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Part IV: Formation tops and isopach maps of Horn River  
Group and basal beds of Imperial Formation, central  
Mackenzie Plain, NTS map sheets 96C-E**

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## SUMMARY

Tops of lithostratigraphic units of Middle-Upper Devonian strata are updated based on new results from central Mackenzie Plain. These strata include the unconventional hydrocarbon prospect known as the Canol Shale Play. The updated lithostratigraphic subdivision includes previously recognized and new members of Hare Indian, Canol, and Imperial formations traceable within NTS map areas 96C to 96E. These lithostratigraphic units are characterized in representative cored sections, identified in outcrops, and traced in the subsurface using spectral gamma, sonic, and resistivity logs, as well as available sample inventory. True vertical thickness (TVT) isopach maps and depth maps were created with Kriging methods in the ArcGIS Geostatistical Analyst wizard.

## UPDATED STRATIGRAPHIC FRAMEWORK

The stratigraphic framework for subsurface data in this study includes Hare Indian, Ramparts, Canol, and basal Imperial formations with their new and previously recognized members (Fig. 1) as defined by Kabanov et al. (2016). The most significant updates in comparison to Pyle et al. (2014) are the spatial restriction of the Bell Creek member to thick “gray-shale member” sections of the Hare Indian Formation, assignment of black shale dominated sections of the upper Hare Indian developed in the off-bank (basinal) paleogeographic areas to the newly defined Francis Creek and Prohibition Creek members (equivalent of the “black-shale member” of Pugh, 1993) and recognition of the Vermillion Creek and Dodo Canyon members in the Canol Formation. The “Upper recessive unit” of Pyle et al. (2014) is correlated with the Middle Canol and probably to part of the Upper Canol informal units traced in the subsurface by Tassonyi (1969). The “Middle Canol” is traced in wells under the newly proposed name Mirror Lake member (Kabanov et al., 2016). The Mirror Lake member is overlain by the newly defined Loon Creek member characterized by the partial recurrence of black pyritic and radioactive shales resembling typical Canol facies (Fig. 1). This newly proposed member is the partial to complete equivalent of the Upper Canol informal unit defined in the subsurface by Tassonyi (1969). In recent cross-sections of Pyle et al. (2014), the Middle and Upper Canol units of Tassonyi (1969) are mostly excluded from the Canol Formation. The uppermost stratigraphic unit discussed here is the Canyon Member (Canyon Creek sandstone of Tassonyi, 1969) that is unequivocally placed into the Imperial Formation. The typical (“Type A”) Canyon Member forms spatially restricted sand-dominated lobes (Canyon sandstone lentils; Tassonyi, 1969; Pugh, 1993) that shale to the west (basinward) into the upper two-thirds of the Loon Creek member. Offshore from type Canyon Member sections (Canyon Creek G-51 and Loon Creek G-78 wells), the fully developed Loon Creek member is overlain by a thin (5-8 m) unit enriched in siltstones and traced in most wells by a distinct low-gamma marker. This thin unit is referred to as the “Canyon member of Type B” (Kabanov et al., 2016).

New lithostratigraphic units are recognized based on core examinations and well logs from recently drilled wells Little Bear N-09, Little Bear N-64, Loon Creek O-06, Mirror Lake N-20, and East Mackay I-78, as well as shorter cores available from older wells. Spectral gamma logs (SGR) appear to be most useful to subdivide the mudrock-dominated succession of the Horn River Group into clay-rich (high K and Th) and clay-lean (low K-Th, high U) packages. In continuous cores the former appear fissile and lighter-colored, referred to as gray-shale units, whereas the latter are dark-colored, harder and more siliceous mudrocks and siltstones usually showing higher uranium-dominated total gamma, historically called black shales (Arthur and Sageman, 1994). Correlation with older wells is based on total GR, sonic, resistivity logs, and the



The zero edges were chosen along the outcrop edges of correspondent formations from the east side. The outcrop zero edge is traced by GSC bedrock map compilation shown on Figure 2 (Cook et al., 2010; Fallas, 2013a-d; Fallas and MacLean, 2013a-b, Fallas and MacNaughton, 2013, 2014a-c; Fallas et al., 2013a-d). The northeast margin of the Horn River Group within the studied area is controlled by the uplifted edge of the group along the Norman Range (Fallas and MacNaughton, 2013; Fallas et al., 2013; Fallas, 2013). On the southwest, the depth and isopach maps are clipped approximately along the axis of the Mackenzie Valley synclinorium, at a distance not exceeding 4 km from available wells. The southwestern limb of the synclinorium is not included in the study area because the Horn River Group there is very poorly constrained by wells, with only one well available (Mirror Lake N-33 on Fig. 2). This well is excluded from depth maps to avoid model distortion.

