# Geochemistry of Pleistocene ash zones in cores from the North Atlantic

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North Atlantic ash zones I (10.6 ka BP), II (57.5 ka BP) and III (340 ka BP) were studied using single grain geochemical analysis (microprobe). The zones were defined only on the occurrence of rhyolitic glass which dominates each zone. The rhyolitic shards are compositionally homogeneous within each zone. We thus validate the use of these rhyolytic ash zones as marker beds representing synchronous events. Within the two younger ash zones basaltic ash of both tholeiitic and transitional alkalic types occur. All ashes apparently came from Icelandic volcanoes. Four major geochemical populations occur within ash zone I: one rhyolitic, one transitional alkalic and two tholeiitic. The rhyolitic and transitional alkalic populations are identical to the two components of the Vedde Ash in western Norway, and they certainly originate from the same eruption(s). The source volcano is suggested to be Katla if the two components were erupted from one volcano, and Hekla and Torfajøkull if they came from simultaneous eruptions of two different volcanoes. Veidivötn and Grimsvötn volcanic systems are suggested as likely sources for each of the tholeiitic populations. Ash zone I is also correlated with ashes found in cores from the Norwegian Sea, the North Sea and in the area between Scotland and Rockall.

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Three rhyolitic ash zones aged around 340 000, 57 500 and 10 000 years BP, respectively (hereafter the unit ka is used for 1000 years) have previously been described from cores from the North Atlantic (Ruddiman & Glover 1972, 1975, 1982; Ruddiman & McIntyre 1981; Duplessey et al. 1981) and extensively used for correlation between cores. The youngest zone, ash zone I, is also used for bioturbation modelling (Ruddiman & Glover 1972, 1982) and for correlation to continental sequences (Mangerud et al. 1984). Stratigraphically, ash zone I has a key position within Termination I (Ruddiman & McIntyre 1976) and in the middle of the Younger Dryas (Ruddiman & McIntyre 1981; Mangerud et al. 1984; Broecker et al. 1988).

A fundamental assumption for all the studies mentioned is that ash zone I, and the correlated ash beds, originated from a single volcanic eruption, and were thus deposited simultaneously. This was a reasonable, but not really demonstrated assumption; two conditions could point in the opposite direction. First, the ash zone frequently consists of two concentration peaks. Secondly, much of the ash was originally deposited on drifting ice that passed close to Iceland or on the Icelandic ice sheet calving into the sea; the ash being subsequently dropped in the North Atlantic when the ice melted (Ruddiman & Glover 1972). If sea ice followed the same path for the entire Younger Dryas, some 600–800 years, one might have expected ash fall from several eruptions on Iceland during that period (Mangerud et al. 1984).

The major problem we focus on in this investigation is therefore whether ash zone I consists of tephra from one or more eruptions, and which of those could possibly be correlated with the 10.6 ka Vedde Ash recorded in lacustrine sediments in western Norway (Mangerud et al. 1984). To compare the ashes, we used single grain geochemical analysis (microprobe).

We emphasize that ash zone I is defined only on the basis of the colourless, rhyolitic glass shards (Ruddiman & Glover 1972). In this paper, we are able to demonstrate that the rhyolitic component of ash zone I indeed originated from one single eruption, the same eruption that produced the Vedde and several other correlative ashes. This eruption produced the most widespread tephra layer that has originated from Iceland in the last hundred thousand years. We present its known distribution and try to trace it back to the source volcano on Iceland.

The rhyolitic shards of ash zone I occur in a vertical interval of 20–40 cm (and even more) in the cores. Within that interval, basic (pale to dark brown) glass shards are also frequent. We emphasize that these shards, according to the definition, are not constituents of ash zone I. However, we will refer to them as populations in ash zone I, as they are found in the same stratigraphic level and thus deposited during the same period. In contrast to the rhyolitic component, the basic component consists of several geochemical populations. These must have originated from several different volcanoes on Iceland, which we try to identify. Also, these components can be correlated with other known ashes; one population is correlated with the basic component of the Vedde Ash. Because these ash types were not counted by Ruddiman & Glover (1972, 1975), the existence of multiple sources does not invalidate the assumption of synchroneity for their ash zone I.

Although our major effort was directed at ash zone I, we also studied the two older ash zones found in some of the cores, and we present the geochemical results as the basis for future correlations.

## Material and methods

We decided to study the same samples as Ruddiman & Glover (1972, 1975, 1982), partly for direct correlation and partly because these samples had already been sieved at 63 $\mu$m. This placed some constraints on availability, because many of the samples had already been used for other purposes.

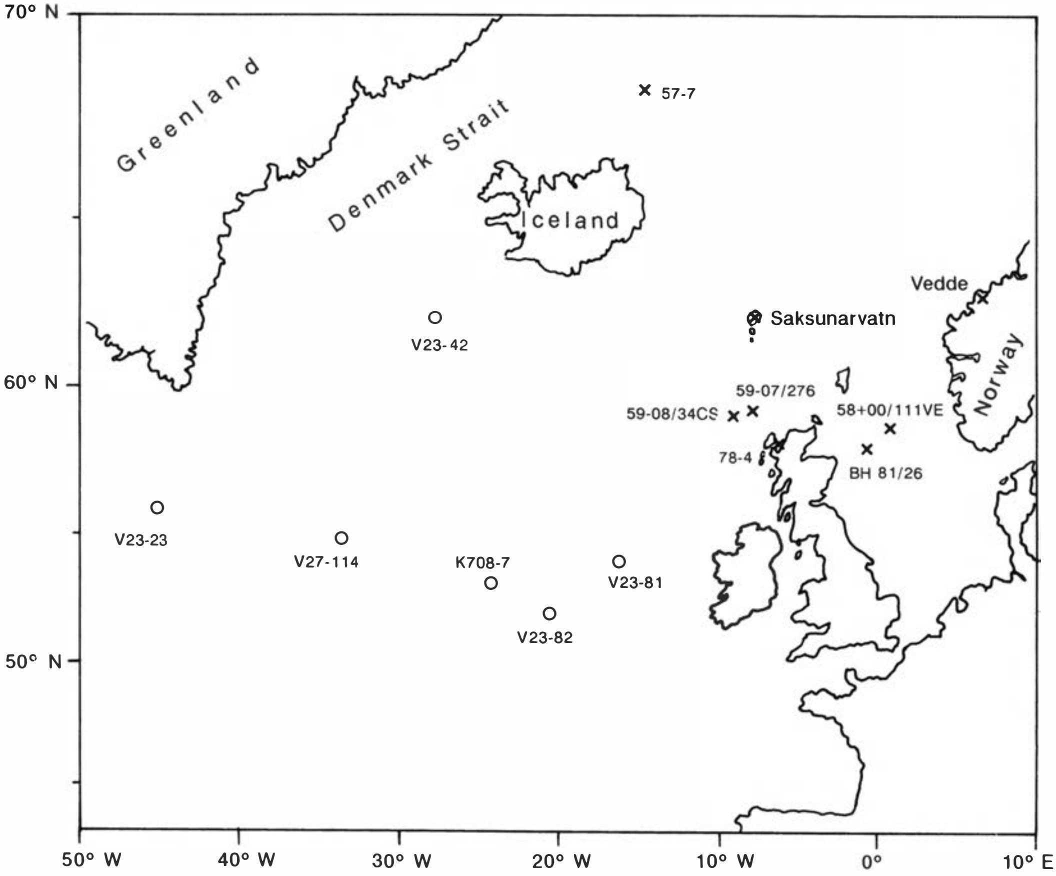

*Fig. 1.* Locations of cores (○) used in this study of ash zones, I, II and III in the North Atlantic. Other ash bed locations discussed in this paper are marked (×).

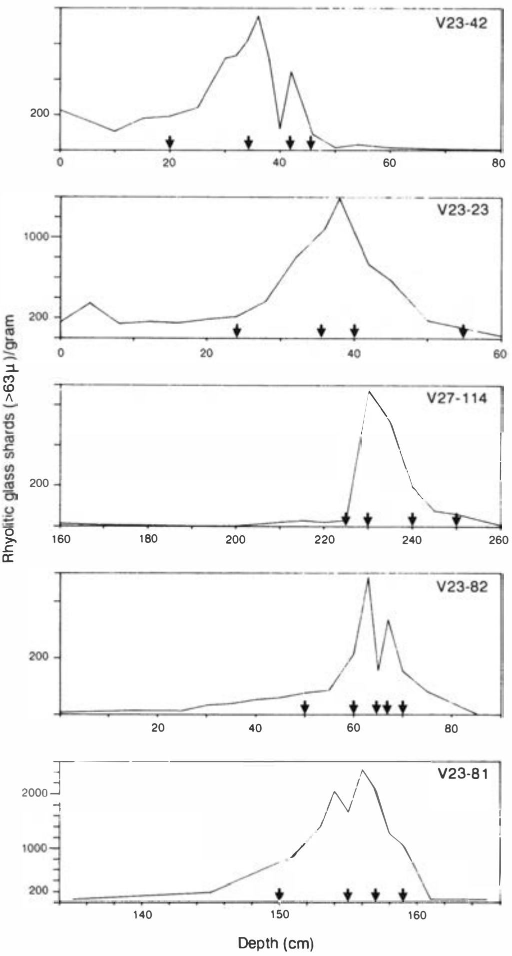

*Fig. 2.* Ash zone I in the investigated cores. The curves show the number of rhyolitic glass shards per gram of sediment. Note the varying horizontal and vertical scale (from Ruddiman & Glover (1982)). The samples studied in the present paper are marked with heavy arrows.

The samples, containing glass shards, microfossils (mostly planktonic foraminifera), minerogenic grains (mostly quartz) and rock fragments in the coarse fraction (>63 $\mu$m), were split. Subsamples of 1.5–4 g were taken to Bergen where the foraminifera were separated out using the heavy liquid $C_2Cl_4$ (sp. w. 1.62). The morphology and geochemistry of the glass shards in the heavy fraction were then examined.

For ash zone I, the sampling strategy was firstly to cover the stratigraphic range of the zone, preferably in at least one core with two concentration peaks. Secondly, we wanted to cover much of the geographic extent of the ash. The location of the cores is shown in Fig. 1 and the stratigraphic position of the samples in Fig. 2.

## *The microprobe analyses*

The geochemical analyses of the glass shards were carried out using an ARL SEMQ electron microprobe and a standard wavelength dispersive technique (Reed 1975) using an accelerating voltage of 15 V and a beam current of 5 nA. The same standards as used for the Vedde Ash and Saksunarvatn ash (Mangerud et al. 1984, 1986) were applied.

Since the glass shards are more or less porous and consequently have a rough surface, the result may be absorption of electrons during the analyses and therefore low totals. This will be a problem particularly in the case of oxides with high concentrations (e.g. $SiO_2$ and $Al_2O_3$). Relationships (e.g. FeO/MgO) will not be affected.

Another serious problem is the loss of $Na_2O$, particularly in rhyolites, due to evaporation (Mangerud et al. 1984).

## *Morphologic descriptions of the ash particles*

The ash consists of vitric shards, of which yellowish white to colourless, transparent fragments dominate in four of the cores (Fig. 3). The remaining glass shards are pale to dark brown. Most of the light shards are very thin, curved and platy, representing fragments of broken walls of gas bubbles. The brown shards are generally blocky vesicular particles. All six groups of glass shards described in the Vedde Ash by Mangerud et al. (1984) were found. In this paper, however, we classify the shards within a light and brown group, because the geochemical analyses show that the light shards are rhyolitic and that the brown are all basaltic. Two different subgroups may have similar geochemistry, and shards in the same subgroup may be different.

## *Glass shard frequency*

As discussed in the introduction, we maintained that the ash zones are defined on the occurrence of rhyolitic glass shards only (Bramlette & Bradley 1941; Ruddiman & Glover 1972). These shards were counted in terms of shards/gram sediment by Ruddiman & Glover (1982). We have not carried out any new counts in these terms.

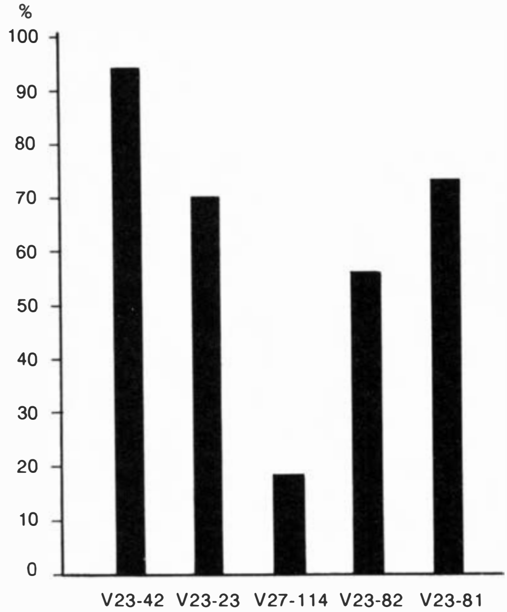

*Fig. 3.* Relative abundance of light ash shards in ash zone I given as a percentage of the total number of glass shards in samples studied in this paper.

However, we have counted the relative appearance of brown (basaltic) vs. light (rhyolitic) shards in several levels within ash zone I. Using the simple relationship brown shards/light shards we were able to estimate brown shard concentrations (shards/gram sediment) by multiplying by the known concentrations of light shards (Ruddiman & Glover 1982) for the respective levels.

## Geochemistry of ash zone I

### *Results*

All the geochemical analyses are listed in Appendix I, but only the analyses with totals >98% are used to define the geochemical populations of ash zone I (Figs. 4A, 5A). We have not discovered any major disagreements between classifications using all analyses and only those with high totals. However, each population is more precisely characterized when only samples with high totals are used.

The basaltic shards are divided into tholeiitic and transitional alkalic basalts (e.g. Jakobsson 1972). The tholeiitic basalts are low in FeO and $TiO_2$-content and relatively high in $Al_2O_3$. The transitional alkalic basalts are different, with high FeO and $TiO_2$ and low $Al_2O_3$ content.

### *Geochemical populations*

The various geochemical populations are identified by a code; first, a number indicating which ash zone they appear in (I, II or III); second, a label indicating the geochemistry (RHY-rhyolitic, THOL-tholeiitic or TAB-transitional alkalic); and third, a number ranking the population (1, 2). For example I–THOL–1 is the most important tholeiitic group in ash zone I.

All the rhyolitic ash in zone I plots in one group, I-RHY-1 (Fig. 4A), except for some shards in core V23–42 grouped as I-RHY–2. The basaltic ash is trimodal (Fig. 5A), consisting of two tholeiitic (I–THOL–1 and I–THOL–2) and one transitional alkalic (I–TAB–1) population. In addition to these well-defined groups there are some shards which cannot be placed in any group (Fig. 5B). The populations are defined from all identified elements (Appendix I). In Fig. 5, we show the relations between three elements (Ti, Fe, Mg) that discriminate clearly between the defined populations. Thus, even though some of the uncorrelated shards (Fig. 5B) apparently fit into the defined envelopes, these shards differ for other elements not shown; they are discussed below.

We assume that each of the defined populations represents individual ash falls from different eruptions, except that I–RHY–1 and I–TAB–1 may originate from the same eruption.

### *Uncorrelated shards*

Even though some of the uncorrelated shards plot within or very close to the envelopes defined by the three basaltic groups in the FeO/MgO vs $TiO_2$ diagram (Fig. 5B), they are not included in these groups because they differ in other elements. Shards 1–6 plot within/close to I–THOL–1. However, they differ slightly from this population for $Al_2O_3$ and CaO. The same holds for shards 7–10 and population I–THOL–2, and shard 11 and population I–TAB–1.

It is possible that some of the uncorrelated shards may be grouped together in a fourth basaltic ash population in ash zone I, though the clusters in Fig. 5B are not so clear in diagrams for other elements (e.g. FeO vs MgO).

### *Geographical distribution*

In Table 1, the geographical distribution of the geochemical populations within ash zone I is

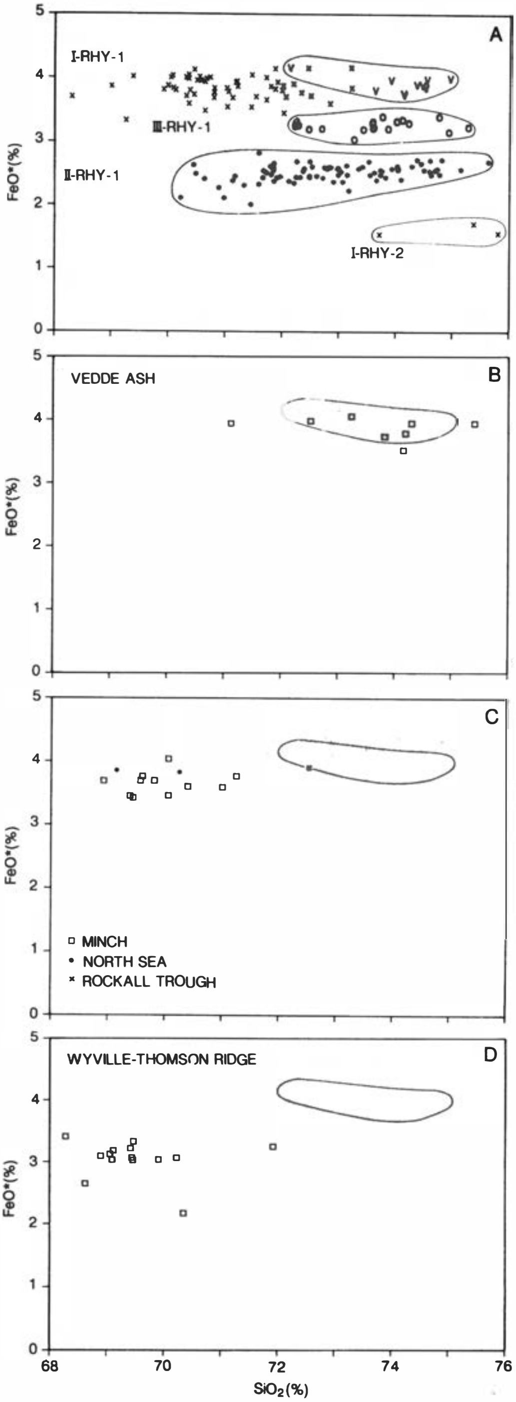

*Fig. 4.* Rhyolitic glass shard composition (FeO* = FeO + 9*$Fe_2O_3$). □ A: The North Atlantic ash zone I (x = totals <98%, V = totals >98%), ash zone II (•) and ash zone III (O). All analyses included. The envelope around the population I-RHY-1 (only analyses with totals >98%) is reproduced on the other diagrams. □ B: The Vedde Ash (only analyses over 97.5% included) compared with ash zone I (source: Mangerud et al. 1984). All analyses are given in Appendix II. □ C: The North Sea, cores BH81/26 and 58+00/111VE, the Rockall Trough, core 59–08/34 and the Minch, core 78/4 (all analyses included) compared with ash zone I (sources: Long & Morton 1987; Morton 1988). □ D: The Wyville–Thomson ridge, core 59–07/276 (all analyses included) compared with ash zone I (source: Stoker et al. in press).

shown as numbers of analysed shards in each core. The light (rhyolitic) shards dominate in all cores except V27–114 (Fig. 3). However, there are more analyses carried out on the basaltic shards because the platy rhyolitic shards are underrepresented at the surface of the thin section used in the microprobe. The reason for this might be that the flakes are easily scaled off during polishing of the preparations.

I–THOL–1 is the dominating basaltic population in all cores. It constitutes 32–63% of the basaltic shards. I–TAB–1 is also present in all the cores. This population is present at a fairly constant value of ca. 12% of the basaltic population except for core V27–114 (21%). The second tholeiitic population, I–THOL–2, is not present in the northernmost core (V23–42), almost negligible in the westernmost (V23–23), and constitutes 10–20% in the central and eastern cores.

