

Feldspar analysis and correlation of early Paleogene volcanic ash layers from the Harre borehole, Denmark.

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ABSTRACT

Analysis of residual igneous feldspars in fifteen tuffs and bentonites from the 'ash-series' of the Harre Borehole has confirmed the presence of ash layers +19 and -12. None of the other layers can be correlated with certainty with the numbered sequence of Fur, though some have distinctive feldspar assemblages that should be identifiable in other sequences. Of particular interest is the presence in the lower part of the sequence of an ash layer whose appearance and biostratigraphic position is close to that of the rhyolitic ash -33. Feldspar compositions in the two ashes are, however, very different, indicating that they do not represent the same eruption. It is concluded that at least two separate rhyolitic ash falls took place in the Danish area, but that distribution of individual layers is patchy as a result of gentle current action during settling of the ash.

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INTRODUCTION

Although most of the ash layers in the Danish 'ash-series', referred to the Ølst- and Fur Formations (Heilmann-Clausen, Nielsen & Gersner, 1985, Pedersen & Surlyk, 1984), are of basaltic composition, several layers of andesitic, rhyolitic or peralkaline composition are also present (Bøggild, 1918). In northern Denmark, where the ashes have been extensively studied at outcrop, individual non-basaltic layers can often be identified in terms of the numbered Bøggild series on the basis of their mineralogy and overall lithology. However, although it is possible to recognize the ash-series over much of the rest of north-west Europe, the sequence of individual layers differs significantly from that of Denmark, due to a combination of differing fall-out patterns, facies variations and stratigraphic hiatuses. Also, the volcanic ash generally displays differing degrees of alteration, so that whereas in parts of Denmark they are preserved as tuffs, they are more usually preserved as bentonites. Under all these circumstances, the general chemical and mineral composition of the volcanic ash is not in itself sufficient to identify individual layers in terms of the Danish sequence. Furthermore most of the records of volcanic ash outside Denmark are from boreholes, from which only limited and sometimes very small samples are available for study, thereby restricting the means of analysis.

For these reasons, Knox (1984), in a study including DSDP cores from the eastern Atlantic, attempted to identify individual ash layers by the composition of their residual feldspars - feldspars being chosen be-

cause of their relative abundance and their wide range in composition. This study demonstrated that it is possible not only to distinguish between individual ash layers, but also to establish long-distance correlations on the basis of widely distributed and distinctive ash layers. All of the results obtained so far indicate that although feldspars may be dissolved as a result of weathering, direct transformation to other feldspar phases does not occur even in the most extreme cases of argillization. The few authigenic phases that have been identified (as overgrowths) have proved to consist of pure orthoclase, as would be expected under conditions of low-temperature precipitation. Distinctive assemblages that lie within the field of igneous feldspar composition may therefore be considered as representative of the primary compositions and as providing a basis for identifying the products of individual ash eruptions.

The coring of the ash-series in the Harre borehole (Nielsen, 1994, this volume, Nielsen, Friis & Korsbech, 1994, this volume) has provided an opportunity to apply the feldspar correlation technique to a sequence close to the classic Danish outcrop area (Fig. 1 in the introductory chapter). Samples from fifteen ash layers, listed below, were analysed for their feldspar composition by means of electron microprobe of separated grains.

SAMPLE DETAILS

Because of the dominantly basaltic composition of the upper part of the ash-series (positive series), only

two distinctive layers were selected for study. Thirteen layers were studied from the negative series. Samples were collected by Dr O.B. Nielsen and are

listed in Table 1, together with brief comments on their appearance.

