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Orphan Knoll as a Window on the Palaeozoic: Seemingly ignored by the petroleum industry for 40 years

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Summary

Orphan Knoll stands as a pronounced topographic high on the ocean floor some 550km northeast of Newfoundland. It was almost 42 years ago since the author, as a Dalhousie University graduate student, nominated Orphan Knoll as a possible site for the Deep Sea Drilling Project (DSDP) in the Fall of 1969. The site was proposed as a possible continental fragment that had become separated from Europe in the initial breakup and left behind hence its proposed name. It was drilled in 1970 and its continental nature was confirmed by the bottommost one-metre-long core at Site 111; the black anthracite-rich, non-marine sandstone yielded a Jurassic age (175Ma).

In 1970 echosounding from the *D/V Glomar Challenger* revealed for the first time a significant field of over 250 pronounced 'mounds' along the northeast margin of the Knoll. The "Enigmatic Mounds" were dredged in 1971 and revealed evidence of the Palaeozoic shallow water marine sediments that lie beneath the Jurassic. The mounds are believed to be the bathymetric expression of diapiric activity that has brought the older sediments to the surface. The Enigmatic Mounds are believed to be bedrock cored and are not living, or dormant, bioherms. The Palaeozoic marine rocks of Orphan Knoll offer the petroleum industry a relatively easy and inexpensive opportunity to sample the marine sediments found deep in Orphan Basin to the west and to the south, found below Porcupine Bank, Porcupine-Seabight Basin and even the western Irish continental shelf to the east and the deeper parts of Rockall Plateau to the north. The presence of marine Palaeozoic rocks under Orphan Knoll implies that the Ordovician-Devonian intracratonic platform sediments had a wider geographic extent than previously recognised and that a marine reentrant must have penetrated the Old Red Sandstone.

Introduction

Orphan Knoll stands 1000m above Orphan Basin to the west and 1600m above the Basin to the south and drops precipitously 2200m to the Labrador Sea Abyssal Plain to the east (Figure 1). It is about 75km in breadth and is kidney bean-shaped over its 190km NNW-SSE length. It was nominated as a drilling site on the basis of bathymetry alone and was drilled by DSDP in 1970.

Orphan Knoll has stood as an isolated topographic high for about 60Ma and has not ever been buried by the continental, or continental shelf-derived, turbidity current deposition that has laid down up to 15,000m of sediments to the west and southwest in Orphan Basin. Orphan Knoll has been blanketed by a thin 250m-thick sequence of a compressed Jurassic-Cretaceous (50m of Bajocian sandstone to Albian limestone to

Maastrictian chalk) to 200m of Tertiary to Pleistocene pelagic sediments. The turbidity current flows have swept around Orphan Knoll to the north and eastward out the gap between Orphan Knoll and Flemish Cap to the south.

Deep Sea Drilling Project, Leg 12, Site 111, in June, 1970

Site 111 continuously cored the Tertiary section then took periodic cores below an unconformity at the top of the Cretaceous. The on-board scientific team misjudged the position of the apparent lowermost unconformity shown on the sub-bottom seismic profiles data and did not order a core to date the bottom of the Cretaceous section (presumed Aptian). The upper Cretaceous is marked by a 10m Maastrictian chalk capped by a hard-ground unconformity. The final core on the 1970 DSDP hole, as the diamond bit wore out 250m below the mud line on top of Orphan Knoll, was a metre-long anthracite-rich non-marine sandstone. The Bajocian (Jurassic) sandstone was interpreted in 1970 as the 'basement' to the small linear NW-SE-trending, thin Cretaceous basin seen on top of the Knoll. The drilling results on Orphan Knoll suggest a much closer relationship to Europe than to North America. There is no source of anthracite coal known in Atlantic Canada, but there are anthracite deposits known in Great Britain not far to the east in the reconstructed pre-drift continent. The Maastrictian chalk can be traced westward from the thick chalk sections in France to England and thinning to the 10m found to the west on Orphan Knoll on the western margin of the reconstructed continent.

