0.0003	0.0000	0.0000	0.0006	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006
tot	4.0096	4.0088	4.0039	4.0055	4.0078	4.0083	3.9989	4.0157	4.0210	4.0012	4.0159	4.0079	4.0094	3.9983	4.0083
NaR3Si2O6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NaTiAlSiO6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R2TiAl2O6	0.0084	0.0089	0.0078	0.0089	0.0106	0.0101	0.0075	0.0082	0.0086	0.0079	0.0093	0.0101	0.0099	0.0089	0.0083
R2R3AlSiO6	0.0195	0.0137	0.0178	0.0192	0.0265	0.0250	0.0125	0.0194	0.0236	0.0097	0.0281	0.0180	0.0224	0.0114	0.0235
Wo	0.0419	0.0410	0.0442	0.0406	0.0429	0.0414	0.0406	0.0376	0.0397	0.0420	0.0404	0.0375	0.0388	0.0357	0.0410
En	0.6276	0.6604	0.6439	0.6734	0.6598	0.6493	0.6536	0.6152	0.6597	0.6155	0.6605	0.6326	0.6709	0.6292	0.6647
Fs	0.3305	0.2987	0.3119	0.2860	0.2973	0.3092	0.3058	0.3473	0.3006	0.3426	0.2992	0.3299	0.2903	0.3350	0.2943
mg#	65.5	68.9	67.4	70.2	68.9	67.7	68.1	63.9	68.7	64.2	68.8	65.7	69.8	65.3	69.3

Makushin orthopyroxene analyses

	LR-06a	LR-06a	LR-06a	LR-06a	LR-06a	LR-06a	LR-06f	LR-06f	LR-06f	LR-06f	LR-11	LR-11	LR-12b	LR-12b	LR-12b
	83mn52	83mn52	83mn52	83mn52	83mn52	83mn52	83mn57	83mn57	83mn57	83mn57	m19	m19	D1-409	D1-409	D1-409
	(core	rim)	gms	core	rim	rim	(core	rim)	core	rim	rim	core	(core	rim)	(core
	3051	3052	3053	3054	3055	3056	3057	3059	3060	3061	11	12	3022	3023	3024
wt% oxides															
SiO2	53.07	53.29	53.48	53.02	53.14	53.15	52.91	53.15	52.47	53.11	48.06	47.52	52.85	53.53	52.85
TiO2	0.32	0.23	0.28	0.32	0.33	0.37	0.31	0.32	0.31	0.23	0.23	0.21	0.30	0.29	0.28
Al2O3	0.92	0.78	0.84	1.01	1.10	1.11	0.92	1.27	0.78	1.08	0.91	1.11	0.81	1.02	0.66
FeO	20.04	19.52	19.41	19.90	19.00	18.30	19.93	19.12	20.29	18.80	17.81	18.51	21.65	19.43	23.64
MnO	0.71	0.69	0.67	0.65	0.62	0.67	0.77	0.66	0.73	0.66	0.56	0.51	0.81	0.70	0.83
MgO	22.79	23.56	23.07	23.09	23.81	23.89	23.13	23.35	22.33	24.30	22.70	21.18	21.47	23.77	20.46
CaO	2.02	1.92	1.95	1.91	1.95	1.98	1.92	2.00	2.01	1.95	1.76	1.56	1.91	1.89	1.96
Na2O	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.02	0.06	nd	nd	nd
NiO	0.01	0.01	0.00	0.03	0.00	0.00	0.02	0.00	0.01	0.01	nd	nd	0.00	0.00	0.00
Cr2O3	0.01	0.03	0.01	0.00	0.02	0.02	0.03	0.02	0.03	0.03	nd	nd	0.00	0.00	0.02
tot	99.89	100.03	99.71	99.93	99.97	99.49	99.94	99.89	98.96	100.17	92.05	90.66	99.80	100.63	100.70
atoms per 6 oxygens															
Si	1.9685	1.9685	1.9789	1.9639	1.9593	1.9632	1.9619	1.9619	1.9695	1.9537	1.9327	1.9451	1.9767	1.9633	1.9772
Ti	0.0089	0.0064	0.0078	0.0089	0.0092	0.0103	0.0086	0.0089	0.0088	0.0064	0.0070	0.0065	0.0084	0.0080	0.0079
Al t	0.0315	0.0315	0.0211	0.0361	0.0407	0.0368	0.0381	0.0381	0.0305	0.0463	0.0431	0.0536	0.0233	0.0367	0.0228
Al o	0.0087	0.0025	0.0155	0.0080	0.0071	0.0115	0.0021	0.0172	0.0040	0.0005	0.0000	0.0000	0.0124	0.0074	0.0063
Fe3+	0.0046	0.0154	0.0000	0.0103	0.0148	0.0042	0.0178	0.0025	0.0081	0.0322	0.0292	0.0406	0.0000	0.0133	0.0001
Fe2+	0.6170	0.5877	0.6007	0.6062	0.5711	0.5611	0.6002	0.5878	0.6288	0.5462	0.5698	0.5930	0.6772	0.5827	0.7395
Mn	0.0223	0.0216	0.0210	0.0204	0.0194	0.0210	0.0242	0.0206	0.0232	0.0206	0.0191	0.0177	0.0257	0.0217	0.0263
Mg	1.2598	1.2970	1.2722	1.2746	1.3083	1.3151	1.2782	1.2846	1.2491	1.3322	1.3605	1.2920	1.1968	1.2993	1.1408
Ca	0.0803	0.0760	0.0773	0.0758	0.0770	0.0784	0.0763	0.0791	0.0808	0.0769	0.0758	0.0684	0.0765	0.0743	0.0786
Na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.0016	0.0048	nd	nd	nd
Ni	0.0003	0.0003	0.0000	0.0009	0.0000	0.0000	0.0006	0.0000	0.0003	0.0003	nd	nd	0.0000	0.0000	0.0000
Cr	0.0003	0.0009	0.0003	0.0000	0.0006	0.0006	0.0009	0.0006	0.0009	0.0009	nd	nd	0.0000	0.0000	0.0006
tot	4.0023	4.0077	3.9948	4.0051	4.0074	4.0021	4.0089	4.0012	4.0041	4.0161	4.0388	4.0217	3.9970	4.0067	4.0001
NaR3Si2O6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0048	0.0000	0.0000	0.0000
NaTiAlSiO6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R2TiAl2O6	0.0089	0.0064	0.0078	0.0089	0.0092	0.0103	0.0086	0.0089	0.0088	0.0064	0.0070	0.0065	0.0084	0.0080	0.0079
R2R3AlSiO6	0.0137	0.0187	0.0055	0.0183	0.0224	0.0163	0.0208	0.0203	0.0130	0.0336	0.0277	0.0359	0.0064	0.0207	0.0070
Wo	0.0415	0.0393	0.0399	0.0393	0.0400	0.0406	0.0396	0.0412	0.0417	0.0401	0.0385	0.0358	0.0395	0.0385	0.0404
En	0.6434	0.6612	0.6522	0.6511	0.6683	0.6724	0.6535	0.6578	0.6374	0.6808	0.6777	0.6609	0.6134	0.6638	0.5822
Fs	0.3151	0.2996	0.3079	0.3096	0.2917	0.2869	0.3069	0.3010	0.3209	0.2791	0.2838	0.3033	0.3471	0.2977	0.3774
mg#	67.1	68.8	67.9	67.8	69.6	70.1	68.0	68.6	66.5	70.9	70.5	68.5	63.9	69.0	60.7

Makushin orthopyroxene analyses

	LR-12b	LR-12b	LR-12b	LR-12b	LR-12b	LR-12b	LR-12n	LR-12n	LR-12n	LR-12n	LR-12n	LR-12n	M1-01	M1-01	M1-01
	D1-409	D1-409	D1-409	D1-409	D1-409	D1-409	D1-931	D1-931	D1-931	D1-931	D1-931	D1-931	83mn41	83mn41	83mn41
	rim)	(core	rim)	(core	rim)	ol rim	core	core	rim	core	rim	ol rim	core	(core	rim)
	3025	3026	3027	3028	3029	3031	3032	3033	3034	3035	3036	1057	3010	3011	3012
wt% oxides															
SiO2	52.80	52.40	52.95	52.33	52.90	53.25	51.63	52.63	52.40	52.75	52.56	53.35	52.59	52.41	52.28
TiO2	0.35	0.27	0.32	0.34	0.38	0.34	0.31	0.31	0.29	0.30	0.30	0.31	0.23	0.31	0.35
Al2O3	0.71	0.84	0.71	0.83	1.15	0.98	0.72	1.12	0.92	0.88	1.05	0.99	0.54	0.94	1.13
FeO	23.34	23.22	22.96	23.20	20.53	19.45	23.46	18.95	20.07	21.21	22.42	19.83	21.44	21.75	20.50
MnO	0.74	0.83	0.80	0.81	0.58	0.68	0.80	0.56	0.70	0.70	0.70	0.71	0.84	0.81	0.67
MgO	20.64	21.14	20.66	20.56	23.01	22.71	20.45	24.36	23.75	22.16	20.89	23.16	21.86	21.62	22.94
CaO	1.99	1.72	2.04	1.97	1.93	2.02	1.83	1.89	1.83	1.83	1.87	1.89	1.78	1.71	1.79
Na2O	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
NiO	0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.03	0.02	0.05	0.00	0.01	0.00	0.00	0.02
Cr2O3	0.03	0.01	0.00	0.01	0.05	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.02	0.02
tot	100.60	100.43	100.44	100.08	100.53	99.43	99.21	99.85	99.98	99.90	99.79	100.26	99.28	99.57	99.70
atoms per 6 oxygens															
Si	1.9744	1.9629	1.9795	1.9683	1.9534	1.9771	1.9638	1.9447	1.9454	1.9672	1.9721	1.9679	1.9770	1.9666	1.9490
Ti	0.0098	0.0076	0.0090	0.0096	0.0106	0.0095	0.0089	0.0086	0.0081	0.0084	0.0085	0.0086	0.0065	0.0087	0.0098
Al t	0.0256	0.0371	0.0205	0.0317	0.0466	0.0229	0.0323	0.0488	0.0403	0.0328	0.0279	0.0321	0.0230	0.0334	0.0497
Al o	0.0057	0.0000	0.0108	0.0051	0.0035	0.0200	0.0000	0.0000	0.0000	0.0059	0.0186	0.0109	0.0009	0.0082	0.0000
Fe3+	0.0000	0.0216	0.0000	0.0070	0.0206	0.0000	0.0146	0.0316	0.0241	0.0095	0.0000	0.0037	0.0092	0.0072	0.0294
Fe2+	0.7299	0.7059	0.7179	0.7228	0.6134	0.6040	0.7317	0.5540	0.5991	0.6520	0.7035	0.6080	0.6649	0.6754	0.6097
Mn	0.0234	0.0263	0.0253	0.0258	0.0181	0.0214	0.0258	0.0175	0.0220	0.0221	0.0222	0.0222	0.0267	0.0257	0.0212
Mg	1.1502	1.1802	1.1511	1.1525	1.2663	1.2567	1.1592	1.3414	1.3141	1.2316	1.1682	1.2732	1.2247	1.2090	1.2745
Ca	0.0797	0.0690	0.0817	0.0794	0.0764	0.0804	0.0746	0.0748	0.0728	0.0731	0.0752	0.0747	0.0717	0.0688	0.0715
Na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ni	0.0000	0.0000	0.0000	0.0009	0.0000	0.0000	0.0003	0.0009	0.0006	0.0015	0.0000	0.0003	0.0000	0.0000	0.0006
Cr	0.0009	0.0003	0.0000	0.0003	0.0015	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0003	0.0000	0.0006	0.0006
tot	3.9997	4.0108	3.9958	4.0035	4.0103	3.9919	4.0112	4.0223	4.0264	4.0048	3.9962	4.0019	4.0046	4.0036	4.0160
NaR3Si2O6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NaTiAlSiO6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R2TiAl2O6	0.0098	0.0076	0.0090	0.0096	0.0106	0.0095	0.0089	0.0086	0.0081	0.0084	0.0085	0.0086	0.0065	0.0087	0.0098
R2R3AlSiO6	0.0060	0.0219	0.0025	0.0124	0.0255	0.0039	0.0146	0.0316	0.0241	0.0160	0.0109	0.0149	0.0100	0.0159	0.0300
Wo	0.0410	0.0359	0.0421	0.0411	0.0398	0.0417	0.0384	0.0388	0.0373	0.0378	0.0390	0.0387	0.0369	0.0357	0.0373
En	0.5867	0.6033	0.5899	0.5893	0.6469	0.6472	0.5895	0.6803	0.6613	0.6291	0.5998	0.6506	0.6242	0.6187	0.6512
Fs	0.3723	0.3608	0.3679	0.3696	0.3134	0.3111	0.3721	0.2810	0.3015	0.3330	0.3612	0.3107	0.3389	0.3456	0.3115
mg#	61.2	62.6	61.6	61.5	67.4	67.5	61.3	70.8	68.7	65.4	62.4	67.7	64.8	64.2	67.6