Basaltic shards that do not fit into the defined groups are present in all cores (10–46%), being most frequent in the northernmost (V23–42) and in one of the eastern cores (V23–82).

## Stratigraphy within ash zone I

Assuming that the concentration peak (in shards/gram sediment) marks the depositional horizon for each geochemical population, we were not able to distinguish a sequence of ash layers.

In most cores, we found only one rhyolitic population (I–RHY–1); thus all peaks are formed by this population, being ash zone I proper. The secondary peaks may be due to different bioturbation, bottom currents, or a lag effect in some stage of ice transport between eruption and final deposition (Ruddiman & Glover 1972). The exception is core V23–42, where the lower rhyolitic peak might be caused by ash layer I–RHY–2, since two of three analysed shards in this peak belong to I–RHY–2. However, this number is insufficient to draw any conclusions.

There may be stratigraphic differences in the basaltic populations which we were unable to

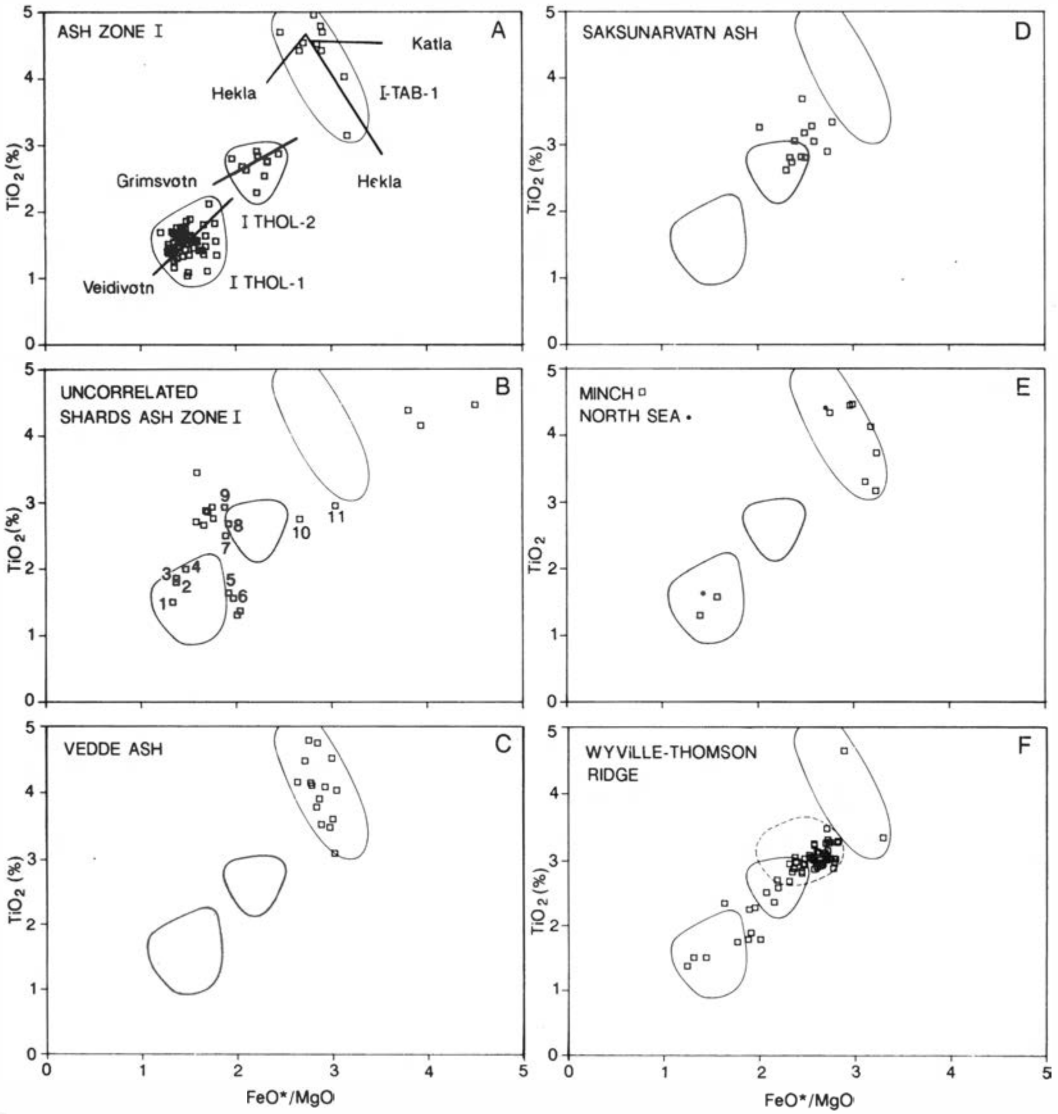

*Fig. 5.* Composition of basaltic glass shards of age 9 000–11 000 years BP. □ A: Populations of ash zone I (only analyses >98% included) given as points with envelope around each of the populations. Trends for the most probable source volcanoes on Iceland are indicated with lines (sources: Jakobsson 1979a; Einarsson et al. 1980). □ B: Uncorrelated glass shards from ash zone I (only analyses >98% included) compared with the populations in Fig. 5A. The numbered shards refer to core and sample no. in Appendix I in the following way: 1 = V23–82–21; 2 = V23–82–23; 3 = V23–82–18; 4 = V23–82–33; 5 = V23–23–26; 6 = V23–81–72; 7 = V27–114–23; 8 = V27–114–41; 9 = V23–81–55; 10 = V27–114–25; 11 = V23–42–12. □ C: The Vedde Ash (only analyses >98% included) compared with ash zone I (source: Mangerud et al. 1984). All analyses are given in Appendix II. □ D: The Saksunarvatn ash (all analyses included) compared with ash zone I (source: Mangerud et al. 1986). □ E: The North Sea, cores BH81/26 and 58+00/111VE and the Minch, core 78/4 (all analyses included) compared with ash zone I (sources: Long & Morton 1987; Morton 1988). □ F: The Wyville-Thomson ridge, core 59–07/276 (all analyses included) compared with ash zone I and the Saksunarvatn ash (stippled) (source; Stoker et al. in press).

detect, because only the rhyolitic shards have been counted continuously through the ash zone (Ruddiman & Glover 1982). Some basaltic peaks are determined from countings of the few samples studied in this paper. These peaks are all at the same level as the rhyolitic peak, or at the lower peak in cores with more than one rhyolitic peak.-

We concluded above that the different geo-

*Table 1.* Geographical distribution of the various geochemical populations within ash zone I in the North Atlantic, shown as numbers of analysed shards in each core. Percentages of total rhyolitic and basaltic populations respectively are given in parentheses. All the analyses are included.

| | Cores | | | | |
|---|---|---|---|---|---|
| Population | V23-23 | V27-114 | V23-82 | V23-81 | V23-42 |
| I-RHY-1 | 16 (100) | 10 (100) | 14 (100) | 34 (100) | 11 (78) |
| I-RHY-2 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 3 (22) |
| I-TAB-1 | 4 (12) | 14 (21) | 4 (11) | 6 (13) | 3 (12) |
| I-THOL-1 | 20 (63) | 30 (45) | 12 (32) | 29 (62) | 12 (44) |
| I-THOL-2 | 1 (3) | 13 (20) | 4 (11) | 7 (15) | 0 (0) |
| Uncorrelated | 7 (22) | 9 (14) | 17 (46) | 5 (10) | 12 (44) |

chemical populations originated from different eruptions probably occurring during some few centuries of the Younger Dryas. However, we were not able stratigraphically to separate them in the samples used in this study, and we cannot determine whether for example the I-THOL-1 eruption occurred before or after the I-RHY-1 eruption.

## Geochemistry of older ash zones

### *Ash zone II*

We consider the rhyolitic component of ash zone II as one population (Fig. 4A), II-RHY-1, differing from I-RHY-1 in having a lower iron content.

We divide the basaltic component of ash zone II into four populations, three tholeiitic and one transitional alkalic (Fig. 6). Three of these, II-THOL-1, II-THOL-2 and II-TAB-1, are geochemically very similar to the three basaltic populations of zone I, I-THOL-1, I-THOL-2 and I-TAB-1 respectively, and may indicate that the same three volcanoes have erupted most of the basaltic ash in the two younger ash zones.

### *Ash zone III*

Only the rhyolitic shards were analysed from ash zone III (core K708-7). The ash, III-RHY-1, has an Fe content intermediate between the two younger ash zones (Fig. 4A). It is remarkable that all the rhyolitic ashes of different ages can be geochemically separated.

## Correlations of ash zone I with other ash layers

Ash layers might be correlated over long distances between different depositional environments, thus being important marker beds. We will discuss the correlation of North Atlantic ash zone I with other ash beds of approximately the same age by using the geochemical populations. All the suggested correlations are shown in Table 2.

### *The Vedde Ash in Norway*

Mangerud et al. (1984) suggested a correlation between the Vedde Ash (10.6 ka BP) and North Atlantic ash zone I because of their similar stratigraphic position and geochemical composition. The geochemistry of the rhyolitic and basaltic glass shards of the Vedde Ash is almost identical to I-RHY-1 (Fig. 4B) and I-TAB-1 (Fig. 5C) respectively. Thus our results strongly confirm the correlation carried out by Mangerud et al. (1984).

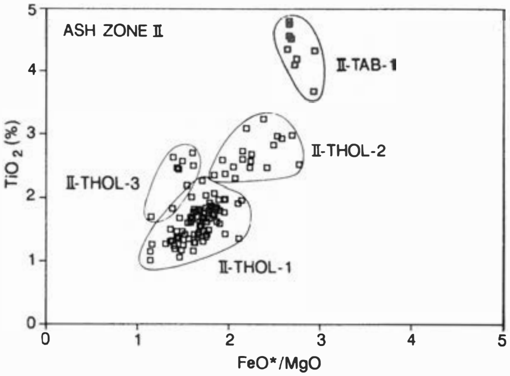

*Fig. 6.* Basic populations of ash zone II (all analyses included).

*Table 2.* Regional correlation between the geochemical populations of North Atlantic ash zone I (named) and ashes in other regions.

| | Regions | | | | | |
|---|---|---|---|---|---|---|
| Age (ka) | North Atlantic | Western Norway | Faroe Islands | Norwegian Sea | North Sea | Scotland–Rockall |
| 9.0 | | | Saksunarvatn ash | × | | × |
| 10.6 | I–RHY–1 | Vedde Ash | | × | × | × |
| | I–TAB–1 | Vedde Ash | | × | × | × |
| 10.2–11 | I–THOL–1 | | | | × | × |
| | I–THOL–2 | | | | | × |

Ash zone I contains basaltic shards from more eruptions than those represented by the Vedde Ash, as postulated by Mangerud et al. (1984). However, except for three grains in I–RHY–2 (core V23–42), all analysed acidic shards are similar, and most probably from one single eruption.

### *The Saksunarvatn ash on the Faroe Islands*

On the Faroe Islands, Mangerud et al. (1986) described an ash layer with an age of 9–9.1 ka. Although the Vedde Ash is 1500 years older than the Saksunarvatn ash, the two ashes could have been mixed by bioturbation.

There is a certain geochemical similarity between the Saksunarvatn ash and I–THOL–2 (Fig. 5D). Nevertheless, they do differ in that I–THOL–2 has a lower $TiO_2$ content and higher CaO and MgO contents (the latter resulting in lower FeO/MgO values). The analyses of the Saksunarvatn ash suffer from low totals (typically 95–96%), which may explain some of the difference in CaO and MgO, but not in $TiO_2$. Therefore, the difference between the two ashes is considered real and not just apparent because of analytic precision.

We conclude that the Saksunarvatn ash and I–THOL–2 represent two different eruptions, 1500 years apart, perhaps from the same volcano.

### *The Norwegian Sea*

Mangerud et al. (1984) found both the rhyolitic and basaltic components of the Vedde Ash in cores (e.g. 31–33) from the eastern Norwegian Sea.

In a core (57–7) from north of Iceland (Fig. 1), Sjøholm (1987) and Sejrup et al. (1989) have performed geochemical analyses of several Pleistocene ash zones. Sjøholm (1987) concludes that the upper zone contains one rhyolitic and one transitional alkalic basaltic population that can both be correlated with the Vedde Ash, a correlation that is quite clear. In addition to the Vedde Ash she identified two tholeiitic basaltic populations in the upper zone; one of these she correlates with the Saksunarvatn ash and the other with North Atlantic ash zone I (our population I–THOL–2). Indeed, some of the analyses (Sjøholm 1987) resemble I–THOL–2, but in our opinion all these are correlative to the Saksunarvatn ash because they differ slightly from I–THOL–2 in geochemistry in the same way as the Saksunarvatn ash and they are (with one exception) picked from a level relatively high in the ash zone; estimated age is 7.8 ka, based on interpolation (Sjøholm 1987). Thus we conclude that the upper ash zone in the Norwegian Sea consists of the Vedde Ash (both populations) and the Saksunarvatn ash (Sejrup et al. 1989).

The most important basaltic population from the North Atlantic, I–THOL–1, is as yet not found in the Norwegian Sea, and, as concluded above, neither is I–THOL–2. This probably means that the ashes from the corresponding eruptions were blown more to the west or northwest assuming Icelandic sources (Fig. 1).

### *The North Sea*

Long & Morton (1987) examined a zone rich in volcanic glass shards in cores from the Witch Ground Basin in the central North Sea (58+00/111VE and BH 81/26, Fig. 1) and correlated it with the Vedde Ash and North Atlantic ash zone I. The rhyolitic shards from the North Sea differ from I–RHY–1 in having less $SiO_2$, which is certainly due to the low totals (ca. 93.5%) of the

North Sea analysis. The FeO content is not so sensitive to low totals and suggests a correlation with the Vedde Ash and I–RHY–1 (Fig. 4C).

The North Sea ash has two basaltic populations, one transitional alkalic and one tholeiitic, the tholeiitic being the dominant one. The transitional type can be correlated with the Vedde Ash and I–TAB–1 and the tholeiitic with I–THOL–1 (Fig. 5E).

### *The Scotland–Rockall area*

In the Scotland-Rockall area, ash layers have been analysed in three cores (Fig. 1): 59–08/34CS in the Rockall Trough (Long & Morton 1987), 59–07/276 on the Wyville–Thomson Ridge (Morton 1987) and 78–4 in the Minch, offshore of the Hebrides (Morton 1988).

In the Rockall Trough, only a few dispersed rhyolitic shards were found in late glacial sediments. The ash was correlated to the Vedde Ash and should thus be similar to I–RHY–1. Fig. 4C confirms this correlation.

At the Wyville–Thomson ridge there were several distinct peaks of ash in the uppermost 70 cm of the core. The ashes have been analysed by Morton (1987), who concluded:

1. The uppermost peak is dominated by an ash correlative to the Saksunarvatn ash. This is supported by Fig. 5F.
2. The lowermost peak is dominated by a rhyolitic ash correlative to the Vedde Ash. Fig. 4D shows that the rhyolitic ash differs from I–RHY–1 (and thus the Vedde Ash), being lower in FeO. This was tentatively explained by aeolian differentiation during the eruption by Stoker et al. (in press). The totals in their analysis are too low (typically 90–92%) for certain geochemical correlations. However, considering the known distribution of the Vedde Ash and the other populations in that core, the correlation with Vedde is very probable.
3. In addition, there are two basaltic populations present; one correlative to the Vedde Ash, the other to North Atlantic ash zone I. Fig. 5F shows two grains in the Vedde/I–TAB–1 envelope. The diagram also implies that ashes correlative to both I–THOL–1 and I–THOL–2 are present.

In the Minch, Morton (1988) performed microprobe analyses of an ash layer and concluded that it contains the two Vedde populations and the North Atlantic tholeiitic ash. The rhyolitic ash differs from Vedde/I–RHY–1 in having a lower $SiO_2$ content (Fig. 4C), but like the North Sea, these analyses suffer from low totals and a correlation is reasonable. Fig. 5F supports Morton's (1988) conclusion on the basaltic populations.

## Correlations to source volcanoes

From a geographic point of view, four areas could have delivered ash to the North Atlantic: Iceland, Jan Mayen, the Azores, and the Laacher See area in the Eifel district of western Germany. Considering the geochemistry of the ashes, however, Iceland is the only possible source with transitional alkalic and tholeiitic volcanic zones (Fig. 7). The other candidates are totally different, Jan Mayen being trachybasaltic (Maaløe et al. 1986), the Azores trachytic (Storey 1981) and Laacher See phonolitic (Bogaard & Schmincke 1985).

When compared to Iceland, there is a good agreement between I–THOL–1 and the Veidivötn volcanic system in the eastern zone (Fig. 5A) and also volcanoes at the Reykjanes peninsula (Schilling 1973). However, Veidivötn is far more productive than the small volcanic systems at the Reykjanes peninsula in postglacial time (Jakobsson 1979a) and is thus the most probable source for I—THOL–1.

The Grimsvötn volcanic system is suggested as the most likely source for I–THOL–2, considering the geochemistry (Fig. 5A). We suggested above a common source for I–THOL–2 and the Saksunarvatn ash. The subglacial Grimsvötn central

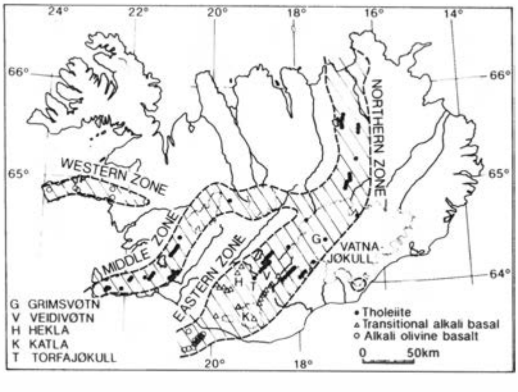

*Fig. 7.* Map of the volcanic zones and some volcanoes in Iceland. Modified from Jakobsson (1972).

volcano has been highly active, at least in historic time (Jakobsson 1979a), and might thus have erupted two such widespread ash layers within 1500 years.

I–TAB–1, and thus the basaltic component of the Vedde Ash is geochemically quite similar to the Hekla volcanic system (Fig. 5A). A certain similarity with the Katla volcanic system exists too (Mangerud et al. 1984).

Mangerud et al. (1984) suggested Katla as the most probable source for the Vedde rhyolitic component and thus I–RHY–1, due to its characteristic high FeO content, and because they assumed that the rhyolitic and basaltic components originated from the same eruption. If both components originated from one eruption, Katla is certainly the strongest candidate.

However, if the basaltic component was erupted from Hekla, the two components of the Vedde Ash might possibly stem from simultaneous eruptions of two different volcanoes. In this case volcanoes other than Katla may be source candicates for the rhyolitic component. Most of the rhyolite-producing volcanoes can be discriminated according to FeO content, but two volcanoes in addition to Katla are possible sources: Krafla has produced rhyolite with FeO content of 3.92% ($SiO_2$ = 73.23) (Jakobsson 1979b) and some of Torfajökull's rhyolitic products show the same high FeO content at $SiO_2$ values higher than 72% (McGarvie 1984). Two other factors pointing towards Torfajökull as the source for the widespread I–RHY–1 are:

1. Torfajökull is the largest rhyolitic complex on Iceland with at least 10 postglacial rhyolitic eruptions (McGarvie 1984).
2. There are postglacial examples of Torfajökull and the I–THOL–1 correlated Veidivötn erupting contemporarily (Larsen 1984).

This question could possibly be settled by analysing trace elements of the Vedde Ash and Icelandic candidate volcanoes.

## The Vedde Ash–ash zone I: a discussion

### Age

The age of the Vedde Ash was obtained by both sedimentation rates and radiocarbon dating of terrestrial and lacustrine organic matter (Mangerud et al. 1984). Both methods gave an age of ca. 10.6 ka, or in the middle of the Younger Dryas.

