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Generation and Migration of Hydrocarbons on Southern Norwegian Shelf

The Southern Norwegian Shelf (56°-58°30′ N) has proved to be one of the most prolific hydrocarbon provinces in Europe. Recoverable reserves of about 2 billion bbl of oil are found predominantly in Upper Cretaceous-Danian age chalk and Jurassic sandstones. The excellent quality of seismic data, moderate-dense well control, and the detailed geochemical evaluations of the Kimmeridge Clay, the principal source rock, make the Southern Norwegian Shelf an ideal area for hydrocarbon generation studies.

A geochemical analysis of the area contained 4 basic steps: (1) construction of a 9-layered 3-dimensional grid summarizing the burial history of the sediments, using well control and seismic data, (2) calculation of geothermal gradients, (3) source rock analysis to investigate variations in thickness and richness throughout the study area of the Kimmeridge Clay, and (4) maturation study based on the results of the 3 initial steps.

Major factors affecting hydrocarbon accumulations in the structural and stratigraphic closures of the study area include the amount of oil generated within the catchment areas of the various closures, and particularly in the case of the chalk fields, the level of hydrocarbon generation of the Kimmeridge Clay directly under the crest of the structure and the presence of faults to act as conduits for vertical migration of hydrocarbons from the Upper Jurassic Kimmeridge Clay to the Upper Cretaceous-Danian chalk. The expulsion and migration efficiency (hydrocarbons in place/hydrocarbons generated within the catchment area of individual closures) for tested closures averages approximately 8% for the study area, with individual culminations having values as high as 40% or as low as 0% based in part on the previously mentioned factors.

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Subsidence, Heat Flow, and Mechanisms of Extension Within Crust

There is now reasonable agreement on the fact that formation of continental margins is accompanied by thinning of the continental crust as well as the mantle part of the lithosphere. Whether or not the amount of thinning is the same in both portions has been debated. However, an equal amount of thinning is a good first approximation. We use this approximation to explore the thermal and mechanical consequences of the initial rifting phase with a kinematic thermal model.

We show on one hand that lateral conduction is not very significant when computing surface heat flow and subsidence values, but that it becomes highly significant in narrow rifting zones to obtain the evolution of the structure at depth. Actually, partial fusion can be prevented by lateral cooling in rifts which are too narrow, thus leading to an abortion of the rifting. On the other hand, we show that high sedimentation rates play a significant role in obtaining heat flow values at the surface and at the base of the sedimentary piles. However, high sedimentation rates do not affect the thermal evolution at depth.

Using this kinematic thermal mode, we explore some mechanical aspects of rifting. First, following England, we estimate the variation in resistance to stretching of the whole lithosphere as rifting proceeds. However, at the difference of England, we introduce a brittle as well as a ductile zone. Our results show that there is no increase in resistance to stretching as rifting proceeds. We then compute the evolution with time of the brittle ductile zone. This limit migrates upward in the thinnest portion of the margin. Thus, it is not safe to use estimates of final brittle crust thickness to obtain a relative amount of thinning. Finally, we compute the body forces which introduce a significant "rift push force" and in addition may result in decollement of the tilted blocks in the lower part of the margin. In view of these theoretical results, we present a model of evolution of the Bay of Biscay margin.

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Effects of Deep-Seated Igneous Intrusions in Northwest Germany on Generation of Hydrocarbons in Lower Jurassic Source Strata

In the Lower Saxony basin of northwest Germany several deep seated batholithic intrusions are indicated by pronounced gravity and magnetic anomalies. At considerable distance from these intrusions, the igneous heat has significantly advanced the rank of coaly particles finely dispersed in shales and siltstones of Upper Carboniferous to Lower Cretaceous-age strata, and isorank patterns have been documented in the literature. The results of a detailed geochemical study of kerogens and extractable low and high molecular weight hydrocarbons in Lower Jurassic Pliensbachian-age source bed-type shales involving a multitude of analytical methods (solvent extraction, MPLC, HPLC, capillary gas chromatography of saturated and polycyclic aromatic hydrocarbons, GC/MS of steranes and triterpanes, hydrogen stripping/thermovaporization of light hydrocarbons, Rock-Eval pyrolysis and reflectance microscopy) are reported in this paper. A reconstruction of the pre-intrusive burial and maturation history based on a modified Lopatin method allowed, for this sourcerock unit, estimation of temperature and maturity increase associated with the intrusion.

The main conclusion from this study concerns a significant influence which the high heating rate exercised, during the period of cooling of the intrusions, on the evolution of hydrocarbon generation processes in these Lower Jurassic source beds. The established relationship between stages of petroleum hydrocarbon generation and maturity progress (expressed, e.g., as vitrinite reflectance), as it has been documented for many case histories worldwide and referred to as "liquid window," cannot be seen in this rapidly heated source rock series. The liquid window is shifted toward higher maturity stages and extends up to 1.75% R_m. This is documented on the basis of maturity trends for the evolution of yields and compositional patterns of the extractable hydrocarbons. The most likely explanation for these observations is that the reaction rate causing vitrinite reflectance to increase is more temperature-dependent than the rates of the hydrocarbon generation reactions. In kinetic terms this means that, although the processes are highly complex, the effective activation energy of the vitrinite reaction is higher than that of the hydrocarbon generation reactions.

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Overthrust Problem—As Exemplified in Western Canada

The Western Canada sedimentary basin contains tar deposits in Lower Cretaceous sands and on the Paleozoic unconformity surface which exceed by 3 times the known recoverable oil reserves of the entire world. The tar was originally liquid oil which has been degraded by aerobic bacteria.

The Athabasca anticline, a drape structure caused by Devonian salt removal, connects southward with the Sweetgrass arch to form a 600-mi long structural barrier on the eastern, updip rim of the basin. Most of the tar deposits are along the anticline or in a giant stratigraphic trap on the west flank of the anticline. There is no oil or gas east of the anticline.

In the deepest part of the basin the Mesozoic section generated gas in enormous volumes. Most of the gas has escaped to the outcrop, a small amount is contained in thousands of conventional stratigraphic pools on the east side, and a very large volume is contained in tight sands on the west side, or in the Deep basin. Most of the reservoirs are Lower Cretaceous sands. The tight, gas saturated sands grade updip into porous water saturated sands. The trap is not tightly sealed but leaks off at a steady rate. Continuing gas generation keeps the trap pumped full. This bottleneck trap contains 1,700 tcf of gas in place.

The gigantic oil and gas accumulations of the Lower Cretaceous make the Western Canada sedimentary basin the richest hydrocarbon province in the world.