Old Red Sandstone Basins
Structure style examples in Central East Greenland

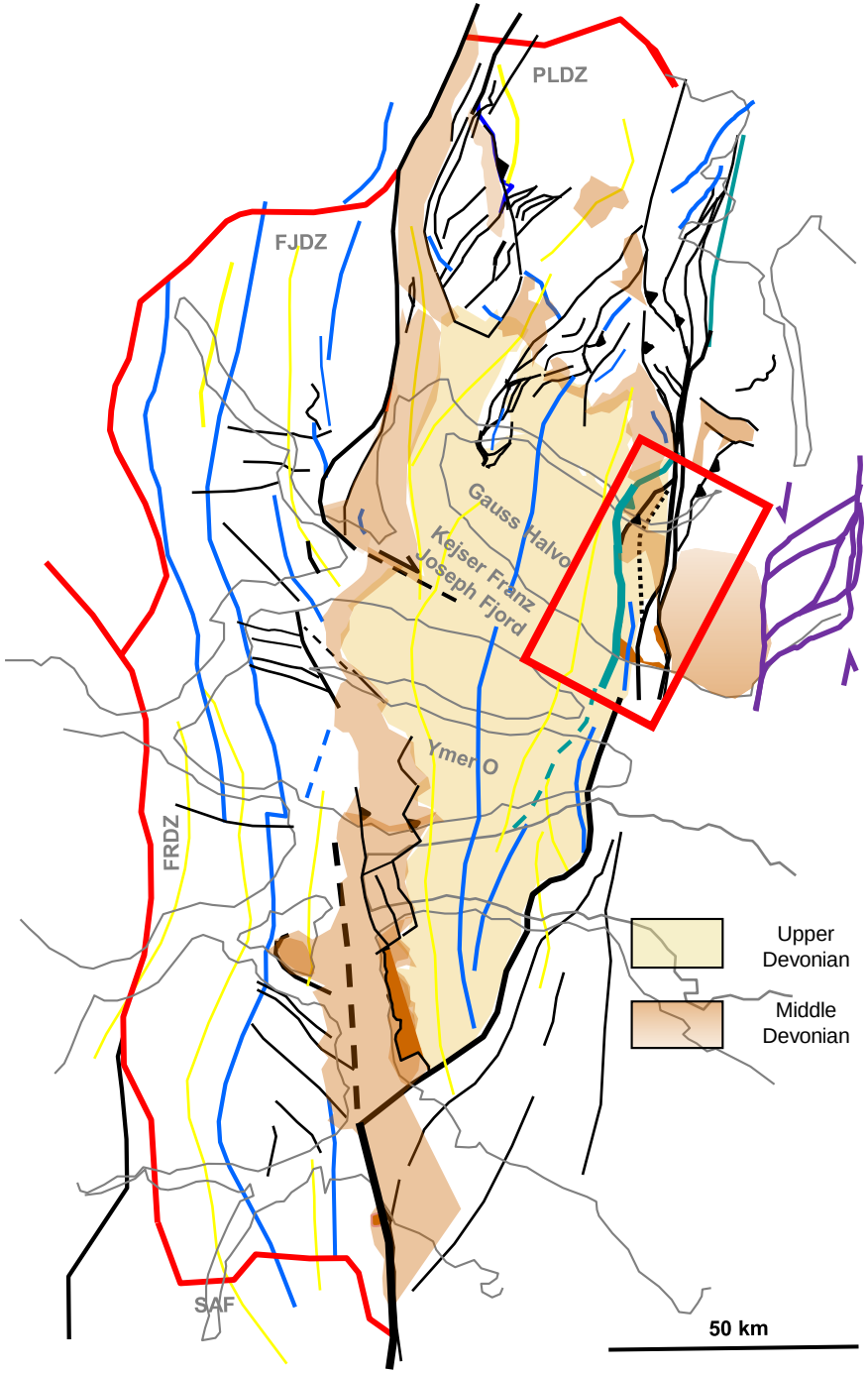
2. Kejser Franz Josef Fjord, huge growth fault on Gauss Halvo

Here we are going to look at the enormous fault which forms the east boundary of the Kap Graah and Kap Kolthoff upper Old Red sequences on Gauss Halvo and Ymer Island. Those very thick sediments on the west side of the fault (green, in the map) more or less vanish as we travel across it to the east. The footwall is Middle Devonian, with a greatly-reduced late Devonian sequence.

Its a key structure in the upper Old Red basin development, there are more like it in the wider basin and if we want to understand how the basin sequences relate to each other, we need to know how these faults drove extension and how they acted in cross-basin compression too. But the fault zone is only a kilometre or so wide and its not clearly seen at outcrop. The outcrops on either side are fabulous but just how the fault zone operated, is not clear.

