1. Introduction

Deep water oil and gas exploration is one of the hot spots of global oil and gas exploration and development, and has become a new growth point of oil and gas reserves in the world [1]. At present, there are more than 60 countries in the world carrying out oil and gas exploration in deep water area (water depth > 300m), and the proved reserves are about $300 \times 10^8$ t [2]. Among them, the central shelf of Norway along the North Atlantic coast has a huge exploration potential due to its low degree of exploration [3]. According to the U.S. Geological Survey's oil and gas potential assessment of the central shelf of Norway in 2008, the oil and gas reserves in the passive continental margin basin of the central shelf of Norway are about 7.32 billion barrels of oil equivalent, including 1.44 billion barrels of crude oil, 914.068 billion m$^3$ of natural gas and 500 million barrels of liquefied natural gas [4]. Based on the previous geological data and previous research results of the central shelf of Norway, this paper analyzes the oil and gas exploration history and future exploration potential of the central shelf of Norway, so as to provide basis for related companies to intervene in the oil and gas exploration in this area.

The central shelf of Norway is located between 62 ° and 68 ° north latitude, and the depth of seawater is between 200-1500 meters. It is the second largest oil and gas producing area in Norway after...
the North Sea (Fig. 1). The deep-water basin of the continental shelf in central Norway is mainly composed of the NE-SW trending Vøring basin and the møre basin.

![Figure 1. Distribution of basins and deepwater oil and gas fields in the shelf of Mid-Norway (modified from references [5])](image)

2. Sedimentary structure evolution

The tectonic evolution of the continental shelf in central Norway is closely related to the North Atlantic Rift, which mainly goes through three stages: the continental craton stage (pre rift stage) before the Early Triassic Indian stage (250mA), the rift stage of the Early Triassic - tertiary Paleocene and the continental drift stage of the early Eocene (53.4ma) and the present. A series of Mesozoic Cenozoic sedimentary depressions (Figure 1) [6] were formed in the basin. Different evolution stages correspond to different sedimentary filling sequences. In pre rift period, the sedimentary filling is Devonian, Carboniferous and Permian continental conglomerates and sandstones deposited on the Caledonian metamorphic basement; in rift period, the sedimentary filling sequences include Triassic, Jurassic, Cretaceous and tertiary Paleocene sandstones, shale, a small amount of carbonate and some turbidite sandstones; continental drift The migration sedimentary filling sequence includes the sedimentary strata from Eocene to present, mainly including the sand mudstone, shale and turbidite sandstone in some areas of the continental margin clastic deposition.
3. Geological characteristics of oil and gas

3.1. Source rocks
The source rocks of the continental shelf in central Norway are mainly marine shale of spekk formation of Viking group of Upper Jurassic. Spekk formation is marine shale deposition, which lasted from the end of Middle Jurassic to early Cretaceous. The transgression of the middle continental shelf of the upper Jurassic in Norway reached its peak, and spekk formation was deposited under anaerobic environment. Spekk formation is a set of highly radioactive shale with high organic carbon content (5-8% TOC) and hydrogen index (hi-800mghcs / gtoc). It is a set of oil-rich source rock, the most important source rock in this area. Kerogen type is type II or III, mainly producing light oil of 7-20million m³ / km² [7].

3.2. Reservoir
The Middle Jurassic shore shallow marine sandstone is a proven reservoir [25], which is dominated by the coastal fangst group, including ile, not and garn sections. The sandy sediments are mainly from the regional dome, which is equivalent to the sandstone of Brent group in the North Sea during the low water stage. The thickness of ile formation is 60-82m, which is a set of marine sandstone with thin shale / siltstone interbedding near the coast. The sandstone of ile formation is considered as a good reservoir. The transformation from Ile group to Not group is represented by transgressive conglomerate with thickness of 10 meters. The not formation is marine shelf deposit, 24-34m thick, with shale at the bottom and siltstone with bioturbation at the top. The formation of garn formation changes from 14-114m, reflecting different sedimentary thickness and local erosion. The southwest is thicker and thinner to the center and North. The garn formation is an important reservoir unit, with good porosity and permeability values. The porosity is about 22%, and the buried depth is about 4.7km, reflecting different sedimentary thickness and local erosion. The southwest is relatively thick, thinning to the center and North.

3.3. Oil and gas migration
In the early morning, two sets of favorable source rocks were deposited in the middle continental shelf of Norway. The continental margin clasts formed at the edge of the basin accumulated into favorable reservoirs. The tectonic activity was very strong, forming a large number of faults and unconformities between structural layers, all of which provided favorable conditions for oil and gas migration. According to the migration path and distance of oil and gas, there are two migration modes of continental shelf in central Norway: (1) short-distance convergence mode of fractures, dredged layers and faults; (2) long-distance migration mode of unconformity surface or connected sand body.

4. Exploration potential
According to BP (2008) survey, Norway has become the fifth largest natural gas producer and the third largest natural gas exporter in the world. However, with the oil and gas exploration and development in the North Sea coming to an end, the main oil and gas growth points in Norway in the future are located in the central shelf of Norway and the Barents Sea. Since 1980, Norway's oil and Gas Exploration Center has turned to the central shelf of Norway. So far, many oil and gas fields have been found in the deep
water area of the basin (Fig. 1, table 1). According to USGS, there are still many oil and gas fields to be discovered in the continental shelf of central Norway, especially the deep water area with low degree of exploration is the main area for future exploration.

