is an indication of strong interaction it may be concluded that intermolecular interaction in *n*-heptane molecule is greater than *n*-hexane molecule.

ACKNOWLEDGEMENT

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SOME ASPECTS OF PERALKALINE RHYOLITE GENESIS

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INTRODUCTION

PERALKALINE rhyolites are generally geochemically more fractionated than metaluminous rhyolites and associated with transitional or mildly alkaline alkali basalts. A model is presented in an attempt to explain the above observation. Before continuing, however, it should be stated that peraluminous rhyolites are to be excluded from the following discussion. Crustal contamination of magmas in the below fractional crystallisation model, based upon feldspars, will be assumed to be minimal. The terms "peralkaline", "metaluminous" and "peraluminous" are based upon the Shand classification which utilizes silica and alumina saturation[1].

THE ROLE OF FELDSPARS IN FRACTIONATION

The feldspar mineralogies of the basalt-peralkaline rhyolite and basalt-metaluminous rhyolite series are important in the crystal fractionation histories of the two series. In southeast Queensland, Australia, it appears that for the tertiary peralkaline rhyolite series, as the parental mafic melt differentiates, the crystallising plagioclase becomes increasingly more albitic at first and thereafter becomes an anorthoclase. In effect, we have at any one stage in the crystal fractionation history of the series the one feldspar, initially a plagioclase and finally, after a "continuum" of compositional modification, an anorthoclase. The intermediate rocks are characterised by one feldspar-bearing (anorthoclase) trachytes. Data on bulk rock and feldspar compositions for this series are plotted[2,3] in figures 1 and 2 and shown in table 1.

