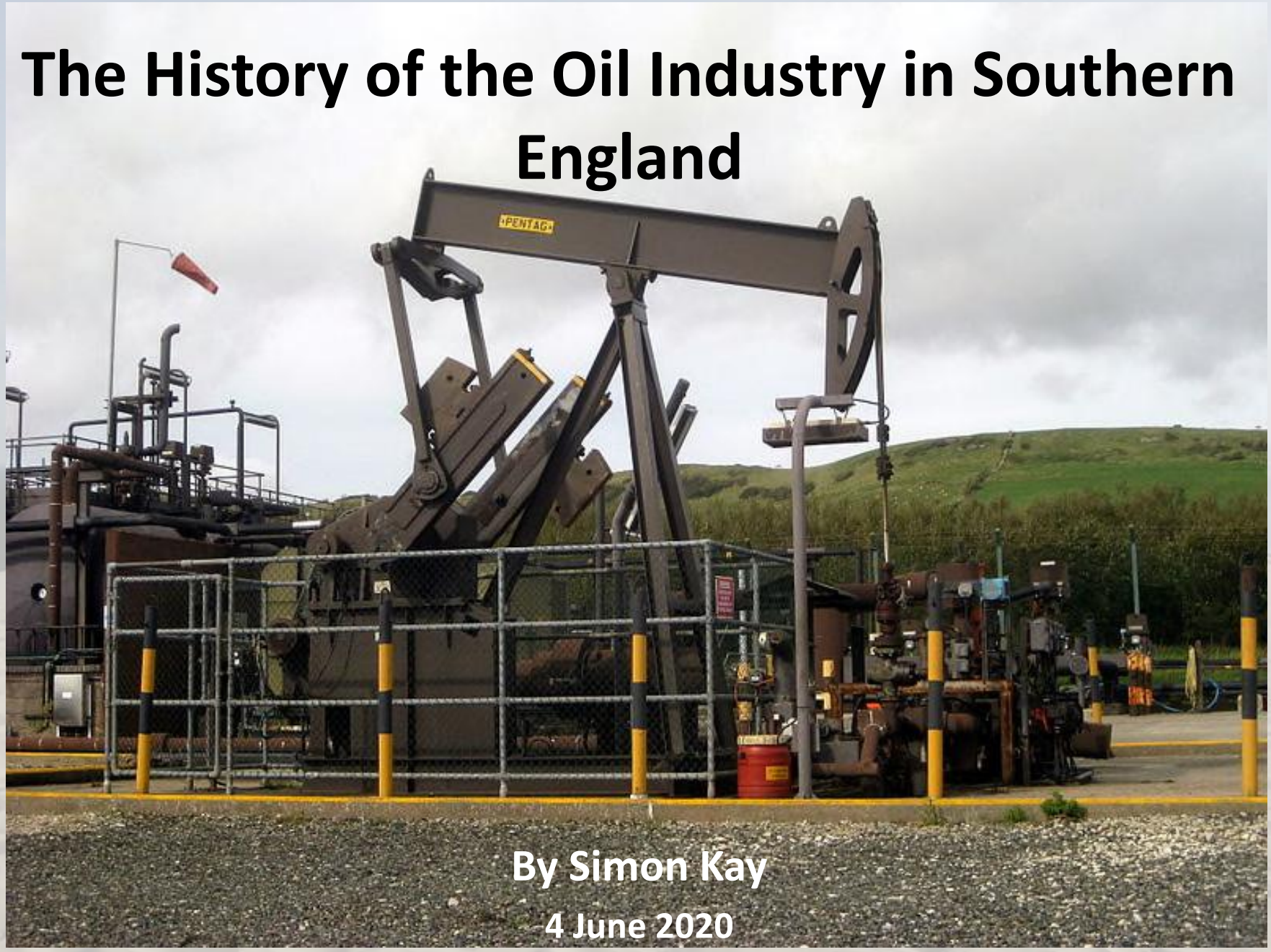
The History of the Oil Industry in Southern England



By Simon Kay

4 June 2020

Overview

- In this talk, Southern England means (mostly) onshore Dorset (Wessex Basin), Hampshire, Somerset and Wiltshire. The Weald Basin (West and East Sussex) also has a long history of oil and gas exploration and will be touched on also

- Introduction – Some oilfield facts and concepts

- UK oil and gas fields - where does the oil come from?

- Mining for oil

- Drilling for oil – around 2,000 wells have been drilled onshore UK for oil and gas exploration. Approx 10% of these have been hydraulically fractured. Today between 20,000 and 25,000 barrels of oil per day are produced from 250 wells spread across 120 fields – ONSHORE!

- The future

Oilfield Units

- Crude oil volumes are commonly quoted in BARRELS (bbl)
- **1 barrel = 42 US liquid gallons = 35 UK gallons**
- The US barrel volume arose from 40-gallon whiskey barrels and 42-gallon wine *tierce* barrels used to transport oil from the Pennsylvania oilfields of the 1860s
- Fully metric countries use CUBIC METRES (m^3) or TONNES
- 1 m^3 = 1 tonne of oil approx = 6 to 8 barrels approx (depending on oil density)

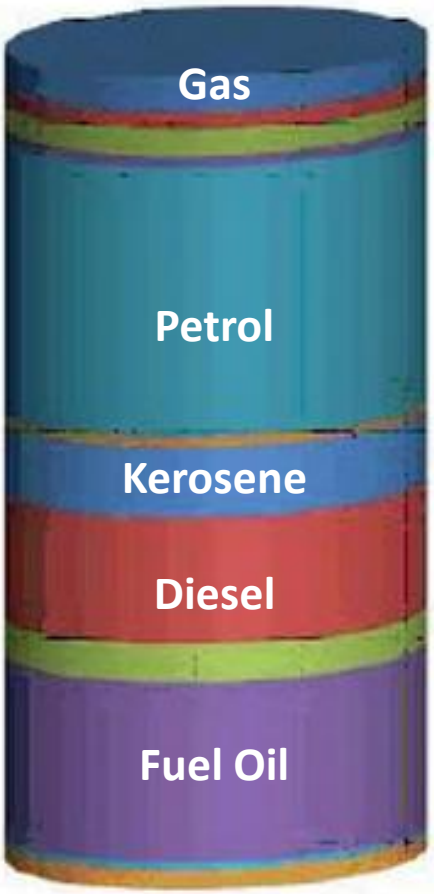
"Colonel" Edwin Drake (top hat) at the first oil well in Pennsylvania, 1859

Who Produces the Most Oil?

- **World production in 2018**
- **4,474 million tonnes produced in total**
- **UK produced 1.1% (same as Libya) – no longer self-sufficient**
- **Oil occurrence is very widespread, but only 99 out of 216 countries have significant oil reserves. Countries with large economies but no oil include: Sweden, Switzerland, South Korea. Others with hardly any include Japan, France, Germany, Italy, Spain**
- **Source: BP Statistical Review of World Energy June 2019**

Position	Country	% World Production
1	USA	16.2
2	Saudi Arabia	13.0
3	Russia	12.1
4	Canada	5.5
5	Iran	5.0
6	Iraq	4.9
7	UAE	4.2
8	China	4.0
9	Kuwait	3.2
10	Brazil	2.8
11	Mexico	2.2
12	Nigeria	2.2
13	Norway	1.9
14	Venezuela	1.6
15	Angola	1.6
	Others	19.6

What's in a Barrel?



- Gases 4-5.5%
- LPGs 2-3%
- Naptha 2-5%
- Solvents 1.5-1.5%
- Gasoline 25-50%
- Kerosene 1-1.5%
- Jet Kerosene 7-12%
- Diesel 10-25%
- Gas Oil 5-5%
- Fuel Oil 10-40%
- Lubes 1-1%

Light – low density and low boiling point

Heavy – high density and high boiling point

Source: http://www.gasandoil.com/

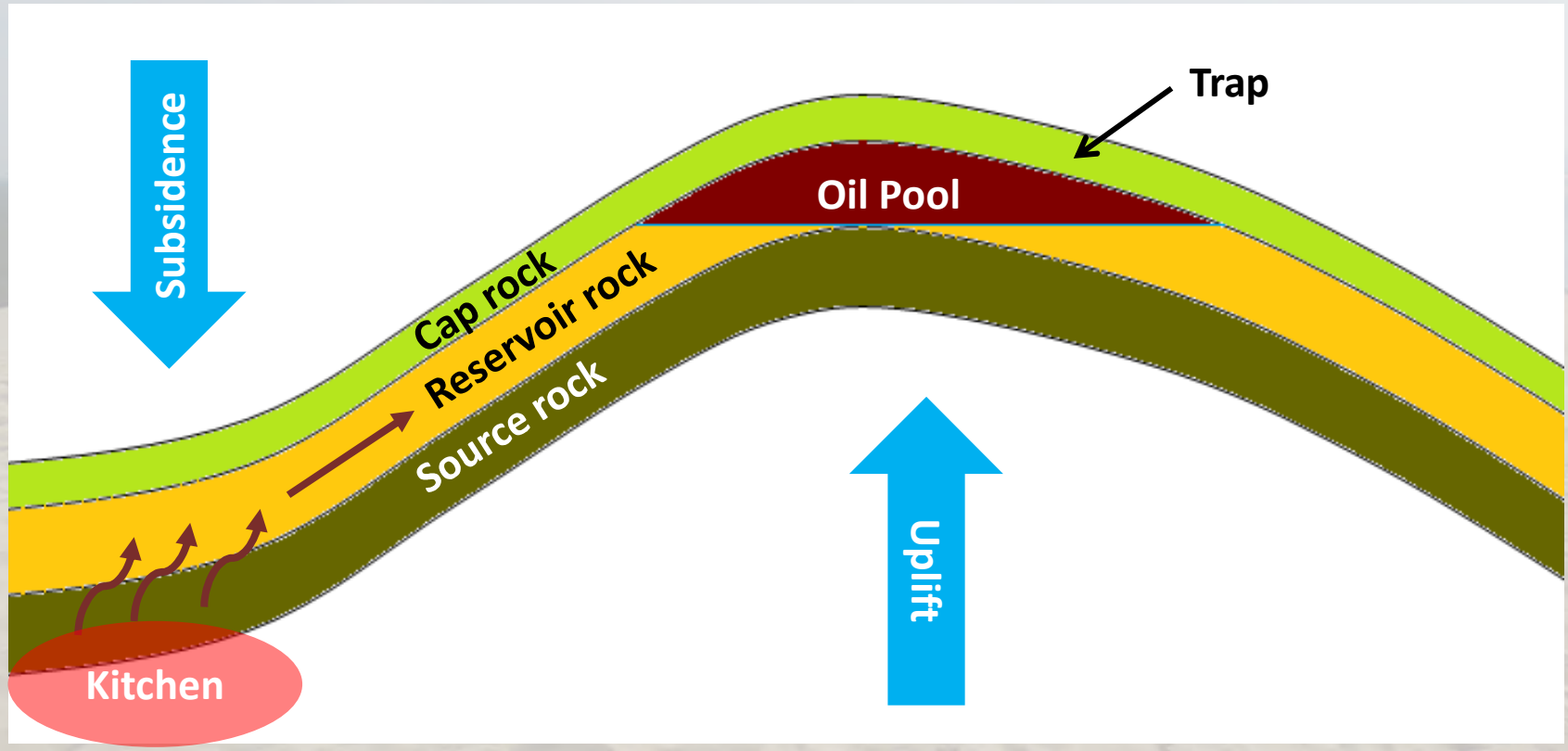
The First UK Well to Discover Shale Oil & Gas