Direct radiocarbon dating of deep sea sediments and thus ash zone I has been more difficult because of low C content, contamination by older carbon from land and bioturbation. In the last few years, this problem has been reduced using accelerator mass spectrometry (AMS) (Bard et al. 1987; Broecker et al. 1988). In core V23–81, Broecker et al. (1988) AMS dated ash zone I to 10.4 ka BP (157 cm).

In terms of geochemistry and stratigraphy, there is little doubt about the correlation between the Vedde Ash and North Atlantic ash zone I (population I–RHY–1 and I–TAB–1). The Vedde Ash is windblown (Mangerud et al. 1984) and thus contemporary with the eruption that produced it. Ash zone I was rafted by sea ice, drifting from the Norwegian Sea, through the Denmark Strait and into the North Atlantic (Ruddiman & Glover 1972). However, the delay in deposition was certainly only a few years or at maximum some decades, and thus within the dating error. Thus we conclude that the date of the Vedde Ash provides the most precise dates also for North Atlantic ash zone I.

We concluded above that the other two populations (I–THOL–1 and I–THOL–2) occurring within ash zone I were erupted by different volcanoes. It is likely that these eruptions were not simultaneous with the Vedde Ash eruption(s). However, in the North Atlantic sediments these ashes are mixed by bioturbation and other processes, so we were not able to resolve whether the tholeiitic eruptions occurred before and/or after the Vedde Ash eruption. Accepting that all the discussed ashes were ice rafted in the North Atlantic, the corresponding eruptions have occurred within a few centuries during the cold Younger Dryas Chronozone.

### Geographic extension

The Vedde Ash/Ash zone I is by far the most widespread tephra layer that has erupted in Iceland during the last 100 ka. From its source, it is mapped 1300 km to the east, 1800 km to the south and 700 km to the north. Since all the ash layers/zones that can be correlated to the Vedde Ash contain only one rhyolitic population (except core V23–42), all grain countings of light rhyolitic shards can be used to construct an isopach map

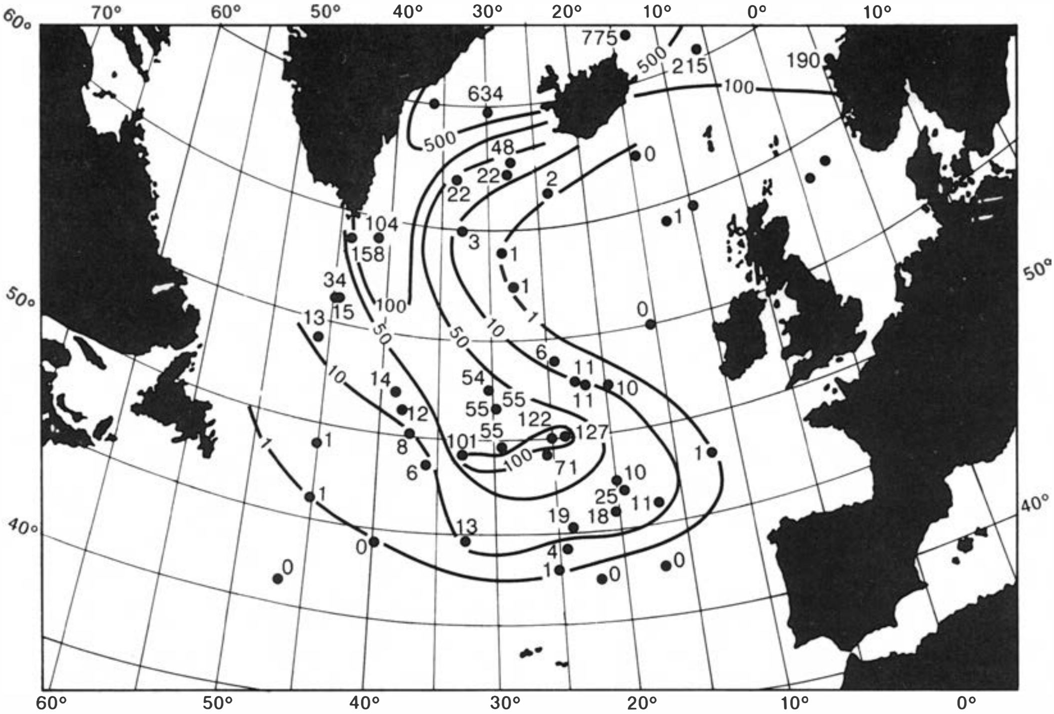

*Fig. 8.* Regional ash (I–RHY–1, Vedde Ash and correlatives) abundance pattern (in $10^3$ sand-sized shards) for a 1 $cm^2$ column (sources: Ruddiman & Glover 1982; Mangerud et al. 1984; Sjøholm 1987).

showing the regional ash abundance pattern. This map (Fig. 8) implies ash blowing ESE towards Norway and the North Sea, and northward across the Icelandic plateau in the Norwegian Sea. In the Norwegian Sea some of the ash fell on sea ice, drifting into the North Atlantic circulation (Ruddiman & Glover 1972). The sea ice gradually melted and lost its load of ash when drifting through the Denmark Strait and in the subpolar gyre until it reached the 48–50th latitude. Here, the ash abundance is two to three times greater than in the surroundings, as a result of accelerated melting of ice along the position of the polar front in Younger Dryas (Ruddiman & McIntyre 1981).

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*Appendix I.* Microprobe analyses from the North Atlantic. A: Ash zone I; B: Ash zone II; C: Ash zone III. In the left column the core no., depth in the core and a number for each individual analysis are given.

A. ASH ZONE I (all oxides in %)

| V23-23 | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $K_2O$ | CaO | $TiO_2$ | MnO | FeO* | Tot | FeO*/MgO | Population |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24cm | | | | | | | | | | | | |
| 1 | 2.66 | 8.05 | 14.50 | 49.90 | 0.09 | 7.63 | 1.48 | 0.18 | 10.79 | 95.28 | 1.33 | Uncorr. |
| 2 | 2.88 | 6.77 | 13.80 | 50.79 | 0.14 | 7.27 | 1.63 | 0.24 | 13.04 | 96.56 | 1.93 | Uncorr. |
| 3 | 2.32 | 8.01 | 14.64 | 49.72 | 0.19 | 11.74 | 1.65 | 0.19 | 11.69 | 100.15 | 1.46 | I–THOL–1 |
| 4 | 2.36 | 8.36 | 14.77 | 51.74 | 0.12 | 11.66 | 1.30 | 0.27 | 11.52 | 102.10 | 1.38 | I–THOL–1 |
| 5 | 2.30 | 5.22 | 12.71 | 48.71 | 0.77 | 9.73 | 4.52 | 0.13 | 14.85 | 98.94 | 2.85 | I–TAB–1 |
| 6 | 2.23 | 8.28 | 15.02 | 50.82 | 0.20 | 12.28 | 1.68 | 0.19 | 11.49 | 102.19 | 1.39 | I–THOL–1 |
| 7 | 2.28 | 7.86 | 14.91 | 50.11 | 0.14 | 12.41 | 1.52 | 0.13 | 11.61 | 100.97 | 1.48 | I–THOL–1 |
| 8 | 2.55 | 0.21 | 14.00 | 74.54 | 3.43 | 1.27 | 0.15 | 0.18 | 3.98 | 100.26 | | I–RHY–1 |
| 9 | 2.12 | 0.24 | 14.24 | 74.95 | 3.32 | 1.45 | 0.41 | 0.09 | 4.00 | 100.82 | | I–RHY–1 |
| 10 | 2.26 | 0.20 | 13.49 | 74.51 | 2.97 | 1.30 | 0.50 | 0.16 | 3.85 | 99.24 | | I–RHY–1 |
| 36 cm | | | | | | | | | | | | |
| 11 | 3.10 | 6.07 | 13.63 | 51.64 | 0.39 | 10.51 | 2.84 | 0.12 | 13.56 | 101.86 | 2.23 | I–THOL–2 |
| 12 | 2.29 | 7.62 | 14.31 | 50.30 | 0.10 | 12.35 | 1.63 | 0.16 | 11.17 | 99.93 | 1.47 | I-THOL-1 |
| 13 | 2.63 | 7.43 | 13.93 | 50.71 | 0.17 | 11.05 | 1.55 | 0.19 | 11.82 | 99.48 | 1.59 | I–THOL–1 |
| 14 | 2.56 | 7.31 | 14.33 | 51.21 | 0.20 | 11.62 | 1.81 | 0.21 | 12.11 | 101.36 | 1.66 | I–THOL–1 |
| 15 | 2.46 | 7.36 | 15.69 | 46.85 | 0.49 | 10.81 | 2.76 | 0.28 | 12.99 | 99.69 | 1.76 | Uncorr. |
| 16 | 2.29 | 7.47 | 14.41 | 51.95 | 0.16 | 11.68 | 1.57 | 0.32 | 11.87 | 101.72 | 1.59 | I–THOL–1 |
| 17 | 2.96 | 5.40 | 13.15 | 48.60 | 0.65 | 9.82 | 4.54 | 0.32 | 14.64 | 100.07 | 2.71 | I–TAB–1 |
| 18 | 2.35 | 0.13 | 13.72 | 74.52 | 3.41 | 1.28 | 0.26 | 0.05 | 3.85 | 99.57 | | I–RHY–1 |
| 19 | 2.29 | 0.14 | 13.73 | 74.14 | 3.09 | 1.35 | 0.39 | 0.09 | 3.74 | 98.96 | | I–RHY–1 |
| 20 | 2.98 | 0.12 | 13.64 | 73.63 | 3.29 | 1.34 | 0.41 | 0.10 | 3.81 | 99.32 | | I–RHY–1 |
| 21 | 2.13 | 0.28 | 13.69 | 74.46 | 3.38 | 1.30 | 0.56 | 0.19 | 3.89 | 99.88 | | I–RHY–1 |
| 22 | 2.28 | 0.26 | 14.10 | 74.36 | 3.38 | 1.36 | 0.39 | 0.05 | 3.90 | 100.08 | | I–RHY–1 |

*Appendix I.* (continued)

| | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $K_2O$ | CaO | $TiO_2$ | MnO | FeO* | Tot | FeO*/MgO | Population |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 cm | | | | | | | | | | | | |
| 23 | 1.51 | 8.70 | 15.18 | 48.77 | 0.19 | 11.39 | 1.51 | 0.24 | 11.20 | 98.68 | 1.29 | I–THOL–1 |
| 24 | 2.80 | 6.92 | 14.03 | 50.24 | 0.23 | 11.55 | 1.56 | 0.02 | 12.39 | 99.74 | 1.79 | I–THOL–1 |
| 25 | 2.33 | 6.96 | 14.16 | 50.14 | 0.26 | 11.11 | 1.83 | 0.04 | 12.39 | 99.21 | 1.78 | I–THOL–1 |
| 26 | 2.89 | 6.55 | 14.51 | 50.21 | 0.24 | 10.74 | 1.64 | 0.33 | 12.57 | 99.69 | 1.92 | Uncorr. |
| 27 | 3.45 | 5.41 | 12.51 | 47.57 | 0.65 | 9.44 | 4.96 | 0.30 | 15.28 | 99.57 | 2.82 | I–TAB–1 |
| 28 | 1.80 | 8.57 | 15.57 | 48.66 | 0.31 | 11.81 | 1.69 | 0.32 | 10.39 | 99.12 | 1.21 | I–THOL–1 |
| 29 | 2.13 | 7.93 | 14.27 | 49.80 | 0.20 | 11.43 | 1.62 | 0.22 | 12.01 | 99.60 | 1.51 | I–THOL–1 |
| 30 | 2.27 | 7.12 | 13.58 | 48.76 | 0.36 | 11.00 | 1.60 | 0.16 | 12.41 | 97.26 | 1.74 | I–THOL–1 |
| 31 | 2.69 | 7.97 | 14.66 | 48.01 | 0.22 | 12.16 | 1.59 | 0.24 | 11.30 | 98.83 | 1.42 | I–THOL–1 |
| 32 | 2.45 | 6.37 | 14.17 | 50.50 | 0.19 | 10.71 | 1.37 | 0.31 | 12.98 | 99.04 | 2.04 | Uncorr. |
| 33 | 2.29 | 7.83 | 13.76 | 49.77 | 0.17 | 11.01 | 1.86 | 0.34 | 11.56 | 97.92 | 1.48 | I–THOL–1 |
| 34 | 2.64 | 7.70 | 14.59 | 49.42 | 0.10 | 12.52 | 1.65 | 0.16 | 11.74 | 100.52 | 1.52 | I–THOL–1 |
| 35 | 2.21 | 0.19 | 13.80 | 72.69 | 3.12 | 1.35 | 0.00 | 0.32 | 3.59 | 97.26 | | I–RHY–1 |
| 36 | 2.47 | 0.21 | 13.55 | 72.15 | 3.32 | 1.42 | 0.53 | 0.16 | 4.09 | 97.62 | | I–RHY–1 |
| 37 | 2.29 | 0.37 | 13.56 | 71.70 | 3.03 | 1.39 | 0.19 | 0.18 | 4.09 | 96.79 | | I–RHY–1 |
| 38 | 2.27 | 0.11 | 13.94 | 73.30 | 3.01 | 1.34 | 0.12 | 0.35 | 3.83 | 98.28 | | I–RHY–1 |
| 39 | 2.32 | 0.21 | 13.97 | 69.90 | 3.21 | 1.36 | 0.15 | 0.13 | 4.05 | 95.30 | | I–RHY–1 |
| 55 cm | | | | | | | | | | | | |
| 40 | 3.85 | 4.42 | 13.40 | 50.79 | 0.57 | 7.52 | 4.03 | 0.24 | 13.88 | 98.70 | 3.14 | I–TAB–1 |
| 41 | 3.25 | 5.51 | 15.39 | 46.81 | 1.49 | 9.16 | 3.38 | 0.17 | 9.66 | 94.82 | 1.75 | Uncorr. |
| 42 | 2.19 | 8.07 | 15.28 | 49.87 | 0.08 | 12.45 | 1.63 | 0.32 | 11.12 | 101.01 | 1.38 | I–THOL–1 |
| 43 | 2.05 | 7.84 | 14.64 | 51.12 | 0.23 | 12.13 | 1.43 | 0.25 | 11.55 | 101.24 | 1.47 | I–THOL–1 |
| 44 | 2.58 | 8.41 | 15.56 | 51.14 | 0.23 | 12.30 | 1.26 | 0.22 | 11.31 | 103.01 | 1.35 | I–THOL–1 |
| 45 | 3.20 | 5.58 | 15.46 | 47.34 | 1.50 | 9.22 | 3.34 | 0.23 | 9.84 | 95.71 | 1.76 | Uncorr. |
| 46 | 2.00 | 0.28 | 13,56 | 70.79 | 2.67 | 1.16 | 0.28 | 0.15 | 3.79 | 94.68 | | I–RHY–1 |
| 47 | 1.94 | 0.19 | 13.69 | 72.18 | 2.67 | 1.05 | 0.34 | 0.19 | 3.92 | 96.17 | | I–RHY–1 |
| 48 | 2.27 | 0.18 | 13.66 | 73.91 | 3.44 | 1.44 | 0.43 | 0.17 | 3.97 | 99.47 | | I–RHY–1 |
| V27-114 | | | | | | | | | | | | |
| 225 cm | | | | | | | | | | | | |
| 1 | 2.23 | 7.70 | 14.55 | 48.11 | 0.14 | 11.51 | 1.72 | 0.07 | 10.92 | 96.96 | 1.42 | I–THOL–1 |
| 2 | 2.78 | 5.90 | 12.52 | 47.83 | 0.45 | 9.70 | 2.77 | 0.42 | 13.61 | 95.98 | 2.31 | I–THOL–2 |
| 3 | 2.97 | 5.30 | 12.45 | 46.17 | 0.79 | 9.04 | 4.30 | 0.27 | 13.91 | 95.20 | 2.62 | I–TAB–1 |
| 4 | 2.25 | 8.64 | 15.00 | 47.31 | 0.15 | 10.45 | 1.28 | 0.16 | 10.64 | 95.88 | 1.23 | I–THOL–1 |
| 5 | 1.90 | 8.54 | 15.01 | 47.70 | 0.09 | 10.82 | 1.64 | 0.35 | 10.58 | 96.63 | 1.24 | I–THOL–1 |
| 6 | 1.93 | 8.83 | 15.30 | 47.48 | 0.23 | 10.39 | 1.52 | 0.16 | 10.40 | 96.24 | 1.18 | I–THOL–1 |
| 7 | 2.73 | 5.48 | 12.39 | 44.34 | 0.68 | 8.42 | 5.04 | 0.23 | 13.80 | 93.11 | 2.52 | I–TAB–1 |
| 8 | 1.95 | 7.35 | 12.64 | 47.29 | 0.22 | 10.10 | 1.36 | 0.17 | 10.79 | 91.87 | 1.47 | Uncorr. |
| 9 | 2.25 | 6.51 | 13.15 | 47.35 | 0.76 | 9.83 | 4.19 | 0.20 | 12.63 | 96.87 | 1.94 | Uncorr. |
| 10 | 2.15 | 7.25 | 13.56 | 50.27 | 0.10 | 10.82 | 1.38 | 0.29 | 11.77 | 97.59 | 1.62 | I–THOL–1 |
| 11 | 1.85 | 7.29 | 13.96 | 48.73 | 0.08 | 10.87 | 0.97 | 0.27 | 11.42 | 95.44 | 1.57 | I–THOL–1 |
| 12 | 1.83 | 7.53 | 13.80 | 49.78 | 0.10 | 11.69 | 1.77 | 0.36 | 9.83 | 96.69 | 1.31 | I–THOL–1 |
| 13 | 2.05 | 8.08 | 13.98 | 47.95 | 0.13 | 11.42 | 1.97 | 0.20 | 10.79 | 96.57 | 1.34 | I–THOL–1 |
| 14 | 2.57 | 6.02 | 12.67 | 47.40 | 0.39 | 9.42 | 2.57 | 0.29 | 13.29 | 94.62 | 2.21 | I–THOL–2 |
| 15 | 2.19 | 6.12 | 13.05 | 47.57 | 0.25 | 9.18 | 2.30 | 0.18 | 12.53 | 93.37 | 2.05 | I–THOL–2 |
| 16 | 2.85 | 5.56 | 13.21 | 46.61 | 0.83 | 9.14 | 4.83 | 0.32 | 14.42 | 97.77 | 2.59 | I–TAB–1 |
| 17 | 2.64 | 5.81 | 13.23 | 48.01 | 0.44 | 9.60 | 2.89 | 0.11 | 13.56 | 96.29 | 2.34 | I–THOL–2 |
| 18 | 2.59 | 6.52 | 15.35 | 45.77 | 0.47 | 9.25 | 2.72 | 0.10 | 13.00 | 95.77 | 1.99 | Uncorr. |
| 19 | 1.86 | 8.34 | 14.56 | 47.79 | 0.19 | 10.40 | 1.49 | 0.27 | 10.55 | 95.45 | 1.27 | I–THOL–1 |
| 20 | 2.85 | 4.24 | 12.76 | 50.70 | 0.72 | 7.08 | 2.97 | 0.25 | 13.01 | 94.58 | 3.07 | I–TAB–1 |
| 21 | 1.82 | 0.27 | 12.46 | 68.30 | 3.01 | 1.23 | 0.13 | 0.18 | 3.72 | 91.02 | | I–RHY–1 |
| 230 cm | | | | | | | | | | | | |
| 22 | 2.73 | 8.08 | 15.00 | 50.85 | 0.18 | 12.72 | 1.67 | 0.29 | 11.83 | 102.90 | 1.46 | I–THOL–1 |
| 23 | 2.89 | 6.74 | 14.31 | 50.43 | 0.33 | 10.50 | 2.50 | 0.18 | 12.77 | 100.64 | 1.89 | Uncorr. |
| 24 | 3.62 | 6.19 | 12.71 | 50.00 | 0.45 | 9.56 | 2.76 | 0.33 | 14.42 | 100.02 | 2.33 | I–THOL–2 |
| 25 | 3.03 | 5.47 | 13.16 | 49.06 | 0.40 | 9.67 | 2.75 | 0.35 | 14.58 | 98.46 | 2.67 | Uncorr. |
| 26 | 3.09 | 5.82 | 12.94 | 51.30 | 0.28 | 10.82 | 2.75 | 0.38 | 13.56 | 100.93 | 2.33 | I–THOL–2 |
| 27 | 3.62 | 5.27 | 13.59 | 48.47 | 0.60 | 10.06 | 4.79 | 0.37 | 15.23 | 102.00 | 2.89 | I–TAB–1 |
| 28 | 2.71 | 6.10 | 13.65 | 50.02 | 0.27 | 10.63 | 2.54 | 0.19 | 14.00 | 100.11 | 2.30 | I–THOL–2 |
| 29 | 3.21 | 5.28 | 12.46 | 47.24 | 0.60 | 9.82 | 4.42 | 0.23 | 15.32 | 98.58 | 2.90 | I–TAB–1 |