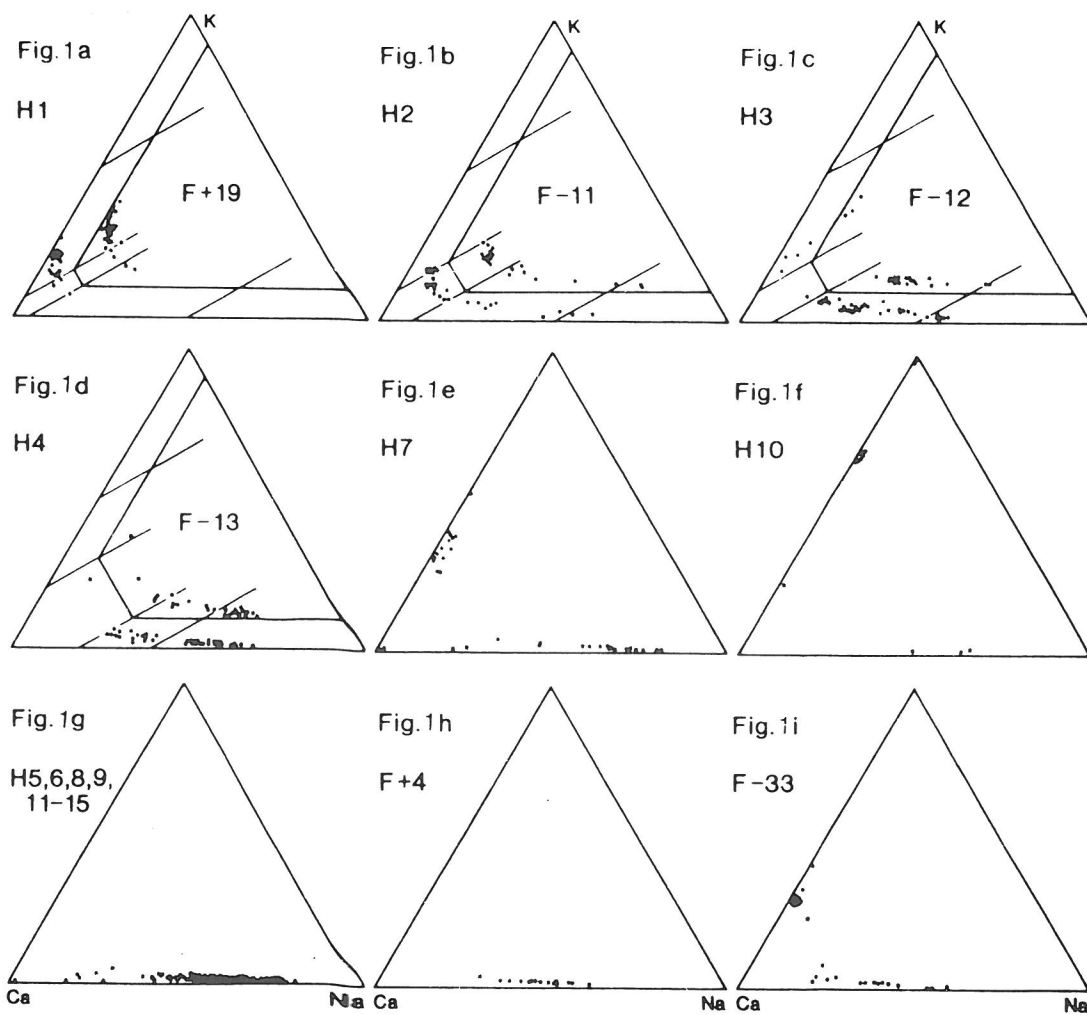


Fig. 1. The feldspar composition of the 15 selected ash layers from the Harre borehole and 6 layers from Fur.

RESULTS AND INTERPRETATION

With the exception of ash H8, feldspars were sufficiently abundant for well defined distribution patterns to be obtained. As would be expected from this sequence, the individual ash layers show widely differing feldspar compositions, ranging from calcic plagioclase in the basaltic layers to sanidine in the more silicic layers. Brief comments on the analyses are given below, and in some cases comparison has been made with analyses of feldspars from specific layers collected from outcrop sequences (author's collection and Ussing/Bøggild collection, Geological Museum, Copenhagen). These comparisons are necessarily incomplete, since, at the time of writing, only a small proportion of the ashes in Bøggild's numbered scheme have been analysed for their feldspar composition.

H1 (Fig. 1a): the feldspars fall entirely within the anorthoclase field, and show a distribution pattern closely similar to that of ash +19 of Fur (Fig. 1a, inset).

