Part 5: Trace Elements

Nickel

Ni ranges from approximately 3 ppm to 198 ppm with most samples containing < 10 ppm (Fig. A2.13a). Select rocks range from 190 ppm (SOB_{12}) to 4–8 ppm (rhyolitic pitchstones). There is only one sample (SOA_{10}) between 18 ppm (top of range for most andesites)and 60 ppm Ni (base of basalt range). Ni in BV is within the range of common igneous rocks (x ppm to x00 ppm).

Ni in SOB_{12} is depleted relative to pyrolite (0.1x), Primitive MORB (0.66x) and Hawaiian Nepheline Melilitite (0.69x), but is enriched relative to Average Continental Crust (1.8x), Rindjani basalt (2.49x), and Fuji basalt (3.87x). Abundance patterns for select BV (Fig. A2.13b) exhibit a steep decline from SOB_{12} to SOA_{10} and a steeper drop to SFA_{09} (0.05x SOB_{12}) with only minor change in the dacite-rhyolite spectrum (0.04 to 0.03 x SOB_{12}), apart from minor peaks for the two rhyolite ignimbrites. Overall, all rocks are depleted relative to Primitive MORB and Hawaiian Nepheline Melilitite, and enriched relative to Mole Granite. All compositions except three rhyolites are enriched relative to Fuji basalt. Basalts are enriched relative to Fuji basalt and Rindjani basalt, and SOB_{12} is enriched relative to Average Continental Crust. All other compositions are depleted relative to Average Continental Crust, Fuji basalt and Rindjani basalt. For SOB_{12}, Mole Granite, Fuji and Rindjani basalts and Average Continental Crust are complementary to Primitive MORB and Hawaiian Nepheline Melilitite.

On **Ni v SiO_2** (Fig. A2.13c) select rocks show an anomalous Main Trend with a long steep Mafic Segment that projects to negative value and is thereafter meaningless. SOA_{10} plots slightly above Cross Trend 2. SFA_{09}, SAD_{24} and SED_{05} form a linear, sub-horizontal cluster that plots close to the end of Cross Trends 1 and 2. Select rhyolites form a tight linear sub-horizontal cluster at the end of the Felsic Segment. Altered basalts (Fig. A2.13e) mainly plot along the Mafic Segment, except for a silicified basalt which, together with two altered basaltic andesites (#03, #45) plot along Cross Trend 2 close to SOA_{10}. Altered andesites and dacites forms a linear, sub-horizontal cluster that extends the select range. Similarly, altered rhyolites overlap and extend the range of select rhyolites.

Ni v SiO_2 (Fig. A2.13g,i,k) shows that the BV mafic rocks overlap the Ni range of BVSP Reference Arc and CRZ basalts and partly overlaps that of CFB and OFB basalts, but are distinct from Primitive MORB, Hawaiian Nepheline Melilitite, and Average Continental Crust. The BV felsic range overlaps that of Mole Granite, select M-type and I-type granitoids, although the latter trend to higher Ni at intermediate SiO_2. Regional comparisons (Fig. A2.13m,o,q,s) show that the BV indicate similar Ni contents at equivalent SiO_2 to most other data suites, although the Petroi and Tertiary basalt trend to marginally lower SiO_2 at comparable Ni, and the Late Carboniferous intermediate rocks tend to marginally higher Ni at similar SiO_2. A notable feature of these comparisons is that data for Early Permian mafic complexes and Tertiary volcanic rocks appear to follow curved trends which would be better modelled by exponential decay or powerlaw curves than the linear trends used herein.

On **Ni v Cr** (Fig. A2.13d), select rocks show a Main Trend comprising a long steep Mafic Segment that projects to negative value and is thereafter meaningless. SOA_{10} plots along Cross Trend 2. Select intermediate and felsic samples form a short linear array that overlaps the ends of the cross Trends and the Felsic Segment and overlaps the Dyke Trend. Altered intermediate and felsic samples mainly plot in this array. Several altered basalts plot along Cross Trend 1, whereas several others plot on the Mafic Segment close to SPB_{39} (Fig. A2.13f). Only one olivine basalt, one silicified basalt, one silicified basaltic andesite and one silicified rhyolite plot distinctly off one or other of the trend lines.

Ni v Cr (Fig. A2.13h,j,l) is striking for the steepness of the BV trends (high Ni/Cr, cf high Mg/Cr) compared to several reference suites. Thus for mafic compositions, the BV are distinct from BVSP Reference Arc and OFB ranges and from I-type granitoids. However, there is an apparent discrepancy in comparative data, with Primitive MORB plotting distinctly separate from BVSP reference OFBs (and from BV). Select BV overlap BVSP Reference Continental basalts (CFBs tend to higher Cr) and select M-type granitoids, and are close to Average Continental Crust and Mole Granite. Similarly, regional comparisons (Fig. A2.13n,p,r,t) clearly distinguish BV basalts from the Petroi Metabasalt and Early Permian central NEO mafic complexes, whereas felsic to intermediate BV are not distinguishable from the Halls Peak volcanics, the Hillgrove and Copeton Plutonic Suites, Late Carboniferous volcanic rocks or from unassigned volcanic rocks from Boggabri. The Werrie Basalt has marginally higher Cr than the BV at comparable Ni, as does the more mafic Tertiary volcanic rocks.

In summary, select BV exhibit about a forty-fold decrease in Ni from SOB_{12} to high-silica rhyolite with most of the variation being in the basalt-andesite range. The Main

Trend for Ni mimics modal data poorly near the Mafic Inflection and is meaningless for more felsic compositions. SOB_{12} contains more Ni than Mole Granite, Fuji and Rindjani basalts, and Average Continental Crust but less than Primitive MORB (0.66x). Si-Cr-Ni systematics for select BV indicate similar Ni to most comparative data sets, but lower Ni than primitive BVSP OFB basalts, low-Si dacitic I-type granitoids and Late Carboniferous andesites and dacites. The Ni/Cr ratio is conspicuously higher than for many comparative data sets.

Copper

Cu ranges from < 1 ppm (detection limit) to 86 ppm (Fig. A2.14a). Select rocks range from 2.1 ppm ($SLPR_{13}$) to 62 ppm (SOB_{12}). These values are within the range of common igneous rocks (x ppm in felsic rocks to x0, sometimes x00 ppm in basalts — Wedepohl, 1978).

Cu in SOB_{12} is depleted relative to Fuji basalt (0.23x),Primitive MORB (0.69x), Average Continental Crust (0.83x) and Hawaiian Nepheline Melilitite (0.92x), but is enriched relative to pyrolite (2.08x). Abundance patterns (Fig. A2.14b) exhibit a significant depletion across the BV range to a trough at $SFBR_{25}$ (0.03x SOB_{12}) followed by a rise through the remainder of the range. Overall, select BV are depleted relative to Primitive MORB, Average Continental Crust, Hawaiian Nepheline Melilitite and Fuji basalt, and all except $SFBR_{25}$ are enriched relative to Mole Granite. For SOB_{12}, Mole Granite is complementary to Primitive MORB, Average Continental Crust, Hawaiian Nepheline Melilitite and Fuji basalt.

On **Cu v SiO_2** (Fig. A2.14c), select rocks show a Main Trend comprising a very short, nearly vertical, negative slope in the Mafic Segment, and an inclined, negative slope in the Intermediate Segment that projects to negative value and is thereafter meaningless. SOA_{10} plots distinctly beside the Main Trend. SFA_{09} and SED_{05} plot distinctly off the Main Trend. SAD_{24} plots beside the Main Trend and the Dyke Trend is indistinct. Select rhyolites are tightly clustered along the end of the Felsic Segment. Altered dacites and rhyolites tend to overlap select rocks of similar composition, although showing slightly greater scatter (Fig. A2.14e). In contrast, altered basalts and andesites show considerable scatter. Zeolitised basalt is depleted, whereas carbonated and silicified basalts are enriched in Cu. Other altered rocks show variable enrichment and depletion with one olivine basalt showing the greatest Cu enrichment.

Cu v SiO_2 (Fig. A2.14g,i,k) shows that the BV mafic rocks overlap the lower range of BVSP Reference Arc basalts and the mid range of BVSP Reference CFB data but have less Cu than Average Continental Crust and Primitive MORB. BV also overlap the lower range of select M-type granitoids and the mid range of select I-type granitoids. Regional comparisons (Fig. A2.14m,o,q,s) show that the BV overlap the range of Early Permian central NEO mafic complexes (which also range to lower Cu), the Late Carboniferous volcanic rocks, and the unassigned volcanic rocks from Boggabri. However, they have marginally to significantly higher Cu contents than most the Werrie Basalt data, and marginally lower values than the Halls Peak volcanics, and the Hillgrove and Copeton Plutonic Suite granitoids. Tertiary volcanic rocks generally have lower Cu values, except amongst rhyolites.

On **Cu v Cr** (Fig. A2.14d), select rocks show a Main Trend comprising a short, gently inclined, negative Mafic Segment, and a steep, negative, Intermediate Segment that projects to negative values and is thereafter meaningless. SOA_{10} plots on Cross Trend 1. SFA_{09}, SAD_{24} and SED_{05} plot along the Main Trend and the Dyke Trend is indistinct. Select rhyolites plot near the end of the Felsic Trend. Most altered andesitic to rhyolitic rocks cluster along the Intermediate and Felsic Trends. However, one andesite plots along a projection of the Intermediate Segment at higher Cu than the Mafic Inflection. Altered basaltic rocks show considerable scatter over a range of 50% above of below the Mafic Segment (Fig. A2.14f).

Cu v Cr (Fig. A2.14h,j,l) distinguishes the BV from many BVSP Reference Arc basalts and CFBs and from Primitive MORB and Average Continental Crust, due to lower Cu and/or Cr in the BV. It also distinguishes BV from I-type granitoids, but not from M-type granitoids. Regional comparisons (Fig. A2.14n,p,r,t) indicate similarity to the most comparative suites, with the greater Cr range of the Early Permian central NEO mafic complexes being distinctive.

In summary, select BV display a slightly irregular decrease through the basalt-dacite range followed by a trough in the middle of the rhyolite range (0.03x SOB_{12}). SOB_{12} contains less Cu than Primitive MORB (0.69x), Fiji basalt, Hawaiian Nepheline Melilitite and Average Continental Crust but more than Mole Granite. Si-Cr-Cu systematics for select BV indicate similar levels of Cu to CFB basalts, M- and I-type granitoids, unassigned Boggabri Volcanics, and some Late Carboniferous volcanic rocks and Early Permian mafic complexes, more Cu than most Tertiary Nandewar volcanic rocks and some Werrie Basalts and Early Permian mafic complexes, but less Cu than most BVSP Arc basalts.

Zinc

Zn ranges from 5 ppm to 116 ppm(Fig. A2.15a). Select rocks range from 27 ppm ($SLPR_{13}$) to 90 ppm (SOB_{12}). These values are within the range of common igneous rocks (x0 to x00 ppm — Wedepohl, 1978).

Zn in SOB_{12} is depleted relative to Hawaiian Nepheline Melilitite (0.57x), Fuji basalt (0.76x) and Average Continental Crust(0.96x), but is enriched relative to Primitive MORB (1.1x), pyrolite(1.4x). Abundance patterns (Fig. A2.15b) exhibit a slight enrichment from olivine basalt to andesite(1.2x SOB_{12}) followed by a sustained, gentle depletion through the dacites and rhyolites and a drop to lower values for $SLPR_{29}$ and $SLPR_{08}$ (0.35x SOB_{12}). The rhyolites are erratic, with troughs at $SMPR_{06}$ and peaks at $SLPR_{13}$ (ignimbrite) and $SFBR_{04}$. Overall, select BV are enriched relative to Mole Granite ($SLPR_{08}$ excepted), and depleted relative to Hawaiian Nepheline Melilitite and Fuji basalt. Basalts and andesites are generally marginally enriched, and dacites and rhyolites generally depleted relative to Primitive MORB, and Average Continental Crust. For SOB_{12}, Average Continental Crust, Fuji basalt and Hawaiian Nepheline Melilitite are complementary to Primitive MORB and Mole Granite.

Zn v SiO_2 (Fig. A2.15c), select rocks show a Main Trend comprising a Main Trend composed of a very short, nearly vertical, positive slope in the Mafic Segment, a gently inclined, negative slope in the Intermediate Segment and a very steep negative slope in the Felsic Segment. SOA_{10} plots distinctly above the Main Trend. SFA_{09} and SED_{05} plot significantly off the Main Trend; a line joining those two points projects to the end of the Felsic Segment and to an intersection with a projected Mafic Segment considerably above the Mafic Inflection. This line constitutes an alternative Intermediate Trend. SAD_{24} also plots below the Main Trend and the Dyke Trend is short but distinct. Select rhyolites are plot close to the FelsicSegment. Altered rocks (Fig. A2.15e) show considerable scatter relative to the Main Trend. Basaltic to andesitic rocks are especially scattered, with most plotting above the Main Trend. Dacites mainly plot below the Main Trend, but with one notable exception (#36) at 111 ppm. Altered rhyolites are offset towards higher SiO_2 and/or lower Zn relative to the end of the Main Trend. Overall, altered samples mimic the alternative Intermediate Trend better than the Main Trend.

Zn v SiO_2 (Fig. A2.15g,i,k) shows that the BV mafic rocks overlap the mid range of BVSP Reference Arc basalts but have slightly lower Zn than BVSP Reference CFB data (only 3 analyses available) and slightly higher Zn than Primitive MORB. Average Continental Crust overlaps the BV Intermediate Segment. Select M-type and I-type granitoids and Mole Granite overlap the range of felsic to intermediate BV analyses, but bear little relationship to the calculated BV Main Trend. Regional comparisons (Fig. A2.15m,o,q,s) show that the BV data and/or Main Trend partly overlap the ranges of Werrie Basalt, Halls Peak volcanics, Early Permian central NEO mafic complexes, most Hillgrove and Copeton Plutonic Suite granitoids, the Late Carboniferous volcanic rocks, and the unassigned volcanic rocks from Boggabri. Only the Tertiary volcanic rocks (marginally to significantly higher) are distinct. However, all data sets show considerable scatter, and this could be a factor in the apparent overlaps.

On **Zn v Cr** (Fig. A2.15d), select rocks show a Main Trend comprising a nearly flat Mafic Segment (≈ 80 ppm Zn), a very short, steep, negative, Intermediate Segment and a nearly vertical, negative Felsic Segment. SOA_{10} plots slightly above the Main Trend. SFA_{09} off the Intermediate Segment, and about twice as far apart as the length of that segment. SED_{05} plot significantly below the Intermediate Segment, and the Dyke Trend is just distinct. Select rhyolites plot along the Felsic Segment. Altered rhyolites and most dacites plot along the Felsic Trend, but three andesites and a dacite plot along a back-projection to considerably higher Zn than the Felsic Inflection (Fig. A2.15f). Basaltic rocks display considerable scatter with most plotting above the Main Trend.

Zn v Cr (Fig. A2.15h,j,l) distinguishes the BV from select I-type granitoids (greater Cr range at lower Zn), from Hawaiian Nepheline Melilitite and Primitive MORB (different Cr, higher Zn in Hawaiian Nepheline Melilitite), and from most BVSP Reference Arc basalts (greater Cr range, marginally lower Zn). The BV overlap the Cr range of select M-type granitoids. Regional comparisons (Fig. A2.15n,p,r,t) also indicate that BV data overlap the range of most comparative suites. Only Tertiary volcanic rocks are truly distinctive (high Zn), and higher Cr and Zn ranges distinguishes most Early Permian central NEO mafic complexes.

In summary, select BV display a slight increase in Zn in the basalt-andesite (≈ 1.08x SOB_{12}), then a steady decline through the rest of the range, marked by erratic behaviour among rhyolites. SOB_{12} contains more Zn than Primitive MORB (1.1x) and Mole Granite, but less than Hawaiian Nepheline Melilitite, Fuji basalt and Average Continental Crust. Si-Cr-Zn systematics for select BV contain similar levels of Zn to unassigned Boggabri Volcanics, some Early Permian central NEO volcanic rocks, some Late Carboniferous volcanic rocks, some Halls Peak volcanics, some Werrie Basalts, and some S-type granitoids, more Zn than most BVSP Arc basalts, most M- and I-type granitoids, some Early Permian central NEO volcanic rocks and some S-type granitoids, but less Zn than Tertiary Nandewar volcanic rocks.

Scandium

Sc ranges from < 1 ppm (detection limit) to 42 ppm with only a few samples containing > 27 ppm (Fig. A2.16 a). Select rocks range from 25 ppm (SOB_{12}) and 26 ppm (SPB_{39}) to 2–4 ppm among rhyolite pitchstones. Sc in BV is within the range of common igneous rocks (x ppm to x0 ppm level — Wedepohl, 1978).

Sc in SOB_{12} is depleted relative to Primitive MORB (0.57x), Fuji basalt (0.72x), Rindjani basalt (0.75x), Average Continental Crust (0.82x) and Hawaiian Nepheline

Melilitite (0.95x), but is enriched relative to pyrolite (1.52x). Abundance patterns (Fig. A2.16b) exhibit a steady decline from basalt (1.04x SOB_{12}) to SED_{05} (0.46x SOB_{12}), followed by a drop to a lower range of erratic values (0.09 to 0.18x SOB_{12}) among rhyolites. Overall, select BV are depleted relative to Primitive MORB, Rindjani basalt, Average Continental Crust, Fuji basalt and Hawaiian Nepheline Melilitite, but are enriched relative to Mole Granite for the basalt-dacite range. For SOB_{12}, Mole Granite are complementary to Primitive MORB, Average Continental Crust, Fuji basalt and Hawaiian Nepheline Melilitite.

On **Sc v SiO_2** (Fig. A2.16 c), select rocks show a Main Trend comprising a very short, near-vertical, positive-slope in the Mafic Segment, an inclined, negative slope in the Intermediate Segment and a short, nearly flat Felsic Segment. SOA_{10} plots distinctly below all trends, whereas SFA_{09}, SAD_{24} and SED_{05} plot along the Main Trend and the Dyke Trend is indistinct. Select rhyolites cluster at the end of the Felsic Segment. Most altered rocks (Fig. A2.16e) also plot close to the Main Trend. Only carbonated basalts and basaltic andesite are exceptional, and those contain distinctly higher Sc.

Sc v SiO_2 (Fig. A2.16g,i,k) shows that the BV mafic rocks are distinct from BVSP Reference Suites, Primitive MORB and Average Continental Crust, having lower Sc and/of marginally higher SiO_2 than Oceanic Suites and Primitive MORB, marginally higher Sc than CRZ basalts, lower Sc than CFB data and Average Continental Crust, and generally lower Sc than Arc basalts. The BV range is generally distinctly lower than select M-type granitoids apart from some overlap among more felsic rocks, and is marginal to or distinctly below the range of I-type granitoids and Mole Granite. Regional comparisons (Fig. A2.16m,o,q,s) show that the BV indicate similar Sc contents at equivalent SiO_2 to the Werrie Basalt, and the unassigned volcanic rocks from Boggabri whereas the Late Carboniferous volcanic rocks and most Halls Peak volcanics have marginally to significantly higher Sc, Early Permian mafic complexes and Hillgrove and Copeton granitoids generally have higher Sc, and most Tertiary volcanic rocks (where data is available) have lower Sc.

On **Sc v Cr** (Fig. A2.16d), select rocks show a Main Trend comprising a nearly flat Mafic Segment (≈ 25 ppm Sc), and steep, negative, nearly colinear Intermediate and Felsic Trends. SOA_{10} plots below both Cross Trends. SOA_{10} plots distinctly below all trends, whereas SFA_{09}, SAD_{24} and SED_{05} plot along the Main Trend and the Dyke Trend is indistinct. Select rhyolites cluster at the end of the Felsic Segment. Numerous altered rocks coincide with the Intermediate and Felsic Segments of the Main Trend (Fig. A2.16f). However, mafic rocks generally do not plot along the Mafic Segment. Silicified basalts plot distinctly below the Mafic Segment and the zeolitic basalt, silicified basaltic andesite plots on Cross Trend 1, two carbonated basalts and one carbonated basaltic andesite plot significantly above the Main Trend.

Sc v Cr (Fig. A2.16h,j,l) largely distinguishes the BV from BVSP Reference Arc, Oceanic and CFB basalts (slight overlap with the latter) and from Hawaiian Nepheline Melilitite, Primitive MORB, Average Continental Crust and select I-type granitoids. The BV overlap the Sc range of BVSP Reference CRZ basalts, although the latter trend to lower Sc at comparable Cr. Select M-type granitoids and Mole Granite plot along the Intermediate Segment. Regional comparisons(Fig. A2.16n,p,r,t) indicate that the BV are similar to the Werrie Basalt, Halls Peak volcanics, Hillgrove and Copeton granitoids, Late Carboniferous volcanic rocks, and some Tertiary volcanic rocks, but are distinct from most Early Permian central NEO mafic complexes.

In summary, select BV display a tiny peak at the Mafic Inflection (1.04x SOB_{12}), a steady decline in the andesite-dacite range and a significant decrease to erratic values in the rhyolite range (0.09 to 0.18x SOB_{12}). SOB_{12} contains more Sc than Mole Granite but less than Hawaiian Nepheline Melilitite, Average Continental Crust, Fuji basalt and Primitive MORB (0.57x). Si-Cr-Sc systematics for select BV indicate similar Sc to Werrie Basalt, higher Sc than many BVSP CRZ basalts, some Oceanic alkalic volcanic rocks and Tertiary Nandewar volcanic rocks, and lower Sc than most BVSP Arc, Oceanic tholeiitic and CFB basalts, Primitive MORB, Hawaiian Nepheline Melilitite, Early Permian mafic complexes, Late Carboniferous volcanic rocks, and most M-, I- and S- type granitoids and variable behaviour compared to most granitoid suites. Altered BV exhibit a greater Sc range than select BV, with carbonated basalts containing up to 42 ppm (i.e. 1.5 x SOB_{12}).

Vanadium

V ranges from 3 ppm to 250 ppm (Fig. A2.17a). Select rocks range from 222 ppm (SPB_{39}) to 9 ppm ($SFBR_{04}$). These ranges among basaltic and rhyolitic volcanic rocks are comparable to those of common igneous rocks (typically x00 ppm among basalts around 10 ppm among granitic rocks — Wedepohl, 1978).

V in SOB_{12} is depleted relative to Fuji basalt (0.56x), Primitive MORB (0.65x), Hawaiian Nepheline Melilitite (0.78x), Average Continental Crust (0.82x), and Rindjani basalt (0.88x) but is enriched relative to pyrolite (2.29x). Abundance patterns (Fig. A2.17b) exhibit a gradual depletion from SPB_{39} (1.18x SOB_{12}) to dacite (0.42x SOB_{12}), followed amongst rhyolites by a steep drop to $SMPR_{06}$, a gradual flattening to $SFBR_{04}$, and a slight rise to $SLPR_{29}$ (0.05x SOB_{12}) and $SLPR_{08}$. Overall, select BV are generally depleted relative to most reference compositions, but are enriched relative to Mole Granite. For SOB_{12}, Mole Granite is complementary to all the other reference compositions.

On **V v SiO_2** (Fig. A2.17c), select rocks show a Main Trend comprising as a very short, vertical, positive-slope in the Mafic Segment, a long, inclined, negative slope in the Intermediate Segment and a short, more gently positive slope in the Felsic Segment. SOA_{10} plots below all trends. SFA_{09}, SAD_{24} and SED_{05} plot slightly off the Main Trend and the Dyke Trend virtually coincide with the Main Trend. Select rhyolites are tightly clustered along the Felsic Segment. Altered basaltic samples (Fig. A2.17e) plot in a diffuse elongate band that roughly coincides with the Intermediate and Mafic Segments, but without an obvious Mafic Inflection. However, silicified basalt plots is depleted in V. Altered rhyolites form a flat, distinctly separate cluster trending to high SiO_2.

V v SiO_2 (Fig. A2.17g,i,k) shows that select BV overlap the lower range of BVSP Reference Arc basalts, the mid range of BVSP Reference CFB data and the mid range of M- and I-type granitoids and Mole Granite, but have lesser V than Primitive MORB and Average Continental Crust. Regional comparisons (Fig. A2.17m,o,q,s) show that the BV indicate similar V contents at equivalent SiO_2 to the middle of the Petroi Metabasalt range, to most Early Permian central NEO mafic complexes, to most Hillgrove and Copeton Plutonic Suite granitoids, and to Late Carboniferous volcanic rocks. Werrie basalts have slightly lower V, Tertiary volcanic rocks have significantly lower V and/or lower SiO_2, and the unassigned volcanic rocks from Boggabri have marginally higher V.

On **V v Cr** (Fig. A2.17d), select rocks show a Main Trend comprising a gently inclined, positively trending Mafic Segment, and steep, negative, nearly colinear Intermediate and Felsic Trends. SOA_{10} plots distinctly beside Cross Trend 1. SFA_{09}, SAD_{24} and SED_{05} plot along the Main Trend and the Dyke Trend is indistinct. Select rhyolites cluster at the end of the Felsic Segment. Numerous altered rocks coincide with the Intermediate and Felsic Segments of the Main Trend (Fig. A2.17f). Mafic rocks are more scattered, with silicified basalt notably depleted.

V v Cr (Fig. A2.17h,j,l) largely distinguishes the BV from BVSP Reference Arc and CFB ranges (generally higher Cr and/or V), from Hawaiian Nepheline Melilitite, Primitive MORB and Average Continental Crust, and from select I-type granitoids (ranges to higher Cr for comparable V). The BV overlap the range of select M-type granitoids. Regional comparisons (Fig. A2.17n,p,r,t) indicate similarity to most comparative data suites except for the Petroi Metabasalt (higher Cr and/or V) and most Early Permian central NEO mafic complexes (greater Cr and V ranges).

In summary, select BV display a tiny rise from SOB_{12} to the Mafic Inflection ($\approx$ 1.34x SOB_{12}), followed by a steady decline in the andesite-dacite range and a significant decrease to the rhyolite range (to 0.05 to 0.12x SOB_{12}) with leucocratic pyroxene rhyolite lavas enriched compared to biotite rhyolites. SOB_{12} contains more V than Mole Granite, but less than Fuji basalt, Primitive MORB (0.65x), Hawaiian Nepheline Melilitite, Rindjani basalt and Average Continental Crust. Si-Cr-V systematics for select BV indicate similar levels of V to some CFBs, M-, I- and S-type granitoids, Halls Peak volcanics, Petroi Metabasalt and Late Carboniferous volcanic rocks, but contain more than Werrie Basalt, some Early Permian central NEO volcanic rocks, and Tertiary Nandewar basalts, and contain less V than most BVSP Arc basalts and unassigned Boggabri Volcanics.

Gallium

Ga ranges from 10 ppm to 27.8 ppm with a notable peak in the distribution at about 18 ppm (Fig. A2.18a). Most data are between 16 and 20 ppm with only a single analysis (#33) greater than 22 ppm. Select rocks range from approximately 14 ppm in a rhyolite pitchstone ($SLPR_{29}$) to 19.6 ppm (SAD_{24}). There is a gap in the rhyolite field at about 15 ppm. The BV range is within the range of common igneous rocks (mafic rocksaverage 15 ppm, felsic rocks average 18.5 ppm — Wedepohl, 1978).

Ga in SOB_{12} is depleted relative to Average Continental Crust (0.91x), Fuji basalt (0.91x) and Hawaiian Nepheline Melilitite (0.94x) but is enriched relative to Primitive MORB (1.06 x), and pyrolite (4.1x). Abundance patterns (Fig. A2.18b) exhibit a broad, mid- range hump, with dacites and one rhyolite ($SLPR_{13}$) enriched about 1.2x SOB_{12}, but with minor lows at SFA_{09} and $SMPR_{06}$, and a significant drop to leucocratic pyroxene rhyolites (0.8x). Overall, select BV are depleted relative to Mole Granite, and most are enriched relative to Primitive MORB except for two rhyolites which depleted relative to Primitive MORB. All are sub-equal to Average Continental Crust, Fuji basalt and Hawaiian Nepheline Melilitite. For SOB_{12}, Primitive MORB is complementary to Hawaiian Nepheline Melilitite, Mole Granite, Fuji basalt and Average Continental Crust.

On **Ga v SiO_2** (Fig. A2.18c), select rocks show a Main Trend comprising a very short, near-vertical, positive-slope in the Mafic Segment, an inclined, negative slope in the Intermediate Segment and a short, more steeply negative slope in the Felsic Segment. SOA_{10} plots between the Main Trend and Cross Trend 2. However, SFA_{09}, SED_{05} and SAD_{24} plots distinctly away from the Intermediate Segment, and the Dyke Trend is distinct. Some select rhyolites plot along the Felsic Segment but others plot in a cluster displaced to higher Ga. Altered rocks (Fig. A2.18e) are also slightly scattered, but mainly plot close to the Main Trend. Exceptions are the zeolitic basalt (#33) which has very high Ga, and various white and silicified rhyolites which have higher SiO_2 and lower Ga than the Felsic Segment.

Ga v SiO_2 (Fig. A2.18g,i,k) shows that the BV mafic rocks plots within the uppermost range of BVSP Representative Arc basalts, but within the lower range of BVSP Representative Continental and Oceanic basalts, and slightly above Primitive MORB. The BV range is marginal to Average Continental Crust, the upper limit of select M-type granitoids and some select I-type granitoids (Uralla Plutonic Suite) whereas the BV Main Trend cuts across the extensive range of other select I-type granitoids (Moonbi Plutonic Suite). Mole Granite has distinctly higher Ga. Regional comparisons (Fig. A2.18m,o,q,s) show that the BV Main Trend substantially overlaps the Ga range of the Werrie Basalt, the Hillgrove and Copeton Plutonic Suite granitoids, the Late Carboniferous volcanic rocks, and is marginal to and/or partly overlaps the Halls Peak volcanics and the unassigned volcanic rocks from Boggabri. Most Early Permian central NEO mafic complexes are distinct (lower Ga), as are most the Petroi Metabasalt range (lower SiO_2, greater Ga range).

On **Ga v Cr** (Fig. A2.18d), select rocks show a Main Trend comprising a nearly flat Mafic Segment (≈ ppm 17 to 20 ppm Ga), and short, steep, negative, nearly colinear Intermediate and Felsic Trends (Ga range 19.6 ppm to 14 ppm). The Cross Trend is nearly straight, and the Dyke Trend virtually coincides with the Intermediate Segment. SFA_{09} and SED_{05} plot on the Main Trend as do select rhyolites, but some of the latter have high Ga and cluster along the Intermediate Segment. Altered andesites, dacites and some rhyolites plot along the Intermediate and Felsic Segments, but other rhyolites have significantly lower Ga (Fig. A2.18f). Most altered Mafic samples plot close to the Mafic Segment but the zeolitised basalt (#33) has substantially more Ga (27.8 ppm) than the Main Trend equivalent. Radial dispersal relative to the Mafic Segment is generally small (up to ≈12%) but for #33 amounts to +100%.

Ga v Cr (Fig. A2.18h,j,l) largely distinguishes the BV from most BVSP Reference Arc basalts (lower Ga), Oceanic and Continental basalts (higher Cr and/or Ga), Hawaiian Nepheline Melilitite and Primitive MORB (lower Cr) and from select I-type granitoids (lower Ga and greater Cr range). Only M-type granitoids are not distinguished. Regional comparisons (Fig. A2.18 n,p,r,t) indicate similarity to the Werrie Basalt and Late Carboniferous volcanic rocks, and unassigned volcanic rocks from Boggabri, Halls Peak volcanics (slightly greater range), the Hillgrove and Copeton granitoids. Only the Petroi Metabasalt (higher Cr, some higher Ga values) and the Early Permian central NEO mafic complexes (lower Ga and/or higher Cr) are distinct.

In summary, select BV display a modest increase to a mid- range hump of about 1.2x SOB_{12} (poorly modelled by the Main Trend) followed by a significant decline to leucocratic pyroxene rhyolites. SOB_{12} contains less Ga than Mole Granite, Average Continental Crust, Fuji basalt and Hawaiian Nepheline Melilitite, but more than Primitive MORB (1.06x). Si-Cr-Ga systematics for select BV contain similar levels of Ga to unassigned Boggabri Volcanics, Late Carboniferous volcanic rocks, S-type granitoids, Werrie Basalt, and some Halls Peak volcanics, more Ga than most BVSP Arc basalts, Early Permian central NEO mafic complexes, and most M- and I-type granitoids but less Ga than some BVSP Continental and OIB basalts. Altered BV broadly mimic values in select rocks at similar SiO_2, apart from high Ga in one basalt (#33), and low Gain several rhyolites.

Yttrium

Y ranges from 7.6 ppm to 46 ppm with the distribution nearly symmetrical (apart from a central gap) around a median value of 28 ppm (Fig. A2.19a). Select rocks range from 15.4 ppm (SOB_{12}) to 46 ppm ($SLPR_{13}$). The BV range is within the range of common igneous rocks (typically x0 to x00 ppm — Wedepohl, 1978).

Y in SOB_{12} is depleted relative to Fiji basalt (0.49x), Hawaiian Nepheline Melilitite (0.51x), OIB (0.53x), Primitive MORB (0.55x), E-MORB (0.7x), Rindjani basalt (0.73x) and Average Continental Crust (0.77x) but is enriched relative to pyrolite (3.57x). Abundance patterns (Fig. A2.19 b) exhibit an enrichment to 2x to 3x SOB_{12} in most andesites, dacites and rhyolites. Notable exceptions are a marked depletion at $SLPR_{29}$ and $SLPR_{08}$ (leucocratic pyroxene lavas), and minor lows at SAD_{24} and $SMPR_{06}$. Overall, all rocks are depleted relative to Mole Granite, and most rocks, other than SOB_{12}, SPB_{39} (in the some cases), $SLPR_{29}$ and $SLPR_{08}$, and are enriched relative to Primitive MORB, Rindjani and Fuji basalts, Hawaiian Nepheline Melilitite, E-MORB, OIB and Average Continental Crust. For SOB12, there are no complementary relationships, due to low Y.

On **Y v SiO_2** (Fig. A2.19c), select rocks show a Main Trend comprising a moderately long , near-vertical, positive-slope in the Mafic Segment, an inclined, positive slope in the Intermediate Segment and a steep negative slope in the Felsic Segment. SOA_{10} plots on Cross Trend 1. SFA_{09} and SED_{05} plot close to the Main Trend. SAD_{24} plots well below the Intermediate Segment and the Dyke Trend is long and distinct. Select rhyolites are scattered close to the Felsic Segment. Altered rocks (Fig. A2.19e) display considerable scatter, with mafic rocks plotting either side of the Mafic Segment, andesites and dacites plotting below the Intermediate Segment, and rhyolites mainly plotting at higher SiO_2 and/or lower Y than the Felsic Segment.

Y v SiO_2 (Fig. A2.19g,i,k) shows that the BV mafic rocks overlap the mid range of BVSP Reference Arc Continental and Oceanic basalts, and overlap Primitive MORB. The BV Intermediate Segment is slightly higher than Average Continental Crust and the upper range of select M-type granitoids, and above the Y range of many of I-type granitoids. However, some fractionated Moonbi Plutonic Suite granitoids and Mole Granite extend considerably above the Felsic Segment. Regional comparisons (Fig. A2.19m,o,q,s) show that the BV indicate similar Y contents to the Werrie Basalt, the middle of the Petroi Metabasalt range (but at slightly lower SiO_2), the Halls Peak volcanics (but extending to higher Y and SiO_2) and the unassigned volcanic rocks from Boggabri. The Intermediate Segment has higher slightly to significantly higher Y contents than most Early Permian central NEO mafic complexes, most Hillgrove and Copeton Plutonic Suite granitoids, and most the Late Carboniferous volcanic rocks, although the latter two suites partly overlap the BV Felsic Segment. Tertiary volcanic rocks have indicate similar Y contents among the basalts but range to much higher Y among intermediate to felsic compositions.

On **Y v Cr** (Fig. A2.19d), select rocks show a Main Trend comprising a gently inclined, positive slope in the Mafic Segment, a short, steep, positive, Intermediate Trend, and a longer, steep positive trend in the Felsic Trends. SOA_{10} plots on the Mafic Trend. SFA_{09} and SED_{05} plot along the Main Trend. SAD_{24} plots well below the Main Trend and the Dyke Trend is long and distinct. Select rhyolites plot close to the Felsic Segments. Altered felsic to intermediate rocks also plot along the Main Trend (Fig. A2.19f). However, mafic rocks display considerable scatter, with most occurring along or well below the Main Trend.

Y v Cr (Fig. A2.19h,j,l) largely distinguishes the BV from Primitive MORB and Hawaiian Nepheline Melilitite (higher Cr), BVSP Representative Arc basalts (lower Y and greater Cr range), and from Continental and Oceanic basalts (generally higher Y and/or Cr). Lower Y distinguishes many select M-type granitoids, whereas higher Cr at low Y or higher Y at low Cr distinguishes many I-type granitoids and Mole Granite. Regional comparisons (Fig. A2.19n,p,r,t) indicate that the BV are similar to the Werrie Basalt and that **Y v Cr** discriminates the BV from most of the Petroi Metabasalts (higher Cr) and many Halls Peak volcanics (higher Y) as well as from Tertiary felsic volcanic rocks (high Y). Early Permian central NEO mafic complexes are partly distinguished (some have higher Cr) but other suites are generally not distinguished.

In summary, select BV display a significant increase in the basalt range from SOB_{12} to the low-Si end of the rhyolite range ($\approx 3x$ SOB_{12}) with minor anomalies at SAD_{24} and $SMPR_{06}$, and a significant drop to $SLPR_{29}$ and $SLPR_{08}$. SOB_{12} contains less Y than all reference compositions, especially Mole Granite. Si-Cr-Y systematics for select BV indicate similar levels of Y to all BVSP data sets except OIP alkalic basalts, Petroi Metabasalt, and Werrie Basalt, more Y than most M-, I- and S-type granitoids (except evolved Moonbi granitoids which are Y-rich) and many Early Permian central NEO volcanic rocks, but less Y than many Tertiary Nandewar intermediate to felsic volcanic rocks.