THE SUB-WEALDEN EXPLORATION IN SUSSEX—BORING AT NETHERFIELD

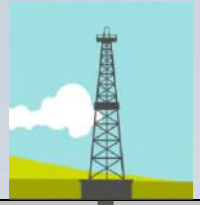
- 1875 – Netherfield No. 1 drilled in East Sussex, in the Weald
- The well found oil and gas in naturally-fractured Kimmeridge shales and limestones
- This was a ‘nuisance’ because the well was drilled for research purposes, not to find oil or gas

Important Concepts

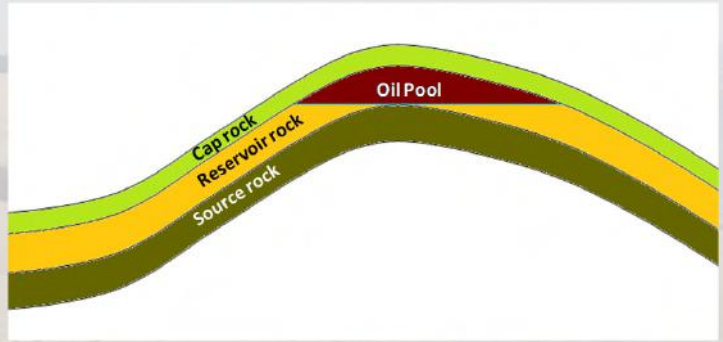
- Source rock, reservoir rock and cap rock – in a trap configuration
- Rock formations are water-saturated and oil replaces water
- Oil kitchen depth >2,000m (>100^{o}C)
- Oil trap depth >1,000m (>60^{o}C)



Source, Reservoir and Cap Rocks in Southern England



Geological Time Period	Rock Formation	Source Rock	Reservoir Rock	Cap Rock
Upper Jurassic	Kimmeridge Clay	Oil		Mudstone
	Corallian			
Middle Jurassic	Oxford Clay	Oil		Mudstone
	Kellaways Beds			
	Cornbrash		Limestone	
	Forest Marble			
	Chalfield Oolite		Limestone	
	Fullers Earth			Mudstone
	Inferior Oolite		Limestone	
Lower Jurassic	Bridport Sands		Sandstone	
	Liassic Clays	Oil		Mudstone
Triassic	Mercia Mudstone			Mudstone/Salt
	Sherwood Sandstone		Sandstone	
Permian	Aylesbeare Mudstone			Mudstone
Carboniferous	Coal Measures	Gas		
	Carboniferous Limestone			

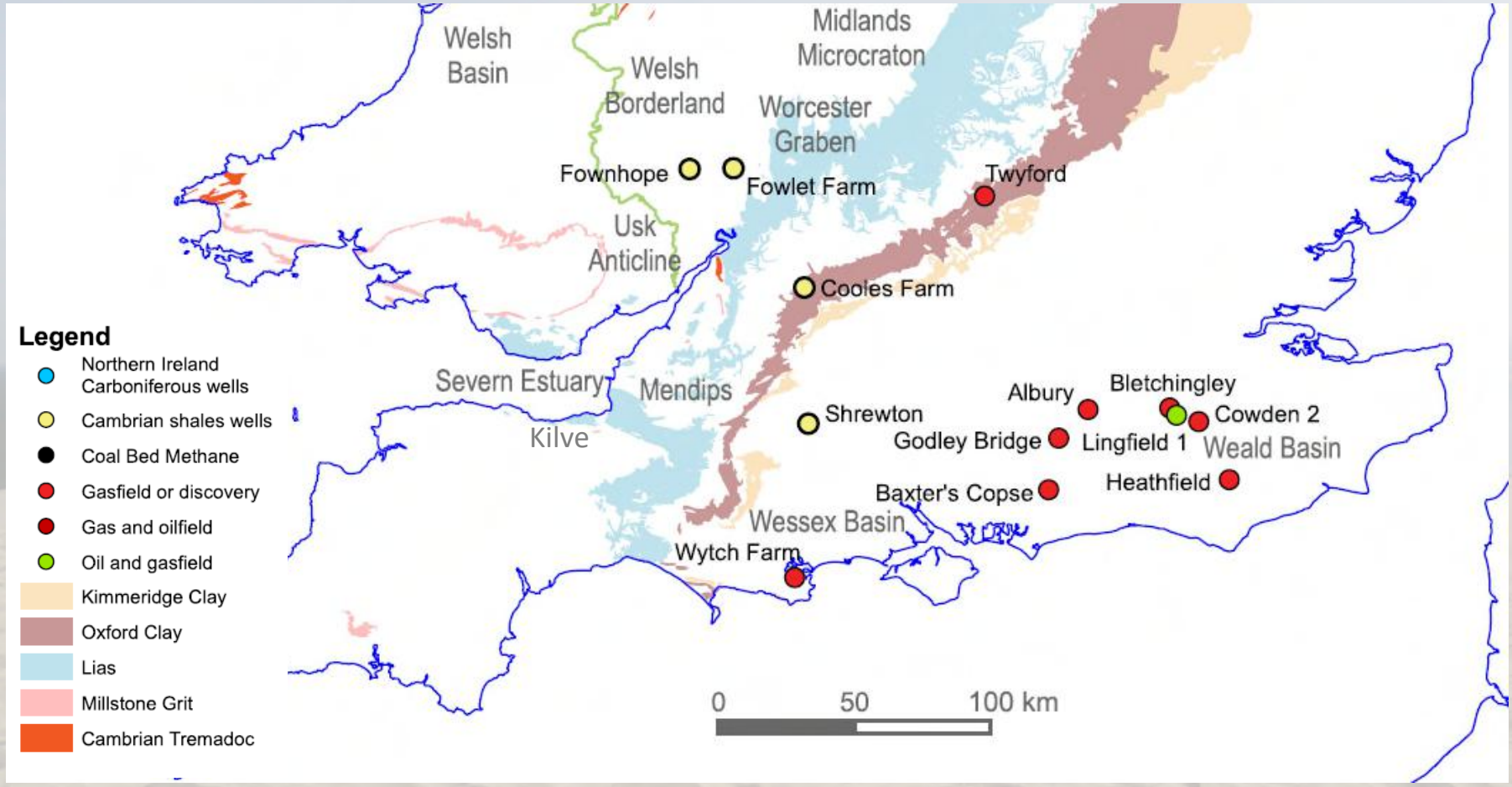


UK Oil and Gas Fields - Where does the oil come from?