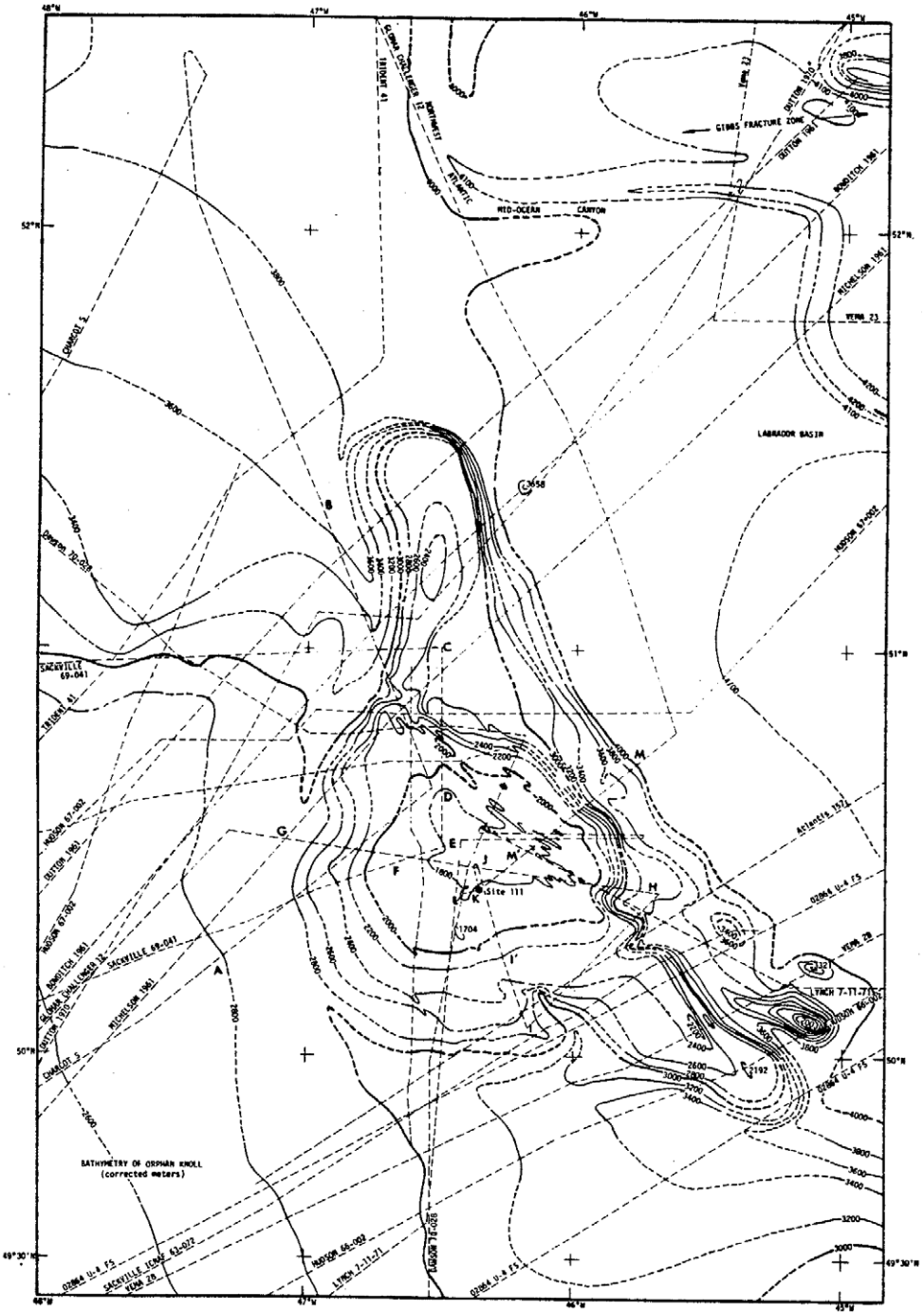

Figure 1: Bathymetry of Orphan Knoll in corrected metres (unaltered from Figure 2 of Laughton *et al.* (1972)). Contour interval 200m except over the Labrador Sea Abyssal Plain to the east where the interval is 100m. Solid contours indicate that the contour is defined, while presumed contours are shown as broken lines. The sources of information are indicated on the ship's tracks. Tracks indicated only by figures are from the U.S. Navy collected sounding sheets and the quality is completely unknown. The exact northwest and southeast extension of the Knoll is unknown though the 1979 cruise of *MV Starella* and the 1981 cruise of *MV Farnella* have done an additional line in the two areas respectively. The minimum soundings to the top of some of the more pronounced peaks are indicated. In this 1971 interpretation the pronounced peaks on top of Orphan Knoll were interpreted as a series of linear ridges; they are now known to be isolated mounds, or groups of mounds. This map does not include the few bathymetric lines gathered since 1971 on top of the Knoll, or the area of *USCGC Healy* multibeam test data gathered in 2000 over the Orphan Seamount area at the southeasternmost margin of the Knoll.

The 'Enigmatic Mounds' of Orphan Knoll

The bathymetric 'mounds' on top of Orphan Knoll were recognised for the first time in 1970 but not understood and, apart from our preliminary analyses, have received very little attention until mid-2010. The narrow, thin, Cretaceous basin on top of the Knoll is flanked by two fields of diapir-like features. These are often buried, or have failed to reach the surface, on the SW margin of the Knoll; they generally protrude above the smooth upper surface of the Knoll along its NE margin. The 'NE mound field' comprises more than 250 mounds, whereas the 'SW mound field' is barely a tenth the size as it is presently known. The NE mounds rise 115 to 320m above the seafloor. Some of the partially-buried mounds exceed 600m in height and the basal widths are in the order of <3km. Other than a 1971 dredging attempt from the *Lynch* and two other dredge hauls from *Hudson* in 1978, the mounds have received no further focused survey attention after two passes by the *Gloria* swath-mapping tool of the British in 1979 and 1981 by *Starella* and *Farnella* respectively. In 2000 two GSI 2D spec lines ran partway up the SW flank of the Knoll and profiled three buried and two protruding mounds of the SW field. Enachescu (2004) has suggested that they are living bioherms of deep coldwater corals possibly related to a methane seep. It was not until July 2010 that the mounds received specific attention when *Hudson* was equipped with a *Ropos* tethered ROV with a 3500m capability designed to examine the ahermatypic corals on the 1930m volcanic seamount that stands just east of the southern extension of Orphan Knoll and on several of the exposed mounds of the NE mound field.

The Biologic Dredge Results from USNS Lynch in 1971

The 1m-wide 1971 biologic dredge recovery of fragments of limestones and skeletal limestones was initially dismissed as dropstone material from icebergs. However a careful processing by Imperial Oil personnel in Calgary yielded some most tantalizing results that have received little industry, or scientific, attention. The dredge was dragged over a 1km track immediately adjacent to the base of one of the mounds in the NE field and excavated at most 5-10ka of sediment. These pebble-sized samples yielded:

a) a unique Ordovician assemblage of silicified ostracods which is endemic at the species level and contains two new species and a new genus, plus eleven other new forms left in open nomenclature. The ostracods have North American and North European affinities. There are no known locations in the NW Atlantic for this material unless one invokes presently-unknown outcrops under the glacial ice of Greenland, or Baffin, Bylot, Devon and Ellesmere Islands.

b) Ordovician basalia sponge spicules which are not known from any source in the NW Atlantic and which bear a close resemblance to obscure Australian forms. The 1971 material also contains Devonian heteractinid skeletal material which is almost impossible to move to Orphan Knoll from any known outcrop locations by ice- or iceberg-transport.

c) Devonian conodonts which again cannot come from any presently-known sources of marine Devonian rocks in northern Canada, or Greenland, in the past 5-10ka.

d) Early Silurian graptolites which could only have come from Cornwallis Island in the central Arctic Islands; this was not possible in the past 5-10ka.