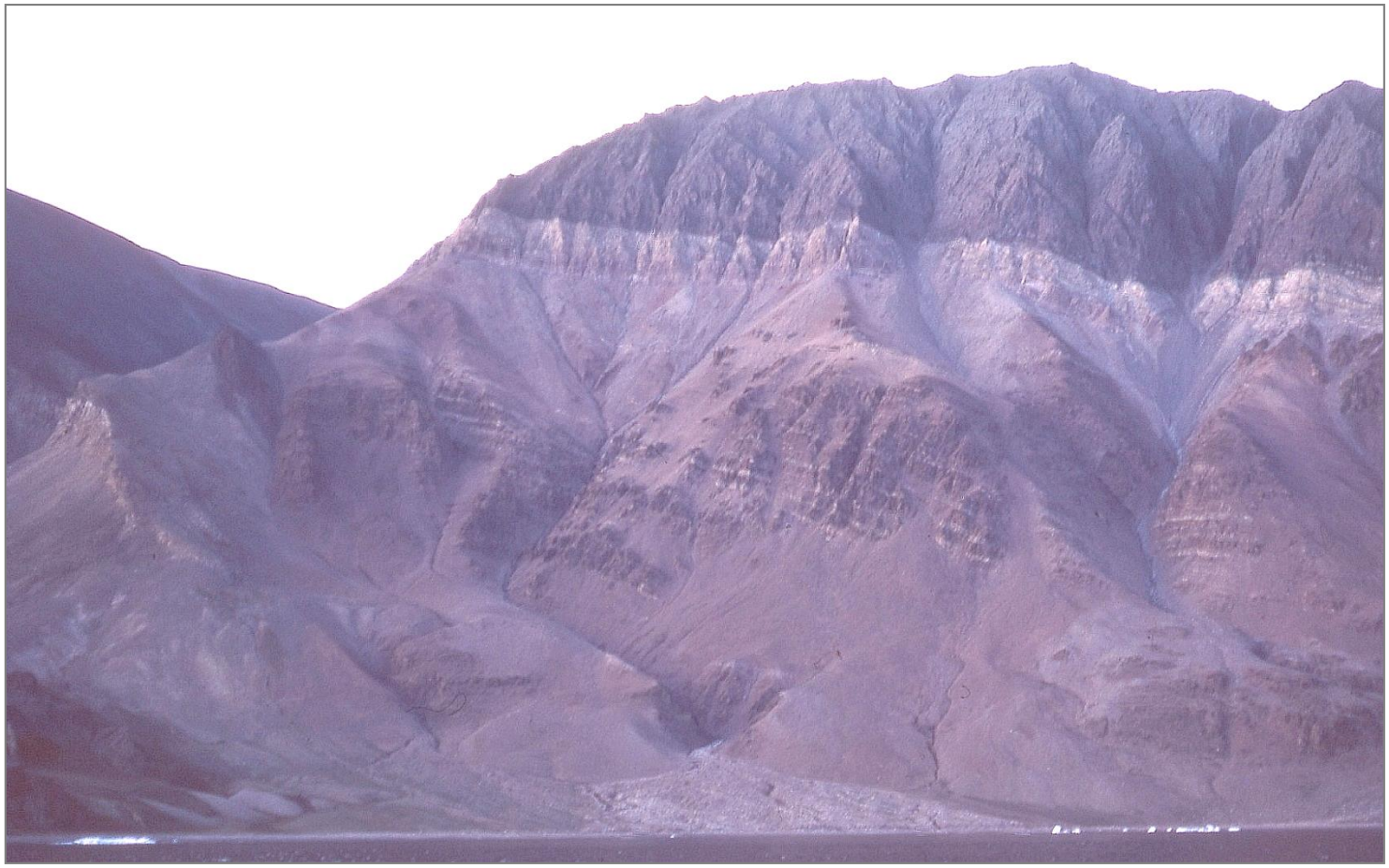
So we need a model, and we can look outside Greenland for this, we suggest that Smith Bank in the UK Inner Moray Firth is a valid analogue for the Gauss situation.

With that Moray structure style for guidance, we can then start to draw cross-basin profiles along the length of Kejser Franz Josef Fjord, which are compatible with the rapid variations in Old Red stratigraphy and give predictive power for regional studies.



