Structural, tectonic and seismo-stratigraphic study of the Terra Nova oil field, Jeanne d'Arc Basin, offshore Newfoundland

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Discovered by Petro-Canada *et al.* in 1984, the Terra Nova field contains 400 million barrels of recoverable oil (estimated by C-NOPB). Terra Nova is the second largest discovery in the Jeanne d'Arc Basin, after Hibernia. The Jeanne d'Arc Basin is the lone oil province on the Grand Banks of Newfoundland and up until now, the only North American East Coast shelf area that contains giant oil fields. Thirty years after the initiation of hydrocarbon exploration in the Canadian Frontiers, Grand Banks of Newfoundland is rapidly becoming an important oil producing region. The Terra Nova field is slated to be developed by the end of this decade and will produce up to 125 to 150,000 bopd by the dawn of the new millennium. A floating production facility (FPF) rather than a gravity based structure (GBS) will be used for Terra Nova development.

Two 3-D marine seismic surveys (shot in the eighties) with 48 and 60 fold data, cover an area of 292 km^2 centered on the field. Within this merged survey, 11 wells (1 discovery, 5 delineations, 3 shows and 2 non commercial discoveries) allow for reliable correlation of the seismic markers to the Mesozoic stratigraphy. Stacked sandstones of the Mid to Late Kimmeridgian aged Jeanne d'Arc Formation constitute the field reservoir. Unfortunately, the individual sand bodies are not uniformly distributed and the top of the pay zone is not a dependable seismic marker. Consequently, the mapping of the field was done at the base of the reservoir, on the intra-Kimmeridgian Unconformity or Top of the Rankin Formation. The pay zone depth ranges between 3,000 to 3,500 m. The field is a complex structural-stratigraphic trap and is located on a large northerly plunging salt-cored arch, that was formed in an elbow of the Voyager Fault. The trap is a multi-side fault bounded depositional wedge, limited toward the east by the Voyager Fault and its lower imbricates, toward the north by the Trinity Fault and toward the west by the King's Cove Fault. An apparent anticline is visible in the downthrown block of the Voyager Fault on a west-east (dip) seismic section. On a south-north line (strike), the oil-prone Jeanne d'Arc Formation constitutes a northerly deepening and thickening structural wedge. The sinuous depositional edge of the pay zone represents the southern limit of the field.

Terra Nova faults are components of two main linked and intersecting systems of extensional listric faults that fragment the basin. The Voyager Fault is the main antithetic of the Murre Fault and marks the eastern limit of the Cretaceous Basin. The deep-penetrating faults trending approximately north-south are antithetic and synthetic to this major fault. They compartmentalize the area into the West Flank Block, the Graben, the East Flank Block and the Far East (undelineated). These faults were active during the main rifting phases in the basin and correspondingly, structural growth is episodically recorded in their hanging walls. The east-west faults are minor and have smaller throws. Knowledge of smaller and sub-seismic fault distribution is important for field development. The quality of the present seismic data sets generally preclude a detailed fault pattern study at the reservoir level. Thorough fault mapping was performed on the clearly imaged B Marker. The fault population observed on the B marker time structural map may be used to evaluate the density and distribution of fracturing in the reservoir interval. Fault distribution and linkage can also be analyzed by means of "Continuity Cube" displays.

The stratigraphic seal is represented by the massive overlying Fortune Bay Shale Formation. Immediately under the base of the reservoir lies the Egret Member. Egret Member of the Rankin Formation contains organic rich limestones and calcareous shales and is the major source rock in the basin. In the southern sides of the field, the Top of the Rankin Formation closely corresponds to Top of the Egret Member and is a regional unconformity, which is strongly channelized. A seismic amplitude study performed on this marker had previously illustrated a paleodrainage system and a possible shoreline associated with the oil-host seismic sequence. Several other workstation implemented displays such as the dip, azimuth

and peneplanum slices were used to identify, map and visualize the paleogeography of the Kimmeridgian Unconformity and Jeanne d'Arc Formation.

Two models of paleo-deposition have been suggested in the past for the Terra Nova reservoir. One implies a continental, mainly alluvial origin for the reservoir sands and shales while the other infers a stronger marine influence on the depositional system. The present seismo-stratigraphic study and reevaluation of electric logs and cores, indicate that the Jeanne d'Arc reservoir sandstones were deposited in a continental to estuarine to marginal marine environment, with the intervening shales clearly of marine origin. The inferred shoreline extracted from the seismic attribute displays extends eastward toward the Voyager Fault. The shoreline represents a stabilized Kimmeridgian paleoshore which was structurally or lithologically controlled and was most likely the southern limit reached by the sea during transgressive highstand episodes. A lowstand shoreline, contemporaneous with valley incision within the field area is probably located north of the Trinity Fault. Marine reworking of alluvial and shallow marine sands took place during sea level oscillations on the broad, gentle sloping shelf occupied now by the Terra Nova field reservoir. Several other erosional surfaces such as the Avalon Unconformity, Petrel Limestone, Sub-Tertiary Unconformity, etc., were mapped using 3-D special attributes and visualization. They all illustrate the persistence through time of the southern drainage system and its structural congruence to the Voyager Fault.