Zirconium

Zr ranges from 85 ppm to 434 ppm (Fig. A2.20a). Select rocks range from 87 ppm (SOB_{12}) to 396 ppm ($SLPR_{13}$). The BV range is within the range of common igneous rocks (typically x ppm, less commonly < x0 ppm if clinopyroxene is abundant — Wedepohl, 1978).

Zr in SOB_{12} is depleted relative to OIB (0.31x), Hawaiian Nepheline Melilitite (0.52x), Fuji basalt (0.75x) and Average Continental Crust (0.87x), but is enriched relative to Primitive MORB (1.18x), E-MORB (1.19x), Rindjani basalt (1.19x) and pyrolite (8.29x). Abundance patterns (Fig. A2.20b) exhibit a steep enrichment in the basalt-basaltic andesite range (to 3x SOB_{12}), a less marked enrichment in the andesite-dacite-low silica rhyolite range marked by a weak low at SAD_{24}, and a sustained slight decline in the rest of the rhyolite range after a weak peak at $SLPR_{13}$ (4.6x SOB_{12}). Overall, select BV are enriched relative to Primitive MORB, E-MORB and Rindjani basalt, to Mole Granite, Fuji basalt and Average Continental Crust (except for SOB_{12}) and to Hawaiian Nepheline Melilitite except for basalts. The olivine basalt-basalt range is depleted relative to OIB, whereas other compositions are sub-equal. For SOB_{12}, Primitive MORB, E-MORB and Rindjani basalts are complementary to Hawaiian Nepheline Melilitite, OIB, Fuji basalt, Average Continental Crust and Mole Granite.

On **Zr** v **SiO_2** (Fig. A2.20c), select rocks show a Main Trend comprising a near-vertical, positive-slope in the Mafic Segment, an inclined, positive slope in the Intermediate Segment and a steep, negative slope in the Felsic Segment. SOA_{10} plots distinctly between the Main Trend and Cross Trend 2. SFA_{09} and SED_{05} plot close to Main Trend. SAD_{24} plots well below the Main Trend and the Dyke Trend is well developed and highly oblique to the Main Trend. Select rhyolites are tightly clustered along the Felsic Segment. Altered rocks (Fig. A2.20e) plot in three diffuse clusters. One, comprising mafic and andesitic rocks plots left or right of the Mafic Trend, and below the Intermediate Segment; the Mafic Inflection is not evident. The second comprises dacites that plot above or below the Intermediate Segment. The third comprises rhyolites that plot at higher SiO_2 and lower Zr than the Felsic Segment.

Zr v SiO_2 (Fig. A2.20g,i,k) shows that the BV mafic rocks overlap the upper range of BVSP Reference Arc basalts, the lower range of CFBs, most CRZ basalts and most Oceanic basalts (except alkalic OIP volcanic rocks which have significantly higher Zr). The BV range is generally higher than that of select M-type and I-type granitoids, although the end of the Felsic Segment overlaps the margin of the latter. Primitive MORB has slightly lower Zr and Average Continental Crust and Mole Granite have distinctly lower Zr than select BV at comparable SiO_2. Regional comparisons (Fig. A2.20m,o,q,s) show that the BV overlap the Werrie Basalt range and that of the unassigned volcanic rocks from Boggabri. There is also slight overlap of the range of the Petroi Metabasalt range (mainly lower SiO_2) and the Halls Peak volcanics (higher SiO_2, ranges to higher Zr). However, the BV have higher Zr than most Early Permian central NEO mafic complexes, most Hillgrove and Copeton Plutonic Suite granitoids and most Late Carboniferous volcanic rocks (note some overlap at the end of the Felsic Segment). Tertiary volcanic rocks generally have higher Zr, apart from some overlap among the basalts.

On **Zr v Cr** (Fig. A2.20d), select rocks show a Main Trend comprising a long, gently, positively sloping Mafic Segment, a steep, positive slope in the intermediate and a steep negative slope in the Felsic Segment. SOA_{10} plots beside Cross Trend 1. SFA_{09} and SED_{05} plot along the Main Trend. SAD_{24} plots close to the Mafic Inflection, and the Dyke Trend is long, but indistinct. Select rhyolites plot close to both the Intermediate and Felsic Segments. Altered dacites and rhyolites also cluster along the Intermediate and Felsic Segments, with a few plotting above of below these segments (Fig. A2.20f). Basalts plot scattered either side of the Mafic Segment. Radial dispersal relative to the Mafic Trend is limited.

Zr v Cr (Fig. A2.20h,j,l) largely distinguishes the BV from Hawaiian Nepheline Melilitite and Primitive MORB (higher Cr), from BVSP Representative Arc basalts (lower Zr and greater Cr range), and from Average Continental Crust (lower Zr). BVSP Representative Continental and Oceanic basalts indicate similar Zr ranges (apart from high Zr in alkalic oceanic basalts) but have a greater Cr range. Lower Zr also distinguishes many select M-type granitoids, but I-type granitoids largely overlap the BV range and only a trend to higher Cr is significant. Regional comparisons(Fig. A2.20n,p,r,t) indicate the similarity to the Werrie Basalt and unassigned volcanic rocks from Boggabri. **Y v Cr** discriminates the BV from most of the Petroi Metabasalt (higher Cr) and many Halls Peak volcanics (higher Y) as well as the felsic Tertiary volcanic rocks many (higher Y). Early Permian central NEO mafic complexes are partly distinct (greater Cr range). Other suites are generally not distinct.

In summary, select BV display a significant increase in the basalt-olivine andesite range (to 3x SOB_{12}) and a modest increase to the low-Si end of the rhyolite range (≈ 3.9x SOB_{12}) then a decline throughout the rest of the rhyolites. By comparison, SAD_{24} is slightly depleted and $SLPR_{13}$ (an ignimbrite) is slightly enriched. SOB_{12} contains more Zr than E-MORB, Primitive MORB (1.18x) and Rindjani basalts but less than Average Continental Crust, Mole Granite, Fuji basalt, Hawaiian Nepheline Melilitite and OIB. Si-Cr-Zr systematics for select BV indicate similar levels of Zr to many BVSP Continental and OIP tholeiitic basalts, many Werrie Basalts, and most Halls Peak volcanics, more Zr than Early Permian central NEO mafic complexes, most M-, I- and S-type granitoids and many BVSP Arc basalts but less evolved OFBs, but less Zr than BVSP OIP alkalic basalts and many Tertiary Nandewar volcanic rocks.

Hafnium

Hf ranges from 1.7 ppm to 10.8 ppm with the distribution virtually symmetrical around a median value of 6 ppm (Fig. A2.21a). Select rocks range from 1.6 ppm (SOB_{12}) to 8.5 ppm ($SLPR_{13}$). The BV range is within the range of common igneous rocks (typically x ppm and increasing with SiO_2 to a peak among dacites and their alkali equivalents — Wedepohl, 1978).

Hf in SOB_{12} is depleted relative to OIB (0.21x), Rindjani basalt (0.42), Hawaiian Nepheline Melilitite (0.46x), Fuji basalt (0.52x), Average Continental Crust (0.56x), Primitive MORB (0.82x), E-MORB (0.82x), but is enriched relative to pyrolite (5.9x). Abundance patterns (Fig. A2.21b) exhibit a significant enrichment in the basalt-olivine andesite range (to 4x SOB_{12}) which is maintained across the range except for a distinct drop to leucocratic pyroxene rhyolite lavas ($SLPR_{29}$ and $SLPR_{08}$ at about 3x SOB_{12}). There is a very weak low at SAD_{24} and a very weak peak at SLPR13 (ignimbrite). Overall, all except SOB_{12} is enriched relative to Primitive MORB and E-MORB, and all except basalts are enriched relative to Average Continental Crust, Fuji and Rindjani basalts and Hawaiian Nepheline Melilitite Basalts are depleted relative to OIB, whereas other compositions are marginally depleted to sub-equal. For SOB_{12}, there are no complementary relationships, due to low Hf.

Hf v SiO_2 and **Hf v Cr** display virtually identical patterns to that of **Zr v SiO_2** and **Zr v Cr** respectively for both select and altered rocks (Fig. A2.21c–f). Comparisons are inhibited by sparse data, but are likely follow the same pattern as Zr.

In summary, Hf displays very similar patterns to Zr, although the pattern of enrichment and depletion across the range is more subdued, and the leucocratic pyroxene rhyolite lavas are more distinctly differentiated.

Strontium

Sr ranges from approximately 48 ppm to 3060 ppm with only a few values above 960 ppm and only one (#02) above 2000 ppm (Fig. A2.22a). Select rocks range from approximately 431 ppm (SED_{05} — dacite) to 930 ppm ($SFBR_{04}$). The BV range is within the range of common igneous rocks (typically x00 ppm, less commonly < 100 ppm or > 1000 ppm — Wedepohl, 1978).

Sr in SOB_{12} is depleted relative to Hawaiian Nepheline Melilitite (0.53x), but is enriched relative to OIB (1.3x), Rindjani basalt (1.76x), Fuji basalt (2.23x), Average Continental Crust (3.4x), E-MORB (5.6x), Primitive MORB (9.7x), and pyrolite (44x).

Abundance patterns (Fig. A2.22b) exhibit a gradual depletion from basalts to $SMPR_{06}$ (low at SED_{05} = 0.49x SOB_{12}) and increasing levels across the rhyolite range (range 0.52x to 1.07x SOB_{12}). Notable exceptions are leucocratic rhyolite lavas which are significantly less enriched than biotite rhyolites, and SAD_{24} which is weakly elevated. Overall, the compositional range is enriched relative to Mole Granite (> 10x), Primitive MORB, E-MORB, Average Continental Crust and Fuji basalt (all 1 to 10x), but are depleted relative to Hawaiian Nepheline Melilitite. Compared to OIB, and Rindjani basalts, mid-range compositions are depleted whereas others are enriched. For SOB_{12}, Hawaiian Nepheline Melilitite is complementary to other reference compositions.

On **Sr v SiO_2** (Fig. A2.22c), select rocks show a Main Trend comprising negligible change in the Mafic Segment, an inclined, negative slope in the Intermediate Segment and a short, more steeply negative slope in the Felsic Segment. SOA_{10} plots slightly above Cross Trend 1. SFA_{09}, SAD_{24} and SED_{05} plot along the Main Trend and the Dyke Trend is indistinct. Select rhyolites are scattered along or just above the Felsic Segment. Altered rocks form three groups. Basaltic and andesitic rocks plot along or above the Main Trend (Fig. A2.22e). The divergence from the Main Trend increases with decreasing silica and reaches 2.5x in the zeolitised basalt (#33). Dacites form a linear array that is closest to, but slightly below, the Main Trend. Altered rhyolites mainly form a linear array at distinctly higher SiO_2 and lower Sr than the Main Trend, and which points to 100% SiO_2.

Sr v SiO_2 (Fig. A2.22g,i,k) shows that the BV mafic rocks overlap the mid range of BVSP Reference Continental basalts but have distinctly higher Sr than BVSP Reference Arc and Oceanic basalts, Average Continental Crust and Primitive MORB. Only Hawaiian Nepheline Melilitite and evolved BVSP OIP alkalic rocks have higher Sr than BV mafic rocks. BV felsic to intermediate rocks have higher Sr than the Uralla granitoids (I-type) and Mole Granite, but the Intermediate Segment overlaps the range of M-type and Moonbi (I-type) granitoids. Regional comparisons (Fig. A2.22m,o,q,s) show that the BV indicate similar Sr contents to the Werrie Basalt and the unassigned volcanic rocks from Boggabri, and overlap the range of Late Carboniferous volcanic rocks and some Tertiary mafic volcanic rocks. However, the BV have significantly higher Sr than the Petroi Metabasalt, most Halls Peak volcanics, most Early Permian central NEO mafic complexes, Hillgrove and Copeton Plutonic Suite granitoids, and most Tertiary volcanic rocks (except basalts).

On **Sr v Cr** (Fig. A2.22d), select rocks show a Main Trend comprising a Main Trend is nearly flat and is followed by a short steep negative Intermediate Segment and a short steep positive Felsic Segment. Select BV plots along the Main Trend and the Cross Trend is nearly straight. SOA_{10} plots distinctly below all trends, whereas SFA_{09}, SAD_{24} and

SED_{05} plot along the Main Trend and the Dyke Trend is indistinct. Select andesite, dacite and rhyolite plot along or close to the Main Trend. Altered mafic rocks plot either as a scattered group close to the Main Trend, or as an apparently linear array with a higher slope and higher Sr than the Main Trend (Fig. A2.22f). Intermediate to felsic rock mainly plot close to the Main Trend, but at slightly lower Sr. One silicified rhyolite has far higher Sr (#02).

Sr v Cr (Fig. A2.22h,j,l) readily distinguishes the BV from BVSP Reference Arc, Continental and Oceanic basalts, from Hawaiian Nepheline Melilitite, Primitive MORB and Average Continental Crust, and from most select I-type granitoids (except some Moonbi granitoids), whereas the BV overlap the range of select M-type granitoids. Regional comparisons (Fig. A2.22n,p,r,t) indicate similarity to the Werrie Basalt and Late Carboniferous volcanic rocks, intermediate to felsic Tertiary volcanic rocks, and unassigned volcanic rocks from Boggabri. However, the BV have higher Sr than most Halls Peak volcanics, most Early Permian central NEO mafic complexes, and Hillgrove and Copeton granitoids.

In summary, select BV display a modest decrease in Sr in the basalt-low-silica rhyolite range (to about half SOB_{12}) and a significant increase within the rhyolite range (mainly 0.73 to 1.07x SOB_{12}), but leucocratic pyroxene rhyolite lavas are distinctly less enriched than biotite rhyolites. SOB_{12} contains more Sr than all reference compositions except Hawaiian Nepheline Melilitite. Si-Cr-Sr systematics for select BV indicate less Sr than Hawaiian Nepheline Melilitite, similar levels of Sr to M-type granitoids, some I-type granitoids, Werrie Basalt, Late Carboniferous volcanic rocks and unassigned Boggabri Volcanics, and more Sr than BVSP Arc and Oceanic tholeiitic basalts, Primitive MORB, Hawaiian Nepheline Melilitite, Average Continental Crust, most BVSP continental basalts, Early Permian central NEO volcanic rocks, and Petroi Metabasalt, many I- and S-type granitoids and Tertiary Nandewar volcanic rocks.

Lead

Pb ranges from approximately 4 ppm to 28 ppm with the distribution symmetrical around a narrow gap at about 15 ppm (Fig. A2.23a). Select rocks range from 6 ppm (SOB_{12}) to 28 ppm ($SFBR_{04}$). The BV range is within the range of common igneous rocks (typically x ppm to x0 ppm, less commonly > 100 ppm — Wedepohl, 1978).

Pb in SOB_{12} is depleted relative to Average Continental Crust (0.77x), Fuji basalt (0.89x), and Hawaiian Nepheline Melilitite (0.98x) but is enriched relative to OIB (1.92x), E-MORB (10x), Primitive MORB (21x), and pyrolite (41x). Abundance patterns (Fig. A2.22b) exhibit a gradual enrichment across the BV range, with select rhyolites typically being further enriched (2.8x to 4.6x SOB_{12}). Only minor fluctuations affect this enrichment, most notably a small peak at $SMPR_{06}$, a slight low at $SFBR_{25}$ (an ignimbrite), and slight depletion in leucocratic pyroxene rhyolite lavas compared to biotite rhyolite lava ($SFBR_{04}$). Overall, select BV are enriched relative to Primitive MORB, E-MORB (all > 10x), and OIB, but are depleted relative to Mole Granite. Most except some basalts are enriched relative to Hawaiian Nepheline Melilitite, Fuji basalt, OIB, and Average Continental Crust. For SOB_{12}, Mole Granite, Average Continental Crust and Fuji basalt are complementary to OIB, E-MORB, and Primitive MORB, whereas Hawaiian Nepheline Melilitite is subequal.

Pb v SiO_2 (Fig. A2.23c), select rocks show a Main Trend comprising a very short, vertical, positive-slope in the Mafic Segment, an inclined, positive slope in the Intermediate Segment and a short, but steeper positive slope in the Felsic Segment. SOA_{10} plots significantly below all trends. SFA_{09} and SED_{05} plot along the Main Trend. SAD_{24} plots beside the Main Trend and the Dyke Trend is indistinct. Some select rhyolites plot along the Felsic Segment and some plot as much as 6 ppm above it. Altered basaltic to dacitic rocks (Fig. A2.23e) form a scattered linear array that is slightly steeper than the Main Trend but overlaps it at the Mafic end. Some altered rhyolites cluster at the end of the Felsic Segment, but most are offset towards lower Pb and higher SiO_2.

Pb v SiO_2 (Fig. A2.23g,i,k) shows that the BV mafic rocks plot slightly above most BVSP Representative Arc and Oceanic basalts and Primitive MORB, but within the range of BVSP Representative Continental analyses. The BV range passes close to Average Continental Crust, cuts across the middle of the extensive range of select M-type granitoids, and marks the lower limit of the extensive range of I-type granitoids. Pb in Mole Granite is considerably higher than in BV. Regional comparisons (Fig. A2.23m,o,q,s) show that the BV have distinctly lower Pb than the unassigned volcanic rocks from Boggabri but similar Pb to mafic to intermediate Tertiary volcanic rocks (felsic rocks have higher Pb). The BV range crosses the extensive range of Halls Peak volcanics and Late Carboniferous volcanic rocks, and marginally overlaps that of the Werrie Basalt and Early Permian central NEO mafic complexes (most have lower Pb), as well as that of the Hillgrove and Copeton Plutonic Suite granitoid (most have higher Pb).

On **Pb v Cr** (Fig. A2.23d), select rocks show a Main Trend comprising a nearly flat Mafic Segment ($\approx$ 7 ppm Pb), and steep, negative, nearly colinear 'Intermediate' and 'Felsic' Trends. SOA_{10} plots distinctly along the Main Trend. SFA_{09}, SAD_{24} and SED_{05} plot along the Main Trend and the Dyke Trend is indistinct. Select rhyolites plot either along the Main Trend, or along the upward projection of it to about 28 ppm Pb. Altered andesitic to rhyolitic rocks generally plot close to the Intermediate or Felsic Segments, but with some altered rhyolites plotting adjacent to SFA_{09} (Fig. A2.23f).

Altered mafic rocks are more scattered relative both to the Mafic Segment and to the Cross Trends.

Pb v Cr (Fig. A2.23h,j,l) largely distinguishes the BV from most BVSP Representative Arc and Oceanic basalts (lower Pb and greater Cr range), from Primitive MORB and Hawaiian Nepheline Melilitite, and from most I-type granitoids (greater Pb and Cr ranges) and Mole Granite, but shows the similarity to BVSP Representative Continental basalts, Average Continental Crust and M-type granitoids. Regional comparisons (Fig. A2.23n,p,r,t) indicate that the BV partly overlap the ranges of most comparative suites, including the Werrie Basalt, the Halls Peak volcanics, Hillgrove and Copeton granitoids, Late Carboniferous and most Tertiary volcanic rocks, and the unassigned volcanic rocks from Boggabri. Only the Early Permian central NEO Mafic volcanic rocks are distinctive — due to their greater Cr and Pb ranges.

In summary, select BV display a progressive increase in Pb across the range so that select rhyolites are about 2.8x to 4.6x SOB_{12}. SOB_{12} contains similar Pb to Hawaiian Nepheline Melilitite, more Pb than Primitive MORB (21x), E-MORB, and OIB but less than and Fuji basalt, Average Continental Crust or Mole Granite. Si-Cr-Pb systematics for select BV indicate similar levels of Pb to many BVSP Continental basalts and Tertiary Nandewar mafic to intermediate volcanic rocks, more Pb than BVSP Arc and Oceanic basalts, Werrie Basalt, Early Permian central NEO mafic complexes, but less Pb than many Late Carboniferous volcanic rocks, unassigned Boggabri Volcanics, most granitoids (except some M-types) and some Halls Peak volcanics and Tertiary Nandewar felsic volcanic rocks.

Cerium

Ce ranges from 24.9 ppm to 105.3 ppm, with only a single analysis above 85 ppm. Select samples range from 28.5 ppm (SOB_{12}) to 105.3 ppm ($SFBR_{04}$). The BV range is within the range of common igneous rocks (typically x ppm to x0 ppm — Wedepohl, 1978).

Ce in SOB_{12} is depleted relative to Hawaiian Nepheline Melilitite (0.17x), OIB (0.36x), Average Continental Crust (0.86x) and Rindjani (0.94x), but is enriched relative to Fuji basalt(1.13x), E-MORB (1.39x), Primitive MORB (3.8x), and pyrolite (17x). Abundance patterns (Fig. A2.22b) exhibit a significant enrichment in SPB_{39} (1.54x SOB_{12}), followed by a smooth enrichment pattern in the basalt-biotite rhyolite range (to 3.7x SOB_{12}) marked only by weak depletion in $SFBR_{25}$ (an ignimbrite). By comparison $SLPR_{29}$ and $SLPR_{08}$ are distinctly less enriched (1.7 to 1.9x SOB_{12}). Overall, select BV are enriched relative to Primitive MORB, E-MORB and Fuji basalt, and all but SOB_{12} are enriched relative to Rindjani basalt and Average Continental Crust. All except $SFBR_{04}$ are depleted relative to Mole Granite and OIB. All are depleted relative to Hawaiian

Nepheline Melilitite. For SOB_{12}, Primitive MORB, Fuji basalt and E-MORB are complementary to Hawaiian Nepheline Melilitite, OIB, Rindjani basalt, Average Continental Crust and Mole Granite.

On Ce v SiO_2 (Fig. A2.24c), select rocks show a Main Trend comprising steep Mafic Segment, a flat, slightly negative Intermediate Segment, and a short, slightly steeper, negative Felsic Trend. SOA_{10} plots between Cross Trends 1 and 2. SFA_{09}, SAD_{24} and SED_{05} plot slightly off the Main Trend, and the Dyke Trend is poorly defined. Select rhyolites mainly plot in an extended range above the end of the Felsic Segment. Most altered rocks plot in one of three diffuse clusters: basaltic to andesitic rocks mainly plot below the level of the Intermediate Segment, dacites mainly plot above and rhyolites mainly plot at slightly higher than the end of the Felsic Segment (Fig. A2.24e).

Ce v SiO_2 (Fig. A2.24g,i,k) shows that the BV mafic rocks overlap the upper range of BVSP Reference Arc basalts, the lower range of Continental basalts, the uppermost range of OFBs, and is distinct from OIP tholeiitic basalts (lowerSiO_2) and OIP alkalic rocks (higher Ce and/or lower SiO_2). Primitive MORB and Average Continental Crust have lower Ce and Mole Granite has higher Ce than BV at comparable SiO_2. The BV range overlaps the upper limit of select M-type and the lower range of select I-type granitoids. Regional comparisons (Fig. A2.24m,o,q,s) show that the BV overlap the Werrie Basalt range, the middle of the extended ranges of Hillgrove and Copeton Plutonic Suite granitoids, and the Petroi Metabasalt range (the latter ranges to lower SiO_2). The BV range is lower than most Halls Peak volcanics, the unassigned volcanic rocks from Boggabri, and most Tertiary volcanic rocks, but is higher than most Early Permian central NEO mafic complexes. Comparative data for the Late Carboniferous volcanic rocks are not available.

On **Ce v Cr** (Fig. A2.24d), select rocks show a Main Trend comprising gently positively inclined Mafic Trend, a short negatively inclined Intermediate Trend, and a slightly longer, steeper Felsic Segment. SOA_{10} plots along the Cross Trends, which virtually coincide there. SFA_{09} and SED_{05} plot off the Intermediate Segment. SAD_{24} plots close to the Main Trend and the Dyke Trend is indistinct. Select rhyolites plot over an extended range above the end of the Felsic Trend. Altered felsic to intermediate rocks overlap most the range of select rocks, and extend it to lower Ga (Fig. A2.24f). Some altered mafic rocks plot close to the Mafic Segment, but others plot as much as 20 ppm above of below (mainly below) it.

Ce v Cr (Fig. A2.24h,j,l) distinguishes the BV from most BVSP Reference Arc and OFB basalts (lower Ce, greater Cr range), from Primitive MORB and Average Continental Crust (lower Ce) and from most OIP basalts and Hawaiian Nepheline Melilitite (higher Ce and/or Cr). There is significant overlap of the ranges of BVSP Reference Continental basalts but those have greater Cr and Ce ranges. M-type granitoids partly overlap BV felsic and intermediate rocks but range to lower Ce. I-type granitoids also overlap the BV range, but most have considerably higher Ce. Regional comparisons (Fig. A2.24n,p,r,t) show that the BV overlap the Werrie Basalt range and the middle of the extended ranges of Hillgrove and Copeton Plutonic Suite granitoids. The BV range is lower in Ce than most Halls Peak volcanics, the unassigned volcanic rocks from Boggabri, and most Tertiary volcanic rocks, but is higher than most Early Permian central NEO mafic complexes (the latter also have a greater Cr range). Higher Cr largely distinguishes the Petroi Metabasalt range.

In summary, select BV display a significant increase in Ce in the basalt range, then a gentler increase across the remainder of the range, apart from leucocratic pyroxenerhyolite lavas which are distinctly less enriched than biotite rhyolites. SOB_{12} contains more Ce than Primitive MORB (3.8x), Fuji basalt and E-MORB but less than Hawaiian Nepheline Melilitite, Rindjani basalt, Average Continental Crust, OIB and Mole Granite. Si-Cr-Ce systematics for select BV indicate similar levels of Ce to BVSP OIP tholeiitic basalt, Werrie Basalt, and S-type granitoids, more Ce than BVSP Arc and OFB basalts, Early Permian mafic complexes and M-type granitoids, but less Ce than BVSP OIP alkalic volcanic rocks, some BVSP Continental basalts, most I- type granitoids, Tertiary Nandewar volcanic rocks, Halls Peak volcanics, and unassigned Boggabri Volcanics.

Niobium

Nb ranges from 3.2 ppm to 11.9 ppm with the distribution nearly symmetrical around a median value of 7.5 ppm (Fig. A2.25a). Select rocks range from 4.1 ppm (SOB_{12}) to 11.9 ppm ($SFBR_{04}$). The BV range is within the lower range of common igneous rocks (typically x ppm to x0 ppm, less commonly x00 ppm — Wedepohl, 1978).

Nb in SOB_{12} is depleted relative to Hawaiian Nepheline Melilitite (0.08x), OIB (0.09x), Average Continental Crust (0.37x), E-MORB (0.49x), and Rindjani basalt (0.82x) but is enriched relative to Primitive Fuji (1.24x), MORB (1.76x), and pyrolite (6.2x). Abundance patterns (Fig. A2.25b) exhibit a gradual increase across the basalt-rhyolite range to 2.9x in $SFBR_{04}$, with minor lows at SOA_{10}, and SED_{05} and a distinct drop to leucocratic pyroxene rhyolite lavas. Overall, select BV are enriched relative to Fuji basalt and Primitive MORB but are depleted relative to OIB, Hawaiian Nepheline Melilitite and Mole Granite. The basalt-dacite range is generally enriched and rhyolites are generally depleted relative to E-MORB and Average Continental Crust, whereas for Rindjani basalt, depletion is limited to basalts. For SOB_{12}, Primitive MORB and Fuji basalt are complementary to Rindjani basalt, E-MORB, Average Continental Crust, Mole

Granite, Hawaiian Nepheline Melilitite and OIB.

On **Nb v SiO_2** (Fig. A2.25c), select rocks show a Main Trend comprising a very short, near-vertical, positive-slope in the Mafic Segment, a gently inclined, positive slope in the Intermediate Segment and a short, negative slope in the Felsic Segment. SOA_{10} plots distinctly below all trends. SFA_{09} and SED_{05} plot along the Main Trend. SAD_{24} plots above the Main Trend, and the Dyke Trend is distinct and normal to the Main Trend. Select rhyolites are scattered and most plot as much as 1.5x the Felsic Trend. Altered rocks (Fig. A2.25e) are scattered but overall define an array that broadly increases with increasing silica. This array broadly parallels Cross Trend 1. Silicified basaltic andesite, and some of the altered dacites and rhyolites, plot significantly above this array, whereas silicified basalt plots well below.

Nb v SiO_2 (Fig. A2.25g,i,k) shows that the BV mafic rocks overlap the uppermost range of BVSP Reference Arc basalts, the lower range of Continental basalts and OFB basalts. OIB tholeiitic basalts have higher Nb, and OIB alkalic volcanic rocks have substantially higher Nb (ranging to 10x SOB_{12}). Primitive MORB contains less Nb than BV Mafic volcanic rocks, whereas Average Continental Crust and Mole Granite contain more than BV at comparable SiO_2. The BV range is higher than that of most select M-type but overlaps that of I-type granitoids (other than fractionated Moonbi Plutonic Suite granitoids which range to much higher Nb). Regional comparisons (Fig. A2.25m,o,q,s) show that the BV overlap the range of the Werrie Basalt, the Halls Peak volcanics and the unassigned volcanic rocks from Boggabri. The Petroi Metabasalt has much higher Nb, as do all Tertiary volcanic rocks, whereas most Early Permian central NEO mafic complexes have lower Nb. The BV range overlaps part of the extended range of Hillgrove and Copeton Plutonic Suite granitoids, and the Late Carboniferous volcanic rocks.

On **Nb v Cr** (Fig. A2.25d), select rocks show a Main Trend comprising a gently inclined, positive Mafic Segment, a steep, positive, Intermediate Trend and a short, steep negative Felsic Segment. SOA_{10} plots distinctly below all trends. SFA_{09} and SED_{05} virtually coincide along the Main Trend. SAD_{24} plots above the Felsic Inflection and the Dyke Trend is distinct. Select rhyolites are scattered from the end of the Felsic Segment to about 1.5x higher. Altered intermediate to felsic rocks broadly overlap the range of select intermediate and felsic rocks (Fig. A2.25f). However, mafic rocks display considerable scatter with silicified basaltic andesite containing about 2x the trend equivalent and silicified basalt distinctly below trend.

Nb v Cr (Fig. A2.25h,j,l) largely distinguishes the BV from BVSP Reference Arc basalts (lower Nb, greater Cr range) and from many Oceanic and Continental basalts (marginally to significantly higher Nb, greater Cr range). M-type granitoids generally have lower Nb (minor overlap). I-type granitoids partly overlap the BV range, but most have higher Cr or higher Nb compared to BV Felsic and Intermediate Segments. Regional comparisons (Fig. A2.25n,p,r,t) show that the BV overlap the range of the Werrie Basalt, the Halls Peak volcanics and the unassigned volcanic rocks from Boggabri. The Petroi Metabasalt and Tertiary volcanic rocks have much higher Nb, whereas most Early Permian central NEO mafic complexes have lower Nb (however, note some overlap). The BV range partly overlaps the extended range of Hillgrove and Copeton Plutonic Suite granitoids, and the Late Carboniferous volcanic rocks.

In summary, select BV display a steady increase in Nb across the basalt-rhyolite range (2.96x SOB_{12}) marked by minor lows, and a distinct drop to leucocratic pyroxene rhyolite lava. SOB_{12} contains more Nb than Primitive MORB (1.76x) and Fuji basalt but less than Rindjani basalt, E-MORB, Average Continental Crust, Mole Granite, Hawaiian Nepheline Melilitite and OIB. Si-Cr-Nb systematics for select BV indicate similar levels of Nb to OFBs, Werrie Basalt, unassigned Boggabri Volcanics and Halls Peak volcanics, and some I-type granitoids, more Nb than most BVSP Arc basalts, Early Permian mafic complexes, M-type granitoids, and most S-type granitoids but less Nb than most BVSP Continental and OIP basalts (especially alkalic OIP basalts), Petroi Metabasalt, Tertiary Nandewar basalts, most Hillgrove S-type granitoids and especially Tertiary Nandewar volcanic rocks and evolved Moonbi I-type granitoids.

Thorium

Th ranges from < 0.5 ppm to 22.7 ppm (#40 — altered dacite) with only two values above 15 ppm (Fig. A2.26a). Select rocks range from 1.2 ppm (SOB_{12}) to 11.8 ppm ($SMPR_{06}$). The BV range is within the range of common igneous rocks (typically x00 ppb to x0 ppm — Wedepohl, 1978).

Th in SOB_{12} is depleted relative to Hawaiian Nepheline Melilitite (0.12x), Rindjani basalt (0.18x), OIB (0.31x), Average Continental Crust (0.35x) and Fuji basalt (0.89x), but is enriched relative to E-MORB (2.1x), Primitive MORB (10x) and pyrolite (16x). Abundance patterns (Fig. A2.26b) exhibit a significant increase in the olivine basalt-andesite range (to 5.2x SOB_{12}), followed by gradual increase to 8.2x SOB_{12} in $SLPR_{08}$. This trend is marked by two small peaks: SAD_{24} at 3.6x SOB_{12} and $SMPR_{06}$ at 9.5x SOB_{12}. Overall, the BV range is enriched relative to Primitive MORB and E-MORB, mainly enriched relative to Fuji basalt, but mainly depleted relative to Mole Granite and Hawaiian Nepheline Melilitite (except some rhyolites). Relative to OIB, Rindjani basalt and Average Continental Crust, rhyolites are mainly enriched, basalts are mainly depleted and intermediate rocks are variable. For SOB_{12}, Mole Granite, Average Continental Crust, OIB, Rindjani basalt, Fuji basalt and Hawaiian Nepheline Melilitite are complementary to Primitive MORB and E-MORB.

On **Th v SiO_2** (Fig. A2.26c), select rocks show a Main Trend comprising virtually no change among mafic rocks, a moderately steep, positive slope in the Intermediate Segment and a short, moderately steep negative slope in the Felsic Segment. SOA_{10} plots significantly below all trends. SAD_{24} also plots well below the Main Trend resulting in a well developed Dyke Trend that is nearly normal to the Intermediate Segment. In contrast, SFA_{09} and SED_{05} plot along the Main Trend. Three select rhyolites plot along the Felsic Segment but another three form a discrete cluster at lower Th. Most altered basaltic to dacitic rocks (Fig. A2.26e) plot below the Main Trend, other than a few dacites which plot above it. Two altered rhyolites plot along the Felsic Segment, but most are displaced to lower Th and/or higher SiO_2. Some white rhyolites are displaced towards 100% SiO_2.

Th v SiO_2 (Fig. A2.26g,i,k) shows that the BV mafic rocks overlap the range of BVSP Reference Arc Continental and Oceanic basalts. Primitive MORB and Average Continental Crust indicate similar Th to BV at comparable SiO_2, but Mole Granite has far greater Th. The BV range overlaps that of the middle of the extended range of select M-type. I-type granitoids exhibit an extended Th range which is systematically higher than that of the BV. Regional comparisons (Fig. A2.26m,o,q,s) show that the BV overlap the range of mafic comparative data, apart from unassigned volcanic rocks from Boggabri (distinctly higher Th), but generally have lower Th than comparative felsic data sets.

On **Th v Cr** (Fig. A2.26d), select rocks show a Main Trend comprising a nearly flat Mafic Segment (≈ 1.5 ppm Th), a steep, positive, 'Intermediate' and a short, steep short negative Felsic Trend. SOA_{10} plots between the Main Trend and Cross Trend 2. SFA_{09} and SED_{05} plot along the Main Trend. SAD_{24} plots beside the Main Trend, and the Dyke Trend almost coincides with the Main Trend. Three select rhyolites plot along the Felsic Segment whereas the other three plot along the Intermediate Segment. Altered andesitic to rhyolitic rocks cluster along the Intermediate and Felsic Trends, whereas basaltic rocks are more scattered adjacent to the Mafic Segment (Fig. A2.26f).

Th v Cr (Fig. A2.26h,j,l) shows that a lesser Cr range is the main difference between the BV and BVSP Reference Arc, Continental and Oceanic basalts, as well as Primitive MORB, Hawaiian Nepheline Melilitite and Average Continental Crust. Select M-type granitoids overlap the BV range, extending to higher Th, whereas all I-type granitoids have higher Th (up to 5x) and Mole Granite has extremely high Th. Regional comparisons (Fig. A2.26n,p,r,t) indicate that BV mafic compositions are similar to the Werrie Basalt and Tertiary basalts, and partially overlap the range of Early Permian central NEO mafic complexes. Unassigned volcanic rocks from Boggabri and felsic comparative suites generally have higher Th than the BV.

In summary, select BV display a significant increase in Th from SOB_{12} to the rhyolite range (≈ 8x SOB_{12}). SOB_{12} contains more Th than Primitive MORB (10x) and E-MORB but less than Average Continental Crust, OIB, Fuji basalt, Rindjani basalt, Hawaiian Nepheline Melilitite and Mole Granite. Si-Cr-Th systematics for select BV indicate similar levels of Th to BVSP Arc and CRZ basalts, Early Permian central NEO mafic complexes, some Werrie Basalts and some M-type granitoids, more Th than OFBs and some Werrie Basalts, but less Th than BVSP CFBs and OIP alkalic basalts, I-type and most S-type granitoids, most Halls Peak volcanics, most Late Carboniferous volcanic rocks, unassigned Boggabri Volcanics and Tertiary Nandewar volcanic rocks.

Barium

Ba ranges from 162 ppm to 2597 ppm, with a peak at about 700 ppm. Only a few values (mainly rhyolitic pitchstones) contain more than 1400 ppm (Fig. A2.27a), and only one ($SFBR_{25}$ — rhyolitic ignimbrite pitchstone) contains more than 2000 ppm. Select rocks range from 205 ppm (SOB_{12}) to 2597 ppm ($SFBR_{25}$). The BV range is within the range of common igneous rocks (typically x0 to x00 ppm — Wedepohl, 1978).