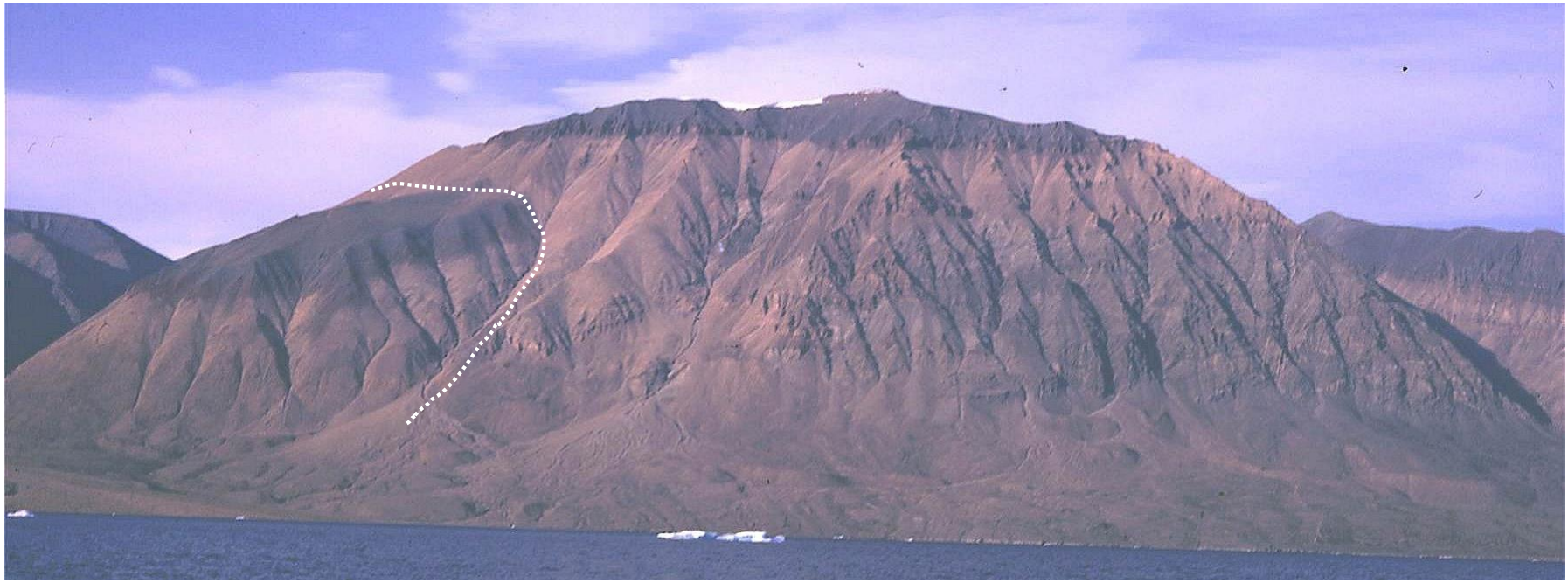
Let’s start by looking at a series of local outcrops from east to west along the south coast of Gauss Halvo, and then we’ll show an extensional fault interpretation which plausibly links them.

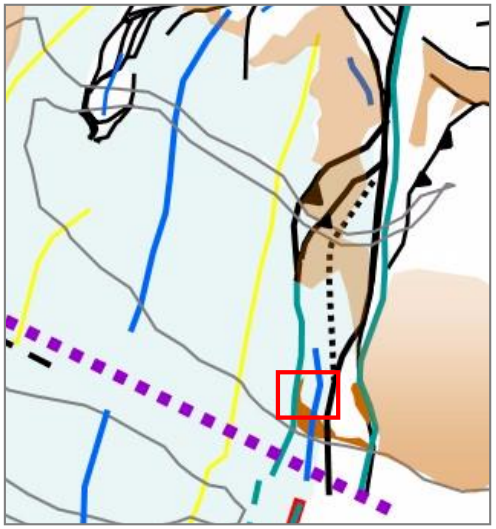
The mountains between Margrethedal and Agda Dal are called the Hjaelmbjergene, this one is Obruchev Bjerg and the photo shows its west side. Its mainly Middle Old Red, red sandstones dipping east; the upper sequence is the latest Upper Old Red: its the lower half of Mount Celsius Supergroup, and its basal unit is the white pebbly sandstone which lies unconformably across the red beds. Above that sandstone is Remigolepis Group mudstone of probable playa lake origin, its colour-banded with a few metres of red siltstone on the white beds. That sequence becomes much thicker, westwards.



Next west we cross a big fault and the mountain is Gross Bjerg, its top is Remigolepis mudstone and the white sandstone is less distinct.

The bulk of the mountain is Middle Devonian still, but now green sandstone. A feature of the Middle Devonian in numerous outcrops is strong duplexing, as seen in the inset, there's been shearing, repeatedly.