On the other hand, the tertiary metaluminous rhyolite series in southeast Queensland, in a crystal fractionation model, is characterised by the crystallisation of plagioclase in the differentiating parental mafic melts and thereafter, in the derived and differentiating trachytes, by the crystallisation of co-existing plagioclase and sanidine. In the metaluminous
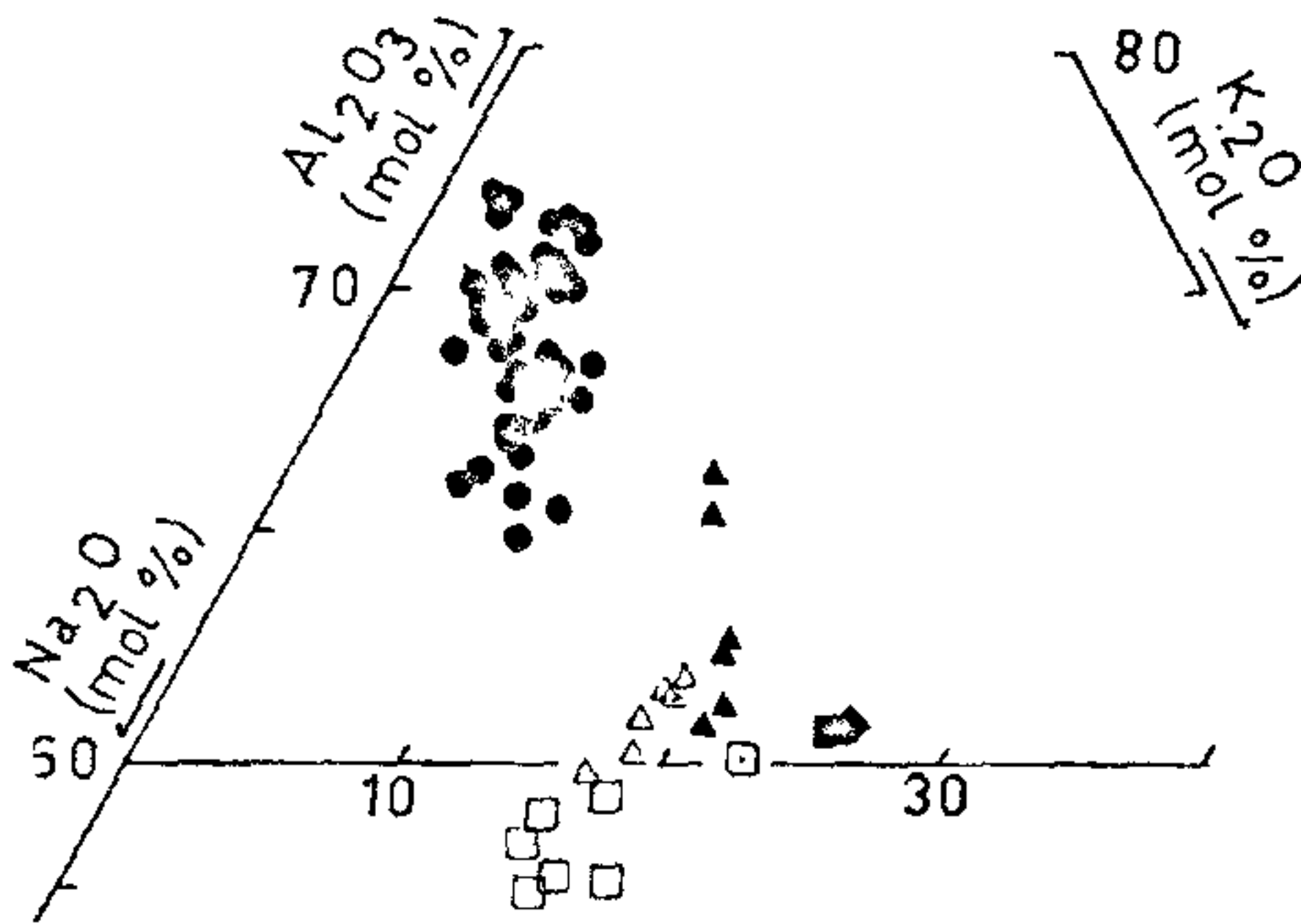
Figure 1. Molecular % Al_2O_3, Na_2O and K_2O components for comendites, metaluminous granophyre, metaluminous rhyolites, trachytes and mafic lavas from the southeast Queensland tertiary volcanics. Note that the peralkaline and metaluminous fields for acidic rocks lie above and below Al_2O_3 (mol. %) = 50 respectively. □ Glass Houses Comendites[2] (peralkalinity index = 1.17) ▣ Metaluminous pitchstone[2] sample 87 (transitional to peralkaline, peralkalinity index = 0.99) ◆ Average metaluminous Mt Barney Granophyre[2] (peralkalinity index = 0.93) ■ Average of selected pitchstones from the metaluminous Mt. Gillies Rhyolite[2] (peralkalinity index = 0.92) △ One feldspar trachytes[2] ▲ Two feldspar trachytes[2] ● Mafic lavas[2] (alkali, transitional and tholeiitic)
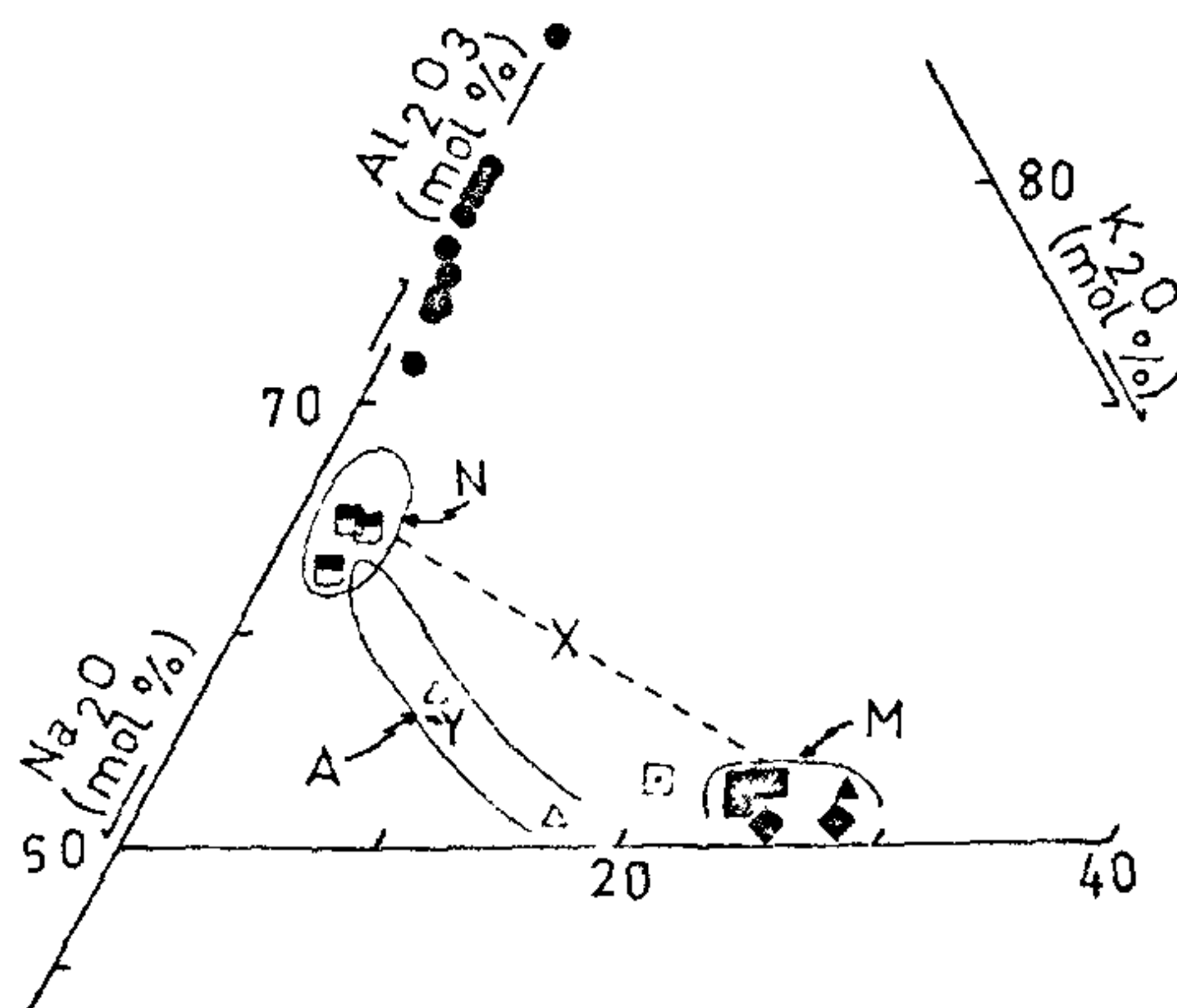