Makushin orthopyroxene analyses

	M1-01	M1-01	M1-51c	M1-51c	M1-51c	M1-51c	M1-51d	M1-51d	Md-04	Md-04	Md-04	Md-04	Md-14	Md-14	Md-14
	83mn41	83mn41	m43c	m43c	m43c	m43c	m43f	m43f	m4	m4	m4	m4	m14	m14	m14
	core	core	(core	rim)	(core	rim)	core	rim	(core	rim)	(core	(core	(core	(core	rim
	3013	3014	7	8	11	12	3	4	8	9	10	12	14	16	17
wt% oxides															
SiO2	52.43	52.08	51.75	52.16	52.68	52.58	51.84	52.09	52.05	52.63	52.03	52.51	49.86	52.02	52.18
TiO2	0.33	0.34	0.31	0.16	0.31	0.23	0.36	0.29	0.32	0.40	0.31	0.37	0.33	0.36	0.35
Al2O3	1.00	1.14	0.81	0.72	0.83	0.81	1.14	0.79	1.14	0.88	0.85	1.07	0.93	0.94	0.99
FeO	21.91	21.80	23.04	23.07	22.01	21.95	21.03	21.49	20.34	18.63	20.57	20.08	21.30	21.79	22.24
MnO	0.87	0.75	1.11	1.04	0.93	0.51	0.77	0.79	0.54	0.46	0.80	0.43	0.60	0.64	0.59
MgO	21.84	21.63	21.39	21.30	22.50	21.97	21.79	22.34	22.49	24.33	22.80	23.64	20.67	22.19	21.96
CaO	1.80	1.81	1.65	1.74	1.62	1.69	1.99	1.82	1.90	2.28	1.97	2.13	2.07	2.07	2.08
Na2O	nd	nd	0.01	0.06	0.02	0.11	nd	nd	nd	nd	nd	nd	nd	nd	nd
NiO	0.00	0.00	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr2O3	0.00	0.03	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	100.18	99.58	100.07	100.25	100.90	99.85	98.92	99.61	98.78	99.61	99.33	100.23	95.76	100.01	100.39
atoms per 6 oxygens															
Si	1.9580	1.9559	1.9495	1.9593	1.9536	1.9657	1.9552	1.9546	1.9565	1.9482	1.9511	1.9431	1.9527	1.9471	1.9483
Ti	0.0093	0.0096	0.0088	0.0045	0.0086	0.0065	0.0102	0.0082	0.0090	0.0111	0.0087	0.0103	0.0097	0.0101	0.0098
Al t	0.0420	0.0441	0.0360	0.0319	0.0363	0.0343	0.0448	0.0349	0.0435	0.0384	0.0376	0.0467	0.0429	0.0415	0.0436
Al o	0.0020	0.0063	0.0000	0.0000	0.0000	0.0014	0.0059	0.0000	0.0071	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fe3+	0.0214	0.0177	0.0184	0.0228	0.0190	0.0200	0.0185	0.0186	0.0183	0.0161	0.0201	0.0261	0.0235	0.0212	0.0239
Fe2+	0.6629	0.6670	0.7075	0.7019	0.6636	0.6663	0.6448	0.6558	0.6211	0.5606	0.6250	0.5954	0.6741	0.6609	0.6706
Mn	0.0275	0.0239	0.0354	0.0331	0.0292	0.0162	0.0246	0.0251	0.0172	0.0144	0.0254	0.0135	0.0199	0.0203	0.0187
Mg	1.2155	1.2106	1.2009	1.1924	1.2435	1.2241	1.2248	1.2493	1.2599	1.3422	1.2742	1.3037	1.2064	1.2378	1.2220
Ca	0.0720	0.0728	0.0666	0.0700	0.0644	0.0677	0.0804	0.0732	0.0765	0.0904	0.0792	0.0845	0.0869	0.0830	0.0832
Na	nd	nd	0.0007	0.0044	0.0014	0.0080	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ni	0.0000	0.0000	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr	0.0000	0.0009	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	4.0107	4.0088	4.0238	4.0203	4.0196	4.0100	4.0093	4.0197	4.0092	4.0215	4.0214	4.0232	4.0161	4.0220	4.0201
NaR3Si2O6	0.0000	0.0000	0.0007	0.0044	0.0014	0.0080	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NaTiAlSiO6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R2TiAl2O6	0.0093	0.0096	0.0088	0.0045	0.0086	0.0065	0.0102	0.0082	0.0090	0.0111	0.0087	0.0103	0.0097	0.0101	0.0098
R2R3AlSiO6	0.0235	0.0249	0.0177	0.0185	0.0176	0.0134	0.0244	0.0186	0.0254	0.0161	0.0201	0.0261	0.0235	0.0212	0.0239
Wo	0.0376	0.0380	0.0342	0.0361	0.0331	0.0349	0.0420	0.0375	0.0398	0.0460	0.0406	0.0434	0.0449	0.0426	0.0429
En	0.6228	0.6202	0.6078	0.6068	0.6305	0.6249	0.6276	0.6312	0.6431	0.6729	0.6437	0.6567	0.6127	0.6242	0.6180
Fs	0.3396	0.3417	0.3581	0.3572	0.3365	0.3401	0.3304	0.3313	0.3171	0.2811	0.3157	0.2999	0.3424	0.3333	0.3391
mg#	64.7	64.5	62.9	62.9	65.2	64.8	65.5	65.6	67.0	70.5	67.1	68.7	64.2	65.2	64.6

Makushin orthopyroxene analyses

	Md-14 m14 (core 19	Md-14 m14 rim) 20	Me-06 m39 core 17	Me-06 m39 rim 18	PC-11 m20 (core 9	PC-11 m20 (core 14	PC-11 m20 rim) 15	PC-11 m20 (core 17	PC-11 m20 rim) 18	PC-11 m20 (core 19
wt% oxides										
SiO2	52.34	52.15	52.26	52.16	52.90	53.07	52.92	52.25	52.56	52.75
TiO2	0.30	0.30	0.33	0.29	0.38	0.26	0.36	0.34	0.28	0.36
Al2O3	0.90	1.02	0.95	0.87	0.77	0.89	0.78	0.70	0.82	0.94
FeO	21.51	21.13	20.80	20.15	17.55	18.16	17.83	18.13	18.40	17.75
MnO	0.64	0.58	0.86	0.78	0.68	0.66	0.64	0.69	0.65	0.66
MgO	22.43	22.26	22.85	23.43	24.61	25.43	24.87	24.62	24.23	25.42
CaO	2.07	2.07	2.09	1.67	2.16	2.11	2.23	2.18	2.17	2.11
Na2O	nd	nd	nd	nd	0.03	0.05	0.03	0.04	0.05	0.03
NiO	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr2O3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	100.19	99.51	100.14	99.35	99.08	100.63	99.66	98.95	99.16	100.02
atoms per 6 oxygens										
Si	1.9518	1.9543	1.9462	1.9497	1.9588	1.9403	1.9512	1.9460	1.9531	1.9380
Ti	0.0084	0.0085	0.0092	0.0082	0.0106	0.0071	0.0100	0.0095	0.0078	0.0099
Al t	0.0396	0.0451	0.0417	0.0383	0.0336	0.0384	0.0339	0.0307	0.0359	0.0407
Al o	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fe3+	0.0227	0.0282	0.0232	0.0220	0.0124	0.0241	0.0139	0.0117	0.0203	0.0208
Fe2+	0.6481	0.6341	0.6246	0.6079	0.5310	0.5312	0.5359	0.5530	0.5516	0.5246
Mn	0.0202	0.0184	0.0271	0.0247	0.0213	0.0204	0.0200	0.0218	0.0205	0.0205
Mg	1.2465	1.2432	1.2682	1.3052	1.3581	1.3856	1.3666	1.3665	1.3419	1.3919
Ca	0.0827	0.0831	0.0834	0.0669	0.0857	0.0827	0.0881	0.0870	0.0864	0.0831
Na	nd	nd	nd	nd	0.0022	0.0035	0.0021	0.0029	0.0036	0.0021
Ni	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tot	4.0200	4.0147	4.0237	4.0230	4.0138	4.0334	4.0218	4.0291	4.0211	4.0317
NaR3Si2O6	0.0000	0.0000	0.0000	0.0000	0.0022	0.0035	0.0021	0.0029	0.0036	0.0021
NaTiAlSiO6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R2TiAl2O6	0.0084	0.0085	0.0092	0.0082	0.0106	0.0071	0.0100	0.0095	0.0078	0.0099
R2R3AlSiO6	0.0227	0.0282	0.0232	0.0220	0.0103	0.0205	0.0118	0.0088	0.0167	0.0187
Wo	0.0425	0.0432	0.0429	0.0343	0.0439	0.0419	0.0447	0.0438	0.0442	0.0421
En	0.6300	0.6336	0.6413	0.6589	0.6874	0.6926	0.6862	0.6808	0.6774	0.6957
Fs	0.3275	0.3232	0.3158	0.3068	0.2688	0.2655	0.2691	0.2755	0.2784	0.2622
mg#	65.8	66.2	67.0	68.2	71.9	72.3	71.8	71.2	70.9	72.6

Makushin pigeonite compositions

	LR-02	LR-02	LR-11	LR-11	LR-11	LR-12n	LR-12n	LR-12n	Mc-18	Mc-18	Md-04	Md-04	Me-03	Me-03	Me-03
	83mn65	83mn65	m19	m19	m19	D1-931	D1-931	D1-931	m30	m30	m4	m4	m36	m36	m36
	rim	rim	core	rim	gm	rim	rim	ol rim	gm	gm	gm	gm	rim	gm	gm
	4001	4002	1	2	24	4003	4004	2065	14	18	6	7	11	20	22
wt% oxides															
SiO2	52.43	51.88	49.67	50.81	49.36	51.71	52.04	52.07	52.94	53.17	50.98	53.44	53.01	52.66	52.66
TiO2	0.33	0.36	0.33	0.31	0.32	0.45	0.34	0.27	0.38	0.25	0.03	0.28	0.37	0.29	0.32
Al2O3	0.94	0.81	2.08	0.71	0.75	0.65	0.63	0.82	0.77	0.56	0.21	0.85	0.84	0.78	0.96
FeO	19.99	19.85	21.08	20.48	24.07	23.49	23.69	22.40	17.12	18.57	32.82	18.47	17.70	17.62	17.83
MnO	0.68	0.70	0.74	0.76	0.81	0.80	0.83	0.83	0.69	0.73	0.08	0.60	0.71	0.62	0.51
MgO	19.94	18.74	20.62	22.62	17.77	17.51	18.38	18.01	22.87	23.23	13.18	22.52	23.87	22.66	24.33
CaO	4.40	6.15	2.21	2.11	4.09	4.41	3.73	5.16	4.75	3.36	2.80	4.19	3.56	4.31	2.87
NiO	0.02	0.00	nd	nd	nd	0.02	0.02	0.00	nd	nd	nd	nd	nd	nd	nd
Cr2O3	0.03	0.00	nd	nd	nd	0.02	0.01	0.00	nd	nd	nd	nd	nd	nd	nd
tot	98.76	98.49	96.73	97.80	97.17	99.06	99.67	99.56	99.52	99.87	100.10	100.35	100.06	98.94	99.48
atoms per 6 oxygens															
Si	1.9810	1.9771	1.9243	1.9407	1.9457	1.9834	1.9807	1.9798	1.9621	1.9683	2.0053	1.9694	1.9530	1.9651	1.9482
Ti	0.0094	0.0103	0.0096	0.0089	0.0095	0.0130	0.0097	0.0077	0.0106	0.0070	0.0009	0.0078	0.0103	0.0081	0.0089
Al t	0.0190	0.0229	0.0757	0.0320	0.0349	0.0166	0.0193	0.0202	0.0336	0.0244	0.0000	0.0306	0.0365	0.0343	0.0419
Al o	0.0229	0.0134	0.0193	0.0000	0.0000	0.0128	0.0090	0.0166	0.0000	0.0000	0.0097	0.0063	0.0000	0.0000	0.0000
Fe3+	0.0000	0.0000	0.0371	0.0142	0.0159	0.0000	0.0000	0.0000	0.0125	0.0105	0.0000	0.0088	0.0160	0.0180	0.0241
Fe2+	0.6317	0.6326	0.6459	0.6401	0.7776	0.7535	0.7541	0.7123	0.5182	0.5644	1.0797	0.5605	0.5294	0.5319	0.5276
Mn	0.0218	0.0226	0.0243	0.0246	0.0270	0.0260	0.0268	0.0267	0.0217	0.0229	0.0026	0.0187	0.0222	0.0196	0.0160
Mg	1.1228	1.0643	1.1906	1.2876	1.0439	1.0009	1.0426	1.0205	1.2632	1.2816	0.7726	1.2368	1.3106	1.2602	1.3415
Ca	0.1781	0.2511	0.0917	0.0864	0.1728	0.1812	0.1521	0.2102	0.1886	0.1333	0.1180	0.1655	0.1405	0.1723	0.1138
Ni	0.0006	0.0000	nd	nd	nd	0.0006	0.0006	0.0000	nd	nd	nd	nd	nd	nd	nd
Cr	0.0009	0.0000	nd	nd	nd	0.0006	0.0003	0.0000	nd	nd	nd	nd	nd	nd	nd
tot	3.9882	3.9944	4.0186	4.0344	4.0273	3.9886	3.9952	3.9941	4.0105	4.0125	3.9889	4.0044	4.0185	4.0096	4.0219
FeCaTs	0.0000	0.0000	0.0371	0.0142	0.0159	0.0000	0.0000	0.0000	0.0125	0.0105	0.0000	0.0088	0.0160	0.0180	0.0241
CrCaTs	0.0009	0.0000	0.0000	0.0000	0.0000	0.0006	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AlCaTs	0.0229	0.0134	0.0193	0.0000	0.0000	0.0128	0.0090	0.0166	0.0000	0.0000	0.0097	0.0063	0.0000	0.0000	0.0000
Wo	0.1108	0.1448	0.0535	0.0291	0.0813	0.1161	0.0970	0.1253	0.1031	0.0717	0.0690	0.0938	0.0720	0.0949	0.0534
En	0.5690	0.5364	0.6136	0.6485	0.5265	0.5043	0.5240	0.5152	0.6360	0.6445	0.3884	0.6236	0.6610	0.6365	0.6794
Fs	0.3201	0.3188	0.3329	0.3224	0.3922	0.3796	0.3790	0.3596	0.2609	0.2838	0.5427	0.2826	0.2670	0.2686	0.2672
mg#	64.0	62.7	64.8	66.8	57.3	57.1	58.0	58.9	70.9	69.4	41.7	68.8	71.2	70.3	71.8