## RESULTS

The isopach maps on Figures 3C-3O show three trends that reflect the lithological nature of mapped units. The Bell Creek, Canyon, Francis Creek, Prohibition Creek, and Mirror Lake members are distinctly thickening towards the easterly located sourceland (Figs. 3C, 3H-K, and 3N), the Canol Formation and its members are basin-centered (Figs. 3E, 3F, 3L, and 3M), and the Ramparts Formation was shaped by the time-specific warm-water carbonate factory developed during net sea level rise (Fig. 3D). These isopach maps are favoring for sedimentary control over the architecture of discussed units with little or no syndepositional tectonics involved.

The Hare Indian Formation is traced across the entire area (Fig. 3A) and shows one major southwesterly trending deltaic fan in the northwestern part of the study area. This sedimentary structure, historically referred to as a shale bank (Muir, 1988; Muir et al., 1984), corresponds to the extent of the redefined Bell Creek member (Fig. 3K) and supports carbonate banks (reefs) of the Ramparts Formation (Fig. 3D). Moderate thickening of the Hare Indian Formation traced in the southeastern corner of the study area may indicate the edge of another delta (Fig. 3C). The Canol isopachs are modelled in two ways: one including Vermillion Creek and Dodo Canyon members (Figs. 3E and 3F) and another including the Vermillion Creek, Dodo Canyon, Mirror Lake, and Loon Creek members (Fig. 3G) as favored by early subsurface correlations (Tassonyi, 1969; Pugh, 1983, 1993). In all models the Canol Formation casts the underlying relief of the Hare Indian and Ramparts formations. The Canyon Creek isopachs show a major siliciclastic fan developed from the east (Fig. 3H). The Francis Creek and Prohibition Creek members are confidently traced in wells from the southern corner of the study area up to the line where they merge into thicker Bell Creek member (Figs. 3I-K).

The Vermillion Creek and Dodo Canyon members of the Canol Formation are confidently traced in areas where they are separated by the low-resistivity “Canyon Creek marker” of Tassonyi (1969). More details on the contact between the two members are given in (Kabanov et al., 2016, Submitted). The Vermillion Creek member pinch out against thicker Ramparts sections, which restricts its confident recognition within approximately the same limits as the Prohibition Creek and Francis Creek members (Fig. 3L). To the north of Norman Wells, the Canol Formation is considered undivided, as only few wells show log patterns indicative of presence of a thin (14-16 m) Vermillion Creek member sections (e.g., Discovery Ridge D-04 and Oscar Creek J-48; Appendix 1). Thin Canol sections on tops of thick (over 80 m) Kee Scarp carbonate banks are likely solely composed of Dodo Canyon member (Kabanov et al., 2016), which renders the coeval sedimentation of the Vermillion Creek member and the Ramparts / Kee Scarp carbonate banks, at least in parts that post-date the Carcajou sedimentation phase.

The Mirror Lake and Loon Creek members are traced across the entire study area (Figs. 3N and 3O). To the south of Norman Wells, the Mirror Lake member is traced in wells and outcrops as a distinct clay-rich recessive gray shale, and log signatures for this unit are also very distinct at Norman Wells oilfield. Further north and northwest, the log signatures gradually obtain more similarity to underlying and overlying black-shale units. The unit is still recognizable in Hoosier F-27 well in the northwestern corner of the study area, but cannot be confidently traced further northwest as it was shown for Maida Creek F-57 and G-56 wells (Kabanov et al., 2016).

