of durbachites during D_2, e.g. during thrusting of the lower over the middle crust. The age of durbachite intrusion has been dated at ~323 Ma (Kröner, unpublished data). The above presented data allow to construct an exhumation path suggesting an exhumation rate of ~3 mm/year. Ar/Ar cooling ages in the footwall Svratka Complex (325–332 Ma; Fritz et al., 1996) suggest very rapid cooling of the whole area after termination of exhumation process.

Controls on Delta Plain Sandstone Geometries and their Implication for Reservoir Exploration in Middle Jurassic Successions: Saltwick Formation, Yorkshire Ness Formation, North Sea

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Delta plain sandstones form hydrocarbon reservoirs in several North Sea oil and gas fields, most prominently in Brent Group reservoirs. These sandstones have restricted lateral extent and are encased in mudstones and siltstones (Mjøs and Prestholm, 1993). It is generally difficult to correlate these sandstones and determinate their geometries even if the well separation is less than 1 km (Livera, 1989). Hence studies of analogous data focused on facies variations and sandstone geometries may help to reduce the uncertainty in the geological reservoir descriptions of the North Sea fields, where the delta plain reservoir sandstones are not detectable on seismic profiles at reservoir depths (Mjøs and Prestholm, 1993). This research aims to apply sedimentary facies and architectural outcrop analysis of the Middle Jurassic Ravenscar Group of the Yorkshire delta to the analogous Middle Jurassic Brent Group of the Brent delta. Despite deposited 700 km apart, the Yorkshire delta and the Brent delta both record the sudden progradation of delta systems over the shallow muddy environment and their subsequent abandonment (Johnson, 1994). The Aalenian Saltwick Formation of the Ravenscar Group (Yorkshire delta) has been studied at the outrops on the N.E. England coast within the area between Whitby and Hayburn Wyke. The Ness Formation of the Brent Group (Brent delta) has been studied in cores of wells of the Strathspey Field and Brent Field in Northern North Sea.

The Saltwick Formation is composed of 10 sedimentary facies – coal (C1), claystone (Cl1), root-penetrated siltstone (Sl1), very fine to fine-grained sandstone sheets (Fs1), very fine to fine-grained sandstone channels (Fs2), medium-grained sandstone channels with lateral accretion surfaces (Ms1), medium-coarse-grained sandstone channels with sporadic bioturbation (MCs1), medium-coarse-grained sandstone channels (MCs2), coarse-grained sandstone channels with siltstone interbeds (Cs1) and conglomerate (Cg1). These facies except Fs1 and Cg1 were observed also within the Ness Formation. Facies of siltstone containing bioturbation (Sl2), very fine to fine-grained sandstone channels containing bioturbation (Fs3) and fine-grained hummocky cross stratified sandstone (Fs4) occur only within the Ness Formation. Marine influence indicators, which are common within the Ness Formation, are rare within the Saltwick Formation and occur predominantly at the Hayburn Wyke.

Sandstone facies can be divided into four groups:

1) Crevasse splay sandstones, which consist of facies Fs1 with sheet-like geometry and width/thickness ratios higher than 50.

2) Distributary channel sandstones cut into delta plain, which consist of facies Fs2, Ms1, MCs2 and Cs1 with channel geometries and width/thickness ratios of three categories – up to 10 at Whitby West Cliff, between 10 and 35 in the area from High Whitby to Pursglove Stye Batts and higher than 35 at High Whitby. Measurements at Whitby West Cliff, where are channels exposed also in longitudal cross sections, e.g. parallel with palaeoflow direction, show width/thickness ratios up to 50.

3) Inlet channel sandstones, which consist of facies Fs3.

4) Wave dominated lagoonal shoreface sandstones, which consist of facies Fs4.

Vertical and lateral relationships between individual channels were studied. Two different depositional geometries were observed. Channels are vertically stacked at Whitby West Cliff, Ravenscar and High Whitby. The High Whitby sandstone body has a width of 465 m and a thickness of 15 m. It has a complex architecture including vertically stacked channels and lateral accretion surfaces and erodes deeply into sheet crevasse splay sandstones and overbank fine deposits. On the opposite side, isolated lenticular channels encased in overbank fine deposits were found at the Whitby East Cliff.