- Most of the largest fields are offshore, and
  - Most oil in the North Sea comes from the **Kimmeridge Clay Formation (KCF)** source rock
  - The KCF was deposited 140 MY ago in deep narrow marine basins. Lack of oxygen allowed preservation of planktonic organic material
  - The KCF was buried deep enough to heat it to between 60^{o}C and 120^{o}C and convert organic matter to oil
  - Oil generation commenced ~ 60 MY ago in the early Tertiary, and still continues in some areas today
  - The gas fields contain gas that has mostly been sourced from coals or where the KCF and similar units have been heated to greater than 140^{o}C in the subsurface

- **Numerous smaller oilfields exist onshore and contain oil generated from the KCF (Weald) but more importantly the Liassic (Dorset, Hampshire) and late Carboniferous oil shales (East Midlands, Northern England)**

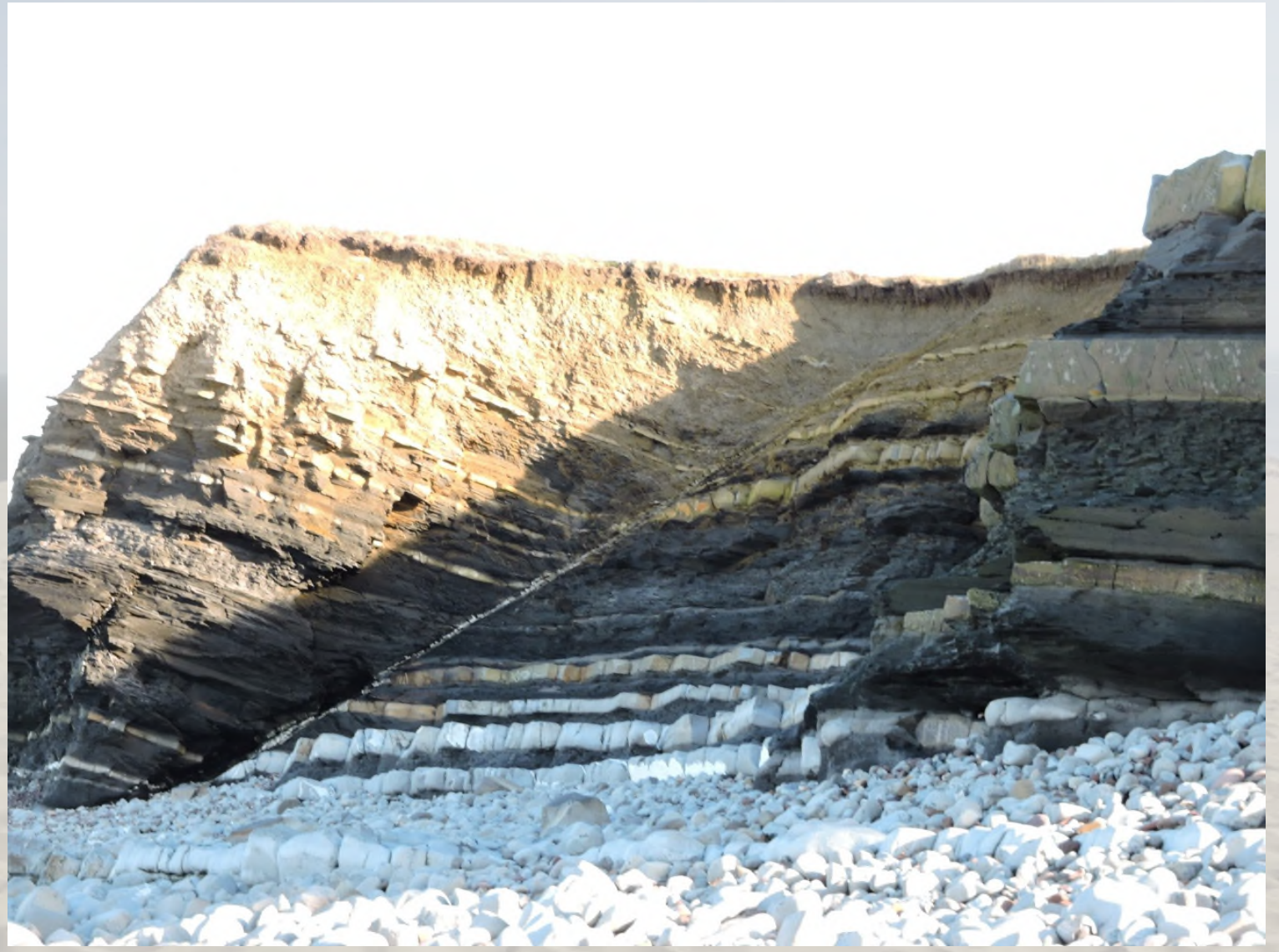
Oil Source Rocks in Southern England



Map from Smith, N., Turner, P. and Williams, G. Proceedings of the 7th Petroleum Geology Conference, 2010. Geological Society, London

Source Rocks – Kimmeridge Clay

Source Rocks – Kilve Blue Lias



Reservoir Rocks - Cornbrash

PART OF THE UPPER CORNBRASH, CALLOVIAN, ON THE SHORES OF THE FLEET LAGOON AT BUTTERSTREET COVE.
This fossiliferous limestone contains the zonal ammonite, Macrocephalites, here, but the exposures are limited in size. The Cornbrash attains a total thickness of 18.2 metres in a borehole at Sea Barn Farm, about 1 km. northwest. Fractured Cornbrash is the reservoir rock at Kimmeridge No. 1 oil well, where the limestone is 27 metres thick. Photograph: 5th August 2005. Ian West (c) 2010.

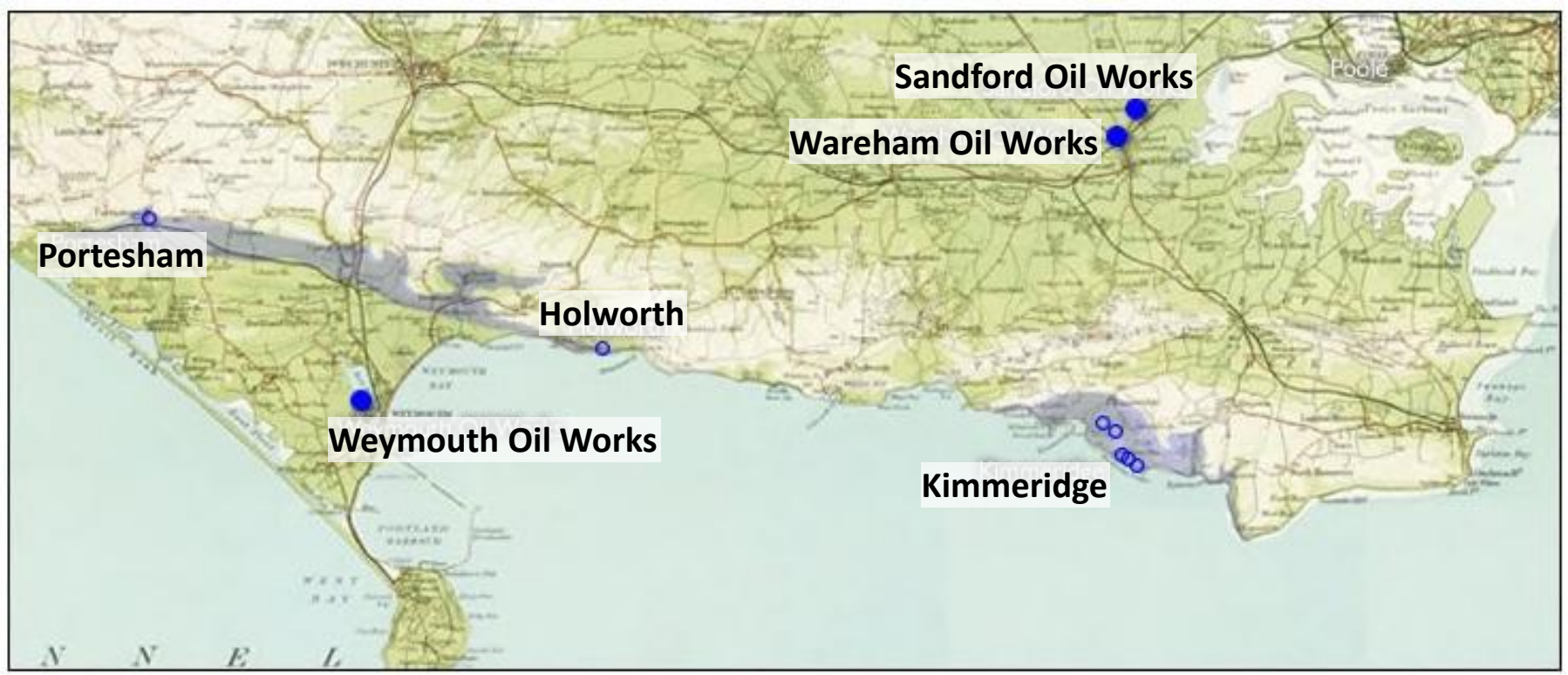
Reservoir Rocks – Bridport Sandstone

Reservoir Rocks – Sherwood Sandstone

Mining for Oil vs Drilling for Oil

- Early oil production was by mining oil shales (oil source rock), heating in retorts to extract the oil, then refining the product. Very inefficient and messy
- Drilling usually targets a reservoir rock containing oil that will flow without the need to extract and retort the rock
- Modern “unconventional” oil production marks a return to targeting the source rock, this time by drilling

Mining for Oil in Kimmeridge Bay



The Dorset coast, showing sites associated with the shale oil industry, and with areas of Kimmeridge shale shaded blue.

The Dorset Kimmeridge oil shales are part of the Kimmeridge Clay Formation, outcropping in the grey-shaded areas

Source: https://www.scottishshale.co.uk/GazBeyond/BSEnglandShale/BSES_Dorset.html

Properties of Kimmeridge Shale

- Up to 70% oily organic matter
- The rock has not been buried deeply enough to force the oil out – it is thermally immature
- Oil yield averages 20 gallons oil/ton of rock, maximum yield 120 gallons/ton
- Shale is heated to 500^{o}C to generate oil
- The oil has a high sulphur, hydrogen sulphide and ammonia content, liberated when retorted
- Sulphur is present as pyrite (iron sulphide) and organic sulphur compounds
- Hydrogen sulphide yield can be reduced by not heating above 200^{o}C (steam extraction)
- The sulphurous nature of the Kimmeridge oil made it unsaleable!

