a contribution to the petrology
of the middle jurassic
of whitby, yorkshire

some results on dogger samples

by K-H.A.A.Wolf
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INTRODUCTION

In July 1986, first and second year Mining and Petroleum Engineering students visited the east-cliff of Whitby during a field-trip to Northern England and Scotland. This cliff-section illustrated beautifully examples of a Middle Jurassic deltaic environment. Clearly recognizable are channels, crevasse splays and lagoonal or swamp deposits. The section can be compared with the Middle Jurassic deltaic environment of the Brent Group. The wavecut platform shows bituminous shales of the Upper Lias. Between these rather interesting eye-catchers, a modest unconformity with overlying Dogger is presented. This thin brownish-red layer can be reached at one place, on which Gerard Kwantes took some samples. Thin sections of these samples showed an interesting mineralogy, that only for a part was described in literature. In September 1986 a second journey was made to Whitby, to examine Dogger and adjacent layers, in greater detail. During this five-day fieldwork, several subjects have been treated:
1) The geology of the east cliff of Whitby and the Dogger formation as a main point.
2) Sampling of the Dogger formation and adjacent layers for geochemical and mineralogical research.
3) An Engineering Geological study on the precise determination of the locations of the Dogger outcrops, together with a study on the stability of the cliffs.

GEOLOGICAL BACKGROUND (Figure 1, 2)

The Lower Jurassic in Yorkshire consists mainly of fossiliferous marine shales and various types of siltstones, sandstones and ironstones. Cyclic sequences from shales to sands often occur. They are most clearly observed in the Upper Lias. The Upper Lias succession is regarded as being laid down in waters of decreasing depth and increasing oxygenation of the bottom sediments. The finely laminated shales contain a high percentage of pyrite and calcium carbonate concretions (for example the jet rock). The original parent mud contained much H₂S and CaCO₃, the products of bacterial breakdown of sulphates in sea water. Fossil remains of bivalves, ammonites, belemnites, fish, reptiles and waterlogged wood can be found in these shales (Hemmingway 1974).

At the end of Toarcian times north-east Yorkshire was folded into a series of shallow basins and low domes. The seafloor was raised to sea-level and marine erosion reworked Upper Lias strata of various thicknesses. During and after this low amplitude folding and uplifting, at the beginning of Bajocian times, the erosion products were deposited mainly in a shallow marine environment (Hancock and Fisher 1981). This basal formation, named the Dogger, is a rather heterogeneous sediment in thickness as well as in sediment content in the Yorkshire area. The sedimentation of the Dogger spans a relatively long period of time, one might speak of a condensed sequence. This thin formation at the beginning of the Middle Jurassic should not be confused with the European usage of the term Dogger which is the term used to denote the whole of the Middle Jurassic (Figure 2).
Figure 1 A: A section of the cliffs on the east side of Whitby with the sample spots (0, I, II, III etc.).

Figure 1 B: A sketch map of the geology at the east-cliff and on the wave cut platform between Whitby and Saltwick Nab.

Figure 2. Nomenclature of Upper Lias and Middle Jurassic strata.
After Powel (1984) and Hemingway & Knox (1973)

<table>
<thead>
<tr>
<th>MIDDLE</th>
<th>SCULBY FORMATION</th>
<th>SCARBOROUGH FORMATION</th>
<th>CLOUGHTON FORMATION</th>
<th>ELLERBECK FORMATION</th>
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Photo 1: A vertical profile of the Dogger at Long Bight, Whitby East Cliff.
After the marine Dogger filled most of the depressions in the Liassic surface, a marshy deltaic facies dominated the Yorkshire basin. The clastic terrigenous sediments were deposited during the Middle-Jurassic and are thought to have a northern provenance (Hemmingway/Knox 1973).

LOCAL STRATIGRAPHY

The stratigraphy as can be seen on the east-cliff of Whitby consists of five recognizable members and formations (Figure 1 a, b, Photo 1, 2, 3):

1) The Jet Rock Member.

