THE PRESERVATION OR REMOVAL OF SOLID BITUMINOUS MATERIAL, AS PART OF THE CORE ANALYSIS PROGRAMME ON THE ELGIN-FRANKLIN FIELD

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The Elgin and Franklin fields are situated 240 km east of Aberdeen, in the southern part of the Central Graben. A number of gas condensate discoveries have been made in the area within Jurassic and Triassic Sandstones. These reservoirs occur at considerable depth (>5000m) and are characterised by high pressures (>1000 bars) and high temperatures (up to 200°C). The Elgin structure lies within the 'Franklin Terrace' area, just to the north of the Franklin Field. Both structures have a predominant NW-SE orientation.

The Elgin and Franklin accumulations are typically very thick and extensive Upper Jurassic Franklin Sandstone sequences, large parts of which are highly porous and permeable. These sands occur within a large structural closure, which was probably charged by hydrocarbons during the early Tertiary. The Upper Jurassic and Lower Cretaceous Shales provide a highly efficient and effective seal. The seal has enabled gaseous fluids to be retained at extreme formation pressures, which approach the formation fracture strength in magnitude.

The high temperature that characterises the reservoirs is felt to have contributed to the degradation of the original liquid hydrocarbons. The end product of this thermal decay is pyrobitumen, found predominantly as pore wall linings. In addition, the extreme conditions lead to the formation of kerogen through the alteration of *in situ* plant material. The kerogen, by virtue of its source, forms discrete particles within the grain framework. In both cases the material is solid, generally amorphous, with a black to brown-black colouration.

The term "pyrobitumen" was first introduced by Abraham[1,2] who based his bitumen classification system on the analysis of chemical composition and physical properties. He distinguished four main groups of petroleum bitumens based on their thermal softening points. Pyrobitumen was judged to have no softening point and was classified as Asphaltic Pyrobitumina. The other key distinguishing feature of pyrobitumen flagged by Abraham is its insolubility in organic solvents. Asphalt and asphaltites are by contrast nearly 100% soluble in the same solvents. Kerogen is placed under the generic heading of pyrobitumen, as it is similar in character but different in origin.

The presence of pyrobitumen was noted during the petrographic analysis of the rock material from the second Elgin appraisal Well in 1994. Its impact on the planned Core Analysis programme was discussed in terms of possible mobilization during cleaning and drying. As Shaw[3] observes, pyrobitumen, whether pore lining or filling, can severely

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occlude porosity and reduce permeability. Therefore any disturbance and/or removal can alter the pore system and artificially enhance Gas Permeability, Porosity and Grain Density. It is assumed that in the field the pyrobitumen will remain in place and the subsequent mismatch in mineral content carries forward into the laboratory and well data sets.

The possibility of pyrobitumen removal was acknowledged to be remote, but it was felt necessary to confirm that the methods and solvents typically used in Conventional Core preparation would preserve rather than disrupt. To address the uncertainty, a comparative study was designed involving benign and harsh cleaning and drying cycles, coupled with staged petrophysical and petrographic data acquisition. The application of a contrasting Benign-Harsh core plug preparation routine provided a measure of the erosion and weathering of the bituminous coatings and grains. The positioning of the measurement phases at the end of each cycle allowed trends to be clearly established and quantified. The testing philosophy was to use extremes at each stage of the preparation process to both inhibit and encourage displacement.

The scope of each cycle, performed sequentially on the same sample set, may be described as follows:

· **Benign.** *Cleaning apparatus:* Corex Constant Immersion-Constant Replenishment Rig. Plugs constantly immersed in warm, clean solvent. Avoids repeated phase changes, increases residence time of solvent in pore system and continuously removes contaminated solvent. Capacity of 20 x 3.8 cm diameter plugs.
Solvents: Propan-2-ol (iso-propyl alcohol), $(CH_3)_2CHOH$, Boiling Point = 82.4°C, selected for its low BP, its affinity for oil and water and its inability to remove solid bitumens. Methanol, CH_4O, Boiling Point = 65°C, to remove salts.
Drying Regime: Humidity controlled oven, 60°C and 40% relative humidity. Selected for low temperature and maintenance of clay water.

· **Harsh.** *Cleaning apparatus:* Standard refluxing soxhlet extractor. Plugs subjected to repeated cycles of liquid immersion/hot vapour soak. Preferred method for minimizing turnaround as it is efficient, accommodates numerous plugs and recycles the solvent.
Solvents: Toluene, $C_6H_5CH_3$, Boiling Point = 110.6°C, selected for proven ability to remove most crudes. Methanol, CH_4O, Boiling Point = 65°C.
Drying Regime: Standard oven without humidity control, 95°C. Preferred for attaining constant weights within 48 hours.

The first screening exercise was performed on the second of two Elgin appraisal Wells, drilled and cored in 1994. A pair of plugs was taken at two locations within the core material, coloured black-brown by the pyrobitumen content and identified by the term "black core". The values for Gas Permeability, Porosity and Grain Density were determined at the end of the Benign and Harsh cycles and are presented in Table 1.

Running in tandem with the cleaning and drying of the plugs were offcut slices taken from the end face of each plug. Thin sections were prepared from a portion of the four slices, on completion of the benign and harsh cycles. A 200 point count was performed on the eight sections and the amount of bituminous grains and coatings was determined. The material of interest was found to be relatively abundant, with an average content of 17.3% after benign preparation. Following harsh cleaning and drying, the bituminous content in the second batch of thin sections had a mean value of 13.3%.

