Thy, P., Lesher, C.E, and Larsen, H.C. (Eds.)
Proceedings of the Ocean Drilling Program, Initial Reports Volume 163X

8. Principal Results[1]

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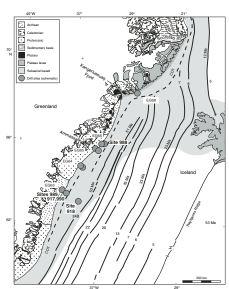
INTRODUCTION

Shallow-offset drilling during Ocean Drilling Program (ODP) Leg 163X was intended to address the magmatic and tectonic development during continental breakup and formation of the southeast Greenland volcanic rifted margin. Basaltic crust accreted to the North Atlantic margin during and following Paleogene breakup is represented by landward plateau lava sequences and seaward anomalously thick crust along the conjugate margins. The offshore magmatism has been seismically identified as seaward-dipping reflector sequences and high-velocity underplated lower crustal plutons. The seaward-dipping reflectors along the southeast Greenland margin were targeted by ODP Legs 152 and 163 (Fig. **F1**) and are mostly located on the continental shelf along a transect at ~63°N. The present shallow drilling project was intended to complement the results of previous ODP drilling on the margin and to address outstanding questions arising from those efforts.

ODP sanctioned this cruise as a continuation of Leg 163. The "X" designation indicates that funding for the program was provided by external sources (Danish National Science Foundation and the U.S. National Science Foundation) without direct oversight from ODP. Leg 163X extended over 2 yr with cruises in August 1998 and August–September 1999 and drilled in four transect areas to the north-northeast of 63°N, where drilling during Legs 152 and 163 had provided a good basement coverage.

F1. Summary map, p. 19.



DRILLING OBJECTIVES

The objective of shallow-offset drilling during Leg 163X was to extend the results obtained during Leg 163, which was cut short by adverse weather. To satisfy these objectives, drilling targets were selected

[1]Examples of how to reference the whole or part of this volume.
[2]Scientific Party addresses.

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along four transects located on the continental shelf between 60° and 70°N (Fig. **F1**). Several seismic surveys prior to and following Leg 163 improved our understanding of the crustal structure of the margin and provided guidance for selecting drilling sites (Hopper et al., 1997; Holbrook et al., 2001; Nielsen et al., 2002). The selected target areas are all in crust approaching the East Greenland-Iceland rise and the inferred trace of the ancestral Iceland mantle plume. These drill targets were chosen to document lateral variability in mantle and crustal processes and volcanism toward the alleged plume track. Furthermore, work following Leg 163 revealed relatively young lavas at Site 988 in crust thought to be much older (Tegner and Duncan, 1999); therefore, it was important to establish the lateral distribution of such young lavas along the rifted margin. Finally, the failure to drill into the break-up unconformity during Leg 163 left to present drilling to determine the nature of the unconformity's contact with the underlying sediments. Other transect-specific goals and site justifications are also summarized below.

Transect EG68, at latitude 68°N (Fig. **F1**), is in crust that extends the volcanic stratigraphy of the flood-basalts succession into the oceanic domain. The transect was supported by several seismic profiles along the Blosseville Kyst. Seismic Line DLC9724 immediately southeast of Nansen Fjord shows that the seaward-dipping reflectors extend to within 20 km of the coast and suggests little sediment cover. Drill sites were selected along this seismic line in two areas, either in smooth basaltic seabed near the coast or in more rough seabed approaching the sediment cover farther seaward. We drilled at 18 sites along Transect EG68.

Transect EG66, at latitude 66°N (Fig. **F1**), is immediately northeast of Site 988. Seismic Lines DCL9711 and DCL9722 suggest that this area is underlain by seafloor representing the eroded featheredge of the seaward-dipping reflectors and not the continental basement, as previously concluded. Drilling at sites on this transect was intended to sample the earliest rift volcanics and possibly the breakup unconformity relatively near the Greenland-Iceland rise. As noted above, the discovery of relatively young lavas at Site 988 was puzzling, and it remained to be shown how widespread this age group of lavas is or whether they represent geographically localized off-axis volcanism. We drilled at two sites along Transect EG66 during the 1998 cruise.

Transect EG65, at latitude 65°N (Fig. **F1**), is along seismic Line DLC9709, and drilling at sites along this transect was intended to sample the continental–oceanic transition of the seaward-dipping reflectors. The SIGMA seismic profiles suggested an increase in crustal thickness between 63° and 66°N that may be related to a change in magma production rate and the proximity of the plume track. An additional objective was to examine possible fault-controlled basins and their sedimentary fillings that were detected by the seismic survey. Drilling on this transect was the most successful and sampled 55 sites.

Transect EG64, at latitude 64°N (Fig. **F1**), is along seismic Line DLC9708 in the embayment south of Ammassalik, Greenland. The objective of drilling in this region was to sample the earliest volcanic flows and their underlying sediments. The H/S *Dana* survey suggested a sediment basin flanked by Precambrian basement to the west and overlain by the featheredge of the seaward-dipping reflectors to the east. This transect was drilled at two sites.

Transect EG63, at latitude 63°N (Fig. **F1**), was drilled during Legs 152 and 163 and was not visited during Leg 163X. Results from this previous ODP drilling (Sites 917, 918, 989, and 990), however, were used in conjunction with the present results.

Further details of the drilling targets can be found in the individual transect chapters of this report.

RESULTS

In this section we summarize the principal observations and preliminary results obtained from the four transect areas as they relate to the volcanic and tectonic development of the rifted margin. More transect-specific results are presented in the individual transect chapters.

Seismic Air Gun Profiles

The general structures of the margin and the volcanic dipping reflector sequences are well known from seismic surveys prior to and following Leg 163. In addition, a number of single-channel air gun sparker seismic lines were collected during Leg 163X using the British Geological Survey's instrumentation. The greater resolution of these seismic lines supplemented the existing multichannel profiles during the final site selection. Sparker seismic Lines DLC99-1 and DLC99-2 are along the navigational track of seismic Line DLC9724 (Transect EG68), sparker Line DLC99-3 is along seismic Line DLC9709 (Transect EG65), and sparker Line DLC99-4 is along seismic Line DLC9708 (Transect EG64). Sparker seismic Line DLC99-2 is a test line in Sermiliqaq Fjord. The results of these air gun profiles acquired during the cruise were used to identify and better define the thickness of the sediment cover, as well as the detailed near-surface fault and flow morphology.

Glacial Sedimentary Cover

The sedimentary cover was not completely recovered at most sites because of drilling disturbances and washout by drill water. At the majority of the sites, the sediment cover was composed of a thin veneer of unconsolidated material, mostly of Quaternary, moderately bioturbated, sorted silt and mud. This sediment often grades into poorly to moderately sorted glacial diamicton with mostly pebble-sized, probably ice-rafted fragments of basalt, gneiss, and sandstone. The pebbles are sometimes observed with weathered surfaces and striations indicating glacial transport. Marine microfossils are often present. Live corals were found on some clasts and recovered intact in the drill core. Grain size, as well as the content of fragments, is found to increase approaching the underlying basaltic basement. Pebble- to cobble-sized clasts with interstitial debris mud are commonly directly deposited on the basement. When the clasts are composed of basaltic fragments they may possibly represent locally derived scree overlying basaltic basement. The diamicton units are interpreted as tills that were subaerially deposited at a time when the inland ice extended over the shelf of the margin. This sedimentary cover is very similar to that encountered during Leg 152 on Transect EG63 and described as layered glaciomarine silt with dropstones, diamicton, and gravel (e.g., Sites 915 and 917) (Larsen, Saunders, Clift, et al., 1994). Diamond coring on Transect EG66 (Site SEG02) recovered a highly compacted diamicton unit with a sharp contact against a brecciated basalt that may have formed in a fault-controlled depression in the basaltic basement.

Seabed Morphology

Gentle stepping and southeast-sloping seabed were observed at many sites on the sparker seismic diffraction profiles. The stepping nature of the basement surface was interpreted to be controlled by basalt flow morphology and flow orientation. The seabed, however, was glacially eroded and covered by a thin glaciomarine sediment. In a few instances, sediment-free basement was recovered in the drill core with intact remains of seafloor fauna. The volcanic basement surface is weathered and sometimes eroded with glacial striations. The seabed is often blocky, fractured, and faulted. In one instance, consolidated moraine appears to be preserved in a down-faulted depression and overlays a brecciated basalt (Site SEG02). Some of these tectonic disturbances may reflect local glacial movements. The flows are generally composed of fine-grained and massive basalt and may be at least 1–2 m thick; however, upper and/or lower contacts were never recovered. The flows occasionally exhibit planar distribution of vesicles and mesostasis and preferred alignment of plagioclase.

Preglacial Sedimentary Basin Fillings

Preglacial sediments were recovered at two sites on Transect EG65. A fine-grained, well-indurated quartzwacke unit with dish-shaped rip-up clasts was recovered at Site SEG38. Carbon flakes are present in the matrix of the sandstone. The sandstone is moderately sorted and cemented by calcite, which suggests that the sandstone was deposited under high-energy conditions, possibly as fall-out from a highly turbulent suspension. Such a depositional environment, however, is not easily reconciled with the setting of Site SEG38, which lies within subaerially erupted flows of the dipping reflector sequences; therefore, the unit may represent a glacial clast.

In contrast, at Site SEG80 we recovered a bioturbated, poorly indurated, micaceous arkosic sandstone with coal flasers. The sandstone is fine-grained, well sorted, and porous (~30%). Lamination and small-scale cross lamination is disturbed by burrows. The coal flasers are present as drapings and alignments parallel to the bedding planes. Fossil wood fragments as much as 2 cm in diameter are occasionally present. The sandstone is cemented by widespread alkali feldspar overgrowth and suffered only slight compaction. There is no indication of strong mechanical compaction from deep burial or strong heating from a volcanic overburden or nearby dike or sill injection. These observations suggest that the sandstone was deposited in an active shallow marine environment. The angular shape of quartz grains and the high coal content indicate little reworking and suggest deposition proximal to the detritial source, consistent with deposition in a fault-controlled small basin as suggested by the geophysical survey. The dinoflagellate cyst assemblages from the sandstone correlates with late middle to early late Albian subzones of the Early Cretaceous (*Chichaouadinium vestitum* to *Wigginsiella grandstandica* subzones). This Albian to Cretaceous dinoflagellate assemblage suggests that the sandstone was reworked.

Sandstones were also encountered during Leg 152. Drilling in Hole 917A progressed through a thick sequence of basaltic flows and penetrated a thin layer of quartz sandstone (Unit V) at 821 meters below seafloor (mbsf). Drilling continued through metamorphosed, steeply dipping, layered silt and sandstone (Unit VI) until terminating at 875 mbsf without reaching the basement (Larsen, Saunders, Clift, et al., 1994).

The top layer (Unit V) of weakly dipping quartz sandstone was interpreted by the Shipboard Scientific Party as being derived from an intensely weathering mature source and reflected multiple transport episodes. The depositional environment was interpreted as either a marine shore facies or fluvial deposit (Vallier et al., 1998) of the Blosseville Kyst region farther to the north. It was speculated that this sandstone correlates with the arkosic sandstone found between the onshore Ryberg and Vandfaldsdalen Formations (Soper et al., 1976; Nielsen et al., 1981; Vallier et al., 1998). The underlying Unit VI is described as laminated and intensely burrowed clay to siltstones with subordinate sandstone layers and a significant volcanic component. Bedding planes and lamination in the sediment indicate a marked discontinuity between the overlying sandstone and lava flow and the underlying clay and siltstones. It was suggested that these sediments were derived from a basaltic source and deposited in a marine environment by distal turbidite flows, indicating shoaling of the succession prior to volcanism. Mineral reactions and replacements in the matrix of the siltstones suggest postdepositional heating, probably from dike intrusion and burial by overflowing lavas. The work of Vallier et al. (1998) showed that the sediments were deposited in a graben basin during early rifting of the East Greenland Margin. The basin was subsequently tilted, raised above sea level, eroded, and buried beneath a thick section of basalt flows. Vallier et al. (1998) further noted that the metamorphic recrystallization so prominent in the Site 917 sediments occurred before burial, possibly by dike and sill injection into the sediments. Subsequent faulting and tilting occurred during opening of the North Atlantic oceanic basin.

Sandstone recovered at Site SEG80 shows some similarities to the onshore Ryberg Formation and Site 917 sandstones; however, some significant differences exist. The Site SEG80 sandstone is only moderately affected by thermal metamorphism, as well as by burial during the construction of the seaward-dipping reflector sequence, which is in contrast to the Site 917 sediments that were compacted, presumably from burial beneath a thick pile of flows (~850 m at Site 917) and thermally metamorphosed. This suggests that at Site SEG80, the sedimentary basin was not covered by a significant thickness of lava during construction of the seaward-dipping basalt sequences. The Site 917 sediments, together with the Ryberg Formation, are estimated to be Late Cretaceous (Maastrichtian) to early Paleogene in age. In contrast, the Site SEG80 sandstone contains dinoflagellate cyst assemblages of late Early Cretaceous (Albian) age and, therefore, this unit or its source is significantly older that the presumed Maastrichtian prerift sediments of Site 917 and the onshore Ryberg Formation, as well as the dominantly Paleogene rifting and seaward-dipping reflectors.