Ba in SOB_{12} is depleted relative to Hawaiian Nepheline Melilitite (0.25x) and OIB (0.77 x) but is enriched relative to Fuji basalt (1.02x), Average Continental Crust (1.08x), Rindjani basalt (1.63x), E-MORB(4.7x), pyrolite (41x) and Primitive MORB (43x). Abundance patterns (Fig. A2.27b) exhibit an irregular but sustained enrichment across the BV range, to a peak at $SFBR_{25}$ (9.6x SOB_{12}), followed by lower values among leucocratic pyroxene rhyolite lavas (5 to 7.2 x SOB_{12}). SOB_{12} is anomalously high compared to SPB_{39} (0.76x SOB_{12}) and the general trend, and $SFBR_{04}$ (5x SOB_{12}) is anomalously low. Overall, select BV are enriched relative to all reference compositions except for SPB_{39} relative to Average Continental Crust and Fuji basalt, basalts relative to OIB and Rindjani basalt, and the basalt-dacite range relative to Hawaiian Nepheline Melilitite. For SOB_{12}, Hawaiian Nepheline Melilitite, Rindjani basalt and OIB are complementary to Primitive MORB, E-MORB, Fuji basalt, Average Continental Crust and Mole Granite.

On **Ba v SiO_2** (Fig. A2.27c), select rocks show a Main Trend comprising a very short, near-vertical, negative-slope in the Mafic Segment, an inclined, positive slope in the Intermediate Segment and a steep positive slope in the Felsic Segment. SOA_{10} plots on the Main Trend, whereas SFA_{09}, SAD_{24} and SED_{05} plot along the Main Trend and the Dyke Trend is indistinct. Select rhyolites are loosely clustered along the Felsic Segment, except for one ($SFBR_{25}$) at considerably higher Ba. Altered basaltic to dacitic rocks (Fig. A2.27e) form a crude linear array that is slightly flatter than the Main Trend. Most altered rhyolites plot at considerably lower Ba and/or higher SiO_2 than the Main Trend, but one plots along the end of the Main Trend.

Ba v SiO_2 (Fig. A2.27g,i,k) shows that the BV mafic rocks plots within the range of BVSP Representative Arc and OIB basalts, but plots towards the extreme lower range of BVSP Representative Continent analyses. The BV range is marginal to the upper limit of the range of select M-type granitoids, and the BV Main Trend cuts obliquely across the middle of the extensive range of select I-type granitoids. Regional comparisons (Fig. A2.27m,o,q,s) show that the BV indicate similar Ba contents at equivalent SiO_2 to the Werrie Basalt, the middle of the Petroi Metabasalt range, some Late Carboniferous volcanic rocks (many rhyolites have lower Ba), some intermediate Tertiary volcanic rocks. In contrast, the BV have lower Ba than the unassigned volcanic rocks from Boggabri, and have marginally to substantially higher Ba than most Early Permian central NEO mafic complexes, the Hillgrove and Copeton Plutonic Suite granitoids and the Halls Peak volcanics.

On **Ba v Cr** (Fig. A2.27d), select rocks show a Main Trend comprising a nearly flat Mafic Segment (≈ 200 to 250 ppm Ba), and steep, positive, nearly colinear Intermediate and Felsic Segments. SOA_{10} plots between Cross Trends 1 and 2. SFA_{09}, SAD_{24} and SED_{05} plot along the Main Trend and the Dyke Trend is indistinct. Select rhyolites plot along the Main Trend or its projection. Altered andesitic to rhyolitic rocks mostly plot along the Intermediate Segment, with only a few along the Felsic Segment. Altered mafic rocks show considerable scatter, and mainly plot above the Mafic Segment and the Cross Trends (Fig. A2.27f).

Ba v Cr (Fig. A2.27h,j,l) distinguishes BV from Hawaiian Nepheline Melilitite, from most BVSP Reference Arc and OIB basalts (but note some overlap), and some Continental basalts (with high Cr), and most I-type granitoids (note mid-range cross-over of contrasting trends), but shows overlap of select M-type granitoids. The steep negative trend of the Moonbi granitoids is striking compared to that of the BV Main Trend and of the Uralla granitoids. Regional comparisons (Fig. A2.27n,p,r,t) indicate that **Ba v Cr** is a poor discriminant and the only significant features are the greater Cr range of the Petroi Metabasalt and the Early Permian central NEO mafic complexes (which partly overlaps the BV range).

In summary, select BV display a general and significant increase in Ba to 5 to 7.2 x SOB_{12} among rhyolites, marked by anomalously low values for SOB_{12} and $SFBR_{04}$. SOB_{12} contains more Ba than Primitive MORB (43x), Mole Granite, E-MORB, Fuji basalt and Average Continental Crust, but less than OIB, Rindjani basalt and Hawaiian Nepheline Melilitite. Si-Cr-Ba systematics for select BV indicate similar levels of Ba to BVSP OIP tholeiitic volcanic rocks, Petroi Metabasalt, and Werrie Basalt, and some Late Carboniferous volcanic rocks, more Ba than BVSP Oceanic tholeiitic basalts, Primitive MORB, Early Permian central NEO volcanic rocks, and M- and S-type granitoids but less

Ba than Hawaiian Nepheline Melilitite, many BVSP Continental basalts, some Tertiary Nandewar volcanic rocks, and unassigned Boggabri Volcanics. **Ba v SiO_2** shows a positive trend opposite that for I-type Moonbi granitoids.

Rubidium

Rb ranges from 6 ppm to 136 ppm (Fig. A2.28a). Select rocks range from 8 ppm (SOB_{12}) to 136 ppm ($SMPR_{06}$). The BV range is within the range of common igneous rocks (typically x ppm to x0 ppm, less commonly x00 ppm — Wedepohl, 1978).

Rb in SOB_{12} is depleted relative to Hawaiian Nepheline Melilitite (0.23x), OIB (0.26x), Average Continental Crust (0.26x), Rindjani basalt (0.37x), Fuji basalt (0.48x), but is enriched relative to E-MORB (1.6x) and Primitive MORB (14.6x). Abundance patterns (Fig. A2.28b) are flat for basalt and rhyolites other than $SLPR_{13}$ (an ignimbrite at 7.6x SOB_{12}), but steadily increase in between. Overall, select BV are enriched relative to Primitive MORB and E-MORB, but are depleted relative to Mole Granite. Relative to Hawaiian Nepheline Melilitite, OIB, Rindjani basalt and Average Continental Crust, relative to Fuji basalt, the olivine basalt-olivine andesite range is generally depleted and the dacites and rhyolites are enriched. For SOB_{12}, Mole Granite, Hawaiian Nepheline Melilitite, OIB, Rindjani basalt, Fuji basalt and Average Continental Crust are complementary to Primitive MORB and E-MORB.

On **Rb v SiO_2** (Fig. A2.28c), select rocks show a Main Trend comprising virtually no change in the Mafic Segment whereas the Intermediate Segment is moderately steep, positive and long, and the Felsic Segment is also positive but shorter and steeper. SOA_{10} plots distinctly below all trends. SFA_{09} and SED_{05} plot distinctly off the Main Trend. SAD_{24} plots distinctly below the Main Trend and the Dyke Trend is indistinct. Select rhyolites are mainly scattered adjacent to the Felsic Segment, but one sample is notably off-trend ($SLPR_{13}$) at about half the Rb of the most felsic samples. Altered mafic to intermediate rocks (Fig. A2.28e) are mainly scattered along the Main Trend whereas rhyolites systematically plot below the Felsic Trend, and two silicified rhyolites contain less than 20 ppm Rb.

Rb v SiO_2 (Fig. A2.28g,i,k) shows that the BV mafic rocks overlap the range of BVSP Representative Arc and OFB basalts and Primitive MORB, but plots at the lower extreme of the range of BVSP Representative Continental analyses. Some BVSP Representative Oceanic data (tholeiites) overlap the Mafic Segment, but alkalic rocks plot at higher levels than the Mafic and Intermediate Segments. The BV range overlaps Average Continental Crust and the upper range of select M-type granitoids, but is substantially lower than that of I-type granitoids. Regional comparisons (Fig. A2.28m,o,q,s) show that the BV range overlaps that of the Petroi Metabasalt, many of the Halls Peak and Late

Carboniferous volcanic rocks (but both groups range to higher Rb) and the unassigned volcanic rocks from Boggabri, and partly overlaps the range of Early Permian central NEO mafic complexes. In contrast, the BV has marginally higher Rb than the Werrie Basalt, and marginally to substantially lower Rb than Hillgrove and Copeton granitoids and Tertiary volcanic rocks.

On **Rb v Cr** (Fig. A2.28d), select rocks show a Main Trend comprising a nearly flat Mafic Segment (≈ 8 ppm Rb), and steep, negative, nearly colinear 'Intermediate' and 'Felsic' Trends. SOA_{10} plots slightly below Cross Trend 2. SFA_{09}, SAD_{24} and SED_{05} plot along the Main Trend and the Dyke Trend is indistinct. Select rhyolites mainly cluster around the end of the Felsic egment. Altered rocks generally plot along the Main Trend, but two silicified rhyolites and silicified basalt are obviously anomalous (Fig. A2.28f).

Rb v Cr (Fig. A2.28h,j,l) largely distinguishes the BV from I-type granitoids, Hawaiian Nepheline Melilitite and Primitive MORB, whereas BV partly overlap Average Continental Crust and the range of BVSP Representative Arc, Continental and Oceanic basalts and completely overlap the range of select M-type granitoids. Regional comparisons (Fig. A2.28n,p,r,t) indicate that the BV range overlaps that of Werrie Basalt, some Late Carboniferous volcanic rocks (most have higher Cr or higher Sr), most Tertiary volcanic rocks, and unassigned volcanic rocks from Boggabri, and partly overlaps the range of Halls Peak volcanics. However, higher Cr and/or higher Sr distinguishes the Hillgrove and Copeton, most Petroi Metabasalt, and most Early Permian central NEO mafic complexes. Mole Granite has much higher Rb.

In summary, select BV displays flat trends for basalt and rhyolite (excepting anomalously low $SLPR_{13}$) and a significant increase in the andesite-rhyolite (to 16.6x SOB_{12}). SOB_{12} contains more Rb than Primitive MORB (13.7x), Fuji basalt and E-MORB, but less than Hawaiian Nepheline Melilitite, Rindjani basalt OIB and Mole Granite. Si-Cr-Rb systematics for select BV indicate similar levels of Rb to BVSP Arc, some Continental and OIP tholeiitic basalts, more Rb than OFBs, some Werrie Basalts, and most M-type granitoids, but less Rb than OIP alkalic basalts, Tertiary Nandewar volcanic rocks, some Early Permian central NEO volcanic rocks, I- and S-type granitoids, and many Late Carboniferous volcanic rocks.

Cesium

Cs ranges from <1 ppm to 40 ppm for both select and altered samples. Only seven samples contain more than 10 ppm Cs (Fig. A2.29a). One of these is an altered rock, the remainder are select rhyolites. Fifteen samples have <1 ppm Cs (INAA detection limit).

The BV range is within that of common igneous rocks (x0 ppb to x ppm and possibly x0 ppm — Wedepohl, 1978), with that of select rhyolites being conspicuously high.

SOB_{12} data are not available, so comparison is based on SPB_{39}. Cs in SPB_{39} is enriched relative to Average Continental Crust (2.57x), Hawaiian Nepheline Melilitite (3.2x), OIB (6.6x), Rindjani basalt (11.18x), E-MORB (41x), pyrolite (122x base of 0.21 ppm — McDonough and Sun, 1995), and Primitive MORB (367x). Abundance patterns (Fig. A2.29b) exhibit minor variations in the basalt-dacite range (1–1.64x SPB_{39}) and a significant jump up to rhyolite compositions (12.5x to 15.7x SPB_{39}) except for $SMPR_{06}$ at 8.03x SPB_{39}. Overall, select BV are enriched relative to SPB_{39}, with most rhyolites being over 1000x Primitive MORB. For SPB_{39}, there are no complementary relationships, due to high Cs.

SOB_{12} and SOA_{10} are below detection limit (< 1 ppm Cs) and therefore the calculated Mafic Segment and Cross Trend 1 are meaningless on **Cs v SiO_2** and **Cs v Cr**. On **Cs v SiO_2** (Fig. A2.29c) select rocks shows negligible change in the Intermediate Segments, but shows a steep positive slope in the Felsic Segment. Select andesite and dacites plot along the Main Trend and therefore the Dyke Trend is indistinct. Select rhyolites are mainly clustered above the Felsic Segment, close to its upward projection. Altered rocks (Fig. A2.29e) almost all have very low Cs, close to detection limits).

On **Cs v Cr** (Fig. A2.29d) the Intermediate Trend is very short and negative, whereas the Felsic Trend is steep and positive. Andesitic to dacitic rocks plot along the Intermediate Segment, and the Dyke Trend is indistinct. Select rhyolites plot along the Felsic Segment or close to its upward projection. Altered rocks generally have low Cs (Fig. A2.29f).

Too few of the comparative data sets contain Cs data for further analysis.

In summary, select BV display an irregular, flat trend in the basalt-dacite range (1.64x SPB_{39}), followed by a steep increase to (mainly 12.5x to 15.7x SPB_{39}), except for lower value for $SMPR_{06}$. SPB_{39} contains more Cs than Primitive MORB (367x), E-MORB, OIB, Fuji and Rindjani basalt and Average Continental Crust.

OTHER TRACE ELEMENTS

Co and W were analysed, but are not reported as these are major contaminants in tungsten carbide equipment (e.g. Tema mills) used in preparing BV samples for analysis.

A number of other elements have been analysed, namely As, Au, Br, Sb, Ta, U. These are reported only briefly, because many data are below or close to detection limit or display erratic patterns, and primary patterns could be masked by contamination or hydrothermal overprint.

Ag, Ir, Mo, Se, and Te were also analysed but were consistently below detection limits of 5 ppm, 20 ppb, 5 ppm, 5 ppm and 5 ppm respectively.

Arsenic

As data are below detection limit (1 ppm) in 19 samples, between 1.5 ppm and 10.5 ppm in 25 samples, and 19 ppm in one anomalous sample (#02) (Fig. A2.30a). Select rocks range from ppm < 1 ppm to 7.2 ppm (SMPR$_{06}$).

As in SPB$_{39}$ is depleted relative to Mole Granite (0.31x SPB$_{39}$), and enriched relative to Average Continental Crust (2.72x), Primitive MORB (4.54x), and pyrolite (54x). Abundance patterns (Fig. A2.30b) are erratic and but rhyolites are enriched (1.9 to 2.6x SPB$_{39}$) relative to other compositions. Overall, the BV range is enriched relative to Primitive MORB, and Average Continental Crust. There are no complementary abundance relationships.

Gold

Au ranges from < 5 ppb to 77 ppb (Fig. A2.30a). Select rocks range from < 5 ppb (SOB$_{12}$) to 54.4 ppm (SAD$_{24}$). Only six of the twelve select samples have gold above the detection limit of 5 ppb.

Au SOB$_{12}$ is enriched relative to Primitive MORB (5.29x), Average Continental Crust (8.82x) and pyrolite (26.5x). Abundance patterns (Fig. A2.30b) are highly erratic. Most samples are about 20 to 30 x SOB$_{12}$, but SAD$_{24}$ contains 54x SOB$_{12}$ and a select dacite (SMPR$_{06}$) contains 9x SOB$_{12}$. Overall, the BV range is enriched relative to Primitive MORB and Average Continental Crust, and there are no complementary relationships.

The erratic nature of the abundance pattern, plus the fact that one of the highest Au values is in SAD$_{24}$ (dacitic vitrophyre from a dyke), raises the possibility of contamination. Vein quartz was used to clean the tungsten carbide Tema Mill in which powders were prepared for XRF analysis. This quartz contained traces of limonite (possibly after sulphides) and could also have contained a trace of gold. No impact on XRF analyses was then expected. However, subsequent use of these powders for INAA analysis (detection limit of 5 ppb for Au) raises the possible need for a revised sample preparation protocol to prevent Au (and possibly As) contamination.

Tantalum

Ta ranges from 1.16 ppm to 2.74 ppm in 23 samples. The rest are below detection limit (1 ppm). Nb/Ta ranges from 2 to 5x amongst basalts and andesites. This is significantly below the preferred primitive mantle ratio of 17. Therefore contamination from the tungsten carbide mill is suspected, and the results are discounted.

Uranium

U ranges from 2.3 ppm to 4.3 ppm in 4 samples. All of these samples are altered, and other samples (including all select rocks) contain less than 2 ppm (detection limit). Therefore systematic interpretation is not attempted.

Nickel

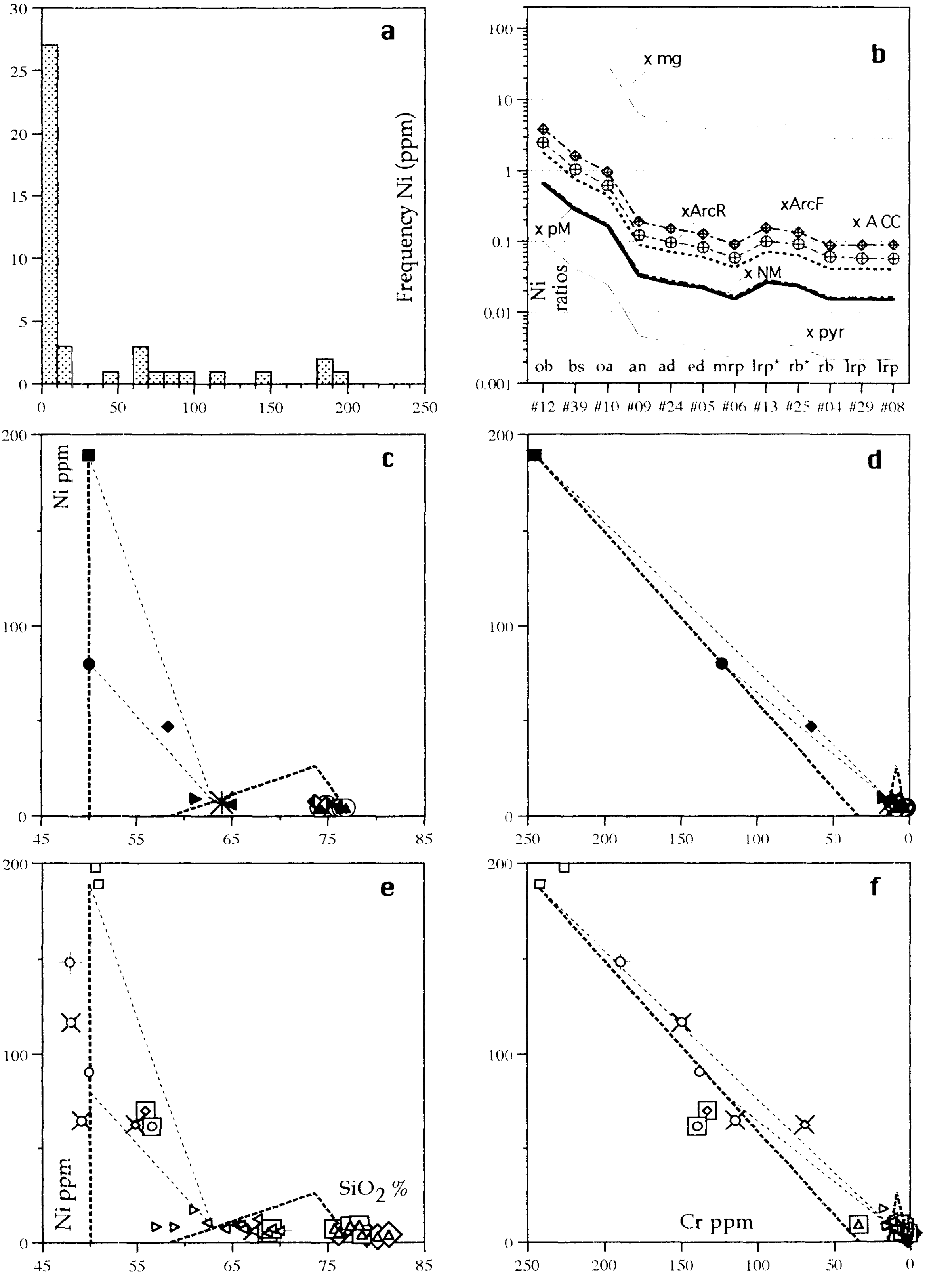


Fig. A2.13 (a–f): Ni in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

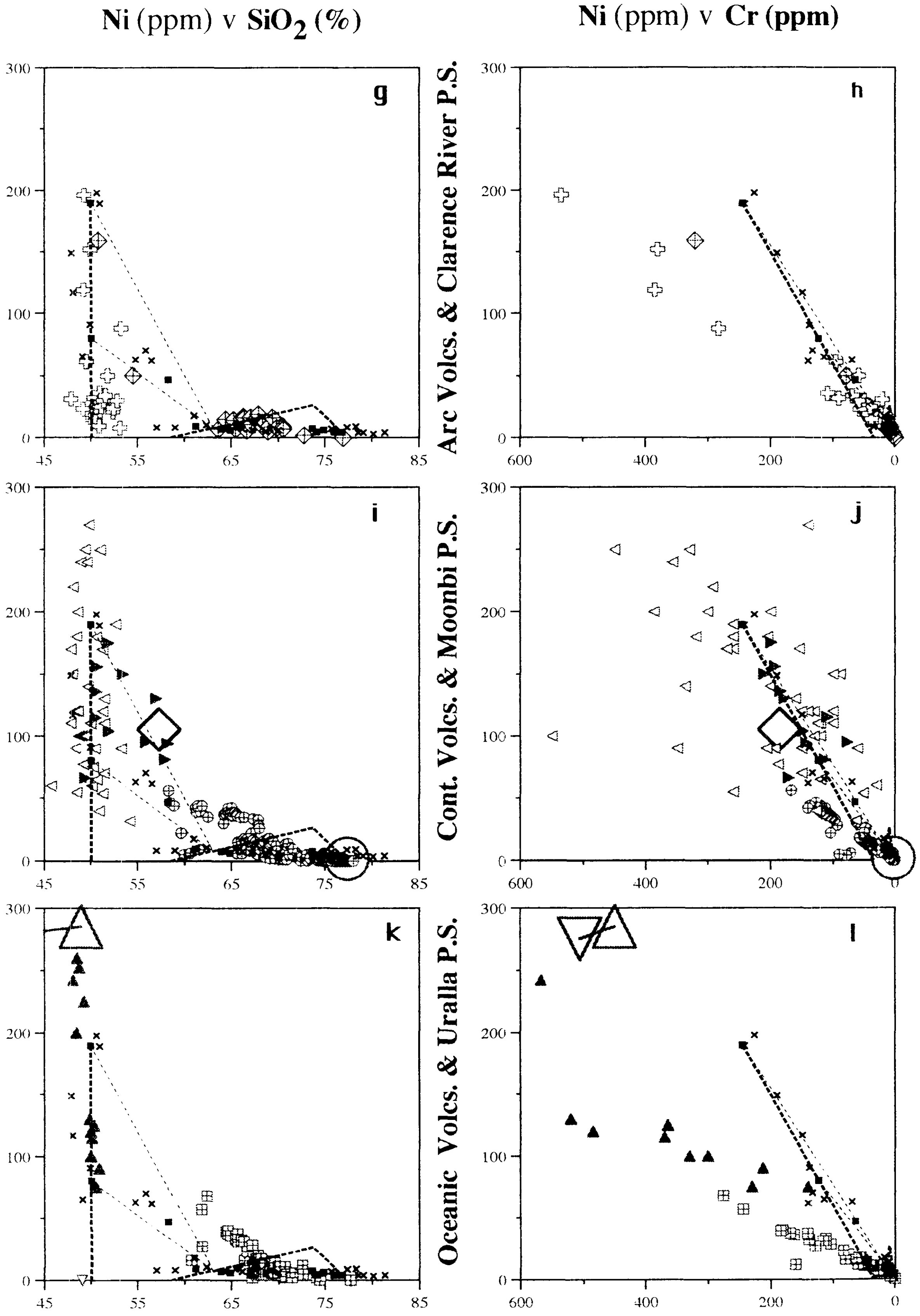


Fig. A2.13 (g–l): Ni in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites

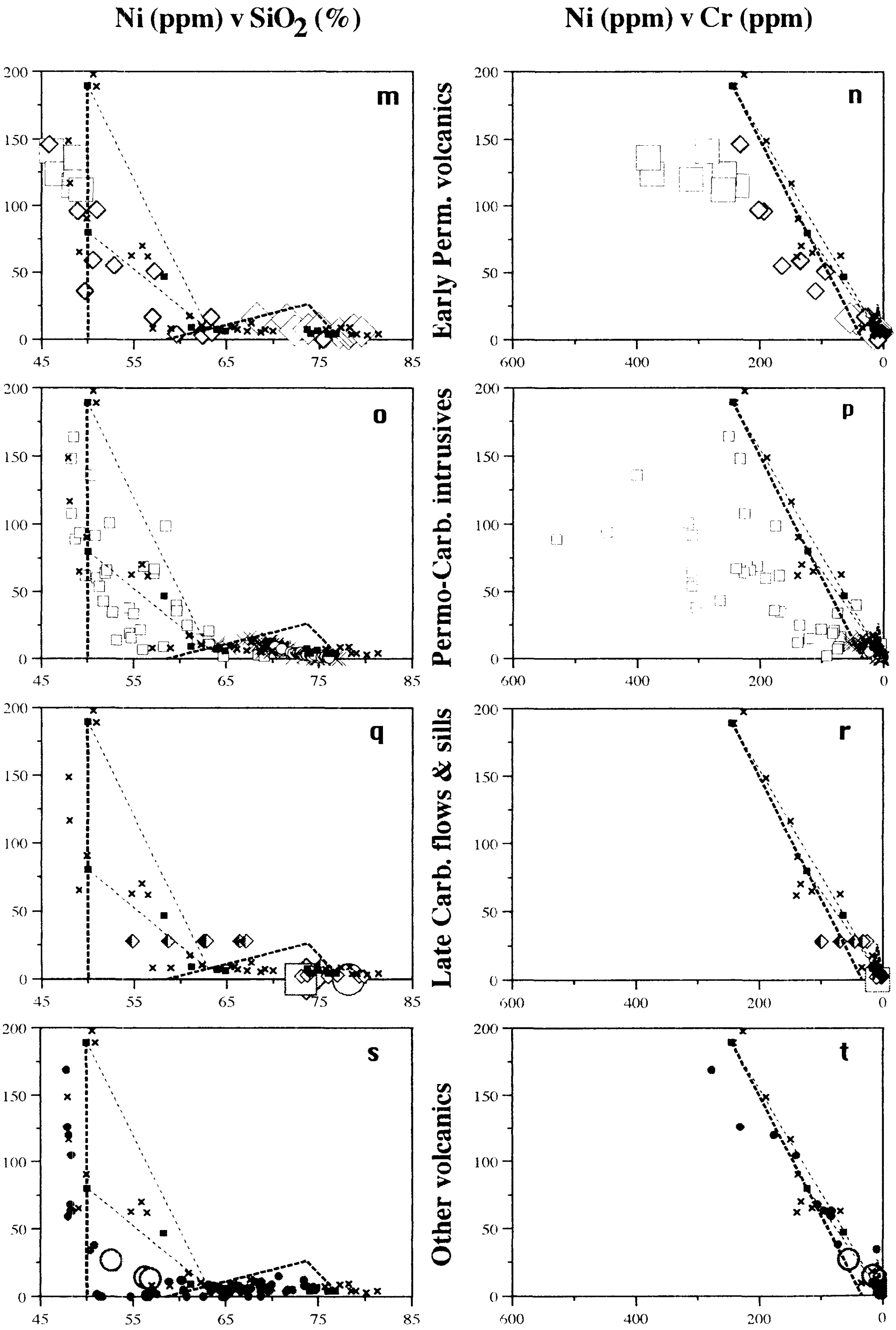


Fig. A2.13 (m–t): Ni in Boggabri Volcanics — regional comparisons

Copper

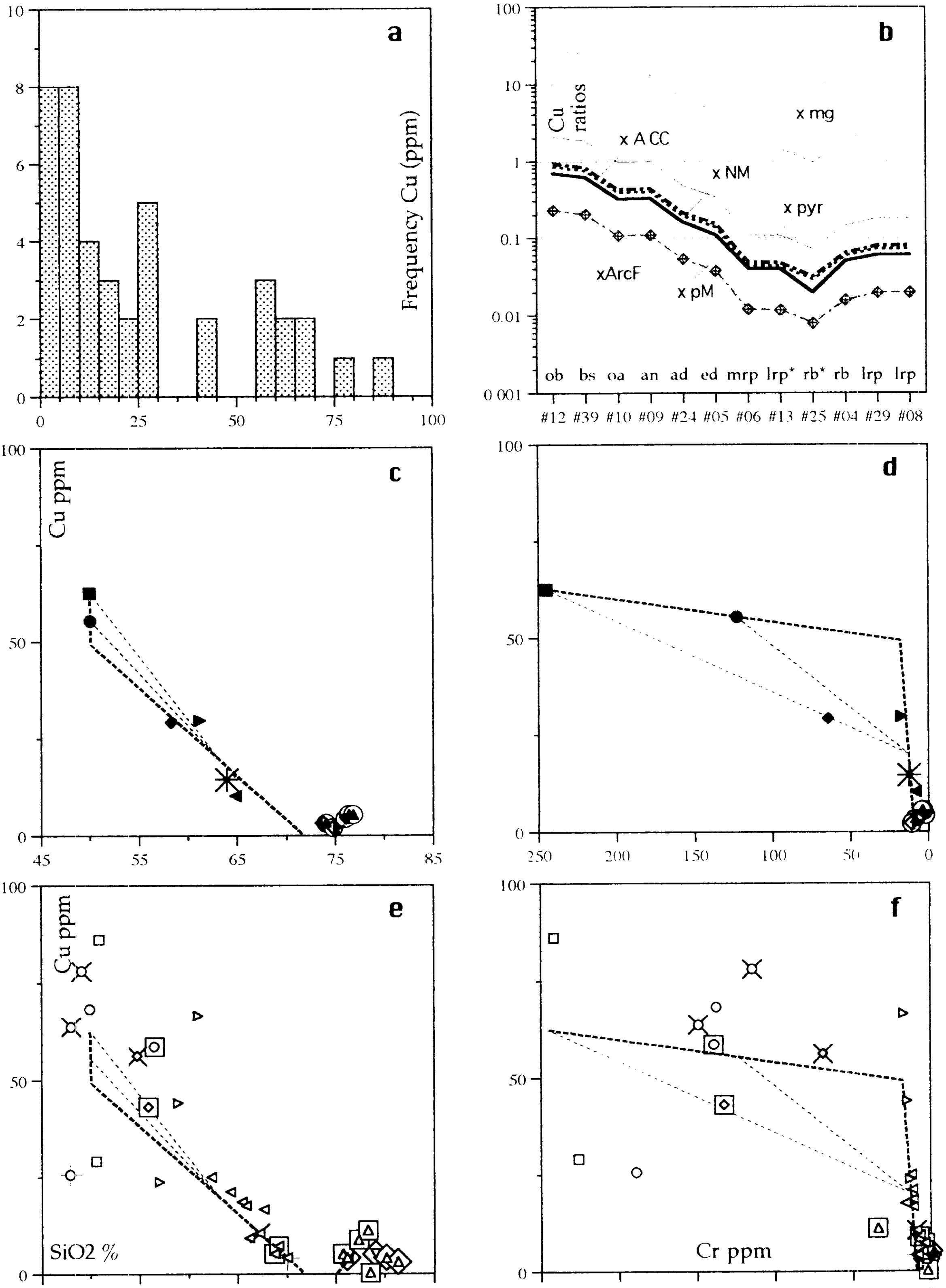


Fig. A2.14 (a–f): Cu in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

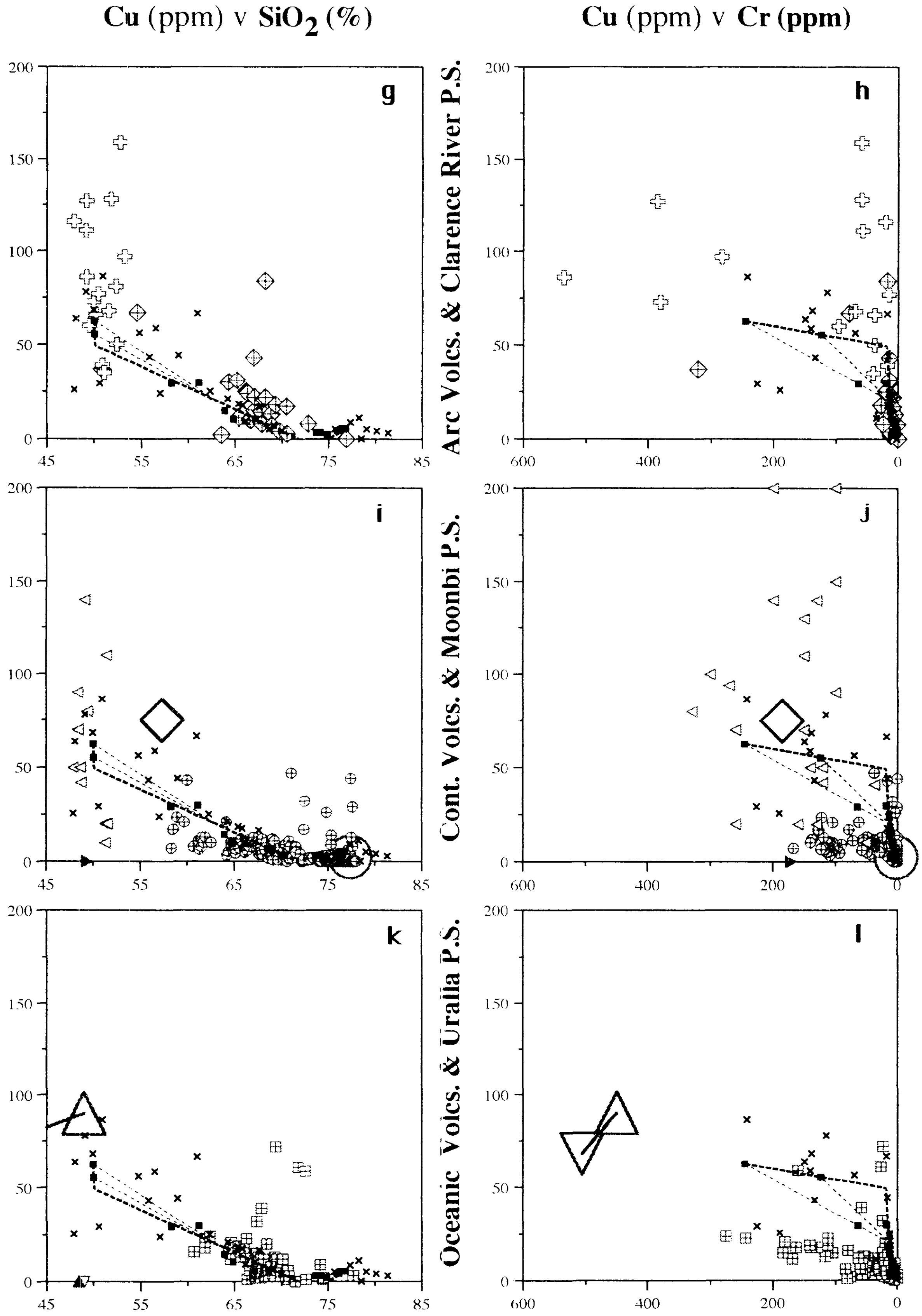


Fig. A2.14 (g–l): Cu in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites

Cu (ppm) v SiO_2 (%)

Cu (ppm) v Cr (ppm)

