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Discrimination of density flow deposits using elemental geochemistry—Implications for subtle provenance differentiation in a narrow submarine canyon, Palaeogene, Danish North Sea

Henrik Friis[a,*], Mette Lise K. Poulsen[a,c], Johan B. Svendsen[b], Lars Hamberg[c]

[a]*Department of Earth Sciences, Aarhus University, C.F. Møllers Allé 120, DK-8000 Aarhus C., Denmark*
[b]*Altinex Oil Denmark A/S, Kongevejen 100C, DK-2840 Holte, Denmark*
[c]*Dong energy, Exploration and Production, Agern Allé 24-26, DK-2970 Hørsholm, Denmark*

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Abstract

Elemental geochemistry of 1131 sandstone samples has been used to characterise five Palaeogene sandstone members in a system of density flow deposits within an incised submarine canyon, Danish North Sea. Diagenetic overprinting has complicated the use of most main and trace elements, but a group of ''heavy mineral bound'' elements with low mobility (Ti, Y, Zr, Nb and Th) has proved highly potential for correlation. The individual sandstone members exhibit very consistent relations between the ''heavy mineral elements'' along the canyon and, based on Zr/Ti plots, two families of sandstone members can be distinguished. The families are recognised on variations in inclination and intersection of linear regression lines which are related to subtle variations in provenance/source area. The inclination is believed to be controlled by the detrital heavy mineral (HM) suite and composition, whereas the intersections are controlled by the background contribution, such as HM inclusions in detrital rock forming minerals, e.g. quartz and/or feldspar, as well as substituted and/or adhered elements in glauconite. The correlation pattern has been used to suggest a re-interpretation of the stratigraphic relation of some of the sands.

Keywords: Elemental geochemistry; Stratigraphic subdivision; Provenance; Siri Canyon; Danish North Sea

1. Introduction

The geological interpretation of thick, massive sandstone successions deposited by gravity flows may be complicated because of scarcity of biostratigraphical components and the frequent lack of primary sedimentary structures. While the lack of fossils hampers stratigraphical correlation of, and between, massive sand bodies, the absence of sedimentary structures causes difficulties when interpreting sediment geometry and processes of transportation and deposition. A number of studies have shown that mineralogical or chemical differences caused by changes in supply can yield a platform for detailed correlation (Andersson et al., 2004; Basu and Molinaroli, 1989; Hounslow and Morton, 2004; Mange-Rajetzky, 1995; Morton et al., 2004; Morton, 1991; Morton and Hallsworth, 1999; Nakashima and Imaoka, 1998; North et al., 2005; Okrusch et al., 2003; Owen, 1987; Pearce, 1990; Pearce and Jarvis, 1995; Preston et al., 1998; Preston et al., 2002; Utzmann et al., 2002). Also microanalyses of chemical composition of single minerals have proved very useful in a large number of provenance studies (e.g. garnet (Morton, 1985), Fe–Ti oxides (Basu and Molinaroli, 1989), rutile (Zack et al., 2004), zircon (age) (Hallsworth et al., 2000)).

We have studied the whole rock chemical variability of very uniform density flow sands in an incised submarine canyon system in order to establish a basis for stratigraphic discrimination. Dense sampling has revealed that individual families of flow units can be distinguished by variation in their trace and major element chemistry. Although the

*Corresponding author. Tel.: +45 8942 2561; fax: +45 8613 9248.
E-mail address: henrik.friis@geo.au.dk (H. Friis).

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detrital variation is partly masked by diagenetic overprinting, subtle detrital variations between largely immobile "heavy-mineral bound" elements (Ti, Y, Zr, Nb and Th) can be documented. Simple cross-plots of these elements show strong linear trends, which relate to heavy mineral sorting. However, when plotted well by well and member by member, it appears that some elements (e.g. Zr and Ti) are seen to separate in two narrow linear trends which also have a stratigraphical bearing, indicating a shift in type of detrital sand supplied to the canyon over time.

