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STRATIGRAPHICAL DISTRIBUTION OF TEPHRA LAYERS IN THE LOWER PALEOGENE OF THE SOUTHWESTERN MARGIN OF THE NORTH SEA BASIN

by

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ABSTRACT

The presence of tephra layers at several levels in the early Paleogene succession of northwest Germany, the northern Netherlands and central eastern England indicates that ash falls took place throughout northwest Europe over this period. The preservation potential of ash layers in the more marginal facies of the London Basin, the Paris Basin, Belgium and the southern Netherlands is, however, relatively low. Tephra layers have nevertheless, been recorded from the Woolwich Beds of the London Basin and from the Sables et Argiles à Ostracodes et Mollusques of Varengeville, northeast France. They may therefore be expected to occur in equivalent strata in the Paris Basin and in the Upper Landenian strata of Belgium and the Netherlands.

KEY WORDS

Tephra, early Paleogene, England, France.

1. INTRODUCTION

Although tephra layers were recognized in the Mo-Clay (Fur Formation) of Denmark in the late nineteenth century (see Bøggild, 1918), and later traced into northern Germany and the Netherlands, it was not until hydrocarbon exploration revealed their extension throughout the North Sea area (see Jacqué and Thouvenin, 1975; Knox and Morton, 1988) that they were actively sought in onshore sections along the southwestern margin of the North Sea Basin. Volcanic ash was first identified in this region by Elliott (1971), who described a well-preserved basaltic tuff layer in the calcite-cemented Stone Band of the Harwich area of East Anglia (Fig.1). This was later seen to represent one of a series of at least 44 tephra layers (Knox and Ellison, 1979).

Subsequent published records of onshore tephra occurrences along the southern basin margin relate entirely to southeast England and northwest Germany, where offshore marine mudstone facies favour the preservation of discrete air-fall tephra layers. It can now be reported that thin bentonite layers have been identified in the more marginal facies of the London Basin and northeast France. The purpose of the paper is to summarize all records to date, and hence to identify the stratigraphic intervals in which a search for additional tephra layers is most likely to be rewarded. Localities mentioned in the text are shown in Figure 1; stratigraphic correlations and tephra occurrences are shown in Figure 2.

2. NORTHWEST GERMANY AND THE NETHERLANDS

The southward extension of the Danish Mo-Clay 'ash-series' (see Bøggild, 1918; Andersen, 1937) into the basal part of the German 'Untereozän 1' was first initially made by Gagel (1907a,b). The close similarity of the tephra sequence in the two areas was subsequently demonstrated by Andersen