Figure 2. Molecular % Al_2O_3, Na_2O and K_2O components for plagioclases and alkali feldspars from the southeast Queensland tertiary volcanics. M and N represent fields of phenocrystic sanidines and plagioclases from metaluminous acidic rocks (excluding

sample 87 which is transitional to peralkaline) and a two feldspar trachyte; the dashed line represents a tieline between co-existing sanidines and plagioclases of the Mt. Gillies Rhyolite. A represents a possible field for anorthoclases from one feldspar trachytes which belong to the basalt-peralkaline rhyolite series. X represents an assumed average feldspar composition of plagioclases and sanidines from the rhyolites and trachytes of the basalt-metaluminous rhyolite series. Y represents an assumed average feldspar composition of feldspars from the rhyolites and trachytes of the basalt-peralkaline rhyolite series. (Both average feldspar compositions should be estimated on the basis of observed feldspar compositions and the weight fractions of feldspars subtracted from the differentiating melts during fractional crystallisation.) Note that this figure is very similar to an An-Ab-Or diagram with An corresponding to Al_2O_3 = 100 where feldspars are plotted in the above figure. As the SiO_2 contents of end member feldspar components increase in the order An, Or to Ab (see table 1), then the average feldspar X is relatively poor in SiO_2 compared to the average feldspar Y—this forms the basis of the feldspar model presented in the text in regard to a possible mechanism for explaining why peralkaline rhyolites are more fractionated than metaluminous rhyolites. ▣ Phenocrystic sanidine from metaluminous pitchstone sample 87[2] (transitional to peralkaline); ◆ Phenocrystic sanidines from the metaluminous Mt. Barney Granophyre[2]; ■ Phenocrystic sanidines from pitchstones of the metaluminous Mt. Gillies Rhyolite[2]; ▣ Partially resorbed phenocrystic plagioclases from pitchstones of the metaluminous Mt. Gillies Rhyolite[2]; △ Phenocrystic anorthoclases from one feldspar trachytes[2]; ▲ Phenocrystic sanidine from a two feldspar trachyte[2]; ● Phenocrystic plagioclases from mafic lavas (alkali, transitional and tholeiitic)[2]