Makushin pigeonite compositions

	Me-03	Me-07	PC-11
	m36	m40	m20
	gm	gm	core
	23	25	13
wt% oxides			
SiO2	53.62	50.64	52.38
TiO2	0.23	0.23	0.38
Al2O3	0.67	0.61	0.98
FeO	17.91	21.63	19.03
MnO	0.50	0.66	0.70
MgO	23.07	20.42	23.85
CaO	4.02	3.43	2.44
NiO	nd	nd	nd
Cr2O3	nd	nd	nd
tot	100.02	97.62	99.76
atoms per 6 oxygens			
Si	1.9754	1.9544	1.9432
Ti	0.0064	0.0067	0.0106
Al t	0.0246	0.0278	0.0429
Al o	0.0045	0.0000	0.0000
Fe3+	0.0073	0.0144	0.0217
Fe2+	0.5445	0.6838	0.5688
Mn	0.0156	0.0216	0.0220
Mg	1.2667	1.1745	1.3186
Ca	0.1587	0.1418	0.0970
Ni	nd	nd	nd
Cr	nd	nd	nd
tot	4.0037	4.0250	4.0247
FeCaTs	0.0073	0.0144	0.0217
CrCaTs	0.0000	0.0000	0.0000
AlCaTs	0.0045	0.0000	0.0000
Wo	0.0885	0.0636	0.0455
En	0.6375	0.5918	0.6669
Fs	0.2740	0.3445	0.2877
mg#	69.9	63.2	69.9

Makushin magnetite/spinel compositions · ulvospinel basis

	PC-09 83mn25 5003	PC-09 83mn25 5004	PC-09 83mn25 5005	PC-09 83mn25 5006	PC-09 83mn25 5007	PC-09 83mn25 5008	PC-09 83mn25 5009	PC-09 83mn25 5010	PC-09 83mn25 5011	PC-09 83mn25 5012	PC-09 83mn25 5013	TT-10 83mn77 5119	TT-10 83mn77 5120
SiO2	0.06	0.15	0.11	0.15	0.10	0.08	0.05	0.10	0.17	0.68	0.09	0.10	0.12
TiO2	0.30	0.97	0.23	7.54	0.77	0.91	1.08	1.10	1.42	4.86	0.55	6.08	8.56
Al2O3	9.27	16.04	7.57	3.95	12.86	13.94	15.39	14.71	10.32	4.80	13.47	6.72	5.74
Fe2O3	20.13	20.42	22.89	49.72	29.86	30.10	30.53	31.30	53.37	48.86	21.59	50.36	46.86
FeO	9.25	8.49	11.93	30.74	13.82	15.14	13.89	13.85	22.50	26.98	9.78	30.23	33.32
MnO	0.21	0.15	0.32	0.42	0.26	0.24	0.25	0.25	0.40	0.06	0.21	0.34	0.39
MgO	10.54	13.19	8.67	4.48	9.83	9.57	10.75	10.69	6.43	5.01	11.47	4.54	4.04
CaO	0.03	0.03	0.02	0.13	0.00	0.00	0.00	0.02	0.48	0.57	0.01	0.03	0.01
Cr2O3	50.77	40.56	48.29	0.97	31.59	30.60	28.14	27.52	3.05	4.01	42.42	0.50	0.44
NiO	0.06	0.08	0.07	0.05	0.13	0.09	0.07	0.14	0.14	0.10	0.09	0.03	0.00
tot	100.62	100.08	100.09	98.15	99.21	100.67	100.15	99.69	98.28	95.93	99.67	98.93	99.49
FeO meas.	27.36	26.86	32.52	75.48	40.68	42.22	41.36	42.02	70.52	70.94	29.20	75.54	75.49
atoms per 4 oxygens													
Si	0.0026	0.0058	0.0048	0.0055	0.0039	0.0030	0.0019	0.0037	0.0061	0.0258	0.0036	0.0036	0.0043
Ti	0.0097	0.0280	0.0075	0.2095	0.0225	0.0259	0.0301	0.0308	0.0381	0.1386	0.0166	0.1651	0.2327
Al	0.4676	0.7259	0.3894	0.1721	0.5884	0.6231	0.6720	0.6460	0.4340	0.2146	0.6360	0.2861	0.2446
Fe3+	0.6482	0.5898	0.7516	1.3826	0.8721	0.8588	0.8509	0.8775	1.4325	1.3946	0.6506	1.3686	1.2748
Fe2+	0.3308	0.2726	0.4353	0.9500	0.4484	0.4800	0.4304	0.4316	0.6713	0.8557	0.3275	0.9130	1.0074
Mn	0.0076	0.0049	0.0118	0.0131	0.0085	0.0077	0.0078	0.0079	0.0121	0.0019	0.0071	0.0104	0.0119
Mg	0.6721	0.7546	0.5638	0.2467	0.5686	0.5408	0.5934	0.5934	0.3418	0.2832	0.6846	0.2443	0.2176
Ca	0.0014	0.0012	0.0009	0.0051	0.0000	0.0000	0.0000	0.0008	0.0183	0.0232	0.0004	0.0012	0.0004
Cr	0.8586	0.6154	0.8330	0.0142	0.4846	0.4586	0.4120	0.4052	0.0430	0.0601	0.6715	0.0071	0.0063
Ni	0.0021	0.0025	0.0025	0.0015	0.0041	0.0027	0.0021	0.0042	0.0040	0.0031	0.0029	0.0009	0.0000
total	3.0006	3.0007	3.0007	3.0005	3.0011	3.0008	3.0006	3.0011	3.0011	3.0009	3.0008	3.0003	3.0001
mol % usp	2.84	8.50	1.94	23.24	4.85	5.63	6.53	6.49	5.03	16.56	4.76	19.41	26.71
Mg#	67.01	73.46	56.43	20.62	55.91	52.97	57.96	57.90	33.74	24.87	67.64	21.11	17.77
Cr/Cr+Al	64.74	45.88	68.14	7.61	45.16	42.40	38.01	38.55	9.02	21.88	51.36	2.43	2.51
YFe	32.83	30.54	38.07	88.13	44.83	44.26	43.98	45.50	75.02	83.54	33.23	82.35	83.56
YCr	43.49	31.87	42.20	0.90	24.92	23.63	21.29	21.01	2.25	3.60	34.29	0.43	0.41
YAl	23.68	37.59	19.73	10.97	30.25	32.11	34.73	33.49	22.73	12.86	32.48	17.22	16.03

Appendix 4 - Silica Variation Diagrams

Silica variation diagrams for most analysed elements follow. Symbols are as follows:

stars - late Holocene Makushin Volcano (M1 series)

crosses - middle and early Holocene Makushin Volcano (M2, M3 and M4 series)

small pluses - Pleistocene QTvc (M5, Mc, Md, Me, Mf, Mg and Mh series)

triangles - Lava Ramp (LR)

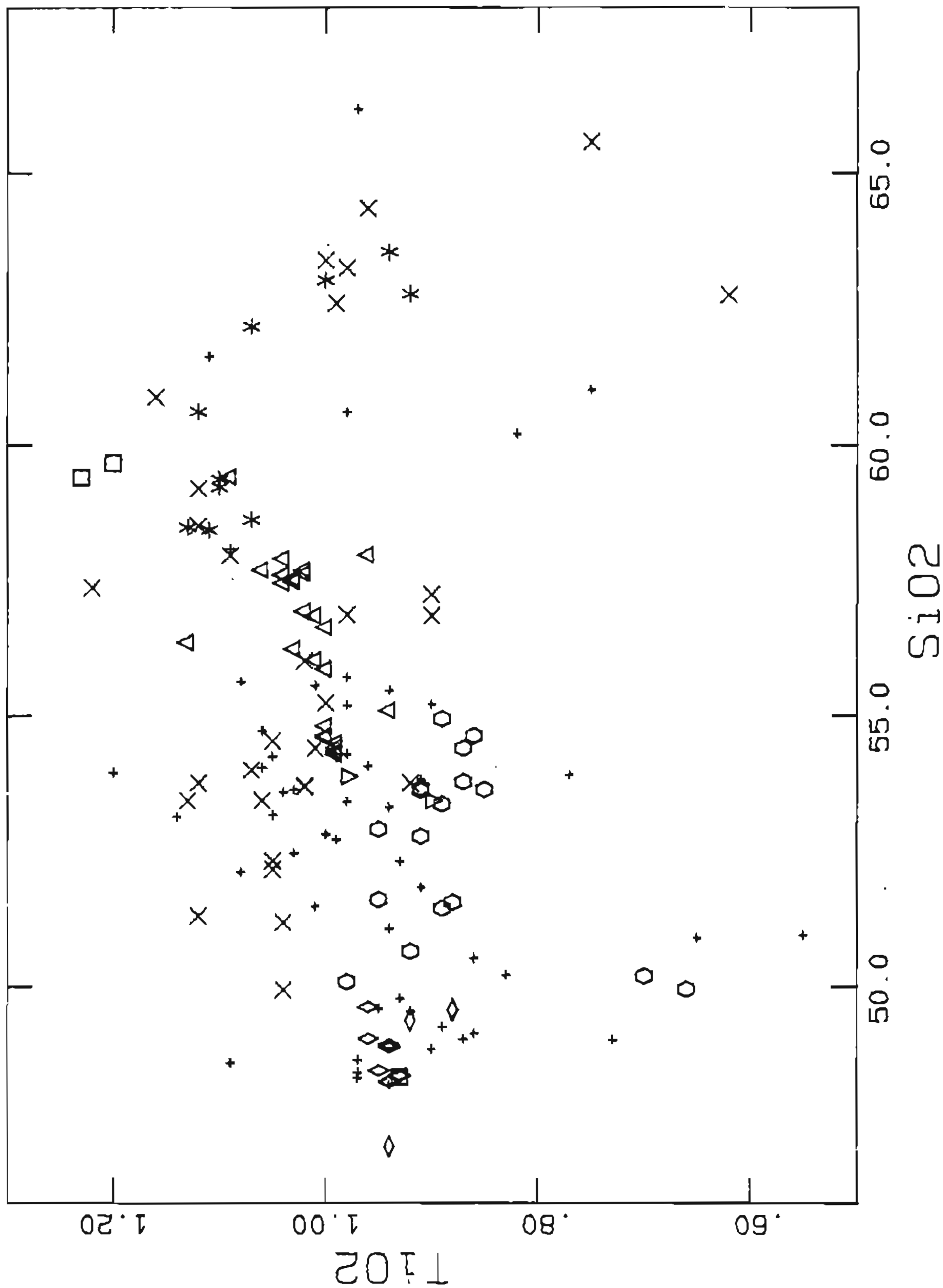
inverted triangles - Sugarloaf (SL)