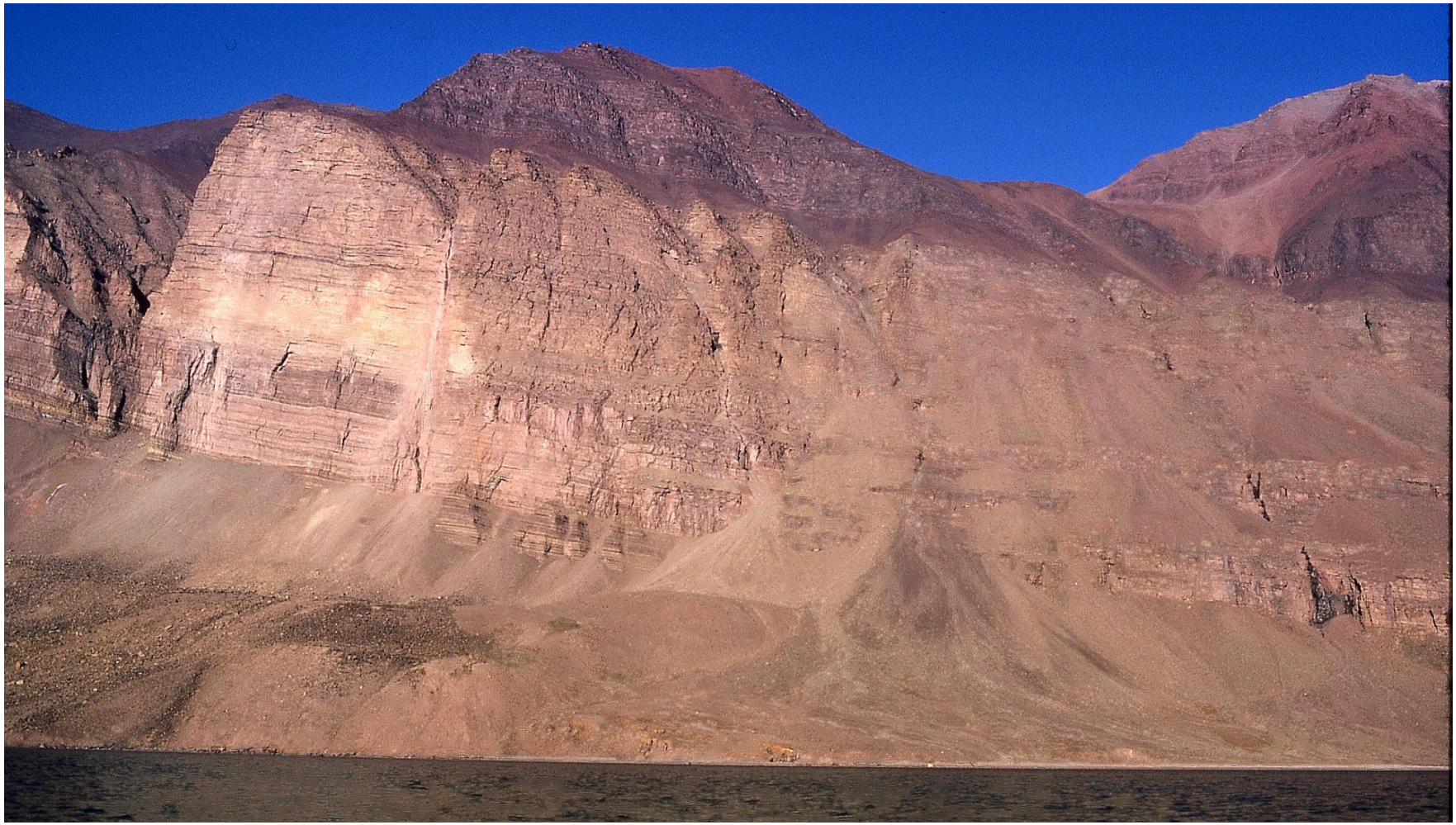


And next west is Mt Gunnbjorn, where we can confirm what we are looking at: the smashed and folded, dyke-intruded Middle Devonian is the footwall to the fault zone we are interested in, which is at Agda Dal just off to the left of the photo. The unconformable Remigolepis Group in the summit area has muted thickening, as late-stage cover to the growth fault. Its now-thicker basal sandstone isn't white and pebbly, as at Obruchev Bj, and we see a more distinct, reddened mudstone above it: the Aina Dal Formation. Gunnbjorn Bjerg's west shoulder has a big fault, which belongs to the growth-fault zone.

The dotted trend line in KFZ Fjord, the inset map, is the approximate trend for our interpreted profile, to be shown shortly.

Between here and Obruchev, by the way, on our first (1968) expedition within its opening few days we met not one but three polar bears. They appeared better equipped in all respects to be there, than we were. Despite them being hungry, fortunately they knew even less about us than we did about them, and they didn't exploit their superiority.

About 2.5 km west of Agda Dal this is Wimans Bjerg and its almost at the base of a gentle hangingwall syncline, with the Remogolepis Group now nearly at sea level having dropped about a kilometre in elevation, westwards from Gunnbjorn. Its suddenly substantially thickened, having added a substantial red mudstone, the dark grey lacustrine mudstone above that is more distinctive, followed by redder muds and sandstones of Britta Dal Formation (famous for tetrapods), and at the top is the Gronlandaspis Sandstone, the topmost Mt Celsius Supergroup formation in the Basin.