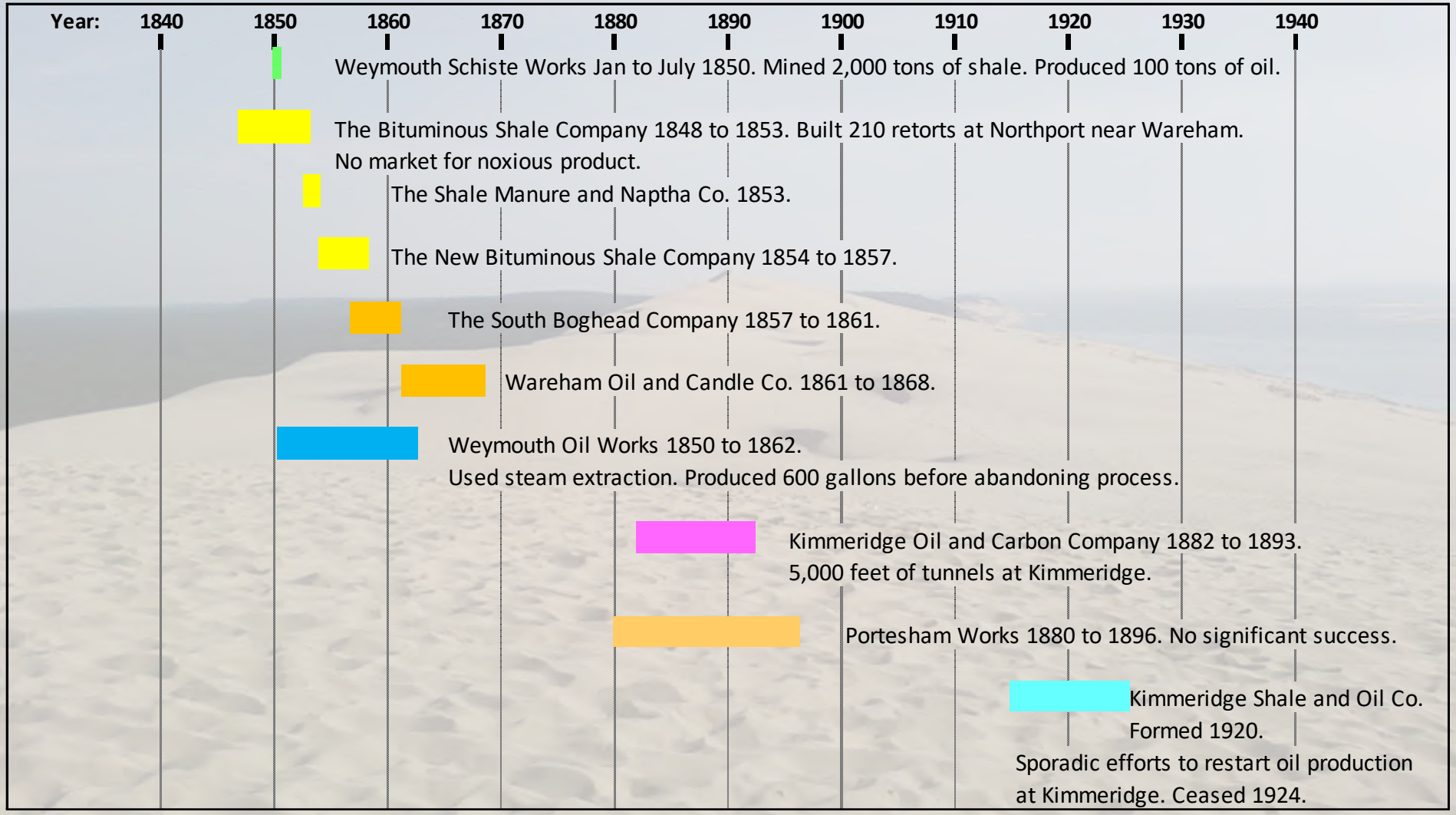
Source: https://www.scottishshale.co.uk/GazBeyond/BSEnglandShale/BSES_Dorset.html

Kimmeridge Shale can Burn!

Early Uses of Kimmeridge Shales

- Kimmeridge “Blackstone” or “Coal” – a hard, black rock similar to jet or anthracite – comprises a small proportion of the shales and is hard to find, having been mined out
  - Blackstone was carved into bracelets and jewellery in the Iron Age. It took a high polish. Waste circular discs were known as ‘Kimmeridge Pennies’
  - Sir William Clavell, in the early 17th Century, used the blackstone to fuel glass-making furnaces. Remains of the furnaces were excavated in 1980 at Kimmeridge Bay
  - In 1849 commercial mining began. Oil extracted from the shales was used to make varnish, paint, lubricating grease, pitch and paraffin

Mining for Oil in Kimmeridge Bay



Source: https://www.scottishshale.co.uk/GazBeyond/BSEnglandShale/BSES_Dorset.html

The Kimmeridge Oil and Carbon Company – 1882 to 1893

The mining ledge at Clavell's Hard, probably in the 1890's from Strachan

The Kimmeridge Oil and Carbon Company – Today

WORKED-OUT OIL SHALE AND COLLAPSED MINE WITH RAILS AND WAGGON, KIMMERIDGE, DORSET.
This is No. 2 Level of the 1890s. The formerly buried waggon, still on its rails, has been recently exposed by cliff erosion.

Photo by Ian West

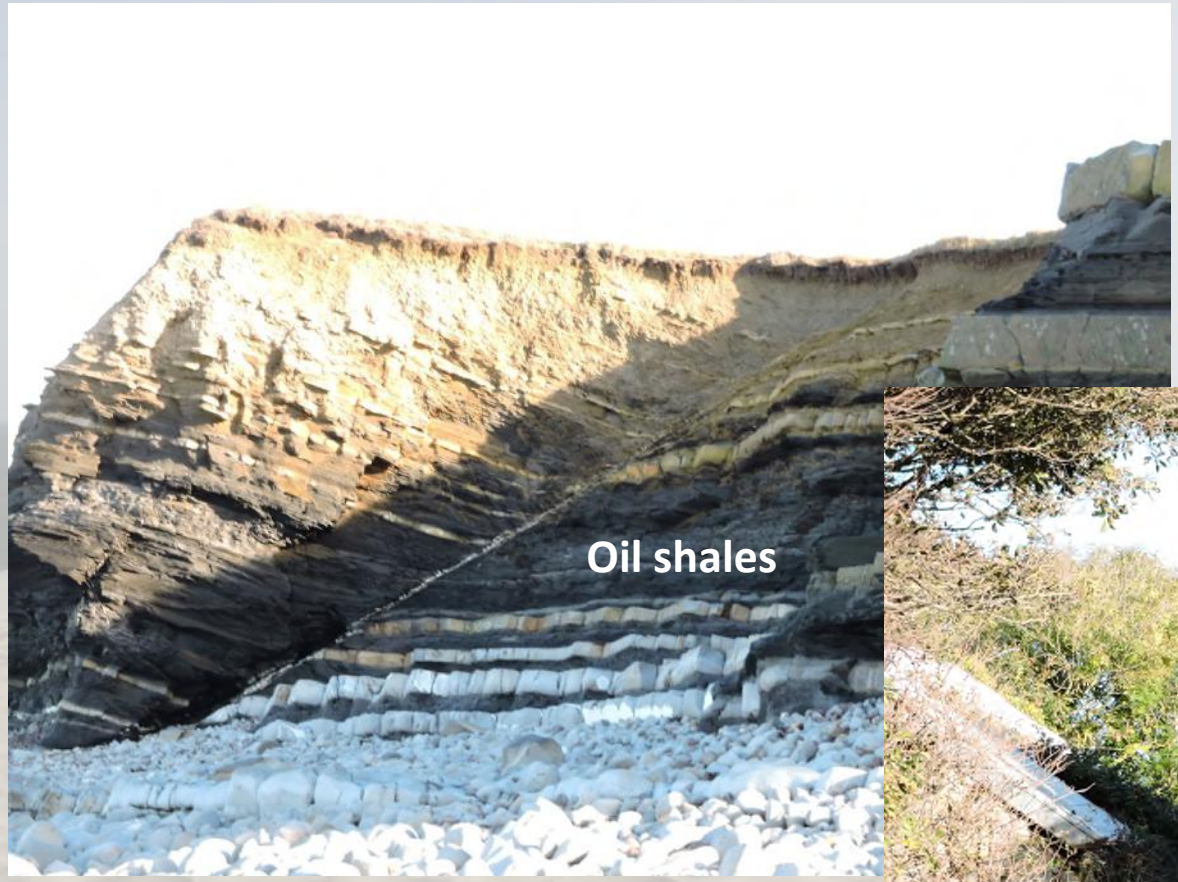
Kimmeridge Bay – Reasons for Failure

- Unpleasant sulphurous smell
- Large volumes of waste rock. Marketed as “manure” but no takers
- Expensive to extract and process
- Transportation difficulties – various railway projects came to naught and the shale had to be transported to the oil works by horse and cart
- Legal difficulties including patent infringement and fraud
- Scotland had a better product:
  - Scottish oil shales (“boghead” or “cannel” coal) were high yield and low sulphur
  - Dr James Young (1811-1883) patented the retorting and refining processes necessary to extract crude oil from oil shales and paraffin from the crude oil. He built the World’s first oil refinery in Scotland
  - The South Boghead Company tried to capitalise on the good name of Scottish boghead coal to sell the high sulphur KCF shale oil. They even imported the Scottish rock to retort in Dorset at the Wareham Oil works. James Young sued to prevent this. The company went bankrupt in 1861.

Kilve in Somerset

- On the coast, east of Watchet
- Liassic oil shales outcrop on the beach
- A borehole near Kilve Priory in 1923 encountered shales with an oil yield of 40 gallons per ton
- The Shaline Company Limited – 1924 to 1925 – established by Dr Forbes Leslie
- One experimental retort
- Another confidence trick with extravagant claims made by Dr Forbes Leslie
- Some oil was produced from the single retort but yields were low and investors could not be found to push the project forwards
- Kilve area was offered for licence applications in 2014/2015.