This rock type is a member of the Whitby Mudstone Formation (Powel 1984) which is a part of the Upper Lias. The Jet Rock member is a group of dense finely laminated, dark brown shales with several beds of calcareous concretions. These shales are cognate to oil shales. They produced on laboratory distillation 54-86 litres of sulphurous oil to a ton (Hemmingway 1973). Besides illite, chlorite and kaolinite as the clay minerals and dispersed sand and silt as quartz content, pyrite is abundant up to 15%. The CaCO₃-content is relatively high, from an average of circa 6% to circa 19% at the top. Fossil ammonites, belemnites, wood (jet) and remains of reptiles can be found. The Jet Rock is capped by a thin and platey argillaceous limestone, the Top Jet Dogger (not to confuse with the Dogger Formation).

2) The Alum Shale Member.

The lower part of the member consists of a hard shale with nodular and tabular siderite mudstones. The overlying Main Alum Shales are grey in colour and weak. They weather very fast in comparison with the shales of the Jet Rock Member. The principal detrital minerals are quartz, muscovite, chlorite and biotite, with small amounts of feldspar, tourmaline, rutile etc. Belemnites, ammonites and small bivalves are common. The Alum Shale series was used for the production of alum for almost 300 years (Photo 1).

Both members represent the top of the Upper Lias in this part of the Yorkshire area. They show a gently folded open structure, unconformably overlain by the Dogger Formation. The upper part of the Whitby Mudstone Formation and the Blea Wyke Sandstone Formation have been eroded during this phase of uplift and slight deformation (Photo 1).

3) The Dogger Formation.

The Dogger at the east cliff is a brown to reddish, pebbly, ferruginous sideritic siltstone about 60 to 80 cm thick with a very irregularly weathered top. The base is marked by a conglomerate. The silt matrix shows random deposited coarser grains of quartz, feldspar, phosphates and siderite (Photo 1, 2, 3).

4) The Saltwick Formation

The Saltwick Formation is a non-marine formation. It comprises marsh deposits and channel deposits. The marsh deposits consist of plane-bedded clays, silts, ill-graded sandstones and silt-rich ironstones. These show local cyclicity and a fining upward from an argillaceous sandstone, trough silt to a leached clay and ends in a carbonaceous clay or a low grade coal. Local folding and faulting are frequent at the channel margins, because of the difference in compaction between the clay-rich sediment (a rather high compaction-rate) and the sand-rich sediments.

The Channel deposits are the washouts, deposits which fill the erosive channels and dissect, both marine (Liassic members and Dogger) and non-marine subjacent sediments. These channels are commonly filled with sandstones and they lie sharply in contact with the sediments into which the channel has cut. Fossil plants and bivalves have been recognized in both marsh deposits and channel deposits. In some sandstone blocks which fell on the wave-cut platform due to erosion of the cliffs, three toed footprints of several reptiles are visible.

5) The Ellerbeck Formation.

The formation comprises marine ironstones, shales and sandstones. They contain bivalves, gastropods, ichnofauna and wood debris. Ammonites are rare.

THE INVESTIGATION

At the east-cliff of Whitby the Dogger formation and adjacent formations were laterally and vertically sampled at eight outcrops. Furthermore samples were gathered at the north side of the Peak Fault at Ravenscar. At each sample point the thickness and content of the layers were recorded.

Basic petrography and modal analyses by optical microscopy (table 1, photo 4, 5, 6) were supplemented by X-ray diffraction (X.R.D.) to confirm and to quantify silica and carbonate mineralogy (table 2).

Simultaneous Differential Thermal Analyses (D.T.A.) and Thermo-gravimetry (T.G.) were carried out by means of the Derivatograph. On recordings of thermal analyses it was possible to recognize the thermal behaviour of particular constituents (figure 3, 4). Powdered samples (325 mesh) were analyzed at atmospheric conditions within the range of 20°C to 1000°C and at a heating rate of 10°C/min.

Scanning Electron Microscopy (S.E.M.) was used to throw light upon the three-dimensional relationship between detrital and authigenic phases (Photo 7-13).

In the first stage of the investigation the samples of the Dogger Formation were being used for an analyses, discern the nature of the sedimentology of the condensed sequence at the east-cliff of Whitby. In a second stage the adjacent layers were examined.

PRELIMINARY RESULTS

Petrography (photo 4, 5, 6, table 1).

Some eighty samples were collected from eight outcrops on the east-cliff at Whitby and from one outcrop near Ravenscar. The majority of the samples described here were collected from the Dogger formation.