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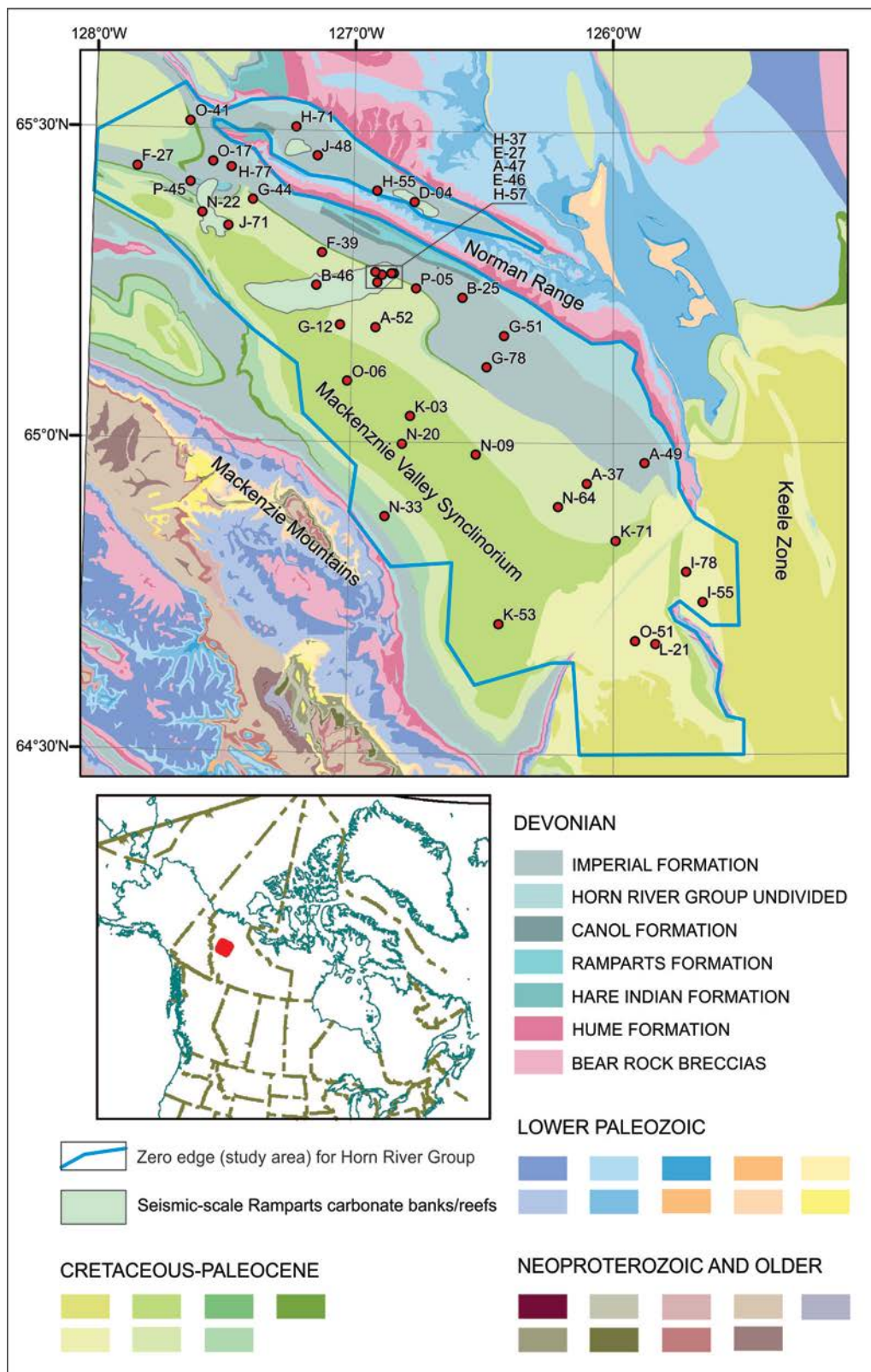
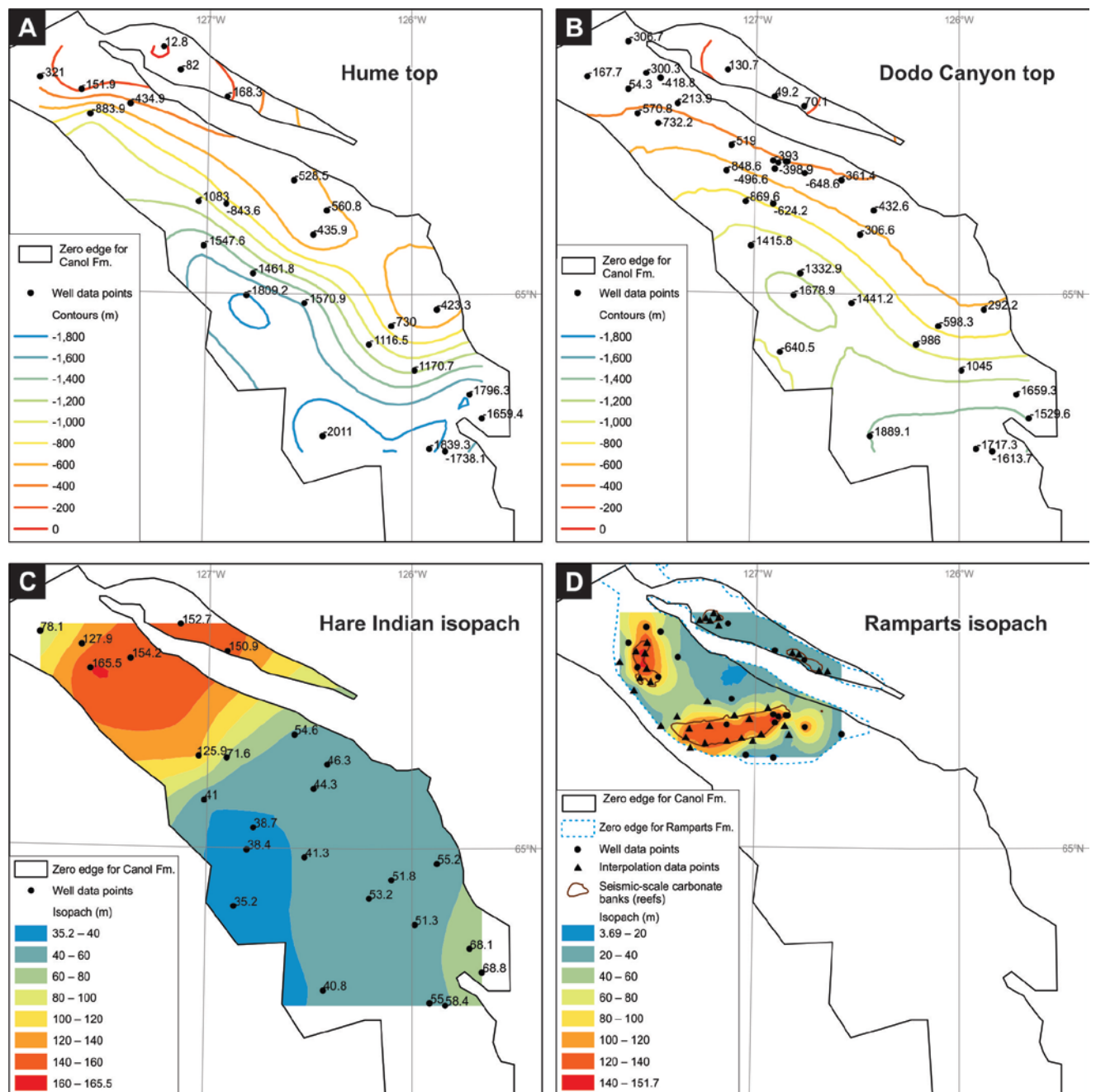