H2 (Fig. 1b): the feldspars range from anorthoclase to labradorite, with the mode lying in the anorthoclase field. This distribution is similar to that obtained from ash -11 at Fur (Fig. 1b, inset). However, its position in the sequence suggests a stratigraphical level near the base of the positive series, so that it is possible that the feldspar composition displayed is not unique to ash -11. Initial stratigraphical analysis had suggested correlation with ash +4, but this layer is characterized by plagioclases of intermediate composition (Fig. 1h).

H3 (Fig. 1c): the feldspars mostly range from oligoclase to labradorite, with a mode close to the oligoclase/andesine boundary. A few grains of anorthoclase and sanidine composition were also identified. This distribution is similar to that obtained for layer -12 of Fur (Fig. 1c, inset).

H4 (Fig. 1d): the feldspars range from oligoclase to labradorite, with an apparently bimodal distribution. This distribution bears some resemblance to that obtained for layer -13 at Fur (Fig. 1d, inset), but additional analyses from other locations would be needed before any correlation can be properly assessed.

H5 (Fig. 1g): the feldspars range from oligoclase to bytownite (non-diagnostic basaltic layer).

H6 (Fig. 1g): the feldspars mostly fall within the labradorite and bytownite fields, with a few extending into the albite and oligoclase fields. In the absence of any more distinctive features, this layer must be provisionally included in the 'non-diagnostic basaltic' class.

H7 (Fig. 1e): the feldspars show a strongly bimodal pattern, with one mode within the labradorite and bytownite fields and the other mode in the anorthoclase and sanidine fields. This distribution is unlike any encountered in previous analyses of Danish ashes. Initial stratigraphical analysis had suggested correlation with ash -28, but analysis of a sample from Fur (Ussing/Bøggild collection) revealed feldspars that fall entirely within the labradorite and bytownite fields.

H8 (Fig. 1g): the feldspar compositions lie almost wholly within the labradorite field (non-diagnostic basaltic ash layer).

H9 (Fig. 1g): the few feldspars analysed lie almost wholly within the labradorite field (non-diagnostic basaltic ash layer).

H10 (Fig. 1f): the feldspars show a strongly bimodal distribution, with one mode in the labradorite field and the other in the sanidine field. The sanidine compositions are more K-rich than those encountered in previous analyses of early Eocene ashes from the N.W. European province. Feldspars of almost pure K-feldspar composition are also present; these may be of detrital origin, but their unusually pure composition suggest a possible hydrothermal origin within the volcanic source area. Although ash -33 from Fur also shows a bimodal distribution of feldspar compositions (Fig. 1i), this is very different from that of H10.

H11 (Fig. 1g): the feldspar compositions range from andesine to bytownite (non-diagnostic basaltic ash layer).

H12 (Fig. 1g): the feldspar compositions range from andesine to bytownite (non-diagnostic basaltic ash layer).

H13 (Fig. 1g): the feldspar compositions lie within the labradorite field (non-diagnostic basaltic ash layer).

H14 (Fig. 1g): the feldspar compositions range from andesine to bytownite (non-diagnostic basaltic ash layer).

H15 (Fig. 1g): the feldspar compositions range from andesine to labradorite (non-diagnostic basaltic ash layer).

Table 1. Sample details.

No. Depth (m.b.s.)	Comments
H1 195.37-195.48	pale grey
H2 196.48-196.515	grey
H3 197.03-197.08	black
H4 197.67-197.75	black
H5 198.58 (2mm)	black
H6 201.805-201.81	grey
H7 215.30-215.32	pale grey
H8 216.725-216.78	pale grey
H9 216.855-216.865	black
H10 217.125-217.200	very pale grey
H11 217.77-217.81	pale grey
H12 221.06 (5mm)	pale grey
H13 221.465-221.495	pale grey (upper part of "double layer")
H14 221.496-221.506	pale grey (lower part of "double layer")
H15 221.590-221.605	pale grey

