The Saglek Basin in the Labrador Sea: Past Exploration History, Current Estimates, and Future Opportunities*

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Summary

New interpretations of industry seismic data in northeast Labrador Sea have been produced to develop a 3-D Petroleum System Model for the Saglek Basin. Improved palynological analysis has provided better age constraints on the timing and geometry of basin in-filling and subsidence. Exploration well cutting samples have been re-analyzed to improve the details of thermal maturity and kerogen source type. A 2-component heat-flow model has been adopted, based on the tectonic history of the Labrador Sea and the timing of significant volcanic extrusions--each producing significant heat pulses. The new petroleum model explains the origins of the discovery at Hekja O-71 and provides an explanation for the dry Ralegh-N18 well only 25 km away (Figures 1 and 2). The revised seismic mapping used for the model building shows the presence of very large structural closures that could represent significant future exploration targets; one very large structure mapped is over 10 times the size of the Hekja structure.

The Saglek Basin is a very large sedimentary basin (over 100,000 km^2) on the northern end of the Labrador Margin. The 2 Tcf Hekja O-71 (H O-71) discovery in 1979 (Figures 1 and 2) lies at the northern end of the Saglek Basin near the mouth of Frobisher Bay offshore Nunavut. The southern half of the basin is within the offshore jurisdiction of Newfoundland and Labrador. The basin contains over 9 km of strata mapped by regional 2-D seismic data.

A basin-wide seismic reflector that is interpreted as basalts in the north leads to a regional unconformity in the south. These basalts have been sampled from the exploration wells and are thought to be part of a major subaerial Paleocene volcanic event corresponding with the initiation of sea-floor spreading (Chron 27N).

A second volcanic episode corresponded with a major change in direction of motion of the Greenland Plate (Chron 24R). Satellite-derived gravity data (Sandwell and Smith, 2009) have been used to produce a marine Bouguer gravity anomaly map (Figure 1), which shows that the now-extinct (Chron 13N) Labrador Sea spreading axis extends into the Saglek Basin and cannot be seismically differentiated from the mapped "basalt" seismic horizon. Based on these tectonically controlled volcanic events, two heat pulses at 65Ma and 56Ma in the basin thermal history wereused in the petroleum system model.

The geochemical analysis of the well cuttings from the Hekja O-71 well indicates that they were thermally too immature to produce the gas and condensate found at the depth of discovery, ~3200 m (Fowler et al., 2005). Terrestrial-based source rocks (deltaic siliciclastics with coals) containing resinites are capable of generating hydrocarbons at low maturity levels (Snowdon, 1991); however, the model suggests that these hydrocarbons were not locally "self-sourced" but filled the structural trap by fluid migration from a deeper more thermally mature deposit of similar source rocks. Along a seismic line, a vertical component of migration is suggested by a probable seafloor feature (Figure 3). We believe that Upper Cretaceous strata beneath the Paleocene basalts were also a significant contributor to the petroleum generation in the basin and the model results show that original in-place gas volumes of 170 to 260 Tcf are possible.

A new synthesis of the exploration-well stratigraphic correlations was made possible by new palynological analysis that greatly improved age dating and depositional environments. Basement blocks responded to changes in the regional tectonic episode, forming numerous structural traps of which only a few have been drilled. The basement-controlled faults formed sediment-bypass fairways in some areas, resulting in a complex distribution of coastal siliciclastic facies farther seaward than expected. Three prospective formations capable of generating petroleum have been identified, and their variable depth-of-burial and proximity to the siliciclastic reservoir rocks are critical factors in the modelling of petroleum generation and trapping.

Although all major tectonic movements ceased in the late Eocene (Chron 13N, ~35 Ma), the area is still seismically active. The "Labrador Sea Seismic Zone" is a linear belt of medium-amplitude earthquakes coincident with the extinct spreading axis. Seismic events from offshore California are known to trigger venting of petroleum (Field and Jennings, 1987). In the Saglek Basin, there is an unaccounted lack of observed reflection seismic indicators of gas-charged sediments or gas hydrates. The presence of seafloor features that appear to be caused by petroleum venting and oil slicks on the sea surface imaged by satellite radar (Jauer and Budkewitsch, 2010) suggests that there has been ongoing periodic seepage of petroleum from the basin and that this process may be augmented by persistent local earthquake triggers.