Site SEG80 is landward of and below the seaward-dipping olivine-rich flows of the lower series of Transect EG65. Only one hole (SEG77A) farther landward and possibly stratigraphically below Site SEG80 encountered basalt flows of the lower volcanic series. The seismic profile collected during Leg 163X suggests that the area landward of Site SEG80 may have been affected by down faulting, therefore, the relative stratigraphic positions of these sites may not be ascertained in detail. Nevertheless, the observations suggest that the sandstone was deposited in an active shallow marine environment by reworked Albian sandstone (100–110 Ma) and was relatively unaffected by overflowing basalt flows during construction of the seaward-dipping sequences.

Precambrian Basement

The Precambrian basement was drilled at Site SEG32, which is farther landward of the sandstone encountered at Site SEG80 and only ~10 km seaward of the coastal line. The rock is a melanocratic hornblende-biotite pegmatitic gneiss indistinguishable from many Archaean quartzo-feldspatic gneisses and supracrustal rocks exposed in the Ammassalik area and elsewhere (Bridgwater, 1976; Bridgwater et al., 1976).

Paleomagnetic Results

Magnetic polarity at the majority of the drilled sites is reversed. The exception is Site SEG01 (Transect EG66), which systematically gave a normal polarity. Site SEG01 is located only marginally landward of Site SEG02, which has a reverse polarity. Both Sites SEG01 and SEG02 were located northeast of Site 988, which shows systematic reversed polarity. All sites investigated during Leg 163X, as well as during Legs 152 and 163, were assumed to be located well within Chron C24r crust that predated all the seaward-dipping sequences. The Leg 152 Shipboard Scientific Party (1994a) concluded in their summary chapter that the broad normal and reverse magnetic pattern landward of Chron C24n represents Chron C24r, possibly with short field excursions and intensity variations. This is consistent with the dominating reverse polarity found during Leg 163X, as well as during Leg 163. The normal polarity found at Site SEG01 may represent a short-lived reversal. Alternatively, the spreading history of the area may have involved a short-lived spreading event during Chron C23r (~53 Ma) or off-axis volcanic events.

Preliminary Age Determinations

Some preliminary ^{40}Ar-^{39}Ar dates were obtained on Leg 163X basalts. Step-heating ^{40}Ar-^{39}Ar experiments were carried out on seven bulk rocks or plagioclase separates. The reliable dates so far obtained confirm a Chron C24r date for the upper series flows drilled on Transect EG65 (55.9–53.0 Ma). These results are consistent with the breakup age of 54–57 Ma inferred from Sites 989 and 990 (Tegner and Duncan, 1999). The lower series flows have not successfully been dated and we cannot confirm whether the lower series flows at Transect EG65 belong to the prebreakup flows of 60–63 Ma found at Site 917 (Sinton and Duncan, 1998). The results from both Transects EG66 and EG68, on or near the Iceland hotspot track, indicate a 48–51 Ma age, which postdates breakup and shows similarities with flows from Site 988 (Tegner and Duncan, 1999). Results from Leg 163X confirm the existence of relatively young postbreakup ages encountered at Site 988.

Volcanic Basement

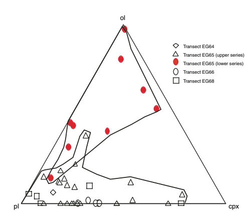
Flow Morphology

Drilling in most holes that penetrated the volcanic basement sampled basaltic flows. The exception is a possible sill at Site SEG71 on Transect EG64. Because typical penetration was limited to a few meters with recovery of <1 m, complete flows were not penetrated at any site. The drilled surfaces are glacially eroded flows that do not retain direct information on flow thickness and position relative to flow tops and bases. Information on flow thickness was obtained from drilling at Site 917, where individual flow units varied widely, with average thicknesses from 4 m (upper series) to 8 m (middle series) to 13 m (lower series). The flows at Sites 917 and 918 were described as pahoehoe in the upper series and as dominantly aa flows in the middle and lower series (Shipboard Scientific Party, 1994b, 1994c). The Site 917 flows were further interpreted as subaerial because of the lack of pillowing and the presence of oxidized flow tops, sometimes with thin soil deposits. Because complete flows, as well as flow contacts, were not recovered during Leg 163X, the nature of the flows is uncertain. The lack of strong grain-size variations that would have indicated chilled margins and pillowing makes it likely that the units represent aa flows. It is possible that these were subaerially erupted, although unambiguous reddened oxidized flow tops and intervening sediments were not recovered. The information from Leg 163X drilling indicates vesicular to massive flows with pipe vesicles occurring in some units. Basaltic breccia was found at some sites but could be tectonic in origin. Marked flow banding can be observed with alignment of plagioclase grains, flattening of vesicles, and weak banding in the groundmass as light and dark parts.

Petrography

The dominating lavas from all transects show many petrographic similarities. They are fine-grained, aphyric to seriated, highly plagioclase-clinopyroxene phyric basalts. Additionally, olivine appears to have been present in relatively low amounts in many units but is replaced by secondary minerals. The relative proportions of olivine and clinopyroxene (Fig. F2), as well as the total amounts of phenocrysts, appear to vary widely, partly because of the small sampling volumes. Plagioclase phenocrysts are present in all units either as isolated phenocrysts or in glomerocrystic clusters, sometimes intergrown with clinopyroxene and/or olivine. There is textural indication that plagioclase nucleated simultaneously with clinopyroxene and olivine. Occasionally euhedral grains of chromian spinel are preserved in relict olivine. The groundmass is composed of an assemblage restricted to the phenocryst assemblage with the addition of Fe-Ti oxide minerals.

F2. Modal phenocryst contents, p. 20.



Landward of Site SEG51 on Transect EG65, or west of ~36°17′W, a distinct group of flows were found that are moderately to highly olivine and plagioclase porphyritic with minor amounts of clinopyroxene (Fig. F2). A distinctive red coloration is caused by olivine alteration. This olivine and plagioclase phyric suite of flows are referred to as the lower series, whereas the upper series seaward of Site SEG51 are dominated by aphyric to highly plagioclase and clinopyroxene phyric flows with minor amounts of olivine.

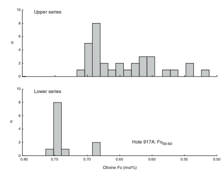
The transition between the two series was recovered from three holes drilled into either the upper or lower series flows at Site SEG51, suggesting that the transition is characterized by intercalated flows of the two series. All flows westward of Site SEG51 petrographically belong to the lower series, and all flows east of Site SEG51 belong to the upper series.

It is of interest to compare the two flow series sampled from Transect EG65 to the results from drilling at Site 917, which also penetrated several series of flows, including olivine phyric and picritic flows (Shipboard Scientific Party, 1994b). At Site 917, olivine phyric flows were occasionally present in a lower series but were more common in an upper series. These flows commonly contain >8% olivine phenocrysts and may contain well over 25%. In contrast, the Transect EG65 lower series flows are highly plagioclase-olivine phyric, unlike Site 917 flows. This does not allow a direct correlation between the lower series of Transect EG65 and the Site 917 olivine phyric flows. Moreover, based on petrographical characteristics the upper series of Transect EG65 cannot be discriminated from many other flows sampled on Transect EG63 during Legs 152 and 163.

Phenocryst Compositions

Fresh olivine phenocrysts were only found in the Transect EG65 lavas. The upper series contains olivine phenocrysts that vary in composition from Fo_{71} to Fo_{52} (Fig. **F3**). There is a peak in the distribution from ~Fo_{71} to Fo_{68}, with a tail toward more iron rich compositions. The most iron rich olivines are found as groundmass phases from a remarkably fresh flow recovered from Site SEG61. Unaltered olivine is present in only two lavas of the lower series. These are $Fo_{69–76}$ in composition and are distinctly more magnesium rich than upper series olivine. However, all olivine phenocrysts analyzed from Transect EG65 flows are markedly more evolved than the olivines analyzed from Site 917. Demant (1998) found olivine phenocrysts in the picritic and olivine phyric flows of both the upper and lower series at Site 917 that reached as high as Fo_{94} and typically were above Fo_{82}. Groundmass olivine compositions in Leg 152 aphyric olivine basalts were between Fo_{56} and Fo_{84}, similar to phenocryst compositions from Transect EG65. Except for an overlap of groundmass compositions, the olivines from Transect EG65, therefore, are markedly more evolved in composition than at Site 917.

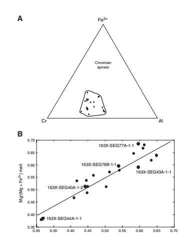
F3. Olivine histograms, p. 21.



Chromian spinel occurs as inclusions in olivine and as a groundmass phase of the plagioclase-olivine phyric flows of the lower series of Transect EG65. Their resistance to alteration make them useful for recovering primary melt information (Allan, 1992; Allan et al., 1999), which are summarized in Table **T1** and illustrated in Figure **F4A** in terms of their Cr-Fe^{3+}-Al contents. The large variation and positive correlation between the Mg numbers of melt and spinel suggest that the spinels record a liquid line of descent during phenocryst to groundmass crystallization (Fig. **F4B**). The most primitive melts inferred have Mg/(Mg + Fe^{2+}) ratios from 68 to 64. These melt estimates are slightly lower than those obtained by Allan et al. (1999) from the picritic flows from the upper series at Site 917 (Mg/[Mg + Fe^{2+}] = 70–61). The relict olivine preserved in two of the Leg 163X samples (Table **T1**) indicates $Fo_{75–68}$ compositions. These olivine compositions are well below the estimated equilibrium olivine of $Fo_{85–87}$ based on the calculated primitive melt compositions and are also well below the coexisting olivine phenocrysts of $Fo_{83–75}$ found in Site 917 lavas (Allan et al., 1999). It is possible that this lack of primitive olivines in the Transect EG65 flows reflects selective alteration of primitive olivines, leaving the more evolved olivines as relict grains.

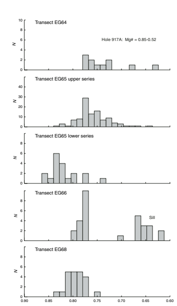
T1. Spinel/melt relations, p. 37.

F4. Chromian spinel, p. 22.



Clinopyroxene phenocrysts and microphenocrysts are present in many of the flows. The pyroxenes are dominately augitic in composition and only occasionally reach into the subcalcic field (Poldervaart and Hess, 1951). The regional variation in the pyroxene Mg/(Mg + Fe) ratio along the rifted margin is illustrated in Figure **F5.** There appears to be a weak trend toward more iron-rich pyroxene phenocrysts southward along the coast from Transect EG68 to Transect EG64. The lower series of Transect EG63 is the exception to this general trend by containing pyroxenes with significantly higher Mg/(Mg + Fe) ratios than

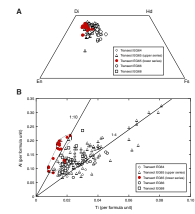
F5. Augite histograms, p. 23.



the upper series, which is consistent with the observations from olivine phenocrysts in the same flows. The available data for Transect EG63 (Demant, 1998) does not allow discrimination between the various flow series; therefore it is not possible to ascertain how these fit the general trend observed for the present transects.

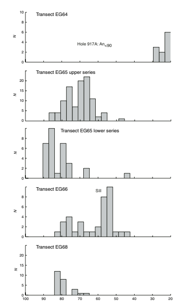
The compositions of the augite microphenocrysts and phenocrysts are illustrated in Figure F6. The lower series flows of Transect EG65 contain pyroxenes with diopside and enstatite contents higher than other flows (Fig. F6A). The Ti/Al ratios of the Transect EG65 lower series (Fig. F6B) are also significantly lower (1/10) than those of the upper series and other transects (1/4). This is consistent with the difference in the Mg/(Mg + Fe) ratios and suggests that the Transect EG65 lower series flows were derived from parental melts with lower Fe and Ti contents than the upper series flows. The flow drilled at Site SEG02 of Transect EG66 contains pyroxenes with significantly lower Mg/(Mg + Fe) ratios than at the nearby Site SEG01.

F6. Augite compositions, p. 24.



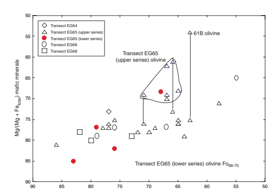
Plagioclase phenocrysts appear to be present in nearly all sampled flows. Because of the susceptibility of plagioclase to alter to albitic plagioclase and other secondary minerals, the number of analyses are more restricted than those for the pyroxene phenocrysts. Figure F7 provides a histogram of An content for the various transects. Similar to the pyroxene compositions, there is weak but distinct trend toward more albitic plagioclase phenocrysts going southward from Transect EG68 to Transect EG64. The exception is again the more primitive nature for the lower series plagioclases of Transect EG65. The upper series at Transect EG65 also contain plagioclases showing a bimodality in An contents (see discussed below). The flow sampled at Site SEG02 on Transect EG66 contains plagioclase that is consistently more albitic than at nearby Site SEG01. The same Site SEG02 flows show reverse magnetization as opposed to the normal magnetization and younger age of the Site SEG01 flows. The only plagioclases analyzed for Transect EG64 are relatively albitic (<An_{30}) as a result of alteration.

F7. Plagioclase histograms, p. 25.