DISCUSSION

Microchemical analysis of feldspars has confirmed the earlier identification of ash +19 (H1). Ash -12 (H3) can also be identified with some confidence by a combination of feldspar chemistry and stratigraphic position. Ash H2 resembles ash -11 in its feldspar assemblage, but differs in being grey rather than black in colour. Also its stratigraphic position suggests that it comes from the basal part of the positive series; if so, this particular assemblage cannot be used as a unique marker. Ash H4 may correlate with ash -13. The remainder of the Harre ashes cannot be assigned with certainty to any of the standard numbered layers, mostly because of the non-diagnostic character of their feldspar assemblages. Ash H10, however, is of interest because it resembles -33 in being of rhyolitic composition and in occupying a similar stratigraphic position (Heilmann-Clausen, pers. comm.). It differs, however, in its feldspar assemblage (see Fig. 1e & i).

Either the two ashes represent different phases of a single complex eruption, with ash of varying composition accumulating in different places at different times, or they represent two separate ash eruptions. Since there is no vertical trend in feldspar composition within -33 at Fur (authors observation), the former interpretation seems unlikely. The presence of only one detectable ash layer at both localities is therefore best explained in terms of lateral impersistence. Since the ash involved consists of extremely delicate and drawn-out particles of silica-rich composition, it is likely that the particles will have been especially buoyant and hence particularly susceptible to redistribution by even the gentlest of currents during settling. In this way the rhyolitic ashes may have been deposited as relatively thick but localized accumulations. The presence of two (or perhaps more) rhyolitic layers at a similar stratigraphical level would suggest that the two eruptions were genetically related.

The absence of ash -17, which is one of the most distinctive layers within Bøggild's negative series, could reflect depositional attenuation, incomplete core recovery, or even the presence of minor stratigraphical hiatuses. Conversely, the Harre sequence includes one ash (H7) with a distinctive feldspar assemblage that has not yet been recorded from the outcrop sections. Hopefully its correlative ash will be found during the current programme of analysis by the author of numbered ashes in the Ussing/Bøggild collection of the Geological Museum, Copenhagen.

The presence of several basaltic layers in the basal part of the section (H12-H15) conforms to the pattern observed at Ølst (Heilmann-Clausen *et al.*, 1985, Heilmann-Clausen & Nielsen, pers. comm.), where the Holmehus Clay is overlain by clays with thin ash layers of basaltic composition.

CONCLUSIONS

The use of feldspar phenocryst composition in correlating between the ash sequence in the Harre Borehole and that established for the outcrop area has proved only partially successful. This is believed to reflect an incomplete record of the eruptive sequence. Several factors may have been involved in the omission of specific ash layers from the borehole record: depositional attenuation of individual ash deposits, small-scale non-sequences, and core loss. For the highly silicic layers, at least, the first of these factors is considered the most likely and could account also

for variability in outcrop sections. It follows that although the detailed ash sequence established by Bøggild and others should be broadly applicable to the whole of the Danish region, not all layers should be expected to occur in every section. Conversely, additional layers may exist that have not been recorded from the outcrop sections.

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DANSK SAMMENDRAG

Analysen af residuale feldspatkorn fra femten vulkanske askelag fra Ølst- og Fur formationerne i kernerne fra Harre boringen har demonstreret tilstedeværelsen af askelag nummer +19 og -12. De øvrige undersøgte askelag har ikke med sikkerhed kunnet henføres til de kendte askenumre, skønt nogle har karakteristiske feldspatselskaber, der burde kunne korreleres til andre lokaliteter. Et askelag i den nedre del, på en position og med et udseende, der meget ligner det rhyolitiske askelag nummer -33, påkalder sig en særlig interesse, idet dets feldspatselskab afviger karakteristisk fra sammensætningen i askelag nummer -33 fra Fur. Dette indikerer, at disse to ensudseende lag formentlig repræsenterer 2 forskellige, men næsten samtidige, eruptioner, hvis horisontale udbredelse er så forskellig, at de ikke endnu begge er fundet på samme lokalitet. Årsagen kunne være, at den større opdrift på de rhyolitiske partikler har gjort dem meget følsomme for selv meget svage strømme i aflejringsmediet under selve aflejringen og dermed medvirket til en relativ begrænset lateral udbredelse af det enkelte rhyolitiske askelag.

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