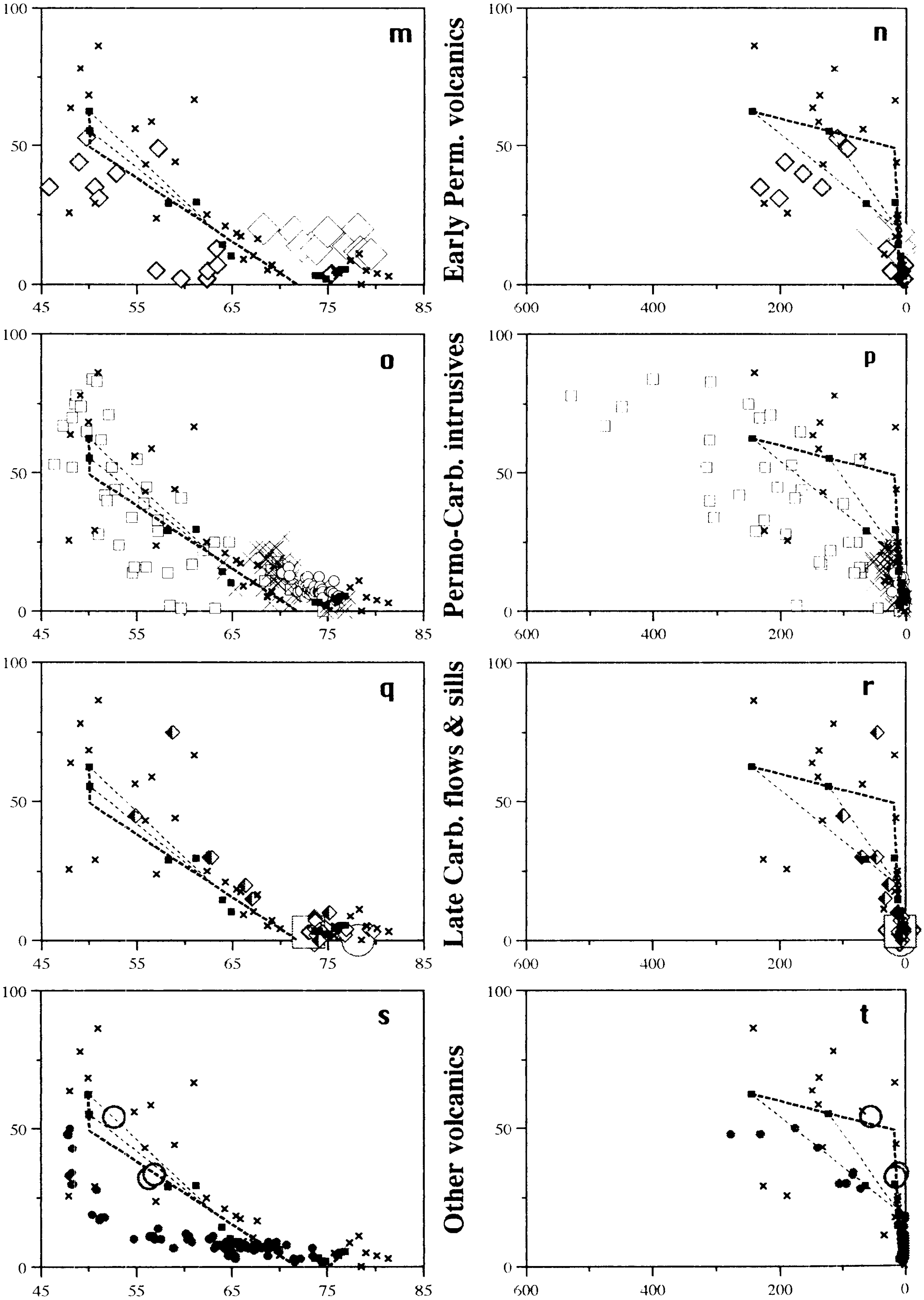


Fig. A2.14 (m–t): Cu in Boggabri Volcanics — regional comparisons

Zinc

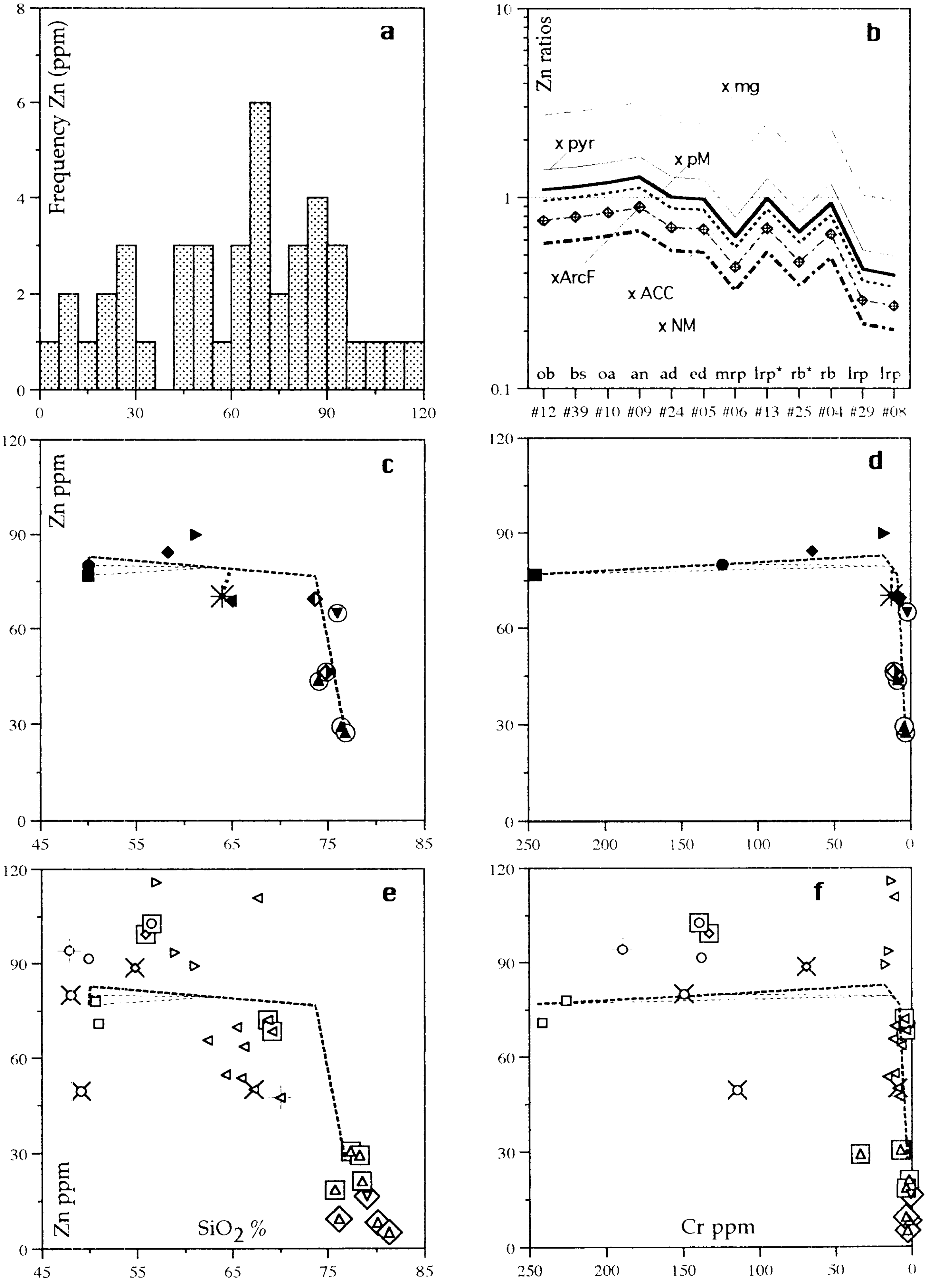


Fig. A2.15 (a–f): Zn in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

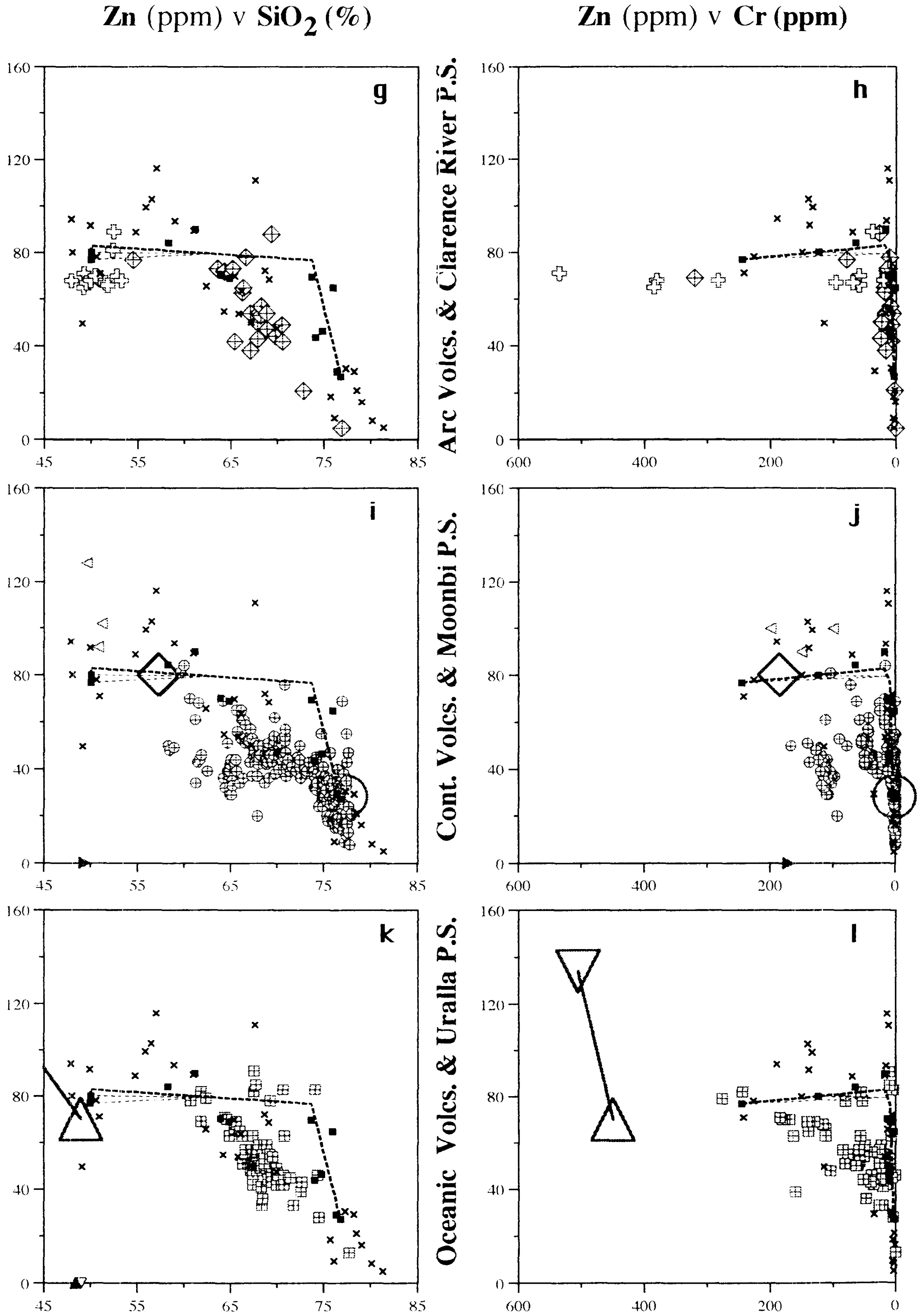
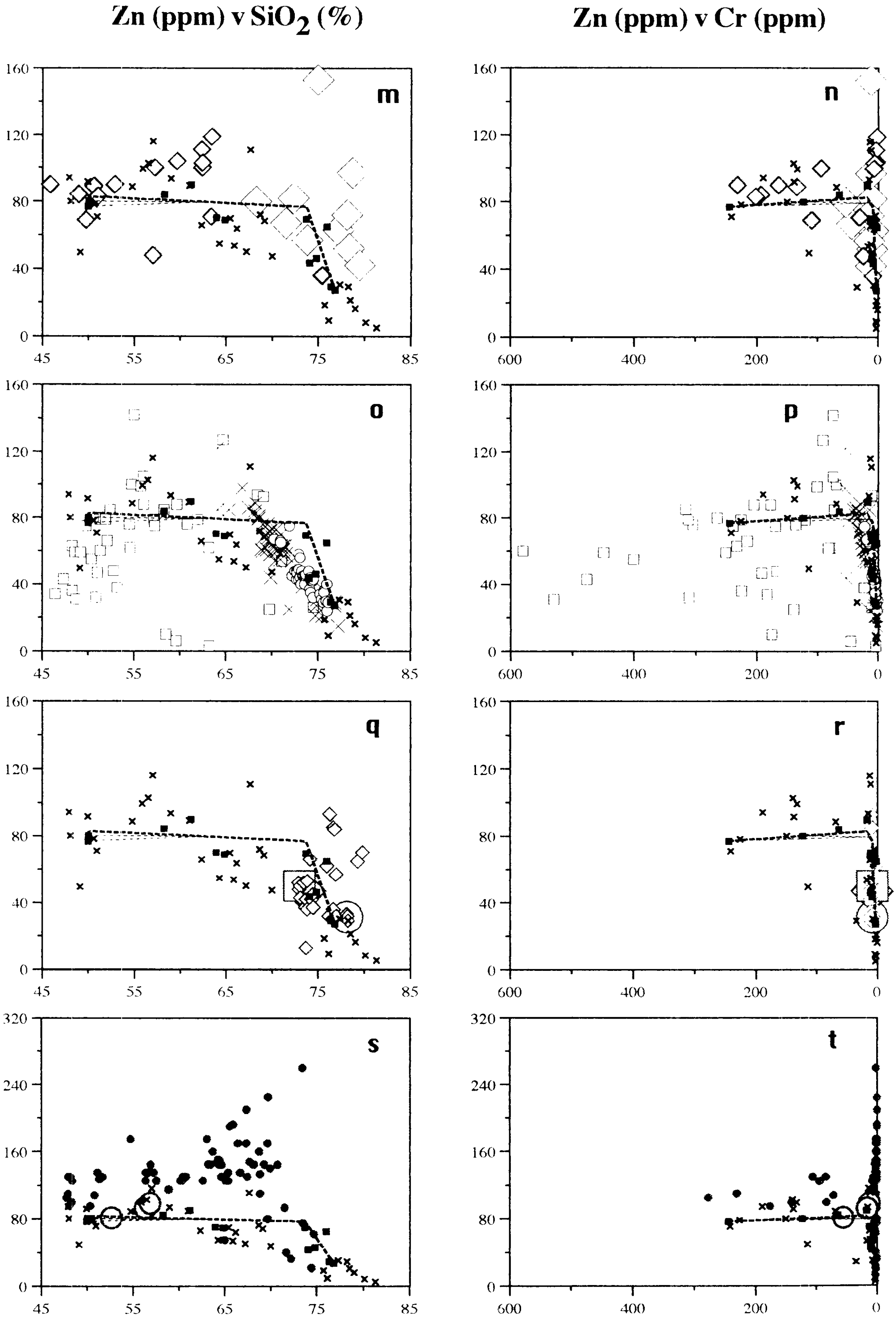


Fig. A2.15 (g–l): Zn in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites


Zn (ppm) v SiO_2 (%)

Zn (ppm) v Cr (ppm)

