Origin of the Giant Drake Gas Field, Canadian Arctic Islands*

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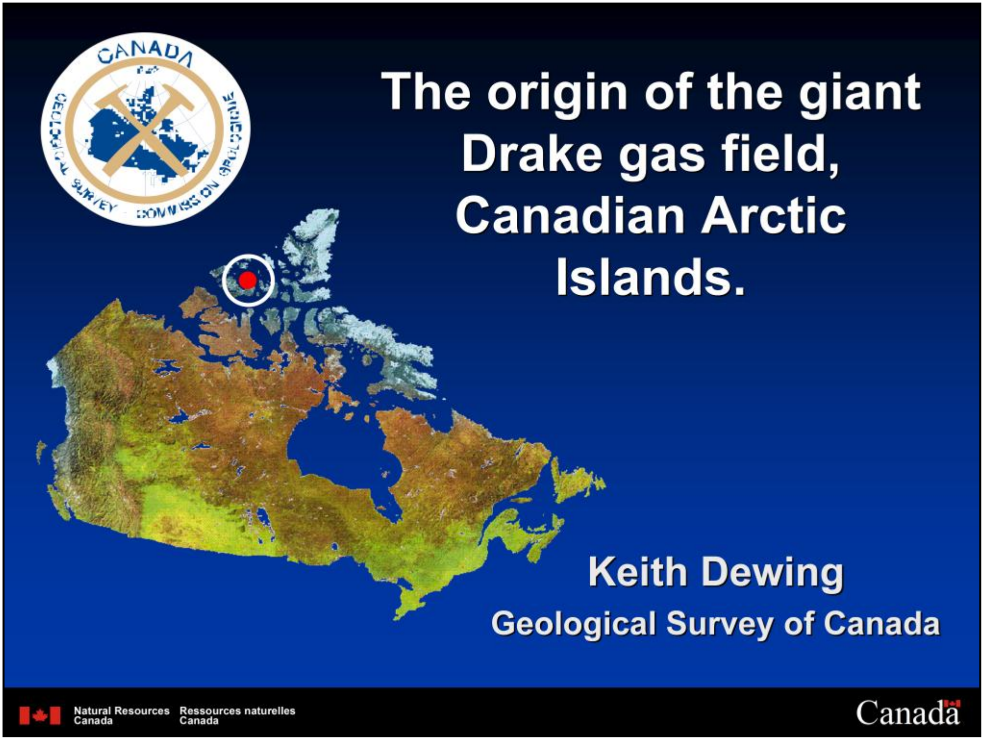
Abstract

The two largest conventional gas fields in the Canadian Arctic are located on Sabine Peninsula of Melville Island in the central Canadian Arctic Islands. The Drake Gas Field was drilled on the closure on an anticline defined both by surface mapping and subsurface seismic data. The field is hosted in Jurassic-aged sandstones of the Heiberg Group. Ultimate recoverable reserves are estimated at 5.3 tcf. Exploration stopped in 1985 and the fields have never been produced.

Modern processing and interpretation methods were applied to more than 3400 line-kilometres of legacy seismic data from onshore Sabine Peninsula. The success of the reprocessing improved the imaging and hence the interpretation of the Devonian through Cretaceous succession. Processing consisted of three main steps: (1) Principal component decomposition was used to remove both coherent and random noise, (2) data were migrated following the principals of Kirchhoff migration through the use of a 3-D geostatistical velocity model, and (3) seismic bandwidth extension was conducted in order to increase vertical resolution. The north-south oriented Sabine Peninsula has three tectono-stratigraphic assemblages: (1) Thrust-faulted and folded lower Paleozoic strata in the lower part, (2) normally-faulted upper Paleozoic carbonate and clastic strata in the middle, and (3) folded Mesozoic to Tertiary clastic strata in the upper part of the succession. Cretaceous sills and dykes locally intrude the succession. The central part of Sabine Peninsula is underlain by a graben containing Upper Paleozoic sediments and overlies folded Lower Paleozoic sediments. The graben fill is only intersected once by drilling but the graben likely contains Late Carboniferous to Early Permian sediments of the Canyon Fiord, Belcher Channel, and Raanes formations. Reflections within the graben are intersected by normal faults, terminating at or near the top of the Upper Paleozoic succession and do not extend into the Mesozoic succession. Upper Paleozoic beds are not folded as part of the Drake Anticline as Mesozoic and younger beds. However, the Lower Cretaceous Christopher Formation thins over the Drake Anticline, indicating that the anticline formed during, or just prior to its deposition. We propose that evaporites were present in the Upper Paleozoic graben, analogous to the evaporitic Fosheim Sub-basin on northern Ellesmere Island. As evaporites were removed in the Early Cretaceous, either due to dissolution or salt withdrawal, the overlying Mesozoic strata were deformed into a rollover anticline.

Reference Cited

Harrison, J.C., 1994b, A summary of the structural geology of Melville Island, Canadian Arctic archipelago, *in* R.L. Christie and N.J. McMillan, eds., The geology of Melville Island, Arctic Canada: Geological Survey of Canada Bulletin, v. 450, p. 257-283.