Kilve in Somerset

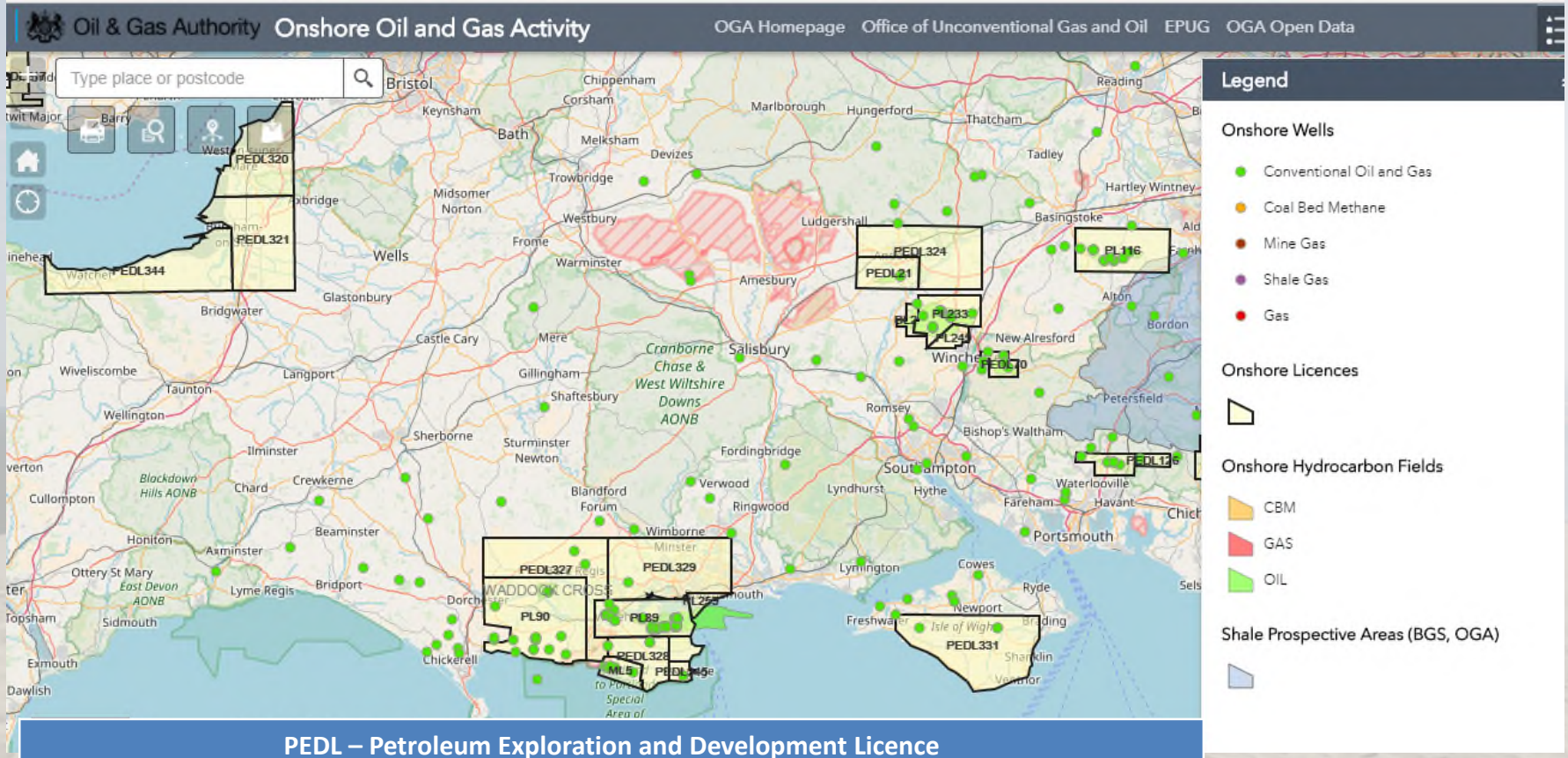


Photos by Alex Kay

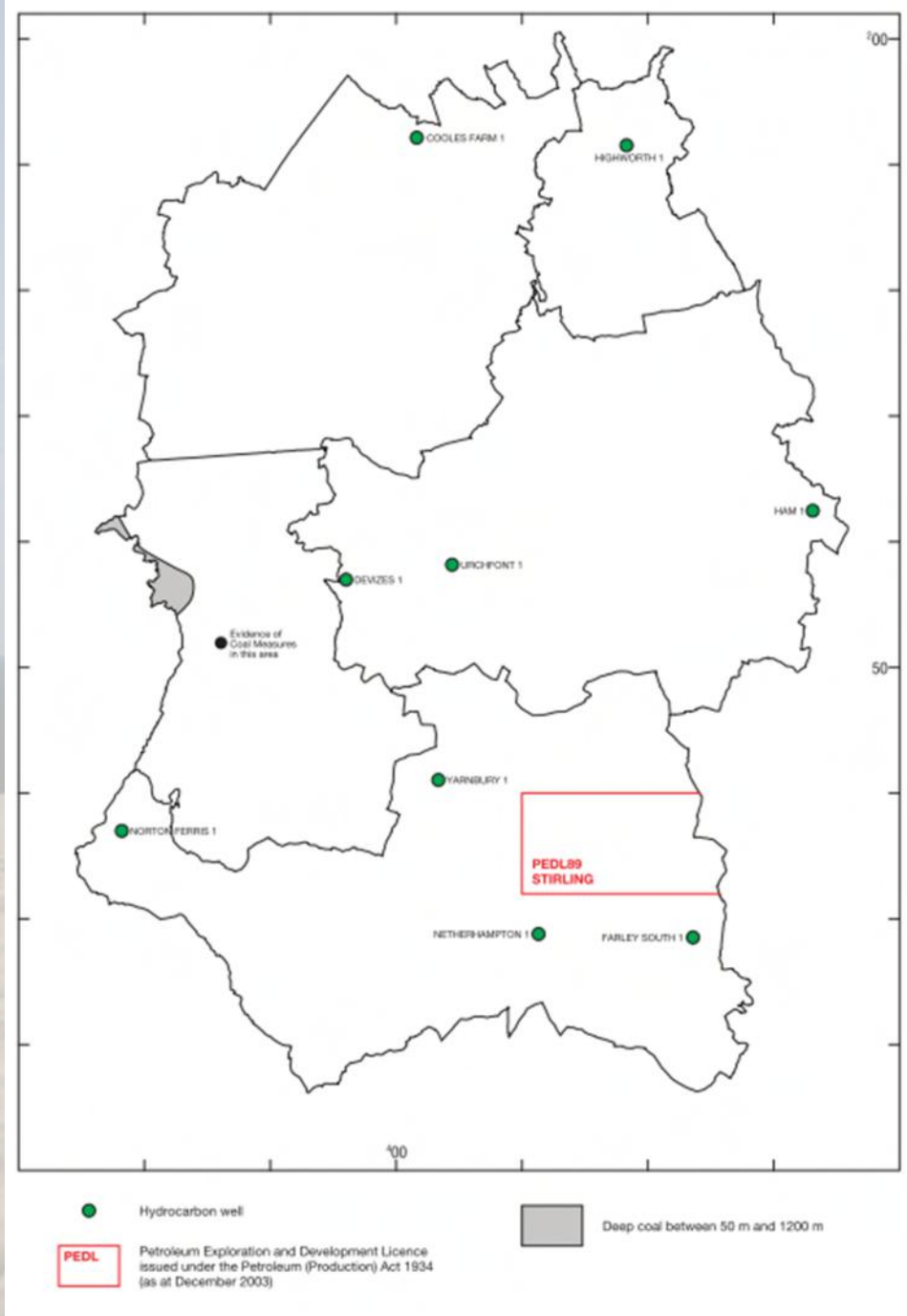
Drilling for Oil – Somerset and Wiltshire

County	Activity
Somerset	**2014** Area around Kilve offered for licences (3 PEDLs). Licensee - South Western Energy Limited. No wells drilled to date. Note: Somerset is not officially listed as ever having had a single oil well drilled! Target may be deeper Carboniferous Shales – The Avon Group below Carboniferous Limestone, not the Lias.
Wiltshire	**1936 to 1986** 9 wells drilled. Most recently by BP in 1986 at Urchfont near Devizes. Nothing found. **2014** 4 licences offered in Wiltshire for coal bed methane. Applicant (South Western Energy Limited) subsequently declined to take them up.

14th Licence Round 2014



PEDL – Petroleum Exploration and Development Licence		
Term	**Duration**	**Commitment**
Initial* Start 2016	5 years	Conduct agreed exploration work programme
Second	5 years	Appraisal and development. Agree development plan
Third	20 years	Production
*Mandatory relinquishment at end of initial term – usually 50%		



Wells Drilled in Wiltshire

Well	Year Drilled
Ham-1	1936
Devizes-1	1972
Cooles Farm-1	1975
Highworth-1	1976
Yarnbury-1	1980
Fairley South-1	1980
Norton Ferris-1	1985
Netherhampton-1	1985
Urchfont-1	1986

Results: No significant oil or gas found

Why?:

- No mature source rock
- No coal for gas source except in grey-shaded area

Wiltshire Recent Activity

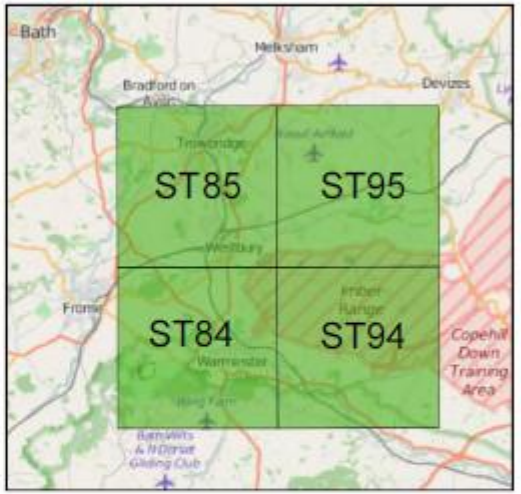
Wiltshire

•4 licence blocks offered in 2015 which encompass Westbury, Warminster, Trowbridge and parts of Bradford on Avon