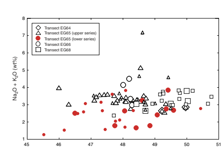


The phenocryst populations are illustrated in Figure F8. The analyzed phenocrysts record a largely positive correlation between An content of plagioclase and Mg/(Mg + Fe) ratio of pyroxenes, with the lower series flow of Transect EG65 having the lowest values. Some flows appear to contain plagioclase with significantly higher An content of plagioclase relative to the Mg/(Mg + Fe) ratios of their coexisting pyroxenes. This records a bimodality in the plagioclase phenocrysts that is best illustrated for the upper series of Transect EG65 (Fig. F7). This observation is tentatively related to the presence of cognate plagioclase crystals recording the past fractionation history of the flow and not the eruption conditions. Alternatively, the An-rich group of phenocrysts may be xenocrystic and may have been picked up by the magma during transit to the surface from lower series or from equivalent primitive flows. The coexisting olivine phenocrysts have a significantly lower Fo content as compared to the coexisting pyroxenes.

F8. Phenocryst compositions, p. 26.



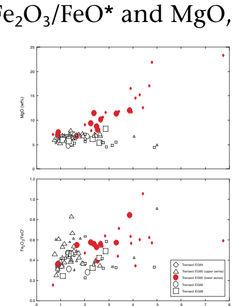
F9. Na_2O and K_2O vs. SiO_2, p. 27.



Lava Major Element Composition

All flows drilled are basaltic in terms of total alkalis and silica (Fig. F9). The volatile content measured by loss on ignition (LOI; corrected for iron oxidation) are typically well below 3% and show little systematic correlation with the Fe_2O_3/FeO ratio and elements susceptible to alteration, such as MgO, CaO, Na_2O, and K_2O (Fig. F10). The Fe_2O_3/FeO

F10. Fe_2O_3/FeO* and MgO, p. 28.

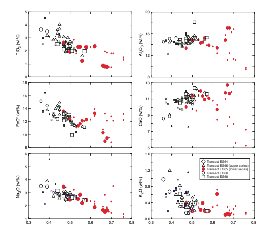


ratios, however, varies widely (<0.80), reflecting the alteration of phenocrysts and groundmass. The olivine-rich flows of the lower series at Transect EG65 all show high levels of alteration, as recorded by their LOI. Despite strong chemical and petrographic signs for alteration of the flows, the lavas appear to have retained their compositional characteristics, suggesting that alteration was mainly hydration and oxidation processes.

The Cross, Iddings, Pirsson, and Washington (CIPW) normative composition of the flows is typically olivine tholeiitic ranging from mildly nepheline to slightly quartz normative. A group of flows of the upper series of Transect EG65 are mildly alkalic, whereas the other flows from the same series cluster within the olivine-hypersthene normative field. There is no stratigraphic control on the distribution of the nepheline normative flows in the upper series. There is a weak negative correlation between normative quartz content and Na_2O that may have contributed to the normative variation; however, it is uncertain whether the nepheline normative characteristics of some flows is a primary characteristic or results from alteration (see later discussion).

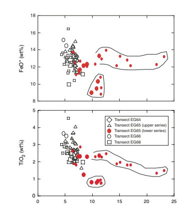
The variation in the major element composition of the flows is illustrated in Figure **F11** as a function of Mg/(Mg + Fe*) ratios and in Figure **F12** as a function of MgO content. There are two groups of samples shown on these and the following figures. Small symbols represent analyses of clasts for which it was not certain whether they represented in situ volcanic basement (see the individual transect chapters). The group identified by large symbols is the flows for which there were good indications that these represented in situ volcanic basement. The correlation between these two groups is good and suggests that the clasts recovered from many drill sites sampled the basement at that site.

F11. Major elements, p. 29.



The majority of the flows cluster with Mg/(Mg + Fe*) ratios <0.57 and show a systematic increase in TiO_2, FeO*, Na_2O, and K_2O with decreasing Mg/(Mg + Fe) ratio. For the same flows, CaO decreases, whereas Al_2O_3 remains relatively constant (Fig. **F11**), again with decreasing Mg/(Mg + Fe) ratio. The exception is the lower series from Transect EG65, which shows large variation in Mg/(Mg + Fe) ratios reflecting their modal olivine content. TiO_2 and FeO* show strong increase with decreasing MgO content (Fig. **F12**). These major element variations reflect typical tholeiitic fractionation trends, as also documented among the flows drilled in the oceanic succession at Sites 918 and 988–990 (Thy et al., 1998, 1999) and the central East Greenland plateau lava succession (Larsen et al., 1989).

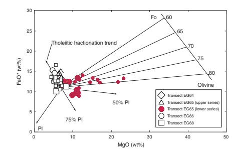
F12. FeO* and TiO_2 vs. MgO, p. 30.



The porphyritic flows of the lower series of Transect EG65 have Mg/(Mg + Fe*) ratios mostly >0.54 and may reach ratios as much as 0.77. In this aspect, the lower series shows similarities to the flows drilled into the continental succession in the lower part of Hole 917A on Transect EG63. The lower series of Transect EG65 shows further similarities with both the upper and the lower series in Hole 917A by indications of crystal accumulation. The petrographic observations suggest that the wide variation in MgO seen for the lower series of Transect EG65 is caused by crystal accumulation of plagioclase and/or olivine in modally variable proportions, which is reflected in the two distinct groups of compositions shown in Figures **F11** and **F12.** One group shows a trend toward high Al_2O_3 and CaO, suggesting dominating plagioclase accumulation. The other group shows a trend toward decreasing Al_2O_3 and CaO, suggesting dominating olivine accumulation. The group indicating high plagioclase accumulation also has lower FeO and TiO_2, as expected, but also contains relatively high MgO content (Fig. F12). This suggests that both olivine and plagioclase phenocrysts are accumulating and control the composition of the flows from the lower part of Transect EG65.

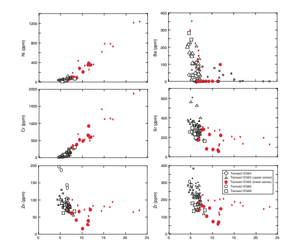
A simple model to illustrate the effects of crystal accumulation in the Transect EG65 flows is shown in Figure F13. The strong cluster for most of the flows with a clear trend toward increasing FeO and decreasing MgO is attributed to fractional crystallization. For a parental melt with ~10 wt% MgO, the observed iron enrichment would require crystallization of plagioclase, olivine, and augite amounting to ~60%–70% fractionation at ~5 wt% MgO (Thy et al., 1999). The variation in FeO and MgO seen for the lower series flows of Transect EG65 can be attributed to various modal proportions of the accumulating plagioclase and olivine assemblages, together with perhaps some variation in the melt composition (Fig. F13). The very high MgO content reaching 24 wt% can be attributed to ~50% olivine accumulation with relatively small amounts of plagioclase. Adversely, the group of flows with enrichment in Al_2O_3 and CaO implies the accumulation of mixtures of phenocrysts (~30%) in proportions between 60% and 45% plagioclase and 40% and 55% olivine. These estimates are consistent with the observed modal proportions (Fig. F2).

F13. Crystal models, p. 31.



The strong olivine accumulation control is also observed for the trace elements in Figure F14. Cr and Ni that are predominantly partitioned into olivine show a strong positive correlation with MgO content, and Ba and Zr show strong increase with decreasing MgO or increasing fractionation.

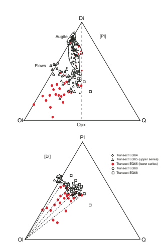
F14. Trace elements, p. 32.



Phase Equilibria and Crystallization Modeling

The normative projections of Figure F15 suggest dominating hypersthene normative basalts. This was also displayed for the main succession of the land-based plateau lavas and the continental succession in Hole 917. Very few flows reach quartz normative compositions common for the oceanic succession of Hole 918. The two transects for which significant quantities of flows were drilled, show systematic differences in their normative compositions. The flows from Transect EG68 are slightly more plagioclase and diopside normative than the Transect EG65 flows (including the upper series), which are systematically more olivine normative.

F15. Normative compositions, p. 33.



The lower series flows of Transect EG65 are systematically enriched in olivine. In this respect, they are very similar to the lower and upper series flows at Site 917; however, as already pointed out, the Transect EG65 flows are much more evolved, as they contain more iron-rich olivine and augite phenocrysts. Furthermore, the evolved middle series found at Site 917 appears to be absent from Transect EG65.

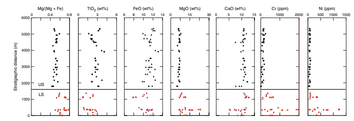
With the exception of the lower series flows at Transect EG65, the compositional variations of lavas was controlled by cotectic crystallization of plagioclase and olivine with some variation in the amount of augite. This is indicated by the relatively constant normative plagioclase and olivine contents with considerable variation in diopside.

Some flows without clearly distinguished petrographic features and stratigraphic control from the upper series of Transect EG65 appears to straddle the olivine-plagioclase-diopside plane and reaches slightly nepheline normative compositions. The same variation is reflected in the augite compositions, suggesting that the nepheline normative nature of this group may be real and not related to alteration and hydration.

Stratigraphic Variation at Transect EG65

The variation in the compositions of the flows drilled along Transect EG65 is illustrated in Figures F16 and F17, plotted against the horizontal distance from the most landward site drilled (Site SEG34). Because of shallow seaward-dipping of the flows, the upper seaward flow will be younger and positioned higher in the stratigraphy.

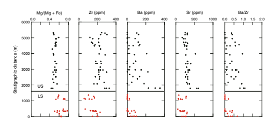
F16. Major and trace element concentrations, p. 34.



The transition between the lower and upper series is principally defined by marked differences in Mg/(Mg + Fe) ratios (Fig. F16), as well as by the petrography.

The two groups belonging to the lower series are stratigraphically distributed with flows showing marked olivine accumulation toward the base of the succession and more prominent plagioclase accumulation higher in the stratigraphy toward the transition to the upper series. The transitional interval between the two subseries was not sampled in detail (Fig. F16). Observations during drilling operations, however, suggest that the two flow types were intercalated over a narrow interval. The lower flows of the lower series show large compositional variability in MgO, as well as in the trace elements Ni and Cr, principally a result of olivine accumulation. The flows collected from the upper part of the lower series show more restricted variation in MgO, Cr, and Ni and also have generally higher CaO and Al_2O_3, reflecting plagioclase accumulation. There is an overlap in most oxides and elements between the two subseries of the lower series.

F17. Trace element concentrations, p. 35.



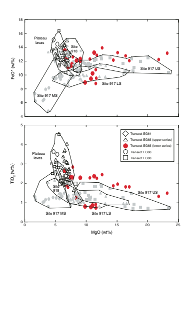
The upper series at Transect EG65 is characterized by systematically lower Mg/(Mg + Fe) ratios and higher TiO_2 concentrations. In addition, some excluded trace elements are markedly higher in the upper series (Fig. F17), as is the case for Zr, Ba, and Sr, as well as for the Ba/Zr ratio. This may be attributed in part to fractionation and the more evolved nature of the upper series compared to the lower series flows.

Despite a large variability throughout the upper series stratigraphic section, there appears to be a marked spike in some trace elements at the base of the upper series, particularly Ba. This suggests that the upper and lower series originated from separate magmatic systems. It is possible that the initial high values of Ba, Zr, and Sr are related to crustal contamination.

Stratigraphic Correlation

Volcanic rocks of the seaward-dipping reflector sequences along Transect EG63 were recovered at Site 917 (Larsen, Saunders, Clift, et al., 1994). Drilling at Site 917 penetrated what is referred to as the continental succession, which is divided into three series. Both the lower and the upper series at Site 917 contains olivine-rich flows that span the compositions of the lower series flows from Transect EG65 (Fig. F18). Detailed petrographic examination of the Transect EG65 flows, however, shows that these are significantly more evolved in terms of phenocryst assemblages and mineral compositions. Figure F18 also shows that the flows from the lower series of Transect EG65 reach higher FeO* and TiO_2 concentrations than seen for the continental succession at Site 917. The exception is a group of flows recovered from the lower series of Transect EG65 with TiO_2 content <1 wt% and MgO content of 10–12 wt% (Fig. F18).

F18. MgO content comparisons, p. 36.



Drilling at Site 918 sampled the central and oceanic succession of the reflector sequence. The flows at Site 918 show many compositional similarities with the majority of the flows sampled during Leg 163X (Fig.

F18). Both groups of flows show strong covariation and enrichments in FeO* and TiO_2, reflecting their evolved nature; however, the lavas of oceanic succession at Site 918 are quartz normative (Thy et al., 1999) and are therefore distinct from the dominantly olivine and hypersthene normative lavas sampled during Leg 163X. The oceanic succession is further represented by the plateau lavas exposed on land (Larsen et al., 1989; Pedersen et al., 1997) that closely match flows drilled during Leg 163X in terms of FeO and TiO_2 contents (Fig. F18), as well as CIPW normative composition.

The main series of the plateau lavas is dominated by evolved tholeiites with subordinate olivine tholeiite and occasional picrite flows in the lower portions of the succession (Larsen et al., 1989). The plateau lavas, furthermore, contain a suite of low-Ti basalt flows that can be related to an ocean ridge series among the flows sampled during Leg 163X. A low-TiO_2 suite closely resembles ocean ridge basalts. Based on the available trace element analyses of flows sampled during Leg 163X, however, it is not possible to unambiguously identify an oceanic suite. Likewise, it is not possible at this point to identify the main formations among the flows drilled during Leg 163X that are well established in the plateau lava succession (Larsen et al., 1989).