Presenter's notes: Colleagues and I at the GSC have been working on seismic from Melville Island
Present some of that work, especially as it pertains to the giant Drake gas field

Thanks!

Co-authors:

Virginia Brake
Mathieu Duchesne
Tom Brent
Nancy Joyce

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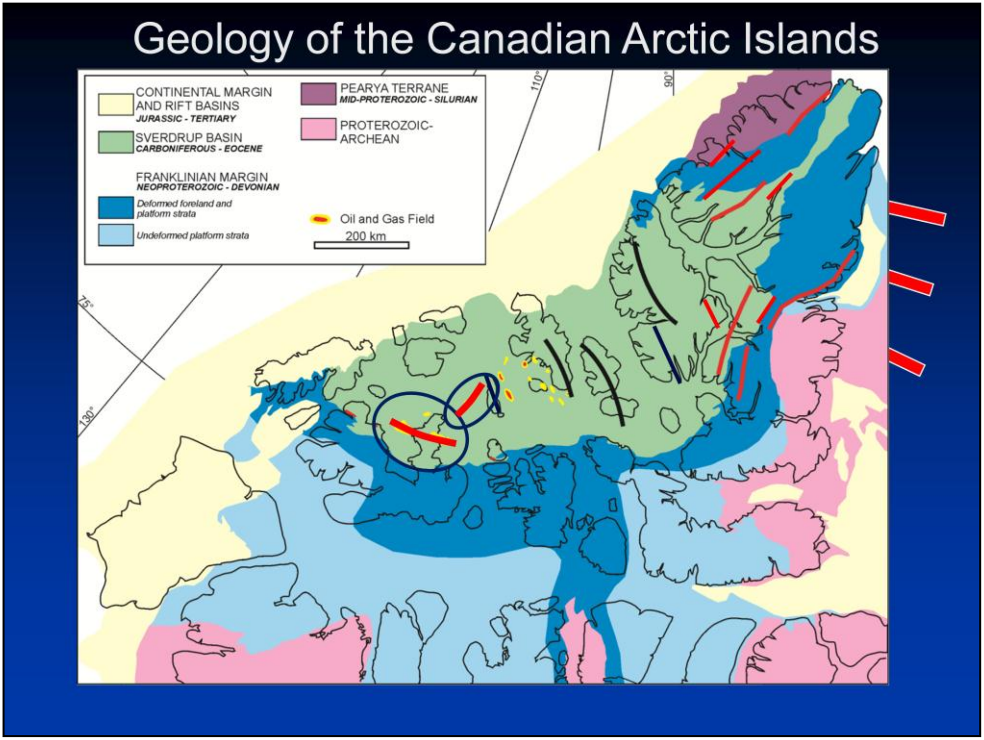
Suncor Energy

Geological Survey of Canada:
Geomapping for Energy and Minerals program

Presenter's notes: Many thanks to:
Coauthors all of the GSC
Suncor – permission to use some seismic images
My employer Funding from the GSC GEM program



Presenter's notes: Canadian Arctic Islands with an overlay of the geological provinces.

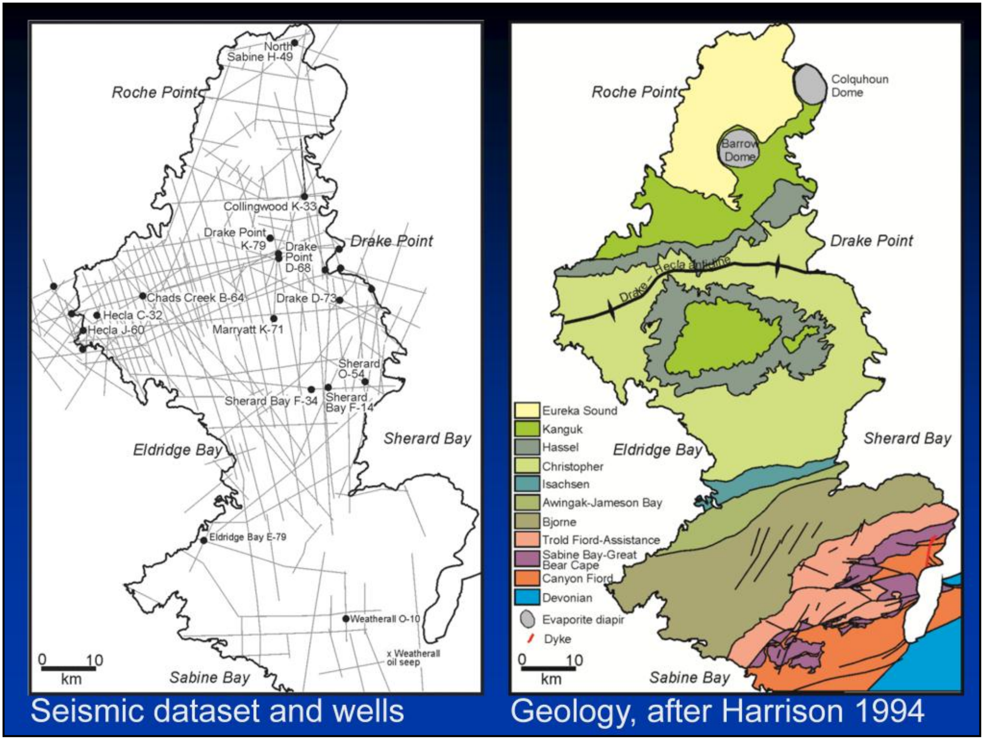
Precambrian to the south – Laurentian craton (pink). Overlain by
Lower Paleozoic strata – undeformed in light blue, deformed by the Caldeonian or Ellesmerian in dark blue
Sverdrup Basin (in green) -- successor basin that formed on deformed lower Paleozoic rocks. Carboniferous to Cretaceous
Margin of the Arctic Ocean – sedimentation from Cretaceous to Recent, yellow