•Target is **coal bed methane**

• South Western Energy (SWE) applied for these blocks, but later declined to take them on, due to high risk of not finding any hydrocarbons

•SWE did accept licences around Kilve and in Dorset



Wiltshire Council
Where everybody matters

Drilling for Oil - Dorset

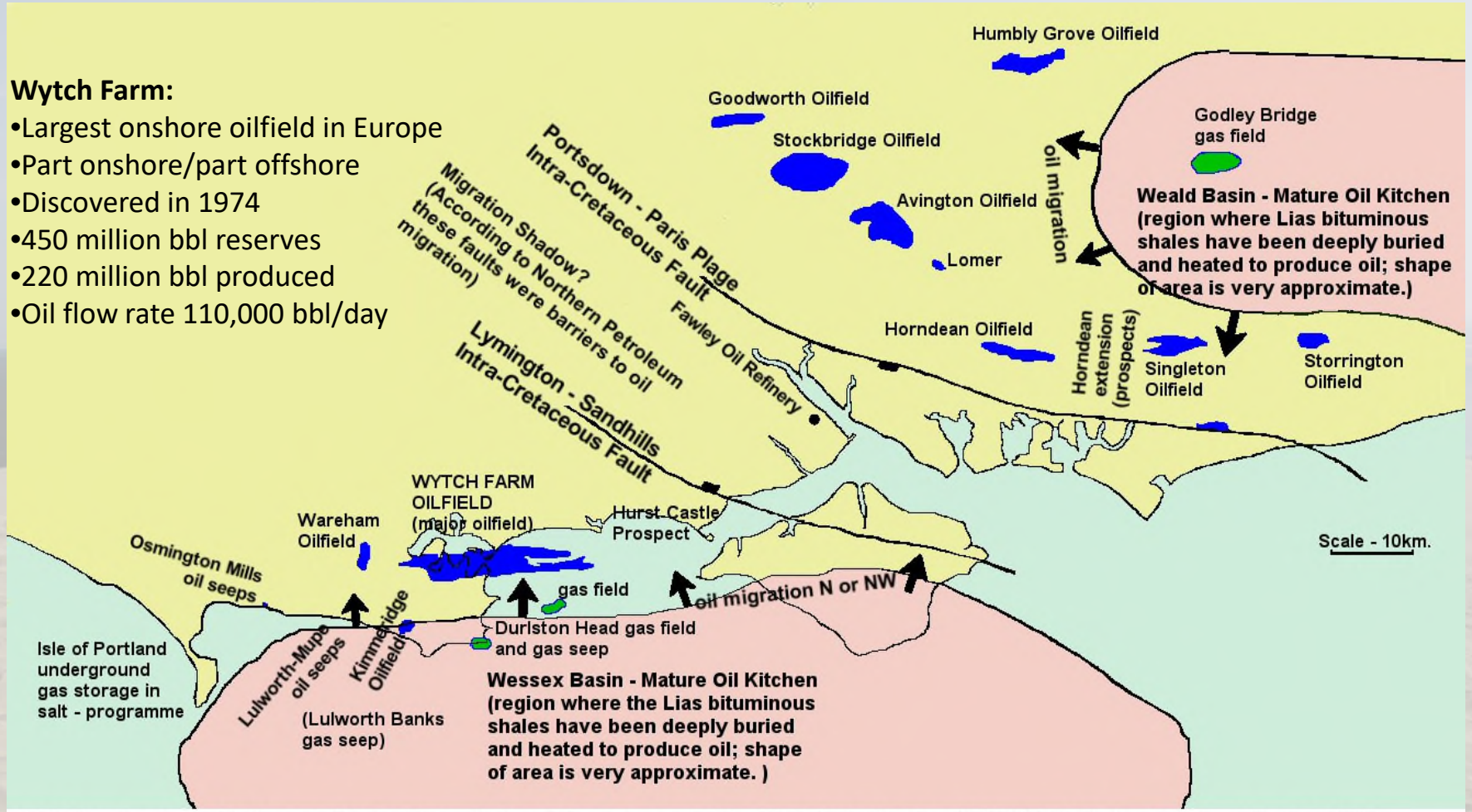
Year	Activity	Result
1934	Petroleum Production Act	Stimulated the search for new oil pools
1959	5 wells drilled at Kimmeridge Bay	Discovery of oil. Only one well produces oil. **Source rock:** Liassic shales – same as Kilve shales. **Reservoir rock:** fractured Cornbrash limestone. **3.5 million** barrels oil reserves
1964	Drilling at Wareham	Wareham oilfield discovered (produced 100 barrels of oil/day from 1970 and tied into Wytch Farm in 1991). 2 producing wells. **Reservoir rocks:** Inferior Oolite and Bridport Sandstone
1965	UK's first offshore well drilled on Lulworth Banks by BP	Unsuccessful. However, the experience helped BP discover Britain's first offshore field – the West Sole gas field – later this year
1974	Drilling at Wytch Farm by British Gas in partnership with BP	Discovery of Wytch Farm oilfield . **Reservoir rocks:** Bridport Sandstone and underlying Sherwood Sandstone. **450 million** barrels oil reserves – 10th largest UK oilfield
1989	BP drills a well from Southard Quarry near Swanage to target gas in the Durlston Head gas field.	Well finds gas. **Reservoir rock:** Sherwood Sandstone.
1993	BP decides to drill extended reach wells at Wytch Farm to avoid having to build artificial islands in Poole Harbour.	Wells have been drilled more than 10 km long to access the Sherwood Sandstone.
2011 to 2018	BP sells Wytch Farm to Perenco (an independent European company)	Continued production of 18,000 barrels of oil per day. Perenco continues to drill wells in Wytch Farm
2014 to 2020	Multiple licences granted for oil exploration in Dorset and Isle of Wight	Planning application submitted for drilling Arreton discovery on Isle of Wight (UK Oil & Gas Ltd) in March 2020. Reservoirs: Purbeck, Portland and Inferior Oolite.

Drilling for Oil – Hampshire

County	Activity
Hampshire	West part of the Weald Basin. A number of oilfields discovered in the **Chalfield Oolite reservoir** (limestone): **1980** Humbley Grove **13 million** barrels reserves **1983** Horndean **10 million** barrels reserves **1984** Stockbridge **50 million** barrels reserves. Most recent wells in 2015 **1986** Storrington **3 million** barrels reserves **2018** Work ongoing on Godley Bridge oil and gas field (gas in **Portland sandstone**, oil in **Kimmeridge limestone** in fractured rock. Operator UK Oil & Gas intend to drill an exploration well nearby in late 2020

Dorset and Hampshire Fields

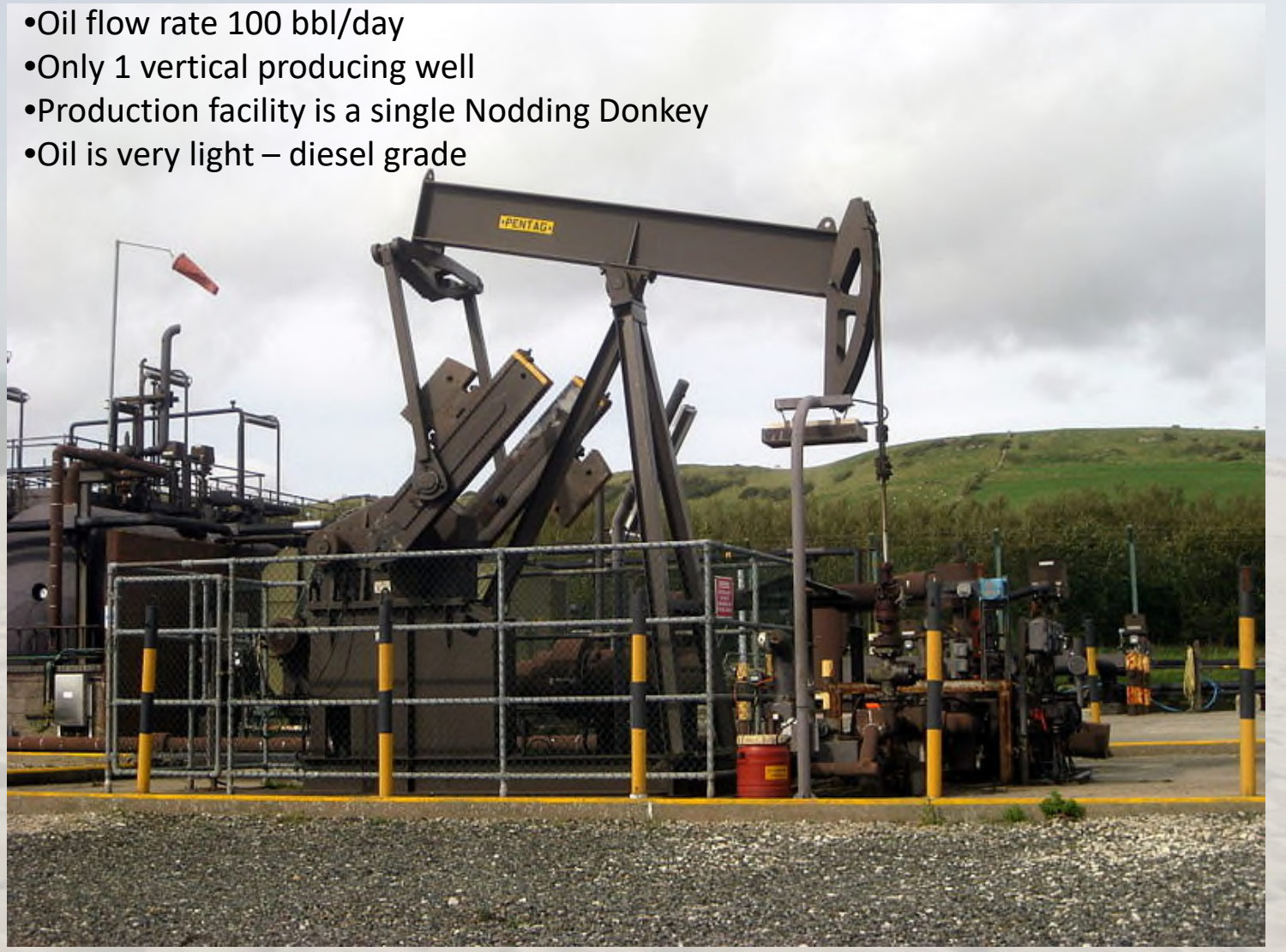
Wytch Farm:
- Largest onshore oilfield in Europe
- Part onshore/part offshore
- Discovered in 1974
- 450 million bbl reserves
- 220 million bbl produced
- Oil flow rate 110,000 bbl/day