rhyolites and the Mt. Barney Granophyre sanidine phenocrysts are common and, generally, partially resorbed plagioclases exist but only in minor amounts. The intermediate rocks are typified by two feldspar-bearing (plagioclase and alkali feldspar) trachytes. Data on bulk rock and feldspar compositions for this series are also plotted[2,3] in figures 1 and 2 and shown in table 1.

Of special importance to the proposed model are the SiO_2 contents of the precipitating feldspars. Na-rich (albitic) feldspars are more SiO_2-enriched than either Ca- or K-feldspars while Ca-feldspars are more Al_2O_3-enriched than Na-feldspars which in turn are more enriched in Al_2O_3 than K-feldspars (see table 1).

Table 1. *Compositions of comendite, metaluminous rhyolite and feldspars from Southeast Queensland*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
No. of Analyses	6	12	44	2	10	8	—	—	—
SiO_2	72.23	73.26	56.20	62.73	66.17	67.23	43.20	68.74	64.76
TiO_2	0.16	0.18	0.04	n.d.	n.d.	n.d.	—	—	—
Al_2O_3	12.58	11.98	27.42	23.79	19.27	19.23	36.65	19.44	18.32
Fe_2O_3	2.05	0.54	—	—	—	—	—	—	—
FeO	1.22	1.06	0.49	n.d.	n.d.	0.14	—	—	—
MnO	0.06	0.03	n.d.	n.d.	n.d.	n.d.	—	—	—
MgO	0.03	0.09	0.36	0.32	—	—	—	—	—
CaO	0.13	0.71	9.65	4.91	0.73	0.30	20.16	—	—
Na_2O	5 98	3.22	5.62	7.98	5.19	7.42	—	11.82	—
K_2O	4.54	5.32	0.27	0.86	8.19	5.75	—	—	16.92
P_2O_5	0.01	0.01	—	—	—	—	—	—	—
H_2O^+	0.47	—	—	—	—	—	—	—	—
H_2O^-	0.23	—	—	—	—	—	—	—	—
LOI	—	3.23	—	—	—	—	—	—	—
Total	99.69	99.62	100.50	100.57	99.53	100.09	100.01	100.00	100.00

(1): Average Glass Houses Comendite[3] (2): Average of selected pitchstones from the metaluminous Mt. Gillies Rhyolite[1] (3): Average of phenocrystic plagioclase from sample F2 of the Albert Basalt (alkali and transitional basalts)[1] (4): Average of partially resorbed phenocrystic plagioclase from sample 96 of the metaluminous Mt. Gillies Rhyolite[1] (5): Average of phenocrystic sanidine from sample 96 of the metaluminous Mt. Gillies Rhyolite[1] (6): Average of phenocrystic anorthoclase from sample 10 which is a peralkaline trachyte[1] (7): Ideal anorthite end member component (8): Ideal albite end member component (9): Ideal K-feldspar end member component. For (1)–(2), Na_2O analysed by flame photometry and atomic absorption, FeO by wet chemistry and other major oxides by xrf. For (3)–(6) by electron microprobe LOI = loss on ignition; n.d. = not detected; — = not analysed/not calculated.

Consequently, the metaluminous rhyolite series is characterised by the precipitation of relatively SiO_2-poor feldspars in plagioclase, with moderately high anorthite content, and sanidine. The peralkaline series, in contradistinction, is characterised by the precipitation of relatively SiO_2-rich feldspars in plagioclase, with a high albite content, and anorthoclase as well as relatively SiO_2-poor plagioclase, with a moderately high anorthite content, in the less differentiated parental mafic melts (see figure 2).