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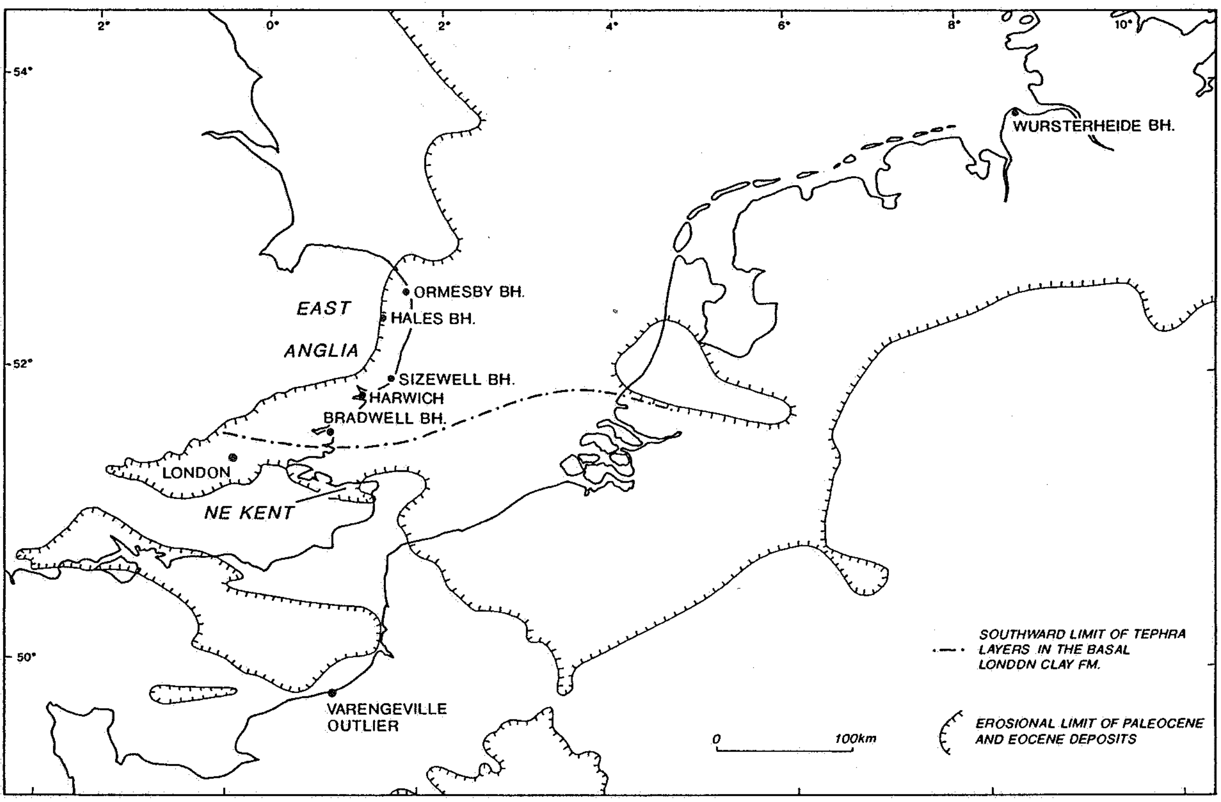

Figure 1. Map showing localities where discrete tephra layers have been identified in Paleocene and Eocene strata of the southern margin of the North Sea Basin.

(1938) and by Knox (1989), in a study of a cored borehole at Wursterheide (Knox 1989). Sporadic bentonites at higher levels in the Wursterheide section are equated with bentonites reported from the Danish Rosnæs Clay by Heilmann-Clausen *et al.* (1984, p.301).

Pannekoek (1956, p.57) reported the extension of the Danish and German tuffs into the northern Netherlands, where they constitute part of the Dongen Tuffite. When traced southwards, the Dongen Tuffite passes into the Dongen Sand, from which tephra layers have not been reported.

No tephra layers have yet been recorded from older Paleogene strata in either Germany or the Netherlands.

3. SOUTHEAST ENGLAND : NORTHERN EAST ANGLIA

The mudstone-dominated succession of Norfolk provides the most complete tephra record for the southern North Sea margin, although representatives of the Woolwich & Reading Beds are missing though hiatus. Cored boreholes at Hales and Ormesby have shown that the London Clay Formation here rests directly on a mudstone equivalent of the Thanet Formation of the London Basin (Knox, 1990, fig.1).

The Thanetian mudstone unit is referred to as the Ormesby Clay (Knox *et al.*, 1990). A distinctive bed of red-brown mudstone in the middle part of the Ormesby Clay separates an upper, transgressive Thanet-equivalent mudstone unit from an older pre-Thanet unit, which is not represented in the London Basin. Three discrete tephra layers were recognized in the lower unit in the Hales Borehole, and one near the top of the upper unit (Knox *et al.*, 1990, p.147-148). In addition, diffuse layers of greenish waxy clay are present that may represent tephra layers that have been partially destroyed by reworking or bioturbation (Knox *et al.*, 1990, p.148). Evidence for the reworking of tephras is also provided by the presence of igneous minerals in a thin sand bed at the base of the Ormesby Clay in British Geological Survey offshore borehole 79/7A (Morton 1982). The assemblage includes euhedral grains of acmite, aegirine, clinopyroxene, arfedsonite, and apatite, indicating derivation from a magma source of distinctive and unusual composition.