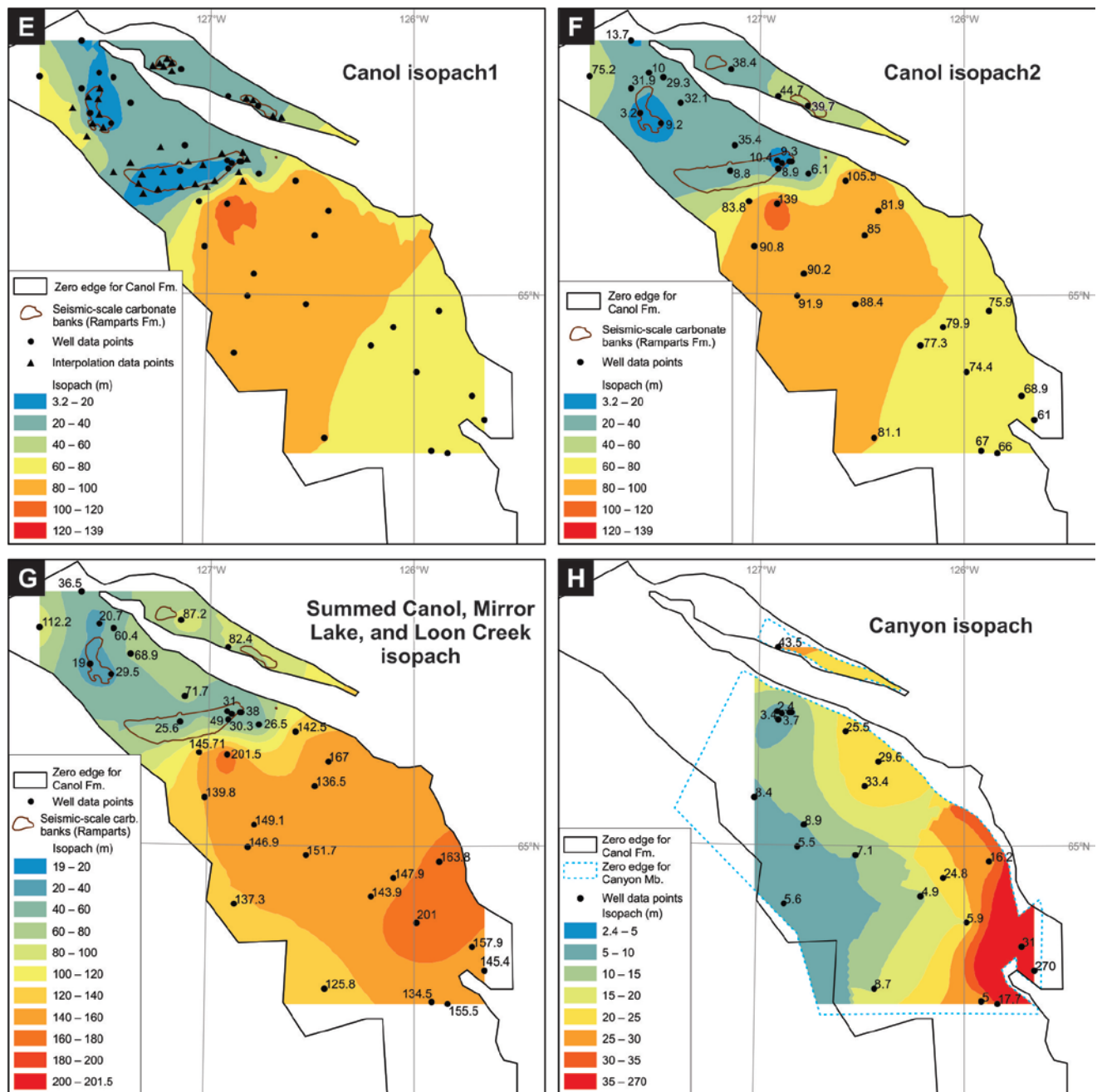
Figure 2. Bedrock map compilation for NTS 96C to 96E with data points (wells in Appendix 1) and seismic-scale Ramparts carbonate banks interpreted by B.C. MacLean (slightly modified). Well indexing refers to WIDs and well names in Appendix 1.