Oilfields and surface indications of oil in the Wessex Basin and the western part of the Weald Basin. Based on BERR (2008), Marinex Petroleum Limited (1980), Northern Petroleum (website) and other sources. This is schematic and simplified and should not be regarded as geographically precise. Refer to specific publications on individual oilfields for detailed information. *Ian West and Tonya West (c) 2008.*

Kimmeridge Bay

- Oil flow rate 100 bbl/day
- Only 1 vertical producing well
- Production facility is a single Nodding Donkey
- Oil is very light – diesel grade

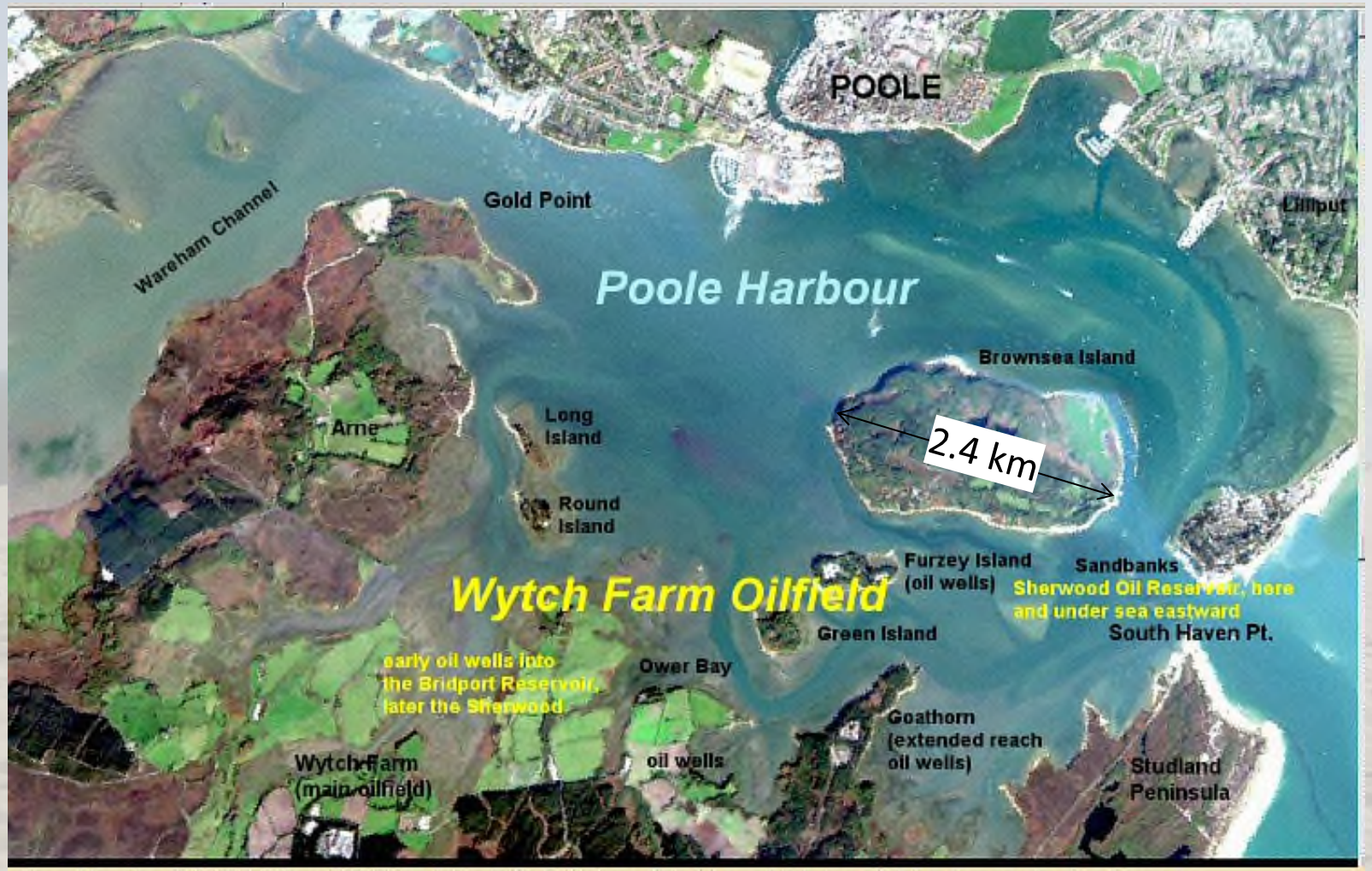


Kimmeridge Bay

- Onshore (just) oilfield discovered in 1959
- Reservoir is fractured limestone, 500m below sea level
- 3.5 million bbl reserves, of which 3 million bbl have been produced

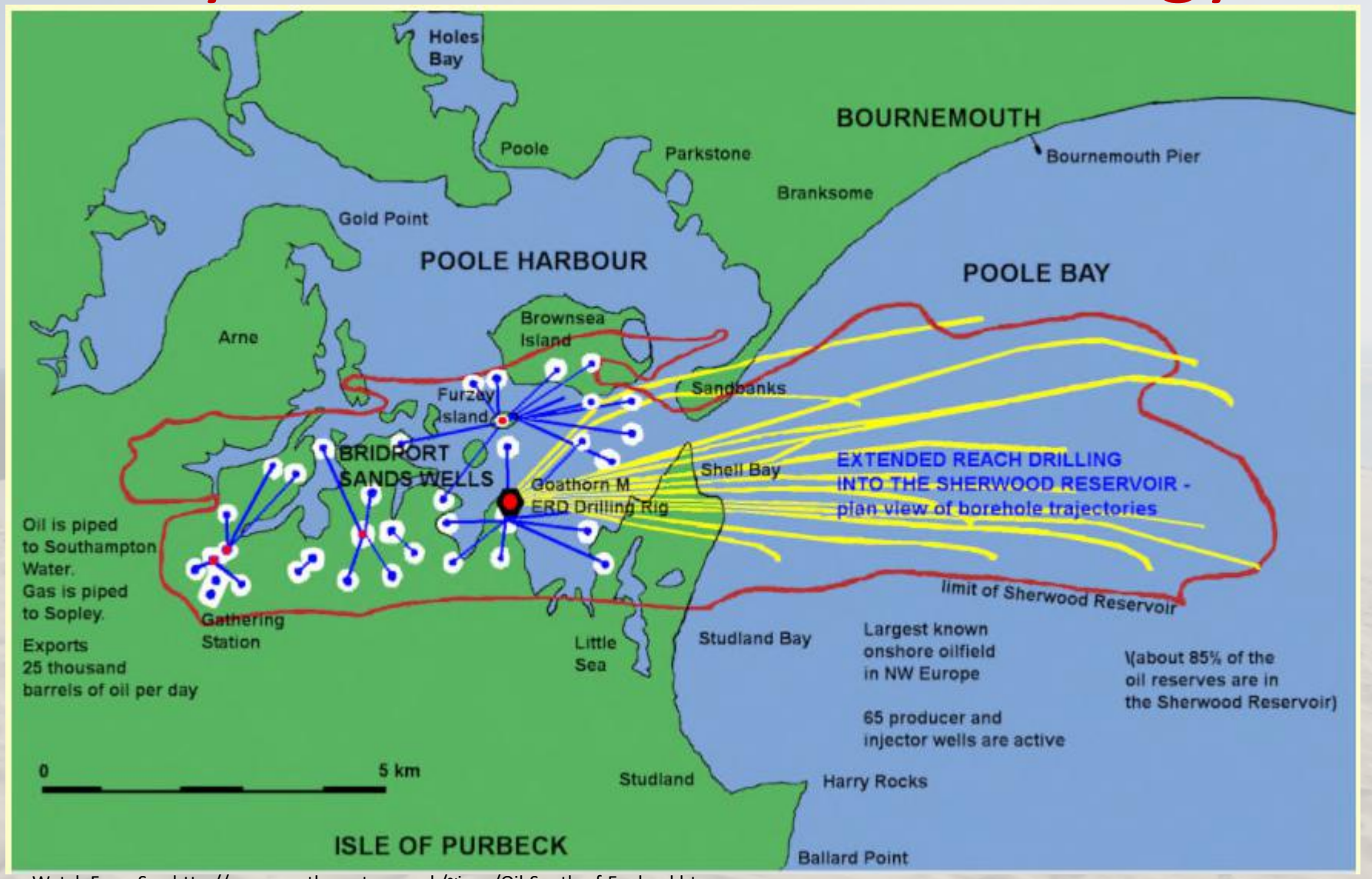
KIMMERIDGE BAY - A GENERAL VIEW WESTWARD FROM THE CORNER OF THE CAR PARK ABOVE GAULTER GAP, AT HIGH TIDE, APRIL 2014.
The route to the beach is to the right, down some steps and the little valley of Gaulter Gap to the sea. Washing Ledge, in the middle distance, is almost covered by the sea at high tide. In the distance is the oil well, not clearly visible from this viewpoint, and the flag, showing that the army firing ranges are closed on this occasion. You cannot go beyond the red notice board, on the beach near the flag. The flat area of rock shore in that area is The Flats Stone Band, a diagenetic dolostone, with internal thrust structures. The higher band in that cliff is the Washing Ledge Stone Band, another dolostone that has risen westward from the shore ledge. Photo: 16th April 2014. Ian West © 2014.