Eocene collision with Greenland, Eurekan orogeny accompanied by development of faults in the NE part of the Sverdrup – thrust and strike slip
Large crustal scale folds and numerous smaller structures

Distribution of oil and gas fields – can see in NE part fields are parallel to the trend of the Eurekan orogeny. High amplitude, under filled

On Melville Island anticlines hosting oil and gas are usually interpreted as forming during the Eurekan Orogeny
The fields are quite different from those in the NE – low amplitude, completely filled, and orientation at a high angle to the Eurekan trend
Another set of low amplitude folds at Cisco and Whitefish fields are also at a high angle to the trend of the Eurekan orogeny.

One of the questions we wanted to address with the seismic study was to look at the origin and timing of the Drake Anticline more closely

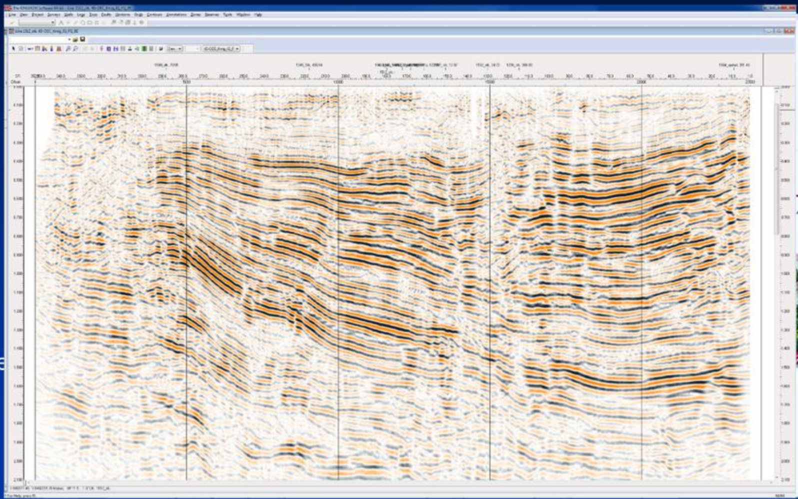


Presenter's notes: Data we have to work with:
3400 km of seismic, densest grid in the Canadian Arctic Islands, shot in the 1970s and 80s

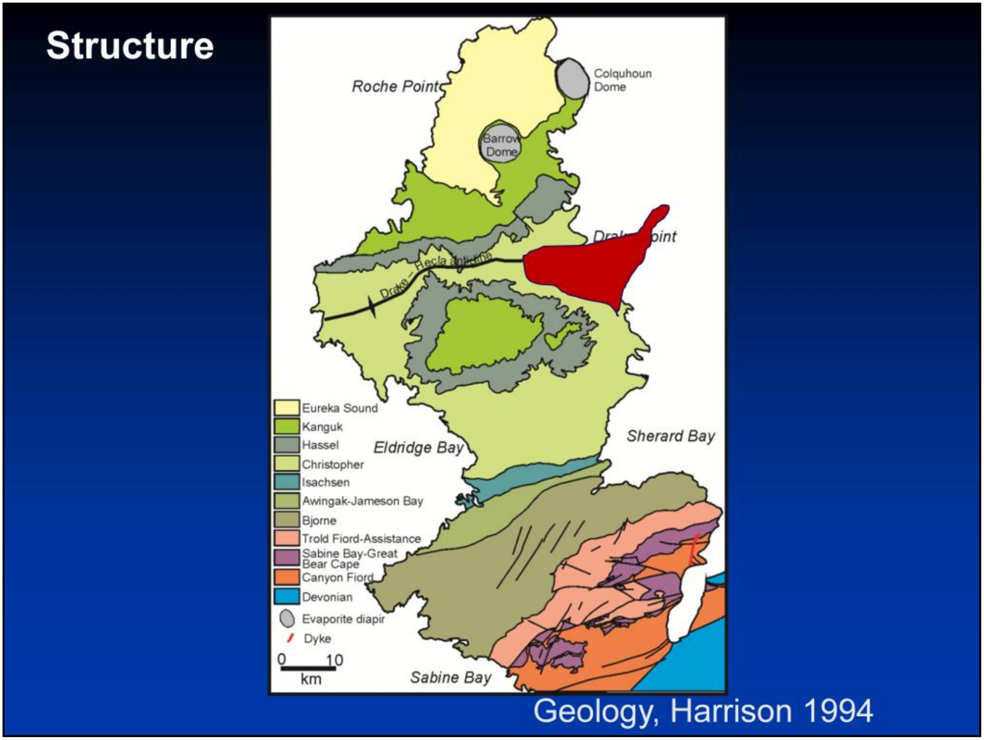
22 wells, two of which are greater than 5 km deep.