The basal part of the London Clay Formation of Norfolk is greatly expanded in comparison to the sandy sections of the London Basin. The Harwich Member of King (1981) is here underlain by an additional mudstone unit, termed the Hales Clay by Knox *et al.* (1990). At least five thin, pyritized tephra layers occur in the Hales Clay, but the most abundant layers are found in the overlying Harwich Member, with 82 layers having been identified in the Ormesby Borehole. The Hales and Harwich

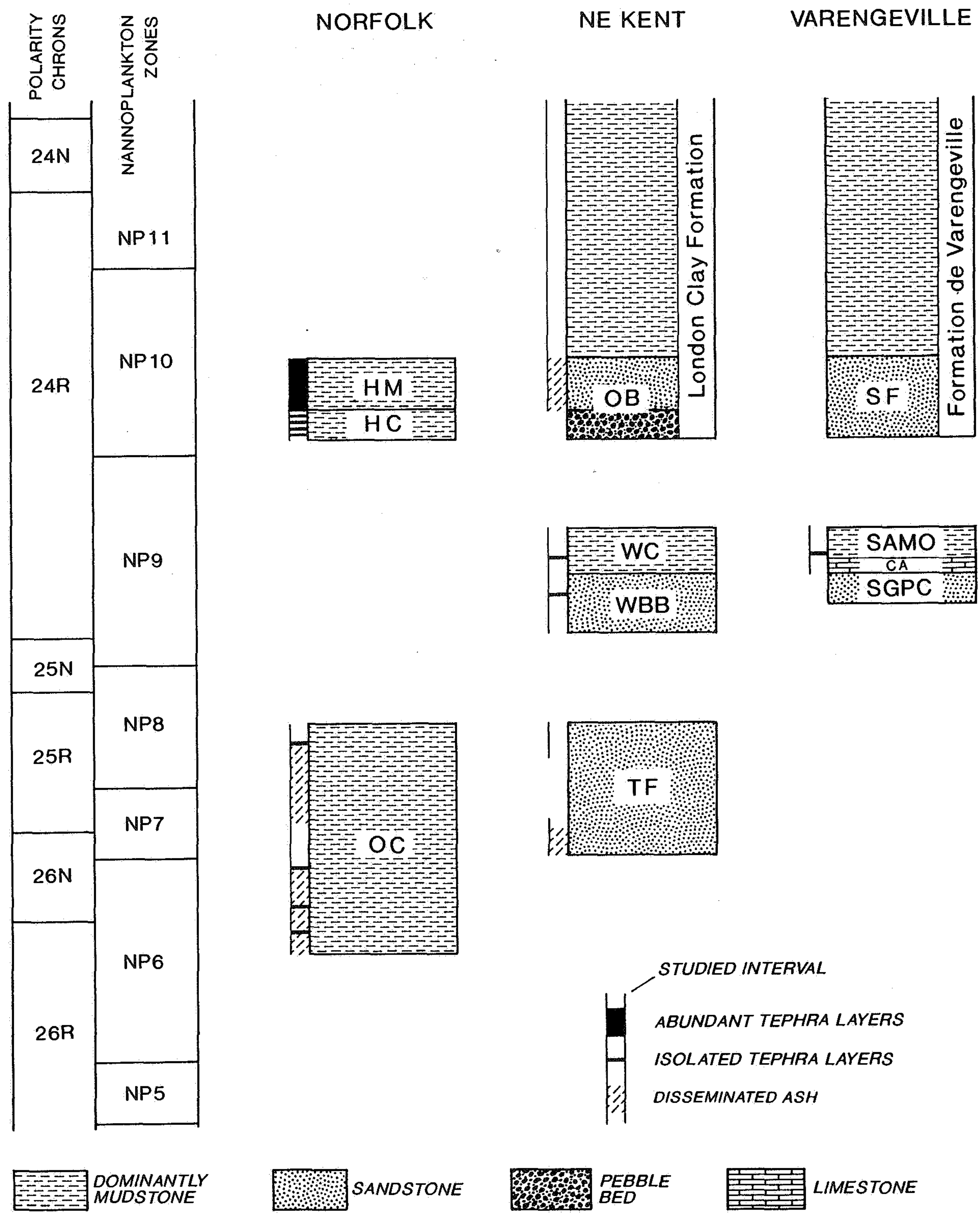

Figure 2. Stratigraphical distribution of tephra in the marginal successions of the southwestern North Sea Basin. Chronostratigraphical assignments modified from Knox (1990). Norfolk succession based on the sections in the Ormesby Borehole (Cox *et al.*, 1985) and the Hales Borehole (Knox *et al.*, 1990). Varengeville succession taken from Dupuis & Steurbaut (1987).