SUMMARY OF RESULTS

Four transects were drilled on the continental shelf of southeast Greenland during Leg 163X. Transect EG68 (68°N) is in crust that extends the volcanic stratigraphy of the flood basalts succession into the oceanic domain. Gentle seaward-sloping basaltic basement was drilled at seven sites on topographic highs just west of the consolidated marine sediment cover farther seaward. Transect EG66 (66°N) is immediately northeast of Site 988 in seafloor representing the eroded featheredge and landward continuation of the seaward-dipping reflectors. Two sites were drilled at Transect EG66. Drilling at both sites sampled the basaltic basement, and at one of these sites normally polarized, relatively young basalt was sampled. Transect EG65 (65°N) is in the continental–oceanic transition of the seaward-dipping reflectors. From seismic surveys, the reflectors are shown to thicken as they approach the East Greenland-Iceland rise. Drilling on this transect was the most successful, with volcanic basement sampled at 40 sites. Granitic gneiss representing the continental basement was recovered from a basement height immediately landward of a seismically imaged escarpment to a small sedimentary basin. Drilling at sites located just seaward of this escarpment recovered friable sandstone. The basin was also overlain by volcanic flows that revealed systematic variation progressing upward in the stratigraphy. The lower part (lower series) of this volcanic stratigraphy includes a distinct suite of highly to moderately olivine and plagioclase phyric basalts. This series is overlain by aphyric to moderately phyric flows more typical for the margin. Transect EG64 (64°N) is in the embayment south of Ammassalik in the featheredge of the seaward-dipping reflectors. Seismic surveys suggested a sediment basin flanked to the west by Precambrian basement and overlain by the featheredge of the seaward-dipping reflectors to the east. This transect was drilled at two sites, but we were unable to confirm the prediction of a sedimentary basin. Transect EG63 (63°N) was drilled during Legs 152 and 163 and was not visited during Leg 163X.

Shallow-offset drilling during Leg 163X fulfilled some of the remaining major drilling objectives from Legs 152 and 163. During Leg 163X four transects between 60° and 70°N were successfully drilled in crust that approaches the East Greenland-Iceland rise northward and provides material for documenting the lateral geochemical variability in mantle and crustal processes and volcanism toward the alleged plume track. Relatively young lavas found in crust assumed to be much older at Site 988 was reaffirmed. Flows drilled on Transects EG66 and EG68 gave preliminary ages of 48–51 Ma that postdate the typical breakup ages of 56–53 Ma obtained from flows of the upper series on Transect EG65. The majority of flows had a reversed polarity and are assumed to be well within Chron C24r, which is known to predate the main seaward-dipping sequence.

A glacial sedimentary cover was recovered at most sites as a thin veneer of unconsolidated sediments of moderately bioturbated sorted silt and mud that often grades into poorly to moderately sorted glacial diamicton. Pebble-sized, probably ice-rafted fragments of basalt, gneiss, and sandstone compositions are often present. Some pebbles are weathered and have glacial striations. Live corals were found on some clasts and recovered in the drill core. Pebble- to cobble-sized clasts with interstitial debris mud directly deposited on the basement are common. The diamicton units are interpreted as tills deposited below sea level at a time when the inland ice extended over the margin shelf. Diamond drilling on Transect EG66 recovered a highly compacted diamicton unit with a sharp contact against a brecciated basalt that may have formed in a fault-controlled depression on the basaltic basement.

The seabed is glacially eroded with a mostly thin glaciomarine sediment cover. The gently seaward sloping basement surface is controlled by basalt flow morphology and flow orientation. Typical seabed is most often blocky, fractured, and faulted. Although no single individual flow was completely transected by drilling, the available information suggests that the flows were fine-grained, massive to banded, and at least 1–2 m thick.

Drilling in most holes that penetrated the glacially eroded volcanic basement sampled basaltic flows, except for one possible sill on Transect EG64. Because drill penetration rarely exceeded a meter, complete flows, as well as flow contacts, were not sampled. The lack of strong grain-size variations that would have indicated chilled margins and pillowing makes it likely that the units represent aa flows. It is possible that these flows were subaerially erupted, even though no unambiguous, reddened, oxidized flow tops and intervening sediments were recovered. The sampled flows are vesicular to massive, often with pipe vesicles and flow banding defined by alignment of plagioclase grains, flattening of vesicles, and weak color banding in the groundmass.

The volcanic flows have many petrographic features in common. They are fine-grained, aphyric to seriated, highly plagioclase-clinopyroxene phyric basalts with olivine present in relatively low amounts and often replaced by secondary minerals. Plagioclase is present in all flow units as phenocrysts or glomerocrystic clusters. Euhedral grains of chromian spinel are preserved in olivine. Landward of 36°17′W, flows are moderately to highly olivine and plagioclase porphyritic. This latter suite of flows are referred to as the lower series, whereas the upper series are dominated by aphyric to highly plagioclase and clinopyroxene phyric flows with minor amounts of olivine. The transition is characterized by intercalated flows of the two series. The lower series of Transect EG65 differs from the picritic flows drilled at Site 917 by their additional content of plagioclase phenocrysts. Furthermore, flows drilled on Transect EG65 are compositionally much more iron rich than the picritic flows at Site 917. The lower series of Transect EG65 can be divided into two subseries: (1) a lower series sequence of olivine accumulative flows and (2) an upper sequence of plagioclase and olivine accumulative flows. The upper series of Transect EG65 are composed of typical plagioclase-augite-olivine phyric flows very similar to the tholeiitic volcanic basement sampled during Legs 152 and 163 and from the onshore volcanic stratigraphy.

Unaltered olivine phenocrysts were only found in the Transect EG65 flows. The upper series contains Fo_{71-68} olivine phenocrysts, whereas the lower series contains Fo_{76} olivine phenocrysts, which are well below the Fo_{94-82} olivine phenocrysts found in the picrites of Site 917. The pyroxene phenocrysts and microphenocrysts are augitic in composition. The lower series of Transect EG63 contains pyroxenes with significantly more Mg content than the upper series, which is consistent with the observations for olivine phenocrysts in the same flows. The lower series pyroxenes also have lower Ti/Al ratios than the pyroxenes from the other flows. This suggests that the Transect EG65 lower series flows were derived from parental melts significantly more primitive than the upper series flows. Plagioclase phenocryst compositions of the lower series of Transect EG65 are systematically more anorthitic (An_{90-75}) than the upper series plagioclase phenocrysts (An_{86-60}) and phenocrysts from the other transects. There is a weak but systematic variation in phenocryst compositions northward along the shelf toward more primitive compositions, as seen by an increasing anorthosite component of plagioclase and iron content of augite phenocrysts. Based on the available major element data, this variation along the coast is not distinguishable in the bulk rock compositions.

All flows drilled during Leg 163X are basaltic, typically with olivine tholeiitic normative compositions. With the exception of the lower series at Transect EG65, all flows cluster with Mg/(Mg + Fe*) ratios <0.57 and show a systematic increase in TiO_2, FeO, Na_2O, and K_2O with decreasing Mg/(Mg + Fe) ratio. This variation is typical for tholeiitic fractionation trends that are widely observed for the onshore plateau lavas. The petrographic and chemical information on the lower series of Transect EG65 (Mg/[Mg + Fe] = 0.54–0.77) can in part be explained by crystal accumulation. The wide variation in MgO content for the lower series can be caused by plagioclase and/or olivine accumulation in modally variable proportions. The stratigraphic upper sequence of flows show a trend toward high Al_2O_3 and CaO, suggesting accumulation of plagioclase in addition to olivine, whereas a lower sequence shows a trend toward decreasing Al_2O_3 and CaO, suggesting dominating olivine accumulation. This indicates that both olivine and plagioclase phenocrysts are accumulating in the lower series of Transect EG65 and that it is the relative proportions of these two phenocrysts that control the composition of the analyzed flows.

The observed variation in the main group of tholeiitic flows can be accounted for by ~60%–70% fractional fractionation. The variation in the lower series flows of Transect EG65 can be attributed to crystal accumulation from ~50% olivine accumulation with relatively small amounts of plagioclase to ~30% plagioclase and olivine accumulation in proportions between 60% and 45% plagioclase and 40% and 55% olivine. These differences are substantiated by incompatible trace element variation.

Because of the shallow seaward dip of the Transect EG65 flows, they can be viewed as a stratigraphic section. The transition between the lower and upper series is principally defined by marked differences in Mg/(Mg + Fe) ratios. The upper series is characterized by systematically lower Mg/(Mg + Fe) ratios and higher TiO_2 concentrations. Some excluded trace elements are markedly higher in the upper series. This may be attributed in part to fractionation and the relatively more evolved nature of the upper series compared to the lower series flows. However, there is an increase in some trace elements at the base of the upper series that may define the upper series as having originated from a separate magmatic system than the lower series. The initial high values of Ba, Zr, and Sr may be related to the initiation of rifting and early crustal assimilation that decreased as the flux of magma through the crust and eruption rate increased. More detailed study of trace element and isotope relations of the transition between the two series will be required to solve this problem.

The variability observed in the erupted lavas (phenocryst assemblages, phenocryst compositions, and crystal fractionation and accumulation) suggests temporal and short-range lateral variation in magma chamber processes. Eruptions may have tapped multiple and perhaps zoned magma chambers. The flows characterized by crystal accumulation (olivine and plagioclase) may have originated from marginal zones of relatively primitive, deep-seated chambers. The more fractionated flows (olivine, plagioclase, and pyroxene) may have originated from more mature chambers higher in the crust. The chamber and crustal depth being tapped may be controlled by the tectonic development and structural buildup of the margin. It is also possible that regional variation in mantle and source melting along the margin may be the cause of some of the observed variability in flow compositions (normative compositions). Future geochemical studies of the margin and its structural development may answer some of these questions.

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Figure F1. Summary map of the south East Greenland continental basement and continent–ocean transition, plateau lavas, plutons, Jameson Land sedimentary basis, and subaerial seaward dipping reflectors. Thick lines = seafloor spreading magnetic anomalies identified by Chron and age. COT = continent–ocean transition.

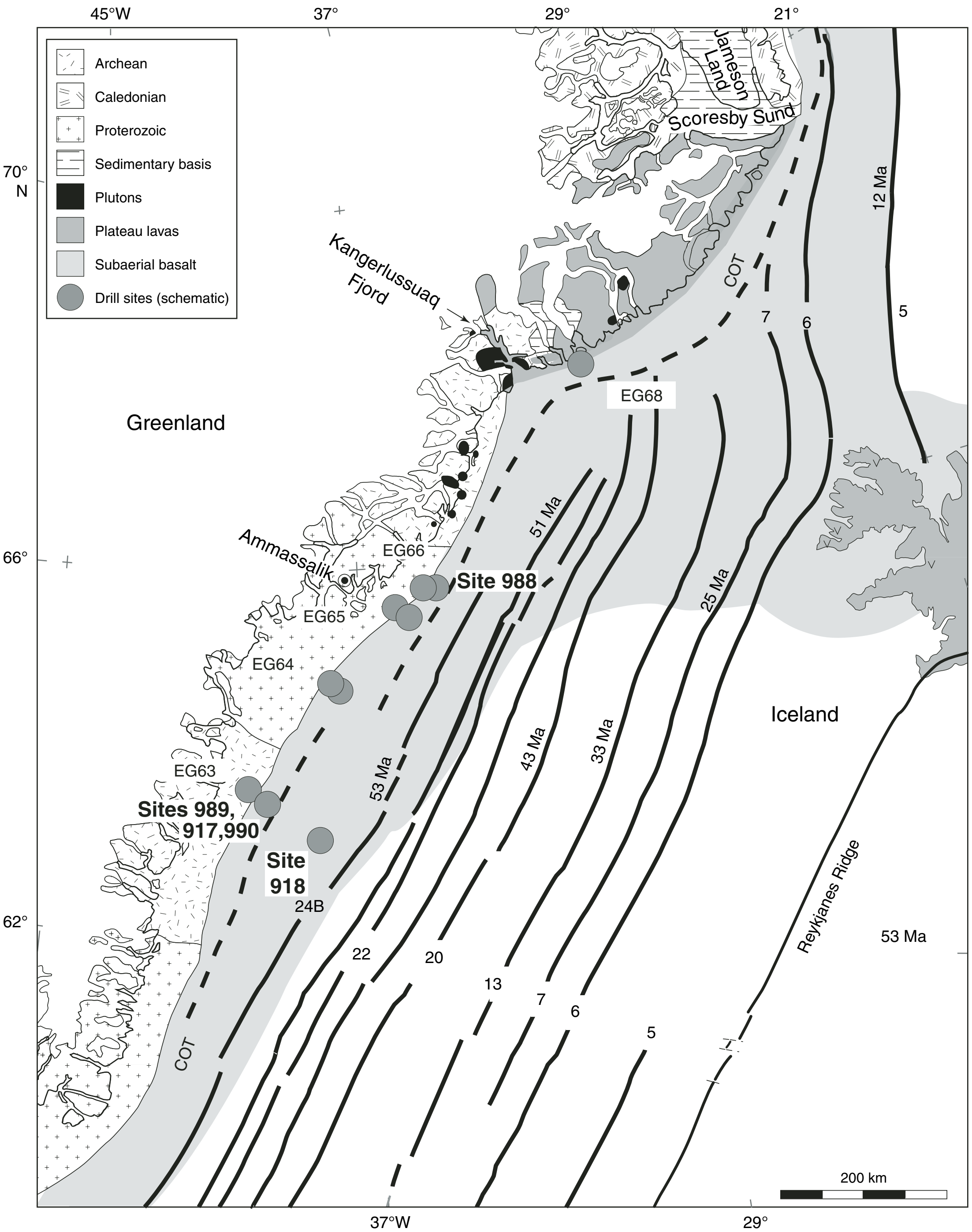

Figure F2. Modal phenocryst contents of flows drilled during Leg 163X. Solid lines = Transect EG65 upper lower series fields. ol = olivine, pl = plagioclase, cpx = clinopyroxene.