The vertically stacked channel geometry could be explained as controlled by relatively high subsidence along the hanging wall of the adjacent faults. (the Whitby Fault at Whitby West Cliff see Alexander and Gawthorpe, 1993, and the Peak Fault see Mjøs and Prestholm, 1993). This explanation is not applicable to the High Whitby stacked channels because no fault is present there. The High Whitby stacked channels could be interpreted as an incised valley infill. Its base can be interpreted as a sequence boundary reflecting relative sea level fall and delta progradation. The implication for the Ness Formation is that although well interconnected stacked channel sandstone reservoir units that bear significant hydrocarbon volumes often occur within the Ness Formation, outcrop analogues show combination of controls on deposition of stacked channel sandstones and high variability in their lateral extent. Thus the prediction of Ness Formation channel sandstones position and relationships with other facies is associated with high risk.

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Lithological Control on Tectonic Deformation of Upper Neogene, Poorly Indurated Strata at Witów, Carpathian Foredeep (Poland)

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Uppermost Miocene and/or Pliocene Witów series (Brud and Worobiec, 2003) crops-out in the Carpathian Foredeep ca. 40 km east of Kraków (Fig. 1). The series, up to 40 m thick, comprises interbedded conglomerate, gravel, sandstone, sand, mud, and clay. In the lower part of the series, clay and mud predominate, whereas the upper part is composed mostly of poorly indurated sandstone and conglomerate. The Witów series has been studied in four exposures located in a single sand-pit in the village Morsko, 3 km west of the town of Nowy Korczyn. Our observations are restricted to the upper, coarse-grained part of the series which was deposited by a braided river. In this part, beds of sandstone and conglomerate pinch out laterally at short distances. Most sandstone beds contain dissipated well-rounded pebbles and cobbles. The conglomerate is mainly sand-supported, whereas clast-supported conglomerate occurs occasionally. The clasts in the conglomerate are well-rounded. They show shallow imbrication which is differently orientated in particular exposures. The clasts are mainly sandstones, siliceous rocks, and carbonates. The large majority of the clasts in conglomerate, as well as the pebbles and cobbles in sandstone were transported from the Outer Carpathians from a distance of at least 30 km. Most of the clasts are less than 10 cm across, although few clasts up to 30 cm in diameter have also been observed.

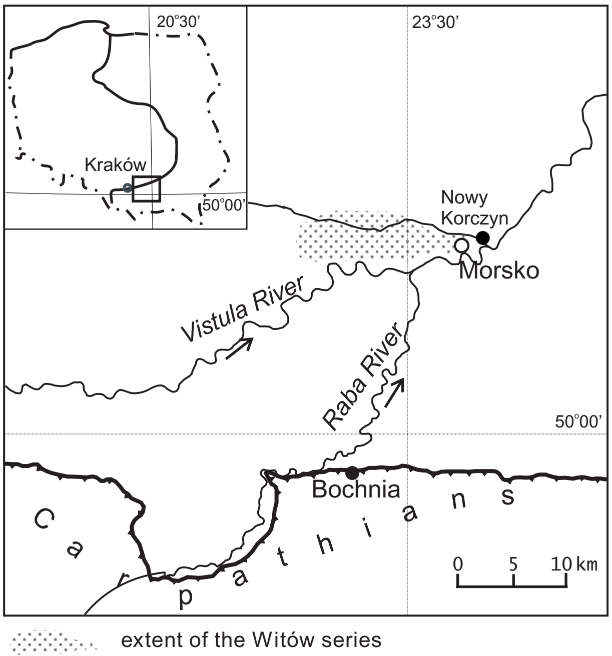

Fig. 1. Location of study area.

Observations

Sandstone

Sandstone beds are cut by numerous metre-scale joints and normal and strike-slip faults. The joints are subvertical. They terminate at the sandstone/conglomerate boundary. The majority of faults are restricted to single sandstone beds. Close to the normal faults, the dissipated discoidal and elongated pebbles and cobbles in sandstone are rotated into position in which AB planes of these clasts (planes containing the maximum and intermediate axes of clasts) are parallel to the faults (Fig. 2). The strike-slip faults do not cut the clasts dissipated in sandstone, but omit them. The offset on the strike-slip faults is only exceptionally visible. The majority of the normal and strike-slip faults termi-