HM = Harwich Member (London Clay Fm.) ; HC = Hales Clay (London Clay Fm.) ; OC = Ormesby Clay ; OB= Oldhaven Beds ; WC = Woolwich Clays, Shell Beds, etc. ; WBB = Woolwich Bottom Bed ; TF = Thanet Fm. ; SF = Sables Fauves ; SAMO = Sables et Argiles à Mollusques et Ostracodes ; CA = Calcaire d'Ailly ; SGPC = Sables et Grès du Pays de Caux.

tephras are believed to correlate with the negative and positive ash series of Denmark, respectively.

4. SOUTHEAST ENGLAND: THE LONDON AND HAMPSHIRE BASINS

Tephra layers in the Ormesby Clay are known only from the two Norfolk boreholes. They are absent from cores at Sizewell, where only the upper part of the Ormesby Clay is present. At Harwich only a very thin representative of the Ormesby Clay is present. South of Harwich the beds are again relatively thick, but are developed in the sandy facies of the Thanet Formation, which is unfavourable to the preservation of discrete ash layers. Disseminated ash particles are abundant near the base of the Thanet Formation at Pegwell Bay (Knox, 1979) and may well occur as isolated particles in higher parts of the unit.

The Hales Clay is identifiable only as far south as Sizewell, but the Harwich Member and its associated tephra layers have been traced as far as Bradwell, beyond which the basal facies of the London Clay become increasingly sandy (Swanscombe and Oldhaven sands of King, 1981). Discrete tephra layers are generally absent, although an unpublished record exists of a single tephra layer in the Oldhaven sands of the central London region (Fig.1). Thin-section analysis of the Oldhaven sands (Knox, 1983) has revealed disseminated ash particles, which presumably represent reworking of the Hales and Harwich ashes. The remainder of the London Clay Formation contains little evidence of pyroclastic activity, although three extremely thin bentonite layers have been recorded in cores from the Hampshire Basin (Knox and Morton, 1983, p.360).

The successions of the London and Hampshire basins also include the highly variable Woolwich & Reading Beds. Very thin pyritized ash layers were reported from Woolwich Clays of central London by Knox and Morton (1983, p.358) and a similarly pyritized ash layer has since been reported by Dr C. King from the Woolwich Clays of northwest Kent (unpublished data). A thin and impersistent bentonite layer has also been reported from the Woolwich Bottom Bed at Aveley (B.E. Moorlock, pers. comm. 1991) and another from central London (R.A. Ellison, pers. comm. 1991). No tephra layers have yet been identified in the Reading Beds, and it seems unlikely that ash would have survived the depositional and diagenetic processes associated with the terrestrial Reading facies.

5. BELGIUM AND FRANCE

The published record of possible pyroclastic material in the early Paleogene of Belgium and France is limited to that of Geets (1993, this volume), who reported pyroxenes in sandy clays at the base of the Ieper Clay. No particles of vitric origin were identified, however.

Discrete tephra layers have, however, recently been identified at Varengeville, in the Sables et Argiles à Ostracodes et Mollusques (for a description of the section see Dupuis and Steurbaut, 1987, fig.2). These were first recorded by Dr C. King, and their volcanic origin confirmed by the author, on the basis of the presence of a residual volcanic feldspar population.