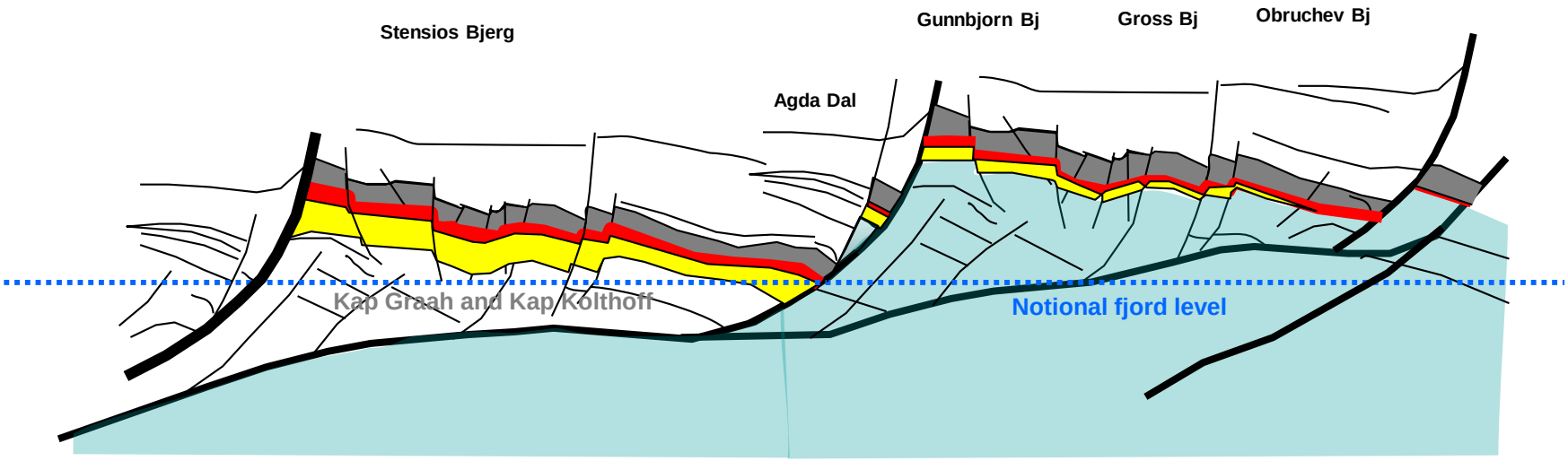


One more km west, the east side of Smith Woodwards Bjerg now presents a huge Kap Graah Group upper Devonian sequence completely unrepresented at Agda Dal. Remigolepis Group is at the skyline.

These cliffs are a test of resolve to measure stratigraphic sections, the screes are live and rocks come flying down the faces and the gulleys which are the access points for detailed studies.

Western Gauss Halvo Old Red outcrops are radically different to central Gauss. The white sandstone sequence is a massive pile of fluvial fan sandstones belonging to the Kap Kolthoff Supergroup, the brown beds are the lower part of Kap Graah Group.

Putting all this together, we think the structure style is like this. The model is based on Smith Bank High and its main boundary fault in the Inner Moray Firth, seismic there shows us a similar-style and comparable-scale faulted profile but we draw a different fault interpretation from the current literature. The difference is that our faults are linked in order to work together in extension. Its a pretty good match for the Gauss geology.