It is likely then that as a result of the above, the SiO_2 contents of the differentiating melts in the two series become increasingly more divergent as fractional crystallisation proceeds when comparisons are made at similar degrees of crystal fractionation (measured in terms of weight fractions of subtracted crystals). In a sense, in the metaluminous rhyolite series SiO_2 content increases quickly during crystal fractionation whereas in the peralkaline rhyolite series the SiO_2 content increases relatively slowly. This may mean that more crystal fractionation has to occur in the peralkaline rhyolite series for the fractionating melts to migrate into the quartz-feldspar ternary minimum than for the metaluminous rhyolite series.

Consequently, the residual elements such as La, Ce and Nb should be relatively enriched in peralkaline rhyolites when compared to metaluminous rhyolites.

Of course, crystal fractionation of minerals such as the rare-earth mineral allanite (which occurs in trace amounts) in glomeroporphyritic aggregates could decrease the degree of enrichment of residual elements in residual liquids and make calculations of likely model melt compositions difficult.

Many peralkaline rhyolites are relatively depleted in Al_2O_3 compared to the Al_2O_3 contents expected normally in metaluminous rhyolites[1]. Southeast Queensland peralkaline rhyolites are, however, not depleted in Al_2O_3 compared to local metaluminous rhyolites (see table 1). Because the Al_2O_3 content, unlike SiO_2 content, decreases progressively from Ca-feldspar through Na-feldspar to K-feldspar, it is not easy to predict whether or not peralkaline rhyolites are more depleted in Al_2O_3 than metaluminous rhyolites using the above feldspar model. More and accurate data on bulk rock and feldspar compositions and the weight fractions of minerals extracted from the differentiating liquids during fractional crystallisation are required in order to make accurate predictions.

CLINOPYROXENE AND PERALKALINITY

Other than feldspars, clinopyroxene is the only major mineral phase involved in fractional crystallis-

ation likely to contain significant amounts of Na and, to a lesser extent, Al which are of fundamental importance in discussions on peralkalinity. Bose[4] has suggested that as Al enters mafic silicates in preference to plagioclase at high water pressure, this may contribute to the formation of peralkaline acidic liquids during fractional crystallisation. Ewart *et al*[3], however, deduced that the southeast Queensland rhyolites are relatively anhydrous.

Because feldspars are generally richer in Na, K and Al than clinopyroxenes and as the weight fractions of feldspars subtracted out of differentiating mafic, intermediate and acidic melts are probably greater than those of clinopyroxene[1], it would be expected that feldspars would assume greater importance in determining the peralkalinity or otherwise of residual liquids than clinopyroxenes. Clinopyroxene is, however, still possibly of some importance, because of its Na and Al content, to discussions upon peralkalinity and this will be examined in a future paper.

PARENTAL MAFIC MELTS

In southeast Queensland some tertiary mafic lavas and near-surface intrusives can be considered to be partial melts of mantle material which have been largely unaffected by fractional crystallisation. This is based upon their magnesium number (molecular $Mg^{2+}/(Mg^{2+}+Fe^{2+})$), high MgO, Cr, Ni and Cu (compared to differentiated mafic lavas) and petrography—the latter being used to exclude rare cumulates. These particular mafic rocks display a range in rock types from tholeiites through mildly alkaline alkali and transitional basalts to strongly alkaline alkali basalts.