Wytch Farm – Hidden from View



General location of the Wytch Farm Oilfield in relation to Poole Harbour. This older aerial photograph is based on an educational resource of the Sunday Times Newspaper CD - Window on the UK 2000, with oil well locations etc taken from the 1997 edition of the Ordnance Survey Landranger, 1:50,000 Bournemouth and Purbeck sheet 195. Note that most of these well sites are not accessible to the public, and most are not even visible on the ground. They are behind banks and security fences in private woodland. *Ian West & Tonya West, 2009.*

Wytch Farm – Well Technology



Wytch Farm See http://www.southampton.ac.uk/~imw/Oil-South-of-England.htm

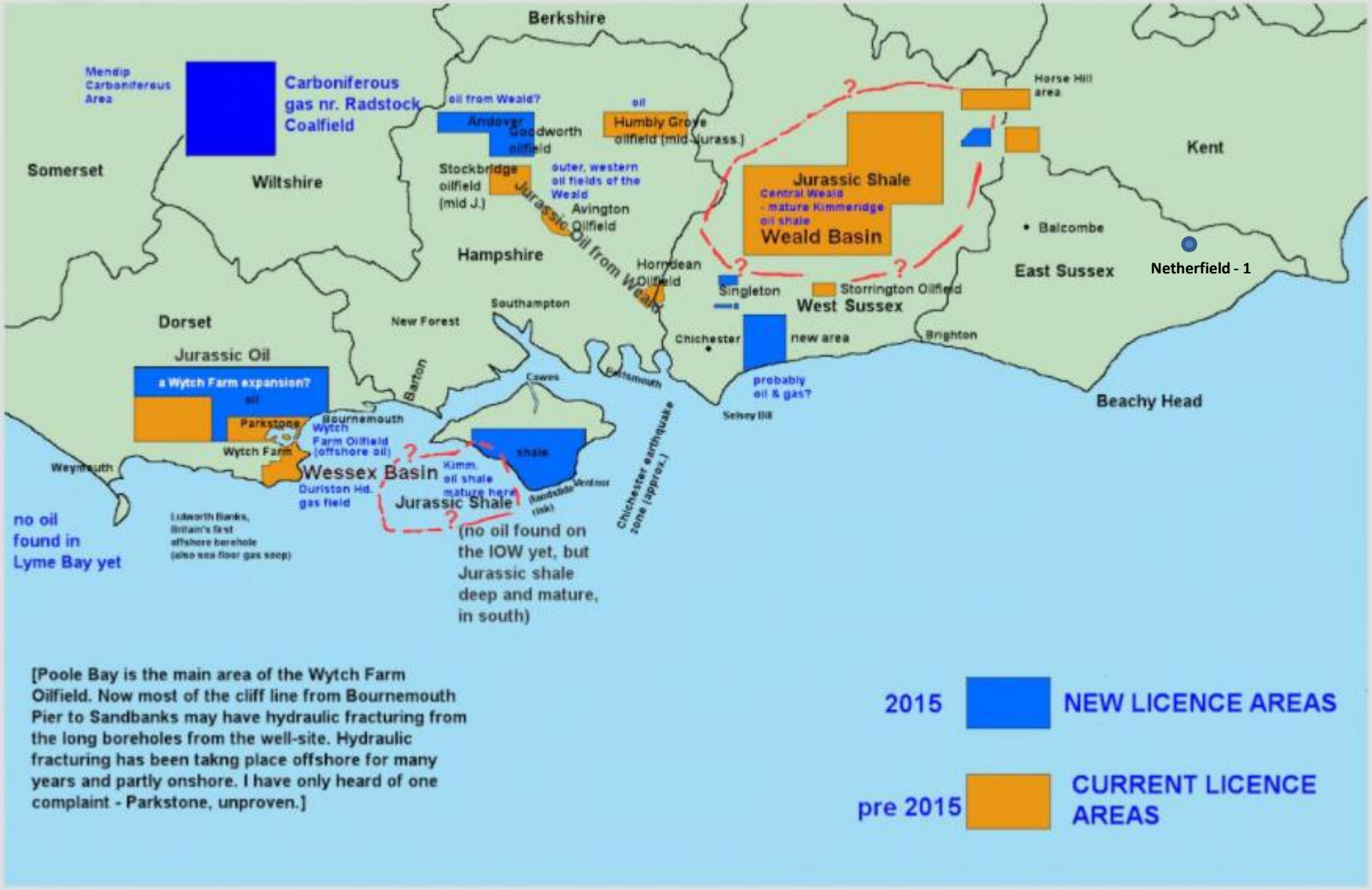
Wytch Farm – Well Technology

- Reservoir is in sandstones 1535m below sea level
- 69 oil producing wells
- 26 injector wells – wells injecting gas and water to force more oil from the rock
- Some wells extend horizontally >10 km from the drill site
- World record extended-reach drilling is achieved by rigs having both a top-drive system to rotate the drill bit (yellow box on photo), and a rotary steerable bit with own power drive. This combination allows precise steering of the drill bit over great distances
- Medium density oil

THE ERD, EXTENDED REACH DRILLING RIG, AT WELL SITE M, GOATHORN PENINSULA, WYTCH FARM OILFIELD.
The rig is not drilling at the time of the photograph. Notice that there is a Top Drive system, a large yellow box with perforations. The Top Drive can be used instead of the traditional rotary table and kelly, and it can move up and down the drilling rig, supported by the (yellow) travelling block. It rotates the drill string when needed. It has pipe connections for drilling fluids. In addition, downhole, there is a Rotary Steerable Bit with Power Drive. Thus the drilling engineer can choose to drill from the Top Drive or from the powered bit at any stage, and can steer the bit precisely into the reservoir. This large rig has drilled 11.3 kilometres to the east (near Bournemouth). Photograph: 7th Map 2011. Ian West (c) 2011.

Wytch Farm See http://www.southampton.ac.uk/~imw/Oil-South-of-England.htm

Licence Areas



Map by Ian West, 2016: http://www.southampton.ac.uk/~imw/Oil-South-of-England.htm

Back to the Weald: Horse Hill-1, 2, 2Z update 3/2020

Year	Well	Result
2014	HH – 1 (vertical)	Discovers oil in Portland sand, Kimmeridge Clay, Oxford Clay and Liassic shale
2016	HH - 1	Well tests: Portland sand flowed 323 BOPD and Kimm micrites flowed 1365 BOPD on test.
2018	HH - 1	Well tests: increased Portland flow rate to 362 BOPD
2019	HH – 1 HH – 2/2Z	Further flow tests of Kimm micrites Horizontal well 2Z flowed 1087 BPD, 60% oil in Dec 2019. Water produced from fracture at toe of well – now successfully shut-off

- Discovered late 2014, 3 km N of Gatwick Airport
- Operator: UK Oil & Gas Ltd
- Portland Sandstone 30m of conventional pay (~21 MM barrels oil-in-place), depth 540 mSS
- Deeper Kimmeridge, Oxford Clay and Lias thermally mature and oil-bearing.
- 96,000 bbls oil produced by extended well tests in HH-1 and HH-2Z (mostly from Portland sand?)
- 90m of pay in Kimm. Limestones (naturally-fractured) 2 connected zones
- Resources: Claimed 9 Billion bbls oil-in-place in Jurassic shale and carbonate
- Oil is dry, 35 to 40 API.
- Field development plan has been approved by UK Gov., for HH-1 Portland sand only. Plan for HH-1 Kimm and HH-2Z horizontal well in Portland sand will be added later

Brockham-X4Z Well 2019

- Edge of Weald Basin NW of Horse Hill
- Brockham Field was discovered by BP in 1987. Flow rates were low (35 BOPD), producing until 2016 from Portland Sst
- Angus Energy has been attempting to produce oil (40 API) encountered in Kimmeridge Micrite intervals (as at Horse Hill).
- Well only produced water when flow tested in 2019
- KCF probably insufficiently mature

Balcombe Field 2019

- Centre of Weald Basin near village of Balcombe
- Field was discovered by Conoco in 1986.
- Angus Energy has been attempting to produce oil encountered in Kimmeridge Micrite intervals (as at Horse Hill).
- A horizontal well has been flow tested in 2018. Rate ~1500 BOPD. Longer term production tests planned
- Angus also have production from Great Oolite at Lidsey Oil Field near Chichester. No info on rates – probably ~20 BOPD. Oil also reported in KCF.

The Future

- Depends on the will to move to a low carbon economy
- Oil products have a high energy density and are an attractive fuel
- But you don't have to burn it! Petrochemicals, plastics, fertiliser
- Future oil exploitation would involve:
  - Target the source rock directly – horizontal wells and fracking. Not known if this will be commercially viable until a number of wells are drilled and tested
  - Small oil pools would become economically attractive if the oil price rises (per barrel:< $30 in 2016, $60-ish/barrel in 2019, $20 rising to $35 so far in 2020). Prices are VERY unpredictable
  - New technology means more oil can be recovered from existing fields (so long as the infrastructure does not rust away)