2. Geological setting

The Siri Canyon is part of a larger system of submarine canyons in the Palaeogene in the Norwegian—Danish Basin running in an E–W to NE–SW direction towards the Central Graben (Fig. 1). It was 15–20 km wide and over 150 km long running from the Stavanger Platform (removed by the Neogene uplift) along the present day Danish–Norwegian North Sea border and terminating at the Coffee Soil Fault (Fig. 1; Hamberg et al., 2005; Clausen and Huuse, 1999; Huuse, 1999). According to Hamberg et al. (2005) the canyon was formed in the Danian as a result of major submarine mass failure in the Danian chalk succession caused by uplift in the Scandinavian hinterlands. The narrow confinement of the canyon may partly be controlled by salt structure growth (Hamberg et al., 2005; Huuse, 1999). The Siri Canyon area comprises up to 200 m of deep marine pelagic and hemipelagic marls and shales of the Upper Palaeocene to Lower Eocene Rogaland Group embedding a series of sandstone intervals (Fig. 2). Gravity flows, initiated by slumping events in the glauconite-producing shelf areas of the Stavanger Platform, transported the sands up to 120 km through the submarine canyon before deposition at their present day location (Danielsen et al., 1995; Hamberg et al., 2005). The sandstones are referred to five different members depending on their position in the shale succession of the canyon fill (Fig. 2).

The sandstone intervals vary from thin (5–20 cm) upwards fining turbiditic units to up to 70 m thick successions of massive sand units, devoid of any sedimentary

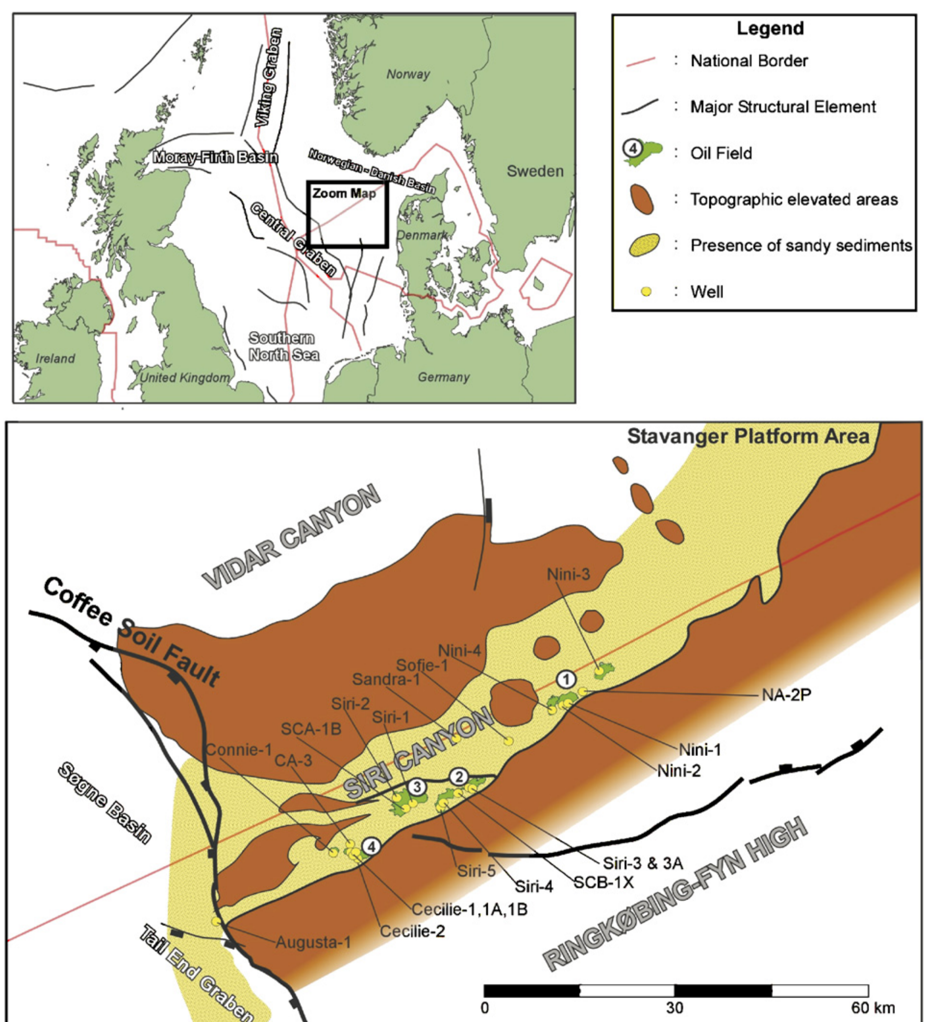

Fig. 1. Location map of the Siri Canyon. (1) Nini Field; (2) Stine Field; (3) Siri Field and (4) Cecilie Field.