Although more data on primary mafic lavas are required there is a hint that transitional and mildly alkaline alkali basalts in southeast Queensland have slightly higher $(Na_2O+K_2O)/Al_2O_3$ ratios than tholeiitic and the more alkaline basalts with the exception of relatively strongly undersaturated basalts (see figure 3)—this is due primarily to fluctuations in the Na_2O content. If this is so, then an inherited tendency towards peralkalinity, derived during the partial melting of mantle material, may enhance the chances of peralkaline rhyolites being derived from transitional and/or mildly alkaline alkali basalts, rather than from the more alkaline basalts and tholeiites, and acts in consort with the above feldspar model.
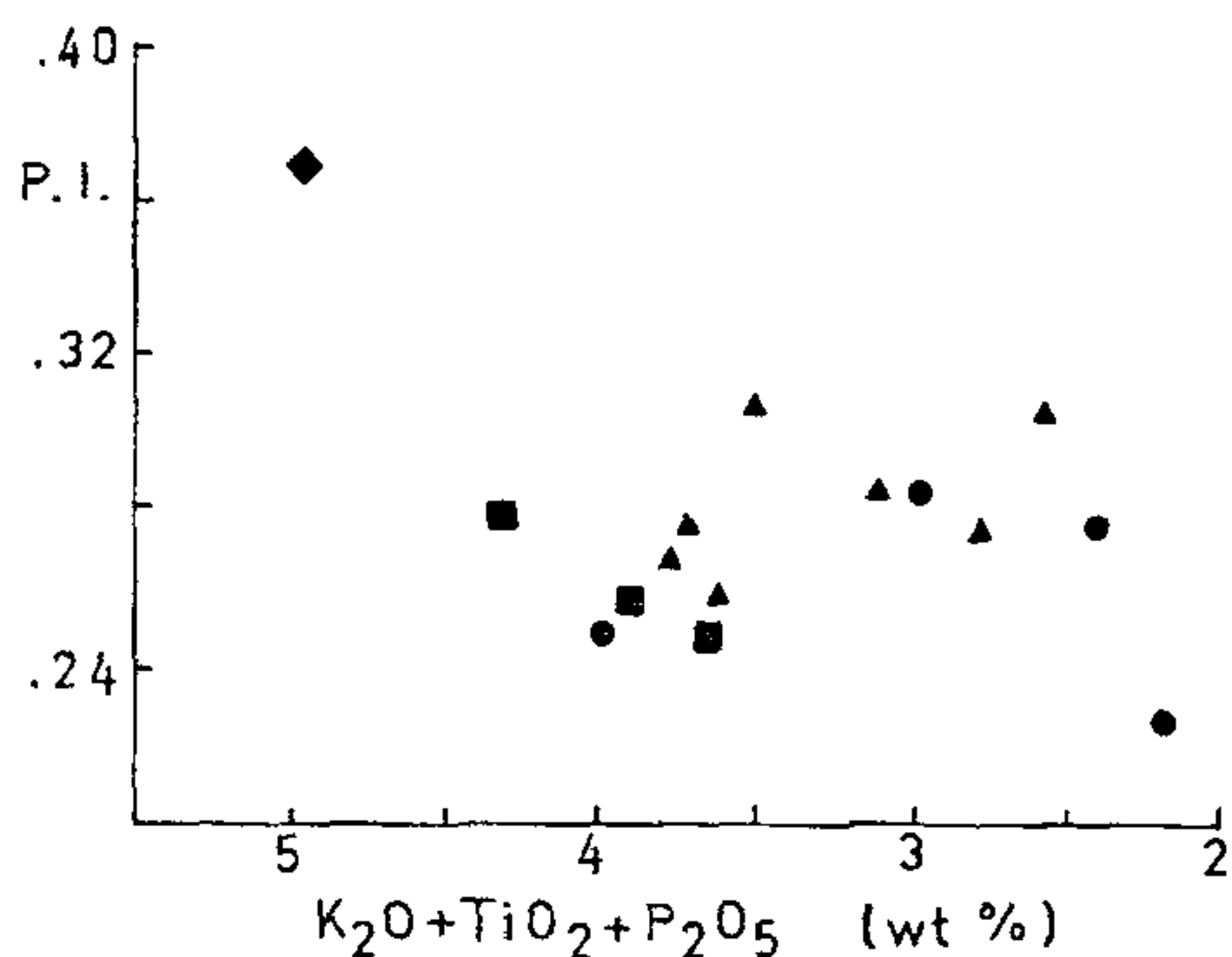