Table 1 - Contrasting Permeability, Porosity and Grain Density Data Sets, Initial Screening

Sample	Gas Permeability (mD)		Porosity (%)		Grain Density (g/cc)	
	Benign	Harsh	Benign	Harsh	Benign	Harsh
1A	29.72	29.89	19.83	20.49	2.661	2.673
1B	40.74	40.77	20.42	21.01	2.657	2.670
2A	18.65	19.76	17.78	18.31	2.606	2.616
2B	18.66	19.53	17.81	18.46	2.600	2.615

It is clear from the data sets that there was an overall rise in the petrophysical parameters and a decrease of the pyrobitumen between cycles. Such a pattern would seem to indicate the combination of toluene, refluxing soxhlet and high temperature drying was successful in removing a minor amount of the supposedly insoluble solid bituminous material untouched by the benign sequence. However, the percentage changes for the petrophysical values are below or slightly larger than the reproducible limits attributed to the measurement techniques. For example, porosity is set at ±0.02 porosity percent and gas permeability at ±4%. Subsequent geochemical analysis performed on a development Well detected traces of waxy alkanes in the molecular range nC25 to nC35 and it possible is that the minor increases in the petrophysical parameters may be related to its preservation under the benign regime and removal by harsh cleaning. Point counting below 300 sites is semi-quantitative and relies upon the technician to select a representative portion of the slide for examination. The average variation at 4% was judged to be within the repeatability limits of the technique.

It was concluded that there was insufficient evidence to confirm that the preparation technique generally employed for the rapid turnaround required, as part of a Conventional Core programme, would adversely impact the quality of the generated data. However, to maintain user confidence, a Benign-Harsh control was applied to all cores taken as part of the Elgin-Franklin development. Plugs were cut at variable depth intervals, typically 1 per 2 metres and each suite was subjected to the aforementioned multistage cleaning and drying regimes. The permeability, porosity and grain density values were measured at the end of each cycle and these were routinely compared to confirm the maintenance of the mineralogical content. If any divergence from the predicted pattern was detected, the preparation of the main body of plugs would have been suspended pending detailed laboratory investigation.

The analysis of the comparative data sets for two of the Wells cut in 1997 and 1998 from Block 22/30c are presented in Table 2 and Figures 1 to 3, to illustrate the level of measured change between stages.

Table 2 - Contrasting Permeability, Porosity and Grain Density Data Sets, Two Control Examples

Well	Number of Plugs in Control Suite	Average Variation between Benign and Harsh Cycles		
		Gas Permeability (% variation)	Porosity (porosity % variation)	Grain Density (g/cc variation)
1	628	1.07	0.45	0.009
2	37	1.27	0.56	0.010

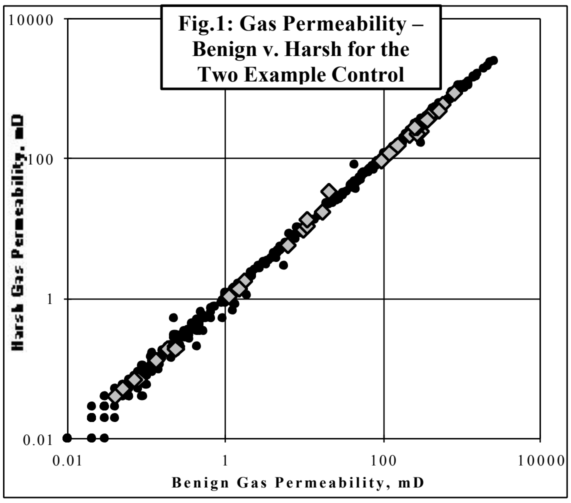

Fig.1: Gas Permeability – Benign v. Harsh for the Two Example Control

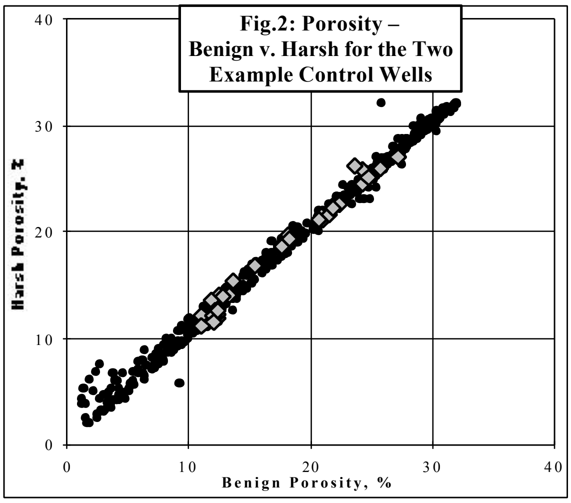

Fig.2: Porosity – Benign v. Harsh for the Two Example Control Wells

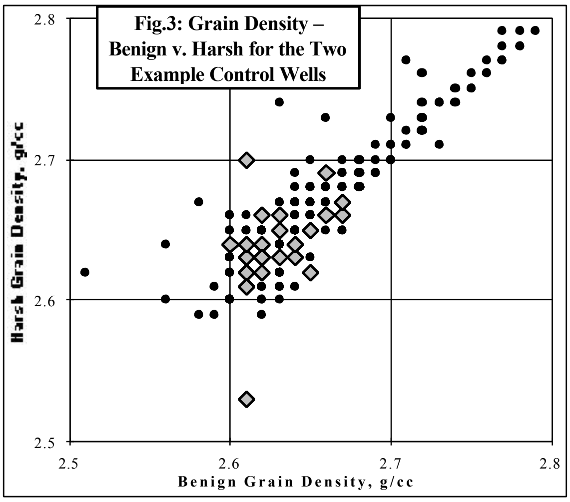

Fig.3: Grain Density – Benign v. Harsh for the Two Example Control Wells

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