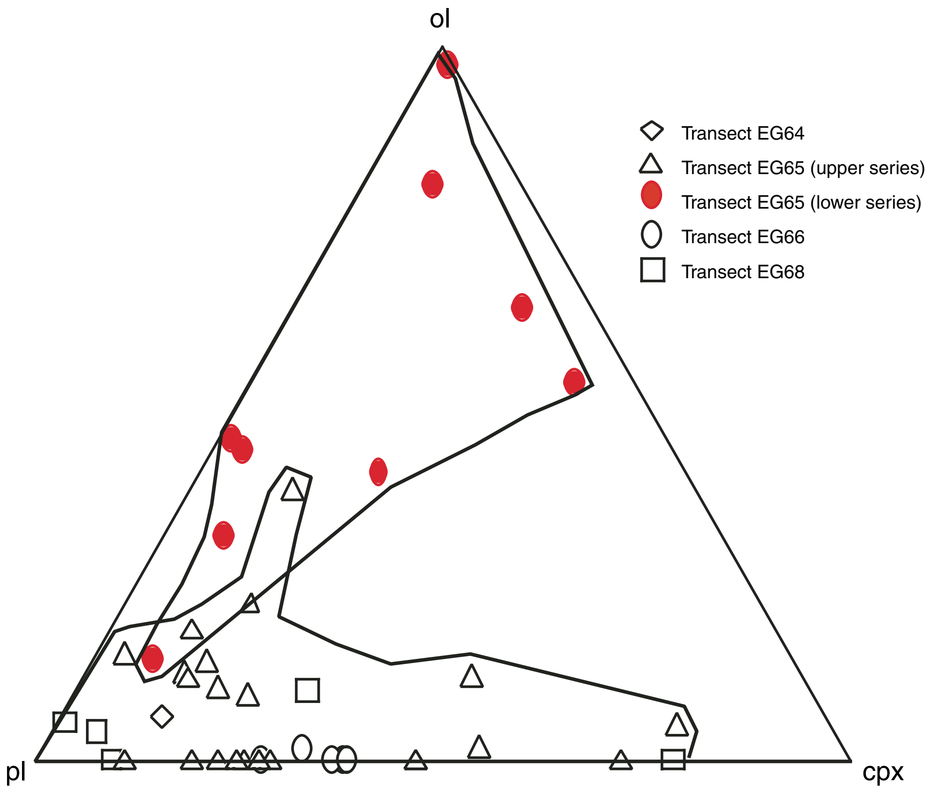

Figure F3. Histograms of olivine compositions (Fo content) in flows drilled on Transect EG65. Other transects did not contain unaltered olivine. *N* = number of observations.

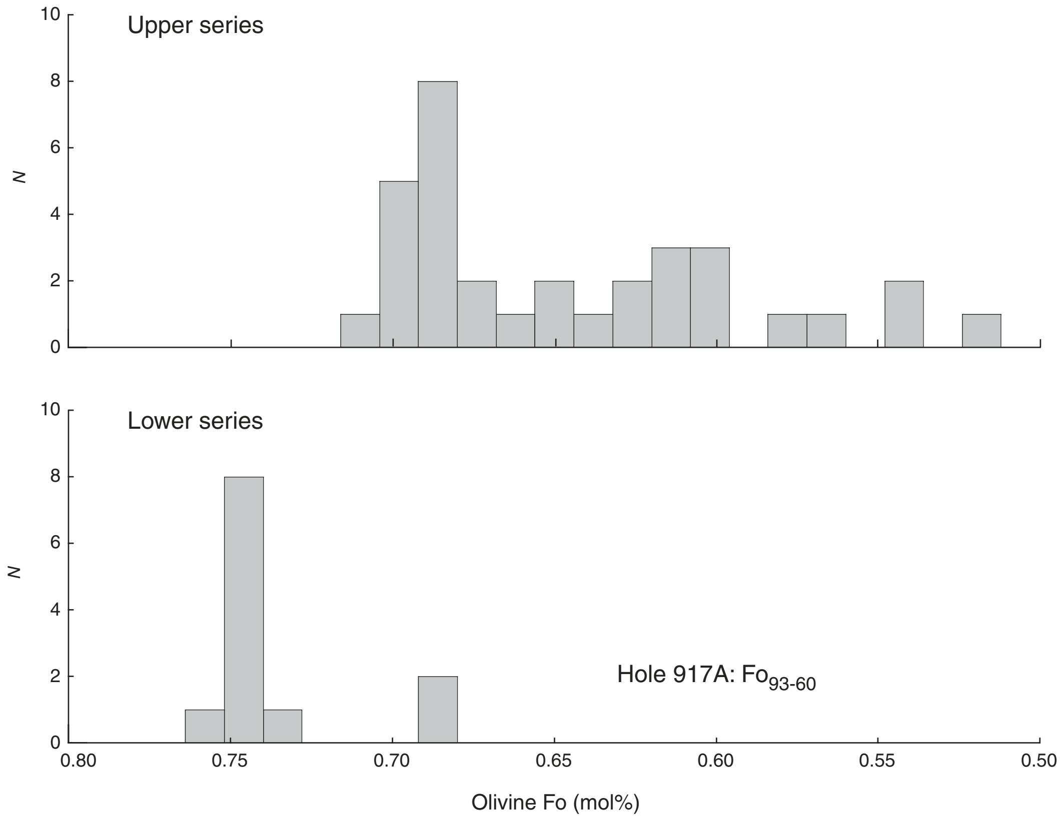

Figure F4. Chromian spinel compositions of the Transect EG65 lower series lavas. **A.** Cr-Fe^{3+}-Al contents calculated assuming ideal spinel stoichiometry. **B.** Estimates of Mg/(Mg + Fe^{2+}) of melt coexisting with chromian spinels. Calculated after Allen (1992) and Allen et al. (1999). Small symbols = individual spinels, large symbols = averages for individual samples as shown.

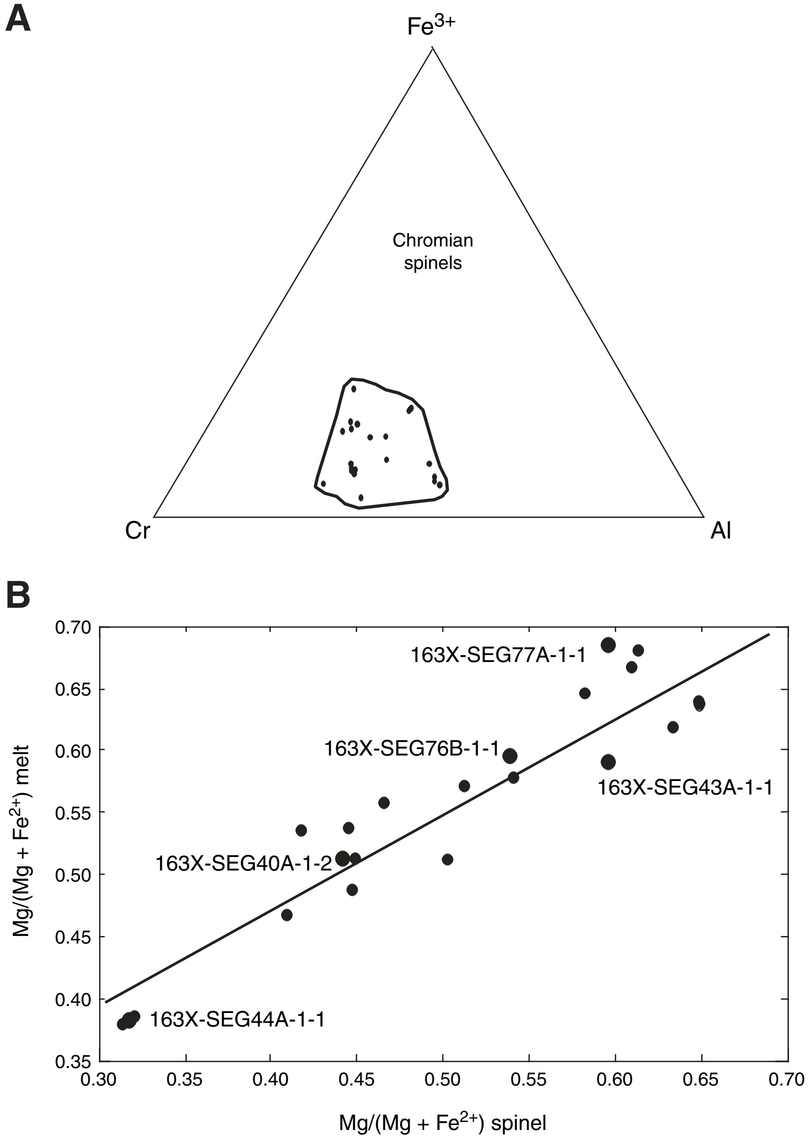

Figure F5. Histograms of augite microcryst and phenocryst compositions (Mg/[Mg + Fe*]) in flows drilled during Leg 163X. *N* = number of observations.

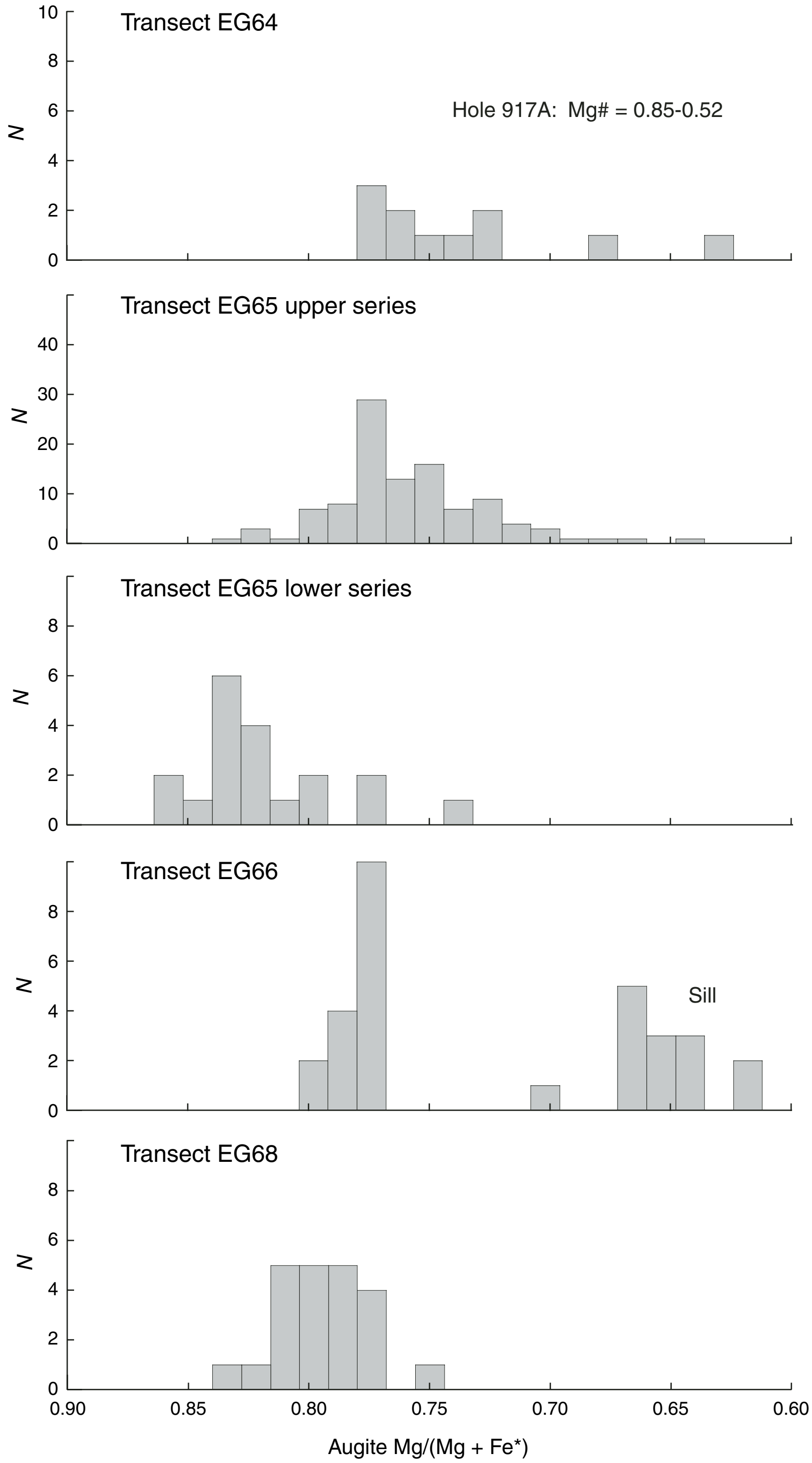

Figure F6. Compositions of augite phenocrysts and microphenocrysts in flows drilled during Leg 163X. **A.** Mg-Ca-Fe relations with all iron calculated as Fe^{2+}. Di = diopside, En = enstatite, Fs = ferrosilite, Hd = hedenbergite. **B.** Al vs. Ti content calculated based on six oxygens in the formula unit.