*Appendix I.* (continued)

| | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $K_2O$ | CaO | $TiO_2$ | MnO | FeO* | Tot | FeO*/MgO | Population |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 | 3.47 | 5.95 | 13.24 | 46.71 | 0.71 | 9.64 | 4.70 | 0.14 | 14.67 | 99.22 | 2.47 | I–TAB–1 |
| 31 | 2.27 | 7.20 | 13.94 | 51.98 | 0.25 | 11.92 | 1.64 | 0.31 | 12.10 | 101.61 | 1.68 | I–THOL–1 |
| 32 | 2.53 | 7.04 | 14.09 | 52.22 | 0.22 | 11.48 | 1.11 | 0.11 | 11.98 | 100.78 | 1.70 | I–THOL–1 |
| 33 | 2.22 | 7.56 | 14.39 | 51.96 | 0.08 | 12.03 | 1.42 | 0.09 | 12.38 | 102.12 | 1.64 | I–THOL–1 |
| 34 | 3.52 | 4.19 | 12.98 | 53.14 | 1.13 | 8.37 | 3.15 | 0.44 | 13.29 | 100.21 | 3.17 | I–TAB–1 |
| 35 | 1.80 | 6.59 | 13.14 | 49.47 | 0.20 | 11.31 | 1.27 | 0.14 | 11.99 | 95.90 | 1.82 | I–THOL–1 |
| 36 | 2.38 | 8.48 | 14.70 | 50.66 | 0.20 | 11.78 | 1.48 | 0.24 | 11.75 | 101.66 | 1.39 | I–THOL–1 |
| 37 | 2.43 | 8.01 | 14.36 | 49.62 | 0.19 | 12.52 | 1.75 | 0.11 | 11.77 | 100.76 | 1.47 | I–THOL–1 |
| 38 | 2.40 | 7.90 | 14.72 | 49.56 | 0.18 | 12.11 | 1.89 | 0.33 | 11.98 | 101.07 | 1.52 | I–THOL–1 |
| 39 | 2.10 | 8.04 | 15.08 | 49.99 | 0.18 | 12.09 | 1.76 | 0.20 | 11.43 | 100.86 | 1.42 | I–THOL–1 |
| 40 | 2.37 | 8.01 | 15.72 | 49.98 | 0.13 | 11.25 | 1.63 | 0.23 | 11.48 | 100.81 | 1.43 | I–THOL–1 |
| 41 | 2.90 | 6.98 | 15.26 | 47.11 | 0.51 | 10.76 | 2.68 | 0.23 | 13.42 | 99.83 | 1.92 | Uncorr. |
| 42 | 2.62 | 0.33 | 13.96 | 72.96 | 3.46 | 1.29 | 0.23 | 0.34 | 4.09 | 99.29 | | I–RHY–1 |
| 43 | 2.93 | 0.15 | 14.08 | 73.79 | 3.03 | 1.35 | 0.31 | 0.03 | 4.00 | 99.66 | | I–RHY–1 |
| 240 cm | | | | | | | | | | | | |
| 44 | 2.16 | 7.32 | 14.89 | 47.97 | 0.27 | 11.96 | 1.40 | 0.06 | 10.81 | 96.84 | 1.48 | I–THOL–1 |
| 45 | 2.82 | 5.28 | 12.88 | 46.40 | 0.69 | 9.06 | 4.74 | 0.17 | 14.56 | 96.60 | 2.76 | I–TAB–1 |
| 46 | 2.38 | 5.46 | 12.52 | 46.94 | 0.75 | 9.49 | 4.72 | 0.00 | 14.13 | 96.39 | 2.59 | I–TAB–1 |
| 47 | 3.05 | 3.85 | 13.16 | 48.56 | 0.79 | 9.72 | 4.38 | 0.27 | 14.69 | 98.47 | 3.81 | Uncorr. |
| 48 | 2.06 | 8.65 | 15.08 | 48.67 | 0.18 | 11.88 | 1.46 | 0.19 | 11.22 | 99.39 | 1.30 | I–THOL–1 |
| 49 | 1.51 | 7.58 | 11.95 | 46.34 | 0.40 | 10.04 | 4.50 | 0.24 | 13.76 | 96.32 | 1.82 | Uncorr. |
| 50 | 2.15 | 8.16 | 14.40 | 48.59 | 0.16 | 11.64 | 1.62 | 0.21 | 11.27 | 98.19 | 1.38 | I–THOL–1 |
| 51 | 2.84 | 6.50 | 13.18 | 48.67 | 0.27 | 10.08 | 2.80 | 0.20 | 13.35 | 97.89 | 2.05 | I–THOL–2 |
| 52 | 1.62 | 7.72 | 13.63 | 47.85 | 0.18 | 10.92 | 1.33 | 0.27 | 10.87 | 94.39 | 1.41 | I–THOL–1 |
| 53 | 1.91 | 7.88 | 14.69 | 48.91 | 0.22 | 11.23 | 1.61 | 0.07 | 11.02 | 97.54 | 1.40 | I–THOL–1 |
| 54 | 2.18 | 5.47 | 13.19 | 48.74 | 0.37 | 8.98 | 4.42 | 0.22 | 14.57 | 98.14 | 2.67 | I–TAB–1 |
| 55 | 2.33 | 7.44 | 14.16 | 49.37 | 0.18 | 10.91 | 1.84 | 0.28 | 11.33 | 97.84 | 1.52 | I–THOL–1 |
| 56 | 2.52 | 4.95 | 12.51 | 46.51 | 0.74 | 8.64 | 4.38 | 0.17 | 14.43 | 94.85 | 2.92 | I–TAB–1 |
| 57 | 2.51 | 0.25 | 13.46 | 72.01 | 3.63 | 1.25 | 0.21 | 0.10 | 3.47 | 96.89 | | I–RHY–1 |
| 58 | 2.14 | 0.20 | 13.42 | 70.34 | 3.31 | 1.20 | 0.36 | 0.31 | 4.00 | 95.28 | | I–RHY–1 |
| 59 | 2.18 | 0.28 | 13.17 | 70.79 | 3.36 | 1.20 | 0.15 | 0.07 | 3.85 | 94.05 | | I–RHY–1 |
| 60 | 1.76 | 0.24 | 13.21 | 70.36 | 3.35 | 1.30 | 0.25 | 0.20 | 3.82 | 94.49 | | I–RHY–1 |
| 61 | 1.93 | 0.19 | 13.39 | 70.43 | 3.11 | 1.11 | 0.43 | 0.03 | 3.75 | 94.37 | | I–RHY–1 |
| 62 | 2.12 | 0.11 | 13.42 | 70.30 | 3.21 | 1.24 | 0.58 | 0.05 | 4.02 | 95.05 | | I–RHY–1 |
| 63 | 2.21 | 0.22 | 13.14 | 70.53 | 3.43 | 1.31 | 0.50 | 0.08 | 4.03 | 95.45 | | I–RHY–1 |
| 250 cm | | | | | | | | | | | | |
| 64 | 2.22 | 6.27 | 13.15 | 47.39 | 0.32 | 9.37 | 2.80 | 0.19 | 12.99 | 94.70 | 2.07 | I–THOL–2 |
| 65 | 2.28 | 6.08 | 13.14 | 48.13 | 0.45 | 9.69 | 2.84 | 0.30 | 13.92 | 96.83 | 2.29 | I–THOL–2 |
| 66 | 2.12 | 7.30 | 14.54 | 49.12 | 0.11 | 10.87 | 1.45 | 0.30 | 11.29 | 97.10 | 1.55 | I–THOL–1 |
| 67 | 2.06 | 6.84 | 14.04 | 49.95 | 0.15 | 9.96 | 1.18 | 0.18 | 12.20 | 96.56 | 1.78 | I–THOL–1 |
| 68 | 2.61 | 5.57 | 12.42 | 45.92 | 0.77 | 8.85 | 4.69 | 0.23 | 14.47 | 95.53 | 2.60 | I–TAB–1 |
| 69 | 2.21 | 5.51 | 12.26 | 46.05 | 0.76 | 8.97 | 4.86 | 0.42 | 14.71 | 95.75 | 2.67 | I–TAB–1 |
| 70 | 2.49 | 6.60 | 13.47 | 49.05 | 0.32 | 10.35 | 1.69 | 0.02 | 12.22 | 96.21 | 1.85 | I–THOL–1 |
| 71 | 2.41 | 5.82 | 12.93 | 48.15 | 0.32 | 9.47 | 2.60 | 0.15 | 13.73 | 95.58 | 2.36 | I–THOL–2 |
| 72 | 2.10 | 5.97 | 13.41 | 49.30 | 0.54 | 9.46 | 2.97 | 0.26 | 13.00 | 97.01 | 2.18 | I–THOL–2 |
| 73 | 2.46 | 5.25 | 13.10 | 48.69 | 0.56 | 8.82 | 3.04 | 0.16 | 14.15 | 96.24 | 2.69 | Uncorr. |
| 74 | 1.93 | 7.48 | 14.17 | 49.79 | 0.23 | 10.61 | 1.63 | 0.28 | 11.40 | 97.50 | 1.52 | I–THOL–1 |
| 75 | 2.49 | 5.69 | 13.06 | 48.93 | 0.38 | 9.58 | 2.67 | 0.19 | 13.97 | 96.96 | 2.46 | I–THOL–2 |
| 76 | 1.85 | 7.23 | 13.56 | 50.53 | 0.12 | 10.87 | 1.21 | 0.15 | 11.94 | 97.46 | 1.65 | I–THOL–1 |
| V23-82 | | | | | | | | | | | | |
| 50 cm | | | | | | | | | | | | |
| 1 | 2.58 | 5.10 | 13.01 | 45.74 | 0.70 | 9.42 | 4.45 | 0.27 | 14.49 | 95.76 | 2.84 | I–TAB–1 |
| 2 | 2.47 | 4.98 | 12.56 | 44.83 | 0.66 | 9.04 | 4.59 | 0.26 | 14.25 | 93.64 | 2.86 | I–TAB–1 |
| 3 | 2.76 | 5.49 | 13.02 | 48.15 | 0.57 | 9.53 | 4.19 | 0.25 | 13.75 | 97.71 | 2.50 | I–TAB–1 |
| 4 | 0.95 | 5.99 | 13.88 | 49.00 | 0.37 | 9.74 | 2.23 | 0.31 | 13.63 | 96.10 | 2.28 | I–THOL–2 |
| 5 | 2.63 | 3.79 | 13.31 | 46.26 | 1.06 | 8.01 | 5.19 | 0.18 | 13.97 | 94.40 | 3.69 | Uncorr. |
| 6 | 1.72 | 4.28 | 12.90 | 46.53 | 0.76 | 8.90 | 5.10 | 0.22 | 16.03 | 96.44 | 3.75 | Uncorr. |
| 7 | 3.16 | 5.46 | 12.88 | 46.37 | 0.66 | 8.95 | 4.43 | 0.31 | 14.67 | 96.89 | 2.69 | I–TAB–1 |

*Appendix I.* (continued)

| | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $K_2O$ | CaO | $TiO_2$ | MnO | FeO* | Tot | FeO*/MgO | Population |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 60 cm | | | | | | | | | | | | |
| 8 | 2.17 | 6.85 | 13.27 | 49.55 | 0.09 | 11.36 | 2.80 | 0.31 | 13.42 | 99.82 | 1.96 | I–THOL–2 |
| 9 | 2.77 | 6.59 | 14.10 | 50.97 | 0.26 | 9.59 | 1.31 | 0.35 | 13.24 | 99.17 | 2.01 | I–TAB–1 |
| 10 | 2.70 | 7.68 | 15.27 | 46.38 | 0.36 | 10.37 | 2.86 | 0.19 | 13.03 | 98.84 | 1.70 | I–TAB–1 |
| 11 | 2.60 | 7.26 | 13.82 | 48.94 | 0.26 | 11.12 | 2.12 | 0.28 | 12.46 | 98.87 | 1.72 | I–THOL–1 |
| 12 | 1.89 | 0.18 | 12.79 | 69.15 | 3.42 | 0.74 | 0.17 | 0.18 | 3.28 | 91.78 | | I–RHY–1 |
| 13 | 2.52 | 0.20 | 13.35 | 69.91 | 2.96 | 1.40 | 0.36 | 0.11 | 3.90 | 94.70 | | I–RHY–1 |
| 14 | 2.43 | 0.07 | 13.36 | 69.88 | 3.14 | 1.23 | 0.00 | 0.20 | 3.96 | 94.22 | | I–RHY–1 |
| 15 | 2.31 | 0.31 | 13.44 | 70.94 | 3.02 | 1.49 | 0.52 | 0.02 | 3.93 | 95.92 | | I–RHY–1 |
| 65 cm | | | | | | | | | | | | |
| 16 | 3.13 | 7.56 | 15.74 | 45.78 | 0.33 | 10.92 | 2.66 | 0.21 | 12.53 | 98.86 | 1.66 | Uncorr. |
| 17 | 2.02 | 7.75 | 13.95 | 48.99 | 0.07 | 11.72 | 1.46 | 0.24 | 11.40 | 97.59 | 1.47 | I–THOL–1 |
| 18 | 2.00 | 8.47 | 15.03 | 49.55 | 0.19 | 11.57 | 1.80 | 0.32 | 11.63 | 100.56 | 1.37 | Uncorr. |
| 19 | 2.67 | 7.64 | 15.64 | 46.80 | 0.36 | 11.13 | 2.88 | 0.20 | 12.84 | 100.16 | 1.68 | Uncorr. |
| 20 | 3.18 | 7.26 | 15.66 | 47.12 | 0.39 | 10.55 | 2.93 | 0.13 | 12.76 | 99.98 | 1.75 | Uncorr. |
| 21 | 1.94 | 8.18 | 15.10 | 49.82 | 0.09 | 10.47 | 1.50 | 0.30 | 10.84 | 98.24 | 1.33 | Uncorr. |
| 22 | 2.53 | 7.73 | 14.35 | 49.27 | 0.10 | 12.28 | 1.62 | 0.32 | 11.85 | 100.04 | 1.53 | I–THOL–1 |
| 23 | 1.67 | 8.33 | 15.50 | 49.17 | 0.19 | 12.08 | 1.86 | 0.04 | 11.42 | 100.27 | 1.37 | Uncorr. |
| 24 | 2.61 | 7.41 | 14.33 | 48.82 | 0.23 | 12.20 | 1.46 | 0.32 | 11.57 | 98.94 | 1.56 | I–THOL–1 |
| 25 | 2.10 | 0.19 | 13.51 | 70.35 | 3.37 | 1.20 | 0.60 | 0.25 | 3.63 | 95.19 | | I–RHY–1 |
| 26 | 2.89 | 0.18 | 13.94 | 73.80 | 2.97 | 1.36 | 0.38 | 0.31 | 3.72 | 99.55 | | I–RHY–1 |
| 27 | 2.52 | 0.20 | 13.25 | 72.59 | 3.29 | 1.40 | 0.11 | 0.09 | 3.97 | 97.42 | | I–RHY–1 |
| 28 | 2.27 | 0.00 | 13.47 | 72.75 | 3.14 | 1.28 | 0.26 | 0.20 | 3.98 | 97.35 | | I–RHY–1 |
| 29 | 2.65 | 0.05 | 13.73 | 73.68 | 3.37 | 1.35 | 0.43 | 0.18 | 3.94 | 99.38 | | I–RHY–1 |
| 30 | 2.38 | 0.32 | 13.64 | 71.95 | 3.22 | 1.33 | 0.20 | 0.17 | 3.92 | 97.12 | | I–RHY–1 |
| 31 | 2.05 | 0.24 | 13.94 | 72.01 | 2.96 | 1.27 | 0.51 | 0.10 | 4.11 | 97.17 | | I–RHY–1 |
| 67 cm | | | | | | | | | | | | |
| 32 | 2.52 | 4.01 | 12.34 | 45.80 | 0.90 | 10.98 | 4.46 | 0.22 | 18.05 | 99.28 | 4.51 | Uncorr. |
| 33 | 2.22 | 8.08 | 15.62 | 46.99 | 0.32 | 11.00 | 2.00 | 0.12 | 11.83 | 98.18 | 1.47 | Uncorr. |
| 34 | 2.06 | 7.86 | 13.57 | 49.63 | 0.08 | 10.95 | 1.00 | 0.31 | 10.97 | 96.43 | 1.40 | I–THOL–1 |
| 35 | 2.18 | 7.66 | 13.50 | 50.83 | 0.03 | 11.23 | 1.04 | 0.32 | 11.43 | 98.22 | 1.49 | I–THOL–1 |
| 36 | 2.30 | 7.95 | 15.37 | 45.36 | 0.37 | 9.85 | 2.55 | 0.25 | 12.94 | 96.94 | 1.63 | Uncorr. |
| 37 | 2.21 | 6.96 | 13.81 | 48.18 | 0.30 | 10.88 | 2.69 | 0.34 | 12.15 | 97.52 | 1.75 | Uncorr. |
| 38 | 2.60 | 5.98 | 12.72 | 48.84 | 0.26 | 9.27 | 2.60 | 0.29 | 14.06 | 96.62 | 2.35 | I–THOL–2 |
| 39 | 1.84 | 8.21 | 14.03 | 50.47 | 0.16 | 11.54 | 1.16 | 0.23 | 11.08 | 98.72 | 1.35 | I–THOL–1 |
| 40 | 2.35 | 6.39 | 13.81 | 49.08 | 0.25 | 10.84 | 2.68 | 0.34 | 13.20 | 98.94 | 2.07 | I–THOL–2 |
| 41 | 1.32 | 0.16 | 13.02 | 71.01 | 3.49 | 1.05 | 0.36 | 0.19 | 3.85 | 94.45 | | I–RHY–1 |
| 70 cm | | | | | | | | | | | | |
| 42 | 2.16 | 7.57 | 15.43 | 46.07 | 0.39 | 10.12 | 2.54 | 0.36 | 12.73 | 97.37 | 1.68 | Uncorr. |
| 43 | 2.22 | 7.64 | 14.09 | 48.26 | 0.34 | 10.92 | 2.05 | 0.16 | 10.43 | 96.11 | 1.37 | I–THOL–1 |
| 44 | 2.00 | 7.60 | 14.21 | 49.88 | 0.20 | 10.79 | 1.00 | 0.21 | 11.19 | 97.08 | 1.47 | I–THOL–1 |
| 45 | 2.46 | 7.98 | 15.50 | 45.53 | 0.50 | 9.95 | 2.66 | 0.27 | 12.20 | 97.05 | 1.53 | Uncorr. |
| 46 | 1.90 | 7.16 | 14.29 | 48.50 | 0.13 | 10.79 | 1.42 | 0.18 | 11.55 | 95.92 | 1.61 | I–THOL–1 |
| 47 | 2.22 | 7.95 | 14.55 | 48.64 | 0.23 | 11.48 | 1.67 | 0.22 | 11.31 | 98.27 | 1.42 | I–THOL–1 |
| 48 | 2.44 | 7.99 | 15.89 | 45.21 | 0.43 | 9.87 | 2.89 | 0.08 | 13.01 | 97.81 | 1.63 | Uncorr. |
| 49 | 1.70 | 7.50 | 14.44 | 49.05 | 0.33 | 10.82 | 2.10 | 0.35 | 10.61 | 96.90 | 1.42 | I–THOL–1 |
| 50 | 1.32 | 0.11 | 13.06 | 68.99 | 3.32 | 1.35 | 0.13 | 0.13 | 3.88 | 92.29 | | I–RHY–1 |
| 51 | 1.75 | 0.16 | 12.12 | 69.24 | 2.42 | 1.12 | 0.36 | 0.05 | 3.35 | 90.57 | | I–RHY–1 |
| V23-81 | | | | | | | | | | | | |
| 150 cm | | | | | | | | | | | | |
| 1 | 2.01 | 8.26 | 15.72 | 49.57 | 0.14 | 11.51 | 1.76 | 0.31 | 11.37 | 100.65 | 1.38 | I–THOL–1 |
| 2 | 3.30 | 5.97 | 13.41 | 49.95 | 0.24 | 10.36 | 2.87 | 0.20 | 14.64 | 100.93 | 2.45 | I–THOL–2 |
| 3 | 2.25 | 8.07 | 14.84 | 48.14 | 0.24 | 12.25 | 1.54 | 0.17 | 10.93 | 98.42 | 1.35 | I–THOL–1 |
| 4 | 2.33 | 8.59 | 15.49 | 49.37 | 0.12 | 12.37 | 1.39 | 0.28 | 11.36 | 101.31 | 1.32 | I–THOL–1 |
| 5 | 2.52 | 8.09 | 14.97 | 52.79 | 0.07 | 11.89 | 1.33 | 0.40 | 11.69 | 103.76 | 1.44 | I–THOL–1 |
| 6 | 2.57 | 0.28 | 14.46 | 72.13 | 3.08 | 1.22 | 0.32 | 0.21 | 4.16 | 98.44 | | I–RHY–1 |
| 7 | 2.72 | 0.07 | 13.41 | 72.05 | 2.82 | 1.31 | 0.16 | 0.03 | 3.72 | 96.30 | | I–RHY–1 |
| 8 | 2.50 | 0.15 | 14.07 | 71.86 | 3.07 | 1.33 | 0.47 | 0.22 | 4.16 | 97.82 | | I–RHY–1 |
| 9 | 2.37 | 0.22 | 13.40 | 72.44 | 3.24 | 1.20 | 0.34 | 0.27 | 4.17 | 97.65 | | I–RHY–1 |
| 10 | 2.31 | 0.04 | 13.37 | 71.20 | 3.27 | 1.09 | 0.40 | 0.33 | 3.88 | 95.89 | | I–RHY–1 |