**Figure 3. Depth and TVT isopach maps: (A) Depth map of top of Hume Formation (base of Horn River Group); (B) Depth map of top of Dodo Canyon member; (C) Isopach map of Hare Indian Formation (Bluefish, Bell Creek, Francis Creek, and Prohibition Creek members); (D) Isopach map of Ramparts Formation;**





**Figure 3 (continued): (E) Isopach map of Canol Formation with interpolation points (Vermillion Creek and Dodo Canyon members); (F) Isopach map of Canol Formation (Vermillion Creek and Dodo Canyon members) without interpolation points; (G) Isopach map of summed Vermillion Creek, Dodo Canyon, Mirror Lake, and Loon Creek members; (H) Isopach map of Canyon Member**

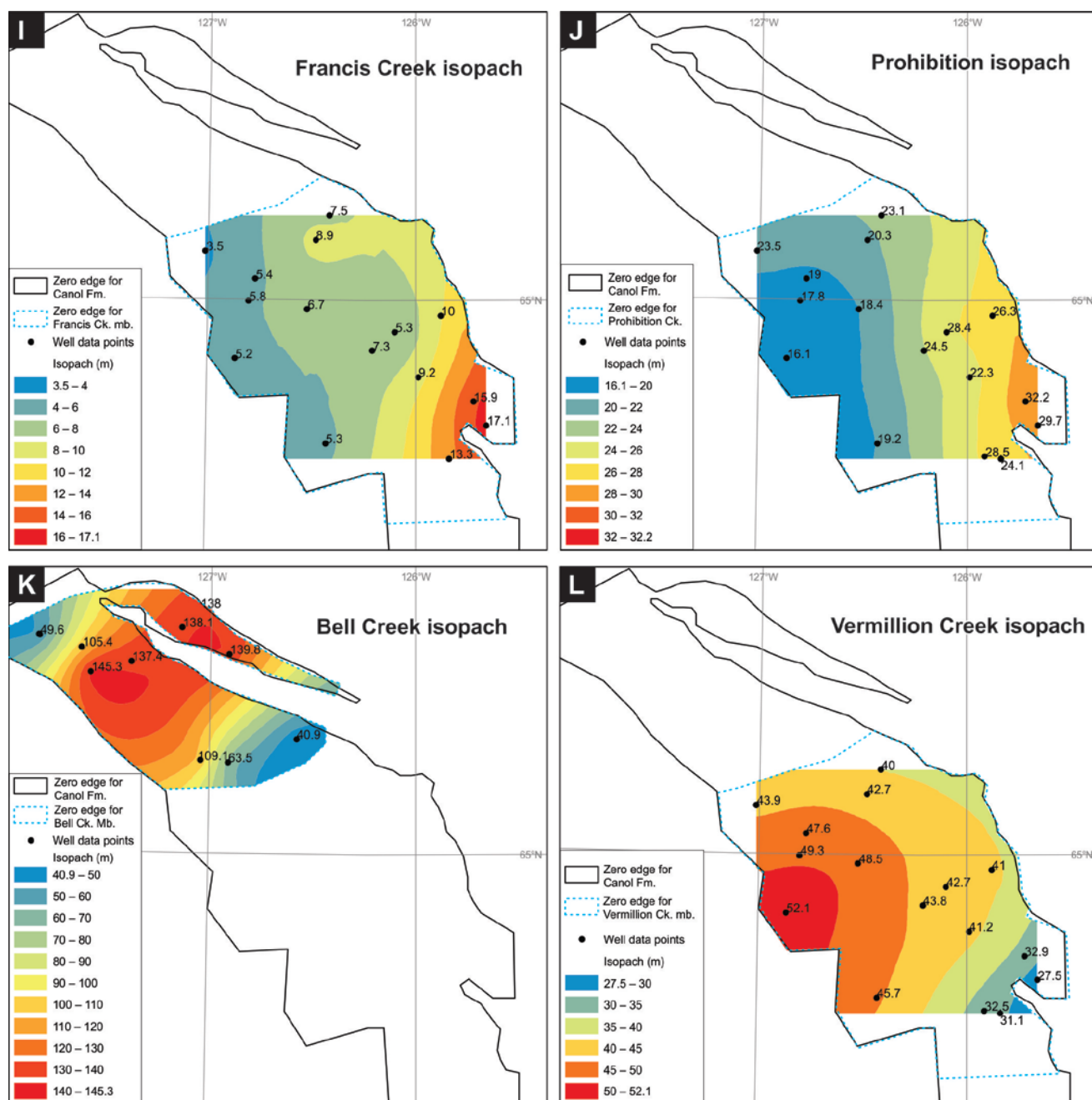


Figure 3 (continued): (I) Isopach map of Francis Creek member; (J) Isopach map of Prohibition member; (K) Isopach map of Bell Creek member; (L) Isopach map of Vermillion Creek member