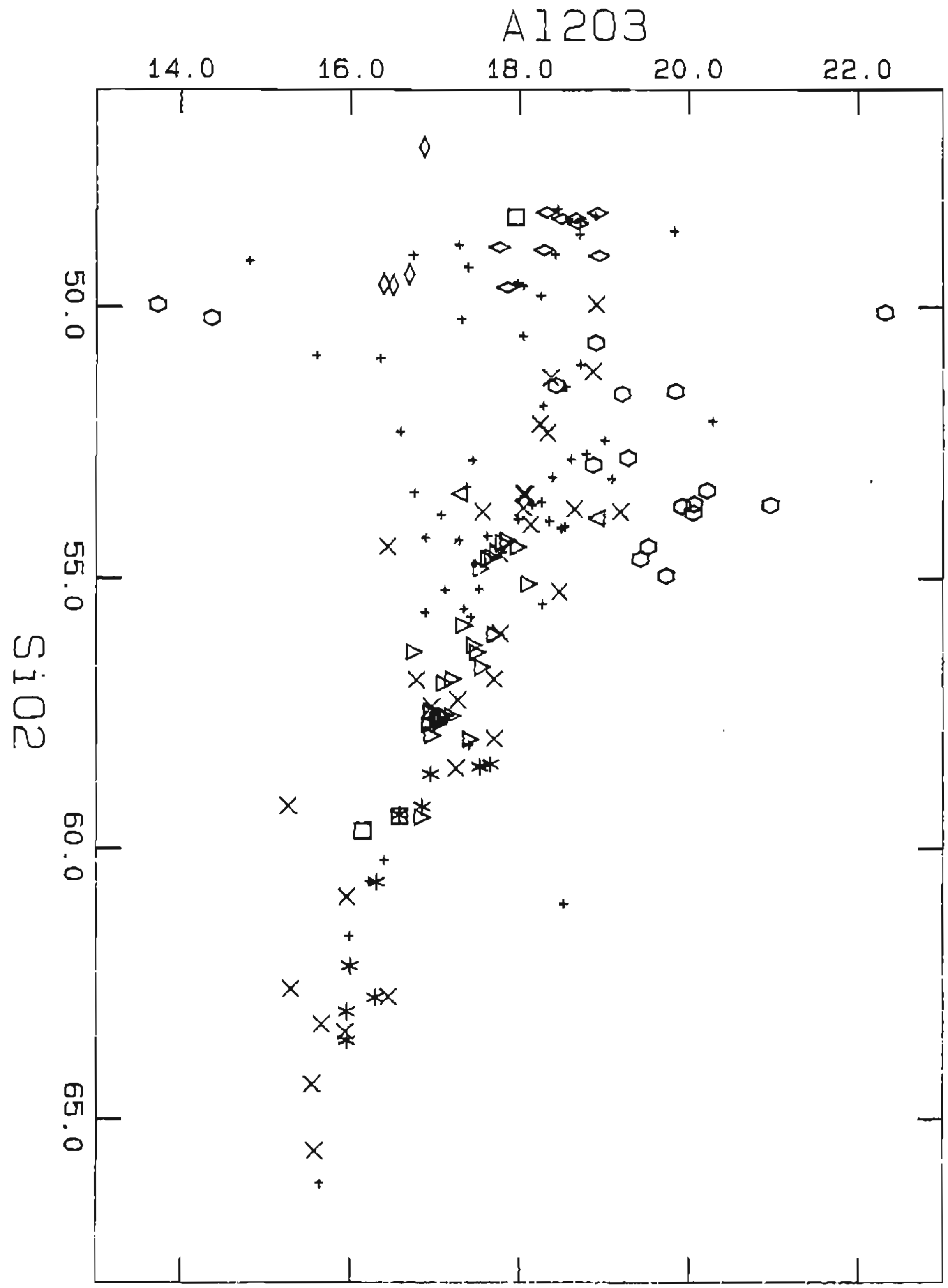
hexagons - Pakushin Cone (PC)

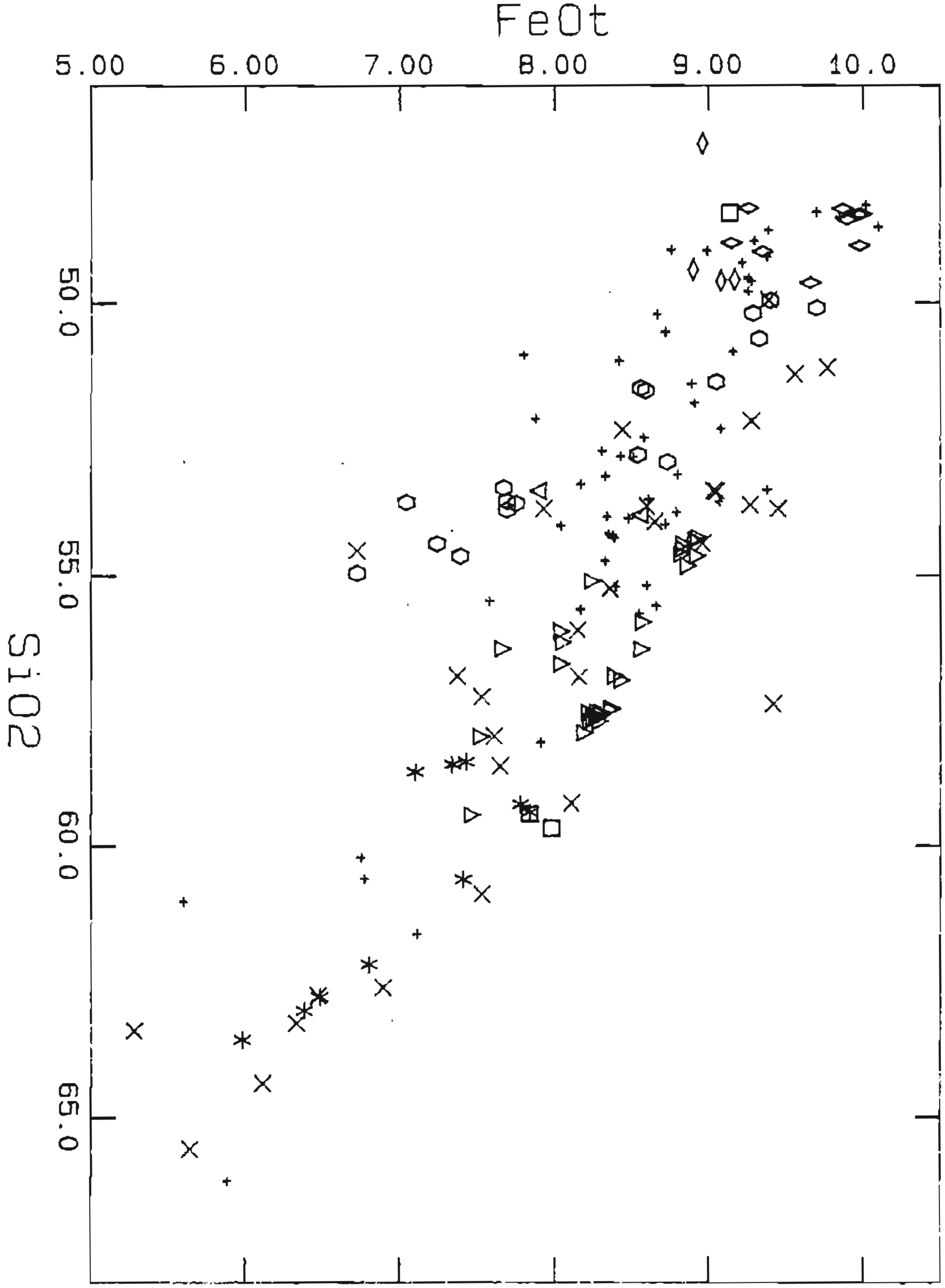
squares - Point Kadin Vents (PK)

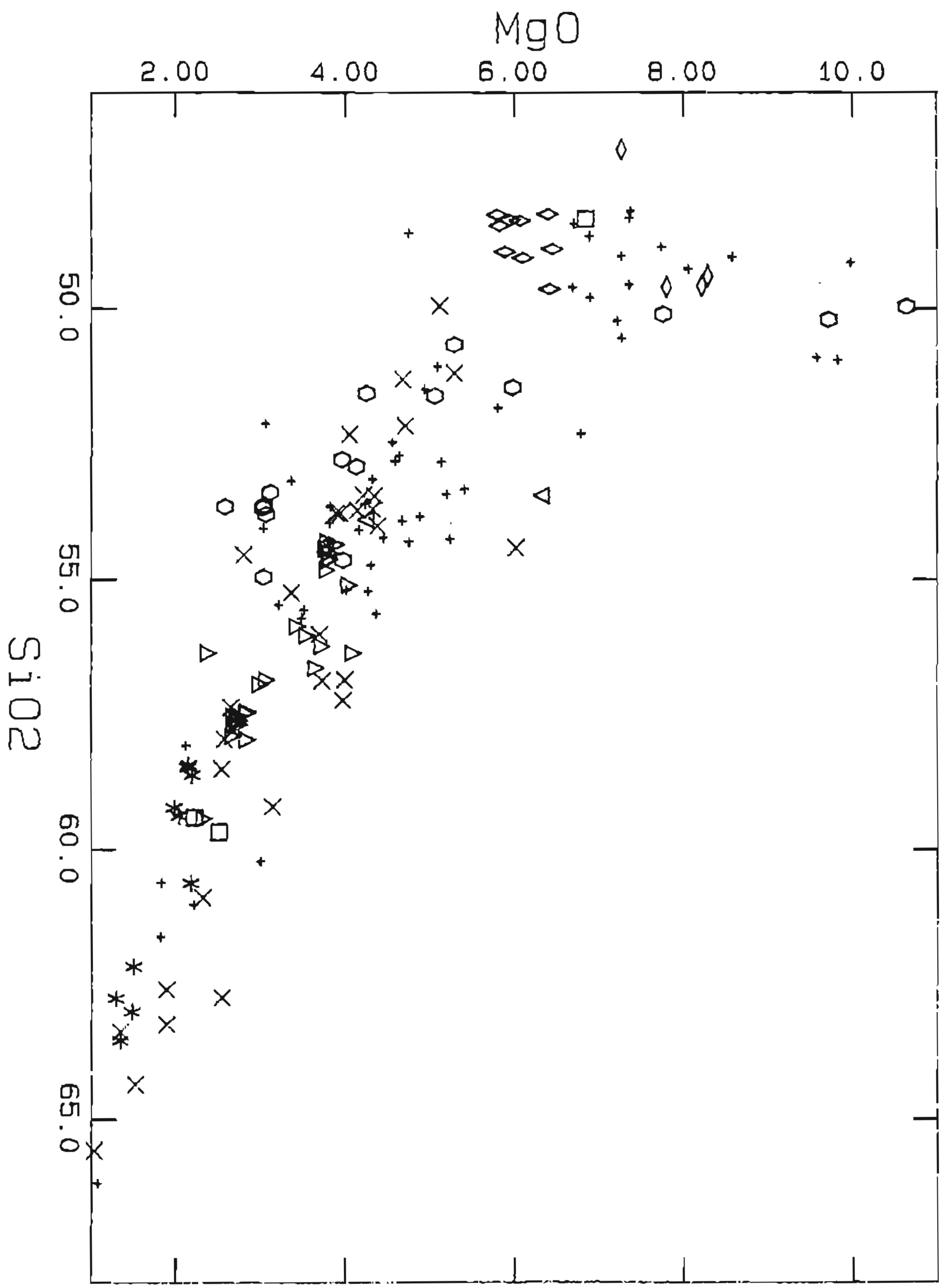
upright diamonds - Table Top Mountain (TT)