The existing understanding of petroleum potential for the Saglek Basin is based on limited seismic mapping, eight drilled exploration wells and one significant discovery. The petroleum system, previously thought to be locally derived and "self-sourcing", is now shown to be generated at greater depths and has migrated into the reservoirs over wide distances. The many untested structures and the hydrocarbon volumes generated by the model suggest that there is significant petroleum potential for the region

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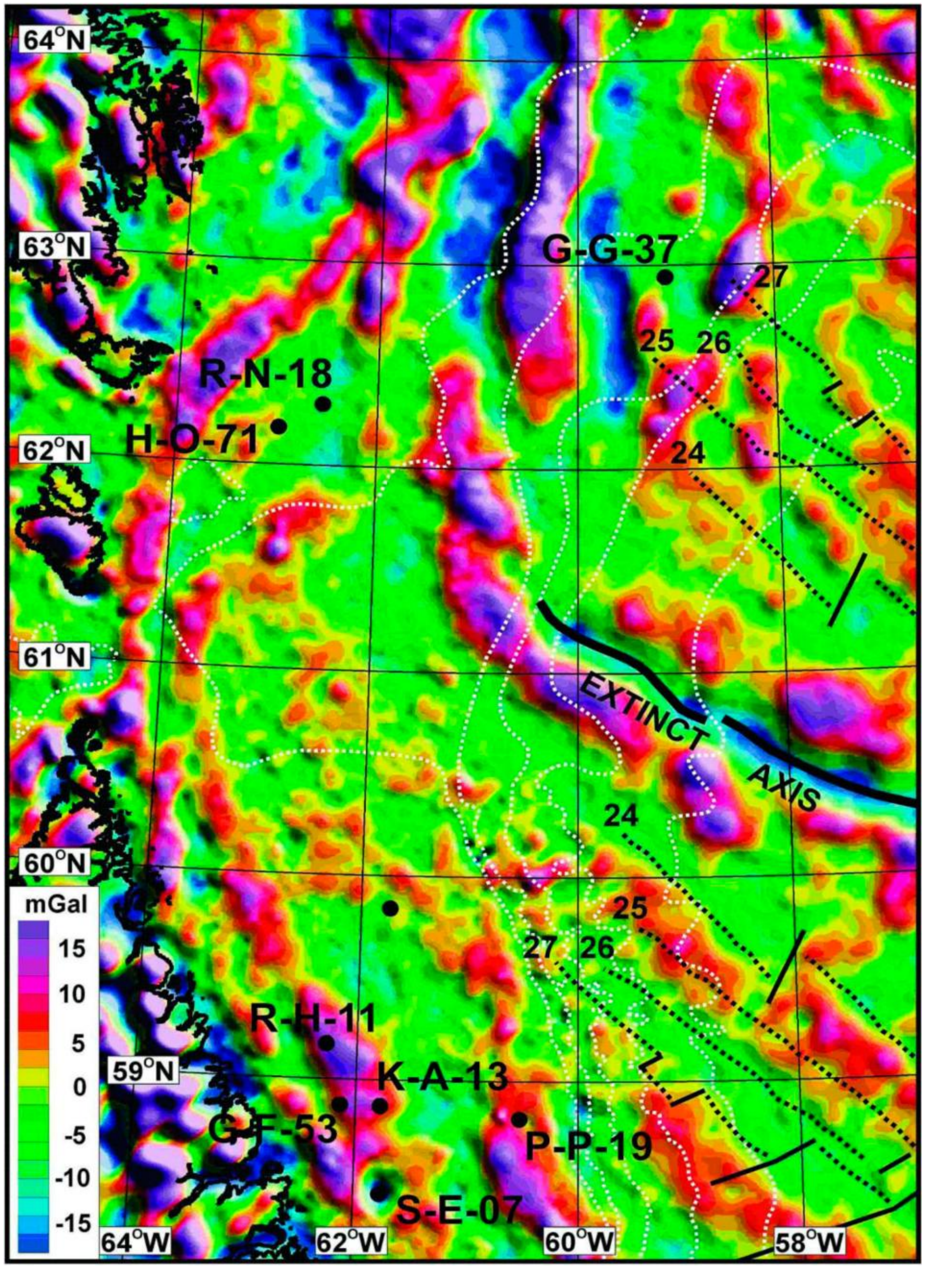

Figure 1. Marine bouguer anomaly map, with magnetic chrons and exploratory wells.