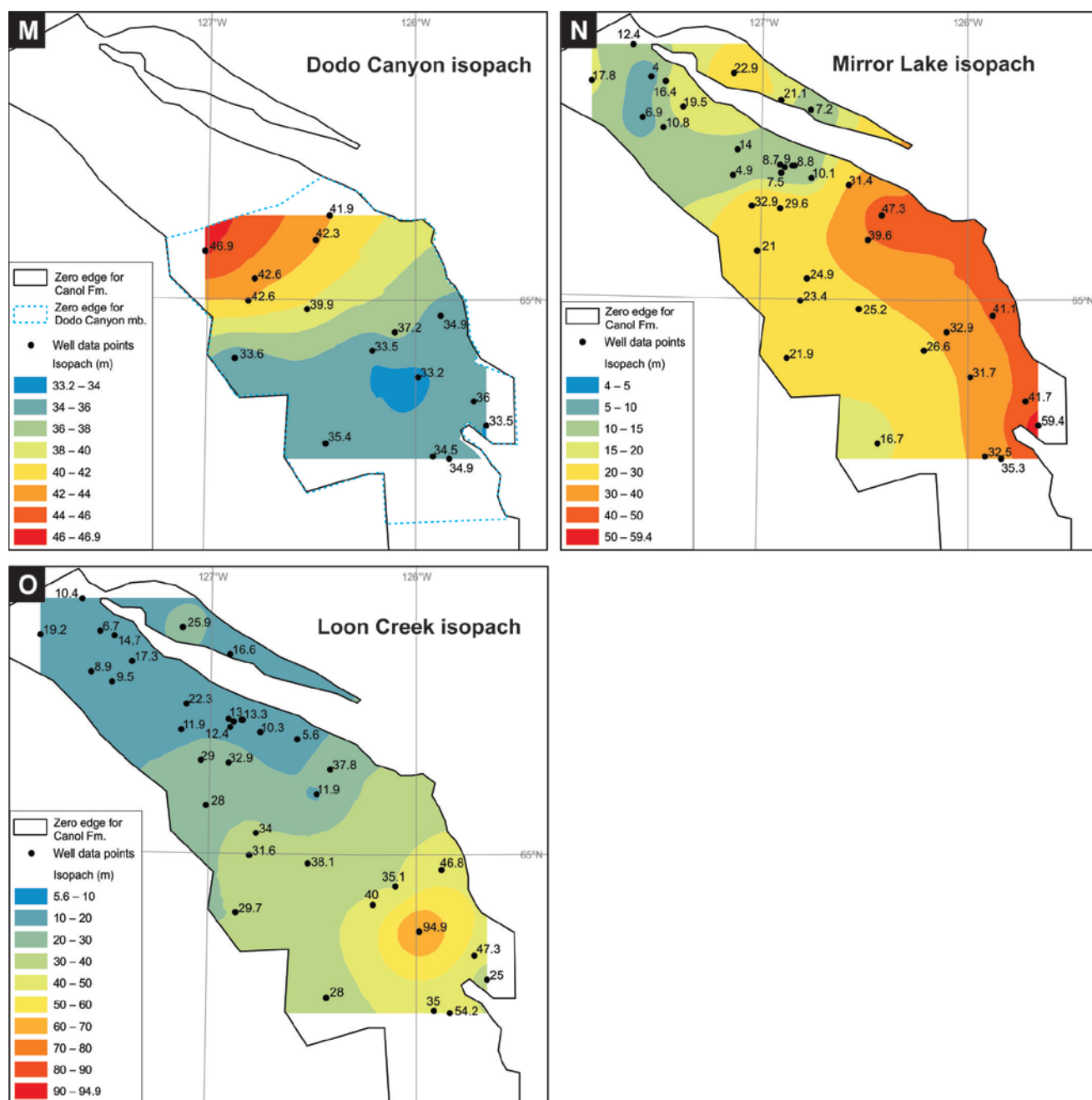


Figure 3 (continued): (M) Isopach map of Dodo Canyon member; (N) Isopach map of Mirror Lake member; (O) Isopach map of Loon Creek member

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