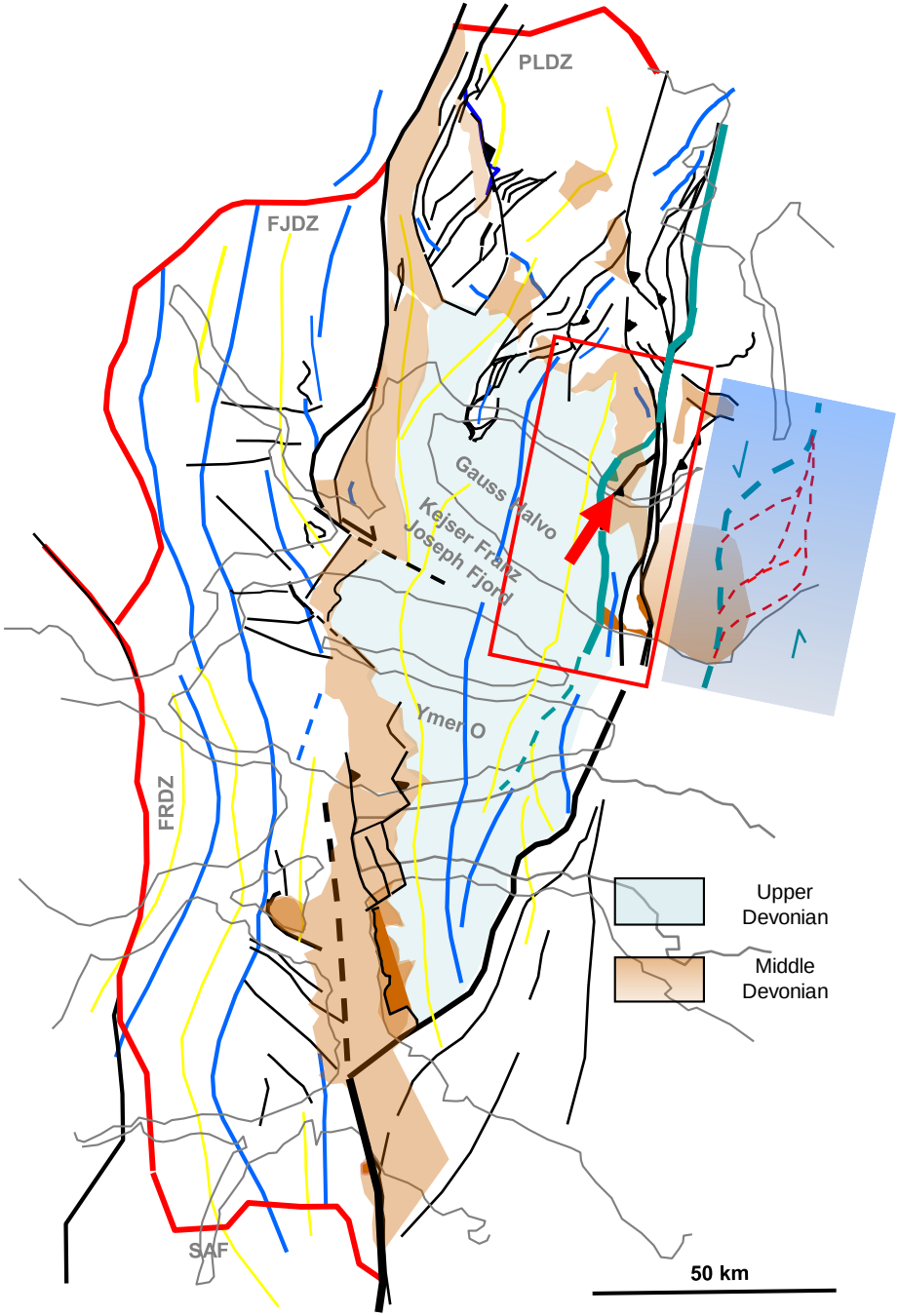
Say that grey, red and yellow are approximately the Wimans Bjerg, Aina Dal and basal sandstone formations of the Mt Celsius Supergroup, these all show thickness and facies changes immediately west of Agda Dal. Blue is the battered Middle Devonian of the Hjaelmbjergene Group (part equivalent of the Vilddal) outcropping between Agda and Obruchev; and we now have an extensional growth fault system drawn at Agda Dal which is the active margin for Upper Devonian Kap Kolthoff and Kap Graah sequence on its hangingwall. Broad inversion anticlines are a guide to the presence of major ramps rooting on top of Middle Devonian, these connected low-angle faults can reverse in Carboniferous compression in the Ymer Phase.