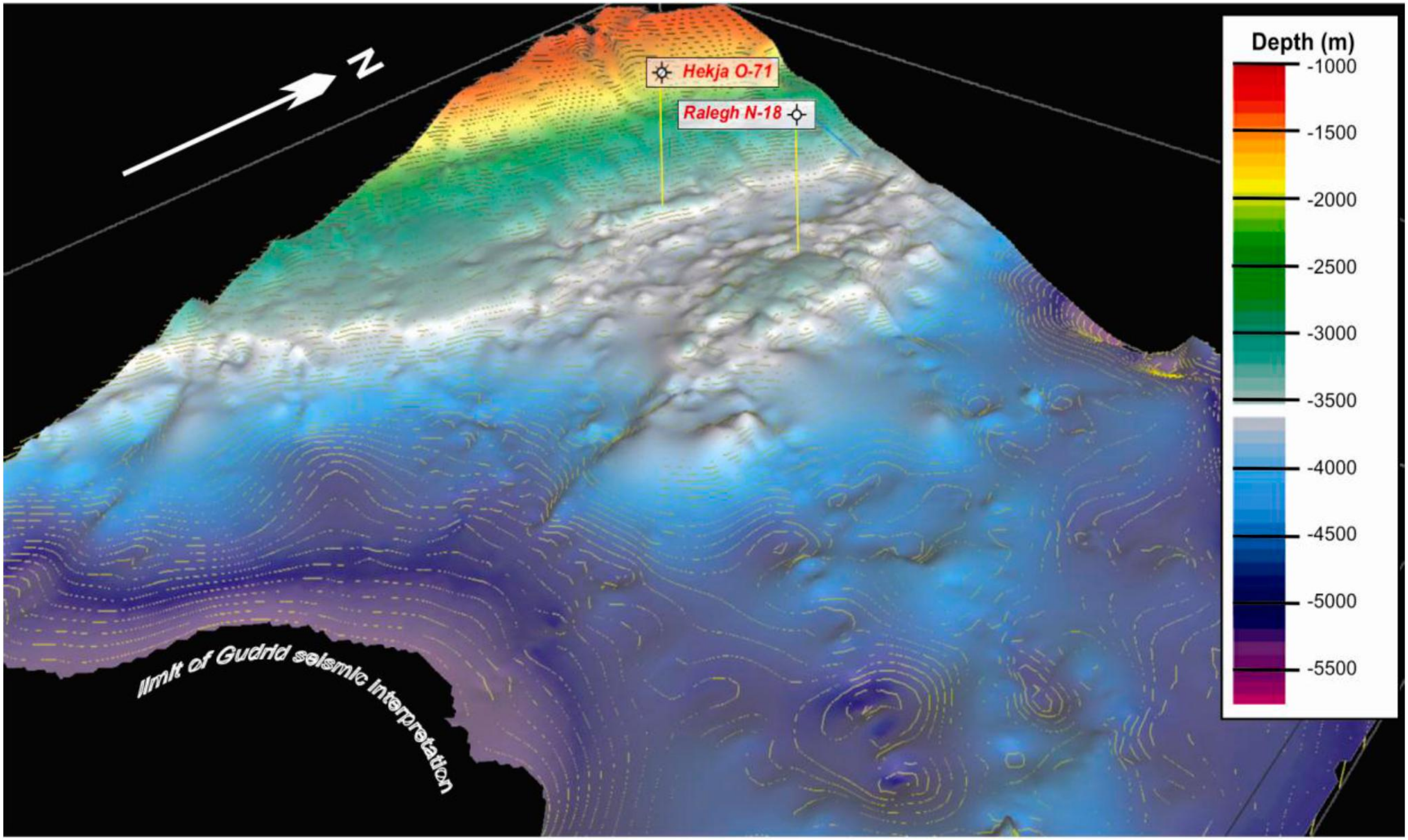

Figure 2. Seismic depth map of Gudrid Member at Hekya O-71 and Ralegh N-18 locations (from Jauer, 2009).