Excellent geological mapping and a recent structural study by Harrison (1995) from which to build.

Seismic processing: post-stack



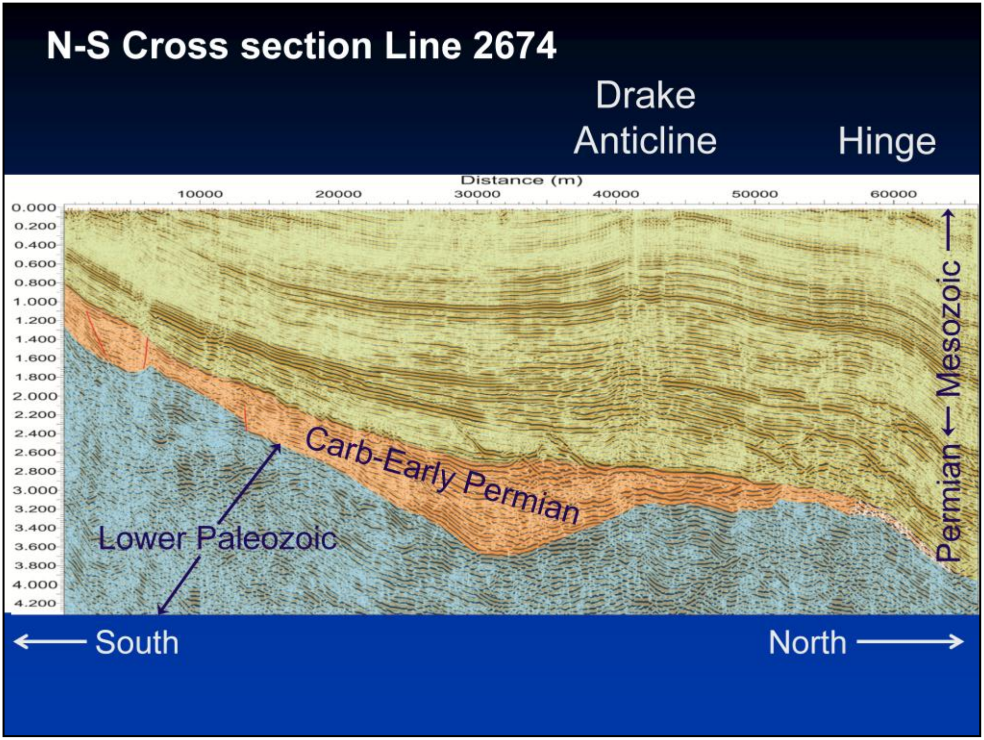
Presenter's notes: Coauthor Mat Duchesne reprocessed the post stack lines
work includes new velocity models and Kirchoff migration
See a before and after view
Loaded to a workstation



Presenter's notes: Overall structure
Lower Paleozoic in south (blue), folded and faulted during the Ellesmerian Orogeny
Upper Paleozoic (orange) deposited during the opening of the Sverdrup Basin. Normal faults

Mesozoic (greens) deposited during the subsidence phase of the Sverdrup Basin and thickens to the north
Gently folded into long wavelength folds

The gas field at Drake was discovered in 1969 drilled on a surface and seismically defined anticline
Gas field hosted in Jurassic sandstone at about 1200 m
99% dry gas, 5.3 Tcf ultimate recoverable
Sister field, Hecla, just to the west