*Appendix I.* (continued)

| | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $K_2O$ | CaO | $TiO_2$ | MnO | FeO* | Tot | FeO*/MgO | Population |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | 2.25 | 0.23 | 13.76 | 73.21 | 2.87 | 1.19 | 0.26 | 0.12 | 3.86 | 97.76 | | I–RHY–1 |
| 12 | 2.25 | 0.08 | 14.03 | 71.70 | 3.14 | 1.10 | 0.09 | 0.18 | 4.02 | 96.57 | | I–RHY–1 |
| 13 | 2.29 | 0.03 | 13.36 | 71.98 | 2.87 | 1.32 | 0.48 | 0.00 | 3.82 | 96.15 | | I–RHY–1 |
| 14 | 2.78 | 0.38 | 13.96 | 73.20 | 3.13 | 1.23 | 0.21 | 0.12 | 4.18 | 99.19 | | I–RHY–1 |
| 15 | 2.69 | 0.18 | 13.16 | 71.90 | 3.13 | 1.24 | 0.38 | 0.34 | 3.95 | 96.97 | | I–RHY–1 |
| 16 | 3.54 | 0.13 | 13.76 | 72.00 | 2.95 | 1.39 | 0.05 | 0.12 | 3.89 | 97.83 | | I–RHY–1 |
| 155 cm | | | | | | | | | | | | |
| 17 | 3.60 | 5.36 | 12.75 | 46.34 | 0.72 | 9.45 | 5.05 | 0.17 | 14.98 | 98.42 | 2.79 | I–TAB–1 |
| 18 | 3.11 | 6.43 | 13.66 | 48.39 | 0.31 | 10.60 | 2.63 | 0.26 | 13.54 | 98.92 | 2.11 | I–THOL–2 |
| 19 | 2.31 | 8.09 | 15.26 | 48.46 | 0.13 | 11.65 | 1.66 | 0.17 | 11.17 | 98.90 | 1.38 | I–THOL–1 |
| 20 | 2.14 | 7.94 | 14.53 | 48.76 | 0.23 | 11.77 | 1.57 | 0.05 | 11.38 | 98.38 | 1.43 | I–THOL–1 |
| 21 | 3.03 | 5.24 | 13.28 | 46.23 | 0.69 | 9.16 | 4.56 | 0.27 | 15.10 | 97.55 | 2.88 | I–TAB–1 |
| 22 | 2.98 | 6.38 | 13.40 | 48.14 | 0.34 | 9.91 | 2.38 | 0.21 | 13.63 | 97.36 | 2.14 | I–THOL–2 |
| 23 | 1.94 | 8.29 | 15.04 | 47.06 | 0.13 | 11.73 | 1.17 | 0.07 | 11.35 | 96.77 | 1.37 | I–THOL–1 |
| 24 | 3.31 | 4.66 | 12.68 | 46.65 | 0.70 | 9.28 | 4.43 | 0.10 | 14.34 | 96.13 | 3.08 | I–TAB–1 |
| 25 | 1.77 | 8.33 | 15.17 | 48.73 | 0.22 | 11.74 | 1.68 | 0.20 | 11.28 | 99.12 | 1.35 | I–THOL–1 |
| 26 | 2.16 | 8.33 | 15.03 | 47.60 | 0.22 | 11.81 | 1.43 | 0.30 | 11.22 | 98.09 | 1.35 | I–THOL–1 |
| 27 | 2.24 | 8.19 | 15.03 | 49.31 | 0.28 | 11.65 | 1.46 | 0.24 | 11.41 | 99.80 | 1.39 | I–THOL–1 |
| 28 | 2.71 | 7.19 | 14.79 | 45.30 | 0.54 | 9.49 | 2.79 | 0.20 | 13.82 | 96.83 | 1.92 | Uncorr. |
| 29 | 3.08 | 5.18 | 12.75 | 46.73 | 0.67 | 9.86 | 4.70 | 0.21 | 15.05 | 98.23 | 2.91 | I–TAB–1 |
| 30 | 2.08 | 7.64 | 14.96 | 45.82 | 0.36 | 11.18 | 3.03 | 0.14 | 11.33 | 96.55 | 1.48 | Uncorr. |
| 31 | 1.85 | 7.67 | 13.88 | 47.77 | 0.15 | 11.27 | 1.62 | 0.01 | 11.35 | 95.56 | 1.48 | I–THOL–1 |
| 32 | 2.07 | 7.93 | 14.74 | 47.10 | 0.16 | 11.06 | 1.63 | 0.16 | 11.38 | 96.23 | 1.44 | I–THOL–1 |
| 33 | 2.24 | 8.45 | 15.19 | 47.51 | 0.09 | 11.77 | 1.70 | 0.19 | 11.24 | 98.39 | 1.33 | I–THOL–1 |
| 34 | 2.22 | 7.63 | 13.89 | 50.15 | 0.00 | 11.85 | 1.09 | 0.27 | 11.46 | 98.56 | 1.50 | I–THOL–1 |
| 35 | 2.11 | 0.29 | 13.75 | 71.17 | 3.21 | 1.29 | 0.41 | 0.17 | 3.94 | 96.35 | | I–RHY–1 |
| 36 | 1.86 | 0.27 | 13.86 | 71.70 | 3.29 | 1.33 | 0.38 | 0.11 | 3.67 | 96.46 | | I–RHY–1 |
| 37 | 2.60 | 0.07 | 13.52 | 70.03 | 3.21 | 1.26 | 0.37 | 0.19 | 4.02 | 95.27 | | I–RHY–1 |
| 38 | 3.41 | 0.07 | 14.21 | 71.19 | 3.04 | 1.38 | 0.40 | 0.07 | 3.96 | 97.73 | | I–RHY–1 |
| 39 | 1.99 | 0.16 | 13.91 | 71.45 | 3.18 | 1.31 | 0.42 | 0.22 | 4.06 | 96.68 | | I–RHY–1 |
| 40 | 2.44 | 0.06 | 13.19 | 70.06 | 3.03 | 1.32 | 0.14 | 0.31 | 4.05 | 94.61 | | I–RHY–1 |
| 41 | 2.74 | 0.34 | 13.00 | 70.65 | 3.17 | 1.33 | 0.03 | 0.09 | 4.00 | 95.34 | | I–RHY–1 |
| 42 | 2.74 | 0.24 | 13.77 | 71.78 | 3.13 | 1.28 | 0.28 | 0.14 | 3.88 | 97.23 | | I–RHY–1 |
| 43 | 2.30 | 0.13 | 13.60 | 70.11 | 3.38 | 1.31 | 0.18 | 0.26 | 3.82 | 95.09 | | I–RHY–1 |
| 44 | 2.25 | 0.19 | 13.50 | 70.34 | 2.90 | 1.35 | 0.32 | 0.11 | 4.06 | 95.02 | | I–RHY–1 |
| 45 | 2.52 | 0.12 | 13.35 | 69.37 | 2.82 | 1.23 | 0.35 | 0.27 | 4.03 | 94.05 | | I–RHY–1 |
| 157 cm | | | | | | | | | | | | |
| 46 | 2.07 | 7.60 | 13.89 | 50.45 | 0.09 | 10.32 | 0.95 | 0.27 | 11.79 | 97.42 | 1.55 | I–THOL–1 |
| 47 | 1.89 | 7.28 | 13.93 | 50.40 | 0.05 | 11.65 | 1.36 | 0.26 | 12.08 | 98.90 | 1.66 | I–THOL–1 |
| 48 | 2.30 | 7.81 | 14.14 | 48.67 | 0.20 | 11.15 | 1.39 | 0.36 | 11.70 | 97.71 | 1.50 | I–THOL–1 |
| 49 | 3.36 | 4.17 | 13.44 | 50.44 | 1.14 | 6.85 | 3.94 | 0.29 | 12.83 | 96.45 | 3.08 | I–TAB–1 |
| 50 | 2.33 | 8.49 | 15.17 | 47.26 | 0.15 | 10.60 | 1.83 | 0.08 | 11.27 | 97.17 | 1.33 | I–THOL–1 |
| 51 | 2.18 | 7.71 | 14.11 | 48.23 | 0.14 | 11.46 | 1.65 | 0.10 | 11.55 | 97.17 | 1.50 | I–THOL–1 |
| 52 | 2.19 | 8.24 | 14.45 | 49.44 | 0.18 | 11.11 | 1.53 | 0.18 | 11.11 | 98.42 | 1.35 | I–THOL–1 |
| 53 | 2.03 | 8.00 | 13.77 | 50.42 | 0.20 | 11.17 | 1.54 | 0.27 | 11.55 | 98.96 | 1.44 | I–THOL–1 |
| 54 | 2.10 | 7.55 | 15.16 | 47.39 | 9.24 | 10.55 | 1.91 | 0.19 | 12.14 | 97.23 | 1.61 | I–THOL–1 |
| 55 | 2.69 | 7.39 | 15.15 | 46.04 | 0.36 | 9.54 | 2.93 | 0.07 | 13.87 | 98.03 | 1.88 | Uncorr. |
| 56 | 1.63 | 8.12 | 15.61 | 48.06 | 0.20 | 11.34 | 1.61 | 0.17 | 11.01 | 97.74 | 1.36 | I–THOL–1 |
| 57 | 2.29 | 8.69 | 15.54 | 48.52 | 0.20 | 11.94 | 1.40 | 0.11 | 11.12 | 99.80 | 1.28 | I–THOL–1 |
| 58 | 2.81 | 6.18 | 13.74 | 48.65 | 0.22 | 10.49 | 2.29 | 0.12 | 13.71 | 98.21 | 2.22 | I–THOL–2 |
| 59 | 2.22 | 8.71 | 15.43 | 47.66 | 0.12 | 11.63 | 1.38 | 0.18 | 11.26 | 98.60 | 1.29 | I–THOL–1 |
| 60 | 2.39 | 8.40 | 15.02 | 48.30 | 0.10 | 11.87 | 1.67 | 0.26 | 11.34 | 99.34 | 1.35 | I–THOL–1 |
| 61 | 2.17 | 8.14 | 14.07 | 48.71 | 0.20 | 12.19 | 1.77 | 0.08 | 11.71 | 99.05 | 1.44 | I–THOL–1 |
| 62 | 3.10 | 0.17 | 13.30 | 70.78 | 3.27 | 1.24 | 0.21 | 0.10 | 3.78 | 95.96 | | I–RHY–1 |
| 63 | 2.33 | 0.06 | 13.54 | 70.78 | 3.25 | 1.29 | 0.24 | 0.11 | 3.70 | 95.29 | | I–RHY–1 |
| 64 | 2.60 | 0.05 | 13.15 | 69.98 | 3.37 | 1.29 | 0.43 | 0.09 | 3.89 | 94.85 | | I–RHY–1 |
| 65 | 2.10 | 0.28 | 13.57 | 70.56 | 3.08 | 1.33 | 0.23 | 0.16 | 3.97 | 95.26 | | I–RHY–1 |
| 66 | 1.99 | 0.33 | 13.61 | 70.07 | 3.37 | 1.11 | 0.35 | 0.18 | 3.85 | 94.86 | | I–RHY–1 |
| 159 cm | | | | | | | | | | | | |
| 67 | 2.13 | 6.96 | 13.65 | 49.78 | 0.21 | 10.82 | 1.27 | 0.01 | 12.74 | 97.57 | 1.83 | I–THOL–1 |
| 68 | 3.13 | 5.94 | 13.30 | 48.29 | 0.31 | 9.48 | 2.67 | 0.20 | 13.63 | 96.95 | 2.29 | I–THOL–2 |
| 69 | 2.54 | 6.11 | 13.15 | 48.80 | 0.42 | 10.35 | 2.43 | 0.15 | 13.38 | 97.33 | 2.19 | I–THOL–2 |

*Appendix I.* (continued)

| | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $K_2O$ | CaO | $TiO_2$ | MnO | FeO* | Tot | FeO*/MgO | Population |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 70 | 2.55 | 7.78 | 13.90 | 49.81 | 0.23 | 11.05 | 1.65 | 0.07 | 11.22 | 98.26 | 1.44 | I–THOL–1 |
| 71 | 2.51 | 7.61 | 12.35 | 46.42 | 0.32 | 11.62 | 4.48 | 0.37 | 12.07 | 97.77 | 1.59 | Uncorr. |
| 72 | 2.86 | 6.56 | 14.62 | 50.74 | 0.36 | 10.77 | 1.56 | 0.28 | 12.90 | 100.65 | 1.97 | Uncorr. |
| 73 | 2.78 | 6.35 | 13.66 | 48.44 | 0.41 | 9.73 | 2.91 | 0.25 | 14.08 | 98.61 | 2.22 | I–THOL–2 |
| 74 | 3.33 | 4.87 | 13.33 | 46.42 | 0.63 | 9.52 | 4.33 | 0.21 | 13.77 | 96.41 | 2.83 | I–TAB–1 |
| 75 | 2.51 | 0.41 | 13.75 | 71.04 | 3.14 | 1.25 | 0.28 | 0.29 | 3.80 | 96.47 | | I–RHY–1 |
| 76 | 2.41 | 0.32 | 13.50 | 70.62 | 3.29 | 1.22 | 0.29 | 0.21 | 3.95 | 95.81 | | I–RHY–1 |
| 77 | 2.18 | 0.24 | 14.14 | 71.52 | 3.25 | 1.22 | 0.37 | 0.13 | 3.72 | 96.77 | | I–RHY–1 |
| 78 | 2.03 | 0.20 | 13.70 | 71.86 | 3.34 | 1.23 | 0.19 | 0.28 | 3.84 | 96.67 | | I–RHY–1 |
| 79 | 2.44 | 0.13 | 13.50 | 70.49 | 3.36 | 1.17 | 0.34 | 0.29 | 3.97 | 95.69 | | I–RHY–1 |
| 80 | 2.29 | 0.15 | 14.38 | 71.11 | 3.44 | 1.36 | 0.55 | 0.12 | 3.70 | 97.10 | | I–RHY–1 |
| 81 | 1.60 | 0.23 | 13.84 | 70.44 | 3.13 | 1.28 | 0.43 | 0.25 | 4.14 | 95.34 | | I–RHY–1 |
| V23-42 | | | | | | | | | | | | |
| 20 cm | | | | | | | | | | | | |
| 1 | 2.45 | 3.73 | 13.71 | 51.64 | 0.73 | 9.42 | 4.15 | 0.28 | 14.67 | 100.78 | 3.94 | Uncorr. |
| 2 | 2.40 | 7.47 | 13.85 | 51.46 | 0.21 | 11.82 | 1.58 | 0.33 | 11.67 | 100.79 | 1.56 | I–THOL–1 |
| 3 | 2.35 | 6.86 | 13.86 | 50.81 | 0.19 | 10.75 | 1.50 | 0.09 | 11.47 | 97.88 | 1.67 | I–THOL–1 |
| 4 | 1.80 | 7.50 | 13.68 | 49.06 | 0.25 | 11.19 | 1.36 | 0.17 | 10.44 | 95.45 | 1.39 | I–THOL–1 |
| 5 | 1.89 | 8.21 | 14.32 | 48.60 | 0.13 | 11.76 | 0.96 | 0.18 | 10.06 | 96.11 | 1.22 | I–THOL–1 |
| 6 | 2.34 | 5.39 | 13.41 | 45.72 | 0.54 | 8.75 | 4.65 | 0.23 | 14.35 | 95.38 | 2.66 | I–TAB–1 |
| 34 cm | | | | | | | | | | | | |
| 7 | 2.30 | 6.87 | 14.08 | 50.34 | 0.30 | 11.07 | 1.48 | 0.14 | 11.50 | 98.08 | 1.68 | I–THOL–1 |
| 8 | 2.50 | 7.31 | 13.57 | 50.59 | 0.18 | 11.39 | 1.35 | 0.15 | 11.02 | 98.06 | 1.51 | I–THOL–1 |
| 9 | 3.40 | 4.07 | 12.82 | 52.31 | 1.29 | 7.59 | 3.36 | 0.21 | 11.40 | 96.45 | 2.80 | Uncorr. |
| 10 | 2.20 | 6.69 | 13.56 | 51.27 | 0.09 | 10.88 | 1.35 | 0.26 | 12.03 | 98.33 | 1.80 | I–THOL–1 |
| 11 | 3.09 | 4.24 | 13.61 | 52.94 | 0.97 | 8.29 | 2.73 | 0.29 | 11.52 | 97.68 | 2.72 | Uncorr. |
| 12 | 4.44 | 4.01 | 13.35 | 53.98 | 0.89 | 7.86 | 2.95 | 0.21 | 12.21 | 99.90 | 3.04 | Uncorr. |
| 13 | 2.20 | 4.47 | 12.76 | 48.24 | 1.38 | 7.82 | 4.50 | 0.11 | 16.16 | 97.64 | 3.61 | Uncorr. |
| 14 | 1.91 | 5.16 | 13.33 | 48.44 | 1.25 | 9.62 | 4.64 | 0.14 | 13.09 | 97.58 | 2.54 | I–TAB–1 |
| 15 | 2.65 | 6.65 | 13.88 | 49.09 | 0.27 | 9.61 | 1.56 | 0.20 | 11.48 | 95.39 | 1.78 | I–THOL–1 |
| 16 | 3.25 | 0.38 | 13.24 | 71.02 | 3.48 | 1.24 | 0.39 | 0.05 | 3.56 | 96.61 | | I–RHY–1 |
| 17 | 2.24 | 0.16 | 13.75 | 72.32 | 3.41 | 1.42 | 0.23 | 0.23 | 3.79 | 97.55 | | I–RHY–1 |
| 18 | 2.53 | 0.20 | 13.76 | 72.49 | 3.38 | 1.32 | 0.40 | 0.16 | 3.74 | 97.80 | | I–RHY–1 |
| 19 | 2.54 | 0.19 | 13.07 | 72.83 | 3.30 | 1.31 | 0.23 | 0.10 | 3.62 | 97.19 | | I–RHY–1 |
| 20 | 2.12 | 0.23 | 13.53 | 74.13 | 3.20 | 1.31 | 0.04 | 0.11 | 3.76 | 98.43 | | I–RHY–1 |
| 21 | 1.69 | 0.08 | 12.69 | 75.37 | 3.17 | 0.91 | 0.16 | 0.09 | 1.73 | 95.89 | | I–RHY–2 |
| 42 cm | | | | | | | | | | | | |
| 22 | 2.03 | 7.08 | 13.63 | 49.02 | 0.21 | 10.24 | 1.58 | 0.16 | 11.80 | 95.75 | 1.67 | I–THOL–1 |
| 23 | 1.91 | 7.79 | 14.04 | 48.57 | 0.44 | 11.35 | 2.27 | 0.22 | 9.97 | 96.56 | 1.28 | Uncorr. |
| 24 | 2.09 | 7.46 | 13.60 | 49.00 | 0.29 | 10.35 | 1.55 | 0.27 | 11.54 | 96.15 | 1.55 | I–THOL–1 |
| 25 | 2.69 | 6.17 | 16.48 | 45.49 | 0.41 | 9.14 | 2.91 | 0.27 | 12.11 | 95.67 | 1.96 | Uncorr. |
| 26 | 2.06 | 4.59 | 19.35 | 48.45 | 0.35 | 12.86 | 3.45 | 0.14 | 7.29 | 98.54 | 1.59 | Uncorr. |
| 27 | 2.19 | 8.02 | 16.40 | 47.11 | 0.17 | 10.75 | 2.12 | 0.26 | 9.43 | 96.75 | 1.18 | Uncorr. |
| 28 | 2.11 | 0.06 | 13.39 | 70.62 | 3.69 | 0.94 | 0.26 | 0.12 | 3.50 | 94.69 | | I–RHY–1 |
| 29 | 2.17 | 0.15 | 13.20 | 70.71 | 3.16 | 1.18 | 0.22 | 0.11 | 4.02 | 94.92 | | I–RHY–1 |
| 30 | 1.74 | 0.29 | 13.38 | 70.34 | 3.23 | 1.24 | 0.46 | 0.24 | 3.61 | 94.53 | | I–RHY–1 |
| 31 | 1.85 | 0.02 | 13.54 | 69.90 | 3.61 | 1.23 | 0.51 | 0.22 | 3.83 | 94.71 | | I–RHY–1 |
| 32 | 1.99 | 0.29 | 13.43 | 70.30 | 3.42 | 1.30 | 0.46 | 0.24 | 3.73 | 95.16 | | I–RHY–1 |
| 46 cm | | | | | | | | | | | | |
| 33 | 2.36 | 6.45 | 13.19 | 49.25 | 0.22 | 10.14 | 1.71 | 0.14 | 12.61 | 96.07 | 1.95 | I–THOL–1 |
| 34 | 3.86 | 4.98 | 12.79 | 47.13 | 0.34 | 10.52 | 4.52 | 0.22 | 14.19 | 98.55 | 2.85 | I–TAB–1 |
| 35 | 2.01 | 7.75 | 13.80 | 49.64 | 0.15 | 11.99 | 1.19 | 0.14 | 9.86 | 96.53 | 1.27 | I–THOL–1 |
| 36 | 2.45 | 7.63 | 15.56 | 46.71 | 0.41 | 10.62 | 2.71 | 0.17 | 12.02 | 98.28 | 1.58 | Uncorr. |
| 37 | 3.39 | 7.53 | 13.12 | 47.93 | 0.38 | 9.52 | 2.48 | 0.25 | 11.48 | 96.08 | 1.52 | Uncorr. |
| 38 | 3.05 | 7.35 | 8.38 | 47.36 | 0.43 | 9.53 | 3.91 | 0.40 | 16.60 | 97.01 | 2.26 | Uncorr. |
| 39 | 1.98 | 0.08 | 12.58 | 73.71 | 3.50 | 0.77 | 0.13 | 0.03 | 1.56 | 94.34 | | I–RHY–2 |
| 40 | 2.17 | 0.00 | 13.00 | 71.44 | 3.28 | 1.28 | 0.03 | 0.18 | 3.56 | 94.94 | | I–RHY–1 |
| 41 | 2.40 | 0.18 | 12.78 | 75.80 | 3.53 | 0.91 | 0.08 | 0.07 | 1.58 | 97.33 | | I–RHY–2 |

*Appendix I.* (continued)

B. ASH ZONE II (all oxides in %)

| | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $K_2O$ | CaO | $TiO_2$ | MnO | FeO* | Tot | FeO*/MgO | Population |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V23-23 | | | | | | | | | | | | |
| 330 cm | | | | | | | | | | | | |
| 1 | 2.36 | 7.35 | 14.02 | 49.39 | 0.20 | 11.04 | 1.42 | 0.28 | 11.17 | 97.22 | 1.52 | II–THOL–1 |
| 2 | 2.95 | 5.25 | 13.45 | 49.38 | 0.38 | 8.24 | 2.52 | 0.24 | 14.54 | 96.96 | 2.77 | II–THOL–2 |
| 3 | 2.63 | 7.21 | 13.50 | 48.80 | 0.19 | 9.55 | 2.04 | 0.26 | 12.63 | 96.82 | 1.75 | II–THOL–1 |
| 4 | 2.14 | 6.77 | 13.22 | 49.99 | 0.23 | 11.33 | 1.80 | 0.22 | 12.04 | 97.74 | 1.78 | II–THOL–1 |
| 5 | 1.89 | 0.14 | 12.01 | 74.02 | 2.76 | 0.48 | 0.17 | 0.00 | 2.60 | 94.07 | | II–RHY–1 |
| 6 | 2.05 | 0.05 | 12.02 | 75.63 | 3.17 | 0.28 | 0.21 | 0.11 | 2.67 | 96.17 | | II–RHY–1 |
| 7 | 1.93 | 0.00 | 11.68 | 74.73 | 3.09 | 0.40 | 0.18 | 0.05 | 2.56 | 94.63 | | II–RHY–1 |
| 8 | 1.77 | 0.04 | 12.20 | 74.73 | 3.95 | 0.38 | 0.00 | 0.08 | 2.54 | 95.70 | | II–RHY–1 |
| 337 cm | | | | | | | | | | | | |
| 9 | 2.55 | 7.24 | 13.42 | 48.24 | 0.23 | 9.96 | 1.66 | 0.28 | 11.59 | 95.17 | 1.60 | II–THOL–1 |
| 10 | 2.39 | 6.52 | 13.24 | 49.96 | 0.12 | 8.96 | 1.43 | 0.32 | 12.77 | 95.70 | 1.96 | II–THOL–1 |
| 11 | 2.68 | 5.98 | 13.05 | 48.03 | 0.33 | 8.58 | 2.68 | 0.30 | 13.46 | 95.09 | 2.25 | II–THOL–2 |
| 12 | 2.17 | 8.59 | 14.21 | 49.44 | 0.21 | 12.39 | 1.26 | 0.16 | 10.00 | 98.43 | 1.16 | II–THOL–1 |
| 13 | 2.05 | 6.59 | 13.28 | 48.46 | 0.25 | 10.66 | 1.97 | 0.16 | 12.44 | 95.85 | 1.89 | II–THOL–1 |
| 14 | 2.25 | 7.62 | 13.76 | 48.58 | 0.19 | 12.09 | 1.36 | 0.17 | 11.08 | 97.08 | 1.45 | II–THOL–1 |
| 15 | 2.38 | 7.11 | 13.53 | 48.81 | 0.18 | 11.34 | 1.16 | 0.23 | 11.45 | 96.18 | 1.61 | II–THOL–1 |
| 16 | 3.49 | 4.96 | 14.98 | 50.15 | 0.25 | 10.70 | 2.02 | 0.16 | 10.43 | 97.13 | 2.10 | Uncorr. |
| 17 | 3.02 | 4.70 | 15.11 | 47.25 | 2.96 | 9.57 | 3.17 | 0.25 | 9.56 | 95.60 | 2.03 | Uncorr. |
| 18 | 2.12 | 0.11 | 11.90 | 74.81 | 2.81 | 0.28 | 0.15 | 0.12 | 2.70 | 95.01 | | II–RHY–1 |
| 19 | 1.77 | 0.01 | 11.70 | 72.47 | 2.45 | 0.32 | 0.21 | 0.08 | 2.42 | 91.42 | | II–RHY–1 |
| 20 | 1.96 | 0.00 | 11.71 | 73.75 | 2.62 | 0.33 | 0.06 | 0.06 | 2.52 | 93.01 | | II–RHY–1 |
| 21 | 2.26 | 0.05 | 11.96 | 72.98 | 3.37 | 0.34 | 0.27 | 0.24 | 2.57 | 94.03 | | II–RHY–1 |
| 22 | 2.31 | 0.03 | 11.42 | 71.16 | 3.37 | 0.32 | 0.00 | 0.00 | 2.43 | 91.02 | | II–RHY–1 |
| 23 | 2.42 | 0.13 | 11.75 | 72.60 | 3.47 | 0.37 | 0.11 | 0.18 | 2.44 | 93.46 | | II–RHY–1 |
| 345 cm | | | | | | | | | | | | |
| 24 | 2.41 | 6.88 | 13.44 | 48.81 | 0.15 | 10.96 | 1.92 | 0.24 | 12.32 | 97.12 | 1.79 | II–THOL–1 |
| 25 | 2.28 | 9.06 | 13.59 | 47.94 | 0.24 | 11.62 | 1.77 | 0.13 | 11.00 | 97.63 | 1.21 | Uncorr. |
| 26 | 2.74 | 6.31 | 13.45 | 48.06 | 0.34 | 10.75 | 2.48 | 0.19 | 12.92 | 97.23 | 2.05 | II–THOL–2 |
| 27 | 2.01 | 7.11 | 13.22 | 49.46 | 0.17 | 11.39 | 1.55 | 0.23 | 11.95 | 97.09 | 1.68 | II–THOL–1 |
| 28 | 2.22 | 7.52 | 13.78 | 49.31 | 0.25 | 11.09 | 1.82 | 0.38 | 12.15 | 98.52 | 1.62 | II–THOL–1 |
| 29 | 2.69 | 7.30 | 15.30 | 49.06 | 0.64 | 12.03 | 1.24 | 0.24 | 8.59 | 97.10 | 1.18 | Uncorr. |
| 30 | 2.59 | 5.35 | 13.45 | 49.09 | 0.29 | 10.01 | 2.47 | 0.26 | 12.96 | 96.46 | 2.42 | II–THOL–2 |
| 31 | 2.52 | 6.33 | 13.78 | 49.06 | 0.39 | 10.54 | 2.30 | 0.45 | 13.11 | 98.48 | 2.07 | II–THOL–2 |
| 32 | 2.10 | 0.00 | 11.80 | 73.62 | 3.64 | 0.33 | 0.19 | 0.16 | 2.50 | 94.34 | | II–RHY–1 |
| 33 | 1.47 | 0.00 | 11.49 | 72.90 | 3.19 | 0.39 | 0.00 | 0.00 | 2.35 | 91.79 | | II–RHY–1 |
| 34 | 1.99 | 0.04 | 12.09 | 73.93 | 3.14 | 0.37 | 0.11 | 0.05 | 2.56 | 94.28 | | II–RHY–1 |
| 35 | 1.84 | 0.03 | 11.55 | 72.71 | 3.30 | 0.37 | 0.18 | 0.00 | 2.41 | 92.38 | | II–RHY–1 |
| 36 | 2.29 | 0.14 | 11.62 | 74.28 | 3.71 | 0.36 | 0.16 | 0.02 | 2.60 | 95.17 | | II–RHY–1 |
| 37 | 2.14 | 0.00 | 11.40 | 74.77 | 3.58 | 0.41 | 0.00 | 0.00 | 2.47 | 94.77 | | II–RHY–1 |
| 38 | 1.42 | 0.05 | 11.42 | 70.62 | 2.77 | 0.38 | 0.13 | 0.03 | 2.39 | 89.20 | | II–RHY–1 |
| V27-114 | | | | | | | | | | | | |
| 450 cm | | | | | | | | | | | | |
| 1 | 2.54 | 5.47 | 12.41 | 49.38 | 0.48 | 9.79 | 2.98 | 0.31 | 14.70 | 98.06 | 2.69 | II–THOL–2 |
| 2 | 2.72 | 8.29 | 15.59 | 47.40 | 0.23 | 10.22 | 2.57 | 0.18 | 12.36 | 99.56 | 1.49 | II–THOL–3 |
| 3 | 0.54 | 6.21 | 13.83 | 49.67 | 0.45 | 10.74 | 2.73 | 0.18 | 13.37 | 97.72 | 2.15 | II–THOL–2 |
| 4 | 2.10 | 8.57 | 16.09 | 48.25 | 0.22 | 11.89 | 1.70 | 0.12 | 9.86 | 98.80 | 1.15 | II–THOL–3 |
| 5 | 2.68 | 5.49 | 12.95 | 50.29 | 0.45 | 9.37 | 2.83 | 0.20 | 13.68 | 97.94 | 2.49 | II–THOL–2 |
| 6 | 1.11 | 0.02 | 11.85 | 73.54 | 2.40 | 0.40 | 0.12 | 0.08 | 2.46 | 91.98 | | II–RHY–1 |
| 7 | 0.99 | 0.00 | 12.15 | 75.14 | 2.26 | 0.39 | 0.24 | 0.07 | 2.55 | 93.79 | | II–RHY–1 |
| 8 | 1.42 | 0.16 | 11.60 | 73.82 | 2.85 | 0.41 | 0.06 | 0.16 | 2.42 | 92.90 | | II–RHY–1 |
| 550 cm | | | | | | | | | | | | |
| 9 | 2.34 | 6.98 | 13.68 | 49.57 | 0.29 | 10.56 | 1.85 | 0.23 | 12.91 | 98.42 | 1.85 | II–THOL–1 |
| 10 | 2.17 | 6.98 | 13.85 | 50.29 | 0.22 | 10.53 | 1.85 | 0.29 | 12.69 | 98.87 | 1.82 | II–THOL–1 |
| 11 | 2.12 | 6.83 | 13.69 | 48.76 | 0.16 | 9.87 | 1.84 | 0.15 | 12.80 | 96.23 | 1.87 | II–THOL–1 |
| 12 | 2.06 | 7.02 | 13.59 | 49.37 | 0.16 | 9.78 | 1.62 | 0.40 | 13.12 | 97.11 | 1.87 | II–THOL–1 |
| 13 | 3.12 | 5.59 | 12.68 | 45.88 | 0.71 | 9.16 | 4.57 | 0.22 | 14.86 | 96.78 | 2.66 | II–TAB–1 |
| 14 | 1.97 | 7.47 | 13.67 | 49.03 | 0.12 | 13.37 | 1.25 | 0.28 | 11.19 | 96.35 | 1.50 | II–THOL–1 |