Fig. A2.15 (m–t): Zn in Boggabri Volcanics — regional comparisons

Scandium

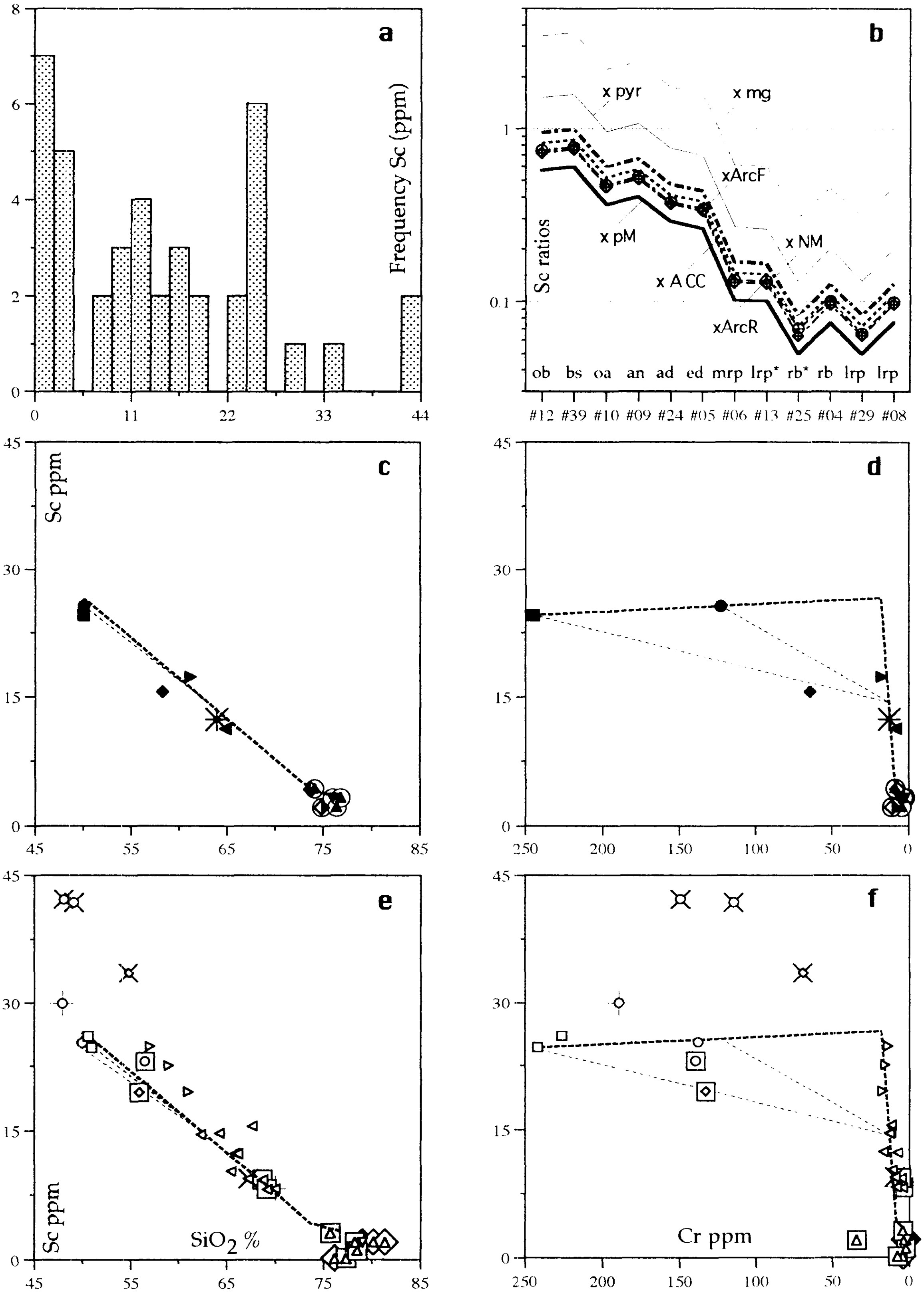


Fig. A2.16 (a–f): Sc in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

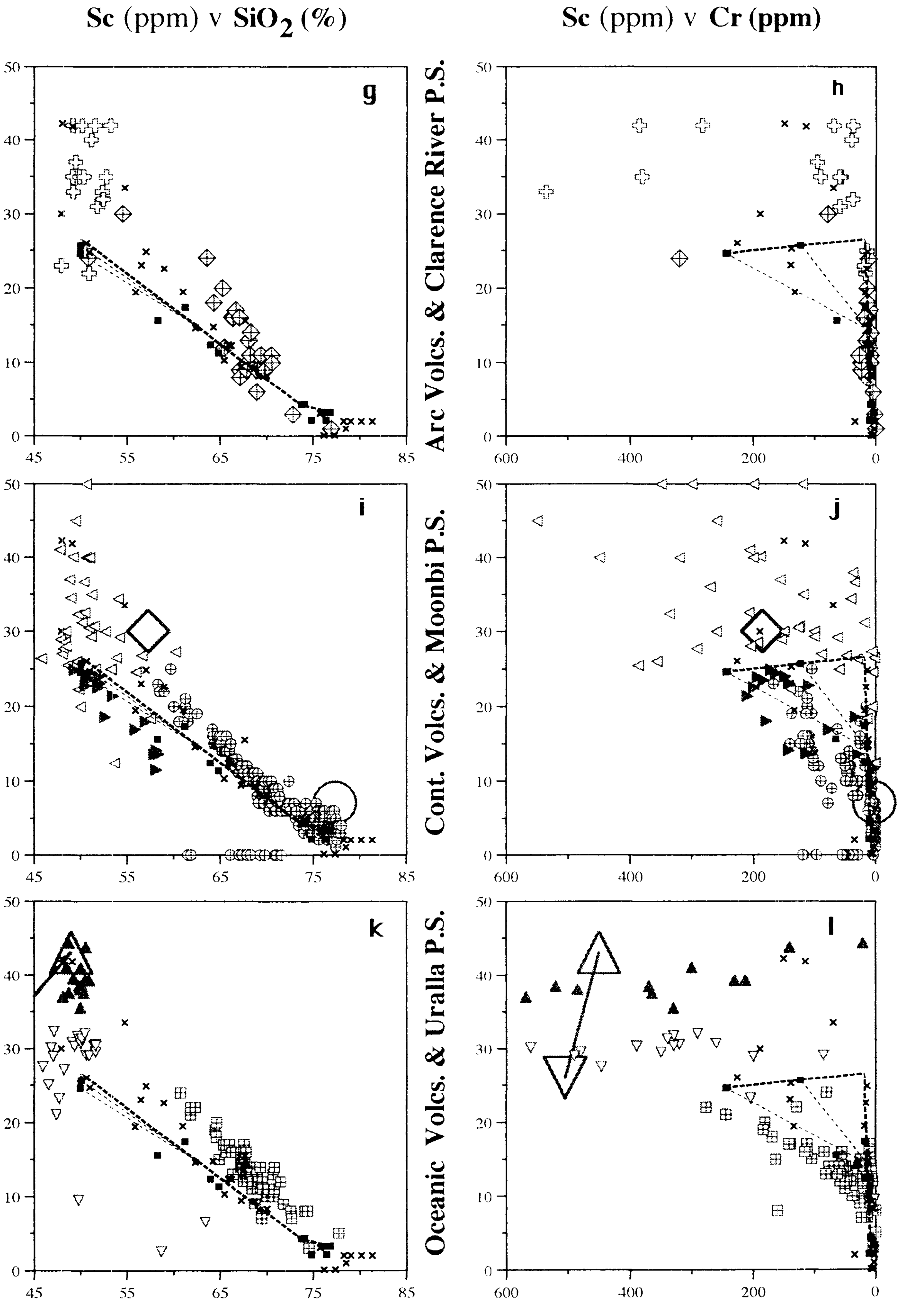


Fig. A2.16 (g–l): Sc in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites

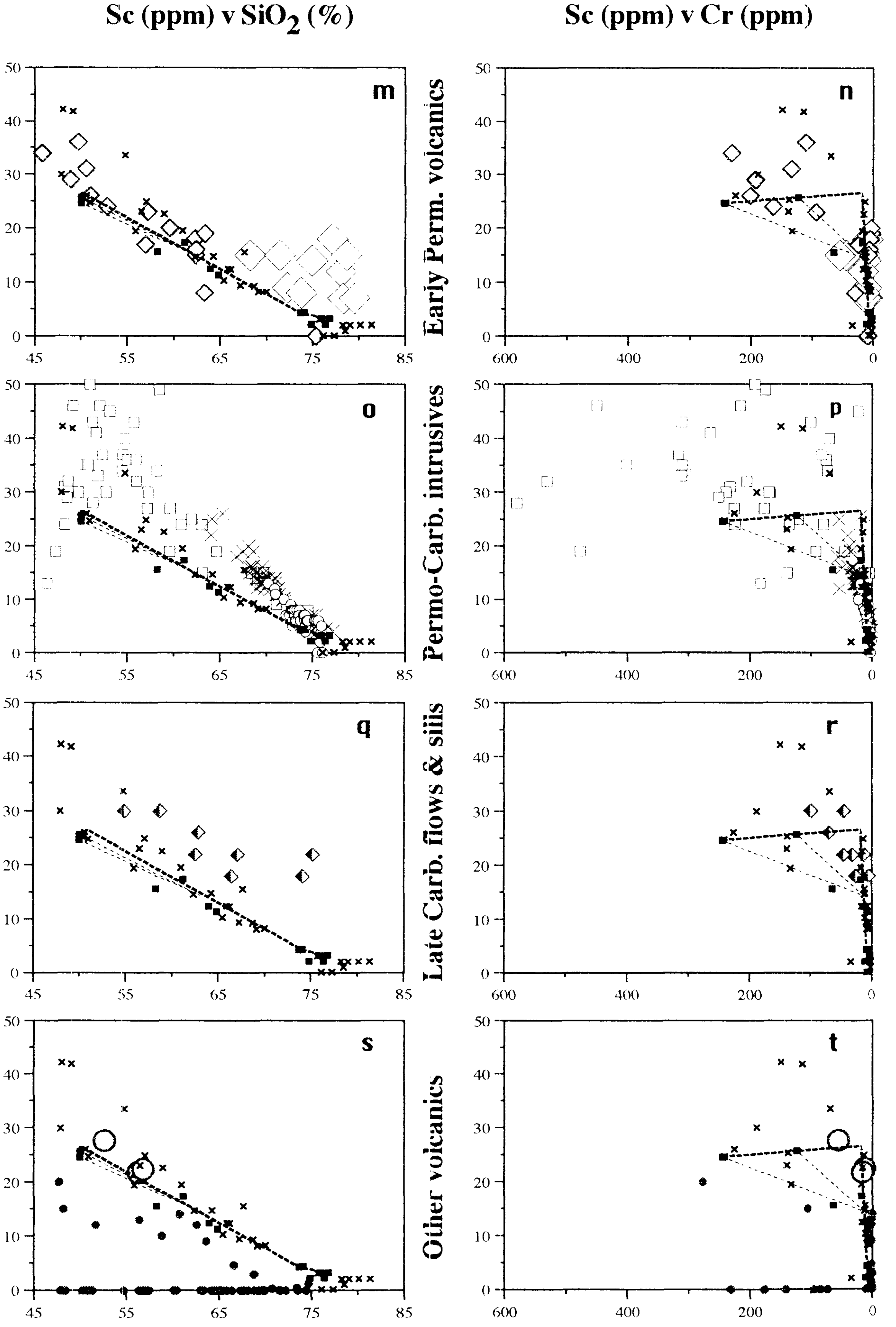


Fig. A2.16 (m–t): Sc in Boggabri Volcanics — regional comparisons

Vanadium

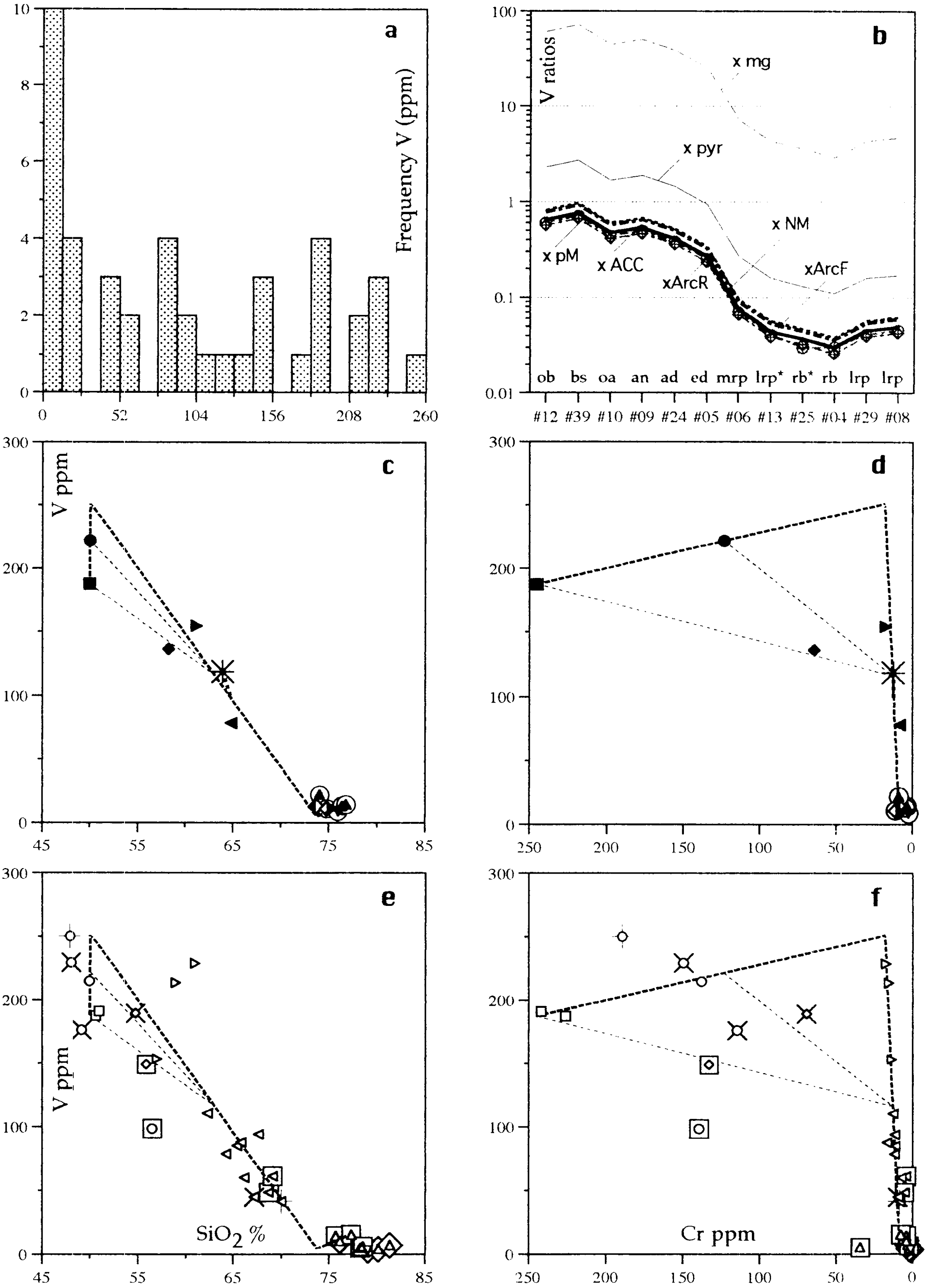


Fig. A2.17 (a–f): V in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

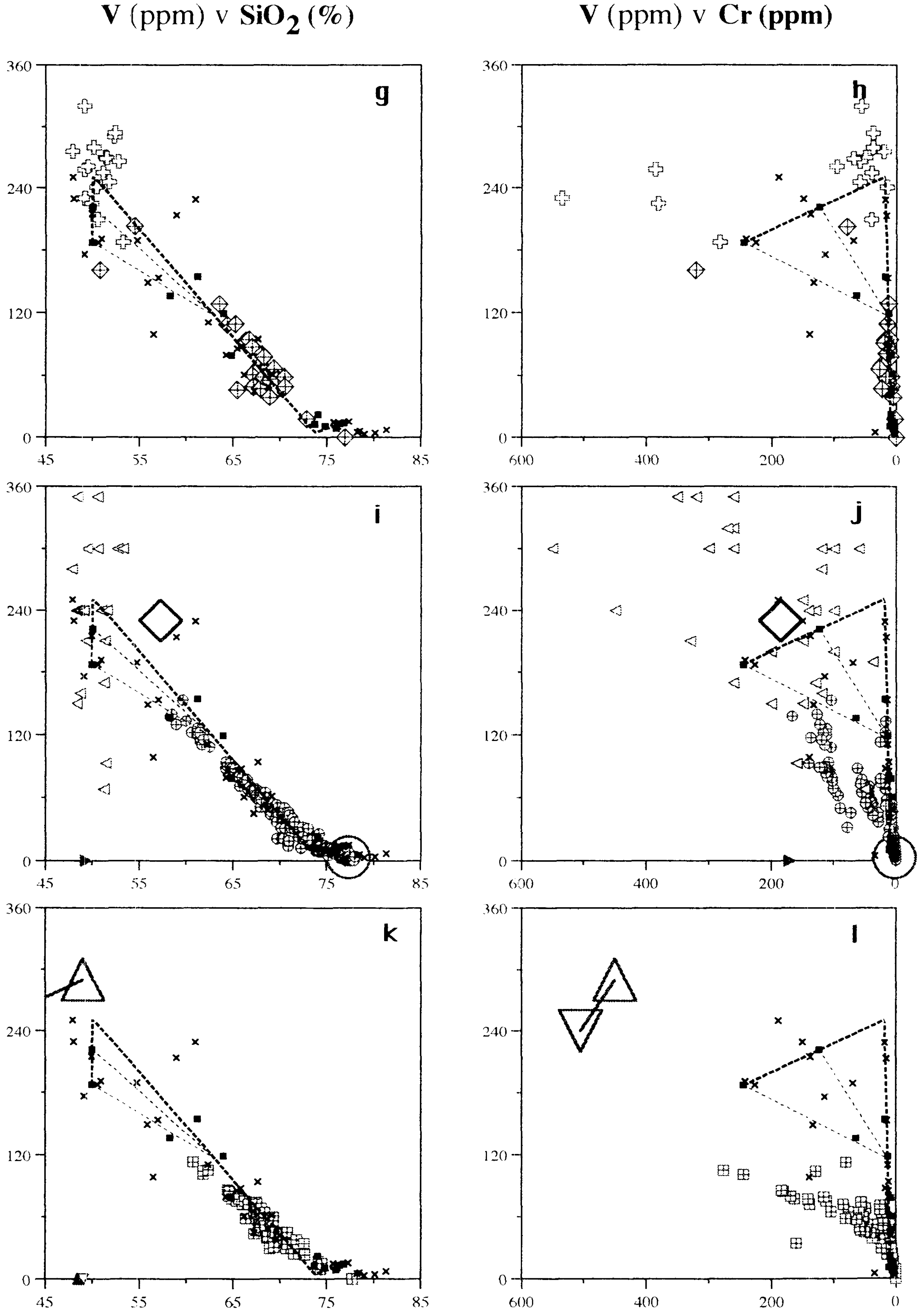


Fig. A2.17 (g–l): V in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites

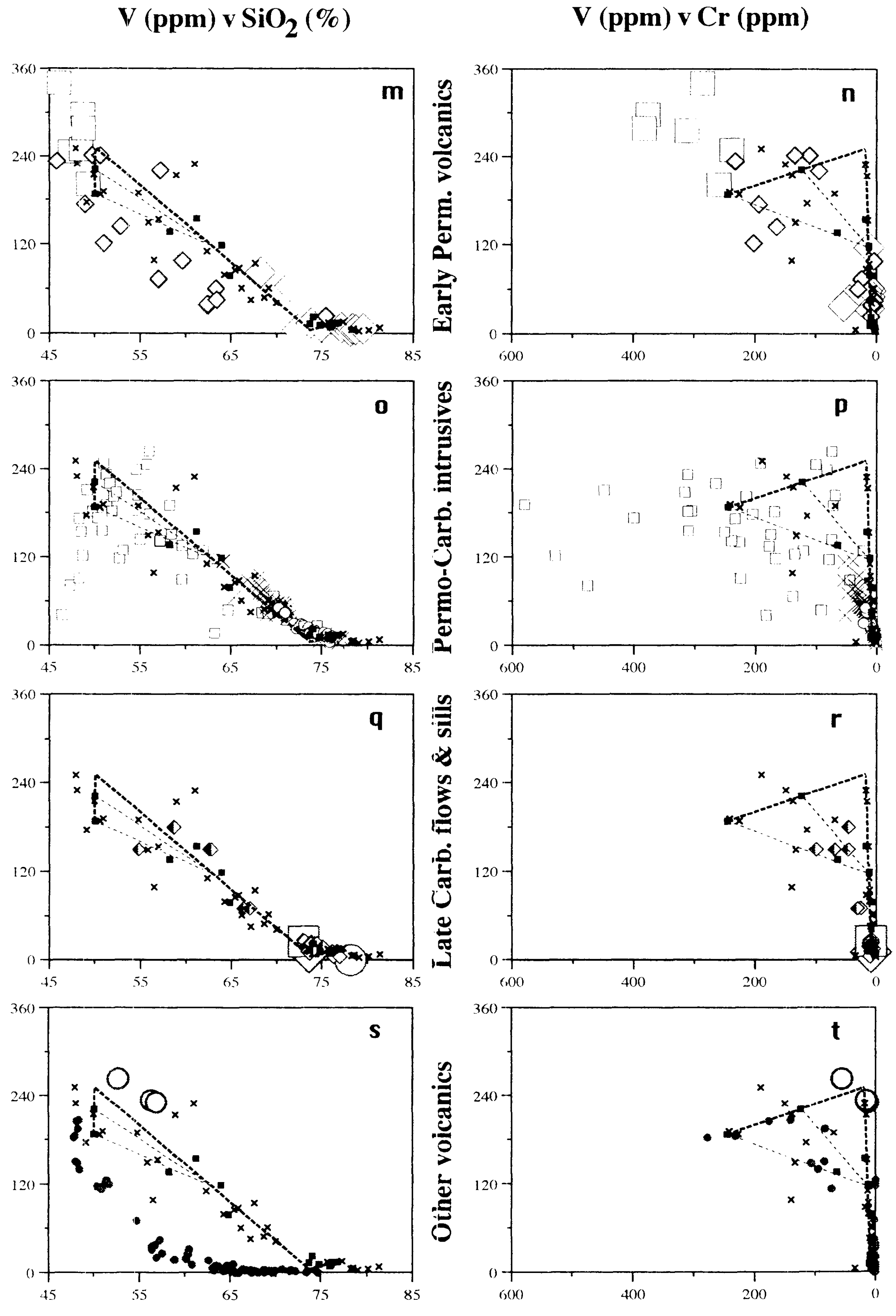


Fig. A2.17 (m–t): V in Boggabri Volcanics — regional comparisons

Gallium

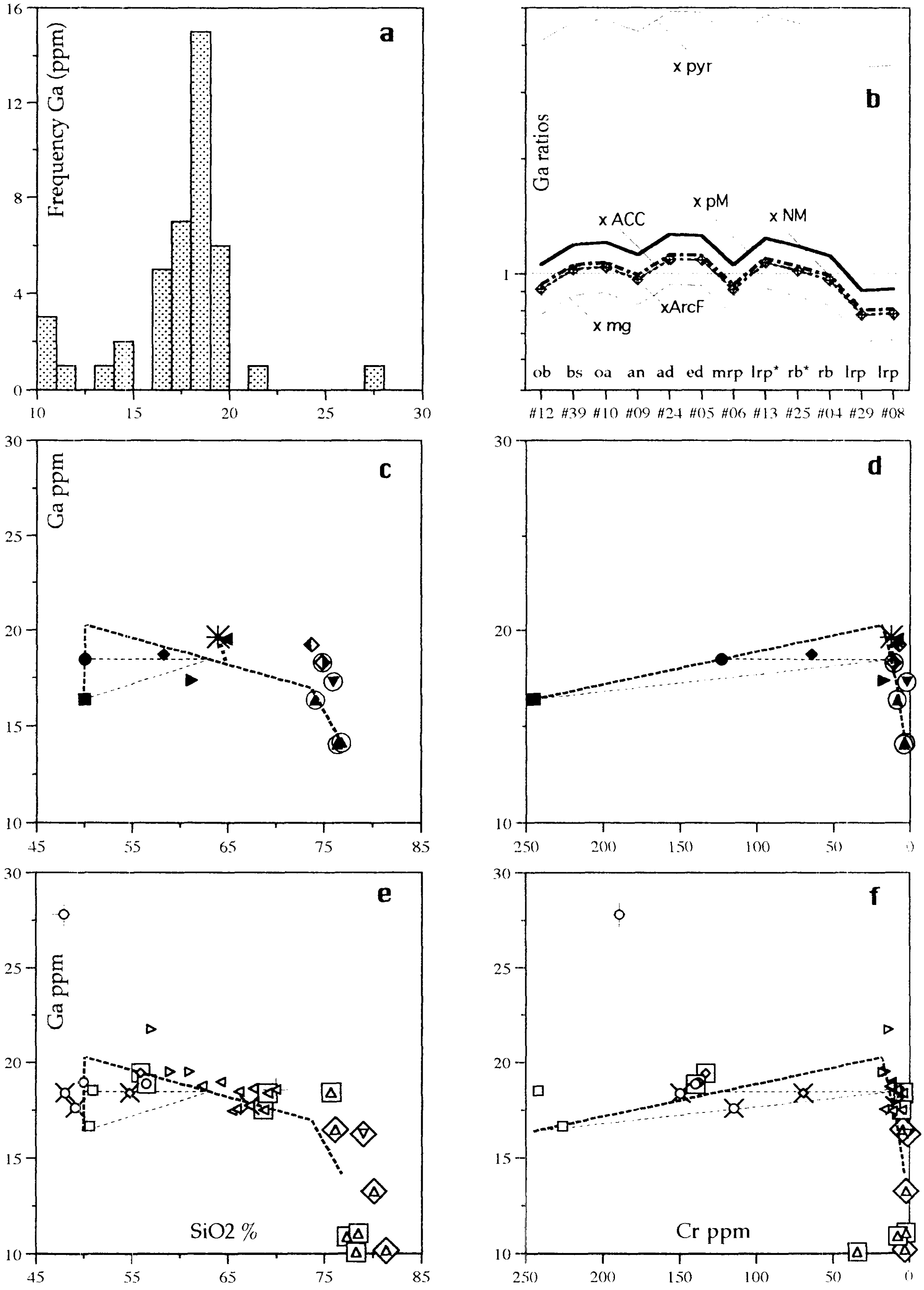


Fig. A2.18 (a–f): Ga in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

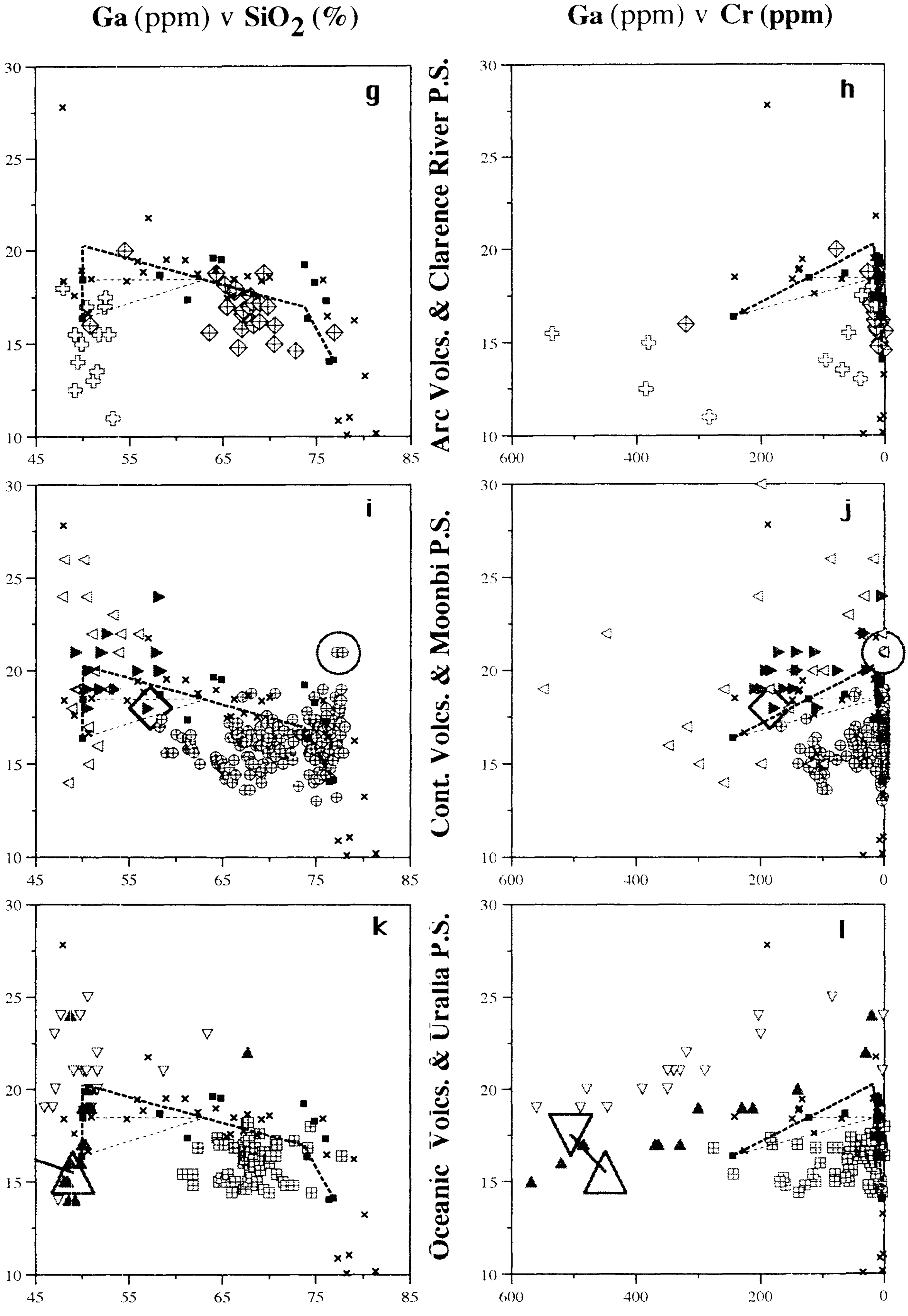


Fig. A2.18 (g–l): Ga in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites

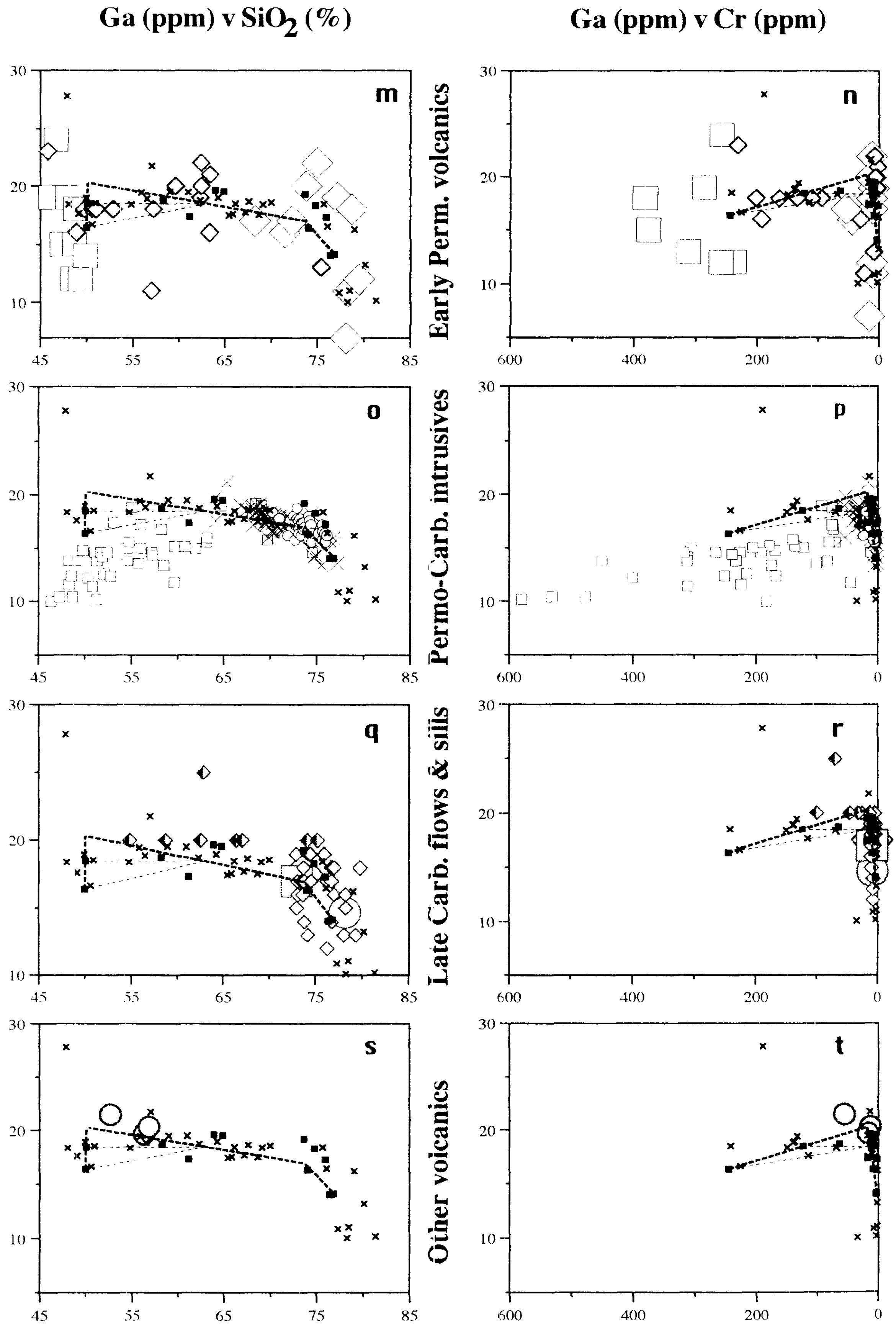


Fig. A2.18 (m–t): Ga in Boggabri Volcanics — regional comparisons

Yttrium