Figure 3. Peralkalinity index (P. I. = mol. (Na_2O + K_2O)/Al_2O_3) versus $K_2O+TiO_2+P_2O_5$, in primary (or near primary) mafic melts from the southeast Queensland tertiary volcanics. Decreasing $K_2O+TiO_2+P_2O_5$ corresponds approximately to an increasing degree of partial melting of mantle material as these oxides are generally relatively high in primary melts derived by low degrees of partial melting compared to those melts derived by higher degrees of partial melting. Note that mafic samples with $K_2O+TiO_2+P_2O_5$ between 2.5 and 3.5 wt % are mildly alkaline and transitional basalts and tend to have higher peralkalinity indices than mafic samples (generally moderately alkaline basalts) with $K_2O+TiO_2+P_2O_5$ around 4 wt %. ◆ Basanite[2]; ■ Alkali olivine basalt[2]; ▲ Hawaiite[2]; ● Tholeiite[2]

CONCLUSIONS

In this note it has been postulated that the following may be important in the petrogenesis of peralkaline and metaluminous rhyolites:

(a) the feldspar crystallisation histories and resulting effects upon the SiO_2 contents of the derivative intermediate and acidic melts;

(b) a possible inherited "peralkalinity" tendency of parental melts derived by partial melting of mantle material; and

(c) to a lesser extent, the amount of clinopyroxene subtracted out of the differentiating melts.

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ON THE SLUMPINGS OF THE VALLEYS ENCOMPASSING IDUKKI RESERVOIR, CENTRAL KERALA, INDIA.

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ABSTRACT

The nature of valley slumping and its effect on the reservoir capacity, have been assessed by studying 200 valley slumpings encompassing the Idukki reservoir, using aerial photographs, field checks and actual field measurements. The study indicates that the siltation from the valley slumps is not so alarming as to affect the storage capacity of the reservoir. It has, however, affected the degradation of slopes causing erosion of precious soil, which, if not checked, would result in ultimate destruction of the rich forest of the catchment area. Different methods to prevent valley slumping have been suggested.

INTRODUCTION

IN the following account, the effect of valley slumping in one of the biggest reservoirs in western Ghats, namely, the reservoir of Idukki Hydro-electric project has been studied. Slumping of valleys encompassing a reservoir[1] would result in (i) degradation of slopes involving erosion of soil; (ii) siltation of reservoir due to accumulation of sediments derived from slides resulting in loss of storage capacity, and (iii) progressive degradation and ultimate destruction of forest cover along the slope. In this background, an attempt has been made to understand the reasons of valley slumping, to assess the quantum of silt already dislodged from the failed horizons and to suggest appropriate stabilization techniques to provide for healthy slope control for the valley slopes.

Study Area

The Idukki reservoir, in the Idukki district of Kerala State, is located between lat. 9°45' and 9°51'N and long. 76°53' and 77°05'E. (figure 1) and is surrounded by tropical forest of the Western Ghats.

The reservoir is formed by three dams; Idukki (170.73 m high), Cheruthoni (135.67 m high) and Kulamavu (99.97 m high)[2]. The reservoir has a total storage capacity[3] of 1691 m.cu.m. and a usable storage capacity of 1008 m.cu.m. It occupies an area of 53 sq. km. The average rainfall[3] in the watershed region varies from 444.5 cm to 508 cm.

Geologically, the catchment area comprises of charnockites and hornblende biotite gneiss and intrusive granites.[4,5]. In general, these rocks have been subjected to varying degrees of weathering, upto 6 m. The relief is diverse, ranging from gentle ridges to precipitous hills. The drainage pattern is mainly sub-parallel, being controlled by large scale structures and lineaments[6].

METHODOLOGY

Slumpings were first plotted by studying aerial photographs of the reservoir area on a scale 1:15,000. On photographs, these failed regions show up as lighter grey with a dark grey tone at its near vertical headwall. Regions of steeper ground slopes (> 25°) with thick soil-cover and no vegetation, have been demarcated as potential regions of failure. The slumpings have been studied further by field checking and detailed measurements in order to get particulars of the volume of silt brought down by each slide. The silt from the slumped horizon has been estimated assuming that a rectangular mass of overburden has been removed from above the full reservoir level and deposited in the reservoir. Figure 2 is a simple model of