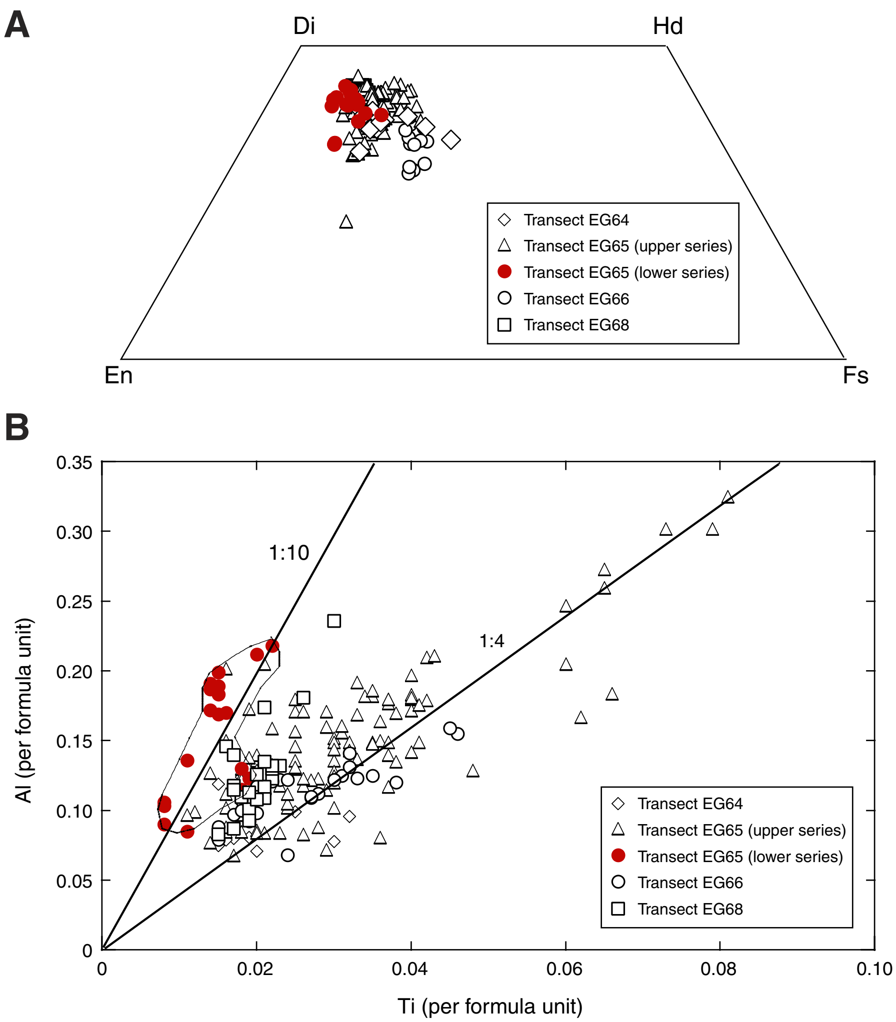

Figure F7. Histograms of plagioclase compositions (An content) in flows drilled during Leg 163X. *N* = number of observations.

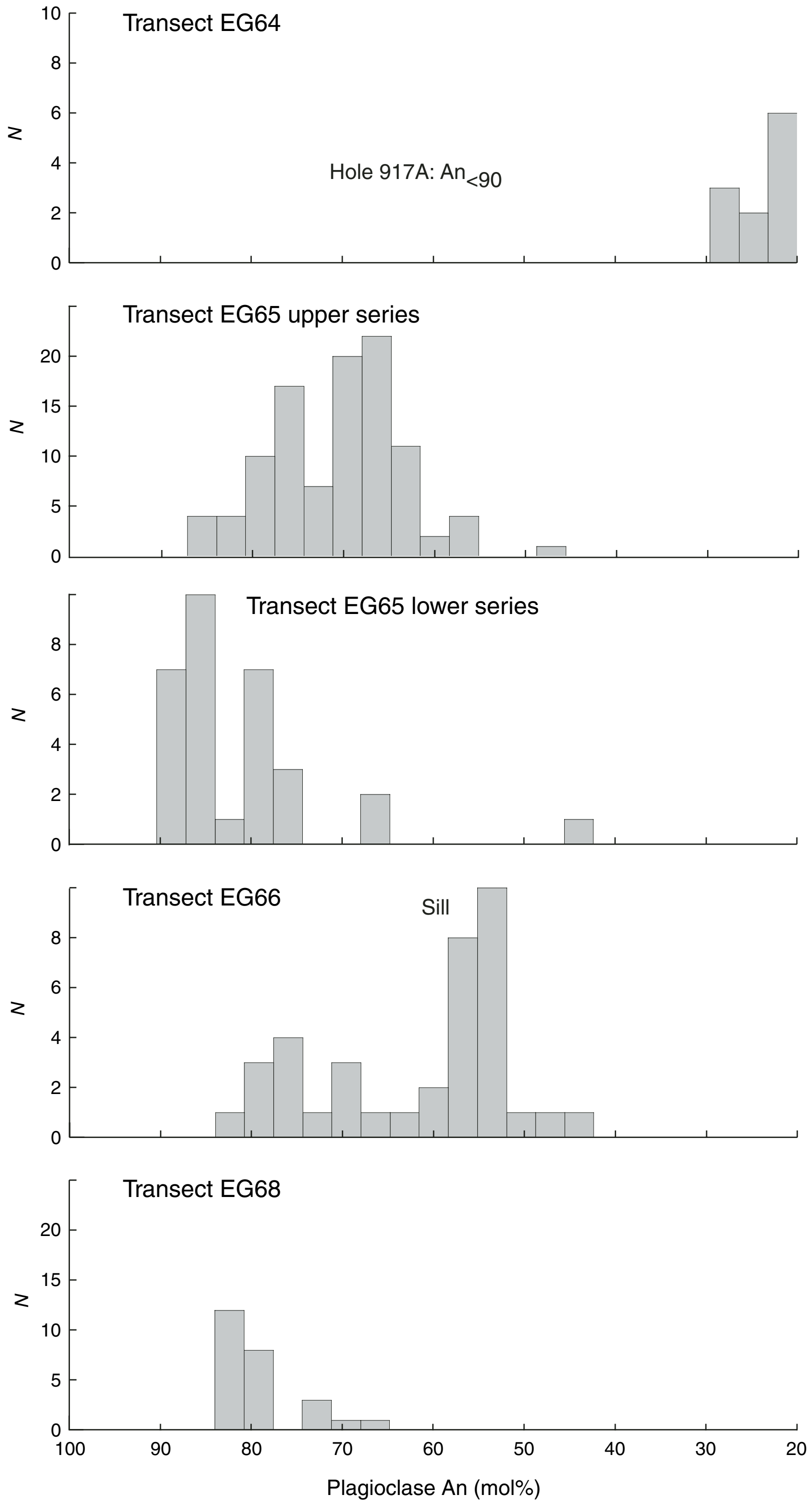

Figure F8. Phenocryst compositions as mafic (olivine and augite, Mg/[Mg + Fe_{total}]) and plagioclase (An content) phenocrysts. Tie-lines are between augite and olivine for the few samples containing fresh olivine in the lower series of Transect EG65. 61B = groundmass phase.

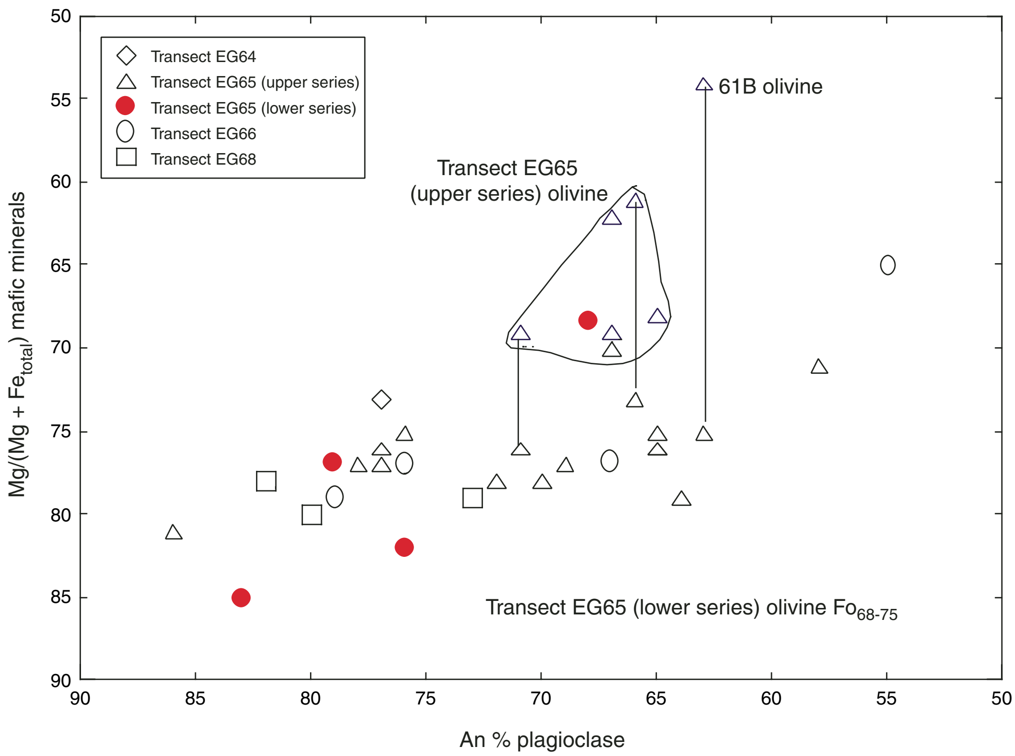

Figure F9. Sum of Na_2O and K_2O as a function of SiO_2. Lavas plot within the basalt field below 5% Na_2O + K_2O and with SiO_2 between 45 and 52 wt% (Le Maitre, 1989).

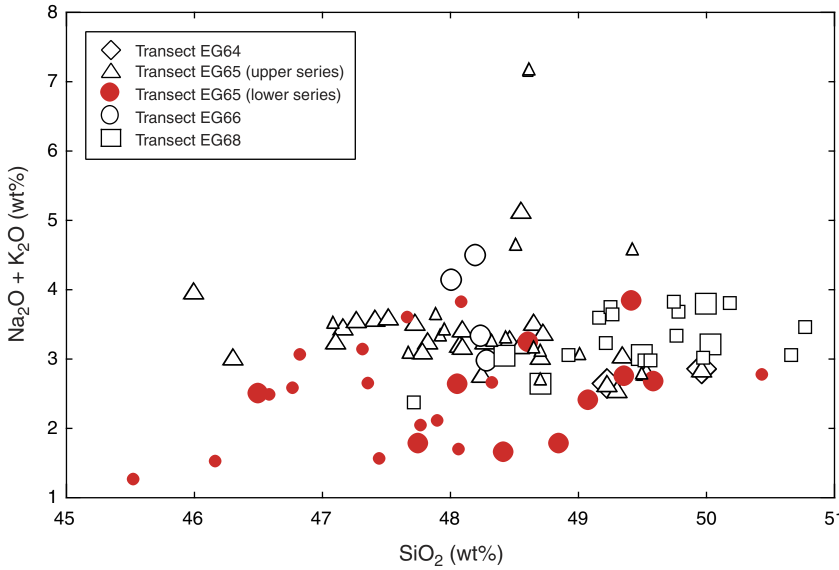

Figure F10. Fe_2O_3/FeO^* and MgO as functions of loss on ignition (LOI) corrected for iron oxidation.