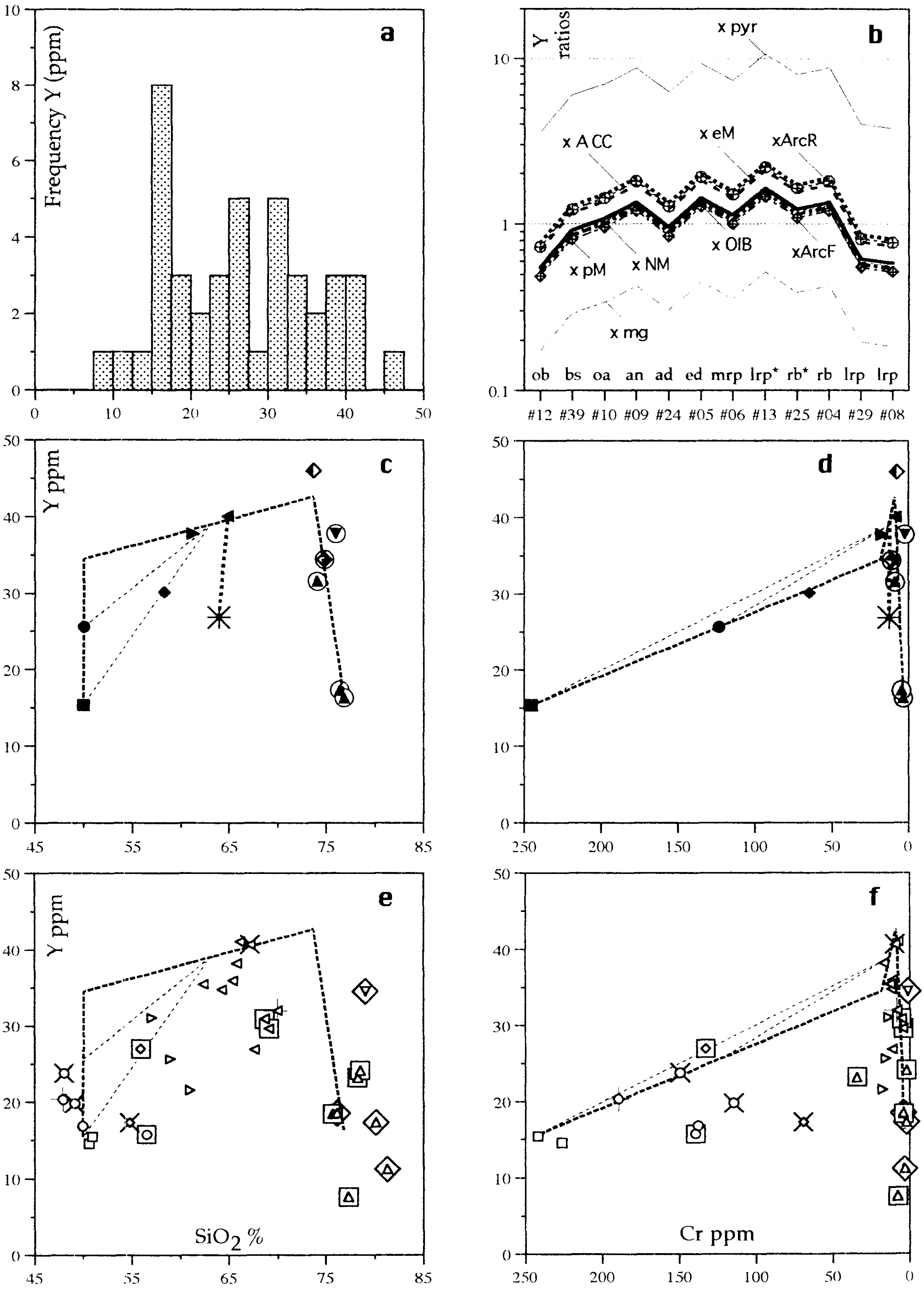


Fig. A2.19 (a–f): Y in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

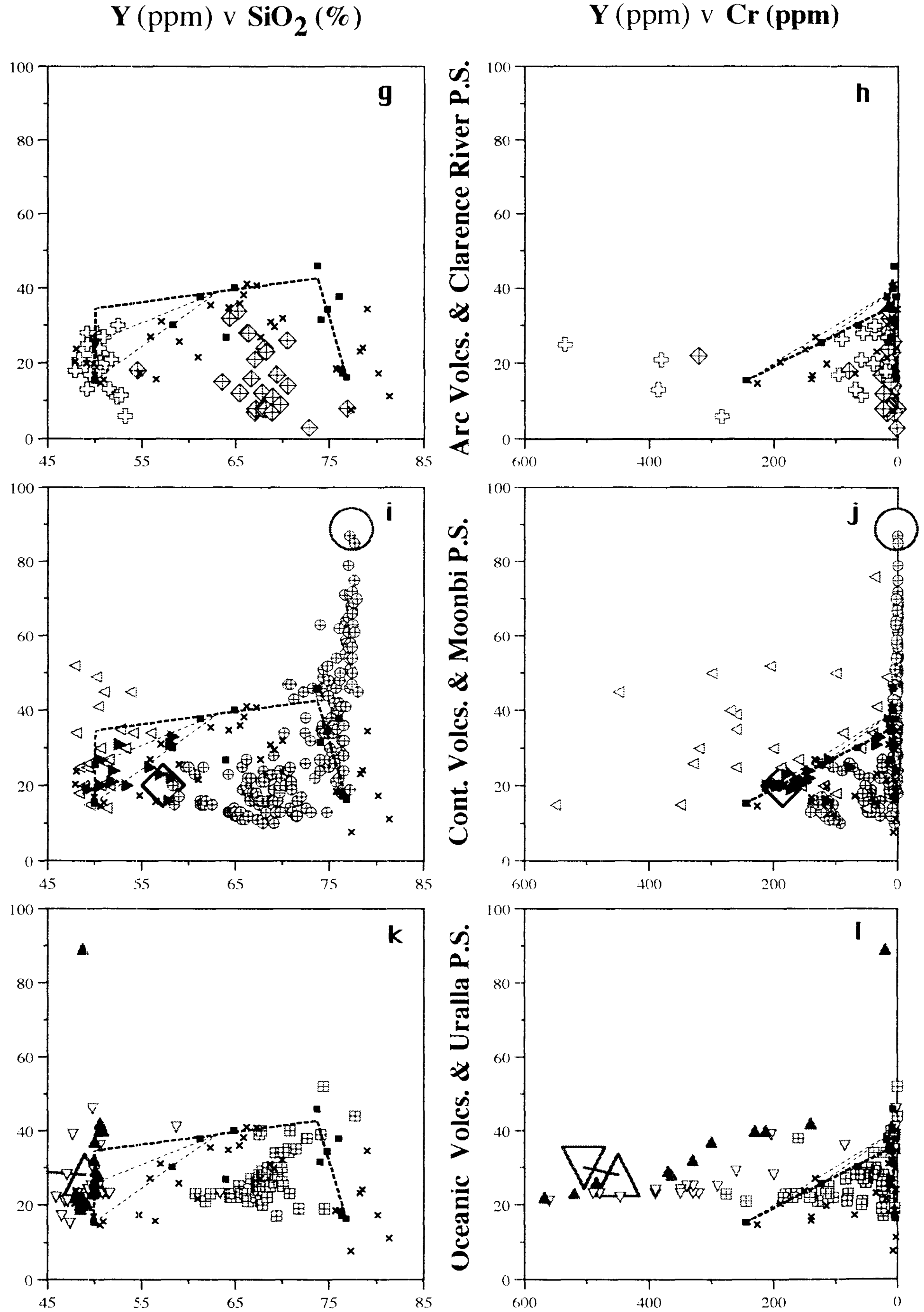


Fig. A2.19 (g–l): Y in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites

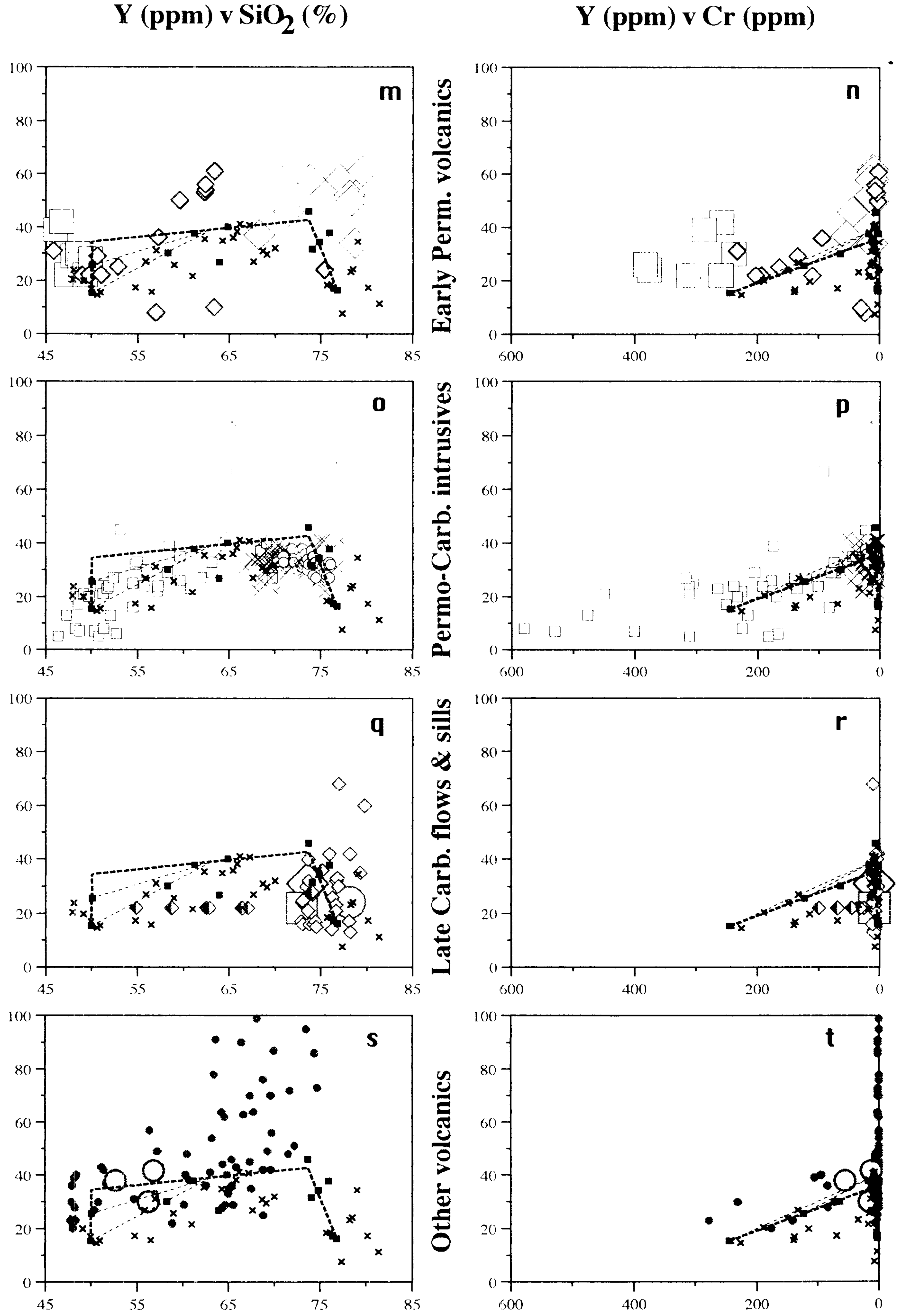


Fig. A1.29 (m–t): Y in Boggabri Volcanics — regional comparisons

Zirconium

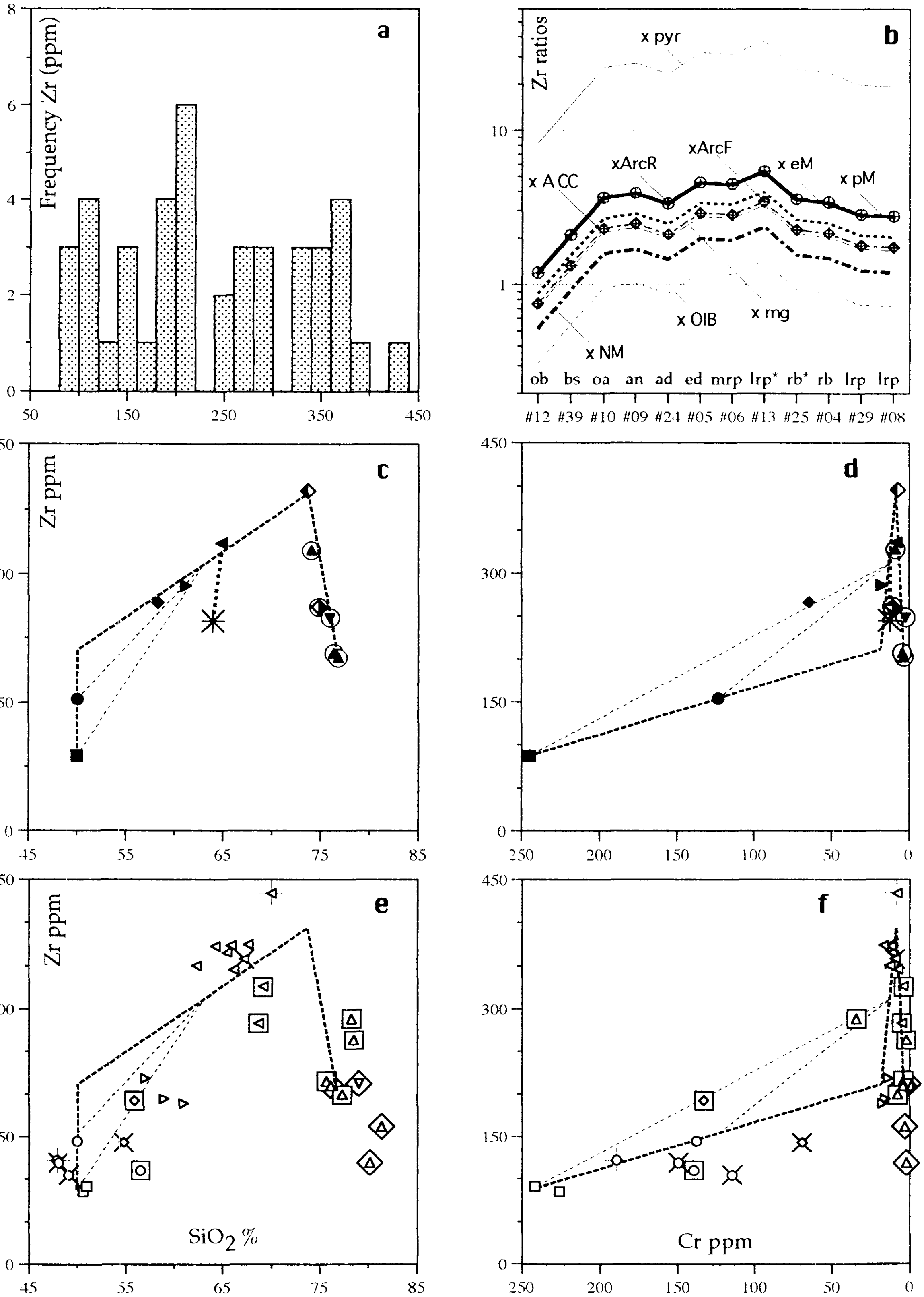


Fig. A2.20 (a–f): Zr in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

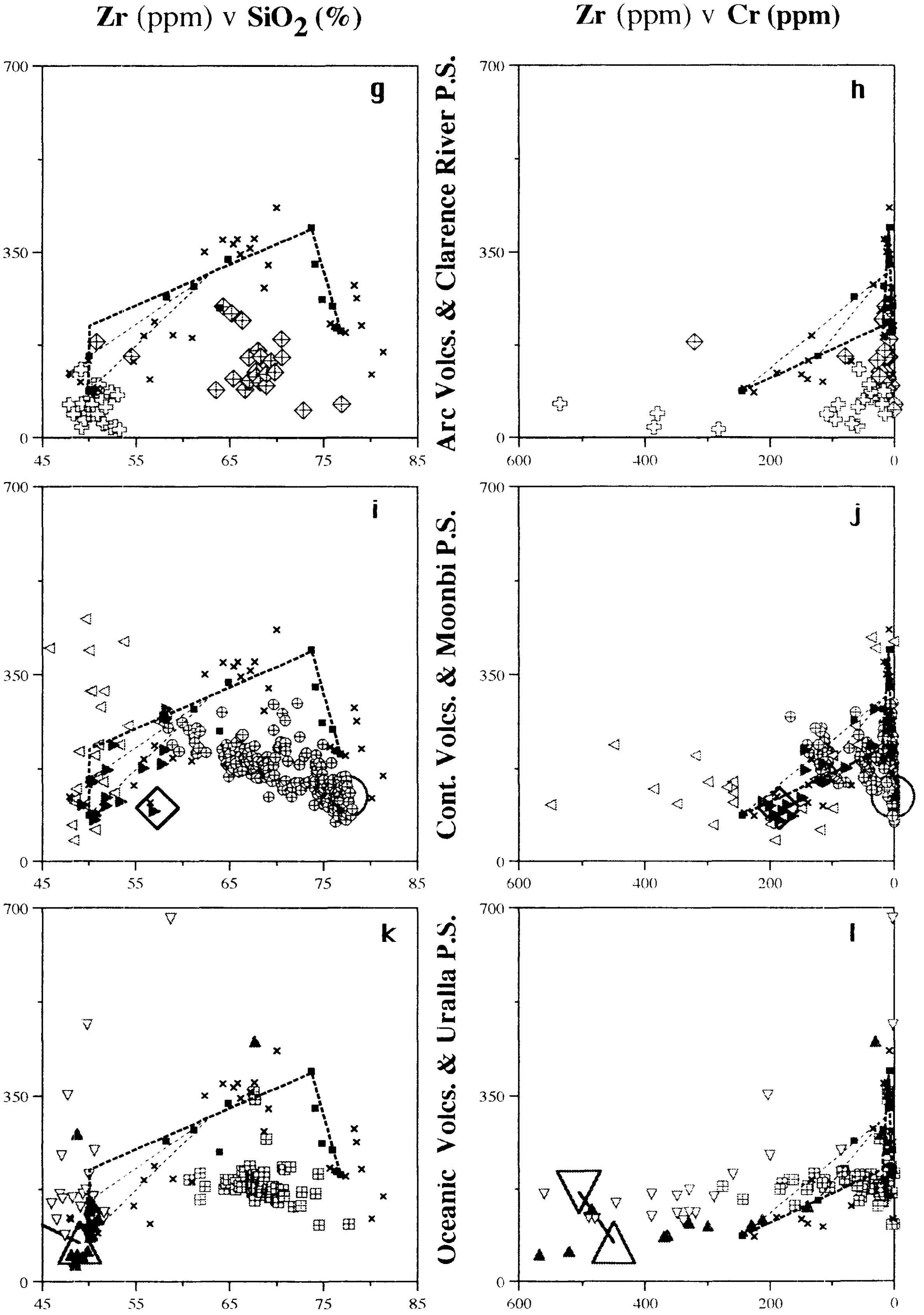


Fig. A2.20 (g–l): Zr in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites

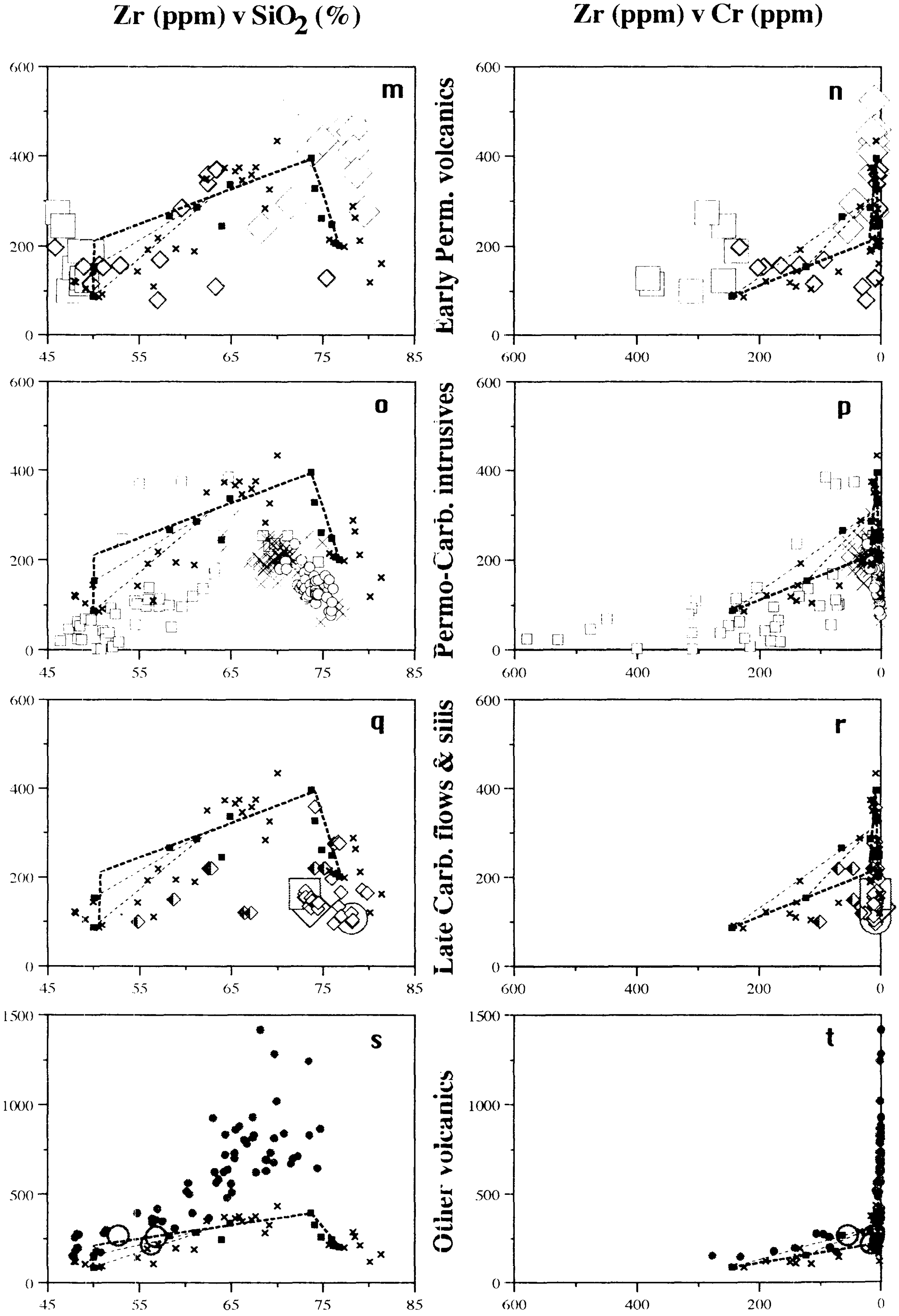


Fig. A2.20 (m–t): Zr in Boggabri Volcanics — regional comparisons

Hafnium

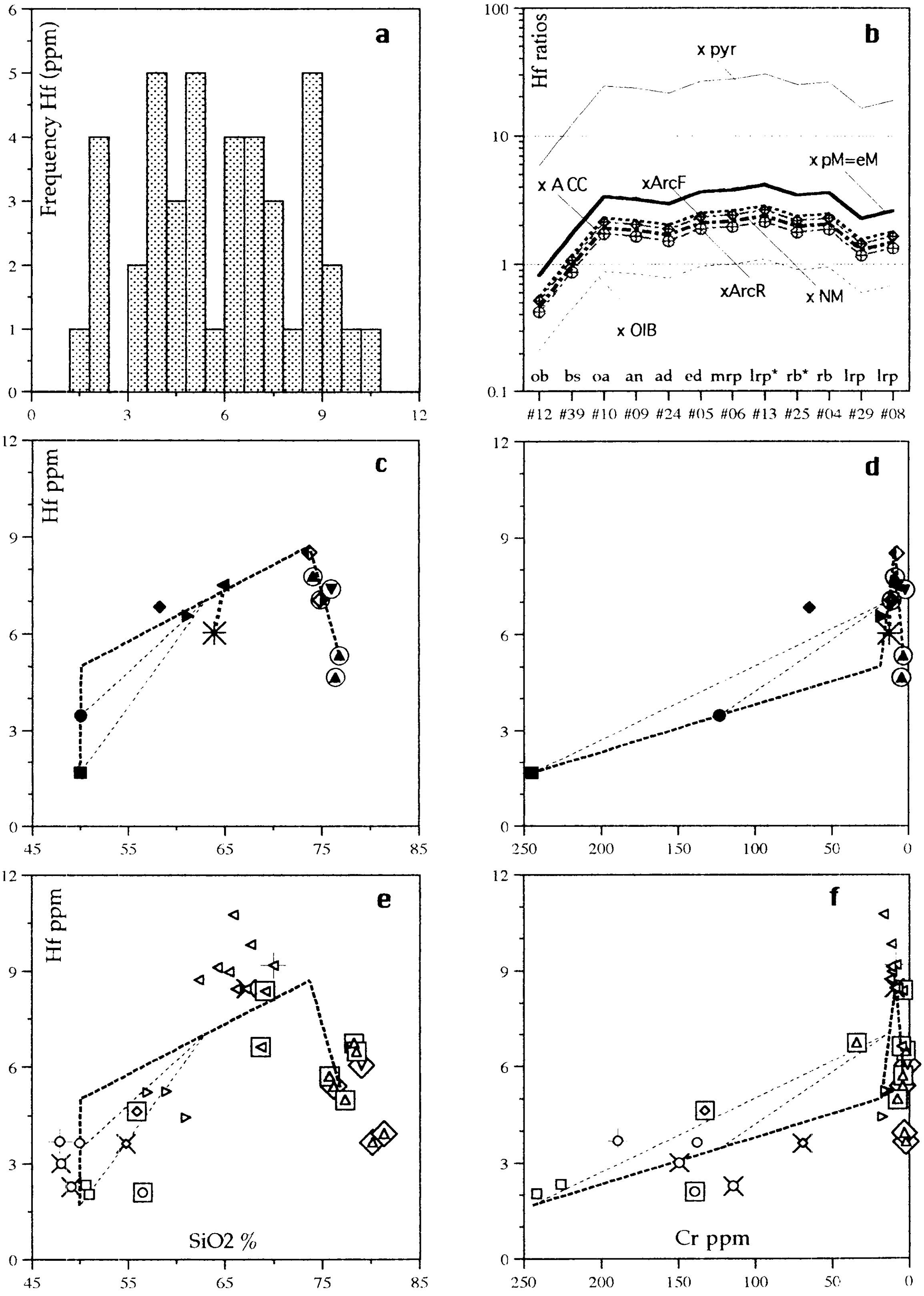


Fig. A2.21 (a–f): Hf in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

Strontium

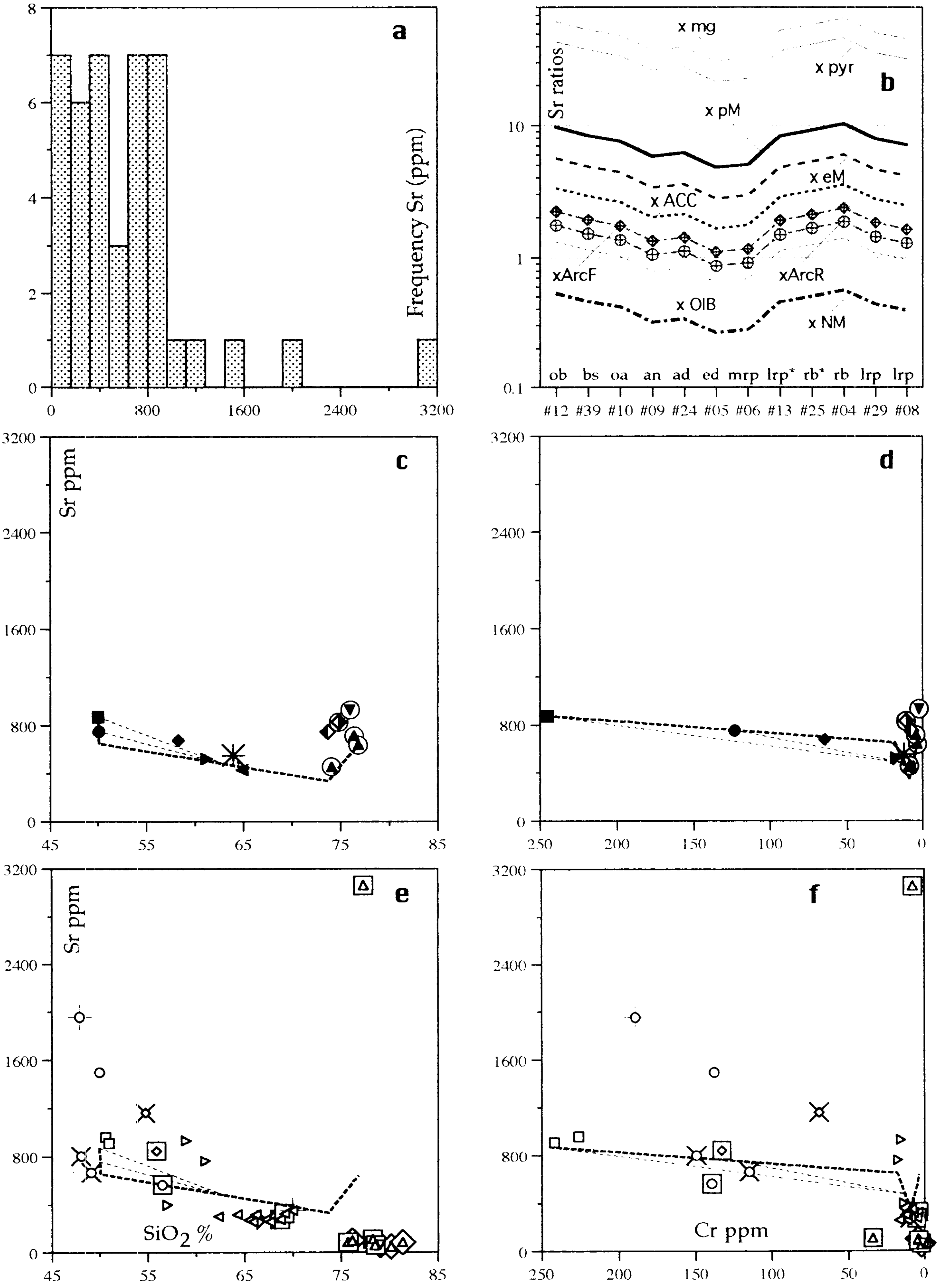


Fig. A2.22 (a–f): Sr in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

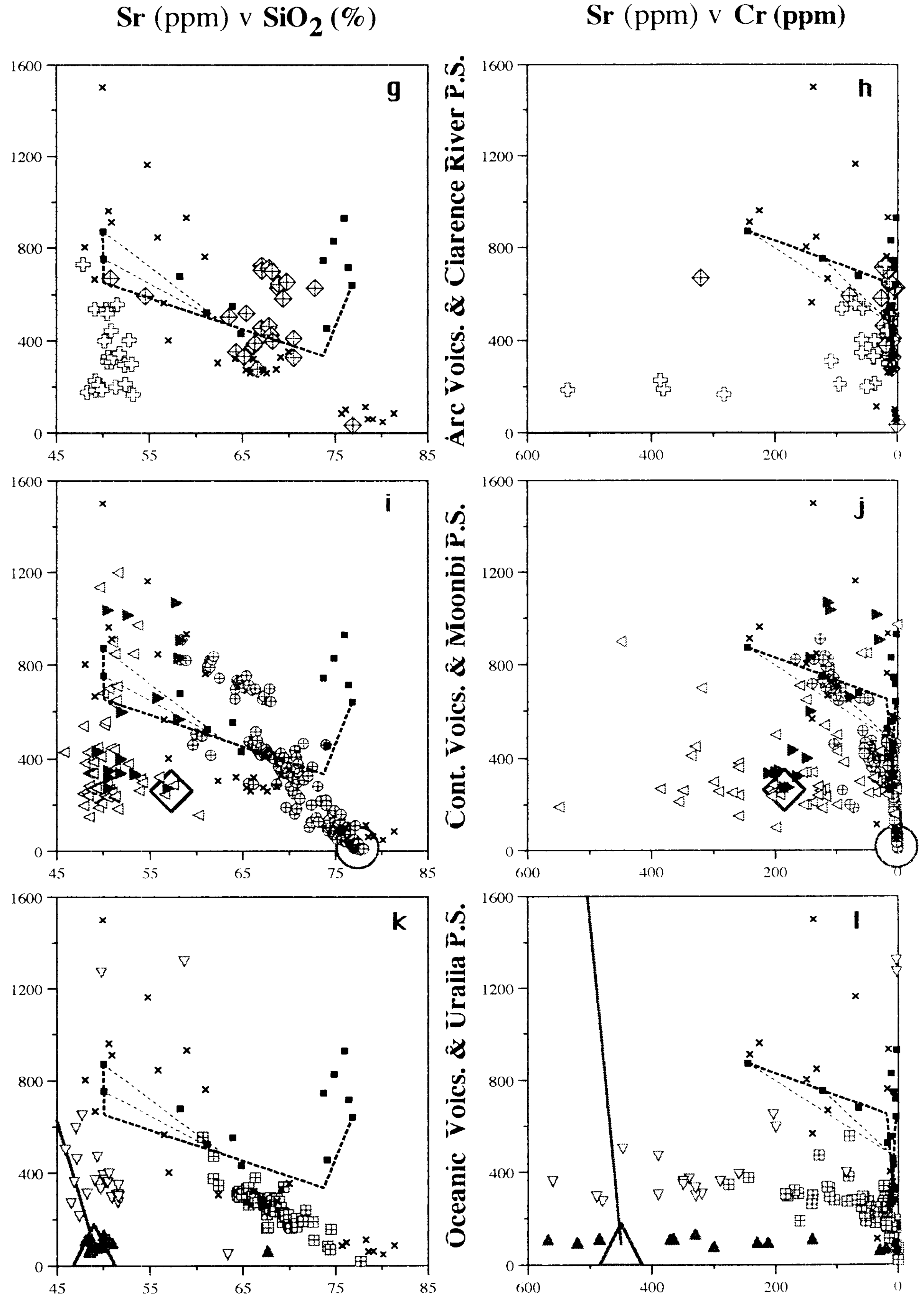
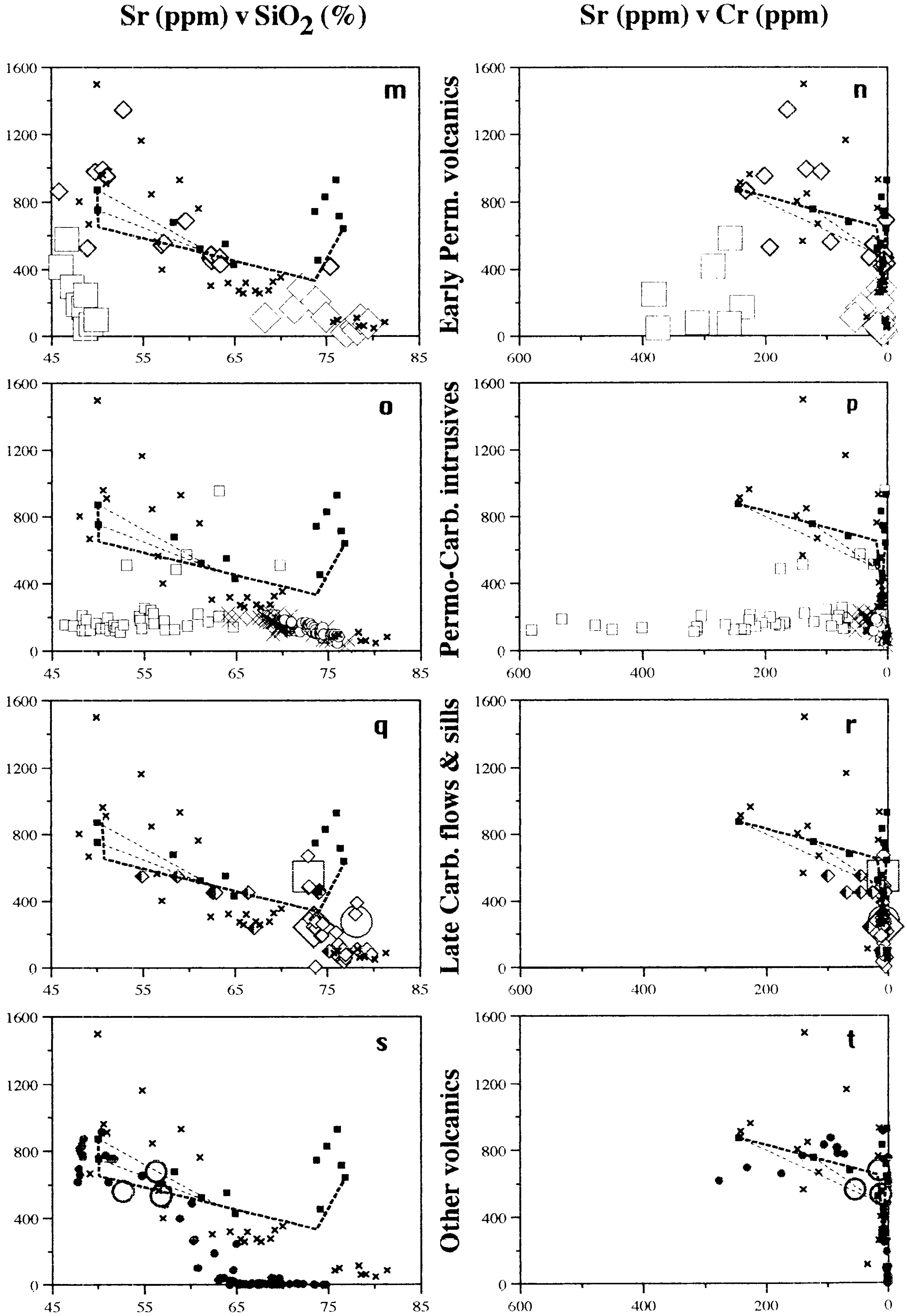


Fig. A2.22 (g–l): Sr in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites



Sr (ppm) v SiO_2 (%)

Sr (ppm) v Cr (ppm)