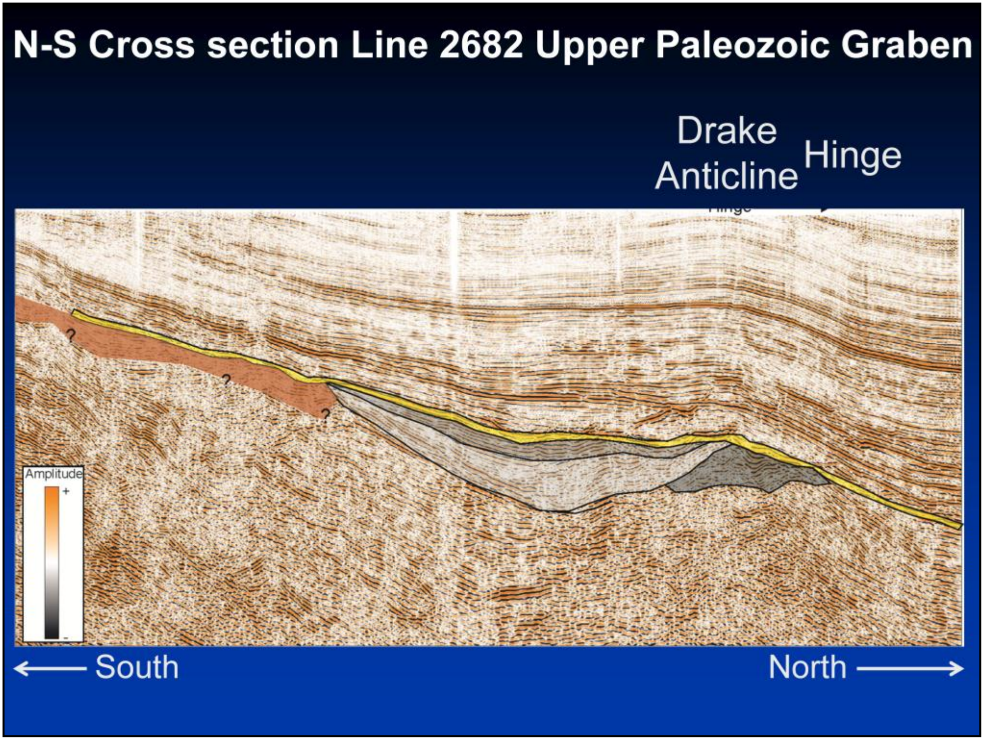


Presenter's notes: N-S oriented seismic line shows a cross section through the peninsula

Lower Paleozoic, folded and faulted (blue). Plunges steeply to the north
Upper Paleozoic (orange) normal faulted – thickens and there is a graben developed under the central part of the peninsula. Thins over a high of probable lower Paleozoic

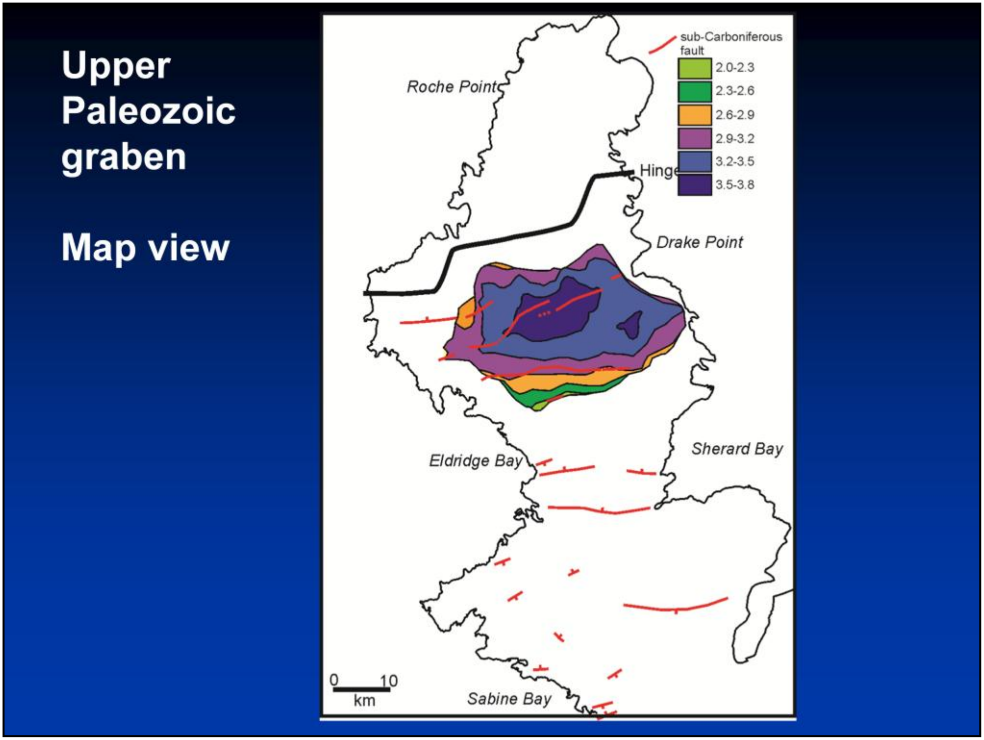
Middle—Upper Permian and Mesozoic (green) thickens to the north.
Intruded by sills.

Folded two ways --
hinge reflected up through the stratigraphy above the steeply plunging lower Paleozoic
Drake Anticline forms over the N end of the graben



Presenter's notes: Closer look at the graben. Expand on the interpretation of Harrison 1995
At updip end overlies or is equivalent to Bashkirian strata (brown)
Two internal packages – lower syn rift (light grey), upper package of more continuous reflectors (dark grey)
Hump at the N end – conservatively interpret as lower Paleozoic, but possible upper Paleozoic reefs?