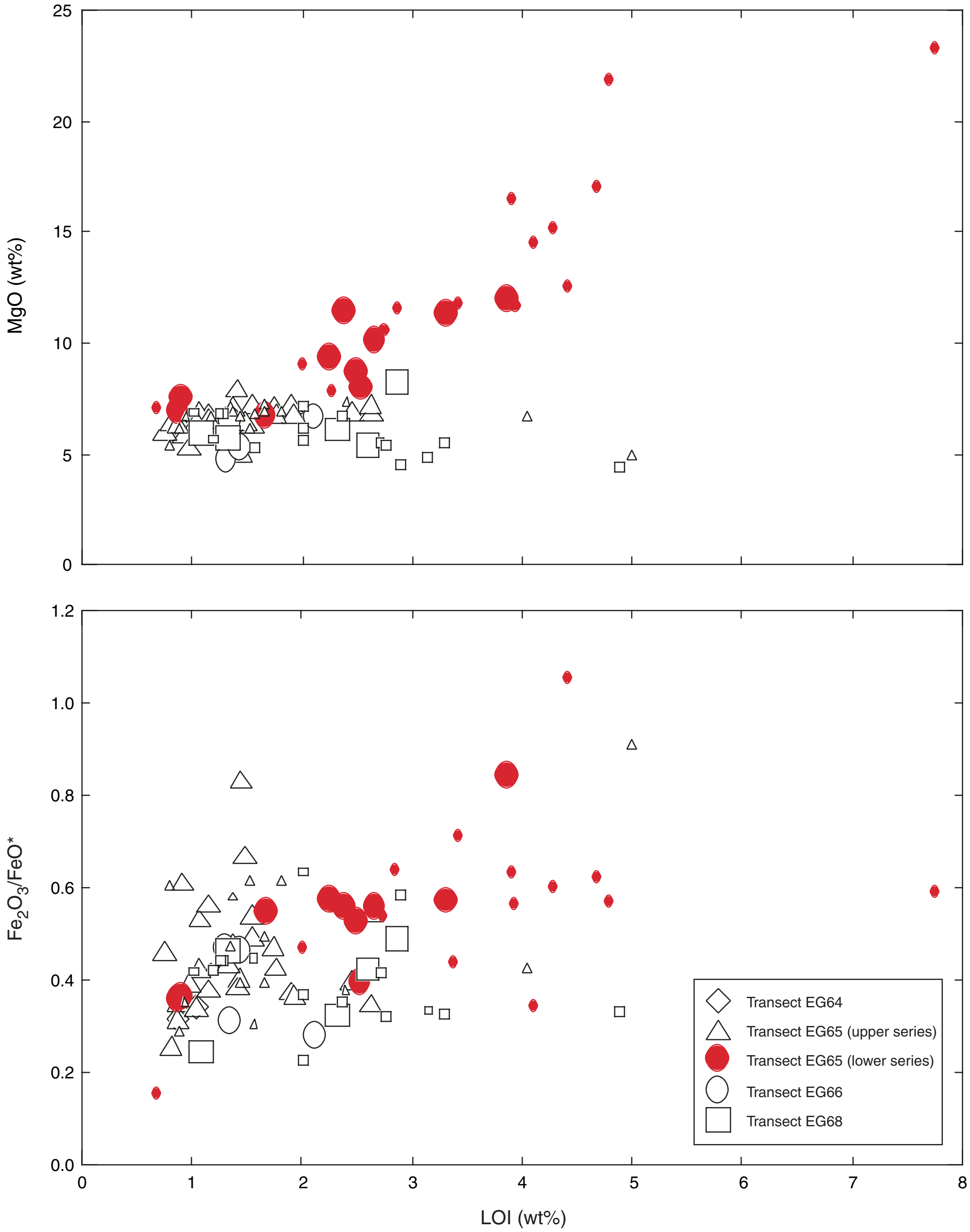

Figure F11. Major element compositions of analyzed samples recovered during Leg 163X. Calculated to 100% without LOI and all iron as FeO. Large symbols = flows, small symbols = clasts.

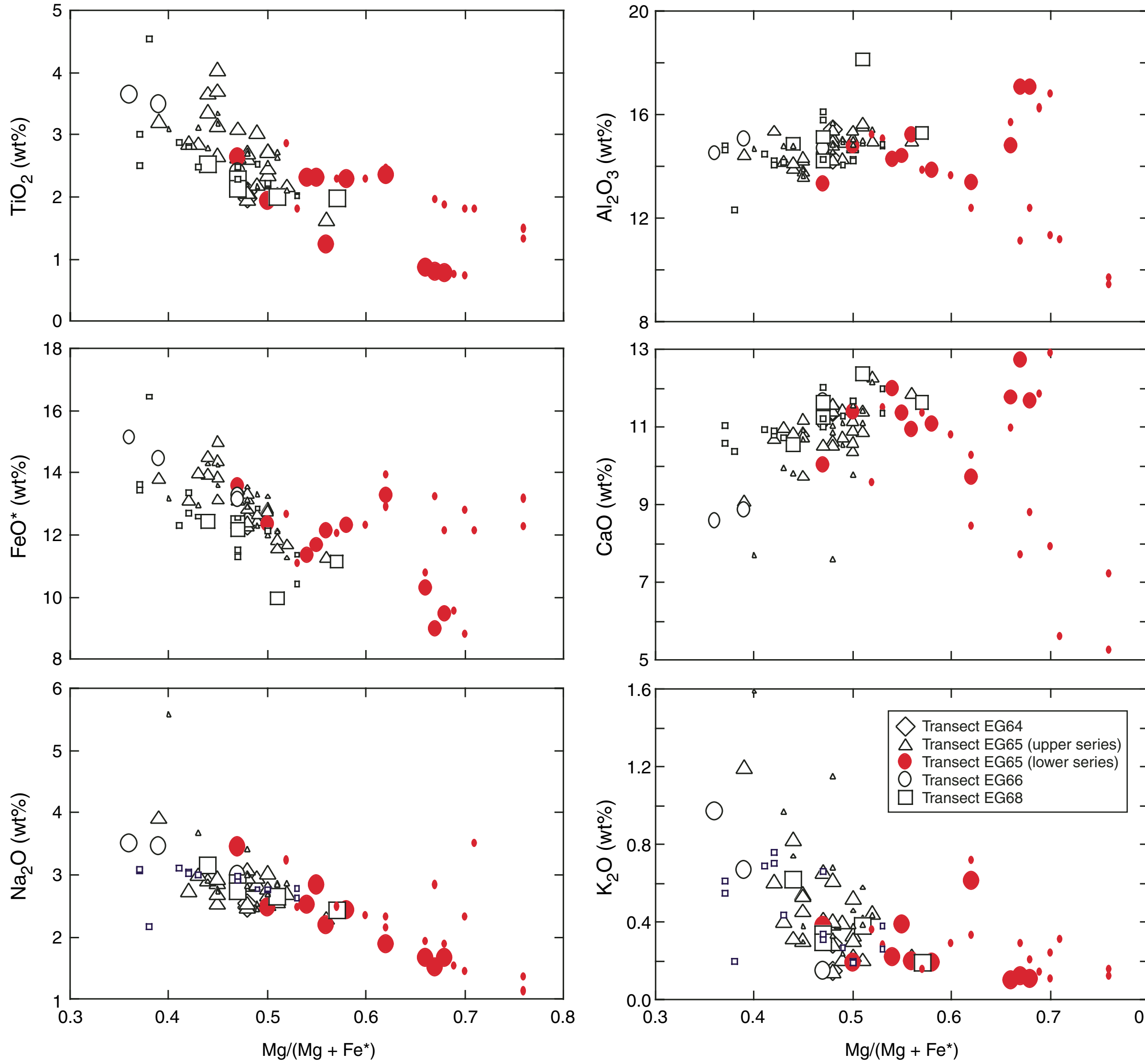

Figure F12. FeO* (total iron) and TiO_2 as functions of MgO content of analyzed flow and clasts sampled during Leg 163X. Large symbols = flows, small symbols = clasts.

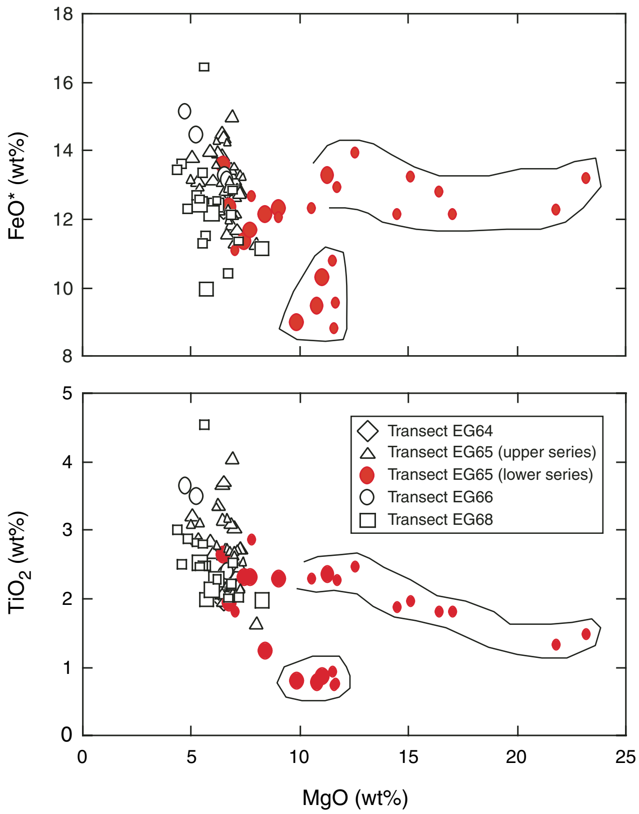

Figure F13. Crystal fractionation and accumulation models for development of contrasting trends seen in lavas sampled during Leg 163X. Large symbols = flows, small symbols = clasts. The effects of accumulating pure plagioclase (Pl), 75% plagioclase and 25% olivine, 50% plagioclase and 50% olivine, and pure olivine (forsterite [Fo]$_{60-80}$). The olivine composition in the mixed accumulation models are Fo_{68}, as found in the flows. Large symbols = flows, small symbols = clasts.

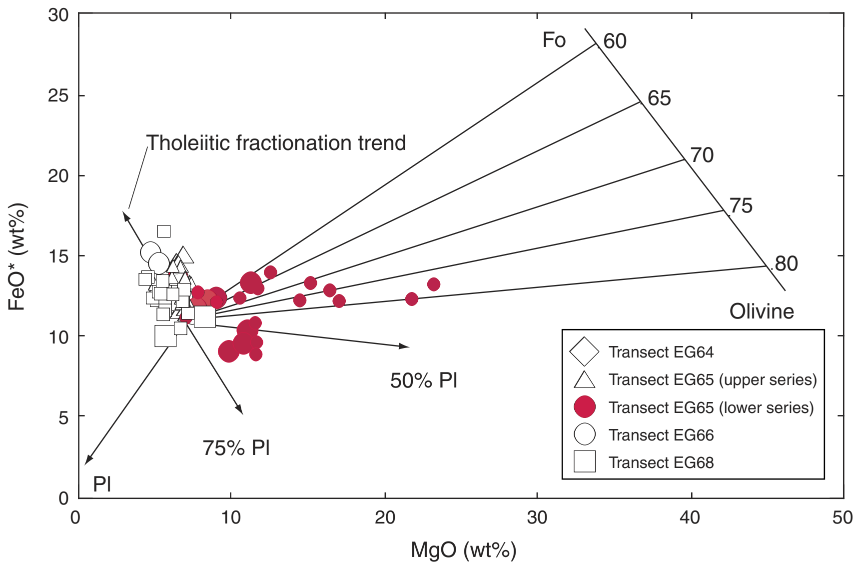

Figure F14. Selected trace elements determined by XRF for samples recovered during Leg 163X. Large symbols = flows, small symbols = clasts.

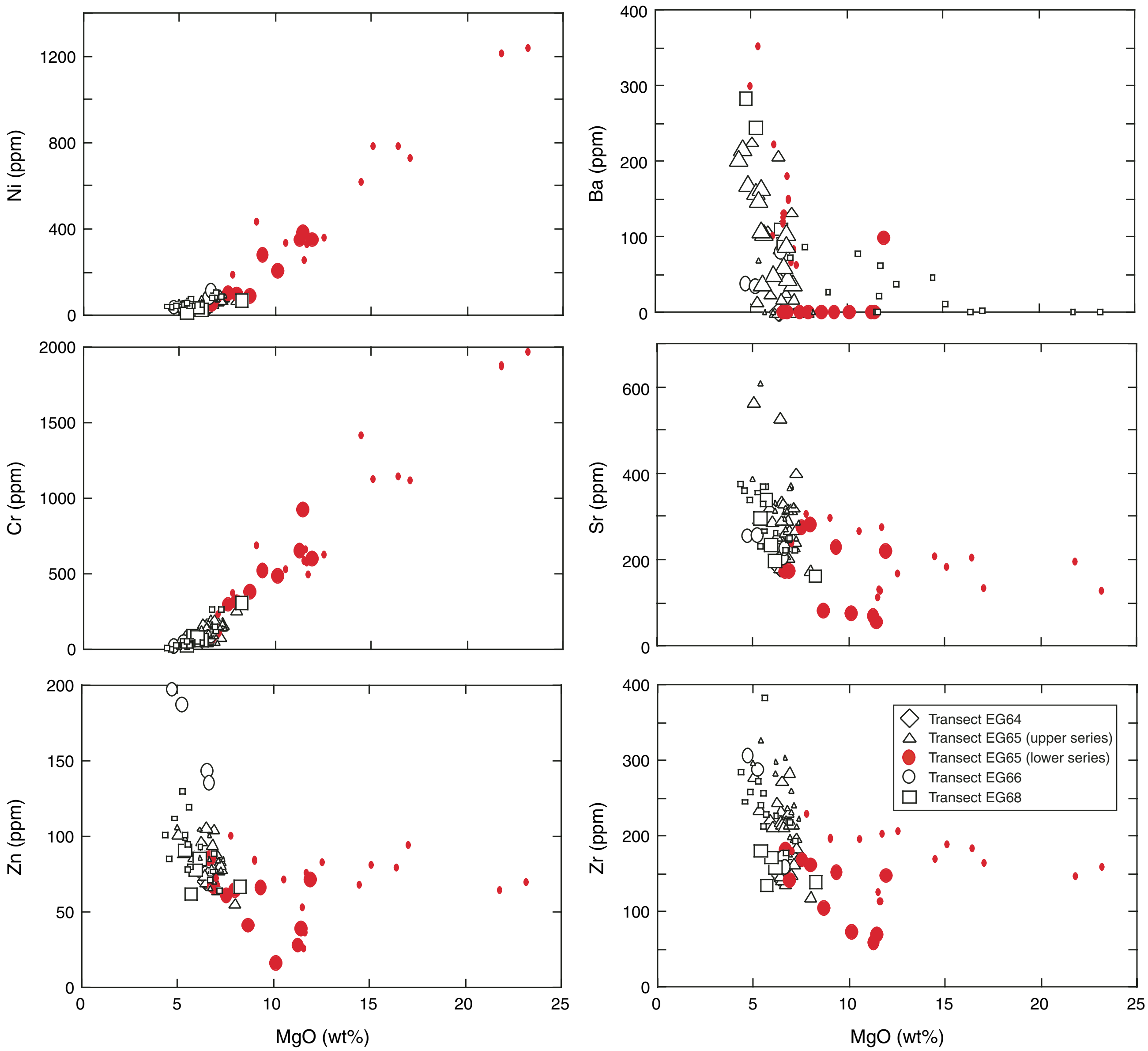

Figure F15. Normative compositions of the CIPW normative mineralogy of the flows sampled during Leg 163X projected onto the olivine (Ol)-diopside (Di)-quartz (Q) and Ol-plagioclase (Pl)-Q triangular diagrams. The projection scheme is as for Thy et al. (1999). Augite compositions are calculated and projected in the same way as the flow compositions. Opx = orthopyroxene.