Early Perm. volcanics

Permo-Carb. intrusives

Late Carb. flows & sills

Other volcanics

Fig. A2.22 (m–t): Sr in Boggabri Volcanics — regional comparisons

Lead

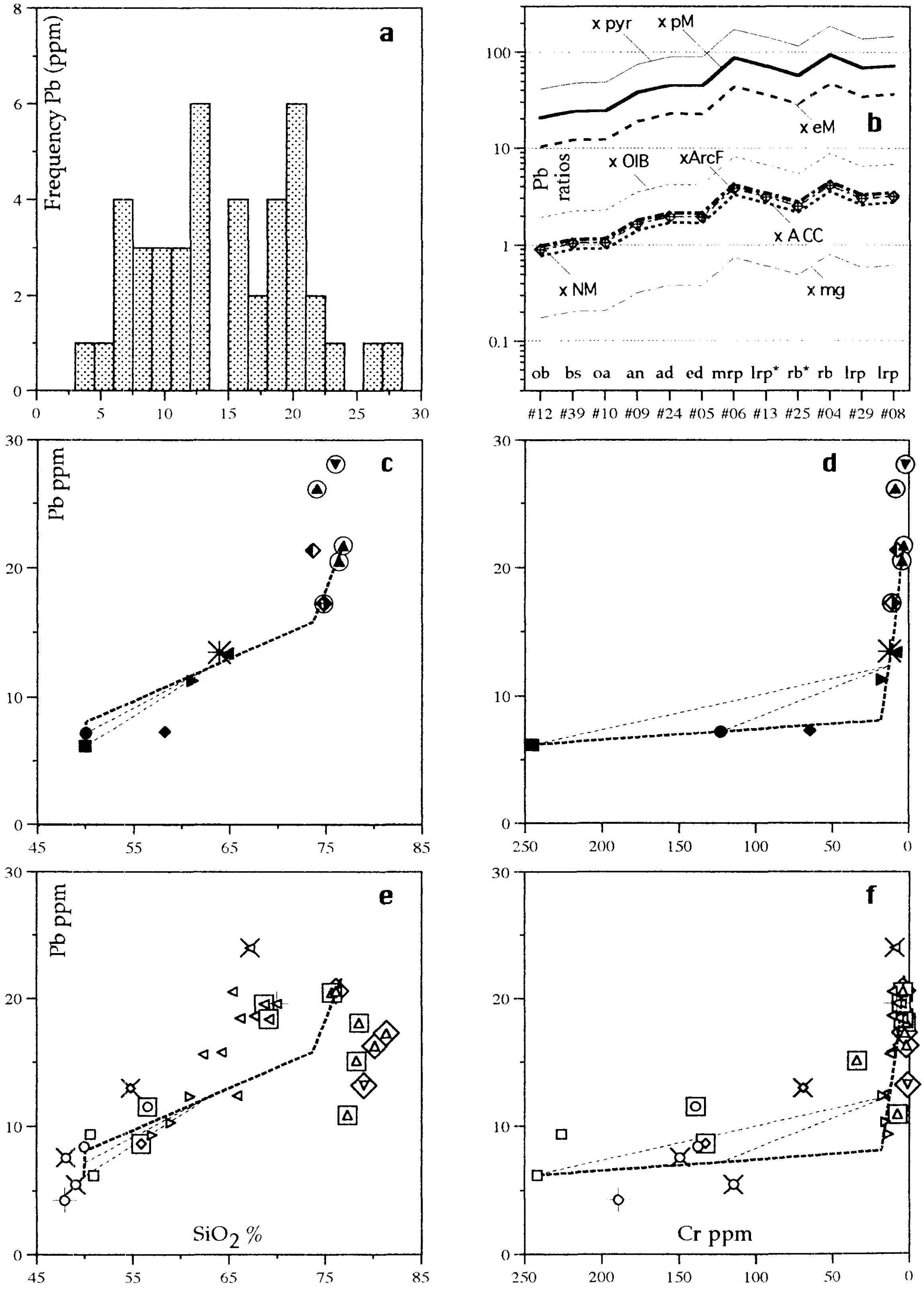


Fig. A2.23 (a–f): Pb in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

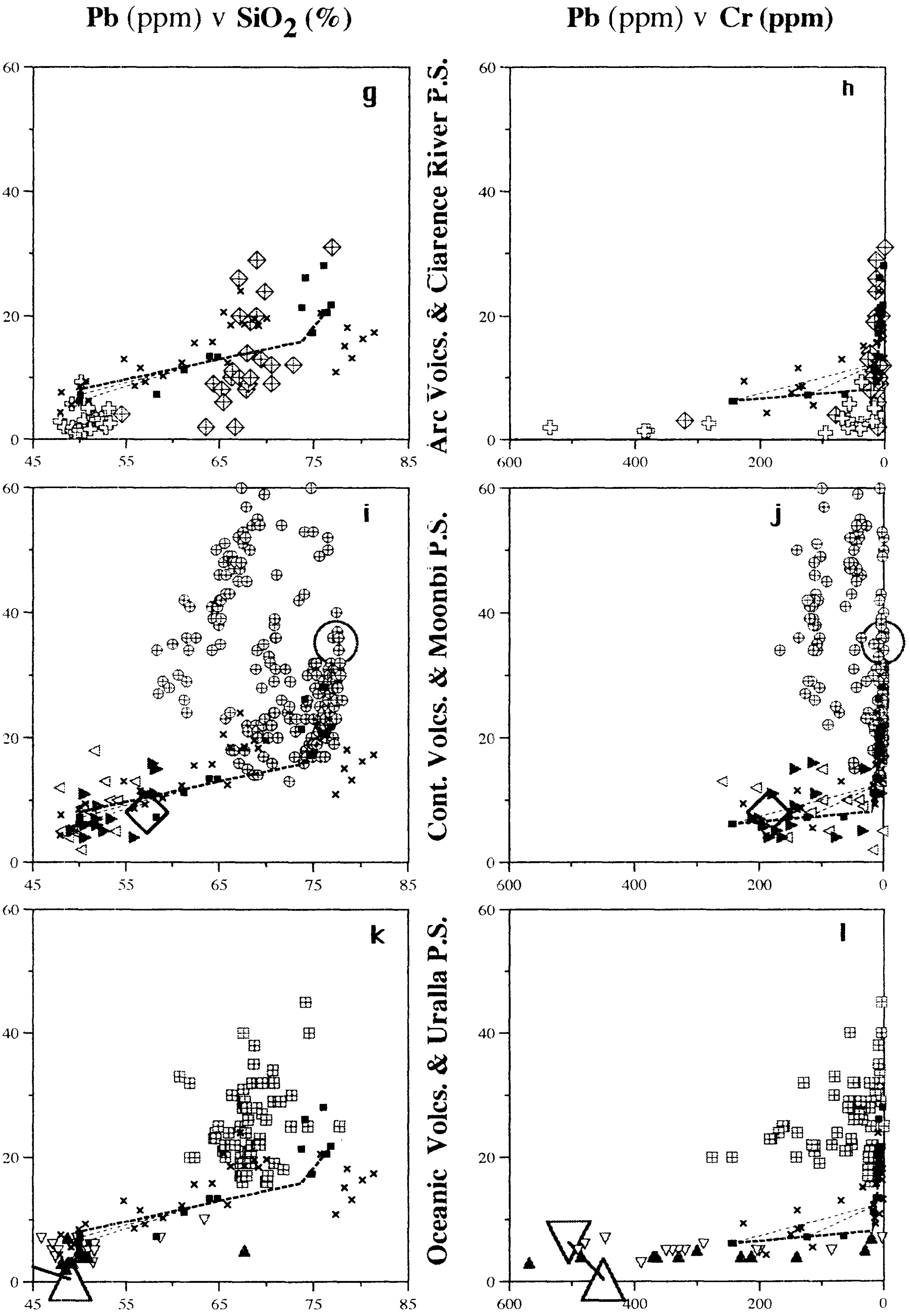


Fig. A2.23 (g–l): Pb in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites

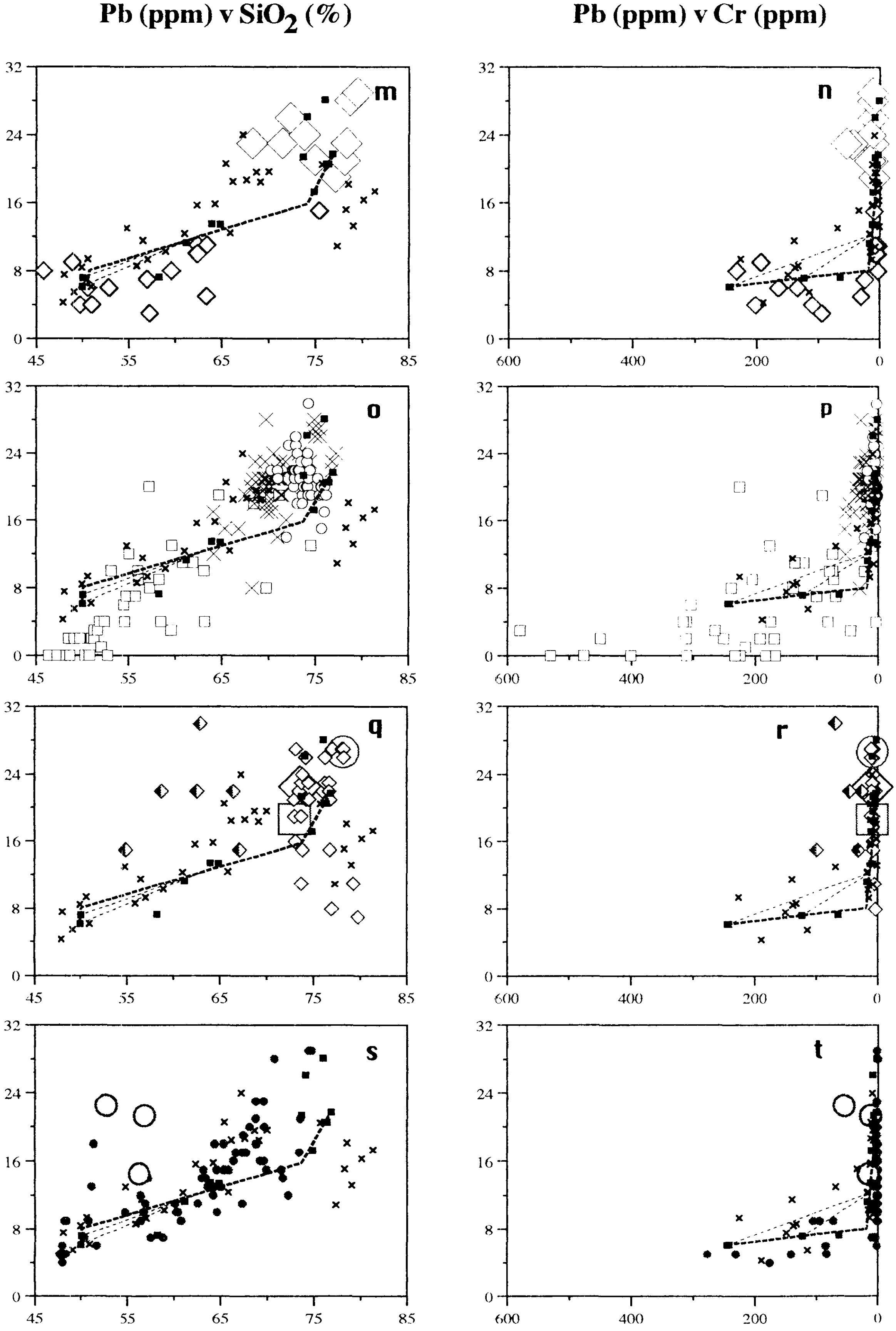


Fig. A2.23 (m–t): Pb in Boggabri Volcanics — regional comparisons

Cerium

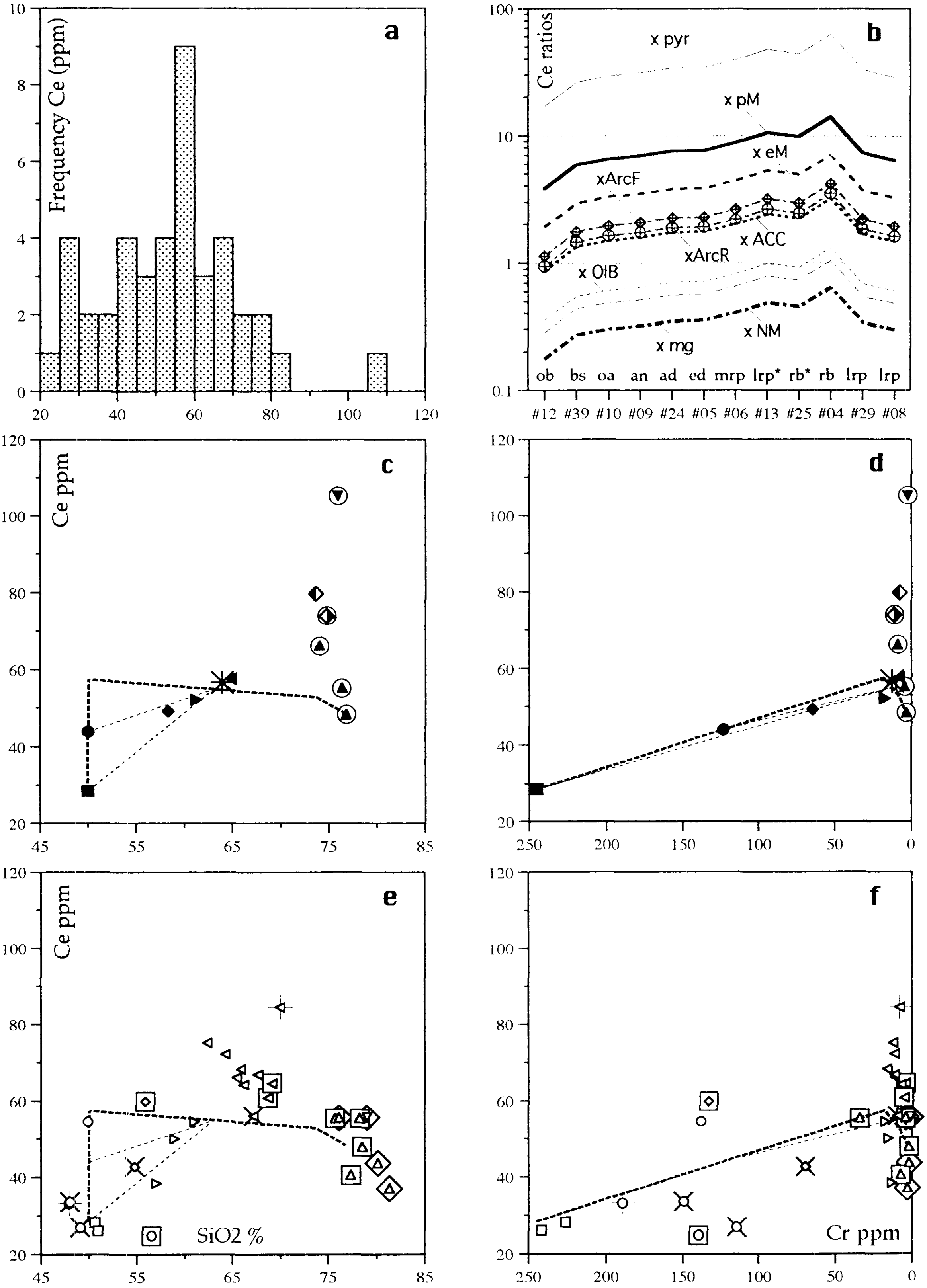


Fig. A2.24 (a–f): Ce in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

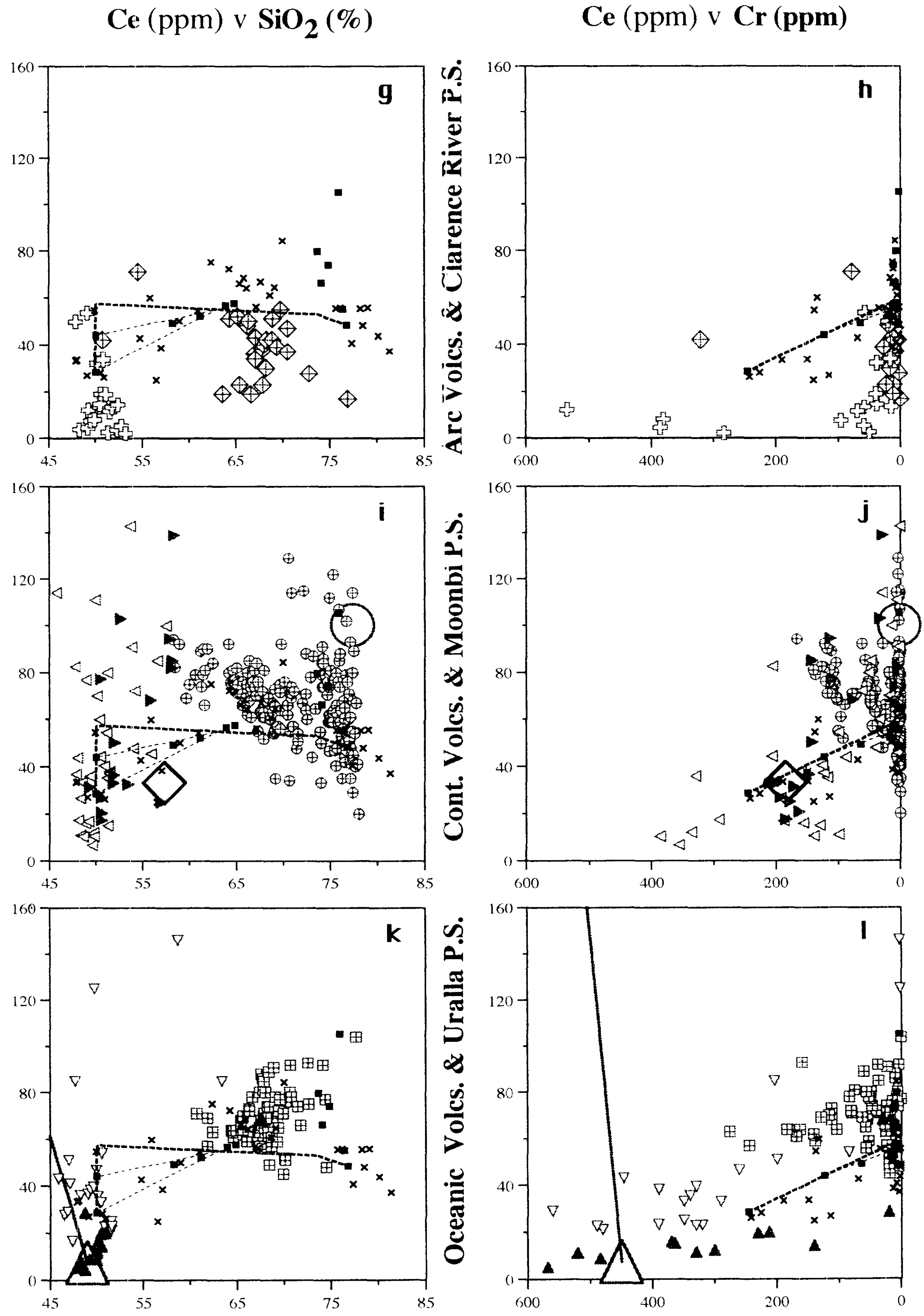


Fig. A2.24 (g–l): Ce in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites

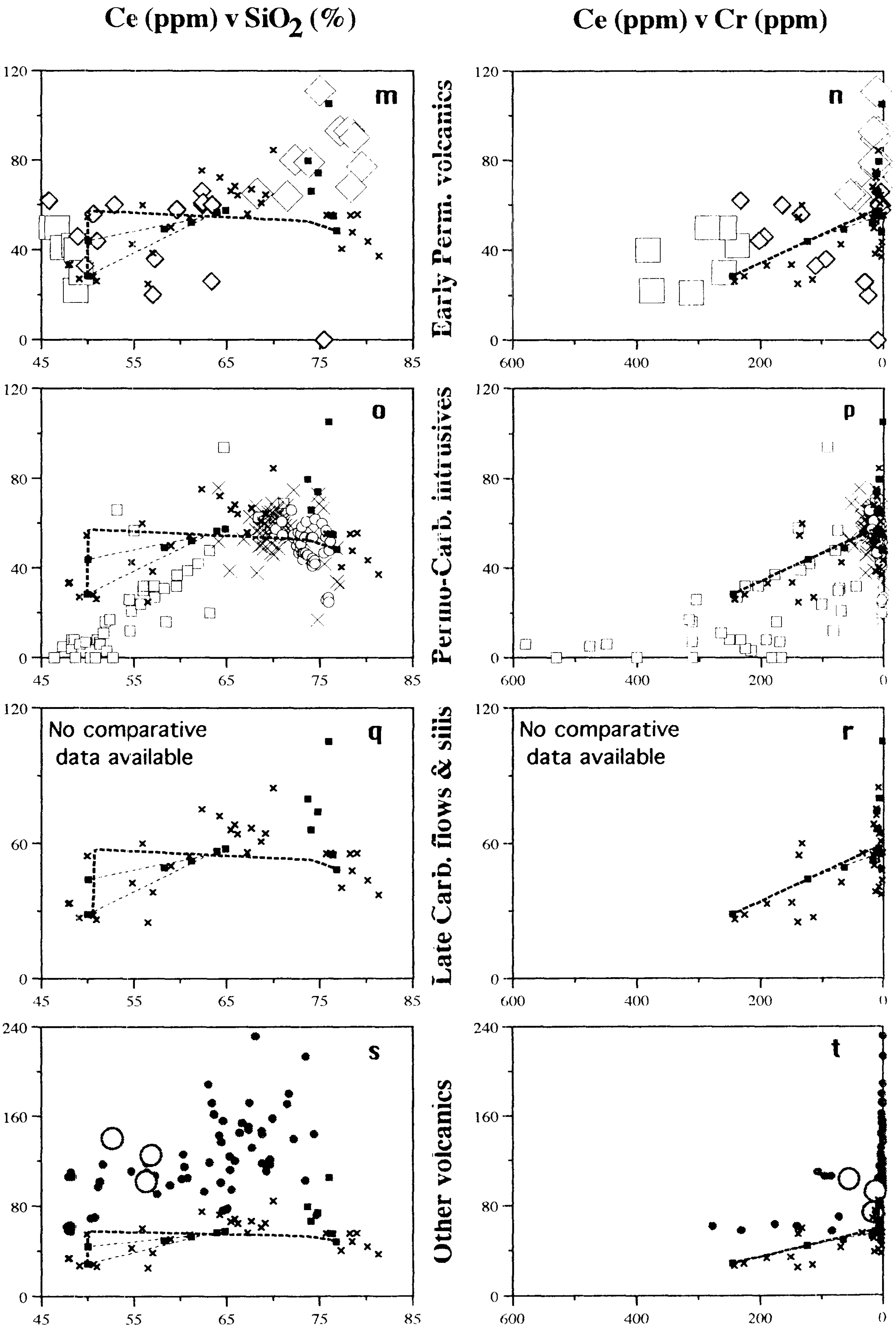


Fig. A2.24 (m–t): Ce in Boggabri Volcanics — regional comparisons

Niobium

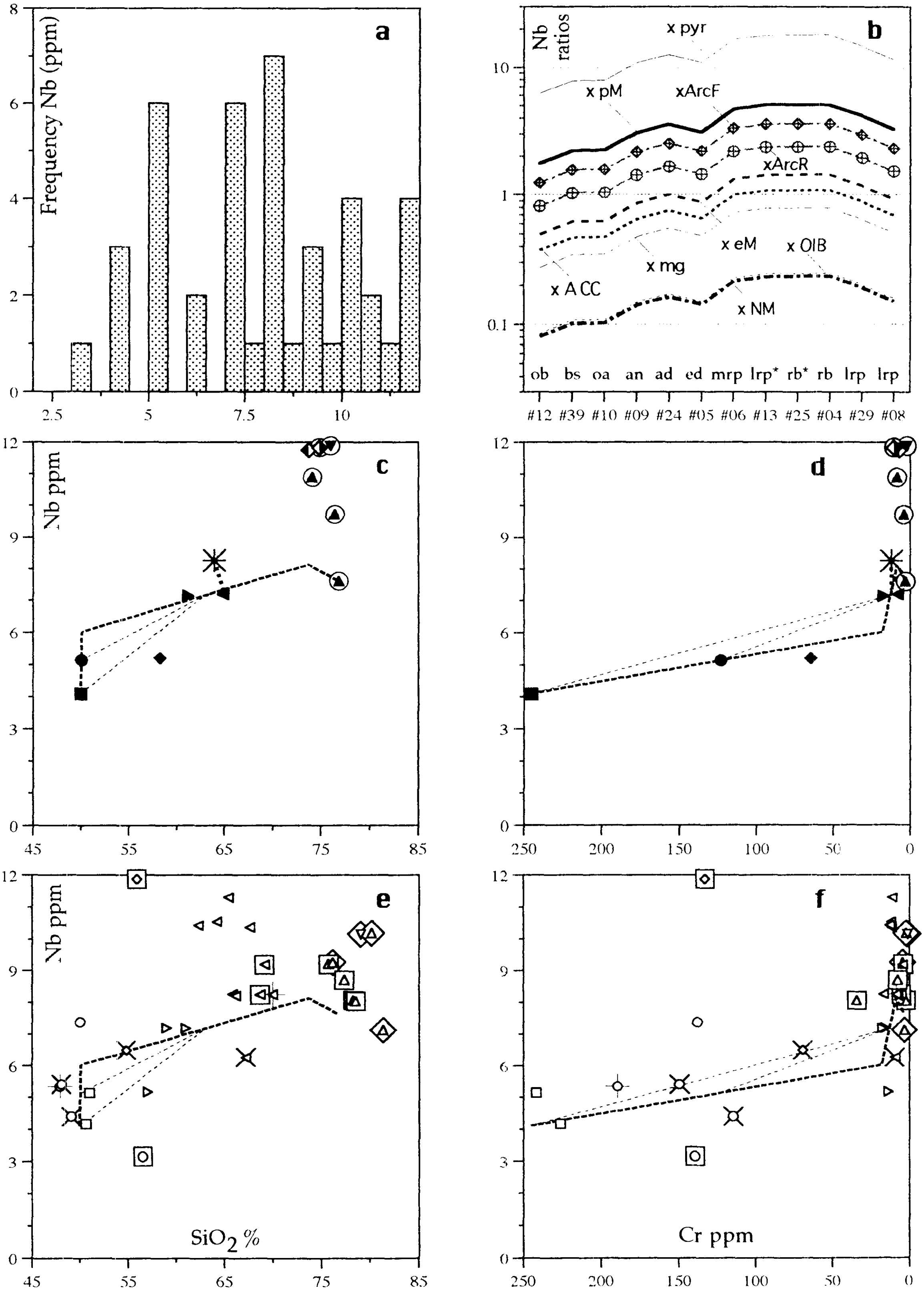


Fig. A2.25 (a–f): Nb in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

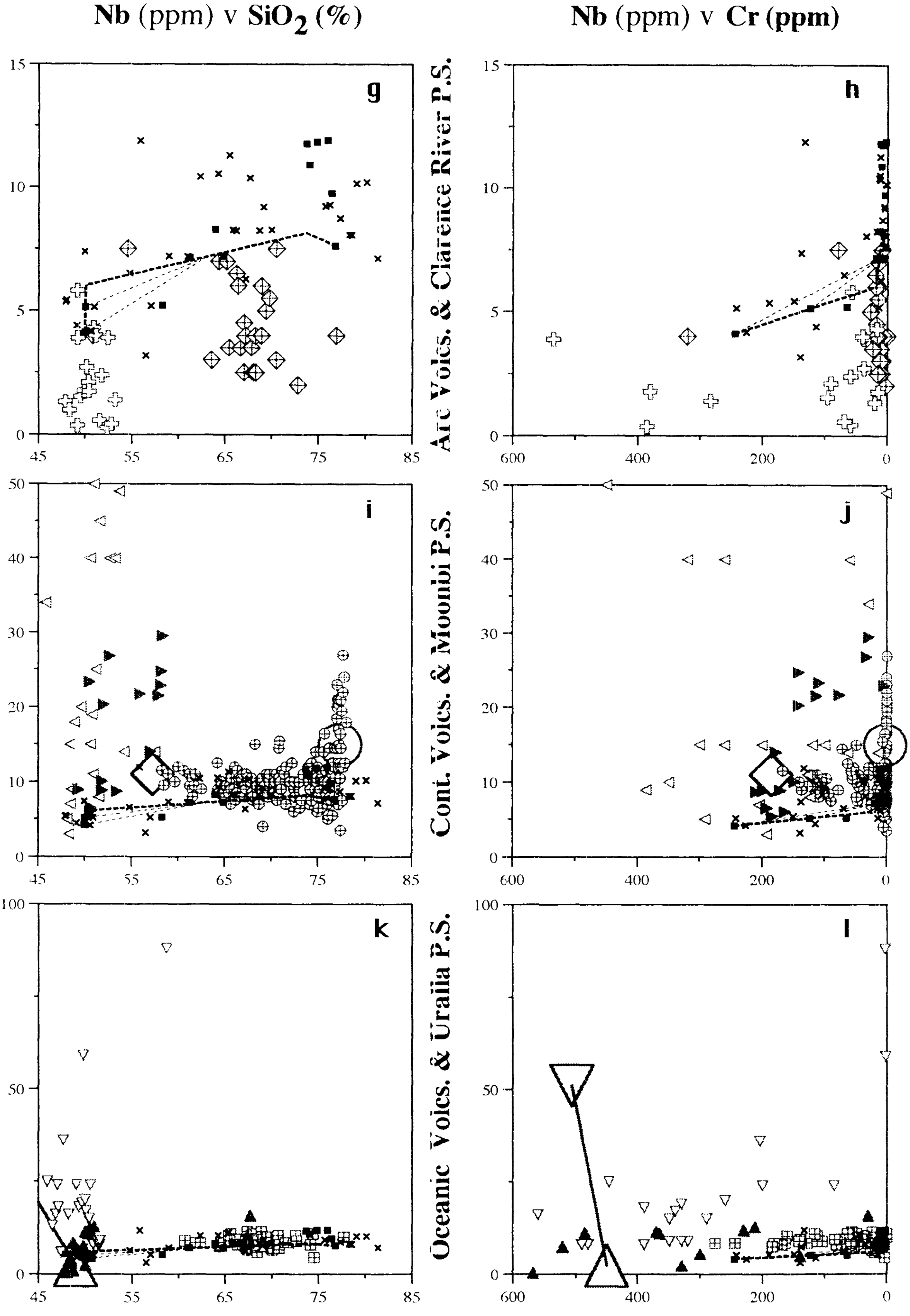


Fig. A2.25 (g–l): Nb in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites

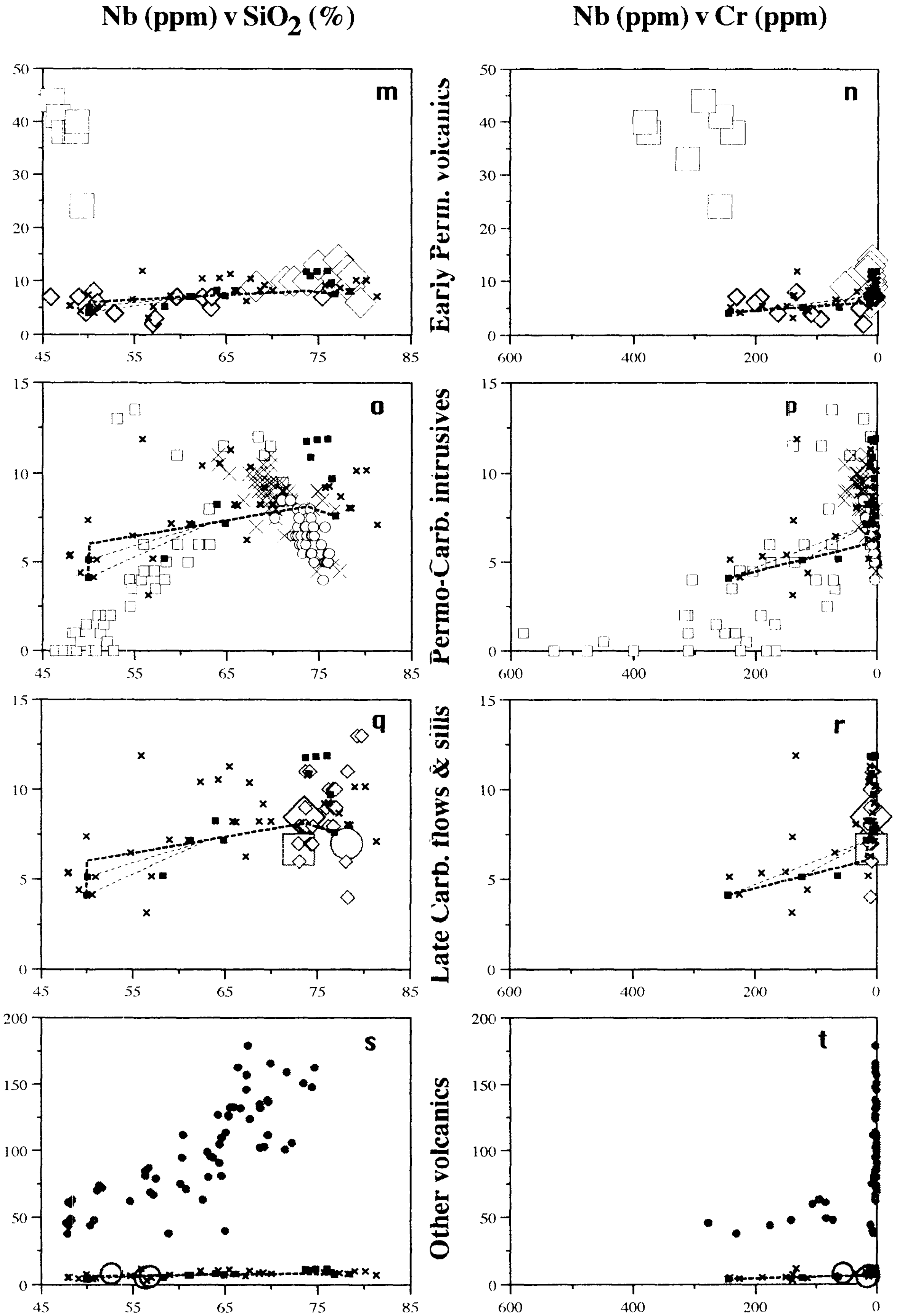


Fig. A2.25 (m–t): Nb in Boggabri Volcanics — regional comparisons

Thorium

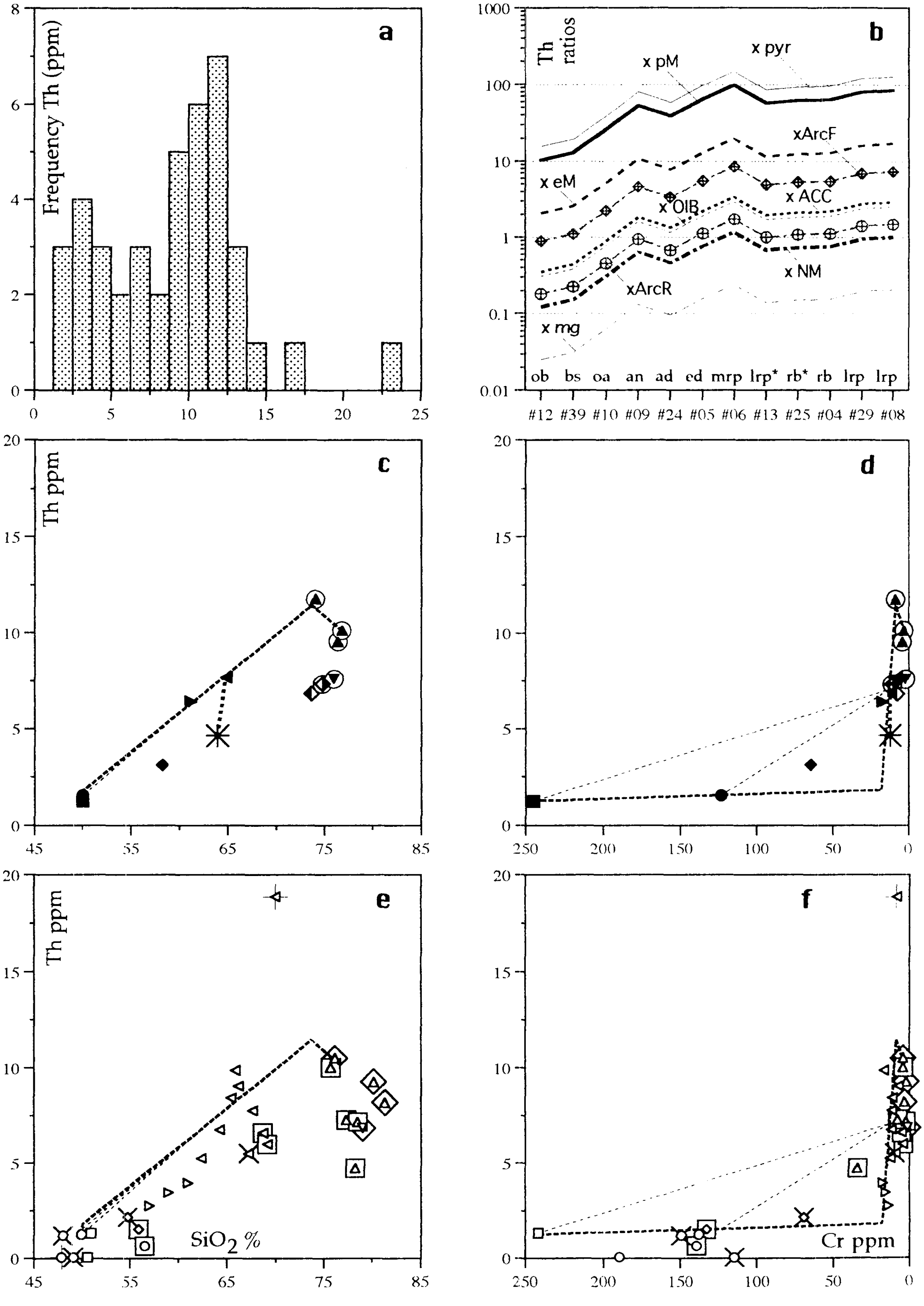


Fig. A2.26 (a–f): Th in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

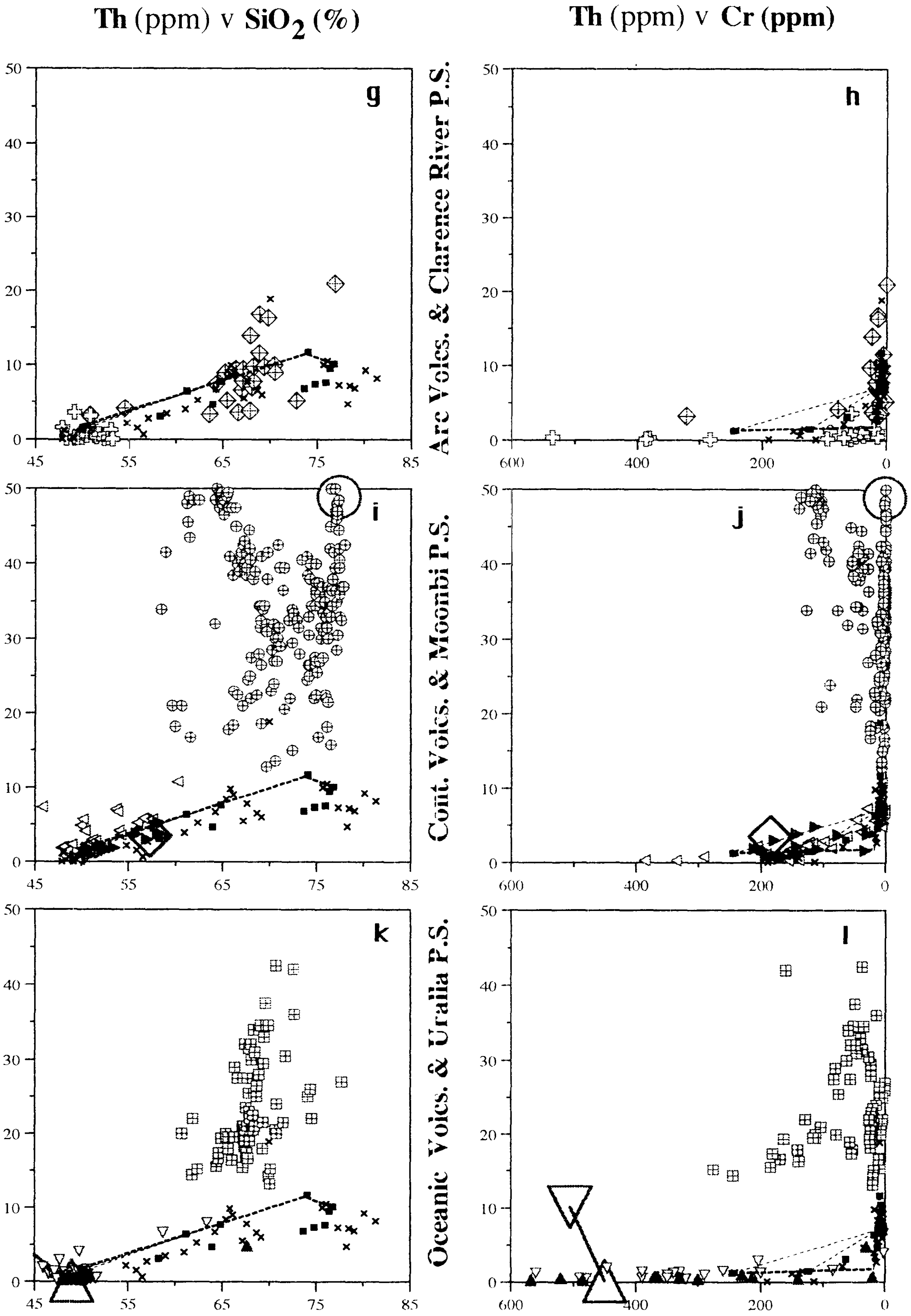


Fig. A2.26 (g–l): Th in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites

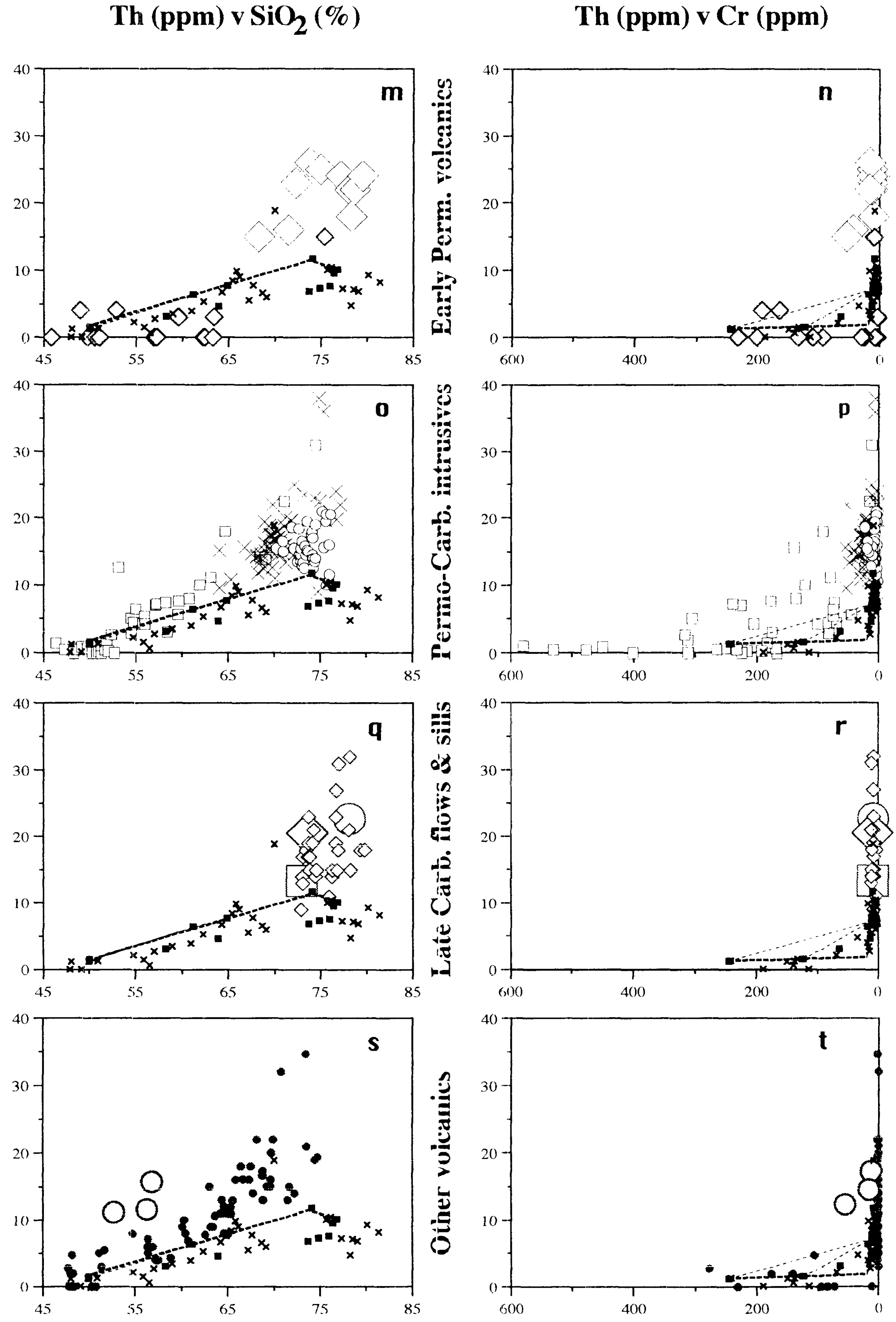


Fig. A2.26 (m–t): Th in Boggabri Volcanics — regional comparisons

Barium

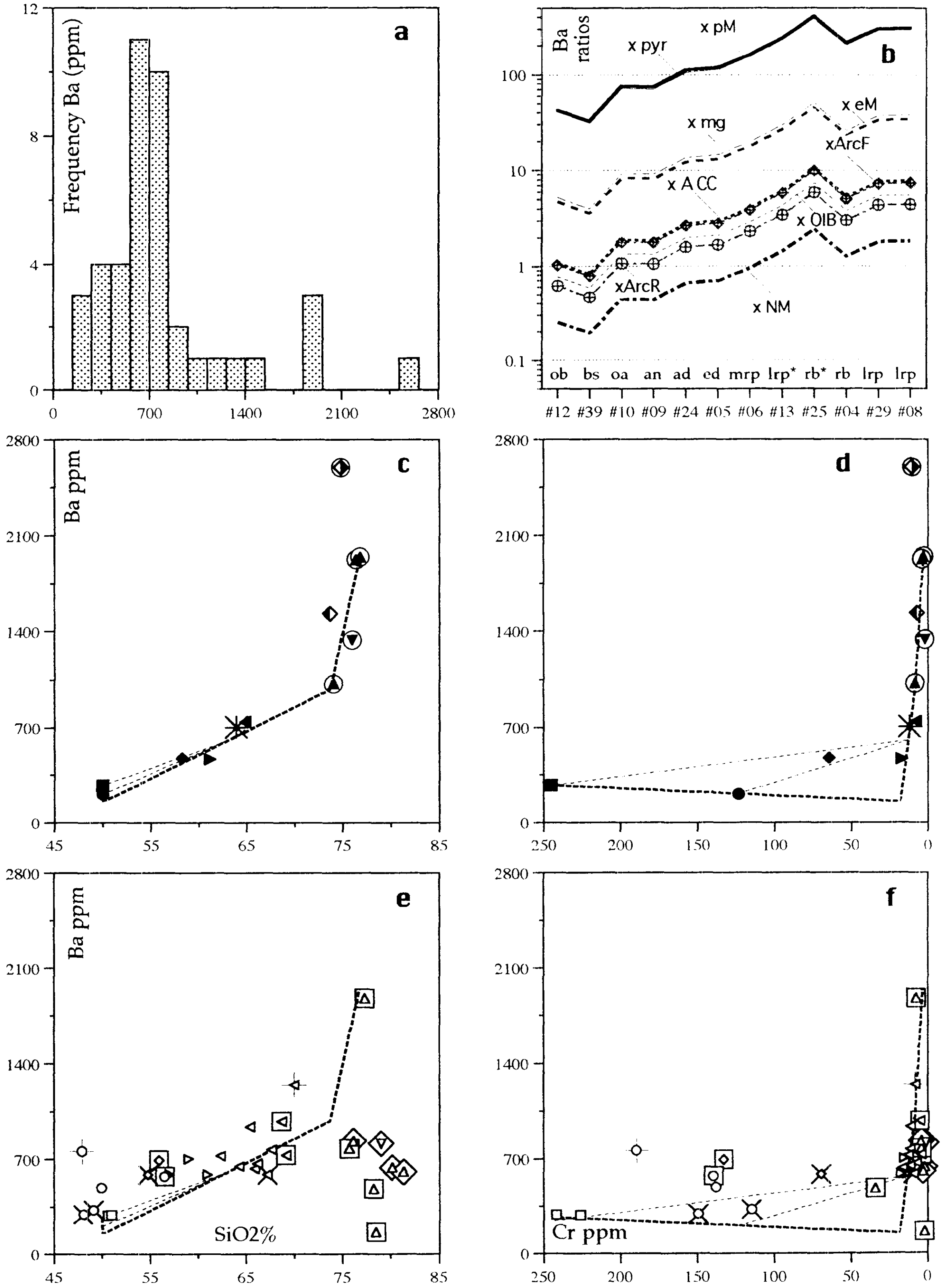
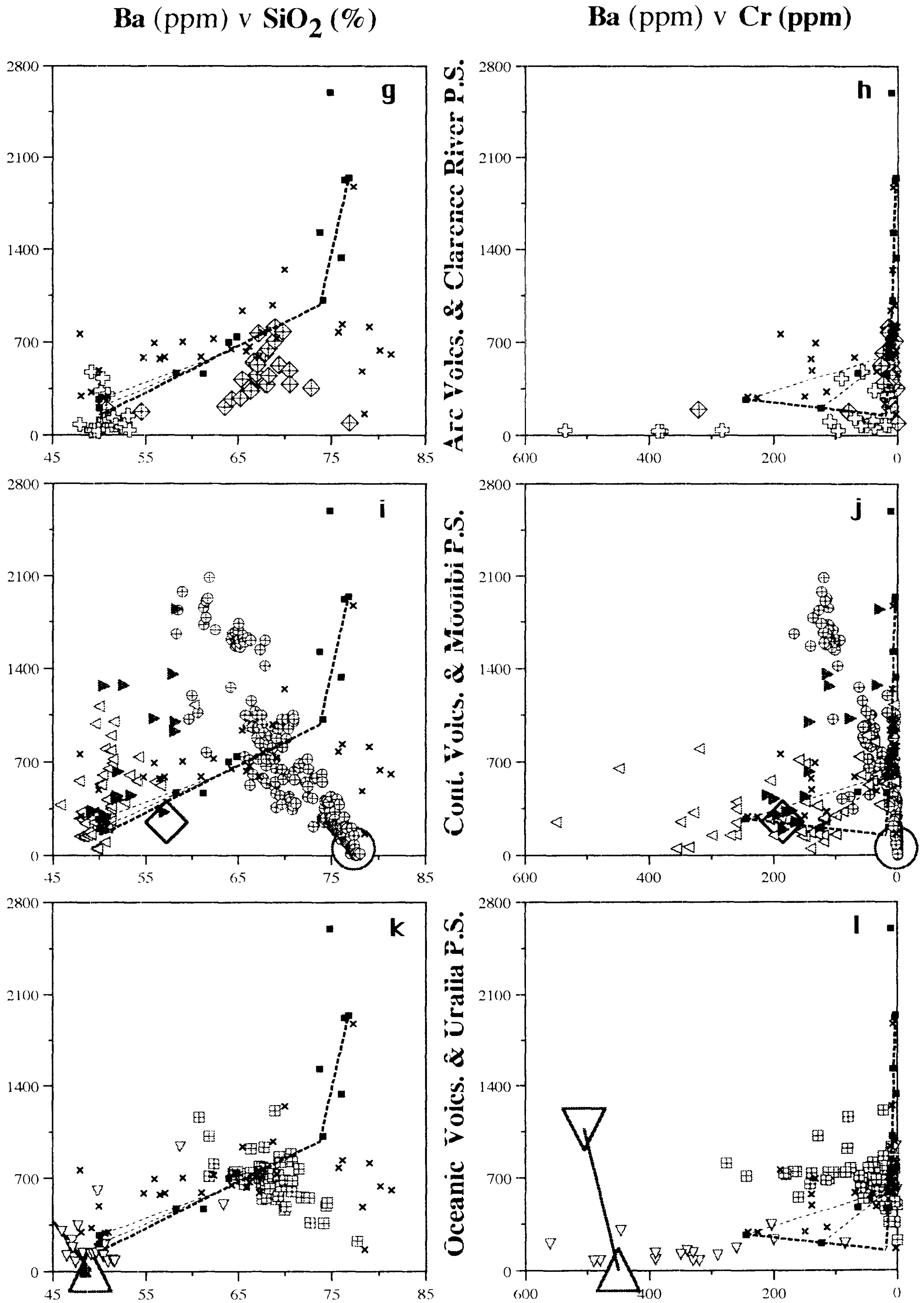
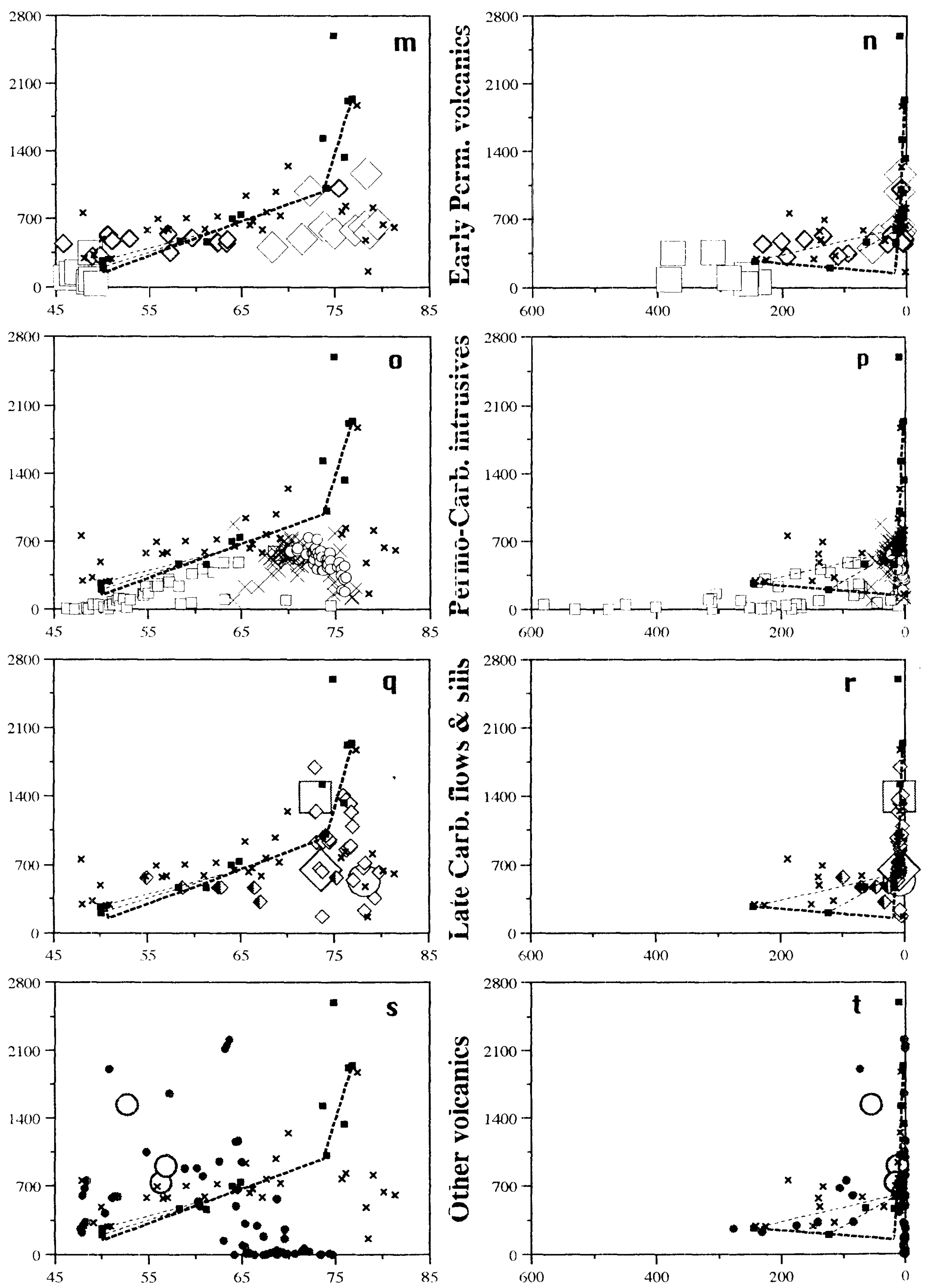


Fig. A2.27 (a–f): Ba in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)


Ba (ppm) v **SiO$_2$** (%)

Ba (ppm) v **Cr (ppm)**

Fig. A2.27 (g–l): Ba in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites



Ba (ppm) v SiO_2 (%)

Ba (ppm) v Cr (ppm)

Fig. A2.27 (m–t): Ba in Boggabri Volcanics — regional comparisons

Rubidium

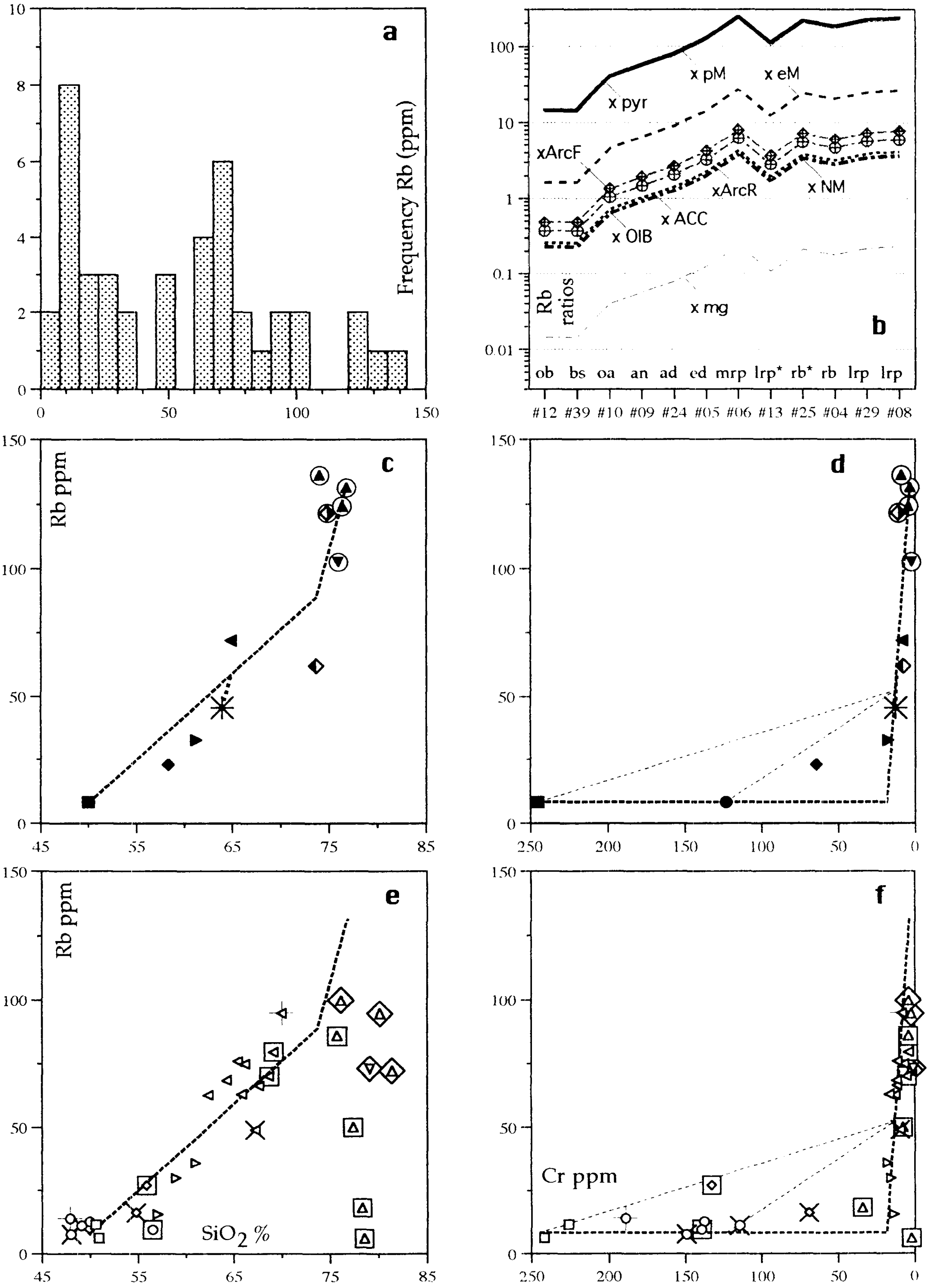


Fig. A2.28 (a–f): Rb in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

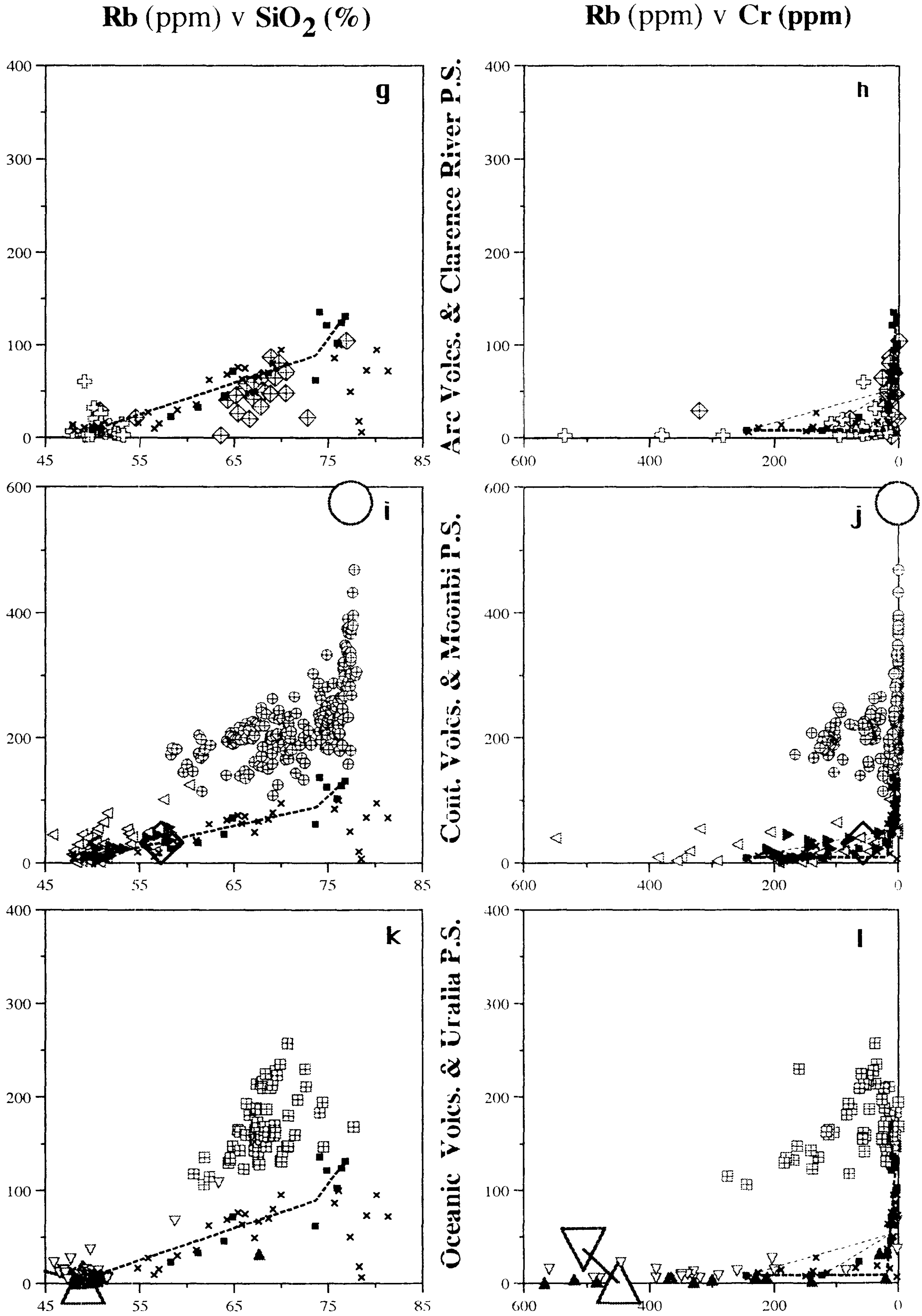


Fig. A2.28 (g–l): Rb in Boggabri Volcanics — comparison with major geochemical reservoirs and select volcanic rocks and granitoid suites