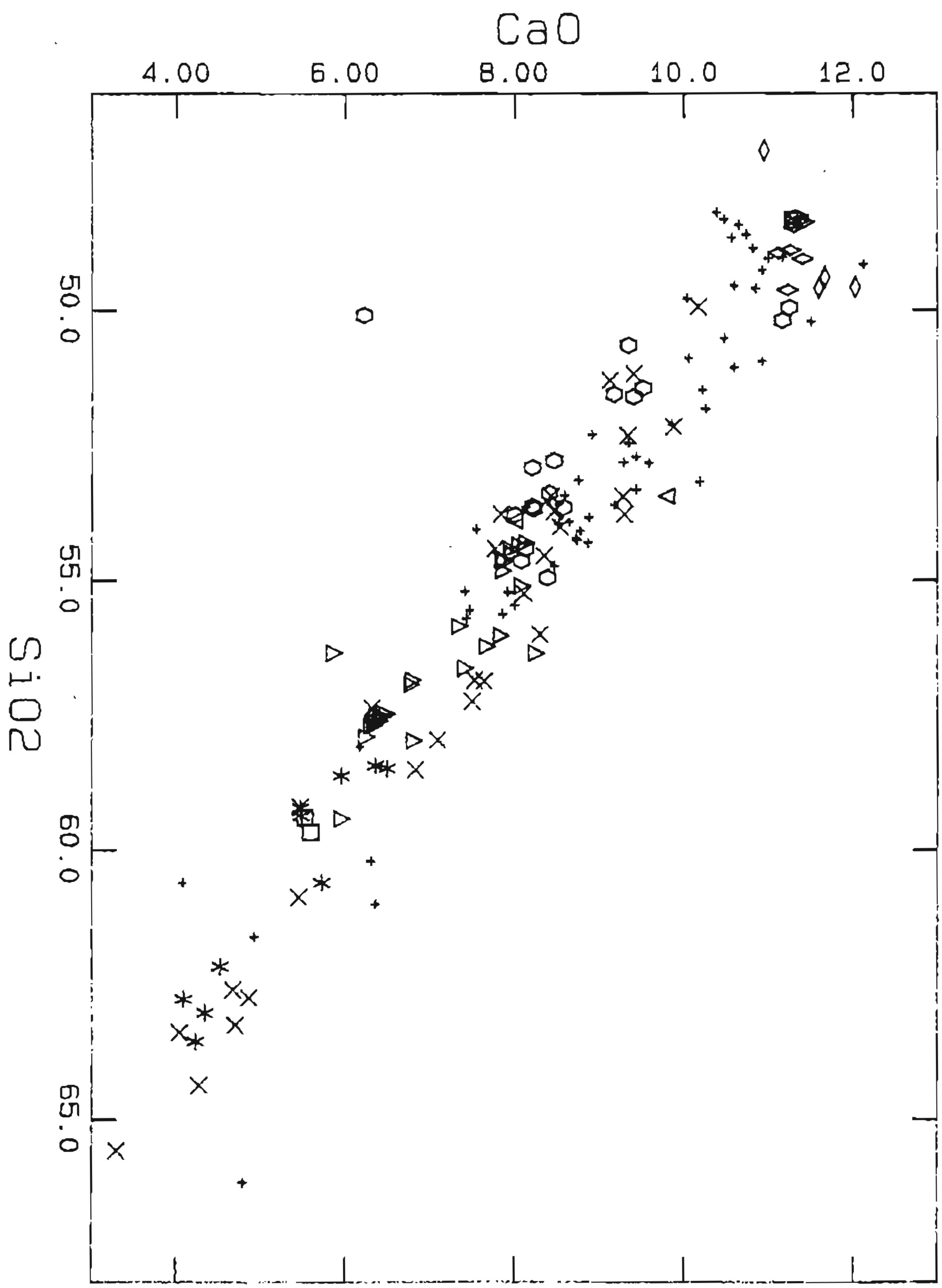
sideways diamonds - Wide Bay Cone (WB).