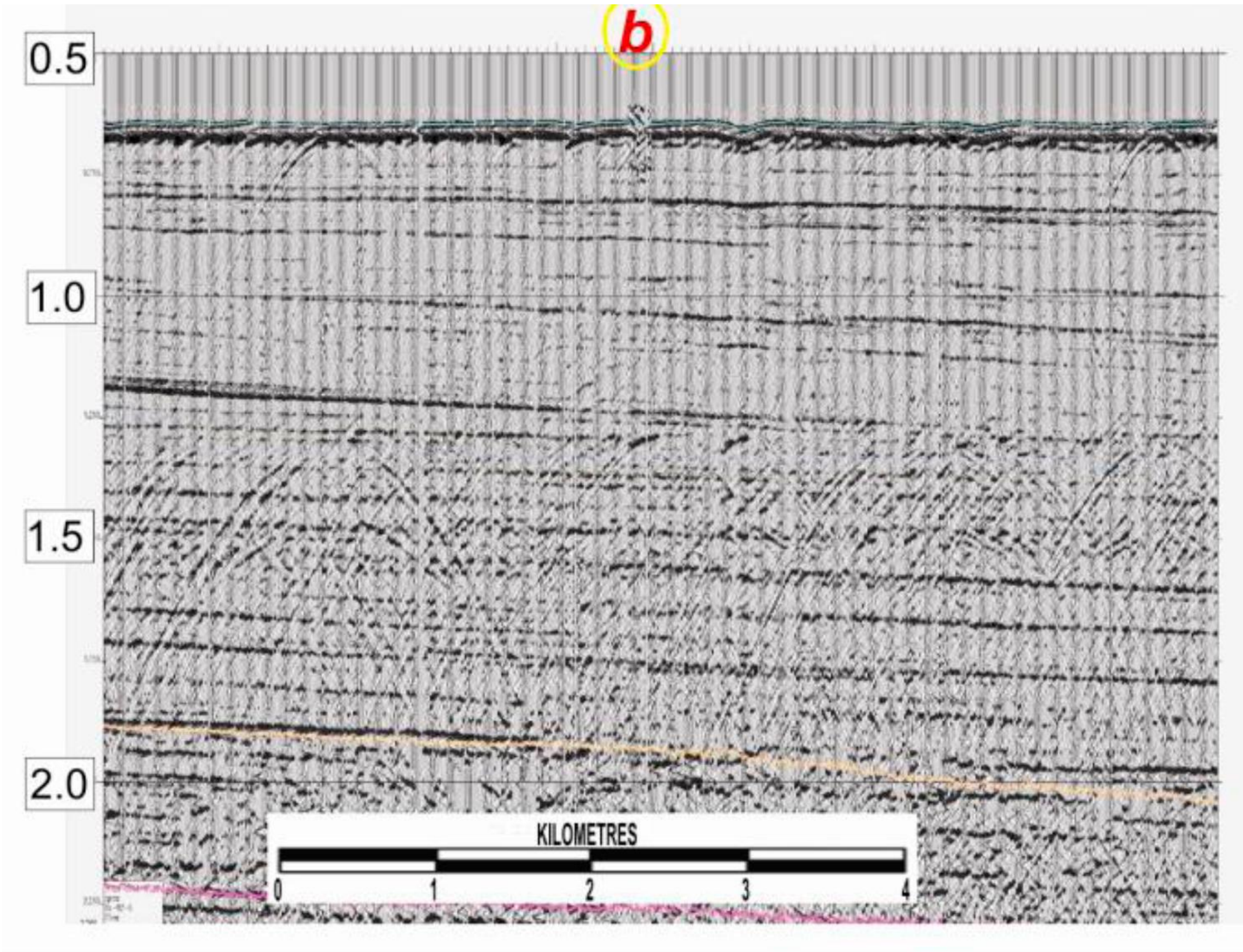

Figure 3. Numerous diffractions associated with this probable hydrocarbon-sourced seafloor feature are present on this unmigrated seismic section at ~1.2 seconds. Hydrate formation may not have occurred here due to the highly faulted nature of the section, as indicated by the many diffractions which would allow leakage. Note the rapid drop in seismic reflectivity to the right of the feature at ***b***.