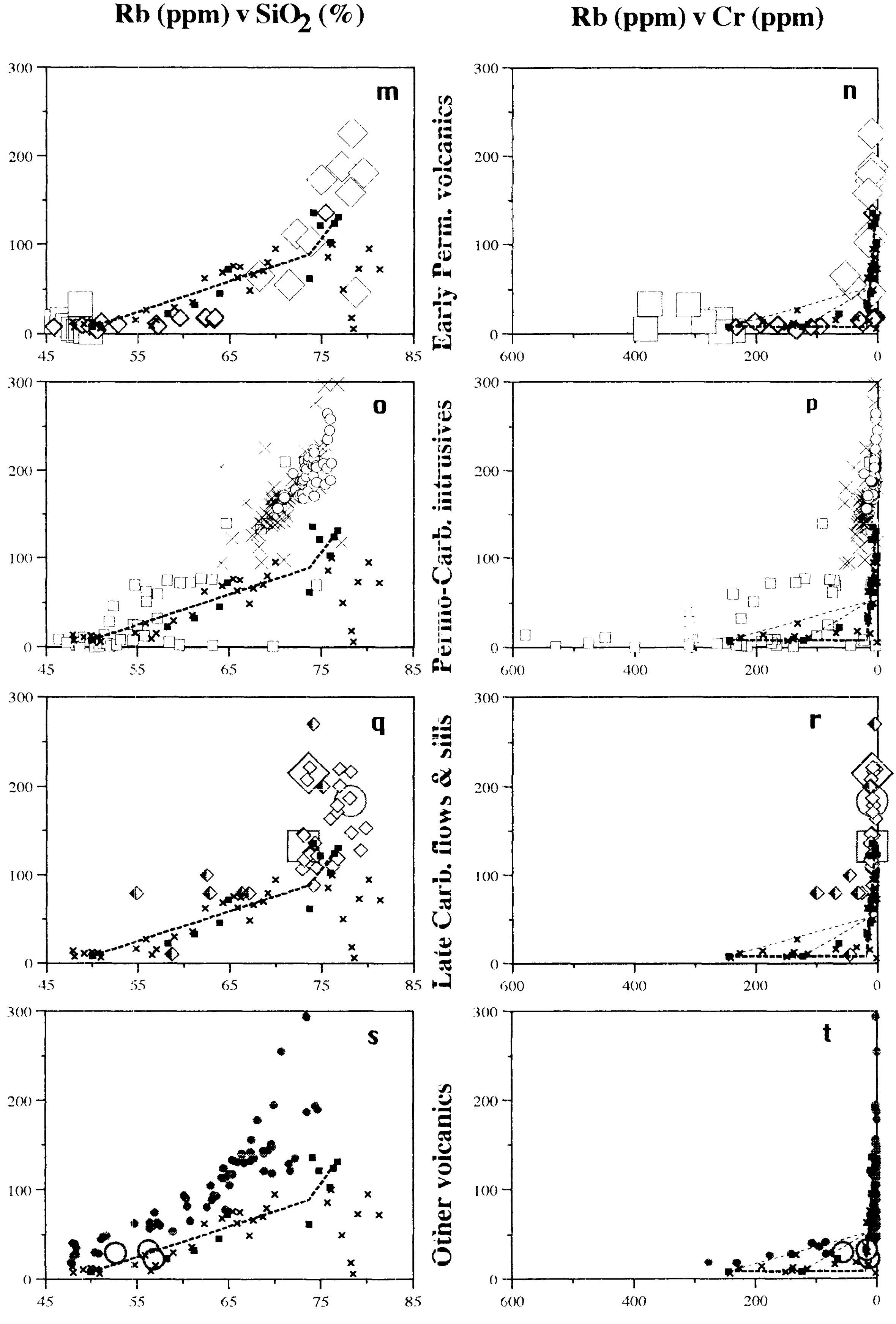


Fig. A2.28 (m–t): Rb in Boggabri Volcanics — regional comparisons

Cesium

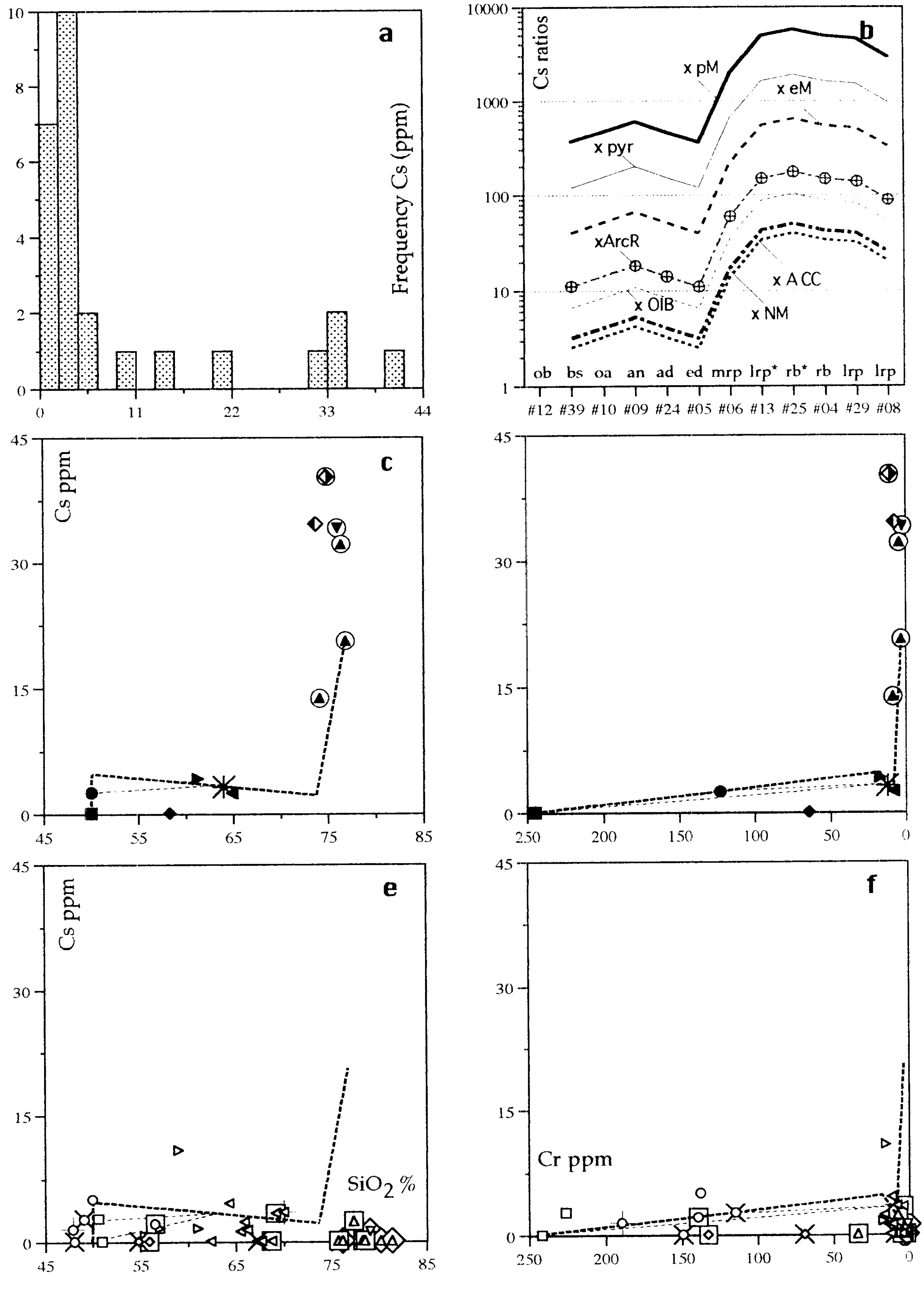


Fig. A2.29 (a–f): Cs in Boggabri Volcanics — histogram for all BV, relative abundance plot for Select BV, and variation in Select and altered BV compared to SiO_2 and Cr (see Fig. A2.1 for legend, and text for explanation)

Other Trace Elements

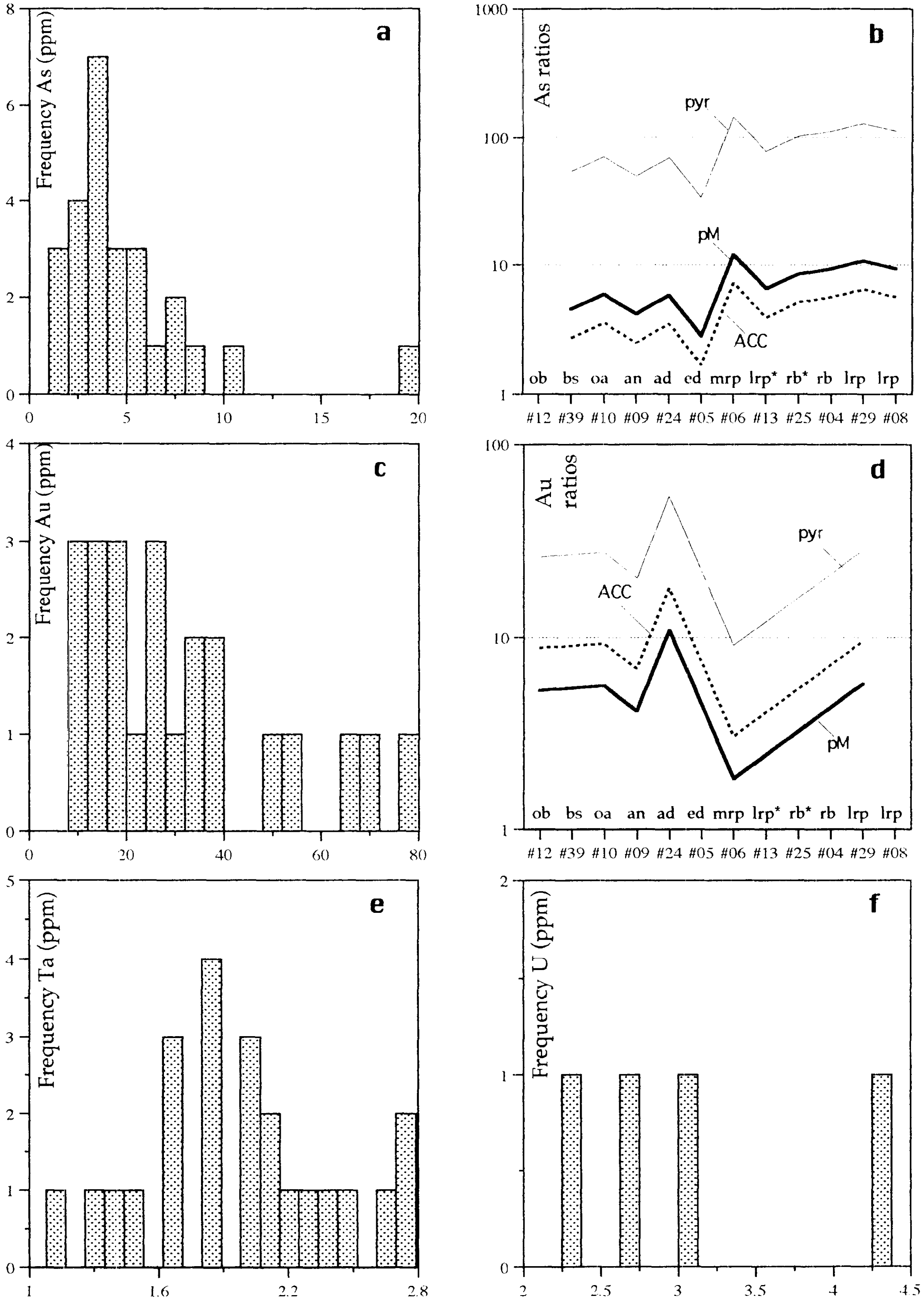


Fig. A2.30 (a–f): Other Trace Elements in Boggabri Volcanics

Part 6:
Summary

ABSOLUTE ELEMENTAL ABUNDANCES IN BV

All analysed elements in BV are within the range of common igneous rocks (Figs. A2.2–A2.30). Al (cf. high-Al basalts), Sr, Cs, Rb, Ba, and Ce are notably high in some rocks, and Mg ranges to magnesian basalt levels, but Ca, Fe, Ti and Nb are in the lower range of common igneous rocks. Silica is notable for its range (≈ 50% in silica-rich basalt to 76.8% among select rocks and to 81.36% among altered rocks) and for its crudely trimodal distribution (basalt, andesite-dacite and rhyolite ranges).

COMPARATIVE ELEMENTAL ABUNDANCES IN SOB_{12}

Elemental abundances in SOB_{12} are subequal to those in certain geochemical reservoirs or reference compositions (Figs. A2.2–A2.30), e.g.:

- **Average Continental Crust** for Na_2O and Pb;
- **Hawaiian Nepheline Melilitite** for Pb;
- **Fuji basalt** (an indicative arc basalt composition) for SiO_2, CaO and Ba; and
- **Rindjani basalt** (an extreme arc basalt composition) for SiO_2, Cr, Al_2O_3, Fe_2O_3t, P_2O_5 and Ce.

SOB_{12} is enriched relative to Primitive MORB in certain elements (Figs. A2.2–A2.30). For these elements, the following are complementary to Primitive MORB (i.e. could be mixed with Primitive MORB to produce SOB_{12}):

- Enriched MORB for Nb;
- **OIB** for K_2O, P_2O_5, Zr, Ce, Nb, Th, Ba and Rb;
- **Hawaiian Nepheline Melilitite** for Na_2O, K_2O, P_2O_5, Zn, Ga, Zr, Sr, Ce, Nb, Th, Ba and Rb;
- **Average Continental Crust** for K_2O, Zn, Ga, Zr, Pb, Ce, Nb, Th and Rb;
- **Mole Granite** for Na_2O, K_2O, Zn, Ga, Zr, Pb, Ce, Nb, Th and Rb;
- **Fuji basalt** (an indicative arc basalt composition) for K_2O, P_2O_5, Zn, Ga, Zr, Th, Pb, and Rb; and
- **Rindjani basalt** (an extreme arc basalt composition) for K_2O, Nb, Th, Ba and Rb.

For elements that are depleted in SOB_{12}, the following are complementary to Primitive MORB:

- **E-MORB** for TiO_2;
- **OIB** for Nb;
- **Average Continental Crust** for Cr, CaO, MgO, Na_2O, TiO_2 and Ni;
- **Mole Granite** for Cr, Fe_2O_3t, CaO, MgO, Na_2O, TiO_2, MnO, Ni, Cu, Sc and V;
- **Hawaiian Nepheline Melilitite** for Na_2O and Sr;
- **Fuji basalt** for Cr, MgO and Ni; and
- **Rindjani basalt** for MgO and Ni.

In addition, SOB_{12} is depleted in Y and Hf and enriched in Cs relative to all of the above compositions.

Note that only limited comparative data are available for OIB and E-MORB. Literature data (BVSP 1981, Floyd 1991) implies that SOB_{12} is depleted relative to OIB for Sc, V, Ca, Ga, Y, and possibly Fe_2O_3t, Na_2O and MgO, and is enriched relative to Al_2O_3. Thus Primitive MORB is also complementary to OIB for Na_2O and Ga.

ELEMENTAL ABUNDANCE TRENDS ACROSS BV RANGE

The select BV compositional range shows the following broad trends relative to SOB_{12} on abundance plots (Fig. A2.2 to A2.30):

- sustained rises for SiO_2, K_2O, Pb, Th, and Rb;
- sustained falls for CaO, MgO, Cr, Ni and Cu (apart from anomalies among rhyolites);
- peaks in the mafic range for Al_2O_3, at about the Mafic Inflection for Fe_2O_3, TiO_2, and MnO, Sc, V, in the andesite range for Zn and P_2O_5; in the dacite range for Ga, between dacite and rhyolite for Y Zr, and Hf, in the rhyolite range (close to the Felsic Inflection) for Na_2O, Ce; and
- complex patterns for Ba (low at SPB_{39} and peak in rhyolites), Sr (sustained fall basalt-dacite range and a peak among rhyolites), Cs (peaks in andesites and rhyolites).

In addition, there are significant increases in some components across the BV range, e.g. between basalt and andesite (Mafic Inflection) for Na_2O and K_2O; between basalt and andesite (Mafic Inflection) for Ba and between dacite to rhyolite for Cs, Sr, Rb, Nb and Ba. There are also significant decreases, e.g. between basalt and andesite for Ni, Cr and MgO and between dacites and rhyolites for Al_2O_3, Fe_2O_3t, CaO, MgO, TiO_2, P_2O_5, Sc, V and Cu.

Several anomalies are evident amongst the rhyolites. The two leucocratic pyroxene rhyolites ($SLPR_{29}$ and $SLPR_{08}$) are consistently distinguished from other rhyolites by slight differences amongst HFSEs, especially Y and Ce. $SMPR_{06}$ exhibits many anomalies e.g., K_2O, Ga and Zn are low but Pb, Th and Rb are high. Ignimbrites ($SLPR_{13}$ and $SFBR_{25}$) are commonly slightly enriched or depleted in elements that are enriched or depleted respectively in basalts compared to rhyolites.

BIVARIATE PLOTS FOR SELECT BV

Bivariate plots **v SiO_2** and **v Cr** (as a proxy for MgO) show a Main Trend clearly differentiated into a Mafic Segment among select basaltic rocks, an Intermediate Segment among andesitic to dacitic rocks, and commonly, a separate Felsic Segment among rhyolitic rocks.

The Mafic Segment from SOB_{12} (245 ppm) to a calculated Mafic Inflection (18 ppm Cr) is sub-vertical in SiO_2 plots (SiO_2 range 50% to 50.09%), but flat to gently inclined on Cr plots (negligible to moderate change in most other components). Relative to SOB_{12} the Mafic Inflection is distinctly higher (in decreasing order) for: Hf (3x), Zr, Y, TiO_2, La, Ce, MnO, Na_2O, Nb, Th, P_2O_5, V, Pb, Ga, Fe_2O_3t , Zn, Sc, K_2O, and Al_2O_3 (1.02x). It is identical for SiO_2, and Rb, but is lower (in decreasing order) for: CaO (0.96x), Cu, Sr, Ba, MgO, and Cr (0.07x). Ni is also severely depleted, but projects to an (unreal) negative number, and the more felsic parts of the Main Trend are meaningless. Cs is below detection limit (0.5 ppm) in SOB_{12} and therefore an enrichment cannot be calculated. Altered rocks typically show significant scatter about the Mafic Segment on Cr diagrams. On SiO_2 diagrams, the Mafic Segment is commonly short and oblique to the Intermediate Segment, and altered rocks commonly plot as a mafic extension to the array developed about the Intermediate Segment.

The Intermediate Segment ranges from the inferred Mafic Inflection (SiO_2 = 50.09%, Cr = 18 ppm) to the inferred Felsic Inflection (SiO_2 = 73.73 %, Cr = 8.48 ppm). This trend is always subvertical on Cr diagrams, but flat to moderately inclined on SiO_2 diagrams. Relative to the Mafic Inflection, the Felsic Inflection is higher (in decreasing order) for: Rb (10.83x), Ba, Th, K_2O, Pb, Zr, Hf, Nb, Y, and Na_2O (1.19x), but lower for Zn (0.93x), Ce, P_2O_5, Ga, Al_2O_3, Sr, MnO, Cs, TiO_2, Sc, Fe_2O_3t, CaO, and V (0.02x). MgO, Cu, and Ni are also lower, but project to (unreal) negative values, and the more felsic parts of that trend are meaningless. The Intermediate Segment models select andesites and dacites well for Fe_2O_3t, Al_2O_3, CaO, MgO, Na_2O, TiO_2, Sc, Ni, Sr, Cs, Pb, Ba, Y, Zr, Hf, Th, and Ce, but less so for K_2O, V, Cu, Rb. However, the Main Trend models P_2O_5, MnO, Zn, and Ga very poorly. In addition, **P_2O_5 v Cr** is unusual in that three andesites have much higher P_2O_5 than both SPB_{39} and the Mafic Inflection.

The Felsic Segment ranges from the Felsic Inflection to $SLPR_{08}$ (76.8% SiO_2, 3.26 ppm Cr). The slope of the trend is highly variable. Relative to the Felsic Inflection, $SLPR_{08}$ is higher (in decreasing order) for : Cs (9.35x), V, CaO, Ba, Sr, Rb, K_2O, and Pb (1.37x), but lower for La (0.96x), Al_2O_3, Nb, Ce, Th, Ga, Sc, TiO_2, Hf, Fe_2O_3t, Zr, Y, Zn, Na_2O, P_2O_5, Ni, and MnO (0.1x). The Felsic Trend models the compositional range of most select rhyolites reasonably well for Al_2O_3, Fe_2O_3t, Na_2O, TiO_2, Sc, Zn, Zr, and Hf but indifferently for CaO, MgO, MnO, Ni, V, Cu, Sr, Rb, and Y and poorly for K_2O, P_2O_5, Cs, Pb, Ba, Ga, Nb, Th, and Ce.

Cross Trends 1 and 2 represent an alternative to parts of the Main Trend, especially in the vicinity of the Mafic Inflection. SOA_{10} lies virtually on Cross Trend 2 for Ba, Ga, Zr, and Ce, distinctly higher than that trend for Al_2O_3, Fe_2O_3t, CaO, Na_2O, Zn, Hf, and marginally high for TiO_2, Ni but is distinctly lower for MgO, MnO, Sc, Cs, Rb, Pb, Nb, Th, and marginally low for K_2O, P_2O_5 (v Cr only) and Cu. It is close to Cross Trend 1 for V, Zr, and Y (v SiO_2 only).

The **Dyke Trend** reflects the departure of SAD_{24} from the Main Trend. It is generally indistinct, but is highly conspicuous on **Y v SiO_2**, **Zr v SiO_2**, and **Hf v SiO_2** and clearly evident on **K_2O v SiO_2**, **P_2O_5 v SiO_2**, **P_2O_5 v Cr**, **MnO v SiO_2**, **Mn v Cr**, **Zn v SiO_2**, **Zn v Cr**, **Ga v SiO_2**, **Nb v SiO_2**, and **Th v SiO_2**.

ALTERATION

Several styles of alteration are recognised, namely zeolitised basalt, carbonated basalt, basaltic andesite and dacite, silicified basalt, basaltic andesite and rhyolite, leached rhyolite, pitchstone (all select rocks) and white rhyolites (see Fig. A2.2 to A2.30):

- **zeolitised basalt** (#33) has conspicuously high Al_2O_3 and Ga, and high Sr, Sc, V and Ba, but low Th and slightly low SiO_2, CaO, Pb and Cu;
- **carbonated basalts** (#11, #44) have high Al_2O_3, CaO (+3 to 6%), MnO, Cu and Sc, but conspicuously low MgO, and low SiO_2 and Ce, and variable Pb and Zn (one low in each);
- **silicified basalt** (#43) has low MgO, K_2O, V, Y, Ce, Nb, and Th but high Fe_2O_3t, Pb, Zn, and Ba;
- **silicified basaltic andesite** (#45) has high Zn, Ce, Nb, P_2O_5 and Ba;
- **carbonated basaltic andesite** (#03) has high Al_2O_3, CaO, MnO, Sr, Pb, Cu, Ba, and low MgO, Fe_2O_3t, Zr, Ce and Y;
- some **altered andesites** have high Sc, V and Zn (one), but variable Ce, Sr, and low Th;
- **carbonated dacite** (#07) has low Al_2O_3, MgO, Rb, Nb, Sr, Ba, and Th but high CaO, MnO and Pb;

- **silicified dacite** (#18, #30) has high Pb, Nb, Ce but low Y, Zr, Hf (one), Sr and Th and variable Fe_2O_3t;
- **leached dacite** (#40) has high Al_2O_3, Ga, Zr, Rb, Pb, Ba, Y, and Ce, and extremely high Th, but low Sr;
- other **altered dacites** have slightly high K_2O, Rb, Pb, Sc, Zr, Hf, Nb and Ce, variable Th and Zn (some high), but low Sr and low to moderate MgO;
- **white rhyolites** (#28, #32, #34, #37) have high Nb, slightly high SiO_2, slightly low Al_2O_3 (all rocks), TiO_2 (some rocks), and K_2O (some rocks), low Fe_2O_3t (all rocks), P_2O_5, CaO (some rocks), Sr, Cs, Rb, Zr, Hf, Th, and low to very low in MgO, Pb, Ba and Y; and
- **silicified rhyolites** (#01, #02, #22, #31) show enrichment to strong depletion in MgO and Na_2O, high Nb, marginally high SiO_2, slightly low Y and Ga (some rocks), variably low K_2O (#01 and #22), low Th, Cs, and Sr (one extremely high value excepted), and moderate to very low CaO, Pb, Ba and Rb.

Additional irregularities are present, but are not mentioned owing to uncertainties in the locus of parts of the Main Trend for some elements (e.g. MgO, P_2O_5, Ni, Cu and Zn).

Radial dispersal relative to the Main Trend has been calculated for select immobile element pairs (MacLean, 1992). #33 exhibits the largest apparent mass change (34% net loss), but bulk changes for other samples are generally less than about 15%.

BIVARIATE TYPE COMPARISONS

The silica range of select BV and the abundance of rhyolites together distinguish BV from most type and regional comparative data sets (except some alkalic basalts range to lower silica). Cr values in select BV are generally lower at equivalent silica than those of most geological settings, except for some oceanic islands and some of continental affinity. **SiO_2 v Cr** distinguishes BV rocks by limited Cr range among basalts compared to BVSP reference Arc, CFB, and Oceanic rocks, among mafic to intermediate rocks compared to Early Permian central NEO mafic complexes, and among dacites compared to select I-type granitoids.

Table A2.3 summarises the relationships between the range of BV and various type and regional references (see bivariate plots Fig. A2.2 to A2.30).

Three symbols (≈, <> and ><) indicate substantial overlap of ranges, two symbols (≥, ≤) indicate partial overlap, and two symbols (>, <) indicate no overlap.

This table shows that for similar SiO_2 and/or Cr:

- **BVSP Arc volcanic rocks** and BV substantially overlap for 10 elements (Al_2O_3, Fe_2O_3t, MgO, K_2O, MnO, Ni, Rb, Ba, Y and Th), partially overlap 11 elements

(CaO, Na_2O, TiO_2, P_2O_5, V, Cu, Zn, Ga, Zr, Nb, and Ce) but do not overlap for 3 elements (Sc, Sr, and Pb).

- **BVSP CRZ basalts** and BV substantially overlap for 14 elements (CaO, MgO, TiO_2, P_2O_5, MnO, Ni, Cu, Sr, Rb, Pb, Y, Zr, Th, Ce), partially overlap for 6 elements (Fe_2O_3t, Na_2O, K_2O, Sc, Ga, Nb), but do not overlap for two elements (Al_2O_3, Ba). BVSP analyses lack data for V and Zn.
- **BVSP CFB basalts** and BV substantially overlap for 6 elements (CaO, MgO, V, Sr, Pb, Ce), partially overlap for 15 elements (Fe_2O_3t, Na_2O, K_2O, TiO_2, P_2O_5, MnO, Sc, Ni, Rb, Ba, Ga, Y, Zr, Nb, Th), but do not overlap for two elements (Al_2O_3, Zn). BVSP analyses lack data for Cu.
- **BVSP OFB basalts** and BV substantially overlap for 3 elements (MnO, Y, Nb), partially overlap for 6 elements (Fe_2O_3t, MgO, TiO_2, Ni, Ga, Zr), but do not overlap for 11 elements (Al_2O_3, CaO, Na_2O, K_2O, P_2O_5, Sc, Sr, Rb, Pb, Th, Ce). BVSP analyses lack data for V, Cu, Zn, and Ba.
- **BVSP OIP tholeiitic basalts** and BV substantially overlap for 11 elements (MgO, K_2O, MnO, Rb, Pb, Ba, Ga, Y, Zr, Th, Ce), partially overlap for 3 elements (TiO_2, P_2O_5, Nb), but do not overlap for 6 elements (Al_2O_3, Fe_2O_3t, CaO, Na_2O, Sc, Sr). BVSP analyses lack data for Ni, V, Cu and Zn.
- **BVSP OIP alkalic basalts** and BV substantially overlap for 2 elements (Sr, Pb), partially overlap for 5 elements (MnO, Ga, Y, Zr, Th), but do not overlap for 13 elements (Al_2O_3, Fe_2O_3t, CaO, MgO, Na_2O, K_2O, TiO_2, P_2O_5, Sc, Rb, Ba, Nb, Ce). BVSP analyses lack data for Ni, V, Cu and Zn.
- **Clarence River Plutonic Suite** (M-type) granitoids and BV substantially overlap for 5 elements (Ni, V, Sr, Pb, Th), partially overlap for 7 elements (Sc, Cu, Zn, Rb, Ba, Ga, Ce), but do not overlap for 12 elements (Al_2O_3, Fe_2O_3t, CaO, MgO, Na_2O, K_2O, TiO_2, P_2O_5, MnO, Y, Zr, Nb)
- **Moonbi** Plutonic Suite (I-type) granitoids and BV substantially overlap for 7 elements (Fe_2O_3t, Sc, V, Cu, Sr, Ba, Y), partially overlap for 10 elements (CaO, MgO, P_2O_5, MnO, Ni, Zn, Pb, Ga, Nb, Ce), but do not overlap for 7 elements (Al_2O_3, Na_2O, K_2O, TiO_2, Rb, Zr, Th).
- **Uralla** Plutonic Suite (I-type) granitoids and BV substantially overlap for 5 elements (Fe_2O_3t, V, Cu, Ba, Nb), partially overlap for 8 elements (CaO, MgO, Sc, Ni, Zn, Ga, Y, Ce), but do not overlap for 11 elements (Al_2O_3, Na_2O, K_2O, TiO_2, P_2O_5, MnO, Sr, Rb, Pb, Zr, Th).

BIVARIATE REGIONAL COMPARISONS

Table A2.3 also list similar comparisons for regional reference data sets:

- **Werrie Basalt** and BV substantially overlap for 16 elements (Al_2O_3, Fe_2O_3t, CaO, MgO, K_2O, TiO_2, P_2O_5, MnO, Sc, Ni, Sr, Ba, Ga, Y, Nb, Ce), and partially overlap for 8 elements (Na_2O, V, Cu, Zn, Rb, Pb, Zr, Th).
- **Petroi Metabasalt** and BV substantially overlap for 9 elements (Al_2O_3, Fe_2O_3t, MnO, Ni, Rb, Ba, Y, Zr, Ce), partially overlap for 7 elements (CaO, MgO, Na_2O, K_2O, TiO_2, V, Ga), but do not overlap for 3 elements (P_2O_5, Sr, Nb). Petroi analyses lack data for Sc, Cu, Zn, Pb, Th.
- **Halls Peak volcanics** and BV substantially overlap for 6 elements (Na_2O, TiO_2, Ni, V, Ga, Nb), partially overlap for 15 elements (Al_2O_3, Fe_2O_3t, CaO, MgO, K_2O, P_2O_5, MnO, Sc, Cu, Zn, Rb, Pb, Ba, Y, Zr), but do not overlap for 3 elements (Sr, Th, Ce).
- **Copeton Plutonic Suite granitoids** and BV substantially overlap for 4 elements (Ni, V, Ga, Ce), partially overlap for 15 elements (Al_2O_3, Fe_2O_3t, CaO, MgO, K_2O, TiO_2, P_2O_5, MnO, Sc, Cu, Zn, Pb, Y, Nb, Th), but do not overlap for 5 elements (Na_2O, Sr, Rb, Ba, Zr).
- **Hillgrove Plutonic Suite granitoids** and BV substantially overlap for 5 elements (Ni, V, Cu, Ga, Ce), partially overlap for 13 elements (Al_2O_3, Fe_2O_3t, CaO, MgO, K_2O, TiO_2, P_2O_5, MnO, Sc, Zn, Pb, Y, Nb), but do not overlap for 6 elements (Na_2O, Sr, Rb, Ba, Zr, Th).
- **Early Permian central NEO mafic complexes** and BV substantially overlap for 2 elements (Ni, Th), partially overlap for 14 elements (Al_2O_3, Fe_2O_3t, MgO, K_2O, TiO_2, MnO, Sc, V, Cu, Zn, Rb, Pb, Y, Nb), but do not overlap for 8 elements (CaO, Na_2O, P_2O_5, Sr, Ba, Ga, Zr, Ce).
- **Late Carboniferous volcanic rocks** and BV substantially overlap for 8 elements (Al_2O_3, Fe_2O_3t, CaO, MgO, K_2O, Sr, Rb, Ba), partially overlap for 7 elements (Na_2O, MnO, Sc, Ni, V, Cu, Ga), but do not overlap for 5 elements (TiO_2, P_2O_5, Pb, Y, Zr). The reference analyses lack data for Zn, Nb, Th, and Ce.
- **Late Carboniferous sills** and BV substantially overlap for 6 elements (Al_2O_3, Fe_2O_3t, CaO, MgO, K_2O, MnO), partially overlap for 1 element (Na_2O), but do not overlap for 2 elements (TiO_2, P_2O_5). The reference analyses lack trace element data.
- **Late Carboniferous rhyolites** and BV substantially overlap for 15 elements (Al_2O_3, Fe_2O_3t, CaO, MgO, Na_2O, K_2O, MnO, Ni, V, Cu, Zn, Pb, Ga, Y, Nb), partially overlap for 7 elements (TiO_2, P_2O_5, Sr, Rb, Ba, Zr, Th). The reference analyses lack data for Sc and Ce.

- **Tertiary Nandewar volcanic rocks** and BV substantially overlap for 4 elements (TiO_2, P_2O_5, Ni, Ba), partially overlap for 12 elements (Al_2O_3, Fe_2O_3t, Na_2O, MnO, V, Cu, Sr, Rb, Pb, Y, Zr, Th), but do not overlap for 7 elements (CaO, MgO, K_2O, Sc, Zn, Nb, Ce). The reference analyses lacks data for Ga.
- **Unassigned Boggabri Volcanics** and BV substantially overlap for 14 elements (Al_2O_3, Fe_2O_3t, CaO, K_2O, TiO_2, Ni, Cu, Zn, Sr, Rb, Ga, Y, Zr, Nb), partially overlap for 5 elements (Na_2O, P_2O_5, MnO, Sc, V), but do not overlap for 5 elements (MgO, Pb, Ba, Th, Ce).

Careful perusal of data for the three Late Carboniferous virtophyres indicated on Figs A2.2–A2.30, especially silica diagrams with steep Felsic Segments (e.g. **Na_2O v SiO_2**) reveals that:

- Piallaway rhyolite vitrophyre has similar elemental abundances to the Felsic Inflection and/or the less silicic of the select rhyolites, except for slightly higher Cr, slightly lower SiO_2, and distinctly lower K_2O, Y, Zn and Nb;
- Taggarts Mountain low-Si rhyolite virtophyre has a similar composition to the Felsic Inflection and/or the less silicic of the select rhyolites except for low Zr, Sr and Ba and high Rb; and
- Taggarts Mountain high-Si rhyolite vitrophyre has elemental abundances comparable to some silicified BV rhyolites, but is generally distinct from the Main Trend or select BV rhyolites.

Table A2.3: Comparison of Select BV with Geochemical Reservoirs and Reference Compositions

	Major Oxides									*Trace Elements*														
	Al	*Fe*	*Ca*	*Mg*	*Na*	*K*	*Ti*	*P*	*Mn*	*Ni*	*Cu*	*Zn*	*Sc*	*V*	*Ga*	*Y*	*Zr*	*Sr*	*Pb*	*Ce*	*Nb*	*Th*	*Ba*	*Rb*
Arc volcanics	<>	≈	<=	≈	≥	<>	≥	≥	≈	≈	≤	≥	<	≤	>	≈	≥	>	>	≥	≥	<>	<>	<>
CRZ volcanics	>	<=	<>	≈	≥	≤	≈	≈	≈	≈	<>	-	≥	-	≤	≈	≈	<>	≈	<>	≤	≈	<	≈
CFB volcanics	>	<=	<>	≈	≥	≤	≤	≤	≤	≤	-	<	≤	<>	≤	≤	≤	<>	≈	<>	≤	≤	≤	≤
OFB volcanics	>	≤	<	≤	>	>	≥	>	≈	≤	-	-	<	-	≥	≈	≥	>	>	>	≈	>	-	>
OIP tholeiitic volcanics	>	<	<	≈	>	≈	≤	≥	≈	-	-	-	<	-	≈	≈	≈	>	≈	≈	≤	≈	≈	≈
OIP alkalic volcanics	>	<	>	>	<	<	<	<	≤	-	-	-	>	-	≤	≤	≤	<>	≈	<	<	≤	<	<
Nundle Plutonic Suite	<	>	<	<	>	>	>	>	>	≈	≤	≥	≤	≈	≥	>	>	<>	<>	≥	>	<>	≥	≥
Moonbi Plutonic Suite	>	≈	<=	≤	>	<	>	≥	≥	≤	≈	≥	≈	≈	≥	<>	>	<>	≤	≤	≤	<	<>	<
Uralla Plutonic Suite	>	≈	<=	≤	>	<	>	>	>	≤	≈	≥	≤	≈	≥	≥	>	>	<	≤	≈	<	<>	<
Petroi Metabasalt	<>	≈	<=	≤	≤	≤	≤	<	≈	><	-	-	-	≤	≥	≈	≈	>	-	≈	<	-	<>	≈
Werrie Basalt	≈	≈	≈	≈	≤	-		<>	≈	≈	>	<	≈	≥	≈	<>	≥	≈	≥	≈	≈	≥	≈	≥
Halls Peak volcanics	>=	<=	<=	≤	≈	≥	≈	≤	≥	≈	≤	≤	≤	≈	<>	≤	≤	>	≤	<	≈	<	≥	≤
NEO mafic complexes	≥	>=	<	≤	<	≥	≥	>	≥	≈	≥	≥	≤	≥	>	≥	>	>	≥	>	≥	≈	>	≤
Copeton Plutonic Suite	>=	<=	<=	≤	<	≤	≥	≥	≥	≈	≤	≥	≤	≈	≈	≥	>	>	≤	≈	≥	≤	>	<
Hillgrove Plutonic Suite	>=	<=	<=	≤	<	≤	≥	≥	≥	≈	<>	≥	≤	≈	≈	≥	>	>	≤	≈	≤	<	>	<
Late Carb. volcanics	≈	≈	≈	≈	≤	<>	>	>	≥	≤	≥	-	≤	≤	≤	>	>	≈	<	-	-	-	≈	<>
Late Carb. rhyolites	≈	≈	≈	≈	><	<>	≥	≥	≈	≈	≈	≈	-	≈	<>	≈	≥	≥	<>	-	<>	≤	≥	≤
Late Carb. sills	≈	≈	≈	≈	≤	<>	>	>	≈	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tertiary volcanics	≥	≥	>	>	≤	<	<>	<>	≥	≈	≥	<	>	≥	-	≤	≤	≥	≤	<	<	≤	<>	≤
Unassigned volcanics	≈	≈	≈	>	≤	≈	≈	≤	≥	≈	≈	≈	≤	≤	≈	≈	≈	≈	<	<	≈	<	<	≈

≈ = BV range similar to reference range

<> = BV range within large reference range

>< = BV range includes small reference range

≤ = BV values overlap lower reference range

≥ = BV values overlap upper reference range

< = BV values smaller than reference values

> = BV values larger than reference values

\- = no data available