*Appendix I.* **(continued)**

| | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $K_2O$ | CaO | $TiO_2$ | MnO | FeO* | Tot | FeO*/MgO | Population |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 1.89 | 8.70 | 11.61 | 49.15 | 0.13 | 12.03 | 1.50 | 0.32 | 11.84 | 97.17 | 1.36 | II–THOL–1 |
| 16 | 2.44 | 6.72 | 13.32 | 49.42 | 0.23 | 9.74 | 1.80 | 0.32 | 12.79 | 96.77 | 1.90 | II–THOL–1 |
| 17 | 2.64 | 6.58 | 13.74 | 49.49 | 0.26 | 10.19 | 1.97 | 0.23 | 12.81 | 97.96 | 1.95 | II–THOL–1 |
| 18 | 2.25 | 6.88 | 13.84 | 48.41 | 0.22 | 10.50 | 1.56 | 0.22 | 11.72 | 95.59 | 1.70 | II–THOL–1 |
| 19 | 2.72 | 6.00 | 13.26 | 48.62 | 0.35 | 9.65 | 2.47 | 0.21 | 13.36 | 96.66 | 2.23 | II–THOL–2 |
| 20 | 2.34 | 6.93 | 13.59 | 47.16 | 0.16 | 10.22 | 1.87 | 0.17 | 12.56 | 94.98 | 1.81 | II–THOL–1 |
| 650 cm | | | | | | | | | | | | |
| 21 | 2.02 | 7.86 | 14.53 | 48.39 | 0.19 | 11.62 | 1.24 | 0.41 | 10.99 | 97.24 | 1.40 | II–THOL–1 |
| 22 | 2.49 | 7.35 | 13.92 | 48.36 | 0.24 | 11.72 | 2.01 | 0.20 | 11.72 | 98.01 | 1.59 | II–THOL–1 |
| 23 | 2.61 | 5.48 | 12.88 | 46.72 | 0.72 | 9.94 | 4.35 | 0.26 | 14.45 | 97.41 | 2.64 | II–TAB–1 |
| 34 | 2.14 | 7.12 | 14.03 | 49.64 | 0.26 | 11.32 | 2.26 | 0.24 | 12.17 | 99.18 | 1.71 | II–THOL–1 |
| V23-82 | | | | | | | | | | | | |
| 380 cm | | | | | | | | | | | | |
| 1 | 2.19 | 8.71 | 14.77 | 50.41 | 0.17 | 12.45 | 1.01 | 0.16 | 9.94 | 99.81 | 1.14 | II–THOL–1 |
| 2 | 2.11 | 7.01 | 14.23 | 49.00 | 0.25 | 10.81 | 1.38 | 0.17 | 12.44 | 97.48 | 1.75 | II–THOL–1 |
| 3 | 2.57 | 6.99 | 13.95 | 49.49 | 0.20 | 10.01 | 2.07 | 0.06 | 12.89 | 98.23 | 1.84 | II–THOL–1 |
| 4 | 1.96 | 8.01 | 14.41 | 49.10 | 0.14 | 10.87 | 1.19 | 0.24 | 11.28 | 97.19 | 1.41 | II–THOL–1 |
| 5 | 2.27 | 6.99 | 14.15 | 50.37 | 0.16 | 10.83 | 1.31 | 0.16 | 11.99 | 98.23 | 1.72 | II–THOL–1 |
| 6 | 2.17 | 8.35 | 12.18 | 49.01 | 0.38 | 11.51 | 3.51 | 0.45 | 10.79 | 98.35 | 1.29 | Uncorr. |
| 7 | 2.31 | 6.92 | 13.74 | 49.73 | 0.22 | 11.44 | 1.82 | 0.26 | 12.77 | 99.20 | 1.85 | II–THOL–1 |
| 8 | 3.15 | 5.58 | 13.08 | 46.54 | 0.53 | 9.31 | 3.69 | 0.34 | 14.40 | 96.61 | 2.58 | Uncorr. |
| 9 | 2.49 | 6.08 | 13.24 | 50.06 | 0.22 | 10.44 | 1.36 | 0.19 | 12.82 | 96.90 | 2.11 | II–THOL–1 |
| 10 | 2.23 | 4.89 | 13.57 | 48.91 | 1.12 | 8.22 | 3.68 | 0.16 | 14.33 | 97.12 | 2.93 | II–TAB–1 |
| 11 | 1.98 | 0.00 | 11.56 | 72.36 | 3.49 | 0.29 | 0.23 | 0.12 | 2.52 | 92.55 | | II–RHY–1 |
| 12 | 1.88 | 0.00 | 11.87 | 73.13 | 3.53 | 0.33 | 0.39 | 0.07 | 2.61 | 93.79 | | II–RHY–1 |
| 13 | 2.09 | 0.08 | 11.89 | 71.85 | 3.58 | 0.33 | 0.00 | 0.04 | 2.64 | 92.49 | | II–RHY–1 |
| 14 | 2.10 | 0.02 | 11.38 | 71.78 | 3.33 | 0.42 | 0.44 | 0.17 | 2.59 | 92.22 | | II–RHY–1 |
| 15 | 2.11 | 0.00 | 12.09 | 73.34 | 3.13 | 0.38 | 0.24 | 0.06 | 2.56 | 93.91 | | II–RHY–1 |
| 16 | 2.22 | 0.00 | 11.17 | 71.12 | 3.32 | 0.38 | 0.20 | 0.00 | 2.36 | 90.76 | | II–RHY–1 |
| 17 | 1.57 | 0.00 | 11.39 | 71.96 | 3.18 | 0.31 | 0.09 | 0.00 | 2.43 | 90.93 | | II–RHY–1 |
| 18 | 1.86 | 0.00 | 12.00 | 72.38 | 3.27 | 0.29 | 0.03 | 0.04 | 2.56 | 92.45 | | II–RHY–1 |
| 396 cm | | | | | | | | | | | | |
| 19 | 3.13 | 5.37 | 13.04 | 47.69 | 0.66 | 10.03 | 4.11 | 0.25 | 14.62 | 98.90 | 2.72 | II–TAB–1 |
| 20 | 2.58 | 7.31 | 14.27 | 50.96 | 0.21 | 12.01 | 1.41 | 0.13 | 12.10 | 100.97 | 1.66 | II–THOL–1 |
| 21 | 2.18 | 6.95 | 13.65 | 51.36 | 0.30 | 11.31 | 1.73 | 0.19 | 12.78 | 100.45 | 1.84 | II–THOL–1 |
| 22 | 3.90 | 5.42 | 12.72 | 46.41 | 0.69 | 9.69 | 4.81 | 0.21 | 14.43 | 98.27 | 2.66 | II–TAB–1 |
| 23 | 2.85 | 6.80 | 13.60 | 49.66 | 0.38 | 11.25 | 2.35 | 0.19 | 12.53 | 99.61 | 1.84 | II–THOL–2 |
| 24 | 2.98 | 5.09 | 13.27 | 47.18 | 0.74 | 10.02 | 4.33 | 0.24 | 14.97 | 98.85 | 2.94 | II–TAB–1 |
| 25 | 2.11 | 7.62 | 15.33 | 47.45 | 0.42 | 12.25 | 2.19 | 0.20 | 11.70 | 99.25 | 1.54 | II–THOL–3 |
| 26 | 2.47 | 7.85 | 15.57 | 49.15 | 0.36 | 12.20 | 1.83 | 0.01 | 10.82 | 100.26 | 1.38 | II–THOL–3 |
| 27 | 2.29 | 6.44 | 13.58 | 50.60 | 0.33 | 10.46 | 1.96 | 0.07 | 13.81 | 99.53 | 2.14 | II–THOL–1 |
| 28 | 2.13 | 7.22 | 14.13 | 51.20 | 0.17 | 11.66 | 1.44 | 0.24 | 12.09 | 100.27 | 1.67 | II–THOL–1 |
| 29 | 2.64 | 4.77 | 11.73 | 48.71 | 0.97 | 9.82 | 4.87 | 0.36 | 16.54 | 100.41 | 3.47 | Uncorr. |
| 30 | 2.28 | 7.50 | 13.64 | 52.13 | 0.17 | 11.76 | 1.61 | 0.23 | 11.85 | 101.16 | 1.58 | II–THOL–1 |
| 31 | 2.28 | 7.03 | 13.66 | 50.58 | 0.27 | 11.65 | 1.67 | 0.14 | 12.00 | 99.28 | 1.71 | II–THOL–1 |
| 32 | 2.66 | 6.70 | 14.20 | 50.55 | 0.18 | 11.33 | 1.77 | 0.22 | 13.06 | 100.66 | 1.95 | II–THOL–1 |
| 33 | 2.06 | 0.02 | 11.86 | 74.44 | 3.27 | 0.45 | 0.18 | 0.10 | 2.64 | 95.01 | | II–RHY–1 |
| 34 | 1.70 | 0.05 | 12.54 | 74.59 | 3.01 | 0.40 | 0.37 | 0.17 | 2.52 | 95.35 | | II–RHY–1 |
| 35 | 1.57 | 0.00 | 11.52 | 72.82 | 3.03 | 0.33 | 0.00 | 0.15 | 2.58 | 92.00 | | II–RHY–1 |
| 36 | 2.24 | 0.00 | 11.99 | 73.66 | 3.75 | 0.36 | 0.22 | 0.07 | 2.38 | 94.66 | | II–RHY–1 |
| 37 | 1.99 | 0.00 | 11.36 | 73.52 | 3.18 | 0.29 | 0.30 | 0.05 | 2.67 | 93.36 | | II–RHY–1 |
| 38 | 1.75 | 0.01 | 11.79 | 74.03 | 2.88 | 0.27 | 0.36 | 0.07 | 2.54 | 93.69 | | II–RHY–1 |
| 39 | 2.31 | 0.00 | 11.67 | 72.98 | 3.28 | 0.50 | 0.28 | 0.21 | 2.46 | 93.68 | | II–RHY–1 |
| 40 | 2.34 | 6.80 | 13.94 | 48.69 | 0.30 | 9.89 | 1.59 | 0.18 | 12.94 | 96.67 | 1.90 | II–THOL–1 |
| 41 | 2.31 | 7.30 | 13.67 | 49.24 | 0.06 | 11.18 | 1.29 | 0.32 | 11.84 | 97.20 | 1.62 | II–THOL–1 |
| 42 | 2.14 | 5.54 | 13.75 | 49.37 | 0.41 | 10.51 | 2.93 | 0.31 | 14.29 | 99.24 | 2.58 | II–THOL–2 |
| 43 | 2.30 | 8.07 | 15.10 | 46.99 | 0.41 | 11.95 | 2.46 | 0.09 | 11.51 | 98.88 | 1.43 | II–THOL–3 |
| 44 | 2.32 | 7.95 | 14.82 | 44.68 | 0.41 | 11.36 | 2.63 | 0.35 | 11.07 | 95.57 | 1.39 | II–THOL–3 |
| 45 | 2.95 | 6.59 | 13.84 | 48.59 | 0.29 | 10.21 | 2.59 | 0.24 | 12.75 | 98.04 | 1.93 | II–THOL–2 |
| 46 | 2.62 | 7.65 | 14.17 | 49.31 | 0.23 | 9.87 | 1.78 | 0.23 | 12.55 | 98.42 | 1.67 | Uncorr. |

*Appendix I.* (continued)

| | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $K_2O$ | CaO | $TiO_2$ | MnO | FeO* | Tot | FeO*/MgO | Population |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 47 | 2.53 | 6.08 | 12.39 | 47.06 | 0.33 | 9.98 | 3.09 | 0.16 | 13.32 | 94.95 | 2.19 | II–THOL–2 |
| 48 | 2.18 | 7.88 | 14.98 | 46.37 | 0.32 | 11.40 | 2.44 | 0.27 | 11.39 | 97.21 | 1.45 | II–THOL–1 |
| 49 | 3.05 | 6.77 | 13.89 | 47.64 | 0.28 | 10.46 | 1.98 | 0.18 | 13.25 | 97.51 | 1.96 | II–THOL–1 |
| 50 | 2.36 | 7.66 | 15.12 | 45.99 | 0.43 | 10.53 | 2.50 | 0.21 | 12.36 | 97.17 | 1.61 | II–THOL–3 |
| 51 | 2.43 | 7.58 | 14.93 | 45.77 | 0.40 | 10.94 | 2.70 | 0.25 | 12.16 | 97.15 | 1.60 | II–THOL–3 |
| 52 | 2.31 | 0.08 | 12.56 | 74.37 | 3.58 | 0.31 | 0.12 | 0.12 | 2.70 | 96.16 | | II–RHY–1 |
| 53 | 1.87 | 0.03 | 11.78 | 72.52 | 3.22 | 0.37 | 0.18 | 0.12 | 2.59 | 92.67 | | II–RHY–1 |
| 54 | 1.68 | 0.00 | 11.81 | 71.84 | 3.50 | 0.31 | 0.21 | 0.18 | 2.53 | 92.05 | | II–RHY–1 |
| 55 | 2.20 | 0.10 | 11.74 | 71.58 | 3.36 | 0.43 | 0.06 | 0.09 | 2.80 | 92.37 | | II–RHY–1 |
| 56 | 2.14 | 0.00 | 11.78 | 73.03 | 3.19 | 0.39 | 0.32 | 0.03 | 2.51 | 93.39 | | II–RHY–1 |
| V23-81 | | | | | | | | | | | | |
| 631 cm | | | | | | | | | | | | |
| 1 | 2.07 | 7.67 | 13.57 | 47.48 | 0.22 | 12.09 | 1.47 | 0.18 | 10.95 | 95.70 | 1.43 | II–THOL–1 |
| 2 | 1.20 | 5.48 | 12.55 | 46.44 | 0.60 | 9.48 | 4.76 | 0.38 | 14.58 | 95.47 | 2.66 | II–TAB–1 |
| 3 | 1.07 | 0.01 | 11.69 | 74.62 | 2.30 | 0.37 | 0.12 | 0.16 | 2.46 | 92.80 | | II–RHY–1 |
| 670 cm | | | | | | | | | | | | |
| 4 | 2.66 | 5.46 | 12.14 | 46.74 | 0.44 | 8.90 | 2.97 | 0.37 | 13.82 | 93.50 | 2.53 | II–THOL–2 |
| 5 | 1.85 | 6.89 | 13.84 | 47.63 | 0.22 | 9.94 | 1.47 | 0.23 | 11.89 | 93.96 | 1.73 | II–THOL–1 |
| 6 | 2.12 | 6.85 | 13.63 | 48.81 | 0.11 | 9.43 | 1.49 | 0.15 | 12.19 | 94.79 | 1.78 | II–THOL–1 |
| 7 | 2.12 | 7.19 | 13.49 | 49.83 | 0.20 | 10.16 | 1.79 | 0.15 | 12.10 | 97.04 | 1.68 | II–THOL–1 |
| 8 | 2.39 | 6.72 | 13.26 | 48.46 | 0.20 | 10.75 | 1.73 | 0.07 | 12.21 | 95.74 | 1.82 | II–THOL–1 |
| 9 | 2.04 | 7.20 | 13.57 | 48.98 | 0.11 | 10.01 | 1.29 | 0.09 | 11.76 | 95.04 | 1.63 | II–THOL–1 |
| 10 | 2.33 | 6.89 | 14.23 | 49.40 | 0.16 | 10.03 | 1.84 | 0.14 | 12.03 | 97.04 | 1.75 | II–THOL–1 |
| 11 | 2.34 | 5.98 | 13.43 | 50.69 | 0.21 | 10.15 | 1.91 | 0.25 | 12.54 | 97.50 | 2.10 | II–THOL–1 |
| 12 | 2.12 | 7.39 | 13.83 | 49.81 | 0.17 | 11.35 | 1.42 | 0.22 | 11.97 | 98.28 | 1.63 | Uncorr. |
| 13 | 2.14 | 5.48 | 12.79 | 46.52 | 0.67 | 9.49 | 4.52 | 0.31 | 14.67 | 96.59 | 2.68 | II–TAB–1 |
| 14 | 2.14 | 6.86 | 13.71 | 48.77 | 0.25 | 11.02 | 1.67 | 0.24 | 12.29 | 96.95 | 1.79 | II–THOL–1 |
| 15 | 2.30 | 6.97 | 13.39 | 48.93 | 0.18 | 10.45 | 1.68 | 0.25 | 12.05 | 96.20 | 1.73 | II–THOL–1 |
| 16 | 2.24 | 7.02 | 13.55 | 49.71 | 0.18 | 11.21 | 1.62 | 0.12 | 12.36 | 98.01 | 1.76 | II–THOL–1 |
| 17 | 2.26 | 7.57 | 13.85 | 49.54 | 0.20 | 11.03 | 1.69 | 0.22 | 11.93 | 98.29 | 1.58 | II–THOL–1 |
| 18 | 1.34 | 0.01 | 11.81 | 74.04 | 2.50 | 0.42 | 0.25 | 0.17 | 2.56 | 93.13 | | II–RHY–1 |
| 19 | 1.16 | 0.03 | 11.75 | 74.49 | 2.49 | 0.37 | 0.19 | 0.05 | 2.54 | 93.07 | | II–RHY–1 |
| 20 | 1.11 | 0.11 | 11.92 | 74.60 | 2.63 | 0.37 | 0.16 | 0.13 | 2.69 | 93.72 | | II–RHY–1 |
| 21 | 1.23 | 0.02 | 11.95 | 73.41 | 2.65 | 0.44 | 0.03 | 0.11 | 2.59 | 92.43 | | II–RHY–1 |
| 22 | 1.19 | 0.00 | 11.80 | 74.69 | 2.61 | 0.40 | 0.11 | 0.06 | 2.53 | 93.39 | | II–RHY–1 |
| 674 cm | | | | | | | | | | | | |
| 23 | 2.74 | 5.71 | 12.37 | 46.74 | 0.20 | 9.50 | 2.60 | 0.30 | 12.30 | 92.46 | 2.15 | II–THOL–2 |
| 24 | 1.80 | 6.06 | 13.15 | 47.84 | 0.35 | 9.30 | 2.57 | 0.20 | 13.56 | 94.83 | 2.24 | II–THOL–2 |
| 25 | 2.24 | 7.14 | 13.61 | 48.82 | 0.26 | 10.90 | 1.62 | 0.21 | 11.29 | 96.06 | 1.58 | II–THOL–1 |
| 26 | 2.03 | 7.19 | 13.85 | 48.57 | 0.27 | 11.02 | 1.77 | 0.21 | 11.56 | 96.47 | 1.61 | II–THOL–1 |
| 27 | 1.85 | 8.40 | 14.46 | 49.53 | 0.15 | 11.52 | 1.15 | 0.08 | 9.61 | 96.75 | 1.14 | II–THOL–1 |
| 28 | 2.36 | 7.03 | 13.88 | 48.73 | 0.19 | 10.85 | 1.82 | 0.19 | 11.72 | 96.77 | 1.67 | II–THOL–1 |
| 29 | 2.14 | 6.93 | 13.46 | 49.26 | 0.24 | 10.88 | 1.69 | 0.27 | 12.00 | 96.87 | 1.73 | II–THOL–1 |
| 30 | 2.44 | 7.02 | 13.64 | 49.76 | 0.30 | 11.07 | 1.75 | 0.24 | 12.14 | 98.36 | 1.73 | II–THOL–1 |
| 31 | 2.25 | 5.83 | 12.73 | 45.36 | 0.81 | 9.05 | 4.20 | 0.25 | 15.98 | 96.46 | 2.74 | II–TAB–1 |
| V23-42 | | | | | | | | | | | | |
| 246 cm | | | | | | | | | | | | |
| 1 | 2.30 | 6.60 | 13.48 | 48.73 | 0.15 | 11.34 | 1.42 | 0.26 | 11.59 | 95.86 | 1.76 | II–THOL–1 |
| 2 | 2.43 | 6.94 | 13.71 | 45.29 | 0.40 | 12.06 | 2.91 | 0.18 | 11.28 | 95.19 | 1.63 | Uncorr. |
| 3 | 2.17 | 7.09 | 13.61 | 48.06 | 0.30 | 11.04 | 1.62 | 0.21 | 11.94 | 96.01 | 1.68 | II–THOL–1 |
| 4 | 1.78 | 6.23 | 10.15 | 48.54 | 1.03 | 11.54 | 4.26 | 0.37 | 11.93 | 95.82 | 1.91 | Uncorr. |
| 5 | 2.91 | 6.74 | 12.87 | 45.61 | 0.36 | 11.62 | 4.32 | 0.05 | 11.99 | 96.47 | 1.78 | Uncorr. |
| 6 | 1.89 | 0.14 | 11.33 | 71.58 | 3.21 | 0.38 | 0.00 | 0.08 | 2.31 | 90.92 | | II–RHY–1 |
| 7 | 1.92 | 0.07 | 11.42 | 72.85 | 3.65 | 0.33 | 0.07 | 0.00 | 2.58 | 92.89 | | II–RHY–1 |
| 8 | 1.97 | 0.06 | 11.53 | 71.71 | 3.21 | 0.20 | 0.08 | 0.14 | 2.49 | 91.39 | | II–RHY–1 |
| 9 | 2.11 | 0.05 | 12.20 | 73.73 | 3.81 | 0.36 | 0.27 | 0.06 | 2.46 | 95.05 | | II–RHY–1 |
| 10 | 2.16 | 0.04 | 11.67 | 72.74 | 3.61 | 0.37 | 0.02 | 0.15 | 2.58 | 93.34 | | II–RHY–1 |
| 11 | 1.96 | 0.00 | 11.63 | 71.66 | 3.41 | 0.32 | 0.41 | 0.10 | 2.52 | 92.01 | | II–RHY–1 |
| 12 | 2.10 | 0.00 | 11.16 | 71.84 | 3.25 | 0.46 | 0.11 | 0.13 | 2.58 | 91.62 | | II–RHY–1 |