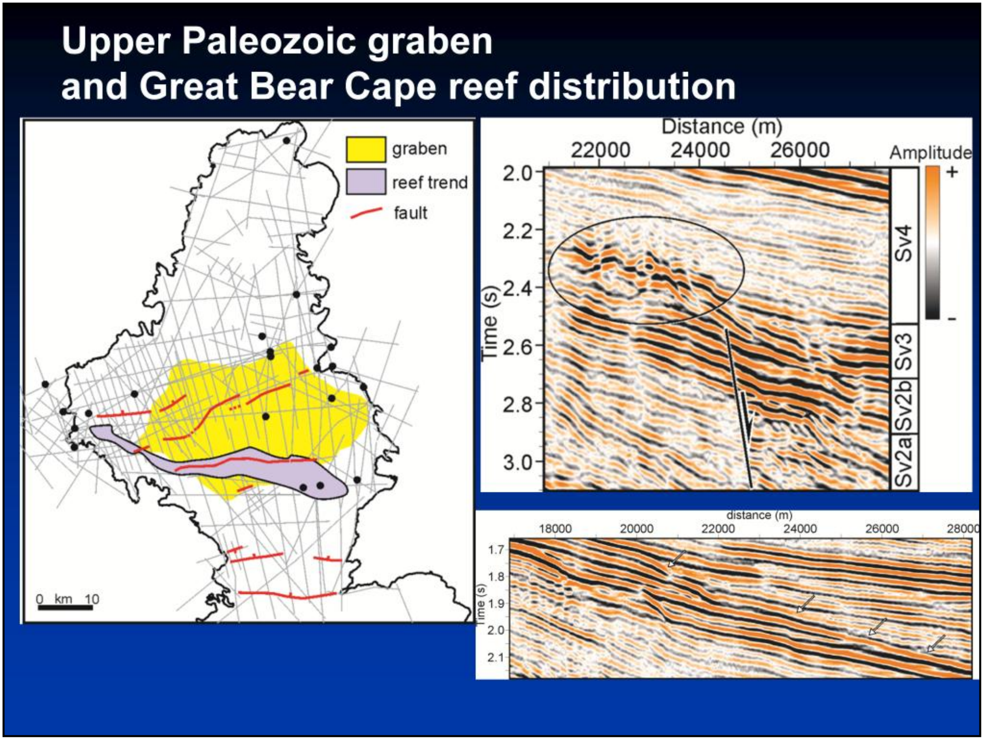
overlain by continuous reflector (yellow)
Yellow package is Great Bear Cape and Raanes fms – Lower Permian
Also Lower Permian (Asselian) in uppermost part of the graben



Presenter's notes: Upper Paleozoic graben in map view

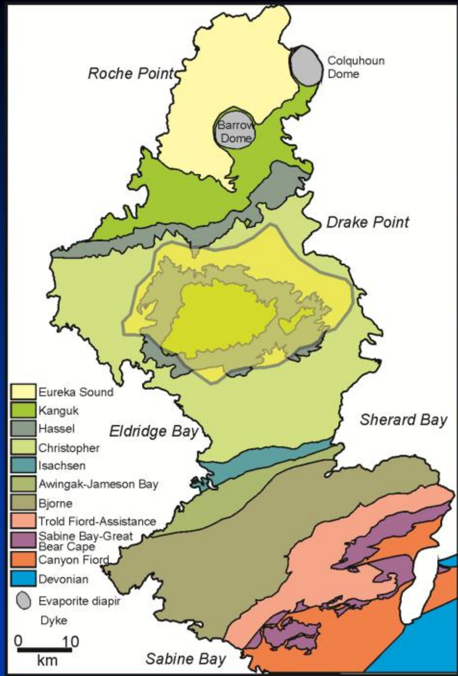
Roughly 40 x20 km
Underlain by faults at the deepest part that cut the sub-Carboniferous unconformity

Graben is distinct from the hinge – steeply dipping edge of the lower Paleozoic
Hinge is stepped – suggestive of a segmented shelf margin but the seismic is too poor at that depth to image much of the lower Paleozoic



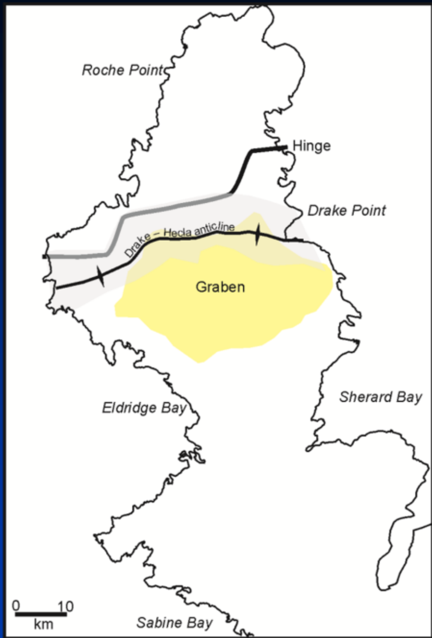
Presenter's notes: Graben appears to exhibit an interesting control on a number of younger features
graben shown by yellow outline
distribution of small reefs in the unit just above the top of the graben along the south side
Reef trend shown in purple
Closely mimics the south edge of the graben
The facies transition from Degerbols carbonates in the south to shale in the north also closely matches this trend.

Upper Paleozoic graben and location of syncline



Presenter’s notes: The upper Paleozoic graben underlies the syncline seen on surface today implying that there has been protracted movements on the graben even into the Late Cretaceous.