6. PRESERVATION POTENTIAL

It is evident from the above account that intermittent pyroclastic activity took place throughout the late Paleocene and into the early Eocene, but that certain periods were characterized by more frequent eruptions than others. This is best appreciated from the frequency of occurrence of tephra layers in the offshore marine mudstone facies, in which primary ash falls are most likely to have been preserved as discrete accumulations on the sea floor. Even here, however, consideration must be taken of the relative rates of sedimentation and of the destructive effects of burrowing. In particular, the relatively sparse occurrence of tephra layers in the Ormesby Clay may not be a true reflection of pyroclastic activity, since abundant, diffuse grey-green clay layers are present that may represent much more frequent ash falls. These appear to have undergone extensive early diagenetic alteration and bioturbation, both as a result of relatively slow sedimentation. By contrast, the ash layers in the more rapidly deposited silty mudstones of the Hales Clay and Harwich Member are sharply defined and only sporadically affected by burrowing.

The preservation potential in the marginal marine and paralic sequences is clearly much lower than in the offshore marine facies. The only facies in which ashes might be expected to occur with some constancy is the lagoonal clay facies of the Woolwich Beds and their equivalents in the Paris Basin and Belgium (Upper Landenian). In the sand units, ash falls are largely represented by disseminated ash particles, reflecting the combined effects of current and wave reworking and bioturbation. Not surprisingly, reworked ash particles are most abundant in the Oldhaven sands, which were deposited at the time of the 'Harwich' ash falls. They are also abundant at the base of the Thanet Formation, where they presumably accumulated during the early, sediment-starved phase of the Thanet transgression.

The records of discrete tephra layers in the sands of the Woolwich Bottom Bed and the Oldhaven Beds indicate that ash layers can survive in shallow, sublittoral environments. These occurrences probably reflect the intermittent nature of wave activity, which allows ash to accumulate on the sediment surface during calm periods. Such accumulations will normally be destroyed by subsequent wave erosion, but occasionally local remnants will survive, especially where ash has accumulated in relatively deep erosional scours. Another factor in the survival of these ash layers is the relative scarcity of burrows. The Oldhaven sands, in particular, show delicate lamination, with burrowing being mainly restricted to large, isolated forms such as Ophiomorpha. Similarly, the Woolwich Bottom Bed retains much of its original bedding structure, as indicated by the common occurrence of thin detrital mudstone layers. By contrast, the Thanet sands, which represent slower and more steady deposition in deeper water, have been largely homogenized by bioturbation. Whereas the preservation potential in both types of sand is extremely low, the nearshore sublittoral sands are most likely to include identifiable tephra deposits, albeit as isolated remnants.

7. TEPHRA LAYER CORRELATION

As demonstrated by Knox (1984) it is possible to fingerprint certain tephra layers by means of their feldspar composition, and hence to correlate these distinctive layers from one section to another. Thus distinctive ashes in the Sele and Balder formations of the North Sea and in the Hales Clay and Harwich Member of East Anglia have been correlated with ashes in the Fur and Ølst formations of Denmark.

Comparable tephra corrrelations are theoretically possible between sections through equivalents of the Ormesby Clay and the Woolwich & Reading Beds, with the possiblility that the chemical fingerprinting of feldspar phenocrysts may be supplemented with data on some of the more distinctive minerals identified in the Thanetian tuffs by Morton (1982). However, the sporadic distribution and chance preservation of tephra layers in the sandier marginal formations greatly reduces the probability of a single layer being preserved in more than one section.

8. CONCLUSIONS

The tephra layers encountered along the southern margin of the North Sea Basin are clearly southerly representatives of the tephra sequence known from the central and northern North Sea area. In terms of the pyroclastic phases identified by Knox and Morton (1983, 1988), the Ormesby Clay tephra belong to Phase 1, and Woolwich Beds and London Clay tephra to Phase 2.

Since the early Paleogene North Sea ash layers are of widespread, distal type, it is reasonable to expect that ashes identified in southern England and northern France will have fallen also in Belgium and in the Paris Basin. The formations and facies most likely to contain ashes can be assessed from the distribution of ash in equivalent strata in southern England. Hopefully more tephra layers will be found in the Franco-Belgian region, since they provide the best opportunity for establishing precise chronostratigraphic correlations within this poorly fossiliferous and highly variable part of the succession. In addition, the presence of tephra layers raises the possibility of obtaining precise ages for the various units through the radiometric dating of residual igneous phenocryst minerals, particularly the alkali feldspars.

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