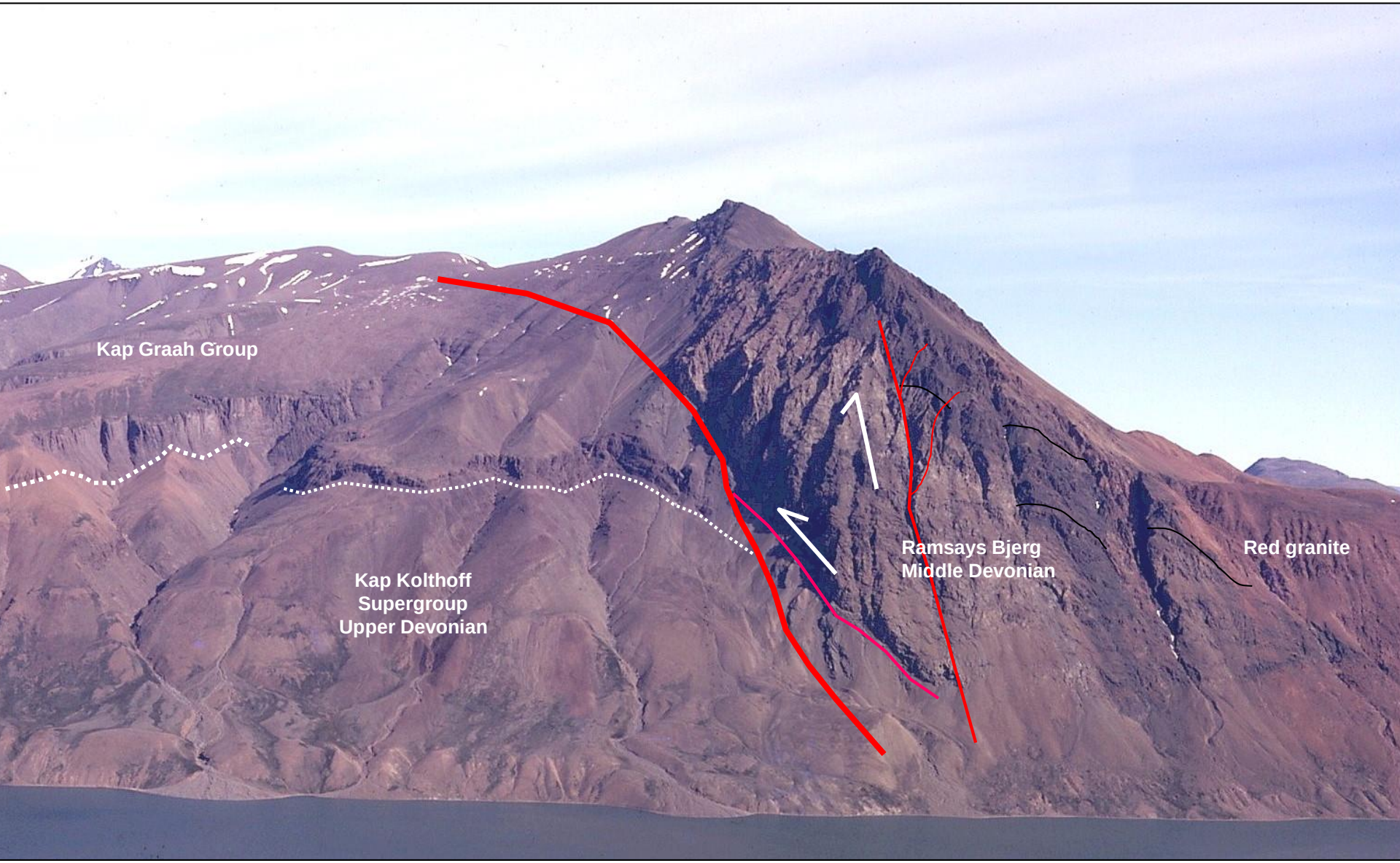
Now we go to Moskusokse Fjord on the north flank of Gauss, there's more there to add to the story.

Some 40 km north from Agda Dal, along the trend of the growth fault, at Moskusoksefjord's southeast end we see Hogboms Bjerg, a striking peak with a huge reverse fault pushing Middle Devonian (Ramsay Bjerg) green sandstones westwards over the east edge of the Upper Devonian basin. So the big faults here seem east-dipping, not westerly. If that is the case, what has caused the change?

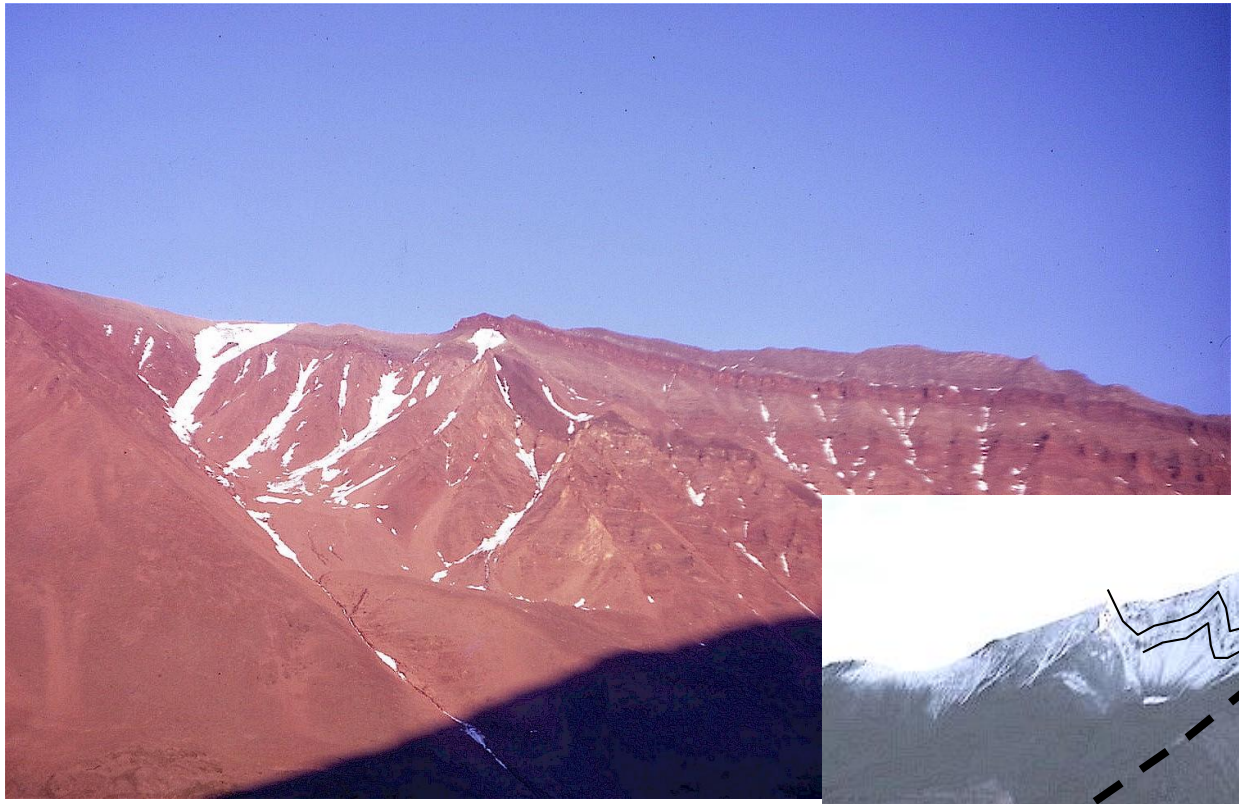
Looking at the geological map our interpretation is that the boundary fault between Middle and Upper Old Red sequences steps right by 5-10 km or so, forming a restraining bend. In effect we are looking at a sidewall jog. The controlling main fault (green) north and south of Hogbom may be west-dipping still, or go to more or less vertical as it steps eastwards before resuming its northerly track. The key thing is, it has left (southward) displacement which breaks down the bend in a set of wedges climbing across the Upper Devonian. From this observation it is likely that the sector south to Agda Dal has an element of extensional strike-slip, as well as being a major down-to-west growth fault.