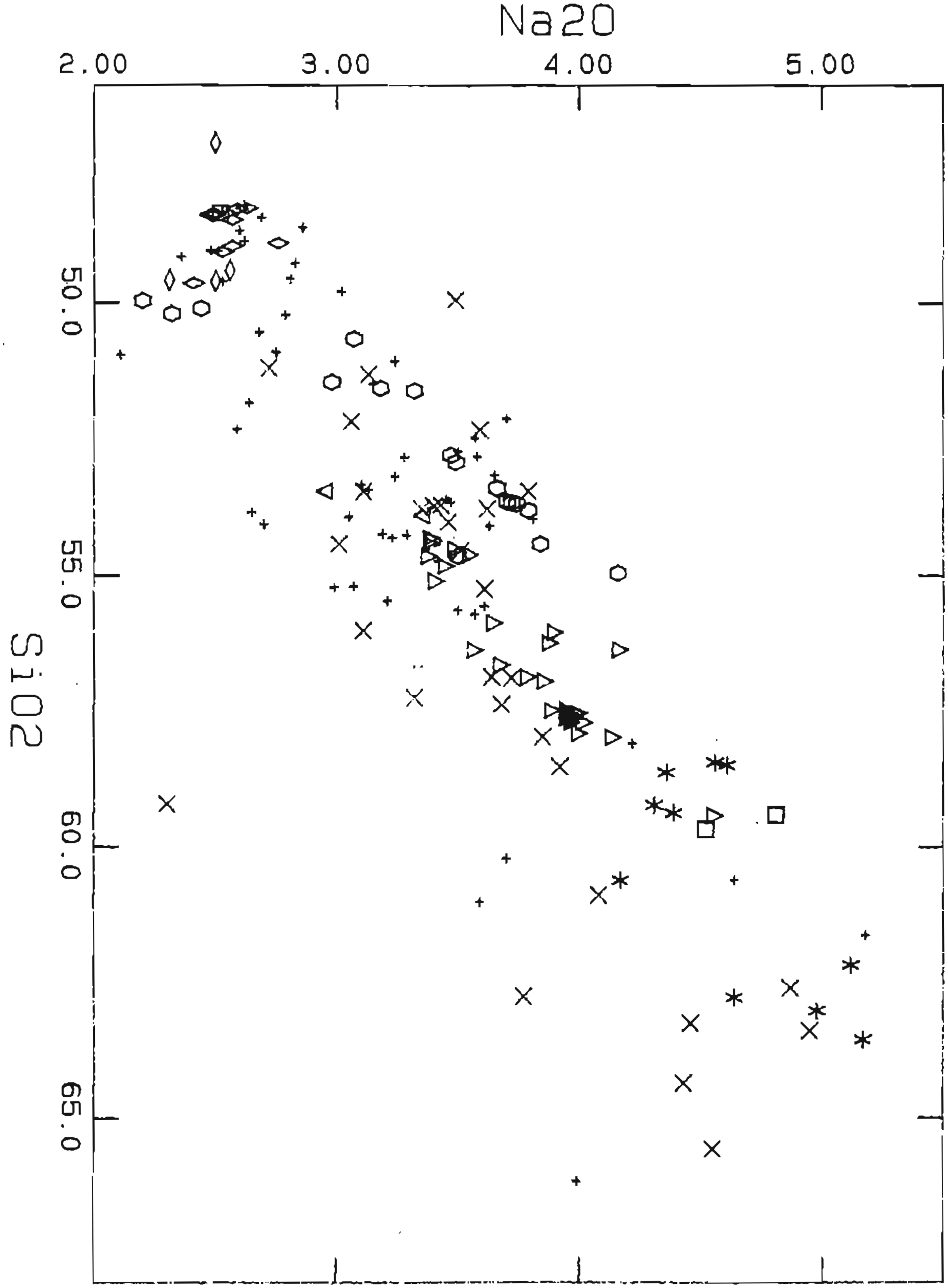

SiO2
50.0
55.0
60.0
65.0
TiO2
.60
.80
1.00
1.20

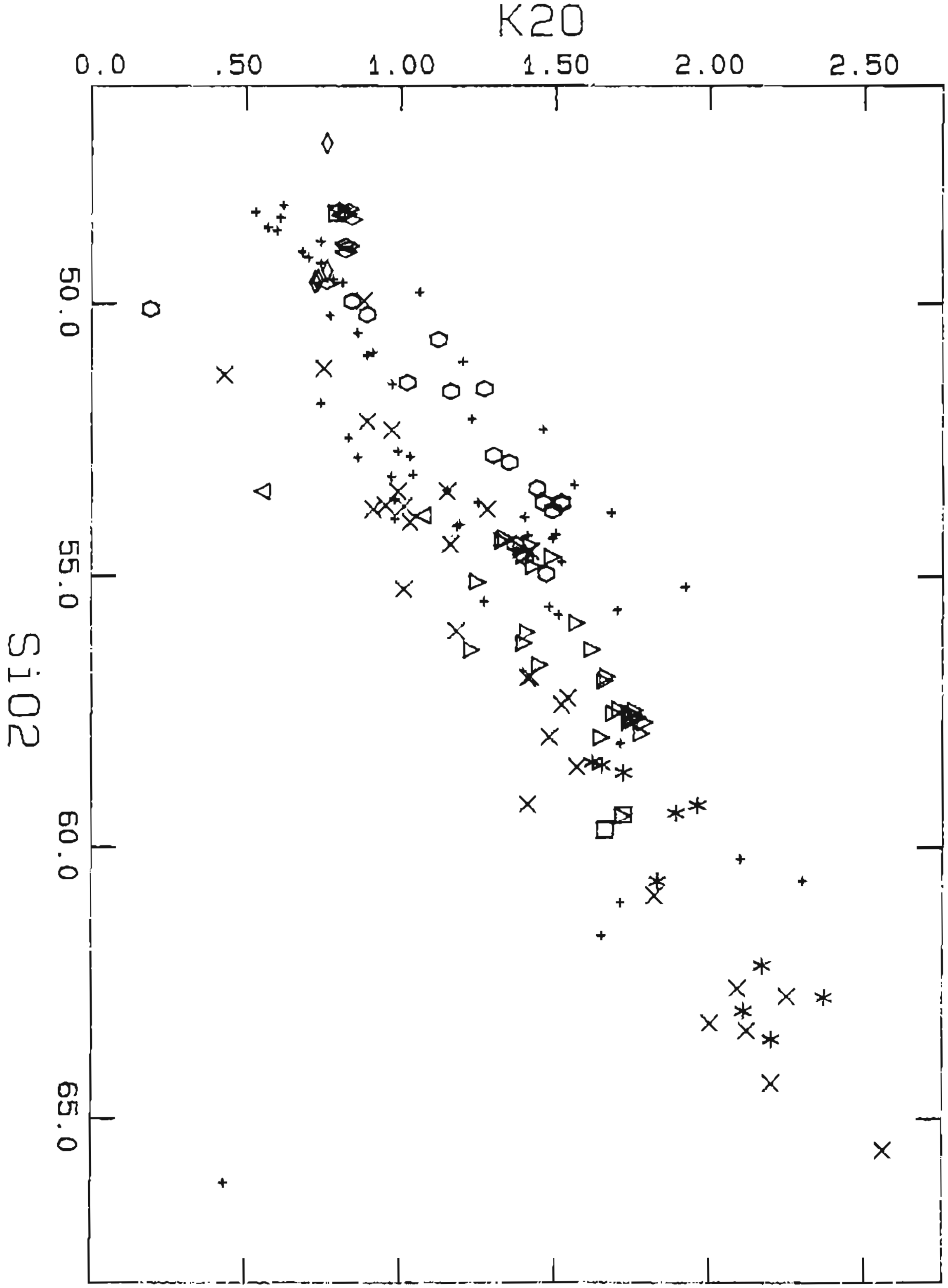

Al2O3
14.0
16.0
18.0
20.0
22.0
SiO2
50.0
55.0
60.0
65.0

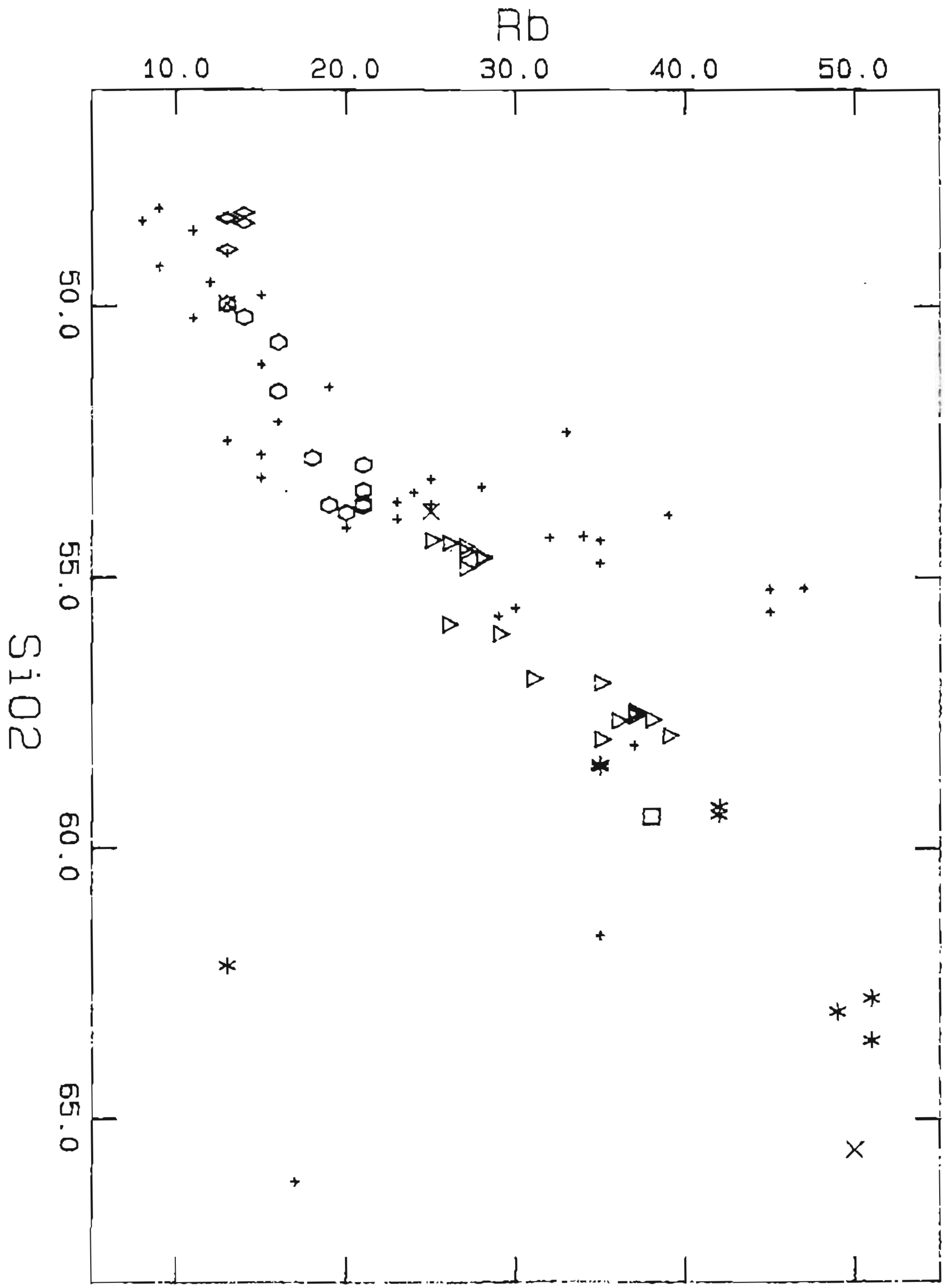

FeOt
5.00
6.00
7.00
8.00
9.00
10.0
SiO2
50.0
55.0
60.0
65.0

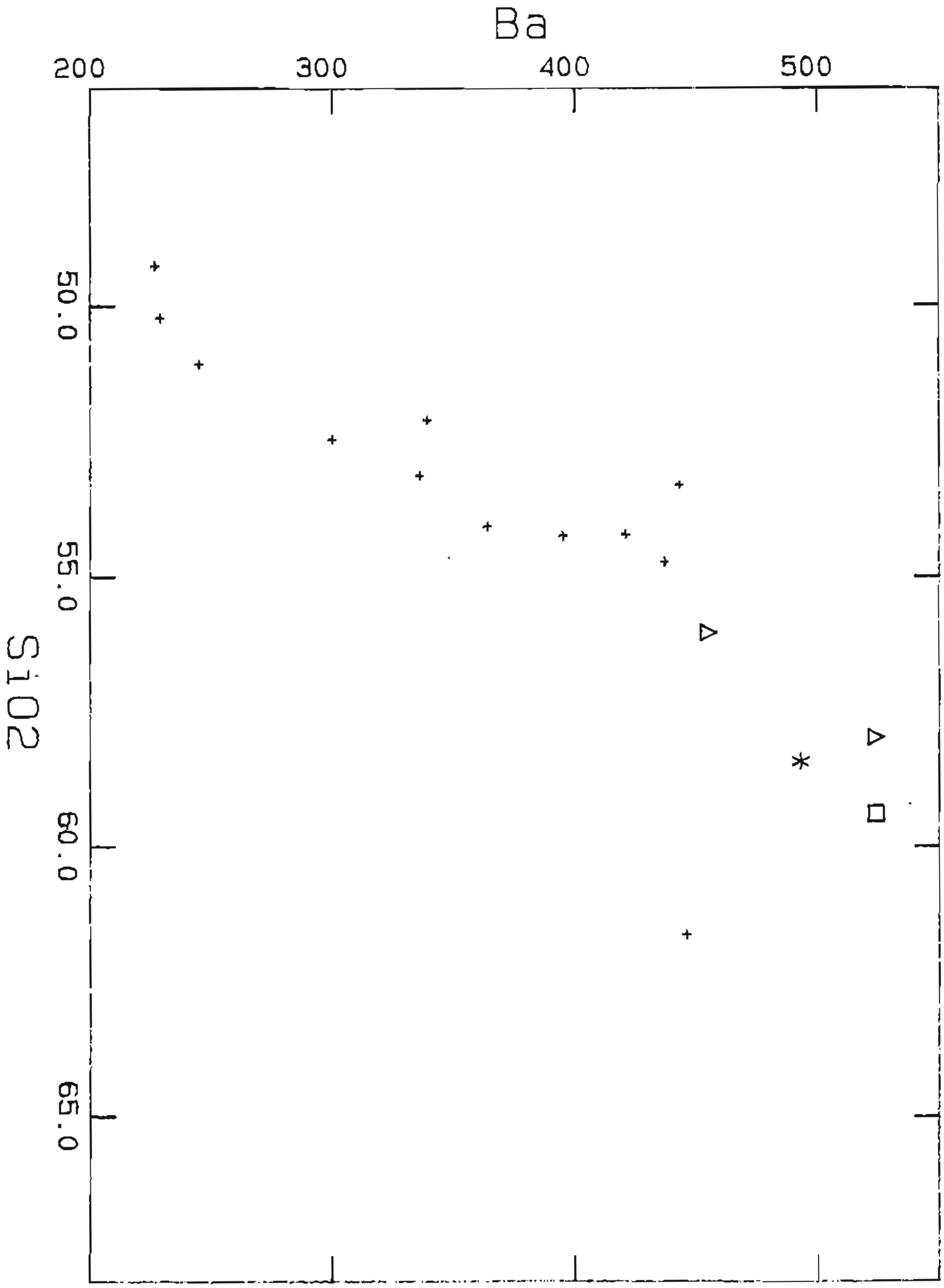

MgO
2.00
4.00
6.00
8.00
10.0
SiO2
50.0
55.0
60.0
65.0

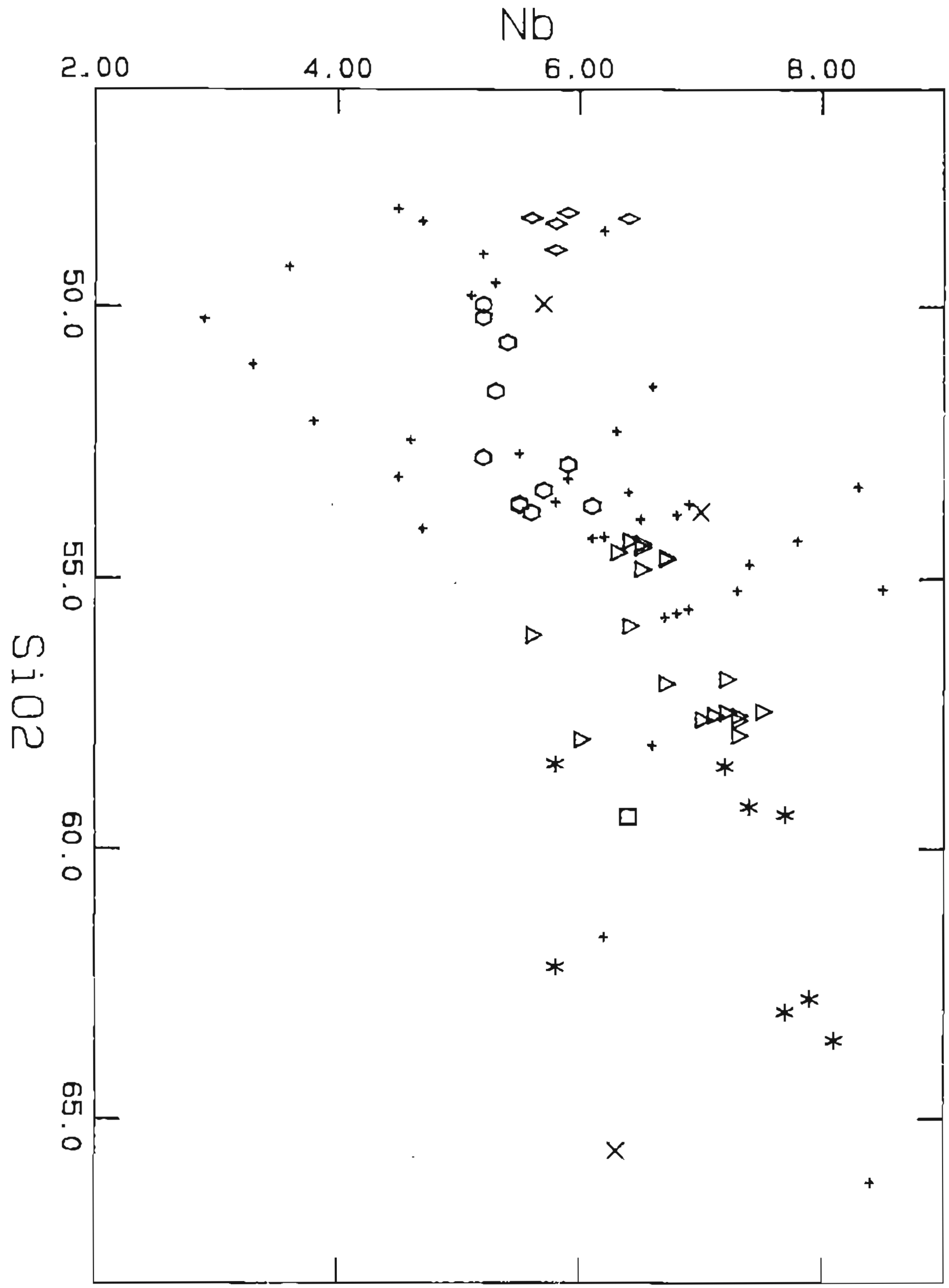

CaO
4.00
6.00
8.00
10.0
12.0
SiO2