Oil and gas exploration and drilling show that the oil and gas accumulation conditions of the continental shelf in central Norway are superior, and the Jurassic high-quality delta plain marine shale, Jurassic neritic sandstone, Cretaceous and tertiary marine turbidite sandstone and shale overlying sandstone developed in the anaerobic reduction environment have a good combination of source, reservoir and cap; the tectonic activity is strong in the rifting period and is caused by the tension environment A series of normal faults, associated with Horst trap, fault block trap, rolling anticline trap and fault anticline trap, are developed. Oil and gas first migrate into the reservoir under the action of overpressure and self buoyancy after they are generated from the source area, and then mainly migrate and accumulate along the fractures, dredge layers, faults, unconformity surfaces and connected sand bodies.

At present, according to USGS (2008), it is estimated that the number of the smallest oil fields to be discovered in the continental shelf of central Norway can reach 3.2, and the number of oil fields with reserves between 32-128 million barrels is the largest, which is expected to exceed 2.2; the number of gas fields with the minimum gas field size over 120 billion cubic feet to be discovered can reach 3.4, and the number of gas fields with reserves between 1920-614.4 billion cubic feet The number of fields is the largest, more than 26. Therefore, with the gradual development of oil and gas exploration, there will be major oil and gas discoveries in the central shelf of Norway.

Table 1 Major deepwater oil and gas fields in the shelf of Mid-Norway

| Gas field name | discovery date | water depth/m | Recoverable reserves Oil/mill Sm3 | Gas /bill Sm3 | Total recoverable reserves/mill Sm3 oe | Reference |
|----------------|----------------|---------------|-----------------------------------|---------------|----------------------------------------|------------|
| 6506/12-1 Smorbukk | 1996/6/6 | 303 | 120.5 | 285.27 | 405.77 | [8] |
| 6305/5-1 OrmenLange | 1997/10/7 | 857 | 18.9 | 296.4 | 315.1 | [8] |
| 6507/7/2 Heidrun | 1985/6/10 | 351 | 186 | 53.88 | 239.88 | [8] |
| 6608/10-2 Norne | 1992/1/29 | 374 | 91.3 | 11.19 | 102.49 | [8] |
| 6507/5-1 Skarv | 1998/5/3 | 323 | 17.9 | 53.55 | 71.45 | [8] |
| 6406/2-3 Kristin | 1997/9/29 | 341 | 25.2 | 41.40 | 66.6 | [8] |
| 6407/7-1S Njord | 1986/4/7 | 328 | 29.6 | 27.47 | 57.07 | [8] |
| 6603/12-1 Gro | 2009/6/20 | 1376 | 0 | 55 | 55 | [8] |
| 6707/10-1 Aasta Hansteen | 1997/7/23 | 1274 | 0 | 45.5 | 45 | [8] |
| 6605/8-1 | 2005/10/22 | 838 | 0 | 33 | 33 | [8] |
| 6406/3-2 Trestakk | 1986/11/22 | 300 | 9.36 | 2.72 | 12.08 | [8] |
| 6506/6-1 Victoria | 2000/12/7 | 434 | 0 | 26.79 | 26.79 | [8] |
| 6406/9-1 Linnorm | 2005/6/2 | 308 | 0.58 | 24.35 | 24.93 | [8] |
| 6407/7-14 S Zidane | 2010/9/26 | 344 | 0.42 | 18.37 | 18.79 | [8] |
| 6705/10-1 Asterix | 2009/3/19 | 1335 | 0.29 | 17.17 | 17.46 | [8] |
| 6506/11-7 Morvin | 2001/7/27 | 356 | 10.1 | 6.98 | 17.08 | [8] |
| 6406/3-8 Maria | 2010/8/10 | 303 | 25 | 6.3 | 31.3 | [8] |
| 6406/12-3 S Pil | 2014/6/11 | 324 | 11.1 | 5.83 | 16.93 | [8] |
| 6201/11-3 Albert | 2012/6/16 | 383 | 0 | 13.3 | 13.3 | [8] |
5. Conclusion

1) The source rocks of the continental shelf in central Norway are mainly the shale of Lower Jurassic delta plain, coal seam and the shale of Upper Jurassic sea. The shale of Upper Jurassic sea is considered as the main source rock, which is a set of high radioactive shale. Kerogen type is type II - III, TOC is 5% - 8%, $hi = 800 \text{mg HCS/gtoc}$, and oil and gas are mainly generated.

2) The main reservoirs are littoral shallow marine sandstone and Cretaceous tertiary turbidite sandstone in the rift period of the Middle Jurassic. The littoral shallow marine sandstone in the rift period of the Middle Jurassic is considered as the main reservoir, especially the sandstone of the garn formation with porosity of about 22%, good permeability and buried depth of about 4.7km, which is proved to be a good reservoir.

3) Oil and gas are migrated and finally formed reservoir through short distance convergence of fracture, dredge layer and fault and long distance migration of unconformity surface or connected sand body.

4) With superior oil and gas accumulation conditions and huge resource potential, the reserves are about 7.32 billion barrels of oil equivalent. The number of oil fields with the smallest oil field size more than 20 million barrels to be discovered can reach 3.2, and the number of gas fields with the smallest gas field size more than 120 billion cubic feet can reach 33.4. With the gradual development of oil and gas exploration, there will be major oil and gas discoveries in the central shelf of Norway.

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