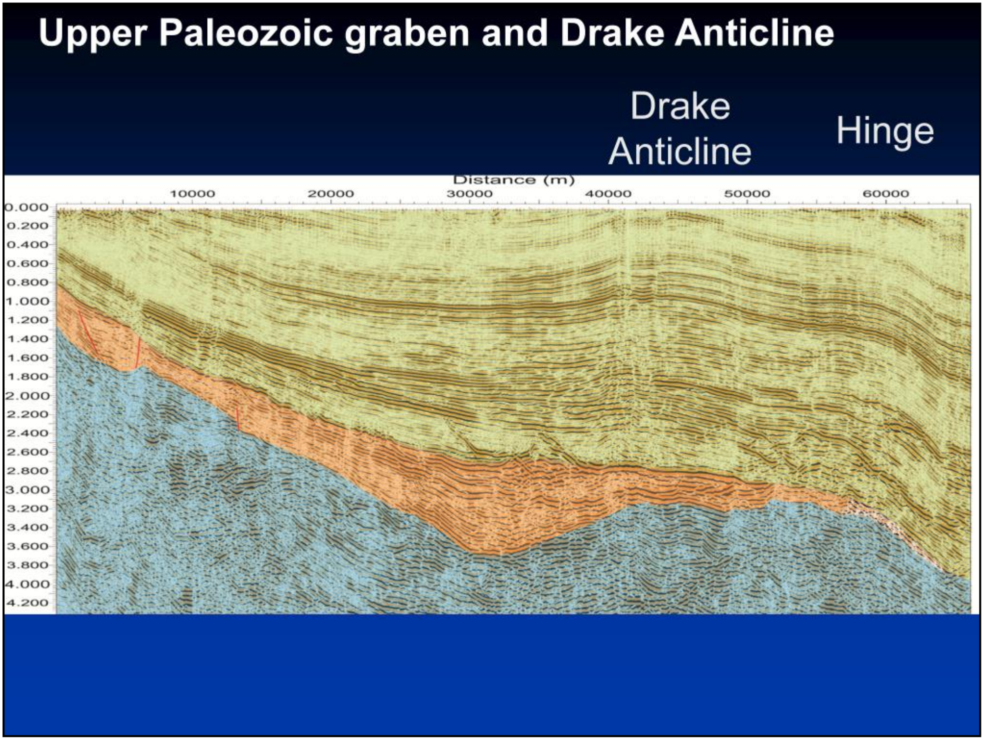
Upper Paleozoic graben and Drake Anticline



Presenter's notes: The north side of the graben seems to control the location of the Drake anticline

In some locations the anticline is parallel to the hinge, they are separate structures

In cross section the crest of the Drake anticline is most closely associated with the north end of the graben, although, oddly, reflectors at the top of the graben do not show much uplift, possibly masked by the intrusions



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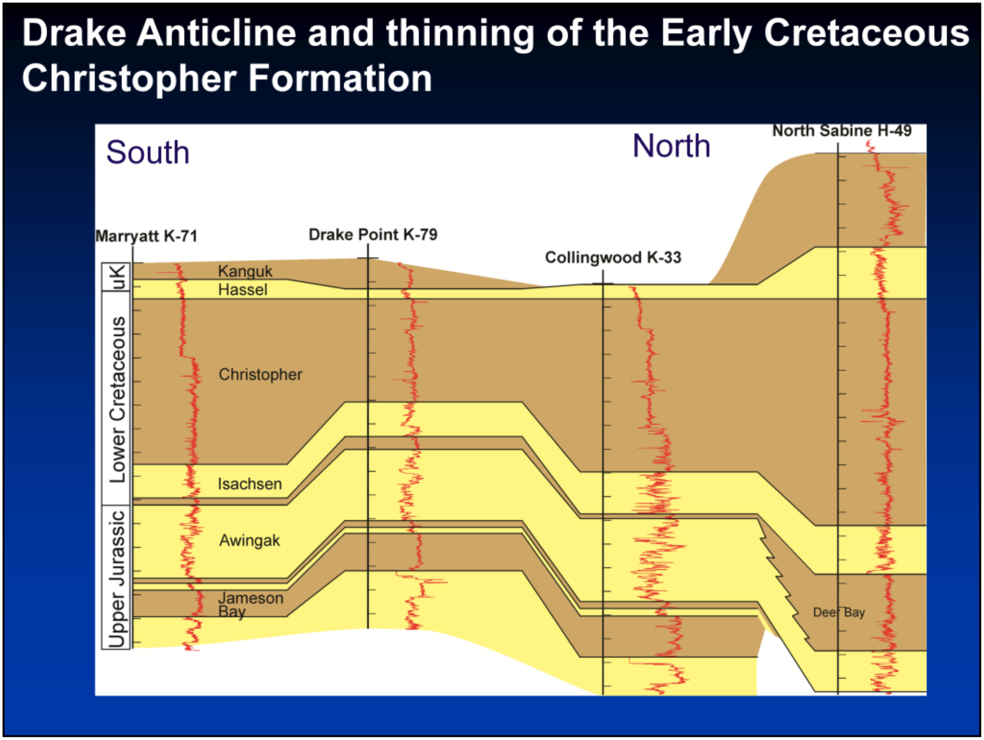