50.0
55.0
60.0
65.0

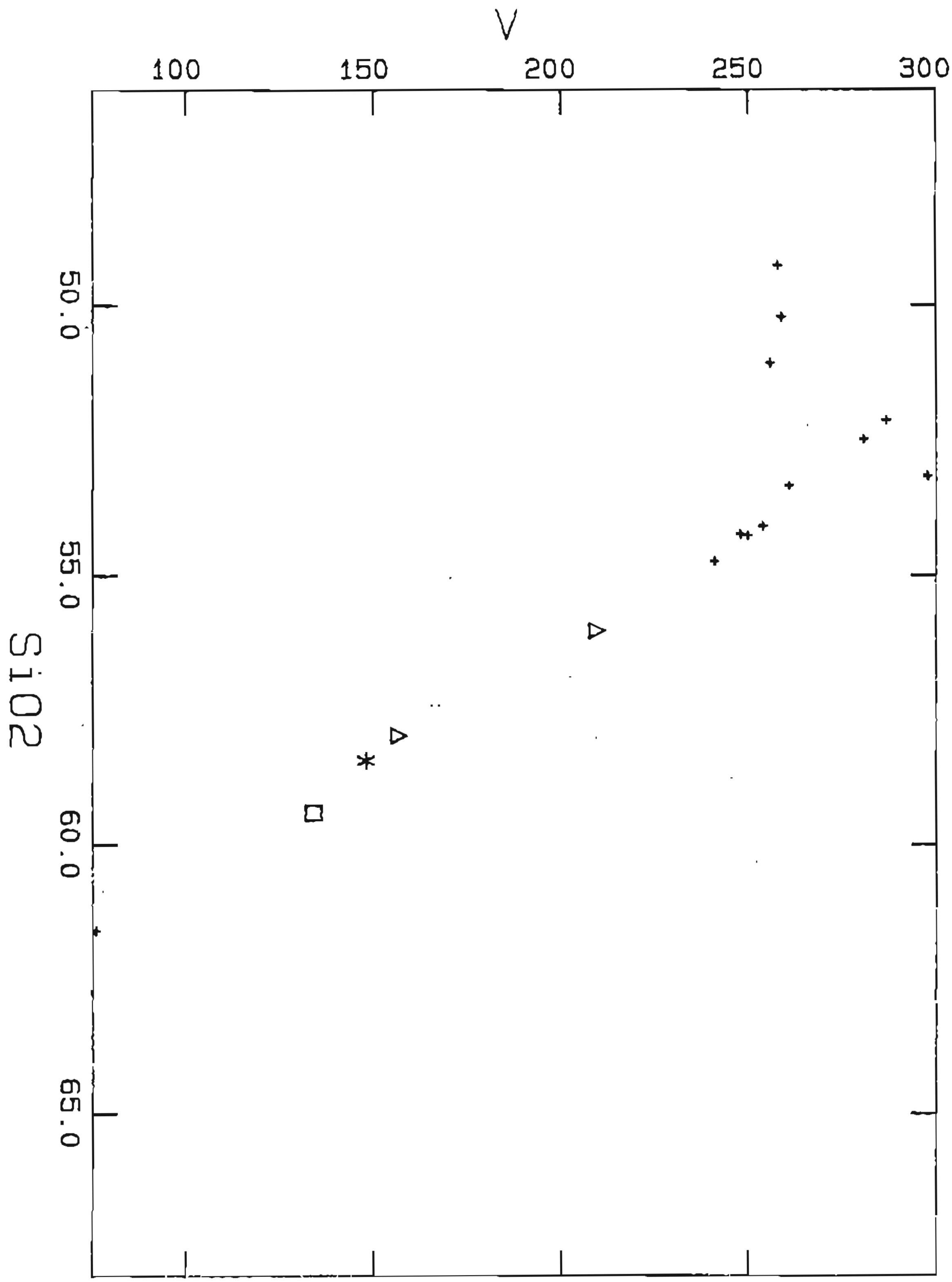

Na2O
2.00
3.00
4.00
5.00
SiO2
50.0
55.0
60.0
65.0

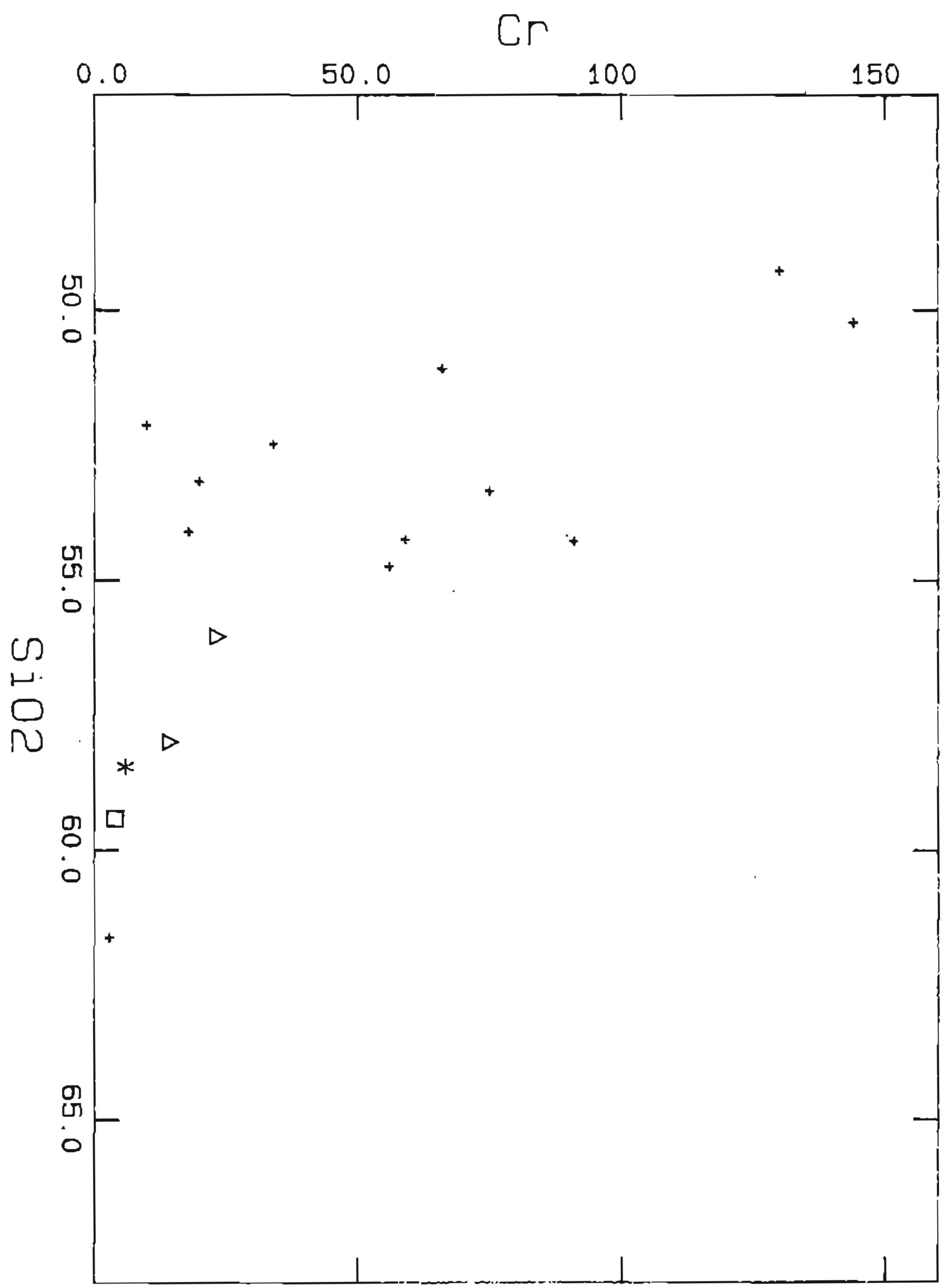

K2O
0.0
.50
1.00
1.50
2.00
2.50
SiO2
50.0
55.0
60.0
65.0

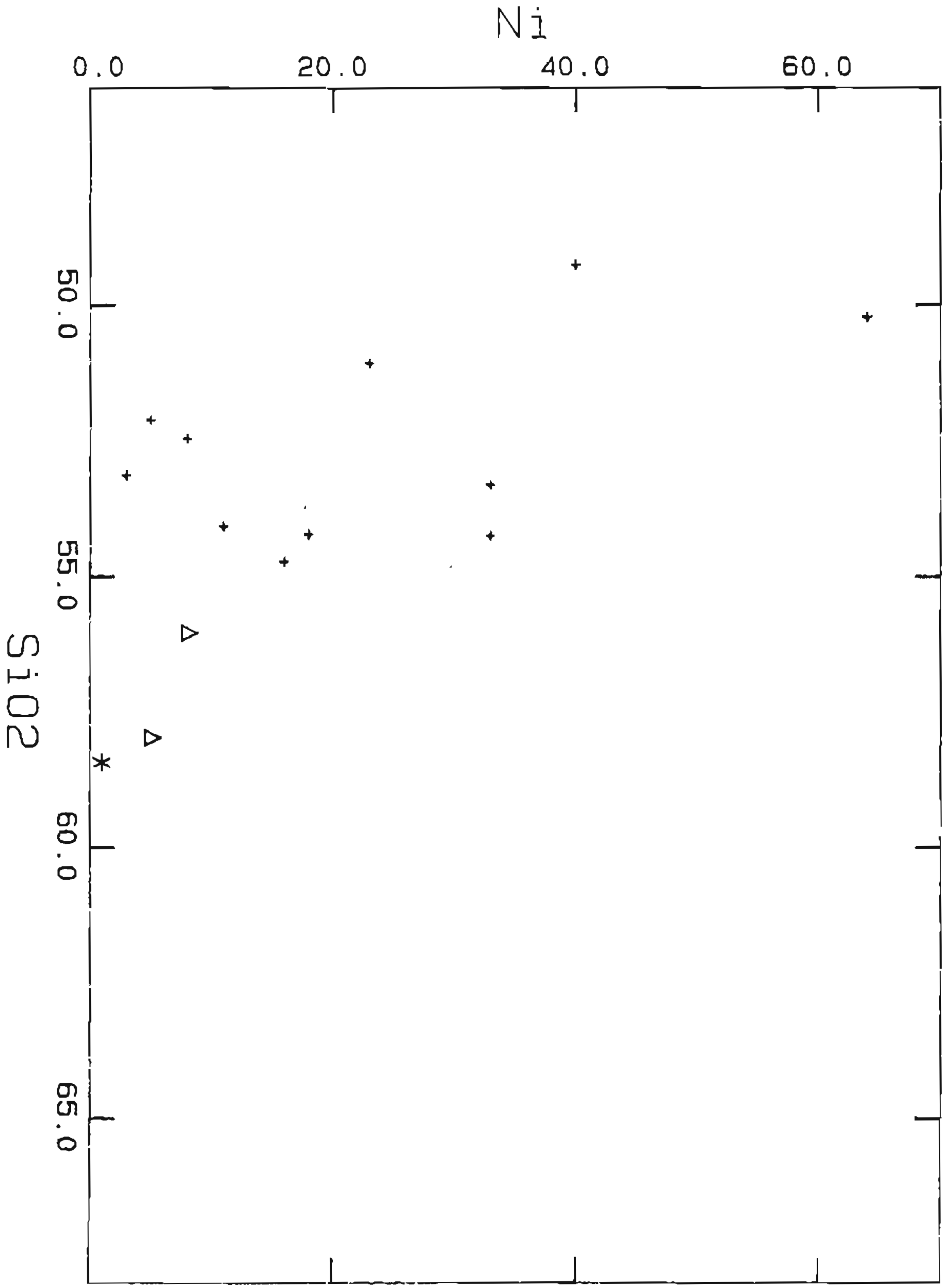

Rb
10.0
20.0
30.0
40.0
50.0
SiO2
50.0
55.0
60.0
65.0

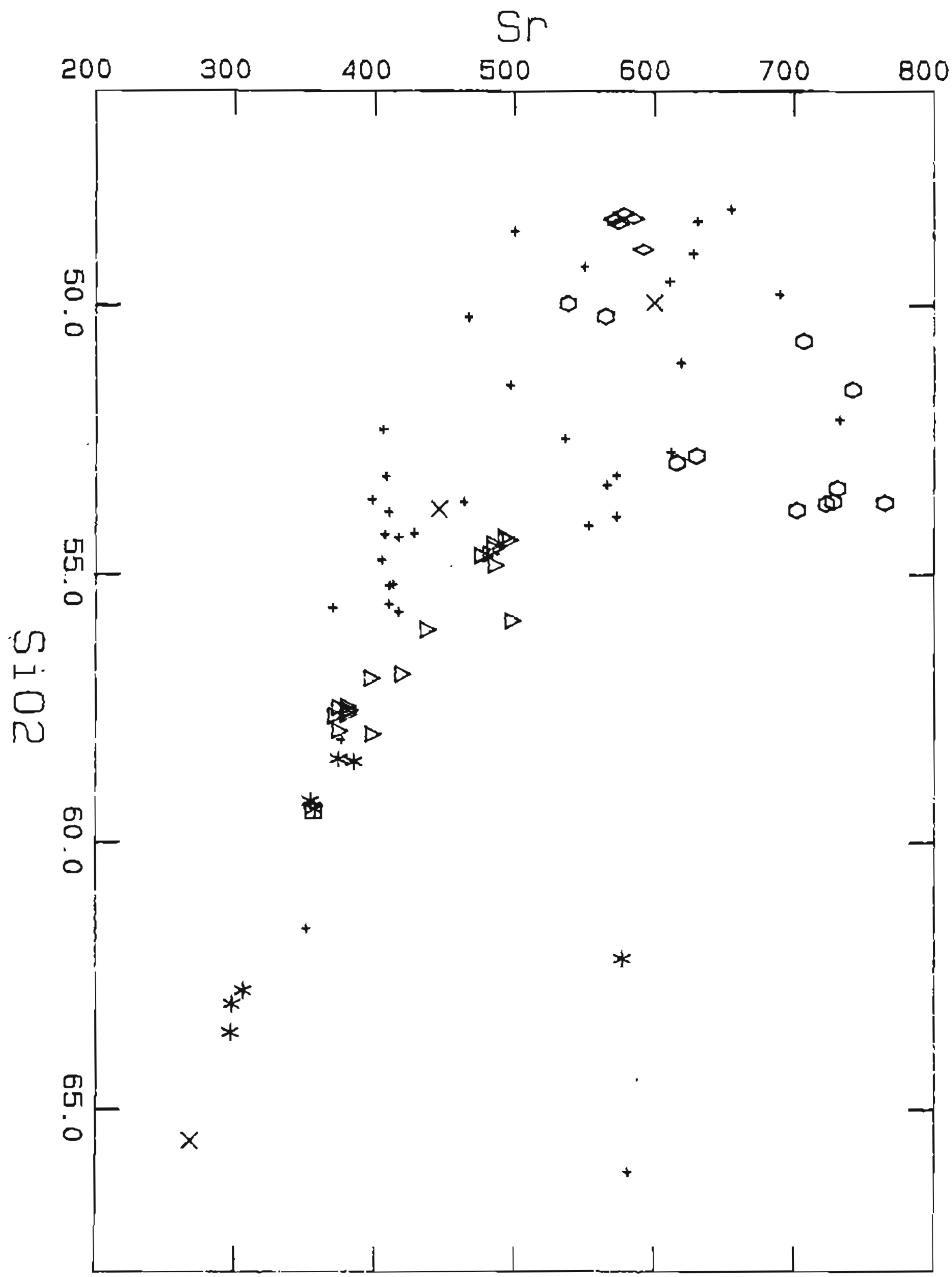

Ba
200
300
400
500
SiO2
50.0
55.0
60.0
65.0

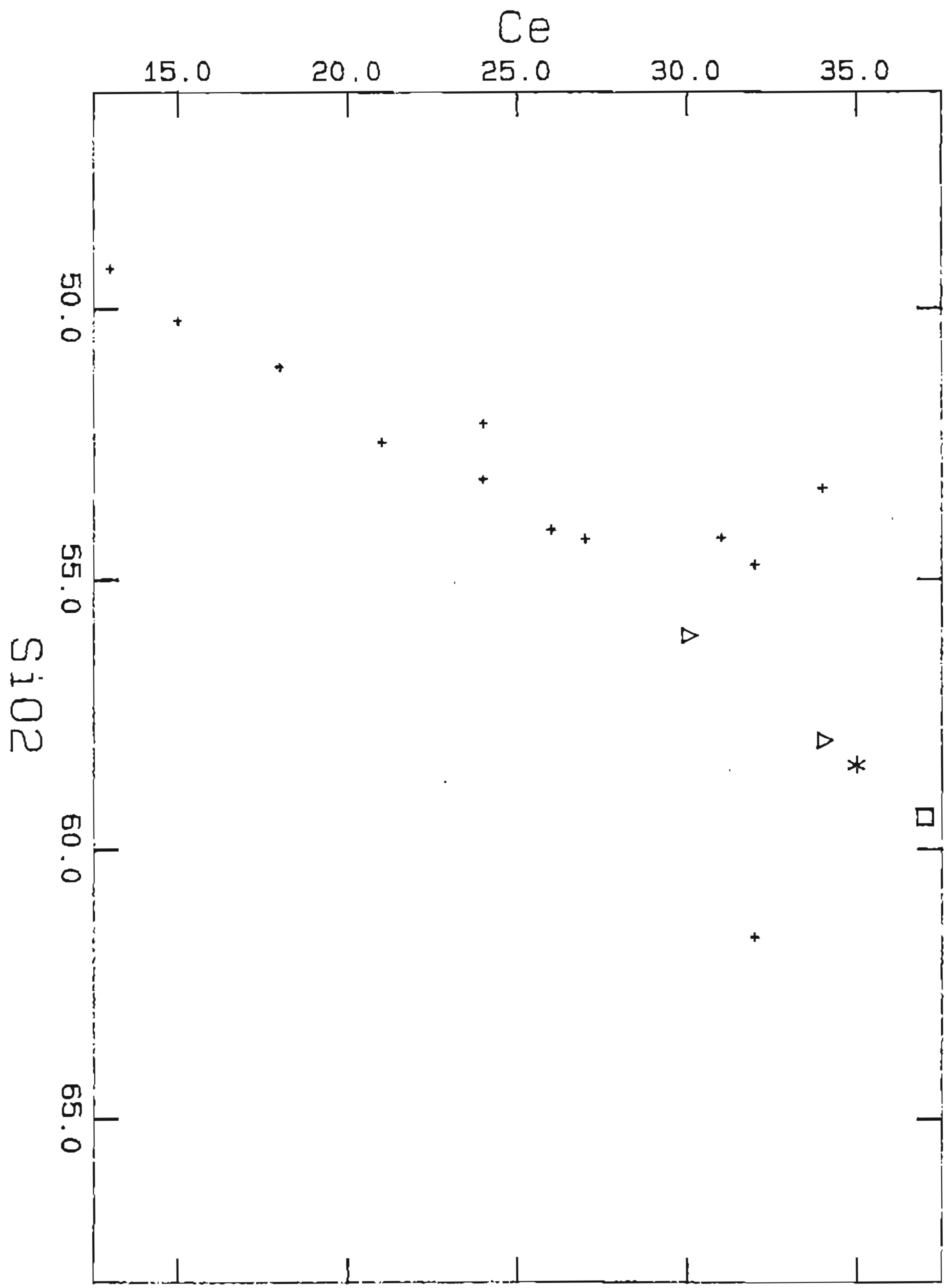

Nb
2.00
4.00
6.00
8.00