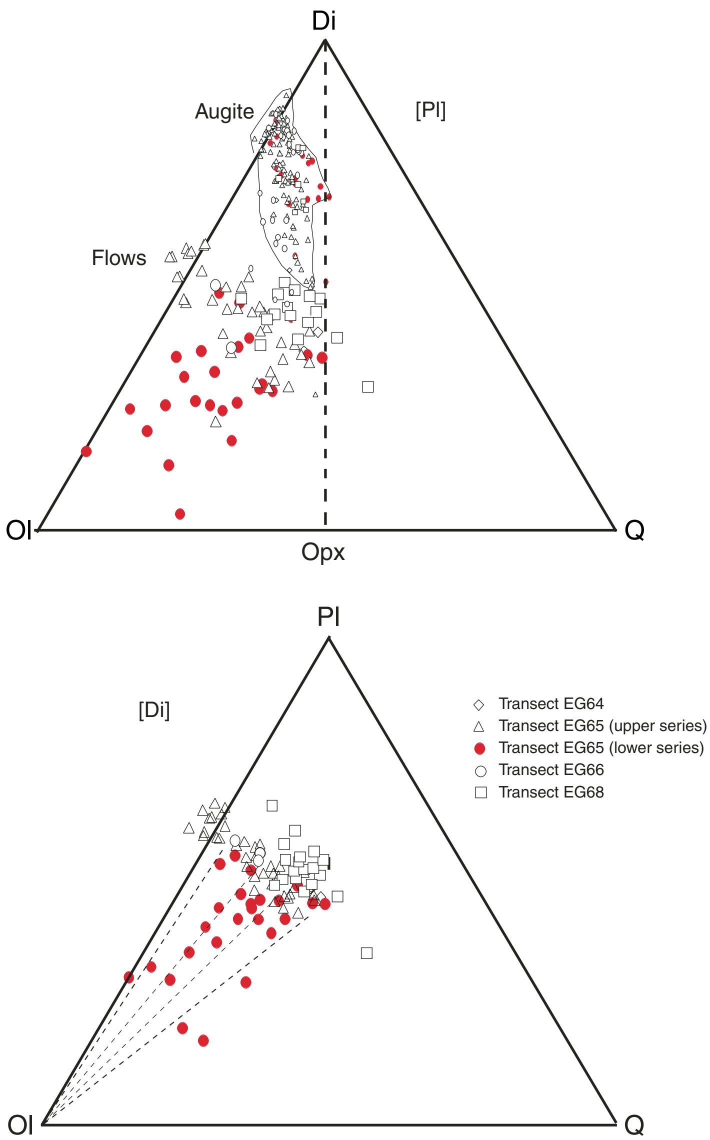

Figure F16. Selected major and trace element concentrations and ratios of the flows sampled along Transect EG65. Stratigraphic distance is the relative seafloor distance from the most landward site drilled. US = upper series, LS = lower series.

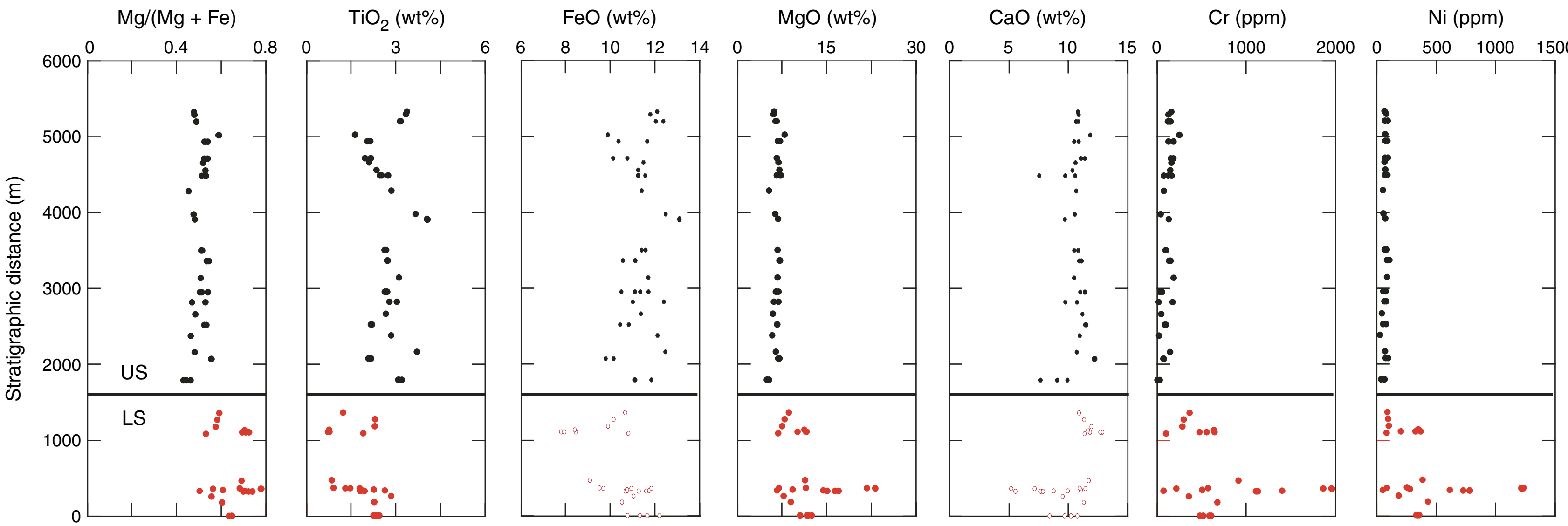

Figure F17. Selected trace element concentrations and ratios of the flows sampled along Transect EG65. The stratigraphic position is the relative seafloor distance from the first site drilled. US = upper series, LS = lower series.

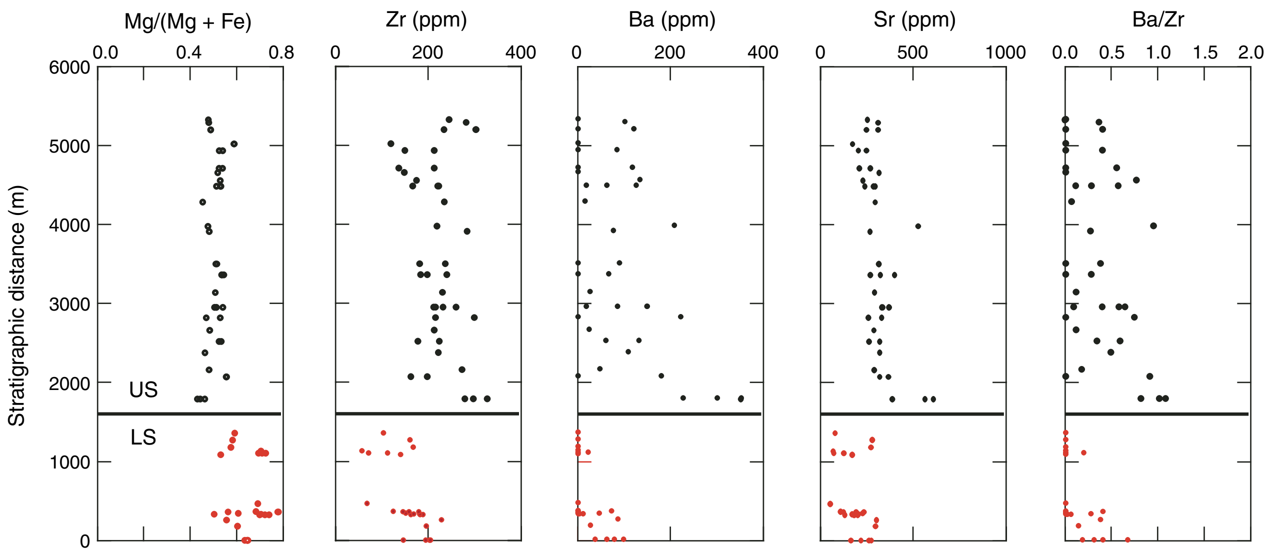

Figure F18. FeO* (total iron) and TiO_2 as functions of MgO content of analyzed flow and clasts sampled during Leg 163X and comparisons. General fields for Sites 917 and 918 are outlined. Large symbols = flows, small symbols = clasts. US = upper series, MS = middle series, LS = lower series. Plateau lava field is from Pedersen et al. (1997).

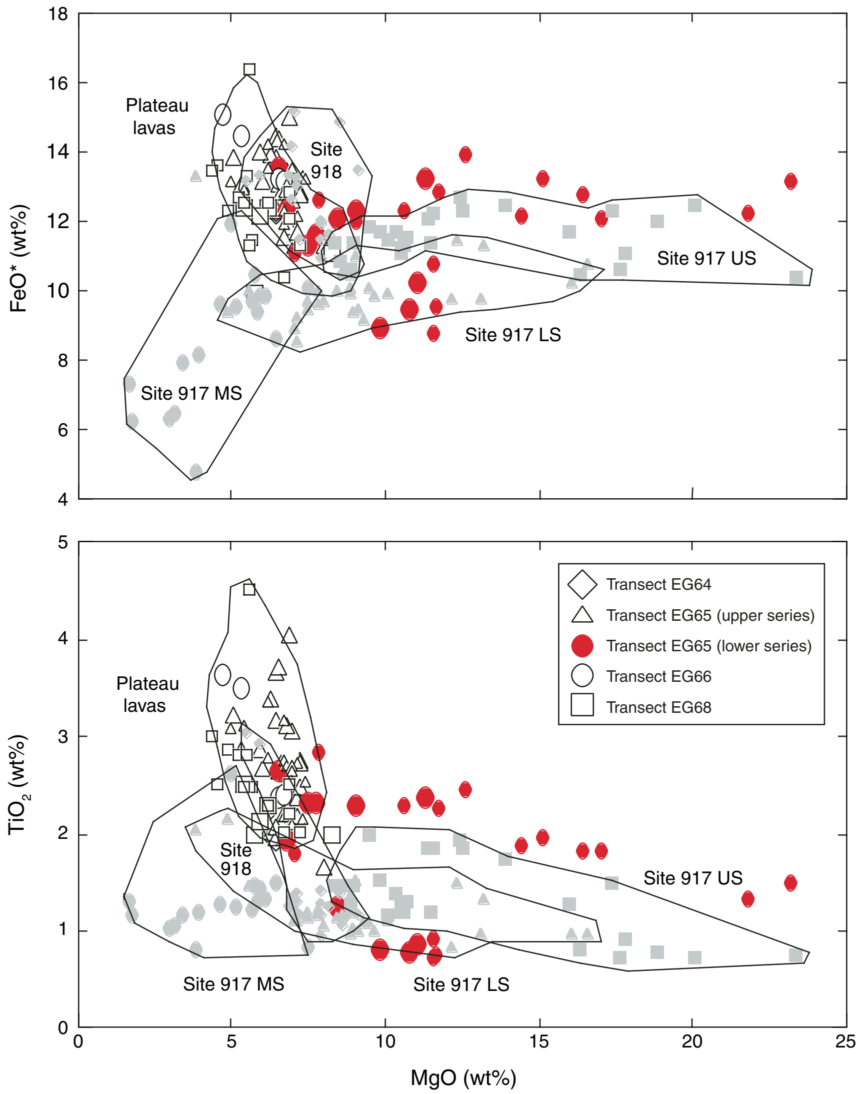

Table T1. Summary of calculated spinel/melt relations.

Core, section	Olivine Fo (mol%)	Mg/(Mg + Fe^{2+})		
		Whole rock	Spinel	Melt
163X-				
SEG40A-1-2		0.700	0.409–0.466	0.465–0.555
SEG43A-1-1		0.714	0.502–0.649	0.509–0.636
SEG44A-1-1	0.746	0.582	0.314–0.321	0.377–0.383
SEG76B-1-1	0.684	0.508	0.449–0.609	0.510–0.664
SEG77A-1-1		0.654	0.418–0.746	0.533–0.678

Note: Fo = forsterite.