*Appendix I.* **(continued)**

| | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $K_2O$ | CaO | $TiO_2$ | MnO | FeO* | Tot | FeO*/MgO | Population |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 247 cm | | | | | | | | | | | | |
| 13 | 1.76 | 8.12 | 13.14 | 49.82 | 0.14 | 12.14 | 1.31 | 0.11 | 11.03 | 97.55 | 1.36 | II–THOL–1 |
| 14 | 2.00 | 7.75 | 13.36 | 48.26 | 0.20 | 12.03 | 1.32 | 0.15 | 10.70 | 95.77 | 1.38 | II–THOL–1 |
| 15 | 3.47 | 5.71 | 13.53 | 49.02 | 0.29 | 10.08 | 3.24 | 0.19 | 13.60 | 99.13 | 2.38 | II–THOL–2 |
| 16 | 1.46 | 7.34 | 13.95 | 49.30 | 0.15 | 11.31 | 1.60 | 0.14 | 11.39 | 97.14 | 1.55 | II–THOL–1 |
| 17 | 2.58 | 7.03 | 13.40 | 49.29 | 0.28 | 11.36 | 1.37 | 0.36 | 11.66 | 97.32 | 1.66 | II–THOL–1 |
| 18 | 2.47 | 0.00 | 11.36 | 72.48 | 3.74 | 0.30 | 0.00 | 0.08 | 2.67 | 93.06 | | II–RHY–1 |
| 19 | 2.10 | 0.00 | 11.57 | 73.06 | 3.80 | 0.42 | 0.21 | 0.14 | 2.35 | 93.63 | | II–RHY–1 |
| 20 | 1.62 | 0.02 | 11.35 | 72.97 | 3.10 | 0.33 | 0.10 | 0.11 | 2.56 | 92.16 | | II–RHY–1 |
| 21 | 1.69 | 0.00 | 11.64 | 74.09 | 3.09 | 0.41 | 0.34 | 0.13 | 2.39 | 93.78 | | II–RHY–1 |
| 22 | 2.07 | 0.09 | 11.72 | 72.79 | 3.70 | 0.46 | 0.03 | 0.11 | 2.56 | 93.52 | | II–RHY–1 |
| 23 | 1.61 | 0.00 | 11.57 | 72.25 | 3.22 | 0.39 | 0.08 | 0.00 | 2.67 | 91.78 | | II–RHY–1 |
| 24 | 1.91 | 0.00 | 11.83 | 73.17 | 3.09 | 0.36 | 0.22 | 0.06 | 2.21 | 92.83 | | II–RHY–1 |
| 25 | 2.09 | 0.00 | 11.79 | 73.14 | 3.20 | 0.28 | 0.26 | 0.17 | 2.46 | 93.38 | | II–RHY–1 |
| 26 | 2.30 | 0.08 | 11.46 | 72.31 | 3.46 | 0.36 | 0.28 | 0.17 | 2.42 | 92.83 | | II–RHY–1 |
| 249 cm | | | | | | | | | | | | |
| 27 | 2.89 | 6.18 | 13.13 | 47.81 | 0.39 | 9.91 | 2.37 | 0.27 | 12.14 | 95.10 | 1.96 | II–THOL–2 |
| 28 | 2.19 | 7.34 | 13.69 | 47.75 | 0.16 | 11.41 | 1.68 | 0.27 | 10.65 | 95.14 | 1.46 | II–THOL–3 |
| 29 | 1.94 | 7.23 | 13.46 | 48.59 | 0.20 | 11.68 | 1.47 | 0.00 | 10.79 | 95.37 | 1.49 | II–THOL–1 |
| 30 | 2.32 | 0.11 | 11.92 | 72.47 | 3.61 | 0.33 | 0.00 | 0.13 | 2.44 | 93.33 | | II–RHY–1 |
| 31 | 2.11 | 0.06 | 11.18 | 70.97 | 3.29 | 0.33 | 0.36 | 0.09 | 2.09 | 90.50 | | II–RHY–1 |
| 32 | 1.95 | 0.06 | 11.90 | 71.65 | 3.44 | 0.32 | 0.24 | 0.09 | 2.41 | 92.04 | | II–RHY–1 |
| 33 | 1.90 | 0.05 | 10.95 | 70.21 | 3.41 | 0.28 | 0.17 | 0.02 | 2.09 | 89.09 | | II–RHY–1 |
| 34 | 1.79 | 0.00 | 11.61 | 70.43 | 3.16 | 0.40 | 0.24 | 0.13 | 2.61 | 90.37 | | II–RHY–1 |
| 35 | 1.92 | 0.00 | 11 62 | 71.32 | 3.28 | 0.47 | 0.27 | 0.17 | 2.29 | 91.34 | | II–RHY–1 |
| 36 | 1.87 | 0.14 | 11.59 | 71.44 | 3.04 | 0.33 | 0.32 | 0.03 | 1.99 | 90.76 | | II–RHY–1 |
| 37 | 2.09 | 0.10 | 11.82 | 72.11 | 3.44 | 0.27 | 0.15 | 0.02 | 2.36 | 92.36 | | II–RHY–1 |
| 38 | 1.73 | 0.00 | 11.39 | 70.47 | 3.01 | 0.25 | 0.32 | 0.14 | 2.47 | 89.78 | | II–RHY–1 |
| 269 cm | | | | | | | | | | | | |
| 39 | 2.04 | 7.45 | 13.91 | 48.76 | 0.08 | 11.77 | 1.06 | 0.39 | 10.91 | 96.30 | 1.46 | II–THOL–1 |
| 40 | 2.02 | 7.82 | 13.43 | 48.55 | 0.13 | 12.16 | 1.27 | 0.26 | 10.26 | 95.91 | 1.31 | II–THOL–1 |
| 41 | 1.98 | 7.42 | 13.16 | 49.61 | 0.07 | 12.07 | 1.17 | 0.05 | 11.01 | 96.52 | 1.48 | II–THOL–1 |
| 42 | 2.06 | 7.13 | 13.81 | 49.98 | 0.21 | 12.15 | 1.35 | 0.22 | 11.14 | 98.05 | 1.56 | II–THOL–1 |
| 43 | 1.95 | 7.70 | 14.05 | 50.11 | 0.12 | 11.59 | 1.38 | 0.21 | 11.03 | 98.13 | 1.43 | II–THOL–1 |
| 44 | 2.19 | 0.00 | 11.91 | 72.20 | 3.28 | 0.36 | 0.20 | 0.00 | 2.33 | 92.46 | | II–RHY–1 |
| 45 | 2.11 | 0.07 | 11.60 | 71.08 | 3.44 | 0.38 | 0.18 | 0.01 | 2.46 | 91.33 | | II–RHY–1 |
| 46 | 1.68 | 0.06 | 11.64 | 71.85 | 3.45 | 0.42 | 0.13 | 0.10 | 2.36 | 91.67 | | II–RHY–1 |
| 47 | 1.63 | 0.17 | 11.66 | 72.24 | 3.40 | 0.34 | 0.47 | 0.00 | 2.42 | 92.33 | | II–RHY–1 |
| 48 | 1.87 | 0.01 | 11.63 | 70.88 | 3.10 | 0.37 | 0.11 | 0.00 | 2.25 | 90.22 | | II–RHY–1 |
| 49 | 1.96 | 0.00 | 11.58 | 71.90 | 3.43 | 0.50 | 0.00 | 0.04 | 2.41 | 91.82 | | II–RHY–1 |

K708-7 C. Ash Zone III.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.09 | 0.08 | 12.10 | 74.01 | 1.79 | 1.22 | 0.28 | 0.03 | 3.33 | 93.91 |
| 2 | 0.98 | 0.09 | 12.19 | 74.93 | 2.50 | 1.28 | 0.13 | 0.15 | 3.16 | 95.40 |
| 3 | 0.96 | 0.05 | 12.37 | 73.59 | 1.72 | 1.28 | 0.23 | 0.14 | 3.22 | 93.56 |
| 4 | 1.09 | 0.14 | 11.77 | 72.27 | 1.67 | 1.11 | 0.24 | 0.05 | 3.26 | 91.60 |
| 5 | 1.21 | 0.08 | 12.08 | 74.22 | 1.77 | 1.20 | 0.24 | 0.08 | 3.30 | 94.18 |
| 6 | 1.17 | 0.03 | 11.78 | 72.69 | 1.92 | 1.19 | 0.40 | 0.15 | 3.21 | 92.52 |
| 7 | 0.98 | 0.06 | 11.64 | 72.46 | 1.82 | 1.20 | 0.22 | 0.15 | 3.20 | 91.75 |
| 8 | 0.85 | 0.04 | 11.91 | 73.42 | 1.72 | 1.19 | 0.24 | 0.18 | 3.20 | 92.76 |
| 9 | 1.24 | 0.04 | 11.97 | 73.61 | 1.88 | 1.24 | 0.21 | 0.11 | 3.23 | 93.52 |
| 10 | 0.94 | 0.21 | 12.31 | 67.77 | 1.62 | 2.62 | 0.36 | 0.13 | 7.01 | 92.95 |
| 11 | 1.04 | 0.00 | 11.82 | 73.86 | 1.68 | 1.24 | 0.31 | 0.10 | 3.21 | 93.26 |
| 12 | 1.05 | 0.11 | 12.02 | 73.76 | 1.96 | 1.20 | 0.33 | 0.08 | 3.40 | 93.91 |
| 13 | 0.68 | 0.11 | 11.77 | 72.21 | 1.46 | 1.15 | 0.26 | 0.04 | 3.25 | 90.94 |
| 14 | 0.81 | 0.04 | 12.12 | 73.26 | 1.61 | 1.26 | 0.34 | 0.05 | 3.04 | 92.53 |
| 15 | 1.69 | 0.10 | 12.15 | 74.11 | 2.17 | 1.25 | 0.23 | 0.06 | 3.35 | 95.10 |
| 16 | 0.99 | 0.07 | 11.86 | 73.58 | 1.80 | 1.22 | 0.20 | 0.90 | 3.30 | 93.10 |
| 17 | 1.38 | 0.00 | 11.99 | 74.76 | 2.25 | 1.27 | 0.28 | 0.13 | 3.40 | 95.45 |
| 18 | 0.81 | 0.01 | 12.05 | 72.23 | 1.59 | 1.25 | 0.30 | 0.18 | 3.31 | 91.75 |
| 19 | 0.98 | 0.08 | 11.79 | 73.59 | 1.72 | 1.09 | 0.27 | 0.03 | 3.32 | 92.85 |
| 20 | 1.15 | 0.05 | 12.09 | 75.27 | 2.16 | 1.13 | 0.33 | 0.14 | 3.24 | 95.55 |

*Appendix II.* The microprobe analyses by Mangerud et al. (1984) of the Vedde Ash (not published by them).

| | $Na_2O$ | MgO | $A1_2O_3$ | $SiO_2$ | $K_2O$ | CaO | $TiO_2$ | MnO | FeO* | Tot | FeO*/MgO |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.64 | 5.06 | 12.73 | 46.21 | 0.83 | 9.78 | 4.35 | 0.17 | 14.65 | 96.42 | 2.90 |
| 2 | 2.63 | 5.02 | 12.67 | 46.95 | 0.70 | 9.29 | 4.58 | 0.34 | 14.96 | 97.14 | 2.98 |
| 3 | 3.16 | 4.93 | 12.54 | 47.26 | 0.87 | 10.91 | 4.52 | 0.24 | 14.74 | 99.17 | 2.99 |
| 4 | 2.91 | 4.91 | 12.63 | 47.55 | 1.00 | 8.84 | 4.35 | 0.28 | 14.10 | 96.57 | 2.87 |
| 5 | 2.91 | 4.80 | 12.84 | 47.10 | 0.86 | 9.18 | 4.27 | 0.29 | 13.98 | 96.23 | 2.91 |
| 6 | 3.17 | 4.75 | 12.63 | 47.84 | 0.78 | 9.17 | 4.23 | 0.13 | 14.13 | 96.83 | 2.98 |
| 7 | 2.82 | 4.72 | 12.41 | 47.66 | 0.80 | 8.96 | 4.48 | 0.21 | 14.50 | 96.56 | 3.07 |
| 8 | 2.01 | 4.66 | 13.19 | 47.83 | 0.98 | 10.53 | 4.80 | 0.28 | 13.62 | 97.90 | 2.92 |
| 9 | 2.95 | 4.88 | 12.69 | 49.28 | 0.87 | 8.69 | 4.75 | 0.23 | 13.85 | 98.19 | 2.84 |
| 10 | 3.16 | 4.55 | 13.04 | 49.02 | 0.92 | 8.52 | 4.20 | 0.35 | 13.78 | 97.54 | 3.03 |
| 11 | 3.05 | 4.47 | 13.14 | 49.42 | 0.99 | 8.35 | 3.97 | 0.17 | 13.47 | 97.03 | 3.01 |
| 12 | 3.28 | 3.34 | 13.00 | 52.55 | 1.19 | 7.91 | 4.09 | 0.29 | 12.68 | 99.33 | 2.92 |
| 13 | 3.20 | 4.25 | 12.81 | 50.89 | 1.32 | 9.12 | 4.04 | 0.39 | 12.90 | 98.92 | 3.04 |
| 14 | 2.54 | 3.89 | 12.77 | 52.07 | 1.32 | 7.66 | 3.21 | 0.17 | 12.91 | 96.54 | 3.32 |
| 15 | 3.11 | 3.85 | 13.07 | 52.69 | 1.44 | 7.52 | 3.38 | 0.32 | 12.23 | 97.61 | 3.17 |
| 16 | 2.52 | 3.85 | 12.70 | 51.16 | 1.20 | 7.61 | 3.53 | 0.18 | 12.61 | 95.36 | 3.28 |
| 17 | 2.39 | 3.81 | 13.07 | 51.57 | 1.42 | 7.71 | 3.77 | 0.18 | 12.20 | 96.12 | 3.21 |
| 18 | 2.79 | 3.68 | 12.78 | 51.44 | 1.31 | 7.58 | 3.31 | 0.18 | 12.28 | 95.35 | 3.33 |
| 19 | 2.40 | 3.57 | 12.70 | 53.28 | 1.43 | 7.02 | 3.01 | 0.25 | 11.99 | 95.65 | 3.36 |
| 20 | 3.11 | 3.76 | 13.14 | 54.34 | 1.50 | 7.24 | 2.84 | 0.29 | 11.34 | 97.56 | 3.01 |
| 21 | 2.15 | 3.04 | 13.31 | 58.34 | 2.08 | 6.25 | 2.71 | 0.28 | 10.19 | 98.35 | 3.35 |
| 22 | 2.98 | 5.32 | 12.11 | 48.96 | 0.74 | 9.53 | 4.48 | 0.35 | 14.43 | 98.90 | 2.71 |
| 23 | 2.92 | 4.88 | 11.98 | 50.61 | 0.96 | 8.71 | 3.91 | 0.22 | 13.94 | 98.13 | 2.86 |
| 23 | 2.62 | 3.91 | 12.92 | 55.82 | 1.36 | 7.17 | 3.31 | 0.22 | 12.29 | 99.62 | 3.15 |
| 24 | 3.11 | 5.32 | 12.40 | 49.05 | 0.76 | 9.11 | 4.79 | 0.13 | 14.66 | 99.33 | 2.75 |
| 25 | 2.99 | 4.26 | 12.07 | 53.37 | 1.30 | 7.95 | 3.61 | 0.00 | 12.79 | 98.34 | 3.00 |
| 26 | 2.68 | 3.93 | 13.15 | 54.78 | 1.40 | 7.34 | 3.10 | 0.35 | 11,86 | 98.59 | 3.01 |
| 27 | 3.01 | 3.80 | 13.42 | 55.32 | 1.47 | 6.75 | 3.48 | 0.22 | 11.57 | 99.04 | 3.05 |
| 28 | 2.61 | 3.67 | 13.38 | 53.98 | 1.43 | 6.64 | 3.25 | 0.27 | 11.49 | 96.72 | 3.13 |
| 29 | 2.90 | 5.15 | 12.92 | 48.84 | 0.75 | 8.99 | 4.15 | 0.23 | 14.27 | 98.20 | 2.77 |
| 30 | 3.04 | 5.50 | 13.53 | 49.87 | 0.66 | 9.12 | 4.16 | 0.31 | 14.45 | 100.64 | 2.63 |
| 31 | 3.24 | 4.91 | 13.16 | 50.24 | 0.99 | 8.63 | 4.11 | 0.24 | 13.66 | 99.18 | 2.78 |
| 32 | 3.13 | 4.64 | 12.91 | 51.28 | 1.12 | 8.21 | 3.53 | 0.00 | 13.38 | 98.20 | 2.88 |
| 33 | 3.07 | 4.27 | 12.97 | 52.62 | 1.20 | 7.97 | 3.49 | 0.08 | 12.70 | 98.37 | 2.97 |
| 34 | 2.93 | 4.48 | 13.07 | 52.71 | 1.25 | 7.94 | 3.79 | 0.32 | 12.66 | 99.15 | 2.83 |
| 35 | 2.35 | 0.19 | 13.03 | 71.54 | 3.12 | 1.19 | 0.12 | 0.00 | 3.81 | 95.35 | |
| 36 | 2.23 | 0.20 | 13.45 | 72.29 | 3.75 | 1.28 | 0.19 | 0.34 | 3.70 | 97.43 | |
| 37 | 2.74 | 0.18 | 13.57 | 73.83 | 3.46 | 1.10 | 0.14 | 0.16 | 3.73 | 98.91 | |
| 38 | 2.09 | 0.24 | 13.10 | 71.41 | 3.28 | 1.36 | 0.00 | 0.18 | 3.78 | 95.44 | |
| 39 | 2.88 | 0.20 | 13.59 | 74.15 | 3.43 | 1.17 | 0.24 | 0.16 | 3.51 | 99.33 | |
| 40 | 2.38 | 0.19 | 13.49 | 71.40 | 3.42 | 1.22 | 0.22 | 0.11 | 3.68 | 96.11 | |
| 41 | 2.79 | 0.14 | 13.14 | 71.12 | 5.02 | 1.48 | 0.52 | 0.14 | 3.94 | 98.29 | |
| 42 | 1.97 | 0.23 | 13.01 | 72.37 | 3.89 | 1.55 | 0.36 | 0.17 | 3.88 | 97.43 | |
| 43 | 2.37 | 0.20 | 13.29 | 71.54 | 3.54 | 1.23 | 0.00 | 0.09 | 3.69 | 95.95 | |
| 44 | 1.87 | 0.27 | 13.04 | 73.24 | 3.30 | 1.34 | 0.31 | 0.26 | 4.05 | 97.68 | |
| 45 | 1.69 | 0.17 | 11.23 | 76.15 | 2.93 | 1.35 | 0.43 | 0.17 | 3.65 | 97.77 | |
| 46 | 1.87 | 0.19 | 13.30 | 71.83 | 2.92 | 1.35 | 0.38 | 0.22 | 4.14 | 96.20 | |
| 47 | 1.81 | 0.21 | 13.36 | 72.46 | 2.94 | 1.32 | 0.00 | 0.00 | 3.87 | 95.97 | |
| 48 | 2.38 | 0.24 | 12.49 | 74.19 | 2.98 | 1.25 | 0.27 | 0.04 | 3.78 | 97.62 | |
| 49 | 2.00 | 0.22 | 12.86 | 74.30 | 3.15 | 1.14 | 0.09 | 0.13 | 3.94 | 97.83 | |
| 50 | 2.44 | 0.31 | 13.03 | 75.41 | 3.43 | 1.43 | 0.49 | 0.27 | 3.94 | 100.75 | |
| 51 | 1.65 | 0.20 | 13.29 | 72.69 | 2.81 | 1.10 | 0.56 | 0.19 | 3.68 | 96.07 | |
| 52 | 1.94 | 0.21 | 13.67 | 72.92 | 2.77 | 1.12 | 0.27 | 0.10 | 3.76 | 96.76 | |
| 53 | 1.58 | 0.17 | 13.20 | 73.12 | 2.57 | 1.13 | 0.32 | 0.28 | 3.55 | 95.92 | |
| 54 | 1.79 | 0.24 | 13.46 | 73.62 | 2.71 | 1.17 | 0.24 | 0.10 | 3.85 | 97.18 | |
| 55 | 1.39 | 0.22 | 13.18 | 73.87 | 2.80 | 1.09 | 0.43 | 0.07 | 3.63 | 96.68 | |
| 56 | 2.00 | 0.27 | 13.31 | 71.94 | 3.19 | 1.22 | 0.21 | 0.16 | 3.76 | 96.06 | |
| 57 | 1.94 | 0.30 | 13.50 | 72.52 | 3.30 | 1.19 | 0.46 | 0.21 | 3.98 | 97.40 | |
| 58 | 2.01 | 0.15 | 13.25 | 72.72 | 3.25 | 1.28 | 0.17 | 0.00 | 3.86 | 96.69 | |
| 59 | 2.03 | 0.25 | 13.11 | 72.88 | 3.17 | 1.23 | 0.57 | 0.14 | 3.58 | 96.96 | |
| 60 | 2.43 | 0.12 | 13.32 | 73.82 | 3.33 | 1.19 | 0.39 | 0.19 | 3.73 | 98.52 | |