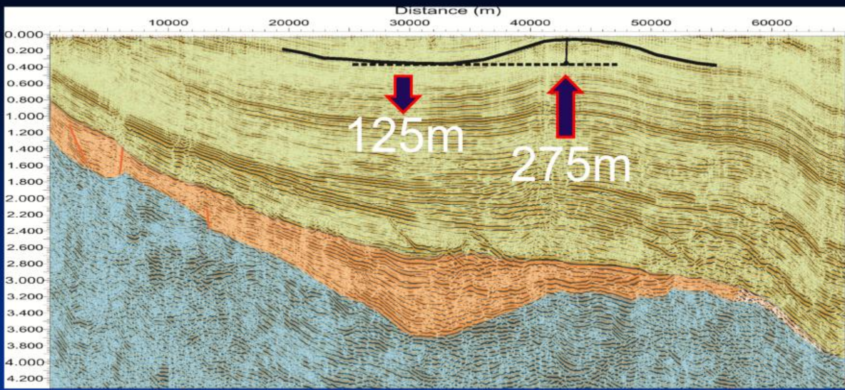
Presenter's notes: What is the timing of the uplift?
S to N cross section though the upper Jurassic and lower Cretaceous
Ss in yellow, shale in brown

The Lower Cretaceous (Albian) Christopher Fm appears to thin over the Drake anticline.
Drake K-79 is the key well. It preserves a full thickness of the Christopher in that it has both overlying and underlying units
K-79 is in an area of structural complexity, but the seismic does not show that there are faults that cut the Christopher Fm and we conclude that we see a true thickness

Either thins or is eroded by Hassel
If this is true, then the timing of the Drake Anticline is Early to Late Cretaceous

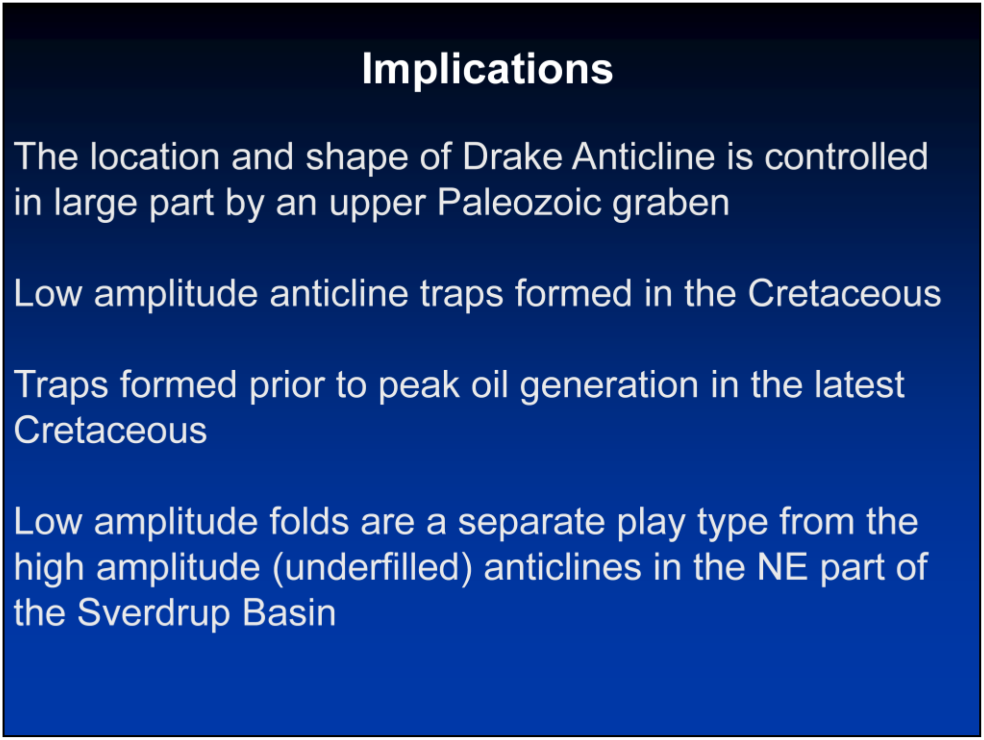
Agrees with thinned Christopher Fm in another low amplitude fold at the Cisco offshore discovery

Drake Anticline movement



400 m of structural relief between anticline and syncline
275 m of uplift based on thinning of the Christopher Fm
125 m of ‘sag’ in the syncline

Presenter’s notes: Drake anticline has 400 m of structural relief between anticline and syncline
275 m of uplift based on how much the Christopher Fm is thinned compared to wells to the north and south.
125 m of ‘sag’ in the syncline
Sag may have happened during times of sand deposition (Sandy Point, Awingak, Isachsen fms) that seem to be marginally thicker in the syncline than at the crest of the anticline



Presenter’s notes: Implications

The location and shape of Drake Anticline is controlled in large part by an upper Paleozoic graben that underlies the central portion of the Sabine Peninsula

Low amplitude anticline traps formed in the Cretaceous, probably close to the Albian – Cenommanian boundary

Low Amplitude traps formed prior to peak oil generation in the latest Cretaceous
Explains why filled to spill

Low amplitude folds are a separate play type from the high amplitude (underfilled) anticlines in the NE part of the Sverdrup Basin. Low amplitude traps should be explored for and assessed separately from the high amplitude anticlinal traps in the NE Sverdrup Basin.


Thank you for your kind attention