At Long Bight the Dogger Formation (Thickness circa 80 cm), a ferruginous sand with phosphatized pebbles was sampled each 15 meter. The Dogger shows four recognizable zones (photo 1, 2, 3): Top Layer D: Circa 5 cm thickness. reddish, ferruginous, carbonate rich sandstone. The inhomogenous sediment composition caused a very irregular weathering of the top (photo 1, 2). Under this zone the colour of the rock changes from red to dark grey.

Top Layer C: Circa 10 cm thickness. reddish-brown, ferruginous, carbonate rich sandstone, very irregularly weathered. Under the weathered skin, the colour of the rock changes from red to dark grey (photo 1, 2).

Both layers are only recognizable at the central part of Long Bight. They seem to disappear to the east and west. Top layer A has a higher sand content in comparison with Top layer B.
Main Layer B: Circa 60 cm thickness. Brownish-grey carbonatic sandstone with a change in mineral composition and in grain size from the top to the bottom. At the top often white spots of kaolinite are recognizable. They disappear downwards. A coarsening upward of the sand fraction, an increase in grain size of the pebbles and an increase of the carbonate content upward, can be seen in all Dogger outcrops. Xenomorphic relics of fossil vegetation and charcoal-like remnants are random in the groundmass. Often kaolinite can be recognized around the particle and in cracks in the particle.

Bottom A: Circa 5 cm thickness. Zone with coarse, irregularly poor sorted pebbles in a matrix of sand. The pebbles consist mostly of Fe/Ca-Carbonate and phosphatic matter (photo 3).

Microscopic results (photo 4, 5, 6, table 1)

The thin sections analyzed by polarization microscopy, show a constant vertical mineralogical content. At each sample point the proportions in mineral content change from the bottom to the top of the formation. The main components are quartz, feldspar and phosphate minerals in a sideritic matrix. Of less frequent occurrence are the clay-minerals (illite, kaolinite and chlorite), muscovite/biotite, organic matter, pyrite and accessory minerals as zircon etc.

•) The quartz grains can be divided in two groups:
  1) sub-rounded to well-rounded grains with a diameter of 1 mm or bigger.
  2) sub-angular to sub-rounded grains with a high to low sphericity, which are often the main part of the grains.

•) The feldspar grains can be divided into the same groups as the quartz-grains. However the fraction of small grains is difficult to recognize. The larger grains often show twinning and some even have microcline gitterung which might point to a pyroclastic origin of the feldspar grains. Many of the plagioclase have been partly replaced by calcite and/or kaolinite.

•) The carbonate minerals are present in three different forms in the thin sections:
  1) Sideritic spherulites as the main constituent of the groundmass. At the top of the formation, in the siderite rich zone, the spherulites are twice as large (0.04 mm) than at the bottom (0.01 mm). The cores of the spherulites often contain more iron than the rim.
  2) Sideritic carbonate at the bottom of the formation is a blocky type cementation between the quartz and feldspar grains. It has often been replaced by siderite spherulites.
  3) Calcite has replaced feldspar grains during diagenesis.
  4) Some quartz, feldspar and phosphate grains have a coating of sideritic carbonate.

Of special note is the absence of carbonate bioklasts like remnants of bivalves and crinoids in this carbonate-rich environment.

•) The phosphatic minerals are grains with a high sphericity and roundness. They often contain very fine clay-minerals, such as chlorite and illite, together with a very fine silt fraction. They also show a concentric zoning. Collophane, a cryptocrystalline apatite forms the groundmass of these phosphatic grains.

•) Most of the clay-minerals are authigenic particles, grown in collophane and feldspar grains. Kaolinite also can be seen as a weathering product in cracks in charcoal remnants.

•) Organic matter mostly consists of charcoal remnants with kaolinite. The kaolinite can be seen in cracks in the particle and around the particle.
The X.R.D.-analyses of some of the Dogger samples show a constant mineral composition. All samples show the presence of quartz, alkali feldspar, siderite, muscovite/illite, chlorite and kaolinite. The samples from the W 0-series also contain a high percentage of calcite, which is sporadically present in the other series (table 2). The phosphate-minerals are not recognizable in the X.R.D.-analyses. The cause might be the cryptocrystalline character of the apatite (Collophane) or the presence of abundance of siderite. The latter has the main-line at the same places as apatite.