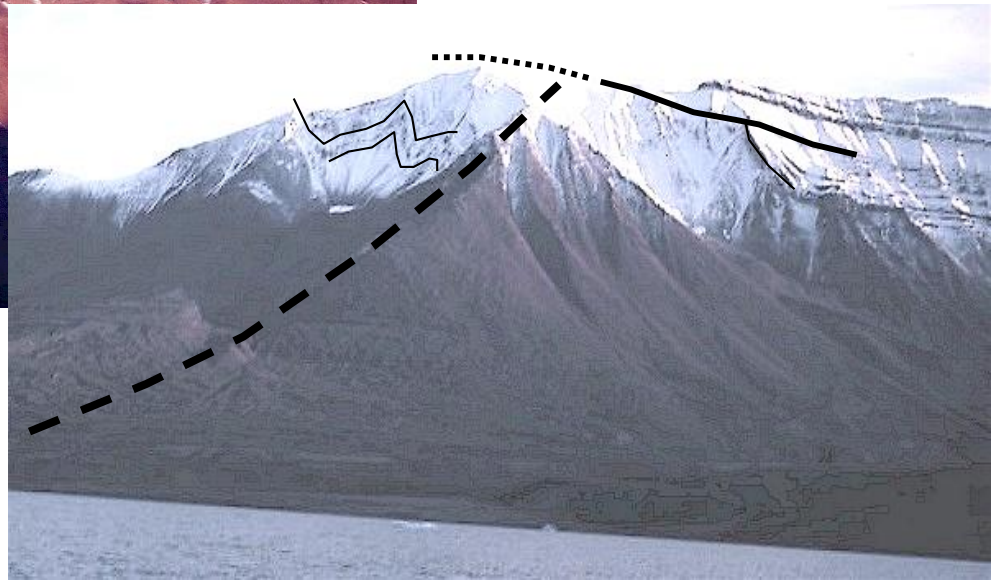
Going north into Hudson Land we see deeper and deeper sequence, the fault style is clearly strike-slip with dominantly left-handed movement. In the Middle Devonian between here and Payer Land Detachment Zone there is a series of narrow deep graben, and there are more of these east-dipping reverse faults.





Hogboms Bjerg in Moskusoksefjord, west-east profile looking north. This is a local reverse fault on a right-stepping restraining bend, Middle Devonian Ramsays Bjerg beds are underthrusted (towards us, being left-handed movement) in a footwall comprising the two Upper Devonian units, Kap Kolthoff below and Kap Graah Group above. These latter two are separated by a base-of-Kap Graah unconformity with local conglomerate, which gets jammed under the thrust surface, corresponding to a phase of transpression in Hudsons Land.





Opposite side of the fjord, looking south now at the end of Sederholms Bjerg, with some new snow marking folding in the hangingwall of the inverting reverse fault. Likewise there's folding in the footwall too, obscured by scree at the fault but clear in the upturning of a basalt sill which is truncated by the latest Mt Celsius Bjerg unconformable sequence pale grey sandstone. This unconformity only persists laterally for a few km, its the unit we saw at Agda Dal. In showing rapid lateral change in stratigraphy and structure that's typical of strike-slip systems.