SiO2
50.0
55.0
60.0
65.0

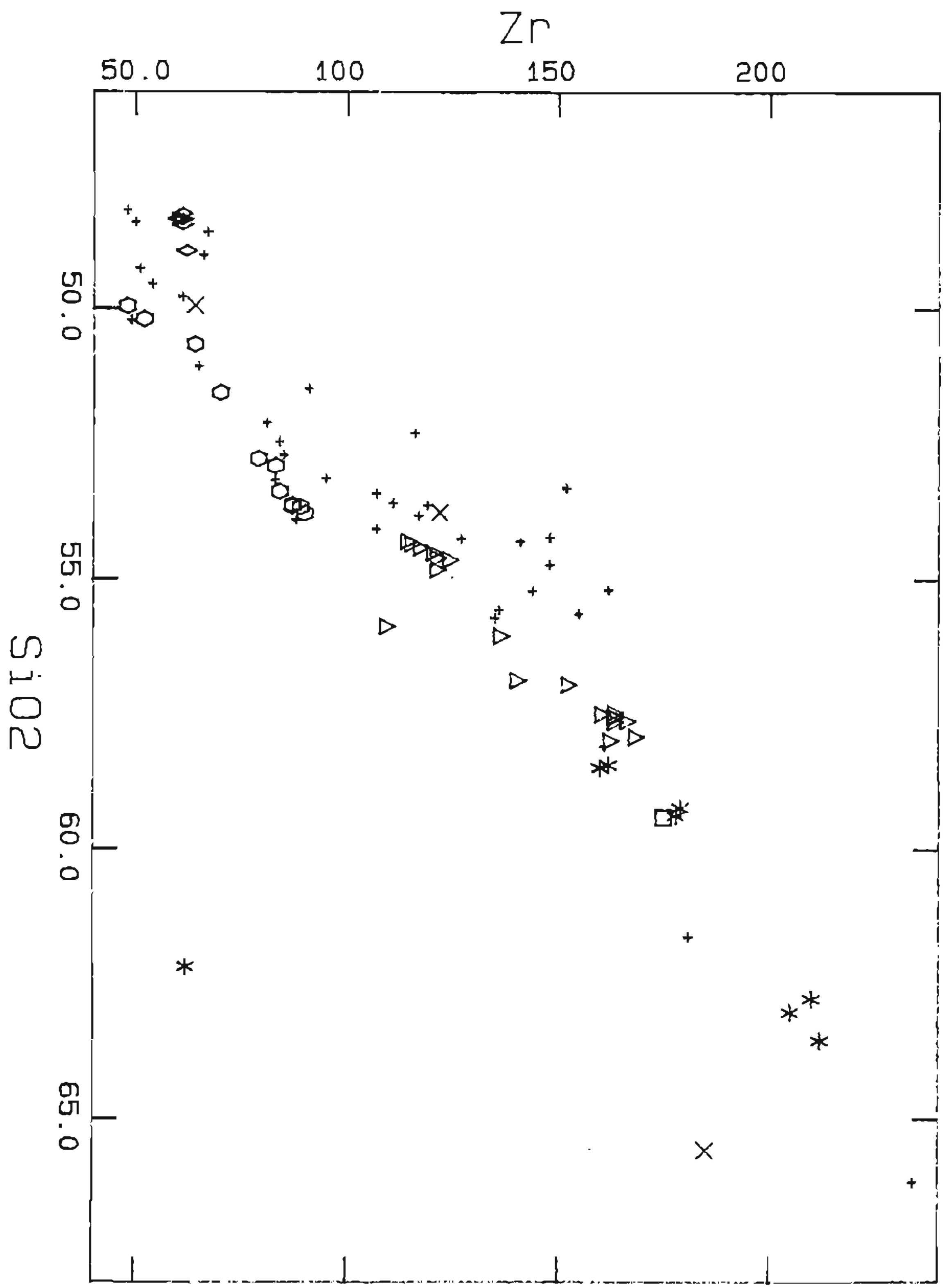

V
100
150
200
250
300
SiO2
50.0
55.0
60.0
65.0

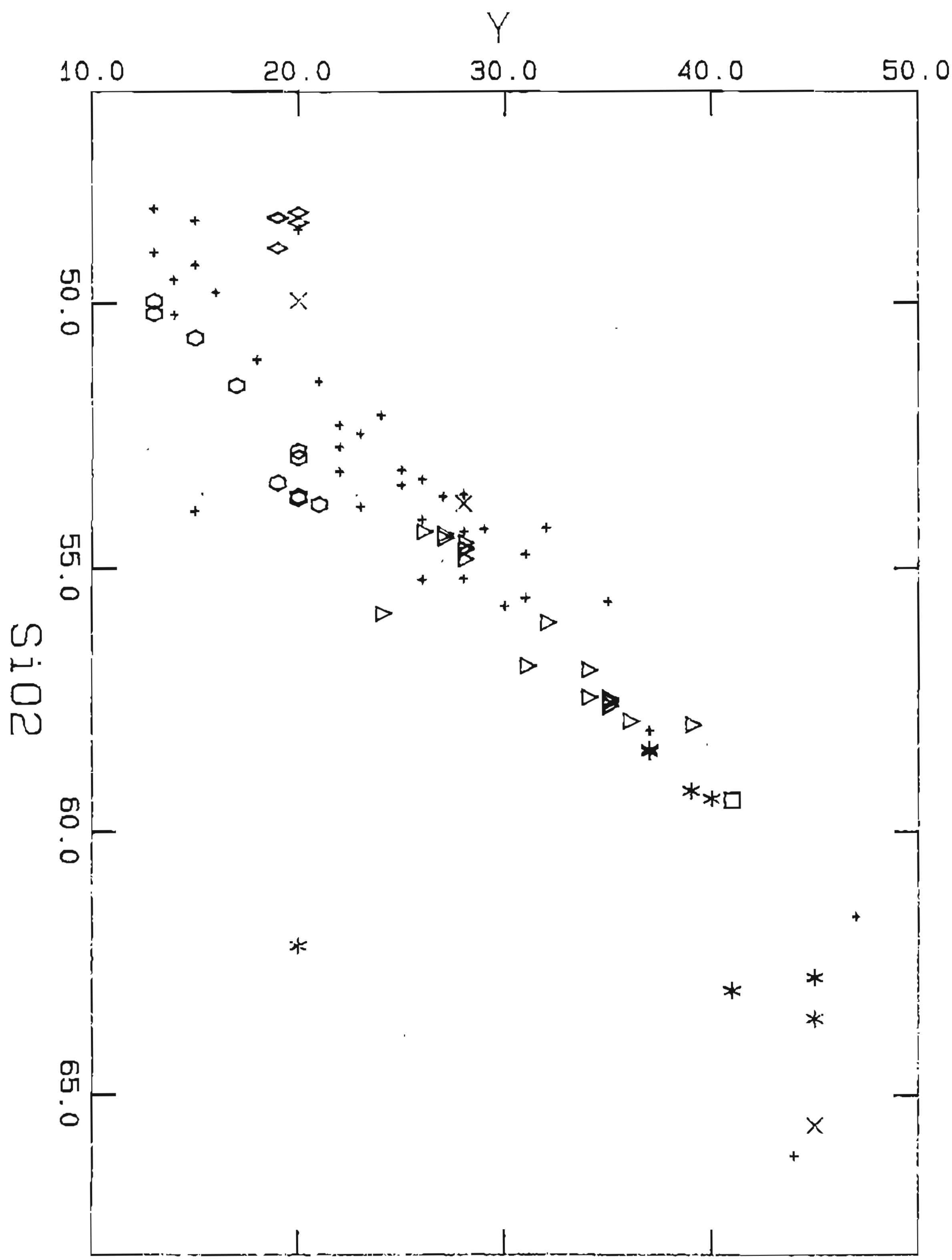

Cr
0.0
50.0
100
150
SiO2
50.0
55.0
60.0
65.0


Ni
0.0
20.0
40.0
60.0
SiO2
50.0
55.0
60.0
65.0


Sr
200
300
400
500
600
700
800
SiO2
50.0
55.0
60.0
65.0


Ce
15.0
20.0
25.0
30.0
35.0
SiO2
50.0
55.0
60.0
65.0


Zr
50.0
100
150
200
SiO2
50.0
55.0
60.0
65.0


Y
10.0
20.0
30.0
40.0
50.0
SiO2
50.0
55.0
60.0
65.0