Thus for a source of the Palaeozoic material one is left with ice- and iceberg-transport from presently-unknown outcrops to the north, or to conclude that the Palaeozoic material was derived from the nearby outcropping mound(s). If a) to d) above all came from the same sample then ice-transport can be invoked. But they did not come from the same sample. Thus the small, but finite, probabilities for each of cases a) through d), having come from a presently-unknown outcrop somewhere to the north under glacial ice and dropped in the same spot on the top of Orphan Knoll, must be multiplied, and this yields a near-vanishing probability that makes Lotto 649 look like a cakewalk. It is much more probable that the 1971 Palaeozoic material came from talus on the nearby mounds and was swept off the mounds by periodic slumps of the steady rain of pelagic material. We are left with the interpretation that the diapiric mounds have carried a selection of the Palaeozoic rocks that underlie the Jurassic of Orphan Knoll up to now outcrop at the present

seabed surface. The suggestion that the mounds are bedrock cored is strengthened by the 1978 *Hudson* dredge hauls that collected a large amount of dead *Desmophyllum dianthus*. This ahermatypic coral's preferred habitat is a vertical, to overhanging, rock outcrop.

Conclusions

We do not believe that the mounds of Orphan Knoll are living, or former, bioherms, but rather are the result of diapiric activity. We also conclude that the Ordovician-Devonian marine intracratonic platform sediments had a wider geographic extent than has been previously recognised. This leads to our conclusion that a marine reentrant must have penetrated the Old Red Sandstone. Thus the deep Palaeozoic section of the European side of the conjugate margin which is buried beneath Porcupine Bank, Porcupine-Seabight Basin, the southern Rockall Plateau, even the western Irish continental shelf and that below Orphan Basin to the west and south (Figure 2), can perhaps be accessed and examined rather inexpensively at Orphan Knoll along its steep NE-facing margin, where there are many probable bedrock outcrop areas, by using both geophysical survey techniques and off-the-shelf tethered ROVs, or submersibles.

Acknowledgments and Selected References

The unsung hero is Maurice Ewing of Columbia University who took a handwritten 1969 drill site proposal and bathymetry map drawn by Dave Monahan and the author, then vetted it against other marine geophysical data, and recommended the site for DSDP Leg 12. The GSC in Dartmouth, N.S. and ESSO in Calgary, Ab sponsored the author and Jan E. Van Hinte as members of the Leg 12 scientific team. The co-authors of the two *Scripta Geologica* papers merit special mention. Thanks to Jan van Hinte, Alan Grant and Art Boucot for their persistent encouragement ant to Sajjad Hussain for magic in Word!

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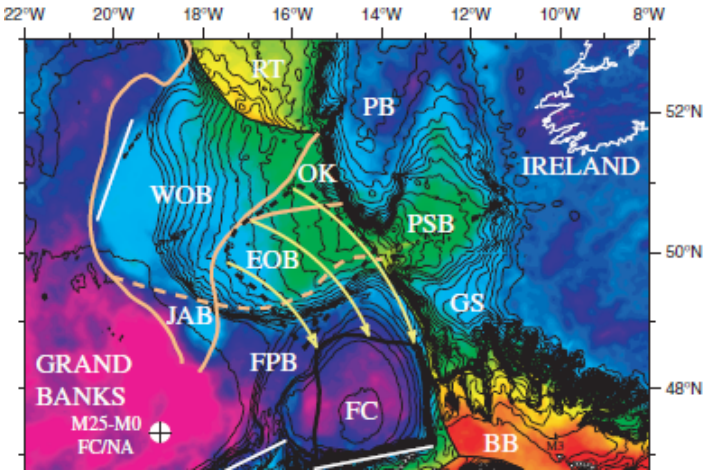

Figure 2: Northern portion of the reconstruction at chron M0 (118Ma, Early Aptian) of Sibuet *et al. Geol. Soc. Lond. Special Publications 2007*, **207**, pp. 63-76, showing the location of Orphan Knoll (OK) relative to West and East Orphan Basin (WOB, EOB), Porcupine Bank (PB), Porcupine-Seabight Basin (PSB), and Rockall Plateau (RT). Flemish Cap (FC) is shown as having been translated and somewhat rotated through ca. 40° clockwise from its original position southwest of Orphan Knoll. The pre-Jurassic rocks of Orphan Knoll are believed to outcrop on the steep NE margin of the Knoll and if mapped and sampled will give data on the Palaeozoic rocks of the Knoll's former neighbours including Flemish Cap if the Sibuet *et al.* reconstruction is correct.