Table 2: The mineral content of some of the Dogger samples, obtained by X-ray diffrac-tion.

<table>
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<tr>
<th>Sample nr.</th>
<th>Mineral name</th>
<th>W 0-27</th>
<th>W 0-29</th>
<th>W I-1</th>
<th>W I-3a</th>
<th>W II-5</th>
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S.E.M. Results (photo 7 to 13)

Scanning Electron Microphotographs gave an impression of the relationship between detrital and authigenic phases, to mention:

- The corrosion of quartz grains in the siderite matrix (photo 7, 9).
- The structure of collophane grains. The cryptocrystalline state causes conchiform fracturing (photo 10, 11).
- Weathering of Alkali feldspar often gives formation of kaolinite-booklets (photo 12, 13).
- The siderite spherulites have a build up of concentric layers (photo 8) in a carbonate rich groundmass.

CONCLUSIONS

The petrology of the Dogger Formation at the east-cliffs, between Whitby harbour and Saltwick Nab, show a lateral variability in thickness and composition. Even on a small scale, as seen at Long Bight, this variability is present and pronounced in proportions between co-existing minerals.

The red colour of top layers C and D is caused by partial oxidation of siderite in haematite in the sedimentary environment. Subaerial conditions resulted into the red colour and possibly the inhomogeneous layering of the Top layer C and D. The grey colour of Dogger is diagnostic for shallow water filled depressions and basins. D.T.A. and X.R.D. results of the parts, where the top layers C and D are absent, show primary calcite in the mineral composition besides siderite.
Some samples suggest effects of volcanic activity, for instance:

- These rocks are highly cemented and contain angular fragments of high temperature minerals. These alkali feldspar grains are often unaltered or partly altered in presence of fully altered feldspar in general.
- The Dogger Formation is a product of uplift (block movement, erosion and sedimentation in shallow water during Toarcian and Bajocian time. Middle Jurassic Volcanism might be the origin of these pyroclasts.

Charcoal relicts are residues of bush fires. All remnants are fragments, replaced due to the complete reworking of Dogger sediments. Due to the high charcoal content of these sediments, it is thought that these were deposited in the vicinity of a non-marine environment.

RECOMMENDATIONS FOR FURTHER RESEARCH

The preliminary results clearly show that the usual and new techniques are required to obtain more mineralogical and chemical information. Presently trace-element analyses on samples of the Dogger Formation and adjacent layers are being performed. New X.R.D./D.T.A. analyses, microprobe analyses and thin sections are expected to give more information about the spatial distribution of minerals and elements.

ACKNOWLEDGEMENT

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Figure 3: D.T.A. and T.G. graphs of Dogger samples.
W 0-28: Top Dogger sandstone (layer B).
W II-9: Siderite concretion.
W III-14B: Shale on the Dogger/Lias boundary.

Figure 4: D.T.A. and T.G. graphs of Dogger samples.
W I-2A: Top Dogger (layer C).
W I-4c: Shale on the Dogger/Lias Boundary.
W I-4a: Siderite concretion.
Photo 8: Scanning Electron Microphotograph. Siderite spherulites. The concentric layering is clearly visible.

Photo 7: Scanning Electron Microphotograph. A corroded quartz grain in the siderite (spherulites) matrix.

Photo 6: Thin section I A1: Top Dogger layer C/D. A siderite matrix with some silt and a aggregate of collophane with kaolinite and illite inclusions.

Figure 5: An example of a X.R.D.-analyse at Dogger sample W 0-27: Bottom of sand layer B.
Photo 9: Scanning Electron Microphotograph. A detail of a corroded quartz grain in contact with the siderite matrix.

Photo 10: Scanning Electron Microphotograph. A collophane nodule (cryptocrystalline apatite) in contact with the siderite matrix.

Photo 11: Scanning Electron Microphotograph. A detail of a collophane/siderite contact. On the right side an idiomorphic alkali-feldspar grain is recognizable.


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Seit mehr als 90 Jahren lösen wir weltweit die kompliziertesten Bauaufgaben – seit mehr als 80 Jahren sind wir auch für den Bergbau tätig.


A HEITKAMP


Eynon, G.: Basin development and sedimentation in the Middle Jurassic of the Northern North Sea.

Perry, C. C. Integration of palynological and sedimentological methods in facies analyses of the Brent Formation.


